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Aging Aircraft Maintenance Costs

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This study was accomplished to investigate the effect of age and flying hours on costs to maintain an aircraft. Available literature was searched on the subject. Depot maintenance cost data for eight years were utilized to compare the costs of different models of four basic aircraft. The different models compared reflect different aircraft age and number of flying hours with similar missions.

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THE EFFECT OF AIRCRAFT AGE AND FLYING HOURS ON MAINTENANCE COSTS

N. W. Foster, PE., H. D. Hunsaker

June 1983

AFLC Technical Report Nr. 82-099

Directorate of Management Science (XRS)
Deputy Chief of Staff, Plans and Programs
Headquarters, Air Force Logistics Command
Wright-Patterson Air Force Base, Ohio 45433

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ABSTRACT

This study was undertaken to determine the effect of aircraft aging and usage on the cost to maintain it. It is a popular and widely held belief that aircraft maintenance costs approximate the bathtub or U curve, i.e., maintenance costs for any aircraft are typified by a high cost initially, decreasing to a relatively low and steady cost for many years, then increasing dramatically to reflect wearout of the then older aircraft.

In the conduct of the study the authors reviewed available literature and related studies on the subject, and collected depot maintenance costs. Depot maintenance costs were available by MDS for the past eight years. Several similar models were selected that had like missions, different average ages, and different total flying hours. Depot maintenance costs were then compared to these categories.

The study concludes that there is little evidence that maintenance costs increase dramatically as an aircraft ages.

PREFACE

The effect of aircraft age and flying hours on maintenance costs has been a long debated subject. This paper responds to the question with a search of the literature and takes a look at current (the last eight years) maintenance costs by aircraft model in attempting to relate maintenance costs of similar models with age and flying hour differences. A precise examination of aircraft maintenance costs cannot be accomplished utilizing available data due to the present data collection technique employed in depot and base maintenance. However, it is believed that with the examination method employed herein, along with the work of other researchers, that reasonably accurate conclusions have been reached.

BACKGROUND

The traditional bathtub curve has been associated with the costs of maintaining aircraft, i.e., as they enter the inventory the maintenance costs are high, then after a year or two they level out at a low level, or the most economical period for maintenance costs. After the system has operated several years the maintenance costs again rise rapidly signifying wear-out of the then older system. Figure 1, page 20, describes the phenomonon. Since this study suggests a less rapid rise in maintenance costs as the system ages we have added background information on the bathtub curve.

During the 1950 time period a movement began primarily in the electronic field, toward predicting reliability. The so-called bath tub curve (see Figure 1, page 20) was developed to describe the reliability of a component, sometimes referred to as the hazard curve (7, 8).

Richard R. Landers (6) on page 337 of his book describes the failure rate of the common incandescent light bulb in which he plots the failure data and relates it to the so-called bath tub curve. He points out that the bulbs burn out at a faster rate in the beginning and that this is indicative of some defect in material or workmanship. Their mean time between failure rate was 0.00202 during the early period. They then level out to a very low failure rate of 0.000345. As the lamps approached their design limit of 750 hours the failure rate increased rapidly (represented by the final part of the bath tub curve).

Keith Henney (7), (8) presents additional detail on reliability as applied in the electronic field. He defines reliabiity as the probability that a component part, equipment or system will satisfactorily perform its intended function under given circumstances, such as environmental conditions, limitations as to operating time, and frequency and thoroughness of maintenance.

Mr Henney also states that reliability is influenced by all aspects of an engineering effort; the ultimate reliability of a component or a system depends upon the quality of research involved in its conception, its design, the manner in which it is manufactured, the external influences on its operation, maintenance considerations and other factors.

He also states that in a system that aggregates a number of units, joint probability relates independent failures of components to the overall reliability of the system. The ability to predict joint probability based on ponent probability is essential, because it is difficult if not impossible, to get experimental failure-rate information on large equipments under widely different conditions, whereas it is somewhat easier to get reliability information on components which may be common to many different equipments and may in fact be duplicated many times over a single equipment. This is especially true of electronic components such as resistors, tubes and capacitors, which are used many times over in the same equipment and are used in many types of equipment.

Mr. Henney describes joint probability as the product of the individual probabilities. This definition assumes an independent relationship of the individual probabilities. Such independence is often not achieved in real situations for two reasons. First, because components of the same type often come from a common source, manufacturing or other considerations common to all the similar components may influence the reliability thereof. Secondly, in any equipment the functional interdependence of components can not be overlooked. The failure of one device may influence the failure of an adjacent device due to load transferral, the influencing of the immediate environment, and many other factors.

Mr Malvern of McDonnell Aircraft Company (9) states the avionics equipment reliability is typically portrayed by the bath tub curve. He describes avionics equipment reliability in the F-15A aircraft. He suggests that the reliability of a complete avionics system can be carefully orchestrated within reasonable limits.

It may be possible that the reliability of components/equipment and small systems can be described with the bath tub curve. As the complexity is increased with many different components that have been produced by different manufacturers the likelihood of different wear-out or deterioration times increases. These components/equipment are then replaced or repaired as they fail at different times with a result that the overall system is part new and part old. During the normal life span of an aircraft system many systems, parts, equipments may be repaired and/or replaced at random times. As this process continues the life expectancy of the entire aircraft system may be extended.

It is logical to consider that modifications performed on an aircraft will extend its life. Some modifications are performed for that specific purpose as the state-of-the-art is improved. Other modifications are accomplished to improve the aircraft capability and often provide an advantage of extending the life of the particular part modified. The converse is also true, that when modifications are withheld, the life of the aircraft may be reduced.

This suggests that diligent aircraft maintenance and continuing modifications will extend the life of an aircraft system. These programs may be influenced by budgetary policies which can also change the reliability and life expectancy of an aircraft system.

CONTENTS

INTRODUCTION

Two questions have been raised regarding aircraft aging. The first, what does it cost to keep an aircraft flying as it gets older? The second, what does it cost to update an aircraft in order for it to meet the threat?

To answer these questions a review has been made of previous papers on the subject. Knowledgable AFLC people have been interviewed. Depot maintenance cost data were selected for study to help answer the questions.

Depot maintenance cost data were evaluated for specific aircraft models to make a comparison of repair costs on similar aircraft models, of different average ages and average accumulated flying hours, all used in performance of like missions. Evaluation of data gave no indication of a dramatic increase in repair costs for older aircraft with high accumulated flying hours.

Class V modifications were also evaluated in an effort to determine the cost of maintaining the aircraft system at the most modern state of the art. Again it was learned that class V modifications (exclusive of parts cost) do not represent a significantly large expenditure. Evaluation of available literature seems to support these same findings.

It is concluded that it may be most cost effective to continue to operate an aircraft system and modify it with up-to-date state of the art innovations as long as the basic airframe can perform its mission or until enemy technology forces development and production of a more capable fighting machine.

DEPOT MAINTENANCE COST DATA

A direct comparison of maintenance costs of new aircraft with similar older aircraft would be desirable. Ideally this would be accomplished by selecting older aircraft and comparing their maintenance costs to those of a like newer aircraft. However, maintenance cost data are not readily available by aircraft tail number. In fact it has only been for the past eight years that depot maintenance cost data have been available by aircraft MDS. Approximately one half of these data are directly related to MDS. The remainder of the cost data are prorated to MDS.

In view of these data availability restrictions aircraft models were selected that are basically similar in design, but where one model was manufactured at a later time period. These selections were also made on the basis of the earlier models having more average flying hours and that each model had similar missions. As a result of these criteria, aircraft model comparisons were made as listed in Figure 2, page 21.

It is important that the reader recognize that no conclusions should be drawn from an eight year trend of a single aircraft model (MDS). Data reporting differences in the eight year period (1975 through 1982) have introduced serious biases. However, since the reporting differences were identical for each model each year, the repair costs can be compared for one model (MDS) to another as accomplished in this study.

Depot maintenance cost data used in cost comparisons of aircraft models described in figures 3 through 9 in this report were selected from the WSCRS system RCS: HAF-ALM (A&AR) 8202, Schedule 1, Part A, reflecting FY75 through FY82 cost factors, all corrected to constant FY84 dollars. They reflect the following depot maintenance costs:

> Aircraft overhaul, engine overhaul, engine accessories, aircraft accessories, avionics instrumentation, avionics communication, avionics navigation and armament accessories. Among the costs reflected are all labor, Stock Fund material and overhead costs. Costs for Class IV and V modifications are included.

These Costs do not include recoverable spares procurement costs, fixed DMIF costs or Class IV and V modification kit procurement. No base maintenance expenses are included.

The depot maintenance costs, including class IV and V modifications for each of these models, were plotted on charts as dollars per flying hour. The reader is urged to observe the difference in costs for each model and not the year to year trend. To help to emphasize the difference in maintenance costs for each model the area between the two cost lines has been indicated by diagonal lines. In those cases where the cost of the newer model exceeds that of the older a diagonal cross hatch is used, as in the case of the B-52 chart, figure 5 and F-4 out year modifications chart, figure 9. The costs in dollars per flying hour for class V modifications alone were plotted to illustrate the cost to upgrade the airplane's capability as it ages. It is noted here that class IV modifications are performed basically to keep the airplane operational, while class V modifications are performed to upgrade its capability. The charts comparing depot maintenance costs per flying hour are illustrated in Appendix 2.

The chart on page 23, Figure 3, shows the C-130 aircraft. Essentially, it compares the C-130B and C-130E (which have nearly the same accumulative flying hours) to the C-130H which is newer and has much less average accumulated flying hours. The reader is again cautioned not to attempt to draw conclusions from the eight year trend, but to observe the cost difference illustrated by diagonal lines. Our purpose here is to compare depot maintenance costs of different model aircraft. In view of this purpose it can be readily observed that the C-130B and E models do have a small increase in maintenance cost over that of the C-130H. The C-130H has significantly less flying hours (approximately 4,000 compared to over 14,000) and is considerably newer (17 years newer than the C-130B). It is also noted that class V modifications costs are insignificant; although the reader is reminded that kit procurement costs are not inluded.

The chart on page 24, Figure 4, arrays each model by its respective age during the eight years of available data. In effect each model offers a "window view" of a part of the entire 24 year life of the C-130 aircraft in terms of cost per flying hour, i.e., 5 years of age is $290, 10 years $350, 15 years $405 and 20 years $451 per flying hour. These are three different models but due to the data limitations to eight years, they have been arrayed by average age of each model to represent the C-130 airplane depot maintenance costs over 24 years of aging. A trend line was drawn based on the average maintenance cost in dollars per flying hour for each model's respective eight years of data. This trend suggests an increase in depot maintenance costs of approximately $250 per flying hour or an increase of about 104% over 24 years of operation.

The chart on page 25, figure 5, shows the B-52 aircraft. This chart compares the B-52D with the B-52G. The model D is on an average about 3 years older and has about 3,000 more average accumulated flying hours, which is not enough difference to draw reasonable conclusions from. It is unfortunate that along with this relatively old airplane we cannot compare it with a like newer model. But it is interesting that the B-52D, which is about to be phased out of operation, reflects minimal higher maintenance costs than the B-52G. It is noted that the chart reflects a large spike for the year 1976, which appears to be driven by class V modifications. Our investigations reveal that there were no large class V modifications scheduled that year. We do find that modification number 12006A, "D" Wing Structure (Pacer Plank) was performed in 1976 by Boeing Aircaft Co. at a cost of $219,400,000.00, which was considered a Class IV modification, but apparently reported as Class V. The Maintenance Production Control representative at OC-ALC stated that this is the only reasonable explanation for such a large spike in 1976. This expensive modification if spread out over the eight years reported here increases the overall B-52D cost over the B-52G about 5%. Conclusions should not be made from the eight year trend. As in the case of the C-130 aircraft, the model that is older and has more flying hours reflects a small increase in maintenance costs over the newer model. As might be expected the B-52 has a higher cost for class V modifications (cost to upgrade its capability) than the C-130 due to its combat mission. However, it is of interest that this is a small amount compared to overall maintenance costs or new weapon acquisition.

Unfortunately there are no new B-52s in the inventory so it is not possible to make a life-time comparison of this aircraft as with the C-130 on page 23, figure 3.

The chart on page 26, figure 6, shows the F-15 airplane. This chart compares the F-15A and the F-15B with the F-15C. The models A and B have nearly the same acquisition date and same total average accumulated flying hours, while the model C is about four years newer and has about one half of the average accumulated flying hours. Data for the F-15 aircraft are limited during 1975 through 1979 due to its newness and that depot maintenance data naturally lags the aircraft's entry into the inventory.

Page 27, figure 7, describes the depot maintenance costs for F-4 aircraft. The F-4C is compared to the F-4E. The F-4E averages about seven years newer than the F-4C and has approximately one third less average accumulated flying hours. The area marked with diagonal lines projects a pattern of higher costs for the older F-4C over the newer F-4E. The older model with more accumulated flying hours has an average cost of about $270 more per flying hour for depot maintenance over the eight year period (32% more).

The chart on page 28, figure 8, arrays each model of the F-4 by its respective age during the eight years of available data. As with the C-130, each model offers a "window view" of a part of the life of the F-4 aircraft-not as complete as the C-130 since the newest F-4 is about 13 years old. A trend for the average maintenance costs of the two models is presented on the chart to represent the 16 years of available data.

The chart on page 29, figure 9, extends the known future class V modifications for the F-4C and F-4E aircraft through 1998. These costs include all estimated modification kit procurement (recall that the other modification costs discussed in this report do not include kit costs) and the maintenance costs described on page 4.

The chart reflects structural modifications projected as necessary to maintain the system through that period. It is noted that class V modifications are projected as dollars per flying hour each year they occur, which accounts for the "spikes" on the charts. As an example, the large "spike" for the 1990-1994 period on page 29, figure 9, represents new wings for the F-4C.

Overall evaluation of depot maintenance costs, by model, suggests that aging and flying hours may affect maintenance costs, however, the increasing cost appears to be gradual. Each of the models examined show an increase in maintenance costs for the older model. The C-130B (with an average age of between 17 and 24 years) an average of $177.09 per flying hour over the C-130H (with an average age of between 1 and 8 years) for the eight year period or 65% increase for the older model over the newer. The B-52 an average of $92.09 per flying hour over the eight year period or 5% increase of the older model "D" over the newer "G", of course this is very small as may be expected with the two models so near the same age. The F-15A has an average of $277.81 per flying hour over the F-15C for the four years of available data on the "C", or 35% increase for the older model over the newer. The F-4C cost an average $270.65 per flying hour over the F-4E for an increase of 32% for the older model over the newer.

On page 4 it was mentioned that the recoverable spares procurement costs were not included in the model comparisons of figures 3 through 9. In order to learn about the inpact of recoverable spares consumed in the repair process, the condemned costs were taken from the WSCRs report referenced on page 4 and were projected on the charts of figures 3 through 9. The condemned costs reflect procurement costs of recoverable spares, excluding the cost of pipeline and safety levels, that have had to be replaced in both the base and depot maintenance repair processes. It was determined that these condemned costs follow the same pattern as other depot maintenance costs, making little or no impact on the respective differences reported for the models compared.

The recoverable spares that make up the pipeline and safety levels are harder to measure. As the airplane becomes older if it requires more maintenance because of increased item failures the pipeline and safety levels will be increased. A hypothetical example is presented here to illustrate:

(see next page for example)

Airplane Age 1 (Young)	Assumes no condemnations	Airplane Age 2 (Old)
Failures = 100 Stock level = 40 Assets = 40	Repair Cost = \$25 Procurement Cost = \$100	Failures = 150 Stock level = 60 Assets = 40
Repair Cost = 100•25 = \$2500		Repair Cost = 150•25 = \$3750
Aircraft repair costs only reflect this amount:	Age 2–Age 1 Difference = \$1250 Ratio = 1.5	
Repair + Buy Cost = 100•25 + (40–40) 100 = \$2500		Repair + Buy Cost = 150•25 + (60–40) 100 = \$5750
The inclusion of recoverable spares procurement costs could reflect this amount:	Age 2–Age 1 Difference = \$3250 Ratio = 2.3	

In addition, recall that modification kit spares costs are not included in our figures. Thus, the increased cost of supporting the older airplane could be more than reflected in this study which looks only at maintenance costs.

STUDIES OF EQUIPMENT AGING

In 1970 Milton Kamins (1) described the aging process of aircraft. He suggests that some evidence indicates that an aircraft actually becomes less costly to maintain as it ages. He supports this claim with maintenance costs on the F-101A/F-101C as illustrated on page 30, figure 10. Similar information from United Airlines on the DC-8 aircraft as illustrated on page 31, figure 11, shows that the DC-8 maintenance costs per mile were cut substantially over an eleven year period. It should be recognized that commercial aircraft are not to be compared with military aircraft, the period is limited to only 10 years and that this represents an indication that DC-8 aircraft experienced reducing maintenance costs over the period represented. He presents statistics on the F-100 aircraft that support his claim that it became a safer aircraft with less accidents as it aged.

Mr Kamins classified wear out in actual practice as being limited to a single cell (e.g., an automobile tire) and/or having essentially a single mode of failure (e.g., a diaphragm). He also states that many people relate an aircraft to a single celled or single mode-of-failure item and erroneously believe that it will wear out or fail at a given time. But, in reality an aircraft is made up of many components in a single structure and that each component or part has a different life expectancy under a varied service profile (i.e., not just the maximum expected stress) and each will be replaced or repaired at its own appropriate point in time, thus making the structure a complex equipment, and suggesting random failure, that is, no wear out.

The philosophy of aircraft failure explained by Mr Kamins is essential to understanding aircraft maintenance requirements as they age. A single cell item, such as a tire, will wear out at a given time (operating cycle related) as compared to a multiple cell item, such as an aircraft, which will have many parts wear out at different times. As a result, the basic aircraft will have parts repaired on a continuing basis, but it will basically never wear out as a whole. Much advertising in the American economy has taught us the "throw away" concept (2) to where we believe our automobile will wear out at a certain age and number of miles. This concept is also refuted by Everett Beals (3) in his article "When Should You Trade Your Car." Mr Beals described that in the beginning of his study he believed failures would follow the traditional bathtub curve, see Figure 1, page 20. This he described as expecting a large number of failures when the car was new, that it would level out with few repairs and then at some point in time with the increased age/miles driven the number of repairs would again rise rapidly. As Mr Beales drove his 1963 Dodge and plotted repair costs he learned that the curve started high as expected, it went down but stayed down with only a very gradual rise as time went on, see Figure 12, page 32. He states that even major repairs, such as an engine overhaul would cause a monthly fluctuation but have little effect on the overall cost of repairs per mile. He projected the curve out for additional years and could not find a time that it would be economically feasible to replace the vehicle. He did concede that there would be a time when the vechicle would not be able to be repaired due to the unavailability of parts. Mr Beals' concluding statement is as follows: "So it seems that if you can forget about keeping up with the Joneses there is no point, within realistic mileage accumulation, when you need to replace your car. Just keep paying for the repairs and maintenance as they occur. Even a sizable repair bill will not significantly affect the total mileage cost of the vehicle."

Colonel Howard M. Williams and his associates in their report of 14 July 1975 (4) concluded that the Medium Lift Helicopter (MLH) requirements of the 1980s and 1990s could best be met by modernizing the existing CH-47 fleet of CH-47As, Bs, Cs and by procuring new modernized aircraft to replace attrition losses. This recommendation was made in spite of the Army Deputy Chief of Staff Logistics guideline established in its 12 March 1974 letter "Army Aircraft Phase Out Planning Data" which would have reduced the Army's CH-47 assets by 50 percent in 1987 and total assets would have approched zero by 1992. Their analysis included consideration of procurement of new aircraft, but not new development. Their studies specify that new acquisition is more costly than continued operation of existing equipment with modifications and continued maintenance.

Frank Brown and his group at Boeing Aerospace Company conducted a life cycle cost study of the C-130E aircraft in July 1977 (5). Their study used the USAF Cost Analysis Cost Estimating (CACE) model. The report readily admitted that the collection of adequate data was the most difficult part of a life cycle study for the Air Force (page 11). The chart on page 33, figure 13, of this study represents depot maintenance costs for the first 14 years of the C-130E life as extrapolated from figure 10 of the Boeing report. While a direct comparision of these data to current data (the past eight years) reported in this study cannot be made, due to differences in data reporting, it is observed that the depot maintenance costs went up the first few years and then drifted downward over the 14 years charted.

CONCLUSIONS

The literature and our own AFLC Depot Maintenance cost data all point in the direction that only single cell items, such as a tire, or other single component will wear out at a specific and predictable point in time or operation cycles. Items that are made up of multiple cells, or that contain many component parts, such as an airplane do not wear out at a specific and predictable age/operating cycles. They in fact have parts failing and being repaired at different times with no overall failure being experienced. It was learned from AFLC depot maintenance cost data that as aircraft become older and accumulate more flying hours the repair costs do increase at a gradual rate. We could find little evidence of a dramatic increase in repair costs at any particular point in time.

It is understandable that although the maintenance costs will not become unbearable, in relation to new acquisition costs, there may be a point in time where it is necessary to develop a new weapon system to compete with and subdue the enemy. To illustrate this point, the old C-47 still flies and could carry the cargo today - nearly fifty years after it entered the inventory - except the state of the art has provided much larger and faster airplanes such as the C-5.

RECOMMENDATION

We reconsider our belief that maintenance costs increase suddenly at some point as an aircraft ages.

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2. "The Waste Makers" by Vance Packard, David McKay Co., Inc., New York

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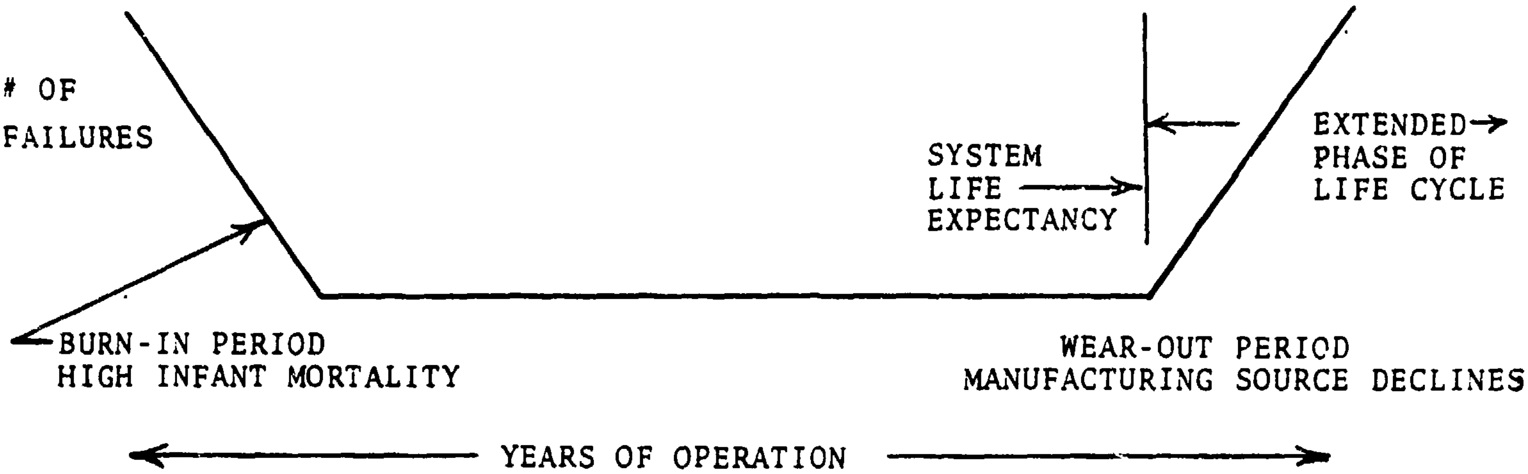
8. "Reliability Factors for Ground Electronic Equipment" by Keith Henney, McGraw Hill Book Co., Inc., New York, Toronto, London.

9. "Defense Management Journal", April 1976, The F-15A Eagle Program, by Donald Malvern, Executive Vice President, McDonnell Aircraft Co., St. Louis, Mo.

APPENDIX 1

FIGURES 1 thru 2

THE BATHTUB DEMAND CURVE



The bathtub curve is typified by a large number of early or infant failures. After the burn-in period, failures decrease to a relatively low and steady rate. This adjusted or normal failure rate usually runs for an extended period. After many years of equipment operation, failures again begin to increase as the part nears the end of normal life expectancy. Failures can be unusually high if the component is retained operational in an extended phase of the system life cycle.

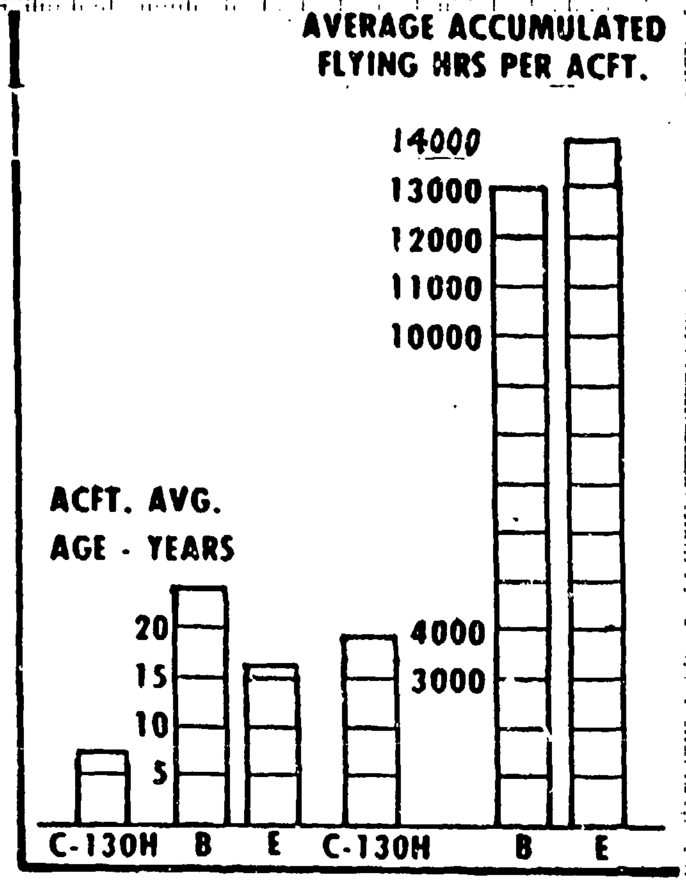
Figure 1

AIRCRAFT MODEL	AVERAGE AGE IN YEARS	AVERAGE ACCUMULATED FLYING HOURS
C-130B	24	12,822
C-130E	16	14,196
C-130H	7	3,946
B-52D	28	13,462
B-52G	25	10,738
F-4C	20	4,418
F-4E	13	3,181
F-15A	8	1,174
F-15B	7	1,359
F-15C	4	478

Figure 2

APPENDIX 2

Maintenance Cost Charts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FLYING HRS PER ACFT.
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13000
12000
11000
10000
4000
3000
ACFT. AVG.
AGE - YEARS
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15
10
5
C-130H
B
E
C-130H
B
E

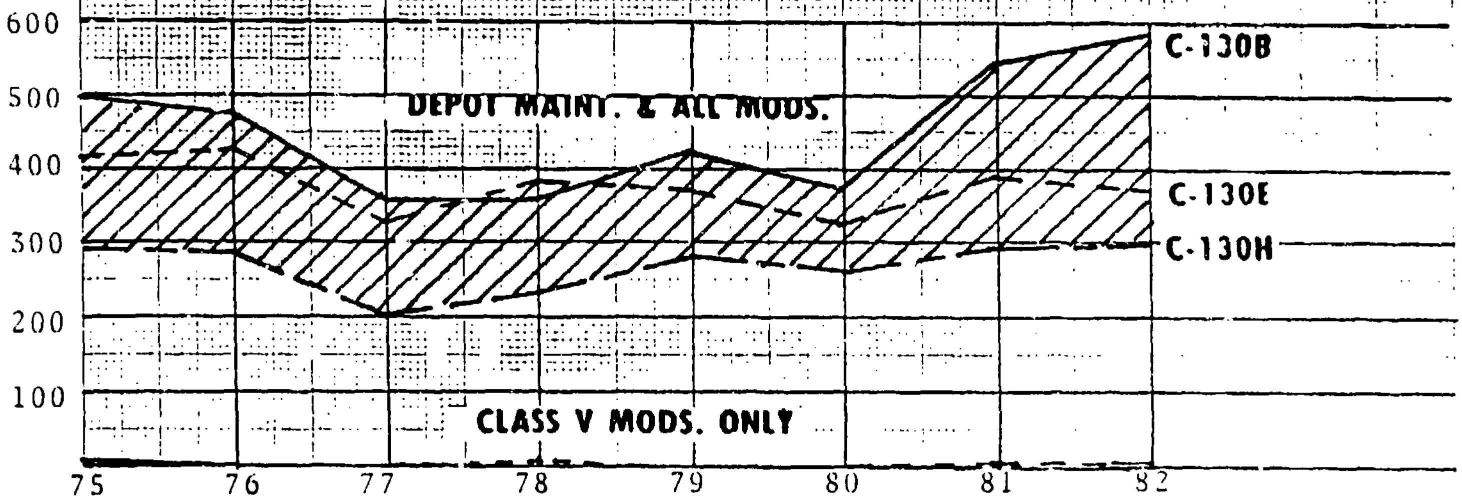

600
500
400
300
200
100
DEPOT MAINT. & ALL MODS.
CLASS V MODS. ONLY
C-130B
C-130E
C-130H
75
76
77
78
79
80
81
82
FISCAL YEAR

FIGURE 3

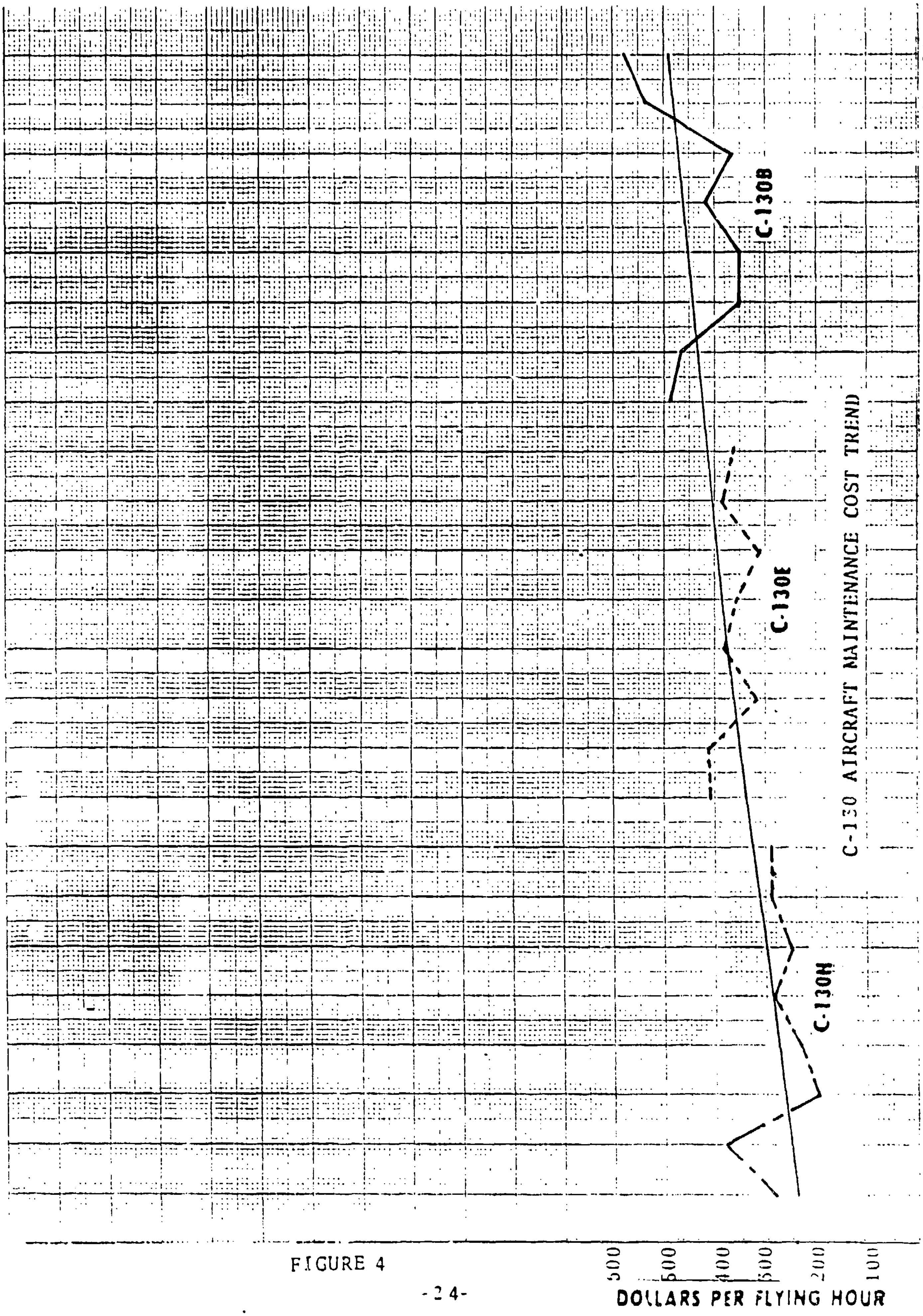

C-130 AIRCRAFT MAINTENANCE COST TREND
YEAR
C-130B
C-130E
C-130H
DOLLARS PER FLYING HOUR

FIGURE 4

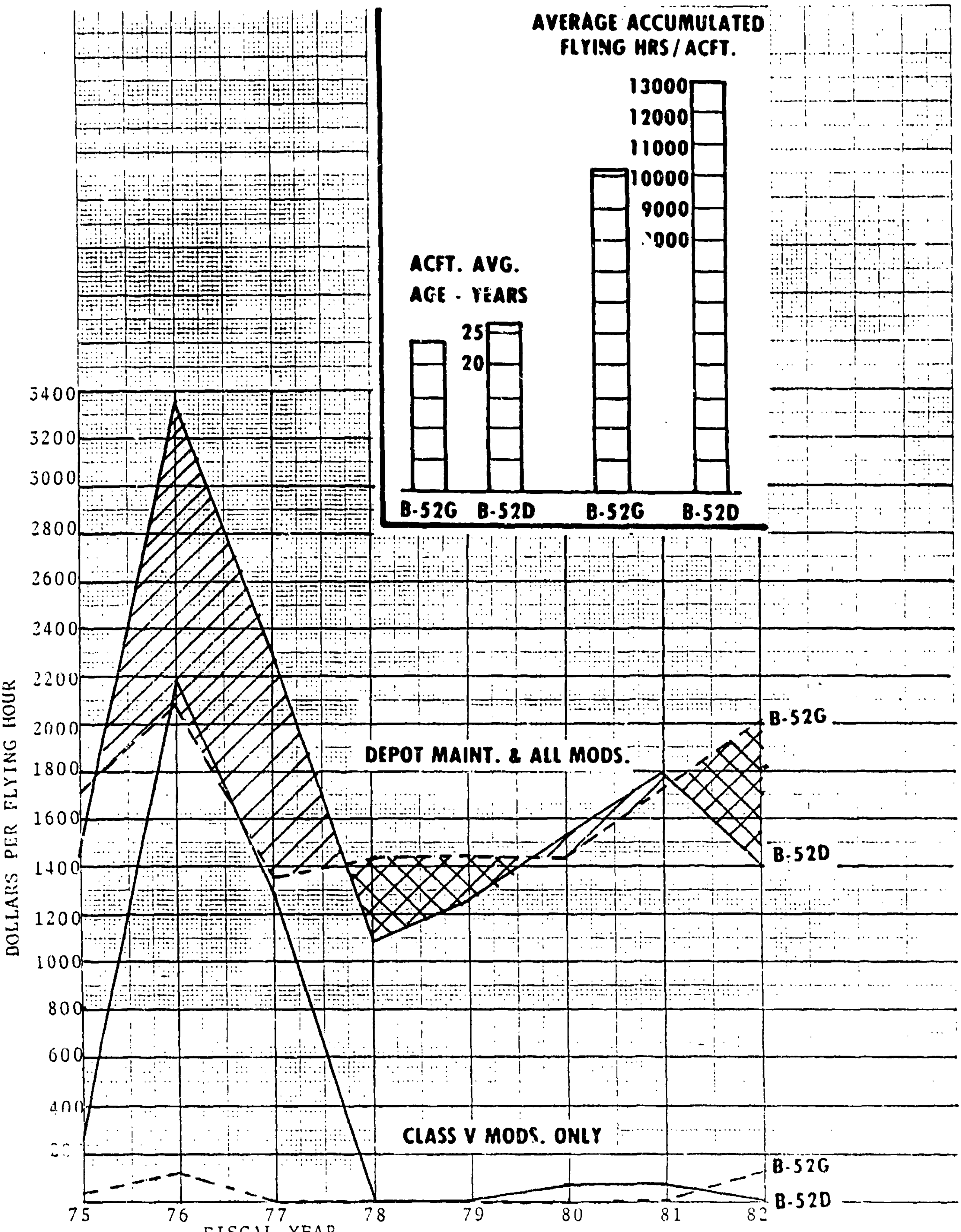
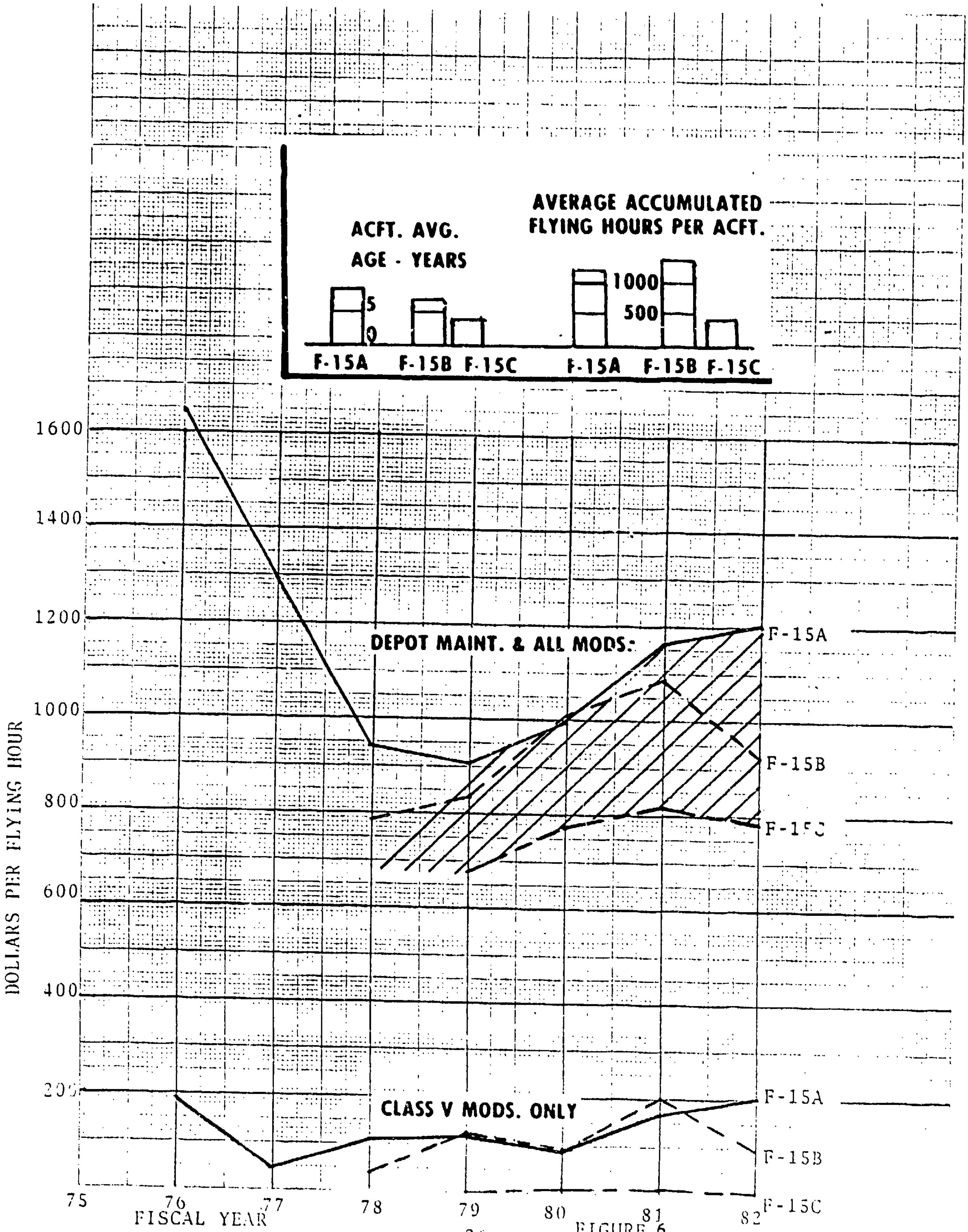

AVERAGE ACCUMULATED FLYING HRS/ACFT.
13000
12000
11000
10000
9000
ACFT. AVG. AGE - YEARS
25
20
B-52G
B-52D
B-52G
B-52D
DOLLARS PER FLYING HOUR
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
DEPOT MAINT. & ALL MODS.
B-52G
B-52D
CLASS V MODS. ONLY
B-52G
B-52D
75
76
77
78
79
80
81
82
FISCAL YEAR

FIGURE 5



AVERAGE ACCUMULATED
FLYING HOURS PER ACFT.
ACFT. AVG.
AGE - YEARS
5
0
1000
500
F-15A
F-15B
F-15C
F-15A
F-15B
F-15C
1600
1400
1200
1000
800
600
400
200
DOLLARS PER FLYING HOUR
DEPOT MAINT. & ALL MODS:
F-15A
F-15B
CLASS V MODS. ONLY
F-15A
F-15B
F-15C
75
76
77
78
79
80
81
82
FISCAL YEAR

FIGURE 6

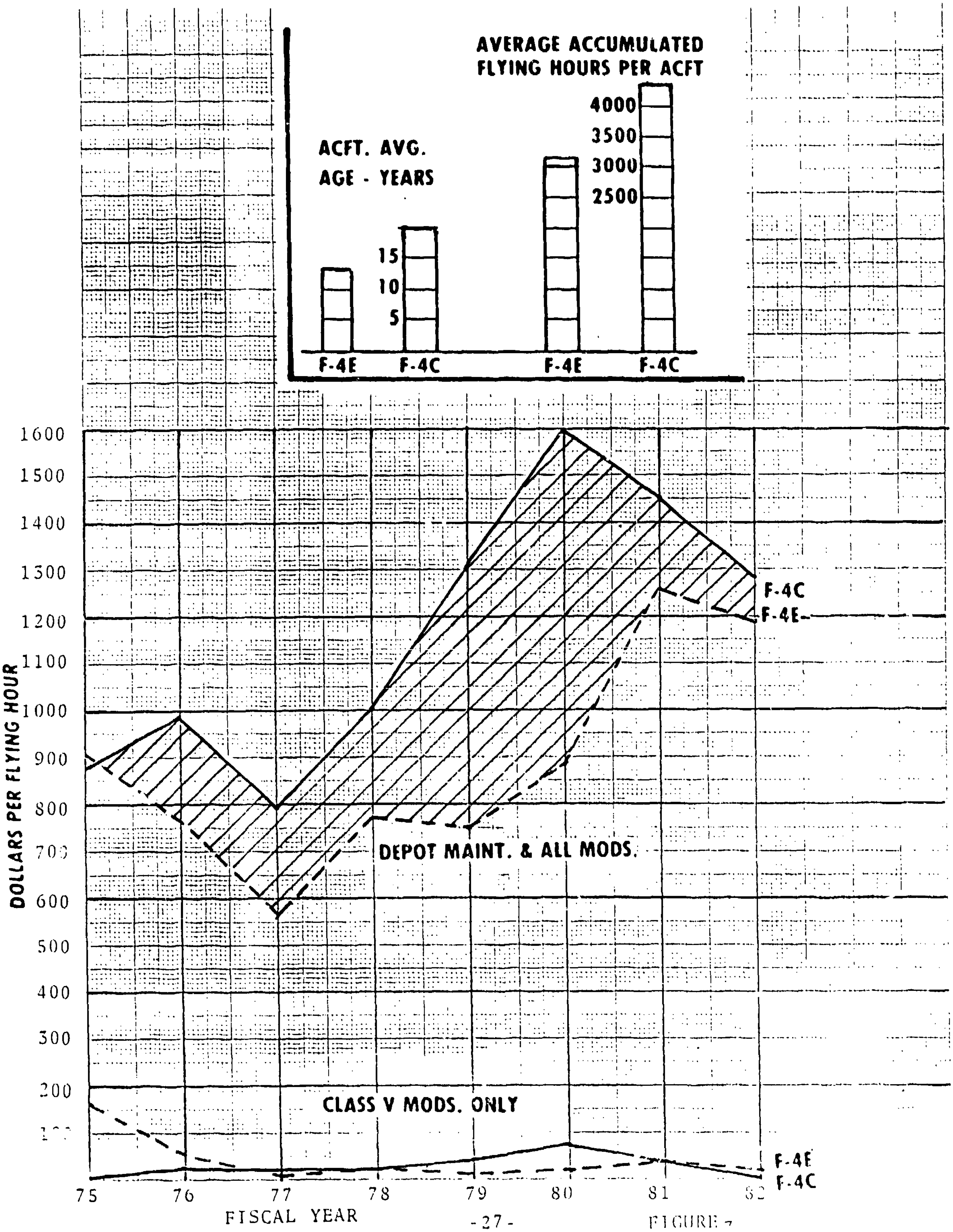

AVERAGE ACCUMULATED
FLYING HOURS PER ACFT
4000
3500
3000
2500
ACFT. AVG.
AGE - YEARS
15
10
5
F-4E
F-4C
F-4E
F-4C
1600
1500
1400
1300
1200
1100
1000
900
800
600
500
400
300
200
DOLLARS PER FLYING HOUR
F-4C
F-4E
DEPOT MAINT. & ALL MODS.
CLASS V MODS. ONLY
F-4E
F-4C
75
76
77
78
79
80
81
FISCAL YEAR

FIGURE 7

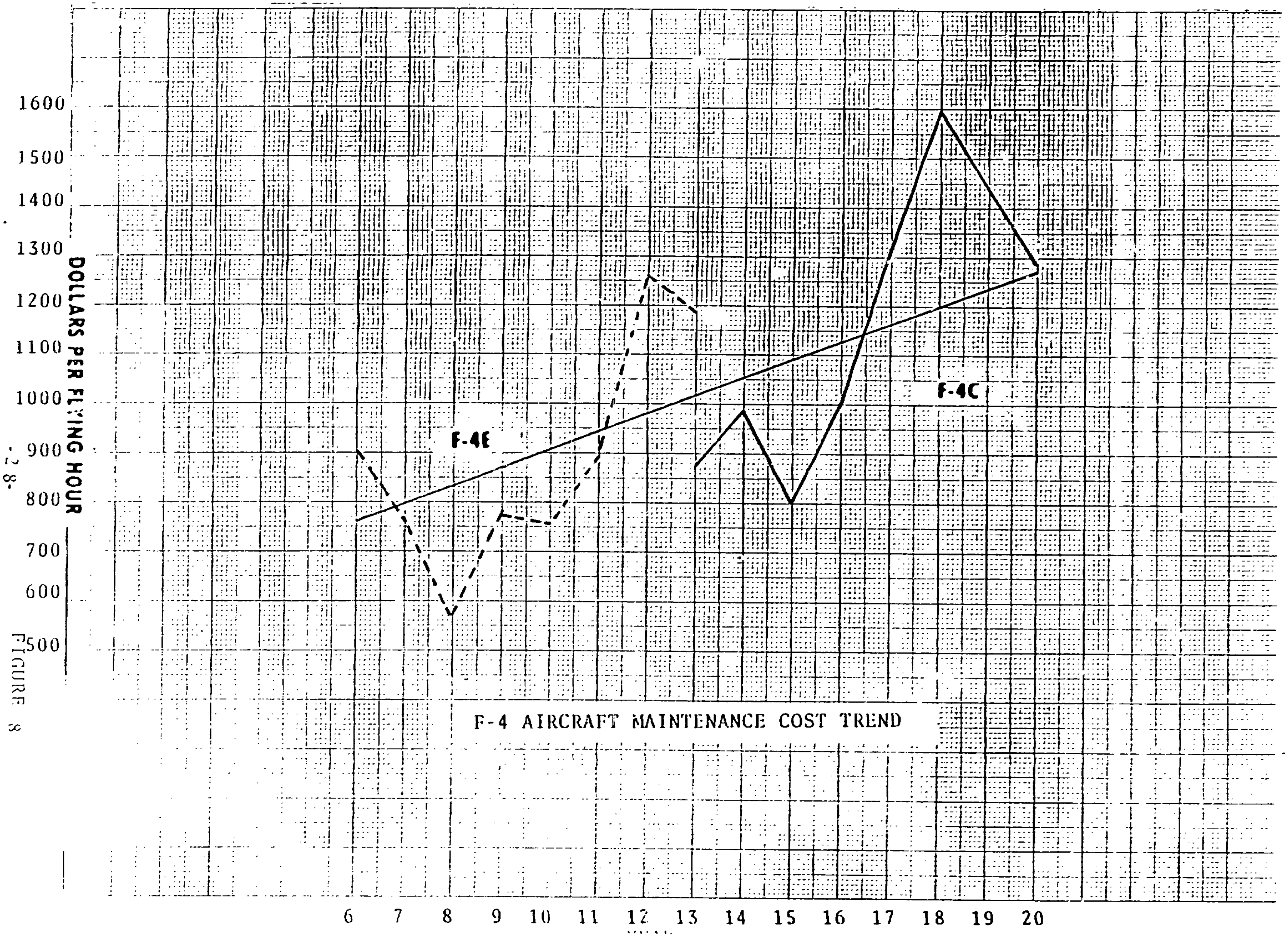

F-4 AIRCRAFT MAINTENANCE COST TREND
DOLLARS PER FLYING HOUR
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
F-4E
F-4C

FIGURE 8

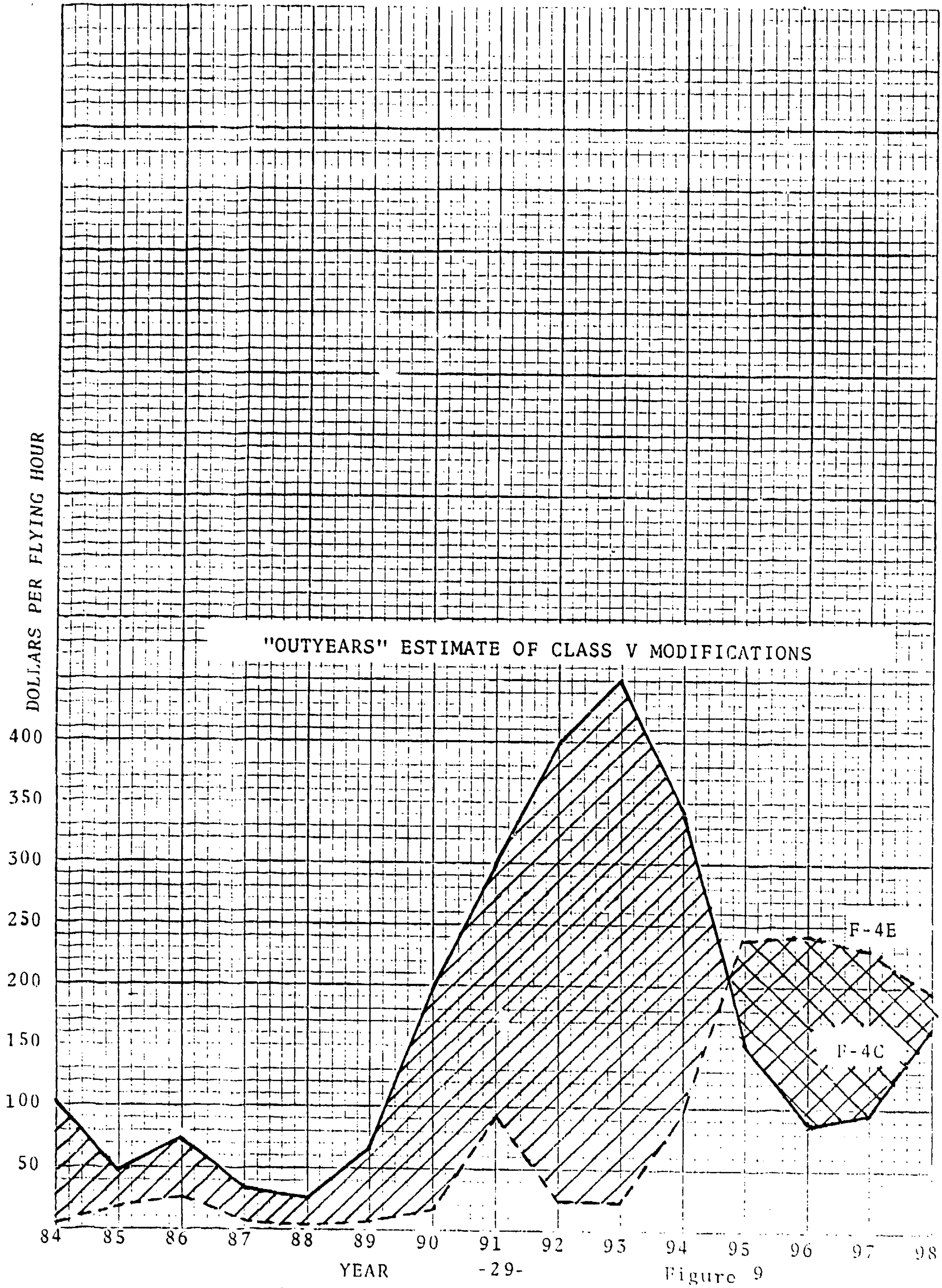

"OUTYEARS" ESTIMATE OF CLASS V MODIFICATIONS
DOLLARS PER FLYING HOUR
400
350
300
250
200
150
100
50
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
YEAR
F-4E
F-4C

Figure 9

F-101A/F-101C MAINTENANCE REQUIREMENTS TRENDS

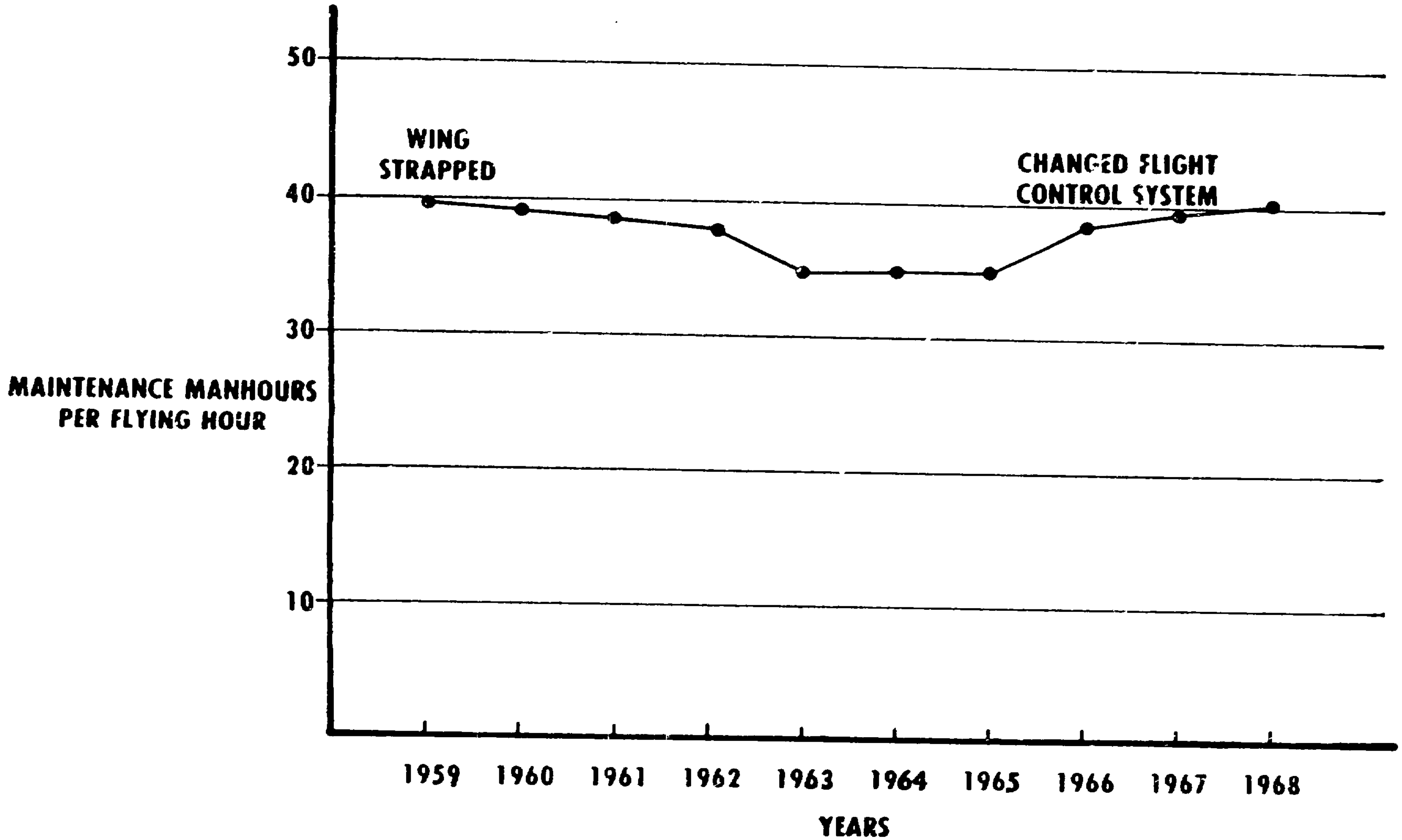


FIGURE 10

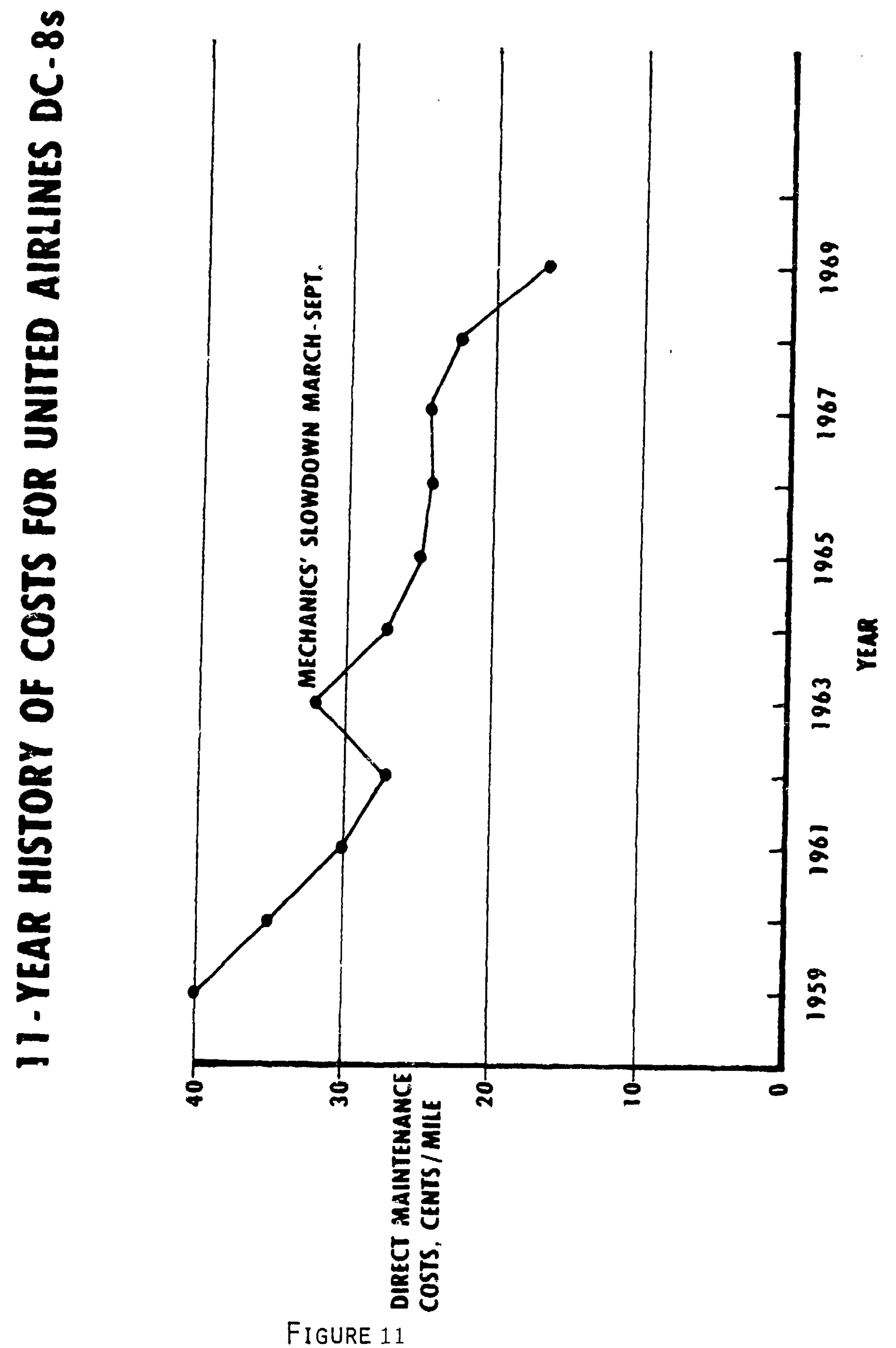

11-YEAR HISTORY OF COSTS FOR UNITED AIRLINES DC-8s
MECHANICS' SLOWDOWN MARCH-SEPT.
DIRECT MAINTENANCE COSTS, CENTS/MILE
40
30
20
10
0
1959
1961
1963
1965
1967
1969
YEAR

FIGURE 11

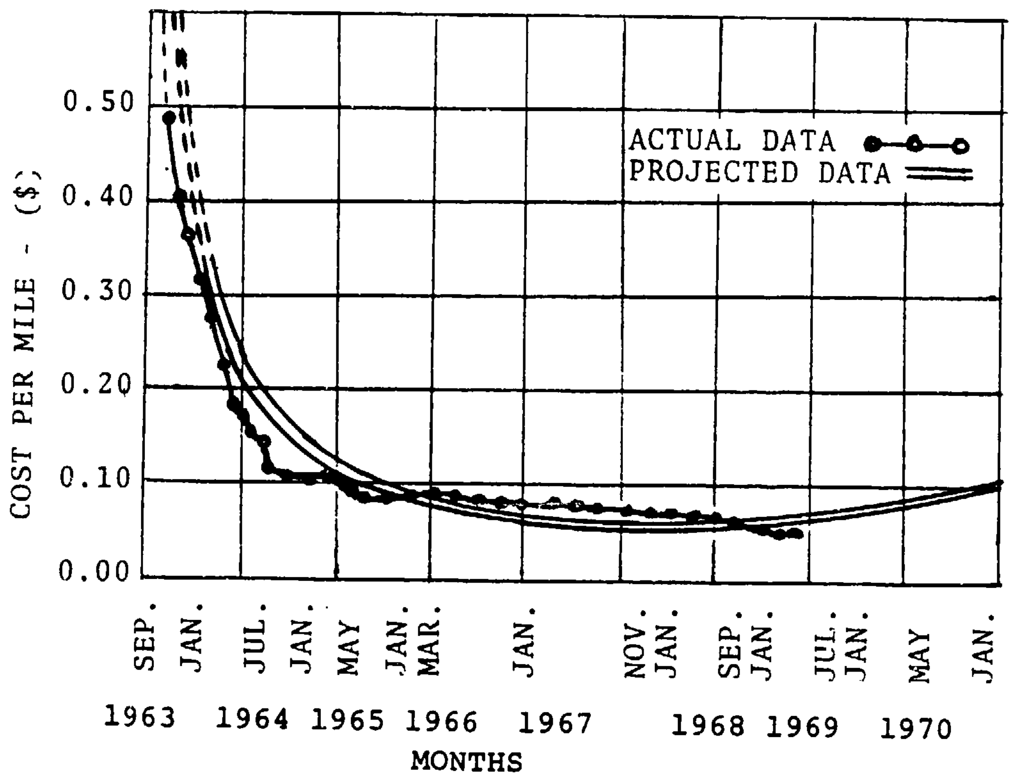

ACTUAL DATA
PROJECTED DATA
COST PER MILE - ($)
0.50
0.40
0.30
0.20
0.10
0.00
SEP.
JAN.
JUL.
JAN.
MAY
JAN.
MAR.
JAN.
NOV.
JAN.
SEP.
JAN.
JUL.
JAN.
MAY
JAN.
1963
1964
1965
1966
1967
1968
1969
1970
MONTHS

Figure 12

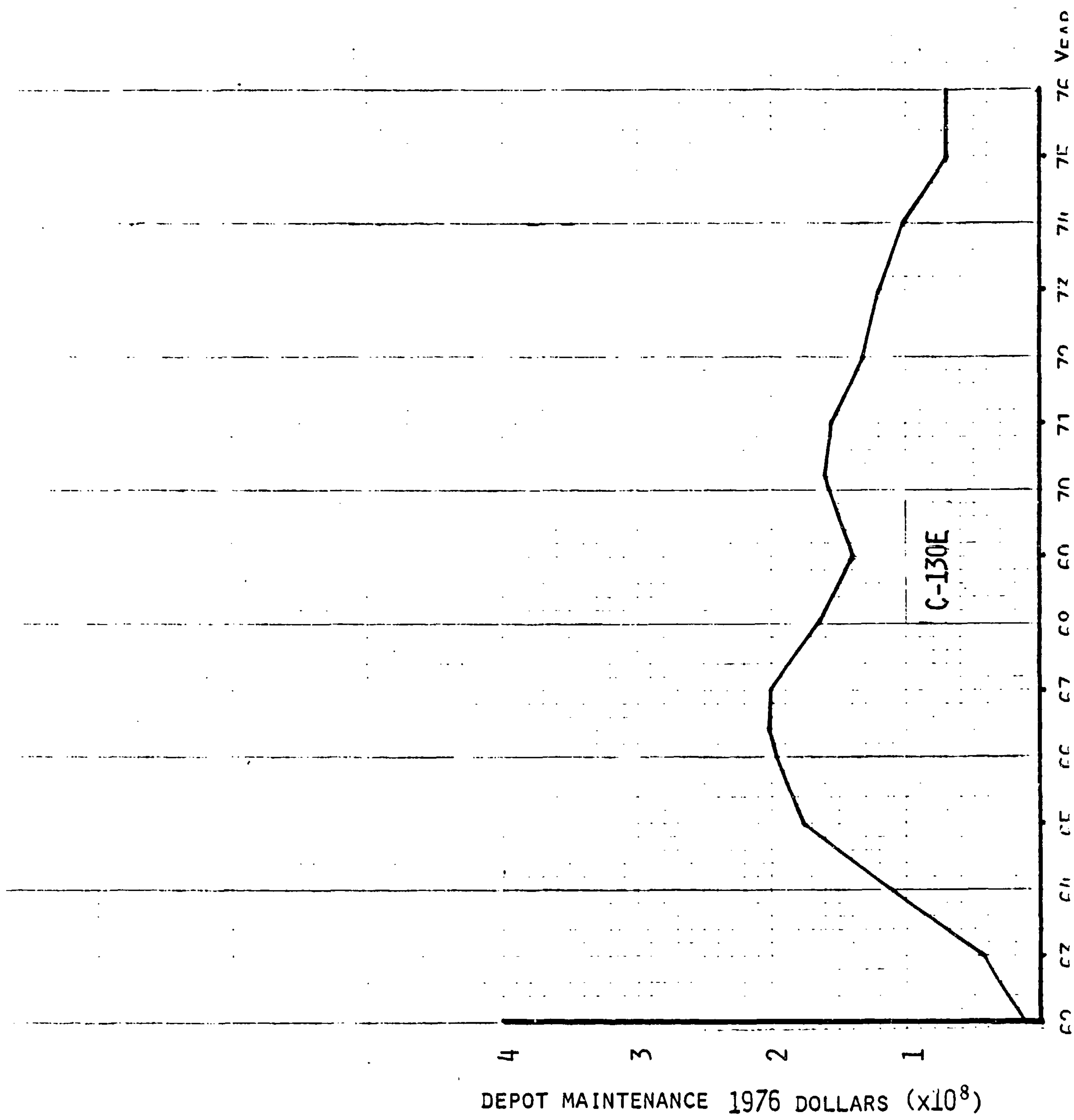


FIGURE 13