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PRELIMINARY ANALYSIS OF THE J-52 AIRCRAFT ENGINE COMPONENT IMPROVEMENT PROGRAM

by

Randall S. Butler

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PRELIMINARY ANALYSIS OF THE J-52 AIRCRAFT ENGINE COMPONENT IMPROVEMENT PROGRAM

by

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ABSTRACT

Increasing budgetary constraints have required program managers within the Naval Air Systems Command to justify their programs as never before. This thesis presents a preliminary analysis of the J-52 aircraft engine Component Improvement Program (CIP). The objectives of the research were to scrutinize the association of the CIP with promised improvements and benefits pertaining to the J-52 engine and to determine the obstacles that existing data bases present when an attempt is made to calculate the success or failure of a component modification. A history of the J-52 engine is provided along with a broad look at various engine performance parameter trends for the period 1984-1990. Ten Engineering Change Proposals (ECPs) are then examined. Analysis shows that while only one of the ten ECP related fixes can be directly correlated to a tangible increase in engine performance, the overall trends have been promising with regard to improving engine maintainability, reliability, and safety related factors.

TABLE OF CONTENTS

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To my wife, Ruth, and daughter, Kim, your understanding of the time I needed to complete this work is deeply appreciated. Your patience allowed me the opportunity to work in the manner required to finish and I thank you.

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I. INTRODUCTION

A. BACKGROUND

As requirements for resources continue to consume a large part of the shrinking defense budget, it is imperative that major claimants, and their related program sponsors, are able to justify the needs of their projects when delivering budget requests. This need to satisfy Congress goes beyond any parochial bickering. It goes to a need to ensure they, as sponsors, maintain sufficient levels of funding to better serve the fleet through properly addressing and ministering to fleet needs. This service to the fleet far outweighs any jockeying for funds that takes place. As each program element undertakes in-house appraisal during budget formulation periods, priorities must be set that truly reflect the sea-going Navy's needs. Proper defense of a given venture will almost certainly determine the life expectancy of that program. Specifically, the author believes, annual pleas for scarce dollars are now more susceptible to detailed analysis and cuts than on-going multi-year or continuing year expenditures. To meet this challenge, sponsors must maintain appropriate data to guard their programs and provide sufficient evidence that appropriated monies are prudently spent.

An important service performed for fleet aircraft, and a program that garners a substantial amount of money within the Naval Air Systems Command (NAVAIRSYSCOM), is the Component Improvement Program (CIP). The CIP plan involves engineering changes and improvements devised by the manufacturer, Pratt & Whitney for the J-52 engine, and NAVAIR-536 to mature engine systems.

The Navy's Component Improvement Program has been well documented in past theses. [Ref. 1] Prior research has provided a thorough background of how the CIP system functions and its importance to the service. The reader should consult these previous works if a deeper understanding of the program is desired. However, to ensure the reader possesses a basic comprehension of the need for CIP, the functions of the program are listed.[Ref. 2]

- *Problem solving*- Investigation and resolution of flight safety problems. Correction of service revealed safety of flight problems is the highest priority of CIP.
- *Problem avoidance*- Aggressive mission testing, analytical sampling and engineering analyses designed to forecast low cycle fatigue rates, life limits and detection of other deficiencies prior to their occurring in fleet aircraft.
- *Product improvement*- Improve engine maintainability, durability and reliability and provide tangible evidence of a reduced cost, of operation and support, of engine ownership.
- *Product maturation*- Provide engineering support to retain the engine's ability to perform over the lifetime of the engine in inventory. To use this opportunity to insert improved technology into the engine, its support equipment, accessories and replacement parts.

Both the Navy and industry agree it is not possible to predict potential deficiencies nor discern every discrepancy that exists in a design at the time of production. While rigorous tests are completed before an engine is accepted, it is not technically feasible to provide any absolutes regarding an engine's performance in a military environment. Thus, an acknowledged need for CIP exists.

The program is a long time fixture in the Army, Air Force and Navy. In 1978, Pratt and Whitney was called upon by Congress to defend CIP. Congressional leaders wanted to know what the taxpayers were getting for the monies spent. The company responded to a congressional inquiry in February of that year with a presentation to the Office of Management and Budget (OMB).[Ref. 3] Pratt & Whitney's convincing arguments resulted in the continuation of the CIP program as an integral part of DOD's effort to maintain readiness at a reasonable cost.

The program is initiated when an engine is placed into full scale development (FSD). Funding support for CIP is proposed annually by the Navy and is appropriated by Congress. In the case of the J-52, apportioned funding is divided among Foreign Military Sales (FMS) customers such as Israel, New Zealand and Indonesia and the Program Sponsor (OP-536).

B. OBJECTIVES

The subject of this thesis deals with the J-52 CIP conducted within NAVAIR-536. To assist upper level decision makers in the justification of the program, it is necessary they possess both an historical comprehension, and tangible proof of CIP's significance to the service.

To that end, the primary objectives of this thesis are:

- To examine the association of the Component Improvement Program (CIP) with promised improvements and benefits as pertaining to the J-52 engine.
- To determine the obstacles that existing databases present when an attempt is made to determine the success or failure of a component modification.

C. RESEARCH QUESTIONS

Questions concerning the effectiveness and worth of CIP on the J-52 engine are many. The continuing research effort at the Naval Postgraduate School has uncovered a few of the answers required to fully understand the significance of CIP's contribution to acquisition planning and related fleet readiness. Theses by other students, such as Sudol and Price [Ref. 4], Davis [Ref. 5] and Borer [Ref. 6], have examined CIP from an overall benefits of the program perspective. However, relating the benefits of the program to the Navy as they pertain to an individual, ongoing effort is the only true measure of whether or not funds have been effectively spent. In that regard, the author used the following questions to guide his research effort:

- Over the history of the J-52 engine, which modules or components have been improved?
- For what reasons were each of these improvements made (safety, reliability, maintainability, etc.)?
- At what level was the improvement completed (manufacturer, depot or Intermediate level)?
- What was the cost and how was it computed?
- What data is available to measure the success or failure of the modification? What new data is needed?

D. SCOPE AND LIMITATIONS

The research effort is focused on a sampling of Engineering Change Proposals (ECPs) that affected various segments of the engine's six sections (inlet, compressor, combustion, turbine, diffuser and nozzle). The changes/improvements were selected from a computer list of ECPs maintained in Pratt & Whitney (P&W) archives and were provided to the author during a visit to P&W Aircraft Group headquarters in West Palm Beach, Florida. The listing spans a time frame of 1972 to 1991, but is not an all inclusive directory of the changes issued during that period. Appendix A presents ECPs that have been issued since the J-52's inception.

To obtain a determination of CIP's success for the J-52, the author researched various aspects of the changes made and their respective impact on engine performance characteristics. In the process it became evident that it is not possible to define a specific set of criteria that must be met to consider the program a success. To determine any program achievements, individual ECPs must be examined for an explanation of the change. Then, a search for any improvement in engine performance must be done. Improvements may range from having no airplanes or crew lost due to a changed component malfunctioning, to the Mean Time Between Failure (MTBF) increasing to Unplanned Engine Removals (UER), or to engine-caused aborts decreasing. The nature of a change determines which performance characteristics should be emphasized.

Because an intent of this thesis is to provide information on the success of CIP, this thesis should be useful to Program Managers and Program Item Managers who are tasked with justifying CIP budget requests to major claimants and Congress.

E. THESIS PREVIEW

The remainder of the thesis focuses on the objectives discussed in section "B" earlier. Chapter II reviews the history of the J-52 engine and its use within the Navy. This is followed by a brief discussion of how a "fix" is generated within NAVAIR and a look at funding levels and engine deliveries since the engine's inception. Chapter III reviews problem areas encountered by the author while conducting his research. Chapter IV deals with the analysis of ten Engineering Change Proposals, chosen at random, that have been generated by the need for an improvement to an existing system. Examination of costs, dates of kit inclusion and the possible effects on engine performance is the essence of this chapter. At the end of the chapter, Pratt & Whitney's "Supportability Assessment" report is discussed in terms of how it may benefit the Navy in assessing the success of CIP. Chapter V summarizes the thesis effort and presents the conclusions and recommendations of the author for further study.

II. J-52 CIP HISTORY

A. ENGINE PRODUCTION HISTORY

The military's use of the Pratt & Whitney (P&W) J-52 turbojet engine as a propulsion system for aircraft dates back three decades. Originally designed in 1956 for use in Douglas Aircraft Company airliners (JT8A-1 version), the engine's capability of generating 7,850 pounds of thrust caught the eye of military planners as well as commercial engineers. While the civilian trade version of the engine would take several years to reach the marketplace, the U.S. Air Force chose the system to power its North American Aviation Hound Dog nuclear missile. Designated the J-52-P-3, the Hound Dog's first successful flight took place in 1959. The Department of Defense's (DOD) various military planners and buyers incorporated the J-52 into the military's inventory during the early 1960's. In 1961, the Navy selected the military variant, the P-8, for installation in the Douglas A-4 *Skyhawk* attack aircraft; the added thrust powered the fleet's "sports car" until the early 1970's. In March of 1957 the Navy had chosen the P-6A variant, rated at 8,000 lbs. of thrust, for the A-6A. In 1966, at the height of the carrier-based bombing campaigns in Vietnam, the P-8A and its additional 700 lbs of thrust, was installed in the plane.[Ref. 7]

The J-52 engine powered both the A-4 and the A-6 *Intruder* in fleet aircraft during the Vietnam war, beginning in August of 1964 with the Gulf of Tonkin incident and continuing until forces withdrew in 1972. During 1969, the Navy and Grumman Aircraft Corporation developed an electronic version of the A-6, designated the EA-6B *Prowler*. The *Prowler's* mission calls for accompanying penetrating A-6's during combat missions and providing electronic defense suppression coverage, a sanctuary for the attackers, to operate in. Engineers produced the P-408 for the EA-6B, increasing thrust to 11,200 pounds, to carry the added weight of the sophisticated electronic gear, two additional aircrew to operate the advanced weapon system and additional fuel requirements. In 1970, the Navy chose the P-408 to power the U.S. Marine Corps' A-4M. Used extensively to provide aircover during the war in Southeast Asia, over 400 planes saw service during 1970-72.

In 1989, three updated versions of the J-52 came on line. Introducing the P-6C, P-8C and P-408A modernized the Navy's fleet of combat aircraft. The last J-52 engine production line, the P-408A, shut down in 1990 completing thirty continuous years of crafting the engines for military use. Due to recent contracts calling for a new engine, the P-409, to be installed in the new Advanced Capability (ADCAP) EA-6B, Pratt and Whitney has initiated plans to reopen the J-52 production line some time in 1993-94. [Ref. 8]

B. J-52 CIP CHRONOLOGY

Component improvement on the J-52 has been in effect since 1963. The means by which an improvement is instigated is uniform throughout the tri-services and serves to provide a strategic base from which the Navy and Pratt and Whitney address an engine problem.

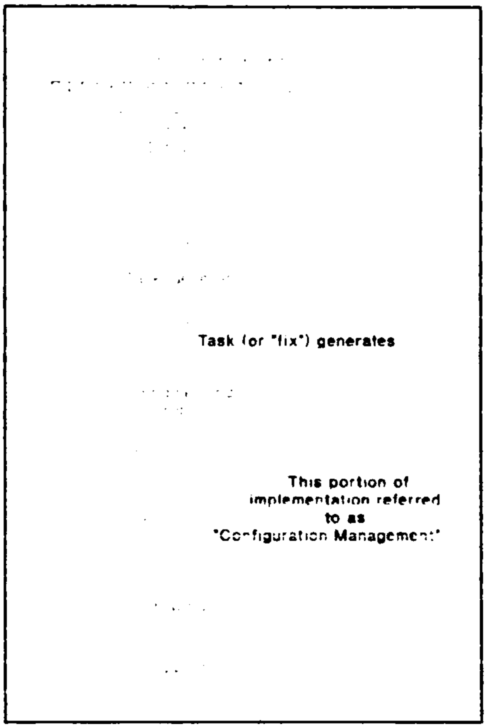

Figure 1. Course of events taken to effect a change/improvement.

Figure 1 depicts the process used by NAVAIR to effect a change to the engine's configuration. Discovery of a problem, in either a test setting or during actual fleet operating conditions, sets in motion a concerted effort on the part of NAVAIR and P&W to rectify difficulties encountered. Upon finding imperfections or defects associated with operational performance, a CIP "task" is generated which, in turn, produces an Engineering Change Proposal. Upon approval of the ECP, numerous activities occur, such as issuing a PPC if necessary, submitting publications updates and ILS support planning (see Figure 1). The proposal is then considered issued. The actual implementation of the change into the inventory of engines begins at a later date and takes anywhere from months to many years to incorporate, depending on the complexity of the task. [Ref. 9]

Although the CIP program has been used throughout DOD for many years, the J-52 program fell behind in approved requests for funding as other agendas were fulfilled during the 1980's. Indeed, during a tri-service CIP briefing in February of 1990 the state of the J-52 program during the early 1980's was addressed. [Ref. 10] The presentation revealed:

- Funding for the program was at an approximate 30% level of known requirements during the FY 74-84 period.
- The impact of the funding shortfall on safety and maintainability was costly. During an eight-year period from FY 77-85, thirty-two engine-*caused* Class-A[1] mishaps occurred (an 80% increase from the prior level), a 75% increase in *failed engine* removals transpired and an extraordinary 150% increase in Not Mission Capable (NMC) rates were observed.

In 1984 a recovery evolution was set in place to once again fund the J-52 at a level that would allow NAVAIR to accomplish the goals of CIP. Steps were taken to create a schedule to improve the reliability, safety and maintainability of the engine. A plan calling for approximately $500 million to be expended from 1984 through 1992 was activated to:

(1) Fund Low Cycle Fatigue (LCF)

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[1]. There are three classes of severity regarding mishaps: Alpha (A), Bravo (B) and Charlie (C). The Navy defines a Class "A" as: Total cost of damage $1,000,000 or greater and/or aircraft destroyed and/or fatal injury and/or permanent total disability incurred. [Ref. OPNAVINST 3750.6Q]

improvement measures, through a special LCF inspection program.

(2) Enhance methods designed to detect and repair "tired metal" in the engine's various components, by establishing new statistical limits.

(3) Increase spares procurement for the aviation supply system through detailed forecasting. [Ref. 11]

Continuing a trend of increased funding for improved readiness of the J-52, several Operational Safety Improvement Program (OSIP) improvements have been generated. The OSIP plan was developed to maintain and improve fleet readiness. Under this plan the Navy annually solicits changes or improvements from all weapon system managers for increased operational capability, Conversion In Lieu of Procurement (CLIP), safety considerations and improved reliability and maintainability for in-service aircraft. To be included in the program, aircraft must have two years of useful life remaining after the fix. [Ref. 12]

Refinements to the J-52 have included: [Ref. 10]

- Compressor blade stall elimination. Improvements to the bleed air system, thus resulting in a higher stall margin, were designed to improve on so called health-of-the-fleet parameters, principally Unplanned Engine Changes (UER), Not Mission Capable rates (NMC) and Engine Caused Aborts ECA). In the past, compressor stalls have accounted for a high percentage of UER, NMC hours and ECA.
- Oil system improvement. The oil system improvements were designed to improve the health-of-the-fleet parameters

also. In the past, oil leaks have accounted for a high percentage of UER, NMC hours and ECA.

- Fuel nozzle spray pattern. Engineers from P&W found that in addition to two aircraft being lost due to faulty nozzle spray patterns, the fuel injector and combustor system significantly impacted J-52 maintenance man-hours and maintenance actions. A changed system was designed to improve engine caused removals (ECR), MTBF and mean time between maintenance actions (MTBMA).
- Related to the change above, improved fuel control acceleration schedule adjustments were designed to increase idle to intermediate acceleration rates by one second. This is a significant number when operating in the carrier landing pattern.

C. EXPENDITURES, FLIGHT HOURS AND DELIVERIES BY FISCAL YEAR

Figure 2 shows that while total J-52 flight hours have remained fairly constant over the last twenty-two years, funds expended were severely decreased until an amount deemed necessary to bring the program back on track was apportioned, (the so called "get well" infusion of the mid-1980's). Figure 3 shows that the number of new engines delivered was severely curtailed after the Vietnam conflict. Finally, Figure 4 shows the number of PPCs that have been issued since 1963.

What may be inferred? The Navy has been forced to rely on fewer dollars expended, and sparse deliveries of new engines while operating at the same tempo as in the past. However, the number of PPCs issued is indicative of the successful impact the CIP program has had on the fleet.

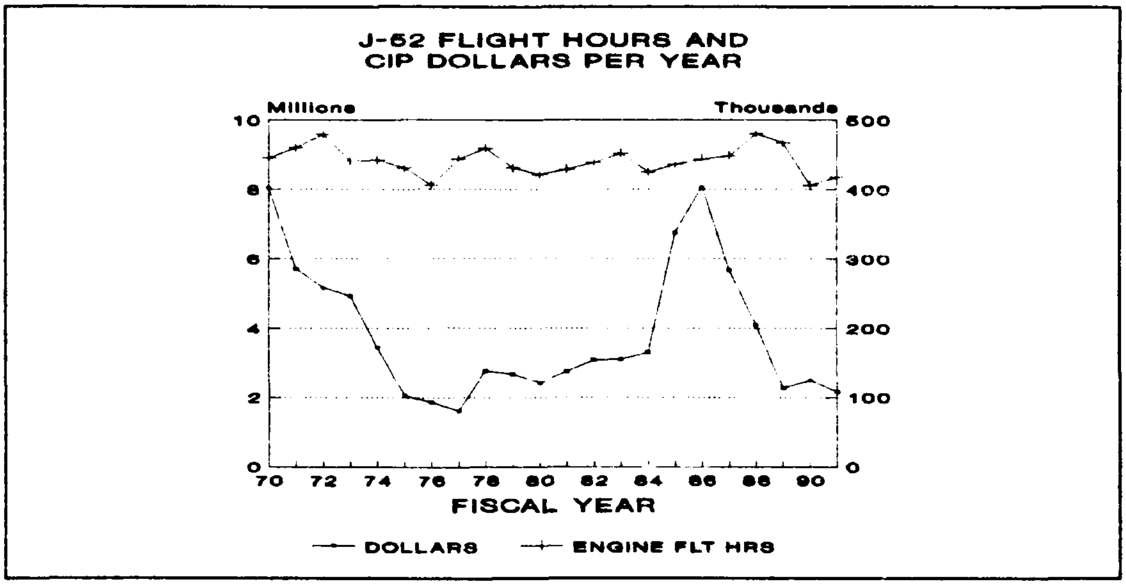

Figure 2. Number of flight hours per FY versus monies spent on J-52 CIP. Millions of dollars spent is indicated on the left with flight hours on the right.

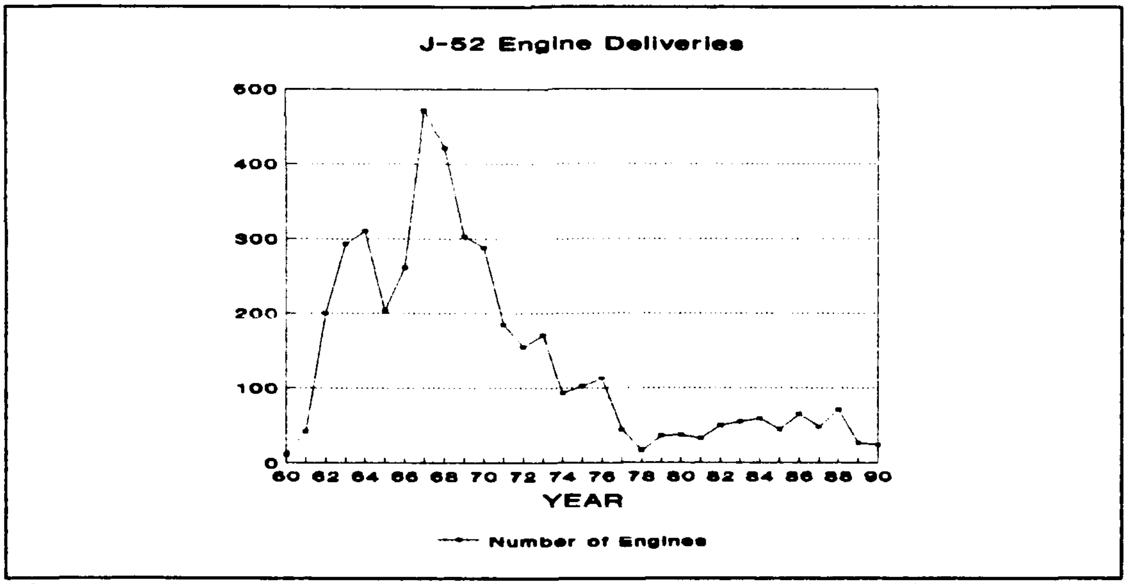

Figure 3. Number of U.S. Navy J-52 engine deliveries per fiscal year.

Figure 5 shows through projected flight hours, that the present family of J-52 engines is scheduled to be phased out by the year 2020. With the expected drawdown of DOD units to continue (fewer squadrons equal fewer planes), the advent of a new generation tactical bomber (AX aircraft) and a new J-52 engine planned (P-409), flight hours for the P-6, 8 and 408 will steadily decline to zero in twenty-eight years.

Assuming a twenty-year life [2][Ref. 13], the older J-52 engines in inventory are quickly nearing the end of their useful lives in 1992 and all engines in inventory will reach their twenty year life expectancy by the year 2010. If a robust, viable program is not in place to stem the loss of presently operating engines, as each year passes and parts are replaced or operating limits are lowered due to fatigue, overall readiness will surely suffer. As noted earlier, readiness has suffered in the past due to a lack of funding for the J-52 CIP. A presentation by Mr. Scott Cote' in 1989 noted during the period of 1983-88 that although overall engine MTBF improved slightly (21 hours to 25), MTTR declined to a NAVAIR defined "unsatisfactory" (from 6.2 to 6.8) and engine caused aborts per 1000 flight hours decreased to an "unsatisfactory" level (from 0.9 to 2.1). Because of this, and other related problems discussed in the following chapter, the need for CIP is even greater now than in the past.

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[2]. Weapon systems are usually acquired with the objective that they will satisfy military requirements for at least twenty years and engines are usually acquired as a unique part of the weapon system.

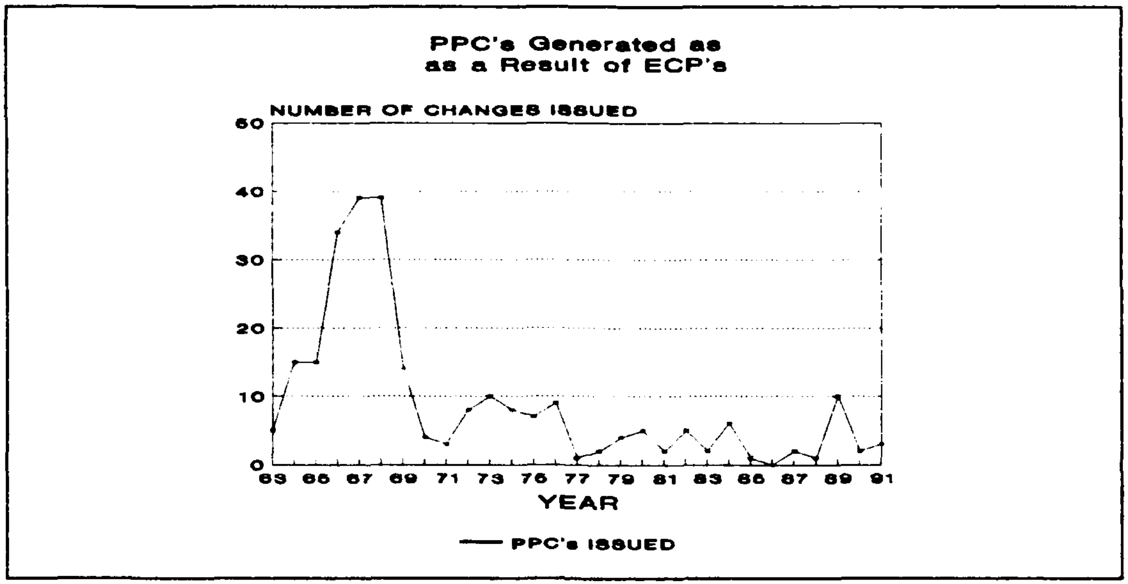

Figure 4. Number of Propulsion Plant Changes per fiscal year generated by Engineering Change Proposals from within the Navy and Pratt & Whitney.

D. CONCLUSIONS

The outlook for operation of the J-52 engine indicates that approximately 230 P-6 engines will be maintained through the year 2000 while roughly 1454 P-8 and 408 engines will support the fleet until the year 2020. Figure 5 shows the projected flight hours for the present variants of the J-52 through the year 2020.

At present, P&W is testing a new version of the J-52 engine, the P-409 (not shown in Figure 5). Scheduled for introduction into the EA-6B Advanced Capability (ADCAP) in 1995, P&W hopes to convince the Navy the engine would be the ideal replacement engine for the A-6 aircraft as well. It is not known at present how far that new engine will carry combat aircraft into the next century. Based on past experience, CIP will be needed for these new engines well into the twenty-first century.

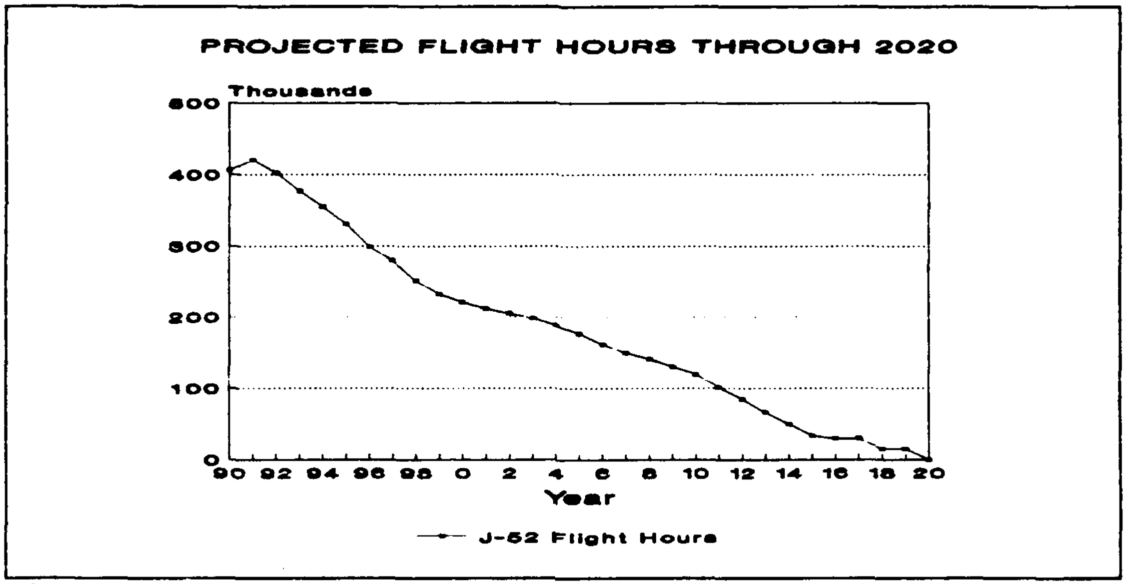

Figure 5. NAVAIR projected total flight hours through the year 2020 for all J-52 engines.

III. DATA COLLECTION PROBLEMS

During the research portion of this thesis, impediments to assembling material became frequent. To gather information, various persons within NAVAIR and P&W were consulted. Each request for data was responded to promptly and individuals graciously provided counsel in their areas of expertise. However, as the author found, having to contact multiple parties for relevant data was time consuming and illustrated the major problem in tracking the success of the CIP program for the J-52 engine. In addition, the sources of useful data are too spread out geographically and in too many locations inside of and external to NAVAIR to allow the data to be easily and quickly collected. Indeed, the author's location on the opposite coast from Washington and West Palm Beach presented a problem in expediting the gathering of data.

What is needed is a system that facilitates efforts to determine:

- if improvements are incorporated at an appropriate rate to realize the cost savings expended based on the ROI model. (i.e., are the Return-On-Investment (ROI) determined categories "years/flight hours to return investment" schedules followed?) Pratt & Whitney ILS managers and project engineers are aware the matter is out of their hands when the payback schedule is not met because the Navy's other priorities and limited funds determine the kit incorporation rate.

- if the advertised increase in safety, reliability, maintainability, supportability, or service life extension is actually achieved.
- if the cost of the proposed change is outweighed by the length of the remaining life of the engine. For example, determination of whether or not an increase in LCF would extend beyond the expected life of the engine or an increase in time between inspections requiring an engine removal stretches beyond the expected remaining life/usefulness of an engine.

This chapter covers the various data bases available that could be used to gather information for developing an insight into the J-52 CIP's success, a discussion of the continuity factor involved in assembling information, the source documents used in Chapter III's analysis and a method of kit incorporation used (attrition incorporation) and its affect on material collection.

A. DATA BASES

There are numerous databases available for use that collect maintenance related engine statistics. They include the Naval Aviation Logistics Data Analysis (NALDA), Maintenance, Material Management (3M); Aviation Engineering Maintenance System (AEMS) and historical records preserved by Pratt and Whitney. While containing an enormous amount of useful data, the databases did prove to be somewhat difficult to use.

1. CENTRALIZED DATA

The largest obstacle confronting the author during the research process concerned the dispersion of data sources. To begin an analytical search of the effectiveness of CIP on the engine, the author required background information on each change. The description of each change is best described in the ECP package. The ten Engineering Change Proposals described in Chapter III were obtained from Pratt & Whitney's project engineer during a visit by the author to the P&W plant in West Palm Beach, Florida. It should be noted that information pertaining to some proposals was also available from NAVAIR during a visit to Washington, D.C. However, NAVAIR staff believed that computerized data might be obtained from the engine's manufacturer. The ECP packages available at NAVAIR are in cardboard folders and only date back to the mid-1980's. To obtain older ECPs, the author had to look to the manufacturer. Pratt & Whitney maintains copies of most ECPs in their archives and copies of these were obtained.

Within each ROI section of the ECP pack, various categories of information are listed. To begin a background check of an ECP, it is necessary to know the time frame each change was incorporated into the inventory of J-52 engines. To gather information pertaining to the dates of incorporation for a particular ECP, the author used the Naval Aviation Logistics Data Analysis (NALDA) data base maintained by the

Aviation Supply Office (ASO) in Philadelphia, PA. The data base was accessed by NAVAIR NALDA operators who in turned provided the author with the output.

Data needed for performing cost analysis does not seem to be used extensively by NAVAIR-536. NAVAIR 524 provides budget analysis. NAVAIR 536 follows cost data only if the expenditure is large. While there is no set value used in deciding if NAVAIR-536 should closely scrutinize the figures, by and large budget analysis is left to others.

Finally, the Return-on-Investment (ROI) analysis provided with each ECP package is performed by P&W following a "cookbook" approach using the Navy supplied ROI manual. Each P&W ECP document contains footnotes listing sources of information used in each ROI analysis. However, not all ECP documents provide the same information (see Chapter III). In addition, the sources are quite varied (Navy pubs, P&W engineering estimates, etc.) and, while they could not possibly be located at one origin, it is the author's opinion that it is important for NAVAIR-536 to gather that information and use it to track progress.

2. ROI/COST DATA

While reviewing the ECPs, it became apparent that the year the document was issued determined the ease with which information could be extracted. When the Navy switched to using the ROI model now in place from what was formerly used to calculate cost savings, information more pertinent to determining program success began to be included. However, because this research is not intended to evaluate the Navy's use of the ROI model, a detailed analysis of whether or not cost savings were computed accurately or if they represent a fair savings to the Navy will not be discussed.

A common problem encountered concerned the data contained in the ROI analysis. Some documents included information that other documents did not.[3] This is partly due to the older ECPs being submitted prior to an ROI model being used by the Navy and because of the attrition incorporation policy discussed in section "D" of this chapter.

B. CONTINUITY

Most of the available data on the J-52 CIP is confined to the present. Recall or substantiation of facts, in most cases, goes back no further than records initiated during the present staff's tenure and, in some cases, no further than an individual's memory. The staff of NAVAIR-536 relies on an informal, impromptu network of personal contacts to gather and disburse information. This is an easier method of operating

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[3]. Specifically, package numbers 1-7 and 9 did not hold expected dates of ECP incorporation because a schedule is not used for attrition incorporation (see section E. of this chapter), numbers 2,3,5,6,7,8 and 9 did not contain years to incorporate into the fleet (see section E.) and numbers 2,3,5,6 and 7 did not have information relating to ROI cost analysis.

for the organization because of the networks of information and the associated friendships that have developed over time.

Records of ECPs dated earlier than the mid-1980's are not maintained in NAVAIR offices in the interest of reduced paper work. The staff of code 536 operates on the premise that data pertaining to ECPs prior to the 1985 time period are no longer as important as ongoing projects. In fact, approximately 109 completed ECPs were canceled in 1975 on order of the Naval Supply Systems Command (NAVSUP).

Pratt & Whitney maintains ECP packets pertaining to most of the ECPs/PPCs contained in Appendix A, with some documents kept on computer disk and others held in boxes in storage. All ECP documents requested by the author were quickly delivered from P&W so it is believed that further research involving obtaining ECP documents can be accomplished.

C. SOURCE DOCUMENTS

In his research for information related to the CIP program, the author was presented with many records by both P&W and NAVAIR-536, whose source was not, or could not be, identified or referenced. Much of the data had to be culled from copies of overhead slide presentations maintained by the two organizations. This presented a difficulty in proceeding from a common source of reference towards gathering information.

Statistical data contained in Chapter III was taken from referenced data that is maintained by various agencies within DOD or the Department of the Navy (DON). The author obtained ECIFR data from Mr. Scott Cote', Naval Air Warfare Center, Aircraft Division, in Warminster, PA to use in the analysis portion of his research. Presentation of the data in the ECIFR book, prepared by the Naval Weapons Engineering Support Activity (NAVWESA) for NAVAIR-536 and used in this thesis, was not compiled by the government's standard definition of fiscal year (FY) for the period from July 1984 to March 1991. Instead of showing information tabulated for a period from October of one year to September of the next year, the ECIFR data was compiled for a period from June to July for several of the publications and from March to April for two other editions of the book. This presented a problem with comparison analysis of various engine performance characteristics from the ECIFR against information that may be tabulated by fiscal year that either NAVAIR or P&W compiles. While monies spent, engines delivered and flight hours[4] are normally totaled by FY, the ECIFR data used here was tabulated by varying periods.

As for ease of use, all of the information in Chapter III that was calculated from the ECIFR could be easier to obtain from the publication if the pages of the section on the J-52

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[4]. Each ECIFR publication contains flight hour data for the period shown on the cover of the publication. This serves to contribute to the disorder of information as most other sources list flight hours by FY.

engine were divided into engine variant. In other words, one page containing only statistics on the P-6, one page of statistics on the P-8 and so on. If that change was made, at-a-glance examination could be accomplished for each variant without having to manually extract figures and calculate the various parameters.

Incident to the information itself, it is no secret that the validity of the numbers are suspect within the aviation community itself. It is ironic, that fleet maintenance personnel have little faith in the data they themselves submit.

D. ATTRITION INCORPORATION

Components that are incorporated via attrition are hard to assess as to their impact on an engine's overall performance. Because parts are changed when they wear out or when it is convenient to do so, there is no way to determine a time schedule for the change to be completed. From NAVAIR's viewpoint, attrition incorporation of ECPs has not been used in nearly two years because the kits are rarely, if ever, completely incorporated into the fleet. It is not cost effective to buy a change and then have parts wait in inventory for an engine to become available. [Ref. 14] From a research point of view, ECPs scheduled for attrition incorporation provide little insight into the impact a "fix" has on performance characteristics. This is because the incorporation of the kit does not follow any set, scheduled installation and is generally too spread out over time to provide any meaningful data that can be looked at and linked to an improvement in engine performance.

E. SUMMARY

A system is needed that allows NAVAIR-536 managers to track incorporation rates and whether or not increases in safety, reliability, maintainability and other advertised improvements are being achieved. Tapping the various data bases within the Navy supply system (3M, AEMS) and NALDA on a regular basis can provide needed statistics for tracking program progress. To aid in this undertaking, slight changes to the ECIFR might prove to be a key in quickly scanning data and deciding which numbers are useful. Finally, accurate recording of documents would enhance the historical perspective that follow-on personnel will need to conduct business in the future.

IV. ANALYSIS OF IMPROVEMENTS

A. SELECTION OF ECPs FOR ANALYSIS

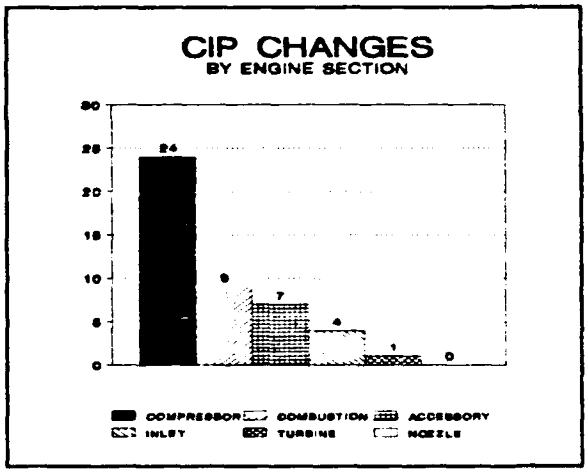

Figure 6. Engine Sections affected by CIP studied for this project.

Pratt & Whitney J-52 project engineer Bob Barrett supplied the author with a computer printout of forty-five component changes that were developed between 1979 and 1989, listed by Engineering Change Proposal number. Figure 6 depicts the breakdown of the number of these improvements by engine section affected. The graph shows that the majority of the changes/improvements occurred in the compressor section, with the combustion chamber a distant second. Interestingly, with the exception of compressor changes, the number of improvements involving the other sections of the engine are relatively close in number. The nozzle (or exhaust area) of the engine rarely affects logistics parameters. There were no CIP changes for that part of the engine between 1979 and 1989. In fact, there have only been four changes to the nozzle area since CIP began on the engine. [Ref. 15]

Ten of the improvements were chosen at random from the list for closer analysis and the author received their complete ECP packages for review from P&W. The packages are divided into six to seven subject areas. These include:

- The proposal itself, covering reasons for the change, background information on the cause of the change, engineering drawings, etc.
- Additions and cancellations caused by implementing the change.
- Return-on-Investment analysis.
- The actual Power Plant Change (PPC). This is the document forwarded to the various maintenance levels who will be installing the improvement.
- Technical directive validation requirements, listing changes to maintenance shop/worker manuals.
- Certification of data.

The information introduced in section B of this chapter was derived from these packages by the author and presents data necessary to begin a discussion of CIP's impact on the J-52 engine.

In the specific ECP sections addressed, various categories concerning costs, engine removal rate and repair rate levels, and years to incorporate the changes into the fleet were gleaned from the documents that contained Return-on-Investment (ROI) data. Where they appear, the charts at the end of the ECP discussions and at the conclusion of the chapter provide a graphic representation of some of those rates for the period 1984-1990. All statistics and data contained in these graphs were derived from the Engine Component Improvement Feedback Reports (ECIFR) extracts obtained from Mr. Scott Cote'. [Ref. 16] The categories, as defined in the ECIFR, that are in the graphs are engine-caused aborts (ECA), defined as any pre-flight or inflight abort due to aircrew perceived, or real engine malfunction and engine caused aborts per 1000 flight hours; Engine Caused Removals (ECR), both scheduled and unscheduled; Mean Time Between Failure (MTBF), derived by dividing flight hours for a given period by the number of failures, Mean Time Between Maintenance Actions (MTBMA), derived by dividing flight hours by the number of maintenance actions; and Mean Time To Repair (MTTR), defined as the maintenance time divided by the number of maintenance actions. In the following section, where no statistics appear in the Cost Information table, none were available in the respective ECP's ROI enclosure.

The data presented in the "cost information" is presented only to show the diversity of information available in ECP's. An in-depth analysis of the data in the tables was not attempted. The estimation of the operational costs after the fix attempt to recognize the changes proposed, planned or possible in accomplishing the fix. There is no simple procedure that can be used to accomplish this. Therefore, each ECP is studied by the manufacturer and perhaps by the Navy to obtain the estimates. [Ref. 17]

B. ANALYSIS OF SELECTED ECPs

1. ECP NUMBER 87XA240 [Ref. 18]

Date: 19 MAR 1989

Engine(s) affected: P-6B, 8B, 8C, 408, 408A

Reason for improvement/change: Service life extension

Subject: Combustion chamber case assembly. Construct a one piece case having a thicker wall with flanges, remove fuel drain valve assembly. Approved as 87XA240C1 on 10 August 1989. Sanctioned as an attrition/production change that has been incorporated into approximately 50 production P-408As and will be the chamber case used on the P-409 when that engine goes into production. [Ref. 19]

Level of maintenance accomplishment: Depot or Intermediate

Expected capability increase: An increase in outer burner case Low Cycle Fatigue (LCF). The walls and flanges of the new case provide a strengthened configuration. Present LCF of 1400 hours will be increased to in excess of 7000 hours. The structural reliability of the case will be improved by reducing the possibility of case fracture due to high stress loads. The new case will reduce engine maintenance and improve aircraft readiness.

Cost information:

Costs / FH w/o fix	$29.95944	Expected ECP start date	
Costs / FH with fix	$4.644068	Expected ECP end date	
Total investment cost	$2978335	Actual start date	2/89
FH to return investment	117649	Actual end date	Continuing
Years to return investment	3.33	Engine removal rate reduction	
Years to incorp into fleet	6.08	Engine repair rate reduction	

The information above shows the expected costs per flight hour both with and without the fix incorporated. They are estimates based on the manufacturer's and the Navy's best approximation of costs. The total investment cost to the Navy is simply the amount of money paid by the Navy to the manufacturer for the fix. The flight hours to return the investment are figured using the engine flight hours accrued for the last calendar year for each variant of the J-52 engine. In this ECP all variants of the J-52 are affected, so the total number of engine flight hours for all J-52 engines for the previous calendar year is the figure used. The figure used for the other ECPs is probably different. Years to return investment are calculated by dividing the number of flight hours to return investment by the engine flight hours per year. Years to incorporate into the fleet is based on the assumption that the modification is performed at a fixed and constant rate. Where a blank appears in the table, the information was not given in the ECP documents.

Results: Although the Navy has not purchased this improvement for existing engines, the change is being incorporated into production line engines by P&W. There is no data available at present to assess this ECP's impact because of the short period of time the change has been in the fleet.

2. ECP NUMBER 427138 [Ref. 20]

Date: 23 FEB 1984

Engine(s) affected: P-6B, 8B, 408

Reason for improvement/change: Safety hazard.

Subject: PPC-282. To increase resistance to fuel leakage by (a) improving seal durability and (b) inhibiting galvanic corrosion between the aluminum heater housing and stainless steel core. Eight instances of fuel intrusion into the A-6 aircraft environmental control system due to fuel heater leaks were reported between November 1979 and April 1982. A Naval Air Station, Jacksonville, Analysis Center study performed from June 1977 through February 1981 indicated that, although the fuel heater failure rate was low (1/26,000 hours), of the 63 observed failures 55 could be attributed to fuel leakage. In addition, during an unspecified period, 15 of 67 heater assemblies examined at Naval Aviation Depot (NADEP), Jacksonville, were found to leak.

Level of maintenance accomplishment: Retrofit at the Organizational or Intermediate level.

Expected capability increase: Elimination of the potential fire hazard presented by fuel intrusion into the environmental control system (ECS). This ECP was proposed before the ROI model was adopted by the Navy. Therefore, not all categories below can be accounted for in the packet.

Cost information:

Costs / FH w/o fix		Expected ECP start date	
Costs / FH with fix		Expected ECP end date	
Total investment cost	$ 868,712	Actual start date	
FH to return investment		Actual end date	
Years to return investment		Engine removal rate reduction	
Years to incorp into fleet		Engine repair rate reduction	

Status: There have been no incorporations as of this date. NADEP, Alameda was originally scheduled to perform this fix on all of the engines affected. In 1991, all depot level J-52 engine work was consolidated to be performed at NADEP, Jacksonville. While the kits have been shipped by the Navy for incorporation, none have been installed due to a stocking problem between the depot and Philadelphia. In addition, the depot is currently checking to determine if its autoclave is the proper machine to perform the change. [Ref. 21]

3. ECP NUMBER 427394 [Ref. 22]

Date: 30 MAR 1984

Engine(s) affected: P-6B, 8B

Reason for change/improvement: Durability (longer life), Safety

Subject: PPC-283. Installation of clamping arrangement, Pt2 tube assembly and related bracket on pressure ratio bleed control assembly.

Level of maintenance accomplishment: Retrofit at depot or I-level.

Expected capability increase: The Pt2 total pressure sensing line was experiencing fatigue cracks due to a high vibratory resonant stress. Two incidents on the P-8B and four incidents on the P-6B were reported between October 1981 and June 1982. The cracked tubes were found to cause mis-scheduling of the engine bleed system components, thus possibly resulting in engine stalls at 2000 and 10,000 foot altitudes. If a stall occurred, the cracked tube might prohibit engine relight capability in the manual mode. Installation of a new clamp incorporating a mounting bracket on the control mechanism was devised. Substantiating laboratory tests revealed the resonant stress was reduced by a factor of more than three times throughout a resonant range of 0-500 Hz thus reducing the possibility of the tube failing. (According to P&W, the normal operating range for the J-52 engine is from 50-220 Hz.) Like the preceding ECP, there is no cost data available because the present ROI model was not in place at the time of issue.

Cost information:

Costs / FH w/o fix		Expected ECP date	
Costs / FH with fix		Expected ECP end date	
Total investment cost	$60122	Actual start date	9/90
FH to return investment		Actual end date	Continuing
Years to return investment		Engine removal rate reduction	
Years to incorp into fleet		Engine repair rate reduction	

Results: Figures 7, 8, 9 and 10 depict abort data and maintenance factors for the P6 and P8 for the period the PPC has been undergoing incorporation. While a definitive cause for the decline in the abort data and reliability factors cannot be directly attributed to this fix, the positive trends are encouraging. The difference in abort data showing a more pronounced decline for the P-8 versus the figures for the P-6 can possibly be due to the airframe that uses the P-6 (A-4 Skyhawk) being older than the airframe which carries the P-8 (A-6 Intruder).

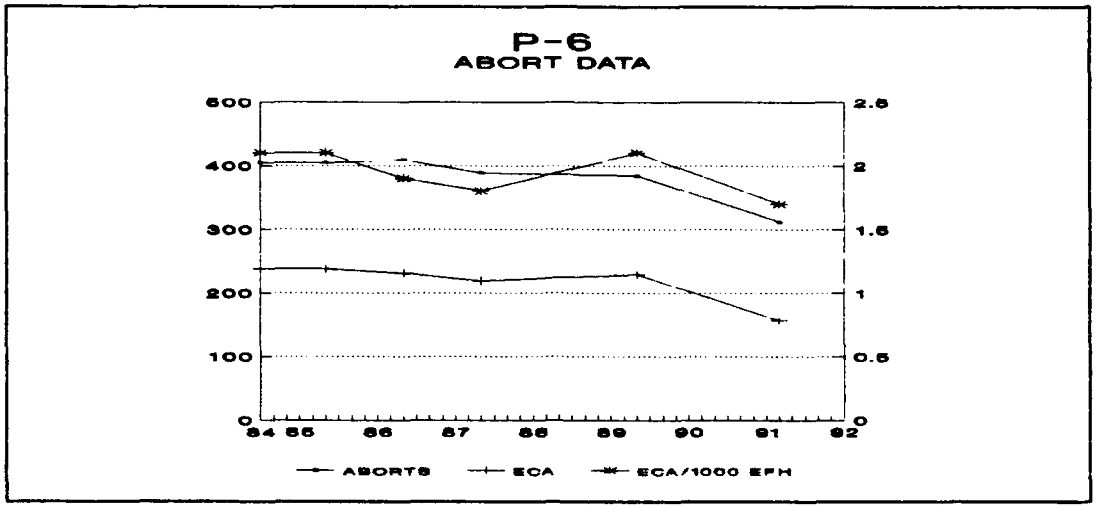

Figure 7. J-52 Abort Statistics; numbers of aborts and engine-caused aborts are depicted on the left axis while engine-caused aborts per 1000 flight hours are shown on the right axis.

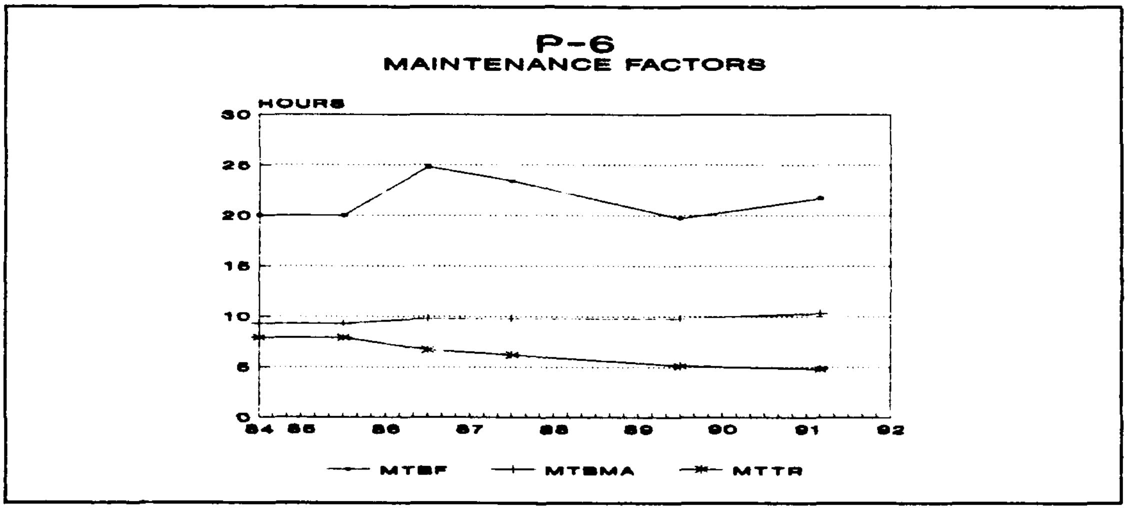

Figure 8. J-52 P-6 reliability factors; also depicts Mean Time To Repair (MTTR) data.

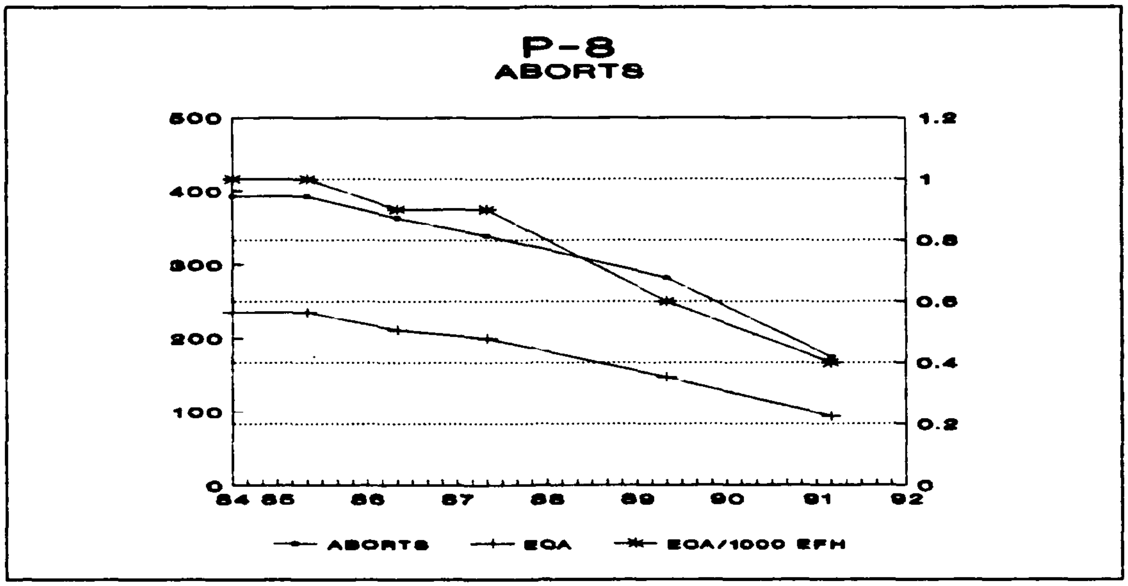

Figure 9. J-52 P-8 Abort Statistics.

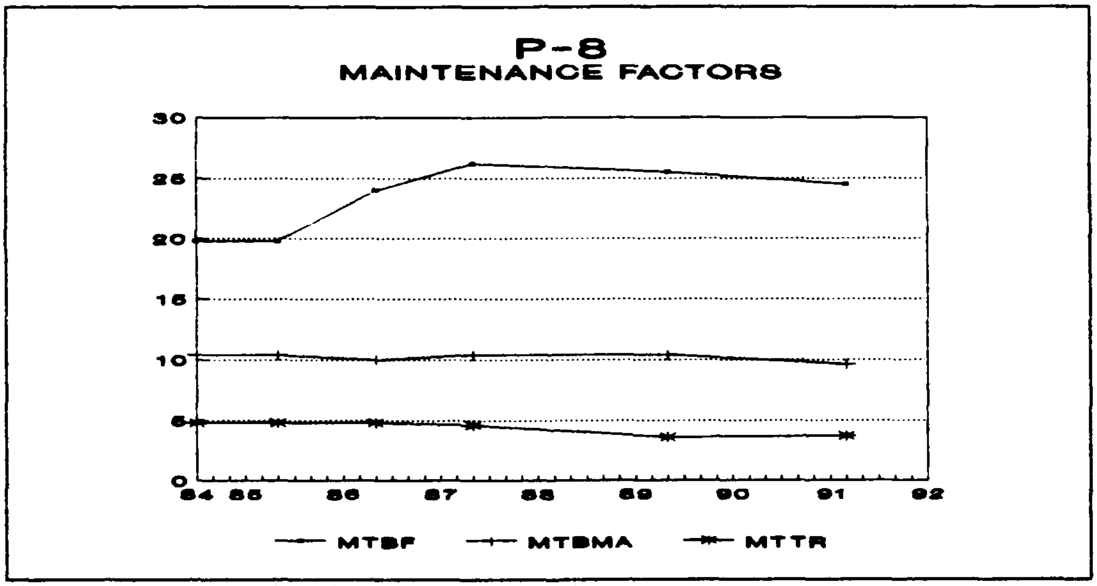

Figure 10. J-52 P-8 reliability factors. Also depicts MTTR data.

4. ECP NUMBER 256313 [Ref. 23]

Date: 27 JUN 1984. The Engineering Change Proposal (ECP) that originally provided this "fix" was first submitted to the Navy in October 1969. The ECP was disapproved by the Navy in May of 1970 because of the small number of reported incidents involving the affected compressor. The ECP was again submitted on 21 APR 1983, requesting approval by 19 AUG 1983. Because the timing of the proposal resulted in consideration extending into the following year, (1984) a Navy request was made to P&W to provide current (1984) pricing information and updated retrofit costs. The final approval came in 1986. This change is being incorporated as an attrition change with no kits and no special funding. The required parts are ordered by the depot when needed. **Engine(s) affected**: P-8B, 408

Reason for improvement/change: Operating procedures

Subject: PPC-275. Provide recambered 3rd and 4th stage compressor vanes for elimination of 5th stage rotor flutter stresses.

Level of maintenance accomplishment: Retrofit was recommended at the first depot-level visit after kits became available.

Expected capability increase: During the early 1980's the Royal New Zealand Air Force (an FMS customer) discovered nine of twenty-three 5th stage disks had fatigue cracks emanating from the blade pin hole in numerous disks on P-8B powered A-4 aircraft after the engine accumulated between 1200 and 2000 flight hours. The U.S. Navy reported seven similar cracks by June of 1982. There had been no reported P-6B or P-408 blade failures.

Pratt and Whitney engineers attributed the cracks to blade flutter. The distribution of mass and stiffness of the blade determine certain natural frequencies and modes of vibration. Flutter occurs when the blade is subjected to forcing frequencies near the natural frequency and oscillations develop. [Ref. 24] In the P-8 this usually happens at high altitude and low speed under "standard day" operating conditions (59 degrees F, 29.92 inches of mercury altimeter reading at sea level). However, under cold weather conditions it may occur at reduced altitudes. Under "standard day" operating conditions, flutter in the P-8 can occur above altitudes of 22,000 feet mean sea level (MSL) while it occurs above 33,000 feet MSL in the P-408. There are two A-6E missions that require possible entry into the flutter region on standard day conditions. Blade flutter in the P-6 does not exist within normal engine operating limits.

The option of not performing the change and merely lowering the operating limits of the airplane was discarded as unacceptable because, if implemented, the aircraft's mission could not be performed as designed and combat readiness would suffer.

Cost information:

Costs / FH w/o fix			
Costs / FH with fix	$29.95944	Expected ECP start date	
	$4.644068	Expected ECP end date	
Total investment			
FH to return investment	$2978335	Actual start date	11/89
	117649	Actual end date	Continuing
Years to return investment			
Years to incorp into fleet	3.33	Engine removal rate reduction	
	6.08	Engine repair rate reduction	

Results: This recambered stator change was incorporated into all production P-408 engines and they have operated without 5th stage problems since 1970. Therefore, it can be stated that there is conclusive evidence that this kit change has directly contributed to higher performance standards and fewer overall problems in the P-408 and is expected to provide the same benefit to the P-8.

Figure 11 shows how engine removals for the P-8 peaked during 1986-87 and has tended downward during the time PPC 275 has been undergoing incorporation. The upward peak in 1990-91 depicted on the P-408 graph can, more than likely, be attributed to problems with a seal in the compressor section of the engine that caused the blades to not contract after shutdown, thus causing the engine to seize up. That problem was corrected in 1990 by an ECP that is not covered in this thesis.

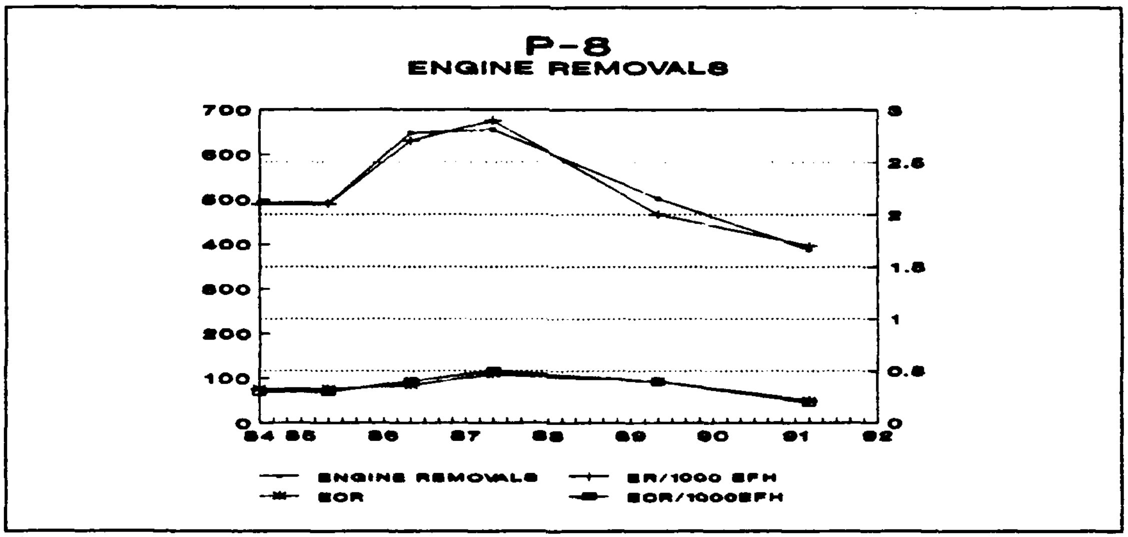

Figure 11. J-52 engine removal data for the P-8; engine removals per 1000 flight hours and engine caused removals (ECR) per 1000 flight hours are shown on the right axis.

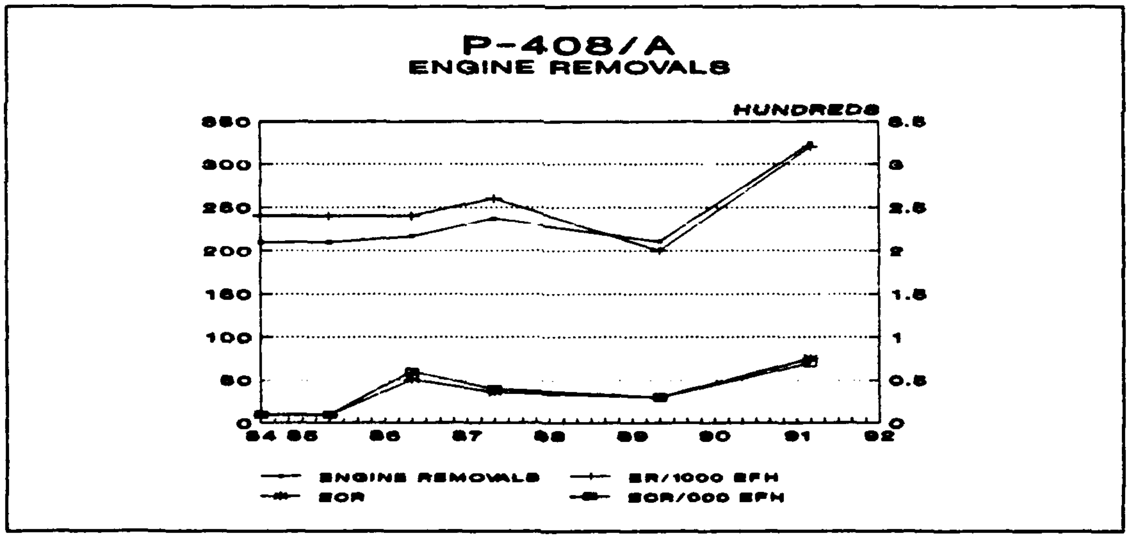

Figure 12. J-52 engine removal data for the P-408. Engine removals per 1000 flight hours and engine caused removals per 1000 flight hours are shown on the right axis.

5. ECP NUMBER 86XA639 [Ref. 25]

Date: 7 JUN 1990

Engine(s) affected: P-408, 408A

Reason for improvement: Safety, Service life extension

Subject: PPC-290. Incorporation of revised clamping hardware, elimination of potential plumbing interferences and the identification of kits for completing P-408A conversion.

Level of maintenance accomplishment: Depot level.

Expected capability increase: This change is complex and extensive. It involves major changes to the oil system, fuel system, inter-compressor bleed air system and the fuel control system. The work required by this ECP supersedes and cancels PPCs 232, 234, 241, 245, 253, 257 and 276.[5]

Cost information:

Cost information for this ECP is broken down as follows for expected cost per flight hour without fix: P-6= $38.80, P-8= $60.40 and P-408= $86.87. Expected costs per flight hour with the fix are: P-6= $13.90, P-8= $15.23 and P-408= $15.28.

Costs / FH w/o fix

Costs / FH with fix

Expected ECP start date

Expected ECP end date

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[5] The superseded PPCs cover changes to the bleed air system, oil line brackets, ignitor can work, combustion chamber improvements, combustion chamber mount pins, inlet guide vane control unit and more modifications to the compressor bleed air system, respectively. See Appendix A for P&W description of change.

Total investment cost	$179,14,972	Actual start date	6/91
FH to return investment	1,270,048	Actual end date	Continuing
Years to return investment	3.15	Engine removal rate reduction	25.2%
Years to incorp into fleet	TBD	Engine repair rate reduction	

Results: This ECP's impact cannot be assessed at this time because the engines which have been changed have not accumulated appreciable flight hours to make a meaningful judgment. However, due to the scope of the improvements included in the ECP it is expected to have a major impact on flight safety through lower Engine Caused Aborts (ECA), the cost of maintaining fleet aircraft through lower Engine Caused Removal (ECR) rates and in improved mission readiness through lower Not Mission Capable (NMC) rates.

6. ECP NUMBER 427906 [Ref. 26]

Date: 30 MAY 1986

Engine(s) affected: P-6B

Reason for improvement: None listed

Subject: No PPC issued. Provides for a different part number for the 2nd stage turbine disk that limits the disk to only be used, after rework, in P-6B engines once it has been installed in that engine.

Level of maintenance accomplishment: Organization level, by attrition of superseded part.

Expected capability increase: The P-6B and P-8B engines use a common 2nd stage turbine disk. The disk, when used in the P-8B engine, has a Life Cycle Fatigue (LCF) of 800 hours. However, the same disk, when used in a P-6B, has an LCF of 4500 hours. Re-identification of the disk and turbine rotor assembly would enable a field activity to reap the benefits of the intended 4500 hours of LCF in the P-6B. The ECP proposed a re-identification of the parts via new part number and two machined "flats" 180 degrees apart, so the difference would be readily identifiable visually.

Cost information:

Costs / FH w/o fix	$ .776	Expected ECP start date	
Costs / FH with fix	$ .135	Expected ECP end date	
Total investment cost	$8004	Actual start date	
FH to return investment	12,501	Actual end date	
Years to return investment	.803	Engine removal rate reduction	
Years to incorp into fleet		Engine repair rate reduction	

Results: Because of its age, there is no information in the NALDA data system on this ECP. In addition, NAVAIR 536 does not maintain any documents on this proposed change either.

7. ECP NUMBER 86XA427 [Ref. 27]

Date: 16 MAR 1987

Engine(s) affected: P-408

Reason for improvement: Safety, reliability and maintainability

Subject: PPC-292. Provides positive bolted attachment of the inlet guide vanes outer end to their respective bearings or coupling assemblies.

Level of maintenance accomplishment: Retrofit at first visit to Intermediate or Depot level maintenance

Expected capability increase: Intended as a follow on to PPC-256, this PPC was submitted because of fleet activities expressing concern over the reliability and the availability of the case assembly PPC 256 used. In addition, four episodes of either catastrophic or fatigue fractures were reported in December of 1985. Engineers from P&W determined that to resolve the safety problem, elimination of the wear between the vane and outer bearings and/or drive couplings was necessary. Positive screw attachment of the vanes at the outer end provides a reduction of the possibility of that wear.

Cost information:

Costs / FH w/o fix	$ 45.59	Expected ECP start date	
Costs / FH with fix	$ 1.86	Expected ECP end date	
Total investment cost	$ 304,358	Actual start date	11/90
FH to return investment	6960	Actual end date	Continuing
Years to return investment		Engine removal rate reduction	
Years to incorp into fleet	3	Engine repair rate reduction	

Results: Figures 13,14 and 15 show the trends for aborts, reliability and maintainability for the P-408 engine. While there is no conclusive evidence that PPC 292 has directly affected the positive trends depicted in the accompanying graphs, it is expected to contribute to a reversal of the recent upswing in safety related factors (aborts), the continued downward trends of failures and maintenance actions, and should reverse the upward trend of maintenance manhours while improving the steady trend of MTTR.

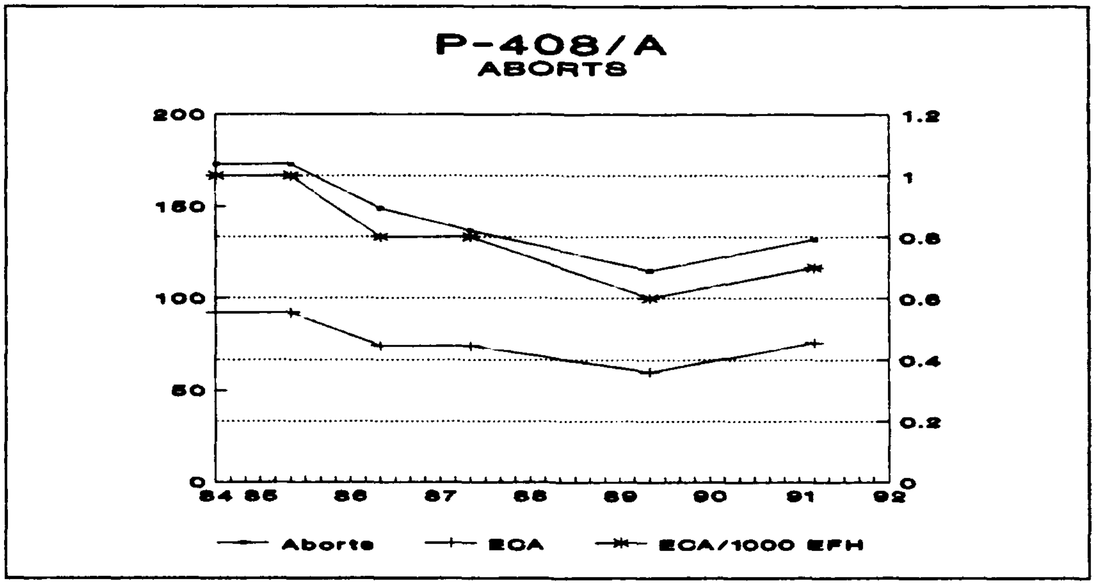

Figure 13. J-52 abort data for the P-408; aborts and engine caused aborts are shown on the left. Engine caused aborts (ECA) per 1000 hours is shown on the right.

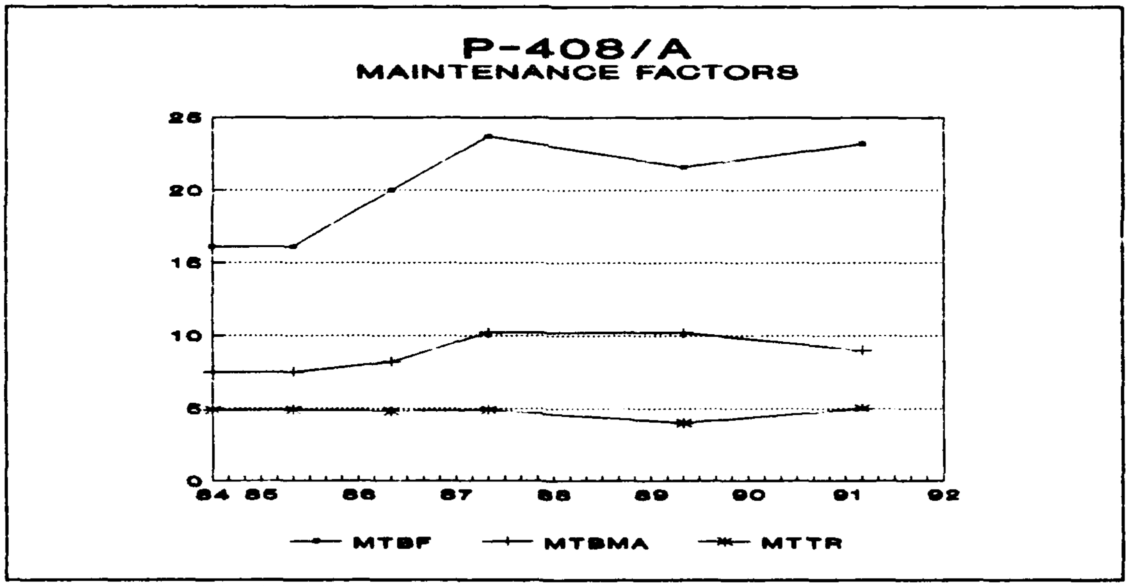

Figure 14. J-52 Reliability data for the P-408. Also includes MTTR.

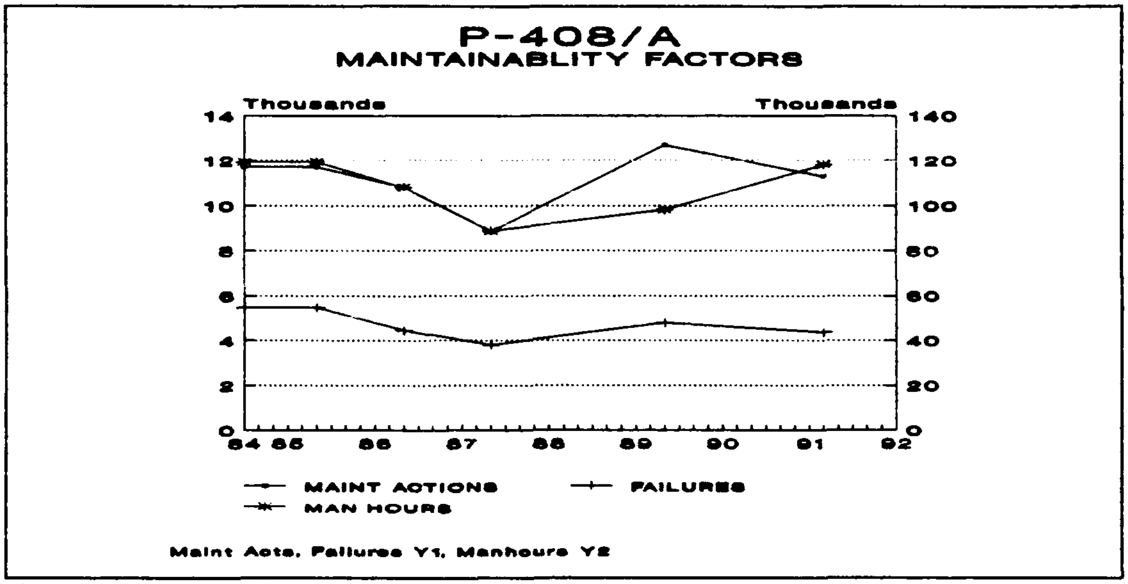

Figure 15. J-52 Maintainability statistics for the P-408.

8. ECP NUMBER 86XA567 [Ref. 28]

Date: 6 MAY 1988

Engine(s) affected: P-8B, 408

Reason for improvement: Increased service life.

Subject: Approved 29 September 1988, there have yet to be any incorporations due to budgetary/priority constraints. As such, there is no information in the NALDA data base pertaining to this proposed change. This change includes renaming of the rear compressor rear hub, providing increased LCF life due to an upgrade of the counterweight flange and saddle type counterweights, creating oil slots in place of drain holes and making the hub out of PWA 1010 material vice the present AMS 5660. This ECP is a production/attrition change and will not receive a PPC number. Thus, this change will not be tracked as a PPC in the NALDA data base because the NALDA data base is not designed to track ECPs.

Level of maintenance accomplishment: Not listed

Expected capability increase: The old hub was found to have low LCF lives at three locations:

(1) the counterweight hole
(2) the bolt hole
(3) the oil drain hole

Upgrade of the counterweight hole LCF is accomplished by adding a flange and saddle type counterweights along with scallops to eliminate hoop stress. Using material made of PWA 1010 for the hub, LCF at the bolt hole is increased. Replacing oil drain holes with oil slots increases LCF life at each slot location.

The rear compressor hubs being replaced on the P-8B and 408 by this ECP have calculated LCF lives of 3500 and 1900 hours, respectively. The new hub's LCF is calculated to be 10,000 hours.

Cost information:

Costs / FH w/o fix	$ 3.23	Expected ECP start date	11/89
Costs / FH with fix	$ .641	Expected ECP end date	11/91
Total investment cost	$103,513	Actual start date	
FH to return investment	39920	Actual end date	

Years to return investment	.13	Engine removal rate reduction	Engine not removed for cause.
Years to incorp into fleet		Engine repair rate reduction	

Results: Some new hubs have been incorporated as production changes only. Because there will be no information in the NALDA data base on this change, serial numbers of the production engine changes need to be known to track any improvements in engine performance.

9. ECP NUMBER 89XA295 [Ref. 29]

Date: 28 SEP 1990

Engine(s) affected: P-6B

Reason for improvement: Maintainablilty

Subject: PPC-296. To provide an alternative to the 5th stage bleed system configuration.

Level of maintenance accomplishment: Depot

Expected capability increase: Simplification of the 5th stage bleed system by removal of eleven 5th stage bleed valves and one manifold assembly will reduce engine weight by 3.4 pounds and result in improved maintainability.

Cost information:

Costs / FH w/o fix	$ .14	Expected ECP start date	
Costs / FH with fix	$. 03	Expected ECP end date	

Total investment cost	$ 8334	Actual start date	
FH to return investment	77742	Actual end date	
Years to return investment	3.88	Engine removal rate reduction	
Years to incorporate into fleet	3	Engine repair rate reduction	

Results: This change was approved by NAVAIR in May of 1991. The lead time on the kits is between 18-24 months. The change is scheduled for incorporation starting in March of 1993. The plan is to buy 230 kits in the first two buys. There are no problems associated with this change and it is expected it will be incorporated as scheduled. [Ref. 30]

10. ECP NUMBER 88XA034 [Ref. 31]

Date: 14 JUL 1988

Engine(s) affected: P-6B, 8B, 408

Reason for improvement: Safety, Reliability

Subject: PPC 291-Revision "A". The original PPC 291 did not provide for strong enough springs. Two more incidents of fuel control problems occurred after PPC 291 was issued. The new PPC, Revision "A", changed the Hamilton-Standard JFC25-3 Main Fuel Control by improving the operating force margins of the droop cam/linkage system. The operating force margins are increased by redesigning the droop cam torsion spring and droop lever load spring, thus preventing deceleration schedule impediment. "Deceleration schedules" determine acceleration/deceleration rates. Both PPCs 291 and 291 revision A addressed incidents during which pilots would decelerate and the main fuel control would undershoot, get hung up and the engine would then fail to accelerate. [Ref. 32]

Level of maintenance accomplishment: Depot

Expected capability increase: Several cases of delayed engine power response to power lever advancement were documented between August 1984 and July 1988. In August of 1984, a TA-4J experienced power response problems when trying to accelerate out of the landing configuration during an attempted landing at sea. After diagnosing the problem, an ECP was submitted in October of 1984 suggesting a more durable mechanism that would increase the cam return margin. The ECP was approved for attrition incorporation in April of 1985.

In November of 1986 a TA-4J crashed during an attempted landing in Massachusetts. After the accident, another PPC was attached to the ECP directing a new mechanism would be incorporated in all P-6 controls when returned to the depot and in all 408 controls whenever work was performed in the area of the controls at any level.

The proposed increased torque droop cam torsion spring and increased force droop lever load spring successfully completed rig testing for 100,000 cycles (idle to military power to idle) during development control.

Cost information:

Costs / FH w/o fix	$5.79	Expected ECP start date	11/89
Costs / FH with fix	$.0	Expected ECP end date	11/91
Total investment cost	$ 589,893	Actual start date (ECP 291)	4/82
FH to return investment	101,814		
		Actual end date	Continuing
Years to return investment	.27	Engine removal rate reduction	
Years to incorp into fleet		Engine repair rate reduction	

Results: A search of Engineering Investigation (EI) logs and Hazardous Material Reports (HMR)[6] by NADEP Jacksonville from 1989 through the present revealed that there have been no reported cases of droop cam hang up for engine fuel controls incorporating this PPC. However, there have been several instances of fuel control hang up in engines that have not incorporated the change: [Ref. 33]

- P-6B, July 89. On approach, fuel flow and RPM decreased. Manual relight was successful. EI confirmed the discrepancy.

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[6]. HMRs are submitted by activities when there is a suspected material failure in a piece of equipment.

- P-6B, July 89. Flameout when throttle retarded to idle on landing rollout. EI confirmed discrepancy.
- P-6B, August 89. RPM rollback when throttle pulled to idle. EI confirmed discrepancy.
- P-408, November 89. Mishap. Pilot ejected following engine flameout. EI did not confirm discrepancy.
- P-6B, December 90. Engine flameout at 17,000 feet. Manual relight was successful. EI confirmed discrepancy.

Hazardous Material Reports (HMR) filed during the same period reveal problems continue to also exist in other unmodified engines different from those listed above.
[Ref. 34]

- P-6B, 3/89. Failed deceleration check.
- P-6B, 5/89. Failed decel check.
- P-6B, 4/90. Failed decel check.
- P-6B, 4/90. Failed decel check.
- P-6B, 5/90. Failed decel check and exhibited fuel flow fluctuations.

The fact that EIs and HMRs have resulted from use of aircraft with engines that have not incorporated PPC 291 Revision A and no subsequent problems with the droop cam linkage have been experienced in those same engines following modification provides conclusive evidence that ECP 88XA034 has served its purpose.

C. SUPPORTABILITY ASSESSMENT REPORT

In the future, Pratt and Whitney will provide a "Supportability Assessment Report" (SAR) (Appendix B) for each PPC being installed if the report is called for by contract. The program is newly developed and due to budget constraints, the Navy has not ordered further reports. The report documents the progress of the PPC, provides an overall assessment of support performance, and establishes a durability (longer life) parameter baseline against which the durability performance of the applicable J-52 PPC can be measured and assessed. (see Appendix B) [Ref. 35]

The progress of the installation will be provided in the form of graphs for each affected model of an engine. In the report example, provided by P&W (dated 28 FEB 1991) for PPC 290, graphs were provided depicting delivery schedules, the quantity of engine conversions completed under the PPC and the number of conversions incorporated in new P&W production line engines. [Ref.33]

An overall assessment of the major ILS elements required to support the conversion engine can also be presented. The assessment reflects the performance of each ILS element in meeting scheduled events identified in P&W's Master Milestone Plan. [Ref. 33]

The durability assessment figures are based on Navy 3M and/or Aircraft Engine Management System (AEMS) data. Engine performance data for PPC 290, for example, can be evaluated through a comparison with the pre-conversion engine fleet baseline as well as monitored for trends. In particular, the three parameters monitored for trends are MTBF, Unplanned Engine Removals (UER) and Scheduled Engine Removals (SER). In addition, in the example in Appendix B, because PPC 290 is designed to improve on loss of engine oil problems, a graph representing oil-caused engine removals is included.

1. EXAMPLE REPORT INFORMATION (see Appendix B)

The graph on page 12 of the report illustrates that delivery of the new 408A engines has consistently been on, or ahead of, schedule since 1989, with a total of 49 delivered through mid-1990.

The graphs on pages 8-10 of the report depicting deliveries/conversions shows that, for the P-6C, kit delivery is on schedule through 1990 while ten conversions were accomplished for the same period. The P-8C kit delivery is also on schedule with nearly twenty conversions completed and 408A deliveries are slightly ahead of schedule with nearly forty conversions done.

Durability performance measurements for the P-6C display a fairly steady MTBF/EFH rate from mid-1985 to mid 1989 with a steady decline of UERs and oil caused removals (OCR) for the same period. While neither the UERs or the OCRs meet the desired goal established by NAVAIR, both are close to achieving their desired mark. Continued installation of the kits should help NAVAIR achieve the desired goals. [Ref. 36]

Durability marks for the P-8C's MTBF are similar to the P-6C in that they are fairly consistent from mid-1985 to mid-1990. The UER and OCR graphs are also similar to the P-6C and show that removals are relatively low per 1000 EFH (approximately 1.5 and 0.5, respectively) for the period.

Performance graphs for the 408A are also similar to the other engine family members showing a fairly steady MTBF/EFH of around 15/EFH, slightly declining UER (from approximately 1.75 to 1) and a constant 0.5/1000 EFH OCR rate.

While the parameters shown in the graphs are not all encompassing with regard to engine performance, they do provide a good overall view of the J-52 family of engine's operating characteristics for the period depicted.

The report also displays delivery schedules for the conversion engines and shows the status of major ILS contract elements that should be of interest to program managers.

D. SUMMARY

From the preceding analysis of data it is evident that correlating any changes in the multitude of parameters used to determine the J-52 engine's "health" is not impossible, but is not easy. While various parameters increase or decrease over time, actually linking a specific improvement to that movement can only be done if the problem is or is not detected in engines that have incorporated the change. The ECP discussed as number ten provides the an example of that connection in this chapter's analysis. An argument could be made that a link was also established, for the P-408, by ECP number four. Perhaps tracking specific engines through their life can provide the answer to the question of determining CIP's success.

For an overall assessment of measurable engine parameters, a program such as P&W's SAR provides an evaluation that is essential to future CIP justification. The different statistics that are used to measure the health of the fleet's engines are presented in an at-a-glance fashion and can provide the reader with an indication of how an ECP may be affecting the engine inventory. Further analysis can then be conducted to determine if a specific link exists.

V. SUMMARY,CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The intent of this thesis is to provide a foundation for answering questions regarding the success or failure of the Navy's J-52 CIP. A secondary concern has been identifying obstacles that hindered the process of determining the extent of any benefits gained through NAVAIR's pursuit of a viable CIP for the J-52.

To answer these questions, the author set out to gain knowledge concerning the history of the program and its impact on the fleet. It became apparent that the J-52 CIP is a program that has accomplished much in increasing the longevity of the engine and improving on the engine's record from a safety standpoint. However, after beginning work, the author found it was obvious that much investigative work needs to be performed, and different information sources tapped, to gain a deeper understanding of any achievements the program has attained.

Chapters I and II discussed the background of the J-52 engine, the engine's CIP and the objectives of the research. Much was learned about the engine's history, problems encountered during the 1980's when other programs took precedence over the program and the revitalization of the J-52 in particular after serious shortfalls in operability and performance were substantiated. Chapter III discussed the data collection process employed and some of the barriers encountered during research.

In Chapter IV, the author examined ten different Engineering Change Proposals selected from Pratt and Whitney archives. The proposed changes were varied and affected different sections of the engines. While a common set of criteria to be met for success or failure determination could not be developed, different logistics support parameters were analyzed. The results showed that of the ten ECPs, only one change could conclusively be linked to a measurable improvement. Others could not be irrefutably connected. However, the author attempted to show that during the middle to late 1980's, when an *extensive* J-52 CIP upgrade was undertaken, various engine parameters showed an overall trend of improvement. The author believes that the J-52 CIP played an instrumental role in those overall positive tendencies. Also briefly covered was P&W's new "Supportability Assessment Report".

B. CONCLUSIONS

There is no question that the J-52 CIP has performed an invaluable service to the Navy in general and the fleet in particular. The large number of PPCs issued (296) is in itself indicative of the impact CIP has had on the fleet's inventory of J-52 engines. Measuring that impact proved to be hard, yet the author believes it can be done.

The central problem encountered during research deals with a dispersion of available information, both geographically and within the Navy. The author believes that even if the information was readily available concerning component improvements, the task of determining any successes or failures would be daunting. The trouble lies in correlating a given fix to any improvements in performance parameters. Associating one fix or improvement with some part of a graphs depicting improvements, or lack of same in engine logistics measures does not take into consideration any other problems currently experienced, nor does it appraise the effects of any other improvements made. In other words, the installation of multiple PPCs may be producing the positive trend that is noted in a graph. However, because a negative trend may be caused by the effects of a new problem, it could mask an improvement resulting from one or more PPCs. By establishing a tracking program which follows the progress of need for changes and reflects the impact of any changes made on parameters such as reliability, maintainability, safety and others would most certainly provide a product that would be useful to program managers and would also provide budget justification for CIP.

C. RECOMMENDATIONS

What is needed to obtain an assessment of CIP's influence on the J-52 is the development of an easy-to-use tracking program that allows program personnel the opportunity to easily link, and then quantify, ECP improvements to increases or decreases in engine performance. The key is to use a building block approach to produce a prototype that completely researches the J-52 first, then evolves into a standardized approach that may be applied to any engine. The standardized approach might follow the following steps:

- Establish contact with the NAVAIR-536 business manager. He controls funding for the research effort and he should be consulted to find out if his office desires the research to go in any particular direction. He can also liaison within NAVAIR-536 for the researcher, identifying individuals who may be able to provide their expertise in the attempt to gain information.

- Next, contact the Navy individual (and/or their civilian counterpart) who "runs" the respective engine desk for the Navy. In the case of the J-52 it is NAVAIR-53611B. This person is the individual who maintains contact with the engine manufacturer. He or she is very conversant on the improvements undertaken on the engine and can provide ample insight into the CIP program for the powerplant. This person proved to be indispensable in the research for this thesis. Also within NAVAIR-536 are dedicated NALDA operators. They work every day with the database and are able to generate a wealth of information that can be used for analyses and evaluation. Maintaining regular contact with that section facilitates the process.

- The next contact should be with the manufacturer's project engineer. For the J-52, he is located at the Pratt and Whitney plant in West Palm Beach, Florida. The NAVAIR representative should be able to provide the researcher with phone numbers. Also, the Integrated Logistics Support manager at the manufacturers plant should be contacted. He works closely with the project engineer and together they can provide documents or contacts within the company for nearly any purpose the researcher may require. They also can provide insight into the manufacturer's perspective with regard to what is being accomplished through CIP. The two men who helped the author provided invaluable information for this thesis.

The next step is to research the particular area of interest. To benefit NAVAIR's future efforts directed towards defining CIP success, developing a portion of the tracking program mentioned earlier will also provide the perspective required to understand CIP. This program can be generated in the following manner:

1. Determine the engine's overall performance with regard to at least the logistics related parameters examined in Chapter IV. Statistics for this step should be obtained from either the Navy's 3-M system or the AEMS databank. In the case of the J-52 this task would have been much easier if the ECIFR data had been broken down and shown with each engine variant as a single page of the report. Mixing the P-6, P-8 and P-408 data together required this author to generate a Lotus spreadsheet to calculate MTBF, MTTR, Aborts/1000 hours and the other logistics parameters. This involved manually breaking down the statistics for each variant of the engine and then plugging the numbers into the spreadsheet to recalculate the "Overall" category of data. Changing the ECIFR report output would provide easy access to valuable information in an at-a-glance format.

2. With the help of NAVAIR-536 personnel who are assigned to the specific engine desk, determine which ECPs have generated PPCs that have been issued and are being incorporated into the fleet's inventory. It may help to pre-determine a cut-off for the ECPs. For example, only studying PPCs that have been incorporated for more than five years. Current information is probably more valuable. However, if the fleet's inventory of engines have not accumulated enough hours of operation since the fix, data may not be available that will provide any indication of the improvement's impact.

3. Sub-divide the performance analysis for ECPs/PPCs into those that (a) affect a particular section of the engine, such as the compressor or turbine; and (b) that influence a

defined set of parameters; for example, safety related matters (OSIP associated ECPs, engine associated Class "A" mishaps) or MTTR/MTBF measurements. Another possibility for study is to look at improvements advertised by the manufacturer. One area that is closely followed at NAVAIR concerns overhaul intervals. Hot Section Intervals (HSI), in particular, affect engine removal and component replacement rates. With an increase in HSI hours, fewer engine removals are required and thus fewer depot related costs. Another approach is to track individual components and their ECPs.

4. Care should be taken to avoid choosing ECPs that have been specified for attrition incorporation. When an ECP is chosen for this type of incorporation, NAVAIR loses configuration control. [Ref. 37] There is no money set aside for the kits and the depot then has to pay for parts when the parts in the engine become unusable. It is the experience of NAVAIR-536 that this process does not work well as the depot usually finds a way to make repairs to the old part instead of replacing it with a new version. In addition, when the parts are finally incorporated, because there is no set time schedule, correlating an improvement in engine performance to a given fix is virtually impossible. Typically, the fix has been installed into such a small increment of the overall inventory, that other influences, such as new PPC's or other, new problems mask any evidence of benefits.

The time that it may require to develop a tracking program for the J-52 adequate enough to be used for other engine CIP programs may be a couple of years. One approach to developing a plan for checking progress is to use the Supportability Assessment Report, already in place, from P&W. The information presented appears to be the type of data that the Navy's CIP needs. However, what may prove to be an even better approach is for P&W and the Navy to work jointly on a program. Using the ideas presented in this thesis and the Supportability Assessment Report already available, a more extensive procedure for tracing CIP achievements could be fashioned. An incentive for this type of an arrangement would be that the Navy acquires information showing how well its program is working while P&W gains a plan for convincing others how well it is accomplishing its responsibilities.

Appendix A

PPC#	SUBJECT	P6	P8	P408	DATE ISSUED
1*	Improved retention of temp sensor bellow & servo filter in fuel control JFC25-3 (clevis & cotter pin)	X	X		
2*	Repair worn surfaces on accessory & component drive housing mount boss	X			04/20/64
3*	Improved combust durability & replacements	X			12/22/65
4*	Provides ignitor plug cable clearance	X			
5*	Provides better lubrication, sealing on fuel pump	X			02/12/64
6*	Improved sealing of sequence valve housing	X			06/12/64
7*	Provides improved spring for fuel heater air shut-off valve	X			12/09/63
8*	Increase durability for compressor intermediate bearing housing	X			04/20/64
9*	Provides improves oil pressure regulation by removing strainer assembly	X			12/27/63
10*	Provides strengthened front hub configuration	X			09/04/64
11*	Provides a one piece #4½ bearing nut for improved nut retention	X			09/15/64
12*	Rework 11th stage spacer	X			05/21/64
13*	Provide more durable attachment for fuel heater	X			01/19/63
14*	Provides stress relieving of 1, 2 & 3 stage compressor blades	X			01/15/64
15*	Provides replacement of oil cooler by-pass valve	X			01/13/64
16*	Provides more durable fuel nozzle nut assembly lock	X			10/15/65
17*	Provides pressure test and reidentification of inner comb. chamber case	X			07/27/64
18*	Provides rework of main oil pump assembly improving wear	X			11/30/64
19*	Improves durability of main oil strainer assembly	X			02/17/65
20*	Provides 6th stage blade with improved durability	X			09/28/64
21*	Replaces tabwasher and rotor disk bolts from 5th stage	X			07/08/64
22*	Provides more durable bracket assembly of oil cooler & flowmeter	X			02/22/64
23*	Replacement of main oil strainer and cover assembly	X			12/29/64
24*	Reinforces #6 bearing sump. increased flexibility of oil and breather tubes	X			10/28/66
25*	Provides parts of increased durability from 12th stage hub/disk	X			12/21/65
27*	Provides improved anti-icing regulator valve	X			04/06/64
28*	Improve cooling #6 bearing compartment & #5 bearing pressure manifold	X	X		02/13/67
29*	Improve oil pressure relief valve assembly	X			05/06/65

(* Denotes PPCs cancelled in accordance with NAVSUP 2002, May 1975)

PPC#	SUBJECT	P6	P8	P408	DATE ISSUED
30*	Revis exciter trigger capacitor circuitry	X			05/04/65
31*	Provide improved oil sealing in #1, 2 & 3 bearing	X			07/16/65
32*	Rework of Pressure Ratio Bleed Control	X			01/13/65
33*	Increases clearance between 2nd stage turbine inner shroud & front face of 2nd turbine disk	X			No date
35*	Improved wear characteristics of flow deflector	X			12/30/65
36*	Provide improved lever pin retention	X			03/08/66
38*	Provides improved bushing to abate wear of gearbox housing bosses	X			03/08/66
39*	To reduce probability of damage to the flexible hoses	X			03/15/67
40*	Retain 2nd stage turbine vanes during horizontal assembly & disassembly	X			12/15/63
42*	Provides improved icing protection for low temperature fuel	X			03/02/66
43*	Provides stronger lock ring for assembling gearbox upper & lower driveshafts	X			09/02/65
45*	Incorporation of improved manual signal system	X			11/29/67
46*	Provides new gasket of anti-icing air valve	X			08/04/65
47*	Provides supporting parts with lower vibratory stresses	X			07/11/66
48*	Improved method of sealing the cooling fuel from the oil	X			01/20/66
49	Improved durability of oil deflector assembly & housing	X			01/18/66
50*	Provides support for the TSSA capillary tube to reduce possible damage by mishandling	X			07/19/66
51*	To remove an aligning rivet (outer combustion case)	X			10/13/66
52*	Increase clearance between gearbox breather tube & door support brace	X			11/04/65
53*	Improves the balancing rear compressor spacer assemblies	X			04/04/66
54*	Replaces oil tank level switch	X			09/26/67
55*	Incorporate clearance between 2nd stage turbine stator	X			07/19/66
56*	Removes engine fuel pump filter drain valve	X			12/28/67
57*	Provides new pressure ratio bleed control yoke shaft	X	X		03/16/66
58*	Provides spiral lock retaining ring and place for the double check valve bore	X			04/07/66
60*	Reduces possibility of blade rubbing during engine operation	X			05/23/66
61*	Deletes requirement for anti-icing req. & provides an orifice metering plate	X			03/02/66

(* Denotes PPCs cancelled in accordance with NAVSUP 2002, May 1975)

PPC#	SUBJECT	P6	P8	P408	DATE ISSUED
62*	Provides longer bolts for main oil strainer cover	X			05/13/63
63*	Provides new scavenge oil line to facilitate removal of gearbox	X			10/03/66
64*	Replaces bolts and inserts in accessory drive housing cover	X			03/16/66
65*	Adds two rivets to #2 bearing retaining nut for strength & safety	X			06/17/66
66*	Removes oil drain valve assembly	X			12/22/65
67*	Increase stud length on fuel screen chamber cover	X			04/04/65
68*	Provides improved main oil pump sealing configuration	X	X		03/02/66
69*	Provides stronger terminal in replaceable discharge tube well	X			10/12/67
70*	To improve gas flow profile in diffuser case	X			07/31/68
71*	To reduce contamination of the fuel pressurizing and dump valve	X	X		03/06/67
72*	To provide a better main fuel filter locking pin	X			10/05/66
73*	Reduce possibility of misassembling the fuel control plug retainer	X			10/03/66
74*	Provide for interchanging of turbine front housing and #5 bearing housing	X			09/08/76
76*	Provides better diaphragms in bleed override control	X	X		07/28/66
78*	Provides comp. bleed valve assembly with corrosive res. seal ring	X	X		07/05/66
79*	Increased durability stator assembly	X			11/08/68
80*	Preclude wear and looseness of diffuser case oil tubes	X			07/14/66
81*	Provides improved pressure ratio bleed control clevis pin retention	X	X		10/03/66
82*	Provides less fluctuating fuel pressure & dump valve assembly		X		04/04/67
83*	Improves strength of bleed override control by decreasing wear at coupling area	X	X		10/11/66
84	Repairs forward flange of heatshield inner turbine shafts assembly	X			06/17/66
85*	Provides preloaded fuel filter cover assembly	X	X		12/27/66
86	Rework fuel pump drive couplings	X			
87	Insured proper seating of 2nd stage inner air seal at assembly	X			11/04/66
88*	Improved retention of speed governor drive plate and split rings	X			03/31/67
90*	Provides better capillary tube shield on fuel control	X	X		08/26/66
91	Improves fuel control trim bar retention eliminating Pin "Z" wire retention	X			10/12/67
92*	Provide revised fuel flow schedule		X		10/12/67
94	Provides more durable oil pump assembly with larger bearing areas	X			08/01/66

(* Denotes PPCs cancelled in accordance with NAVSUP 2002, May 1975)

PPC#	SUBJECT	P6	P8	P408	DATE ISSUED
95*	Improve wear characteristics of rear comp rotor front hub	X	X		09/18/68
96*	Improve durability at threaded areas of main gearbox	X	X		03/20/67
97	Provides rework of main gearbox assembly and gearbox bearing housing	X	X		03/06/67
98	Provides more durable transition duct assembly (Comb. Chamb.) cancelled 08/30/84	X			07/03/67
99*	Provide a more accessible tail cover configuration	X			06/08/67
100	Provides additional blade tip clearance (compressor)	X			04/06/67
101*	Facilitate installation/removal of special thermo cable assembly	X			05/27/67
102	Provides more durable rear bearing support rod locknut	X	X		05/25/67
103	Provides stronger quick disconnect assembly drive rear bracket assembly	X			03/13/67
104	Provides better packing & seal of comp. internal front bearing seal	X			02/02/67
105*	Removes fuel derichment system	X			07/26/68
106*	To standardize comp. vanes & shrouds between the P6 and P8	X			06/26/67
107	To provide for new main accy. drive gear with relocated oil out annulus	X			05/01/67
108	Rework turbine exhaust strut assemblies	X			02/28/68
109*	Eliminates sharp bends in fuel control sensing lines	X	X		10/26/68
110*	Provides reinforced back-up screen for fuel control fine filter	X			04/04/67
111	Shortens outer knife edge seals of 12th stage air seal	X			06/30/69
112	Improve diffuser case serviceability by incorporating a threaded boss Ps4		X		01/15/68
113	Provides more durable fuel heater support		X		08/21/67
114	Provides more durable fuel nozzle support boss	X			06/27/69
115*	Provides better electrical thermocouple cable assembly		X		01/26/67
116*	Preclude the possibility of inner seal rubbing during engine operation	X			10/19/66
117*	Facilitates maintenance of 12th stage air seal retaining rivets	X			10/19/66
118*	Provides improved bearing lubrication in fuel control	X			12/01/66
119*	Insure correct alignment between comp. inlet case & front accy. support assemblies	X	X		05/01/67
120	Replaces fuel pump filter retainer clips (Pesco 028330-060-03)	X	X		
121	Adds last change filter to fuel control	X	X		11/15/68
122	Modification of Holley Bleed Override Control	X	X		06/07/68

(* Denotes PPCs cancelled in accordance with NAVSUP 2002, May 1975)

PPC#	SUBJECT	P6	P8	P408	DATE ISSUED
123	Reduce possibility of fuel control speed set level riding of trim bar	X			07/02/68
125	Prevents spinning of #3 bearing outer race	X			01/12/68
126	Incorporates a vibration damping filter in fuel control	X	X		11/11/68
127*	Provides improved pressure ratio bleed control adj.	X	X		04/13/67
128	Provides better security of access holes in plugs in #4 bearing area	X	X		03/21/69
129	Improves sealing of Pt2 canister in F/C	X	X		04/06/67
131	Permit P8 1st turbine blades in P6 engines	X			09/19/67
132	Provides a more durable gearbox housing	X			04/06/67
133*	Provides more durable oil tube gaskets, #4 bearing	X	X		01/18/68
134*	Rework #5 bearing nuts & locking plate	X	X		10/18/67
135	Revised turbine pressure sensing tube assembly to eliminate interference		X		07/13/67
136	Standardize design/lesser parts of anti-icing manifold assembly	X	X		07/13/67
137	Provides bolt circle attaching hardward to eliminate bottoming out of nut	X	X		04/04/67
138	Provides combustion hole pattern to decrease spread in TIT.		X		05/09/67
139	Facilitate comp. 12th stage air sealing ring replacement	X			04/13/67
140	Insure proper #4 Bearing nut seating at assembly	X	X		10/23/67
141*	Provides one piece turbine rotor air seal to decrease cracking	X	X		04/06/67
142	Provides #4 bearing heatshield with less axial slippage		X		
143	Provides better #5 turbine bearing	X			10/29/68
144	Provides better comp. inlet air manifold	X	X		05/26/69
145	Front comp. drive turbine shaft lock ring	X	X		11/08/68
146	Provides improved #4 and #5 bearing scavenge pump	X			02/07/68
147*	Provides nozzle vane with increased resistance to TE bow	X			08/13/68
148	Rework pressure ratio bleed control by reducing hysteresis	X	X		08/13/68
150	Improve wear between comb. chamb. & rear support assembly	X			01/26/72
154*	Incorporates counterweights in rear comp. spacer assembly	X	X		09/19/67
155	Relocation of remote oil fill bracket	X	X		07/24/69
156	Prevent fuel flowmeter lead from disengaging due to vibration	X	X		07/12/68
157	Prevent chafing of temp sensing line & fuel control casting	X	X		08/02/68
158	Rework #6 bearing strut boss	X			
160	Replacement of main gearbox P/L cross shaft and parts	X			01/29/68

(* Denotes PPCs cancelled in accordance with NAVSUP 2002, May 1975)

PPC#	SUBJECT	P6	P8	P408	DATE ISSUED
161	Provides proper seating of seals in oil pump cover/housing	X	X		01/29/68
162	Provides better QC on fuel control assembly	X	X		11/11/68
163	Replaces chafing sleeve straps with tape on Ps4 bleed control		X		05/20/68
164	Decreases vibration on pressure ratio bleed control assembly	X	X		07/01/68
165	Decreases movement of #6 bearing oil pressure tube		X		03/04/68
166	Installation of positive step for gearbox level drive shaft	X	X		11/15/68
167	Provides main oil strainer cover retaining nuts with increased life	X	X		10/19/68
168	Provides increased axial clearance of 2nd stage turbine air seal		X		03/11/69
169	Provides more accurate oil tank liquid level sensor	X	X		10/29/68
170	Incorporate steel bushings in #6 scavenge pump tube bores	X	X		08/07/68
171	Provides more durable ignition exciter		X		02/15/68
172*	Standardize vane/shroud assembly, 1st stage, to reduce weight	X	X		02/20/68
173	Conversion of TFN-14 ignition exciter 10-369510-1		X		12/08/69
174	Rework of 1st stage turbine inner support assembly	X			12/31/68
175*	Provides inspection for non-harden comp. inlet vanes	X	X		04/15/68
176	Rework of 12th stage disk, increasing its life	X			05/20/68
177	Provides additional clearance of fuel flowmeter adapter "O" rings	X	X		02/13/69
178	Revised fit—#3 bearing to housing and accy. drive gear to hub	X	X		02/17/69
179	Improve oil distribution and sealing between the shaft and #4 bearing	X	X		02/13/69
180	Shot peening of 2nd, 3rd and 4th stage hub and disk	X	X		07/15/68
181	Incorporates self-retaining bolts in fuel control linkage	X	X		12/19/69
182	Modifies manual system throttle valve assembly in fuel control	X	X		12/20/68
183	Additional blde tip clearance (comp. rotor 1st, 2nd, 3rd, 4th and 5th stages)	X			02/12/68
184	Reduces carbon formation on fuel nozzle by rework	X			11/17/69
185	Rework C/C/ assemblys to reduce exhaust smoke and improve low temp starting characteristics		X		04/11/69
186	Removal of 2nd stage turbine vane inner foot seal	X	X		01/17/69
187	Facilitates maintenance of thermocouple cable assembly	X			09/03/69
188	Replacement of comp. inlet case assembly	X			03/27/9*
189	Strengthened #4/5 bearing heatshield with stiffeners	X	X		02/24/70
190	Improve maintenance in area of #6 bearing sump bolts	X	X		04/18/72
192	Removes fuel flowmeter (dummy)	X	X		08/10/70

(* Denotes PPCs cancelled in accordance with NAVSUP 2002, May 1975)

PPC#	SUBJECT	P6	P8	P408	DATE ISSUED
193	Inlet case oil tubes	X	X		12/15/71
194	Engine conversion into P8A to P8B		X		07/09/70
195	Engine conversion into P6A to P6B	X			06/25/70
197	Reworks turbine stator seat to reduce axial cracking	X	X		09/09/71
198	Reduces therm cracking in fuel nozzle nuts with keyhole slots		X	X	04/04/72
199	Revise Ruel control filter & spring assembly	X	X		04/05/91
200	JFC 25-3 Main Filter Insert	X			10/15/73
202	Main oil pump housing bolt	X	X	X	10/02/72
203	P6 1st turbine inner support snap repair	X			08/06/74
205	Diffuser case to clear gang channel nuts	X	X	X	
206	2nd vane inner support	X			
207	Revise accel schedule for P408			X	09/04/73
208	2nd blade shroud clearance	X	X	X	03/01/73
209	Revise minimum flow & ratio for P8B		X		03/27/72
210	IGV assembly revise anti-icing holes			X	10/11/72
211	PRBC metering plug rework			X	10/11/72
212	Inlet case rework			X	06/03/74
213	Flex hose rework (shrink tubes)	X	X	X	04/16/73
214	Bleed override control rework	X	X	X	11/26/73
215	Increase lip height exhaust case	X	X		09/22/75
216	Fuel flowmeter electrical connector	X	X	X	08/20/73
217	Installs nine screws in 2nd vane grabber	X	X	X	03/01/73
218	Vane actuator tube assembly			X	07/19/73
219	Rework TT7 probes for PPC-185 burner		X		02/19/74
220	Fuel nozzle support stiffeners on P8/408		X	X	11/30/73
221	P408 tailcone heatshield removal			X	03/13/75
222	Revised PRBC support boss	X			02/10/75
223	Cover for manual fuel switch	X	X	X	04/12/76
224	Installs IN-X750 2nd grabber in P6 & P8	X	X		05/18/73
225	1st OAS P408 (high spoiler blade) increased clearance			X	12/18/72
226	Remove #6 bearing outer strut heatshield			X	03/15/74
227	Plated fuel control bellows	X	X	X	04/23/76
228	Cast struts—exhaust case	X			06/21/75
229	Relocate fuel heater bracket & remove unused bracket			X	07/18/74

PPC#	SUBJECT	P6	P8	P408	DATE ISSUED
230	Spacers, comb. chamb. support plate & supports, outer rear comb. chamb.			X	07/04/76
231	Slotted #4 heatshield (cancelled)	X	X	X	09/30/74
232	Revised Bleed overrid schedule			X	04/30/75
233	Increased turbine cooling—inner B?C secondary holes			X	09/20/74
234	Bracket rework for #6 oil line	X	X	X	04/22/74
235	Extended lug 2nd turbine vane	X	X	X	05/01/82
236	Replaceable diffuser case bushing (burner mount pin bosses)		X	X	10/18/76
237	P408 Retrofit of #6 oil tube (attrition for P6 & P8)	X	X	X	12/19/75
238	Revised bleed manifold clipping	X	X	X	12/15/75
239	Service repair front accy support assembly	X	X		01/29/76
240	Provide loose fly weight pin dash pot dampened speed govr. for fuel control	X	X	X	01/24/77
241	Removed leaning tube on ignitor cans		X	X	10/18/76
242	#4 brg. oil tube H/S weld in diff. case	X	X	X	
243	Unholey 2nd turbine vane POsitioning Plate	X	X	X	12/17/76
244	#6 H/S/ Support Doubler	X	X	X	
245	Comb. Chamb., 6 & 7th liner hole pattern			X	12/16/76
246	Improved lubriaction for gearshaft journal in the main pump assembly	X	X	X	04/25/78
247	More durable comp. stator inlet arm stop & synchronizing ring covers by plasma spray coating			X	11/10/80
248	Revised diff. case assembly featuring a brace welded to rear side of the fuel manifold support bosses	X			02/04/80
249	Gearbox mount pin retaining plate with increased thickness			X	03/01/78
250	Longer threaded insert in the PRBC oil pressure transducer boss	X	X	X	02/05/79
251	Provides additional security for the lower inlet guide vane actuator			X	04/15/80
252	Improved lubriaction for P6B main oil pump gearshaft journals	X			08/27/79
253	More durable comb. chamb. mount pins for P408			X	12/31/79
254	Provides a disposable 15 micron oil filter	X	X	X	08/25/80
255	Recontoured support bracket for the inverted flight breather tube in the oil tank	X	X		08/27/79
256	Provides new moveable IGVs with coating on vane hex to insure a shear fit at vane/arm interface			X	11/03/80
257	Inlet Guide Vane Control			X	08/31/82
258	Reoperation of P6 12th stage tierod bolt holes for LCF	X			06/25/84

PPC#	SUBJECT	P6	P8	P408	DATE ISSUED
259	Provides larger diameter stop pin/lockwire for bleed valve assembly				
260	Provides new 2nd and 3rd stage outer comp. vane shrouds incorporating stiffening rings	X	X	X	11/30/84
261	Provides an anti-rotation device for the comb. chamb. mount pin		X	X	08/31/81
262	Rework of front comp. case assembly	X			10/21/83
263	New lubrication oil tank incorporating a strainer over the oil tank outlet port	X	X	X	11/15/83
264	F/P & F/C reduced height bolts	X	X	X	05/01/82
265	Provide new main oil pump assemblies incorporating outer gear housing and cover assemblies with additional lubrication features	X	X	X	01/31/84
266	Improved ignition exciter connectors	X			12/31/82
267	Ps4 signal tube bracket	X	X	X	12/14/82
268	Main fuel pump internal pline wear	X	X	X	
269	12th stage comp. rotor, rework of rear flange	X	X		03/29/84
270	Air-cooled 1st stage turbine vanes		X		08/31/84
271	Abradable material, 6th, 7th and 8th stage comp. assemblies & front comp. case assembly to decrease seal land diameters	X	X	X	09/87
272	8th stator stiffening ring	X	X	X	04/89
273	LPC inner airseal abradable seals	X	X	X	09/87
274	LPC rubber abradable outer shroud	X	X	X	05/89
275	New recambered 3rd/4th stage vanes		X		10/89
276	Modify compressor bleed system	X	X	X	04/88
277	Standardize diffuser case with P408		X		12/85
278	Turbine case material change	X	X		02/90
279	12th disk redesign	X	X	X	08/89
280	1st stage hub & blade	X			08/89
281	Exhaust cone—capped nuts	X	X	X	03/90
282	Fuel heater seal	X	X	X	In process
283	PT2 tube clamping	X			12/89
284	IGV actuator tube			X	12/89
285	2 piece 1st stage turbine	X	X		09/89
286	Mfc Emergency solenoid transfer plate	X	X	X	01/91
287	GBX felt lube pad	X	X	X	05/89
288	LPC dogbone stators				Cancelled
289	No. 4 bearing housing	X	X	X	12/89

PPC#	SUBJECT	P6	P8	P408	DATE ISSUED
290	Bleed, oil & combustion area "OSIP" improvements	X	X	X	Final Review
291A	MFC droop cam spring, follower & pin	X	X	X	04/91
292	IGV bolt retention			X	08/91
293	Internal No. 1 scavenge			X	Final Review
294	J52—P409 change—turbine area improvements				-------
295	Capacitance oil sensor	X			Final Review
296	Struts, ICC, inner turbine vane supports	X			Final Review

FR-20861-2
28 February 1991

APPENDIX B

J52-P-6C/-8C/-408A
CONVERSION PROGRAM
SUPPORTABILITY ASSESSMENT REPORT

Prepared for
Department of the Navy
Naval Air System Command
Washington, D.C. 20361-0001

Prepared under
Contract N00019-87-G-0153
PR # N00019-89-PR-LA140
CDRL Sequence No. A00S

Prepared by
United Technologies Corporation
Pratt & Whitney
Government Engine Business
P.O. Box 109600, West Palm Beach, FL 33410-9600

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UNITED TECHNOLOGIES PRATT&WHITNEY

This submittal contains the J52-P-6C/-8C/-408A Conversion Program Supportability Assessment Report as defined by DID DI-S-7121 and SOW Paragraph 9.2.

FR-20861-2
28 February 1991

J52-P-6C/-8C/-408A CONVERSION PROGRAM
SUPPORTABILITY ASSESSMENT REPORT

This Supportability Assessment Report documents the progress of the J52-P-6C/-8C/-408A Conversion Program, provides an overall assessment of support system performance and establishes a durability parameter baseline against which the durability performance of the J52-P-6C/-8C/-408A conversion engine fleet can be measured/assessed.

As specified by CDRL Sequence No. A00S, this report was presented at the Integrated Logistics Support Management Team (ILSMT) Meeting held at Pratt & Whitney Government Engine Business on 15-17 January 1991, and future updates will be presented/submitted in conjunction with subsequent ILSMT meetings.

A. CONVERSION PROGRAM PROGRESS

A summary of Conversion Program efforts to date is provided in the form of a graph for each engine model (i.e., P-6C, P-8C and P-408A). Contractual PPC 290 kit delivery schedules for firm orders placed through FY '90 are presented, as well as, Pratt & Whitney kit deliveries through December 1990. For each engine model, the lag in actual vs. scheduled kit deliveries has been attributable to delays experienced in the verification process of PPC 290. In addition, the quantity of actual P-6C, P-8C and P-408A engine conversions are represented on the graphs. The J52-P-408A conversion engine fleet has been 'supplemented' by Pratt & Whitney's engine production line through December 1990 and an overview of the production P-408A delivery schedule and operational experience accumulated to date is also presented.

Initial fleet operations involving the J52-P-6C and P-8C conversion engines were just commencing at the time of the 15-17 January 1991 ILSMT meeting, [illegible] as such, a summary of operational experience for these two (2) engine models was not available. This information will be provided in the next report.

B. SUPPORT SYSTEM PERFORMANCE

An overall assessment of the major ILS elements required to support the conversion engine fleet is presented in a chart using a red/yellow/green symbology to indicate status. The assessment reflects the progress/ performance of each of the ILS elements in meeting scheduled events identified in the Master Milestone Plan, CDRL Sequence. No. A002.

C. DURABILITY PERFORMANCE ASSESSMENT

An assessment of key durability parameters for the J52-P-6C/-8C/-408A conversion engine fleet will be based on USN 3M and Aircraft Engine Management System (AEMS) data. Conversion engine performance will be evaluated upon a comparison with the preconversion engine fleet baseline, and the data, presented in a 12-month rolling average format, will be monitored for trends. Data presented in this report only establishes the pre-conversion durability parameter baselines, as the J52-P-6C/-8C/-408A engine fleets have not yet accumulated a significant number of engine flight hours (EFH's) to provide for a meaningful comparison.

J52-P-6C/-8C/-408A
CONVERSION PROGRAM
SUPPORTABILITY ASSESSMENT

15 - 17 January 1991

Ron Palmatier
J52 NAVAIR MIC
(703) 486-5680

J52 OSIP
ILSMT
15 Jan 1991

SUPPORTABILITY ASSESSMENT PLAN

OBJECTIVES

1. Track conversion program progress
2. Assess support system performance
3. Assess durability performance of converted engine fleet
   - MTBF
   - UER's
   - SER's

J52 OSIP

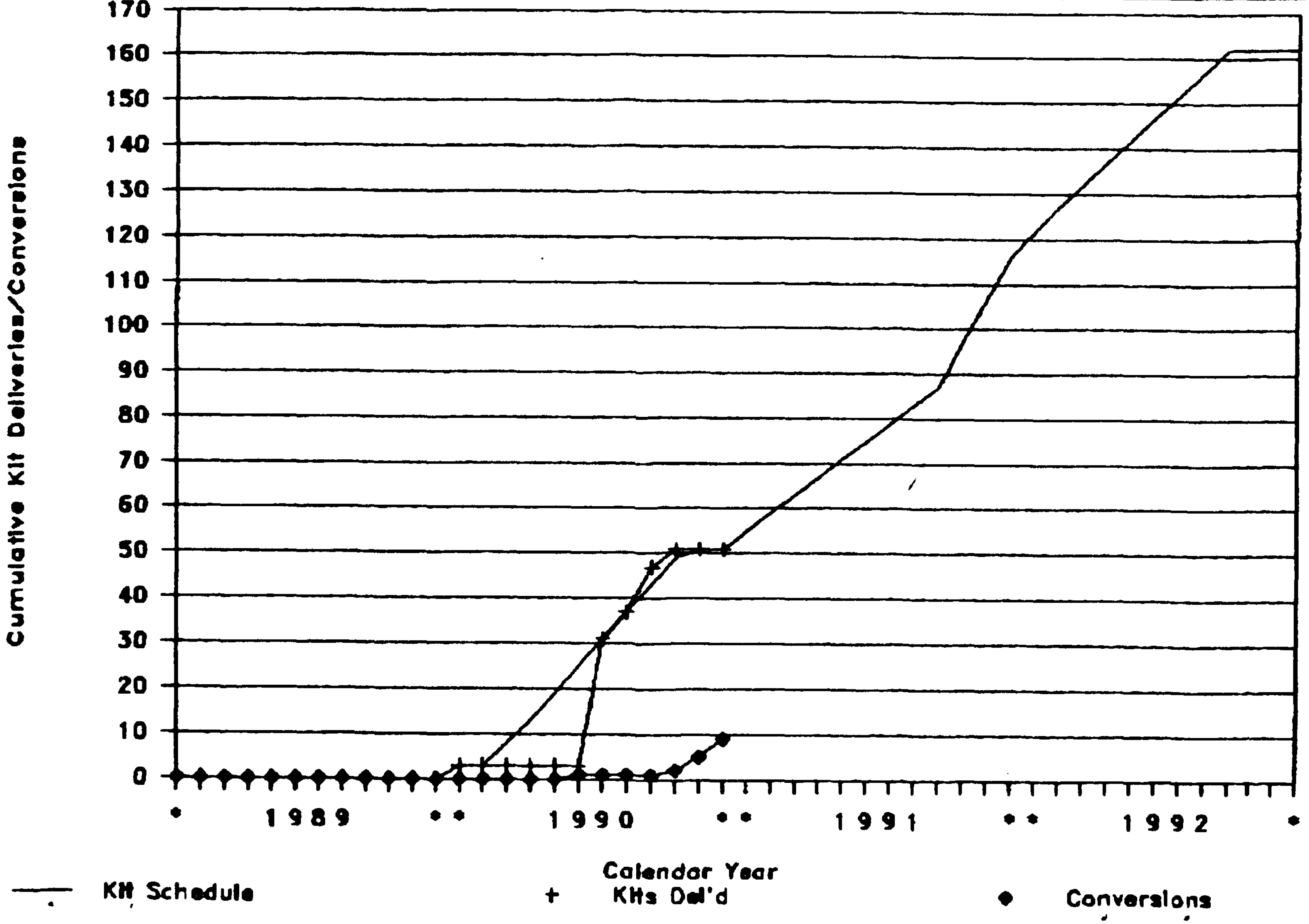
ILSMT

15 Jan 1991

J52-P-6C

PPC 290 KIT DELIVERIES/CONVERSIONS

Kit P/N 2189113

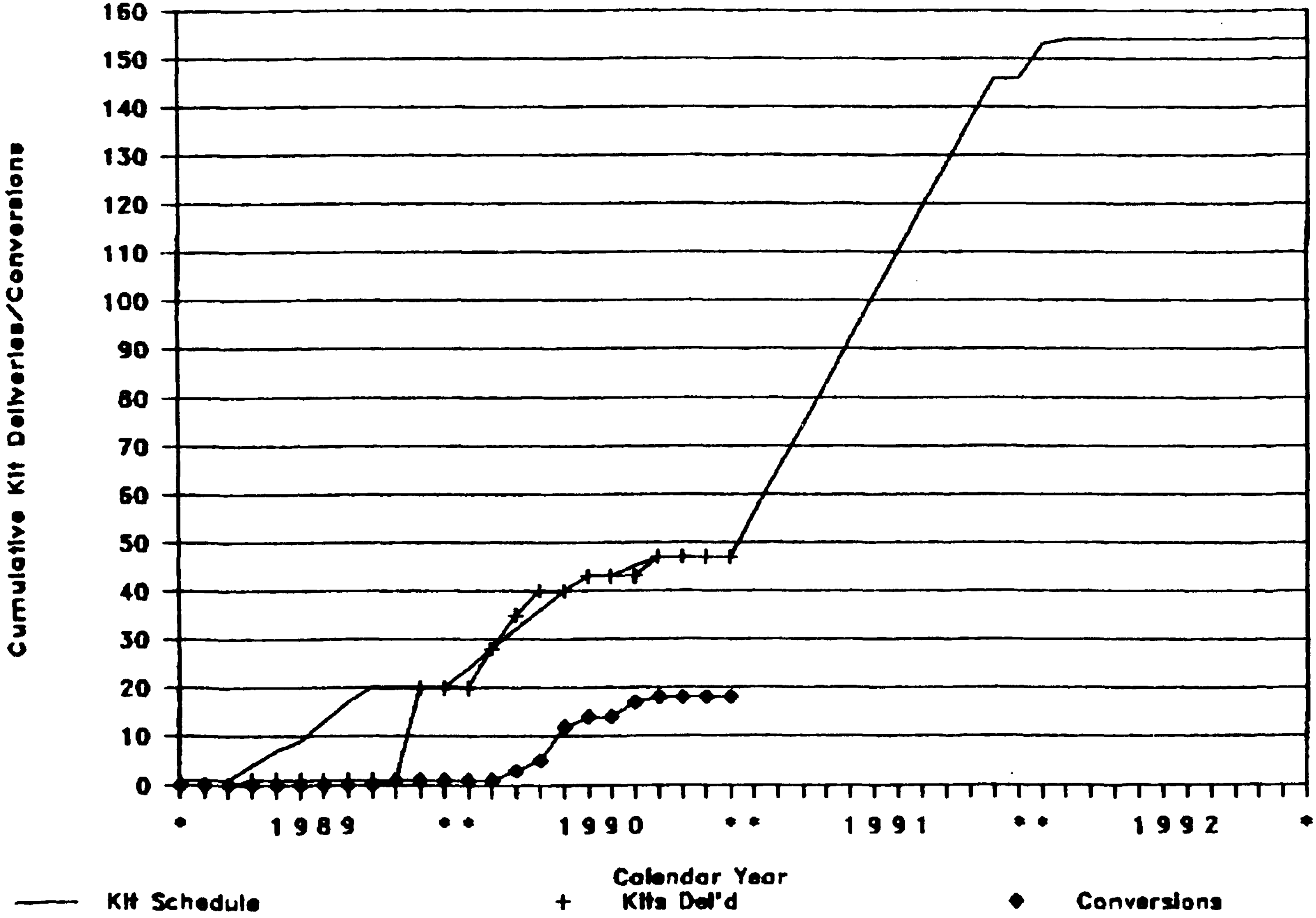


J52 OSIP
ILSMT
15 Jan 1991

J52-P-8C

PPC 290 KIT DELIVERIES/CONVERSIONS

Kit P/N 2187689

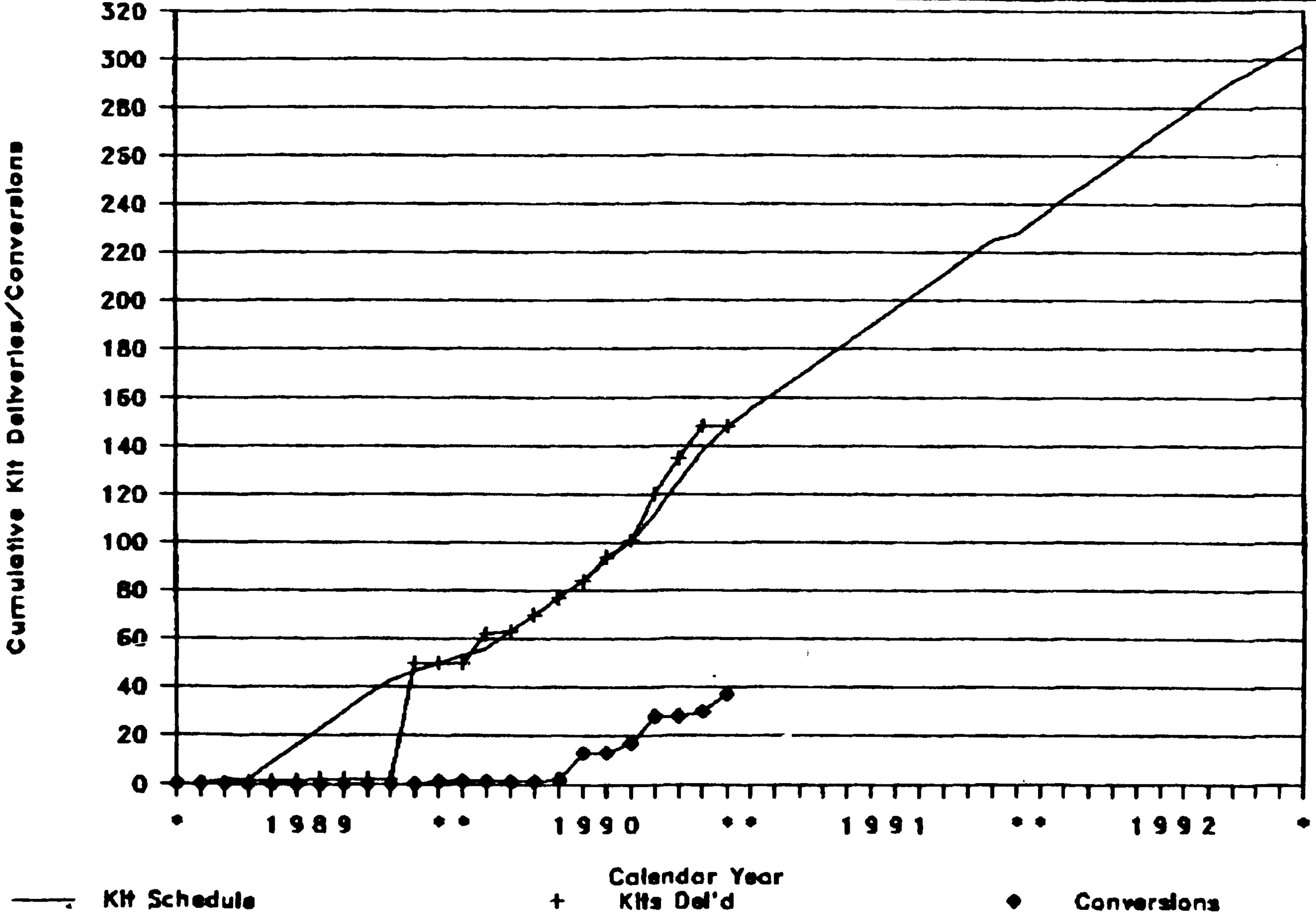


J52 OSIP
ILSMT
15 Jan 1991

J52-P-408A

PPC 290 KIT DELIVERIES/CONVERSIONS

Kit P/N 2188171



J52 OSIP
ILSMT
15 Jan 1991

J52-P-408A

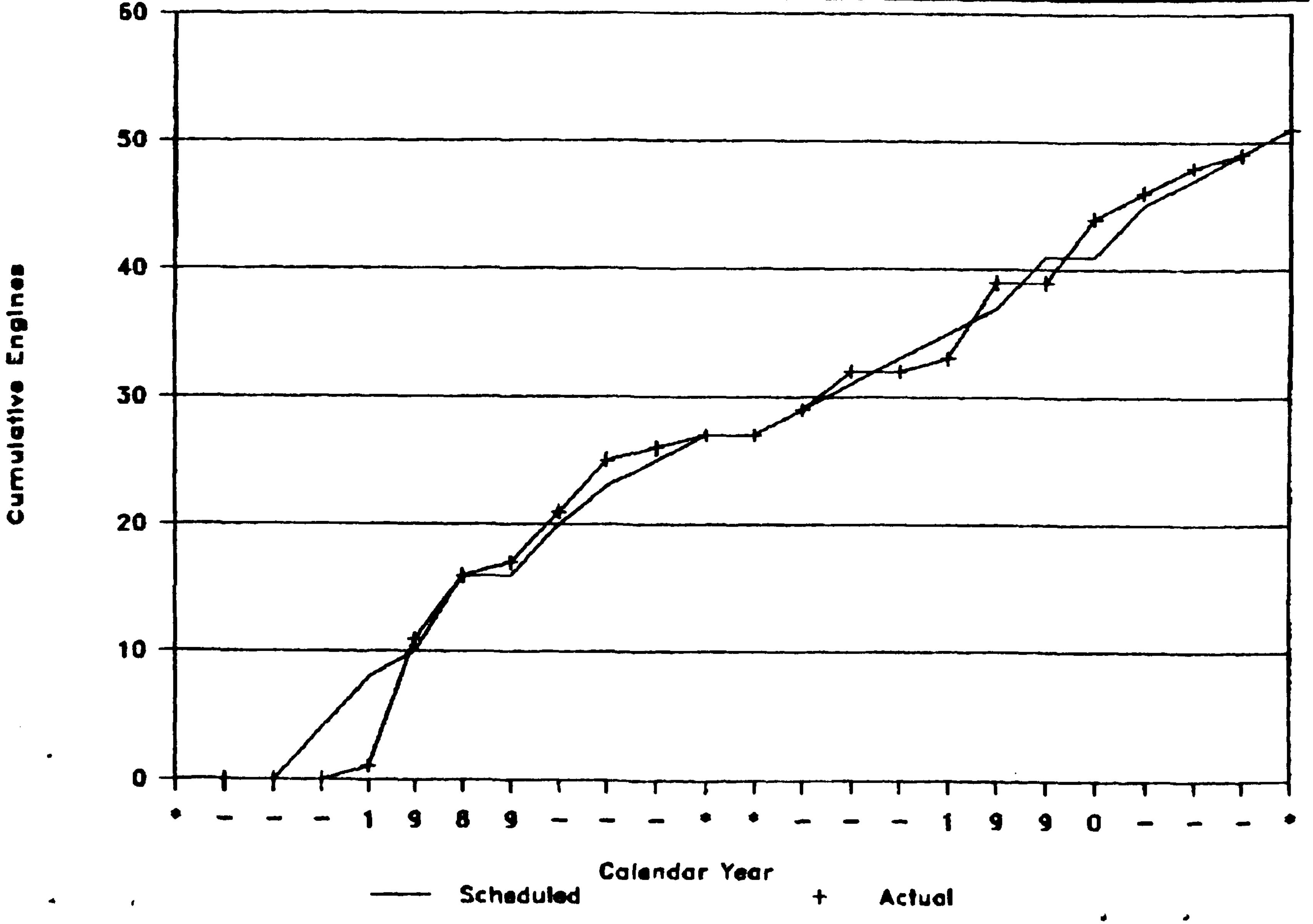
OPERATIONAL P-408A EXPERIENCE

• Initial fleet introduction	
- NAS Whidbey	August 1989
• 45 engines on-site/36 installed	
- 29 P&W production engines	
- 16 conversion engines	
• Total EFH's accumulated	7,633 hrs
• Hi-time engine	616 hrs

J52 OSIP
ILSMT
15 Jan 1991

J52-P-408A

P&W PRODUCTION ENGINE DELIVERIES



J52 OSIP
ILSMT
15 Jan 1991

J52-P-6C/-8C/-408A

CONVERSION SCORECARD

	P-6C	P-8C	P-408A
NADEP JAX	9	10	37
NADEP ALA	-	8	-
CNATRA	0	-	-
NAS WHIDBEY	-	-	0
TOTALS *	9	18	37

** Conversions thru Dec 90*

J52 OSIP
ILSMT
15 Jan 1991

ILS CONTRACT OVERVIEW

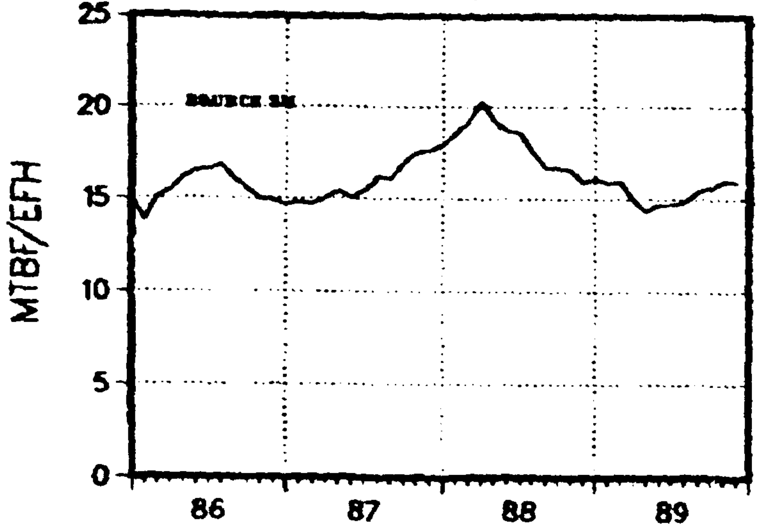
MAJOR CONTRACT ELEMENTS

Contract Requirement	*Status*		
LSA Deliverables	☒ Green	☐ Yellow	☐ Red
Maintenance Plan	☒ Green	☐ Yellow	☐ Red
Support Equipment	☒ Green	☐ Yellow	☐ Red
Post-Production Support Plan	☒ Green	☐ Yellow	☐ Red
Training	☒ Green	☐ Yellow	☐ Red
Provisioning	☒ Green	☐ Yellow	☐ Red
Site Activation Plan	☒ Green	☐ Yellow	☐ Red

* *Maintenance Plan Review Scheduled February*

J52-P-6C

DURABILITY PERFORMANCE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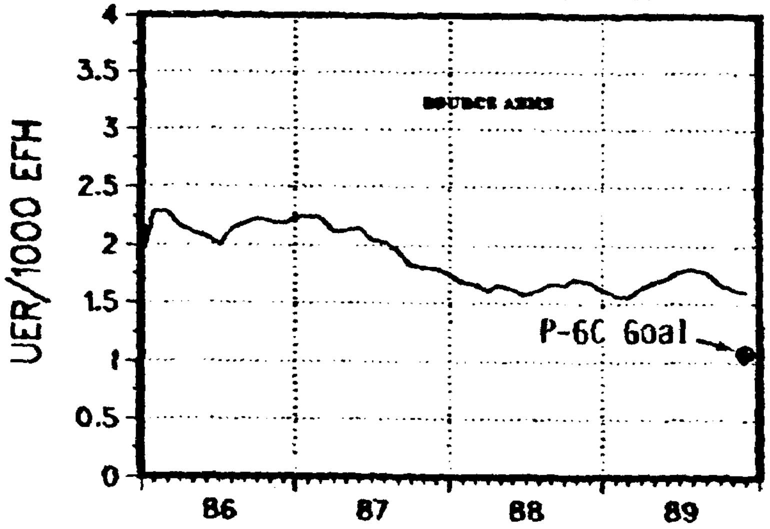
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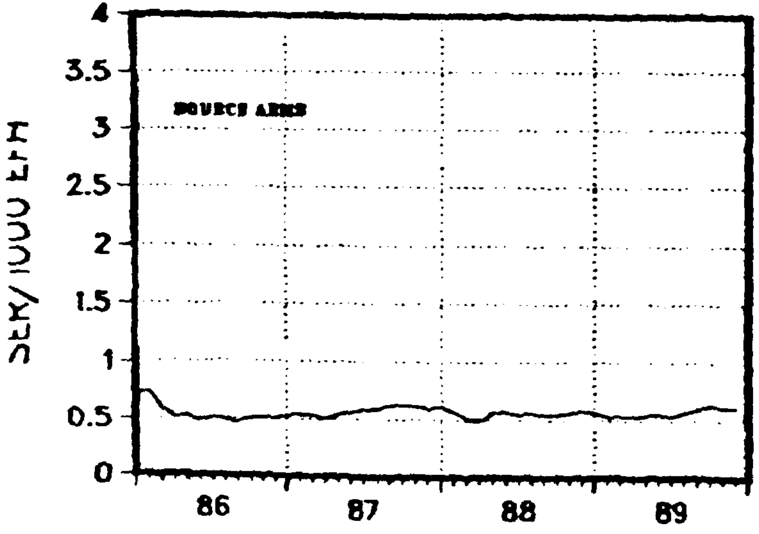
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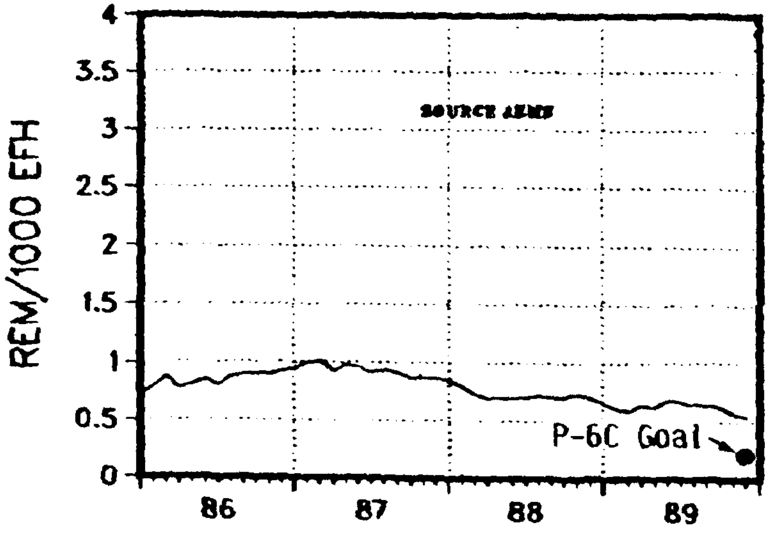
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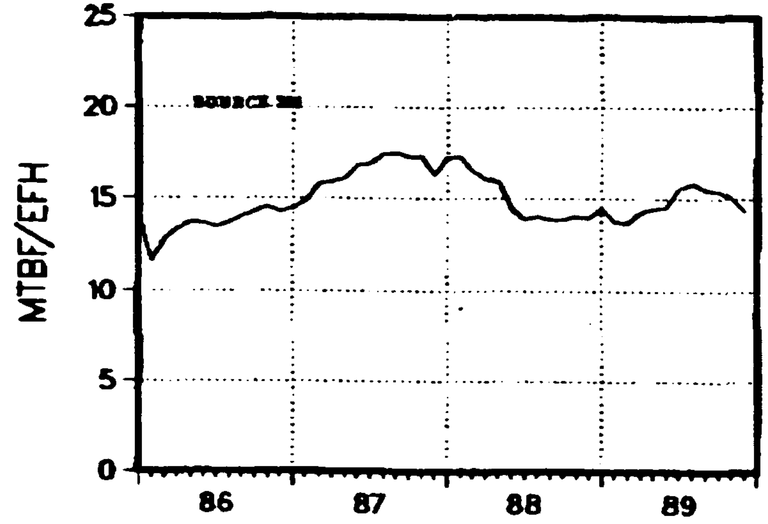
J52-P-8C

DURABILITY PERFORMANCE



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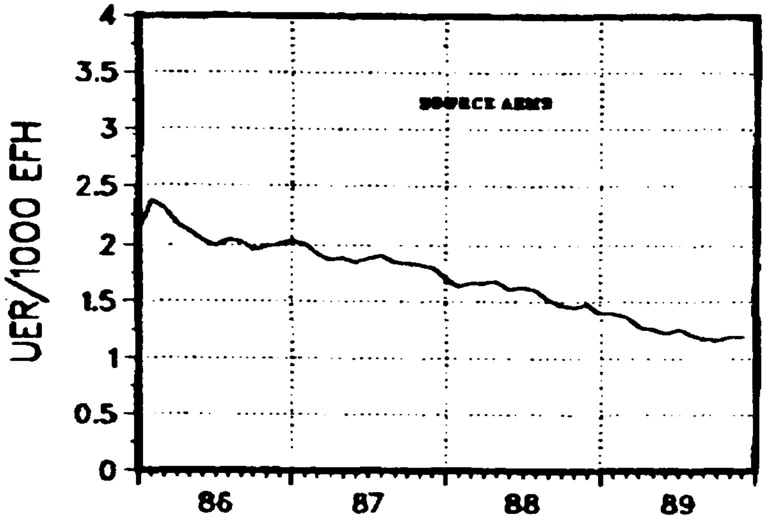

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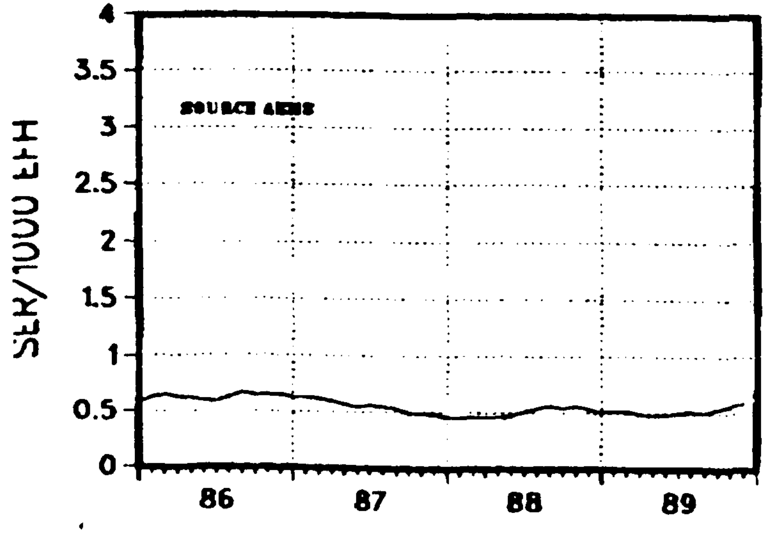

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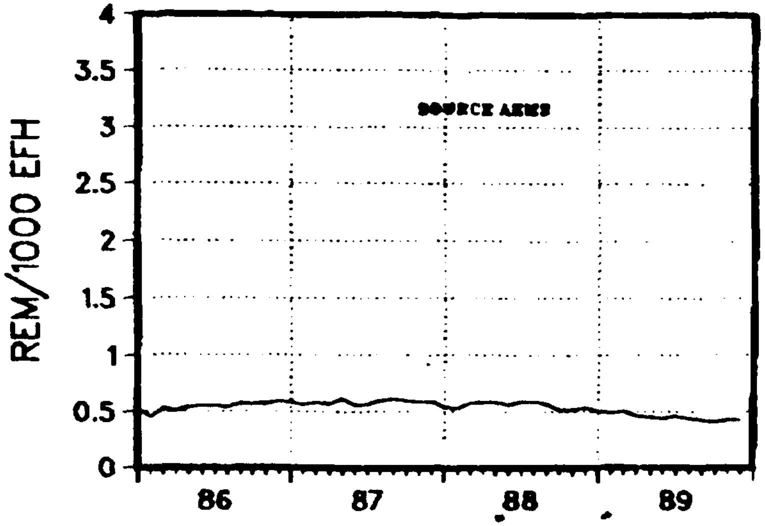
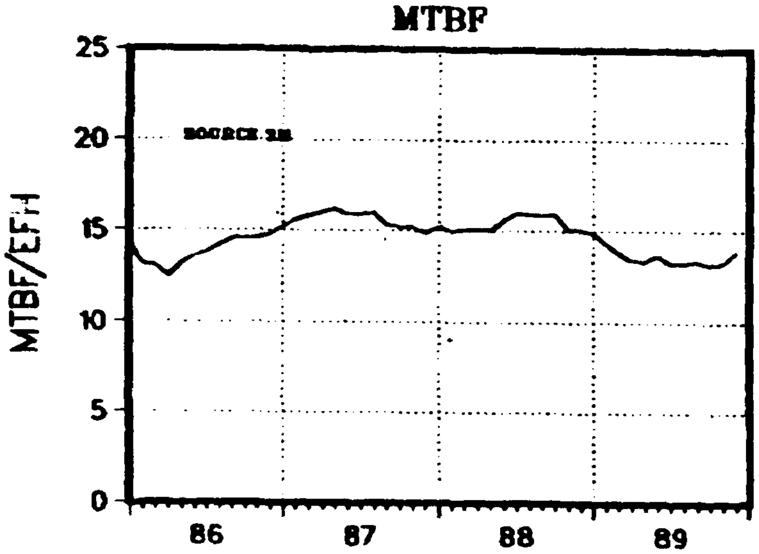


OIL CAUSED REMOVALS

J52-P-408A

DURABILITY PERFORMANCE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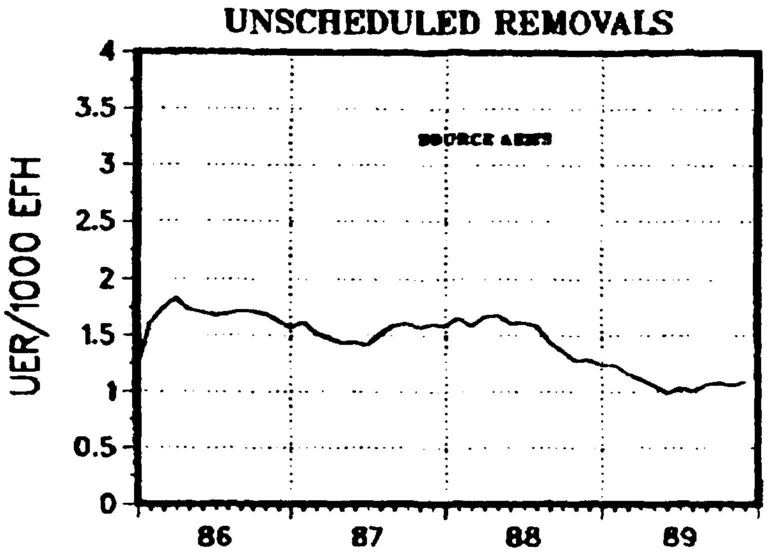
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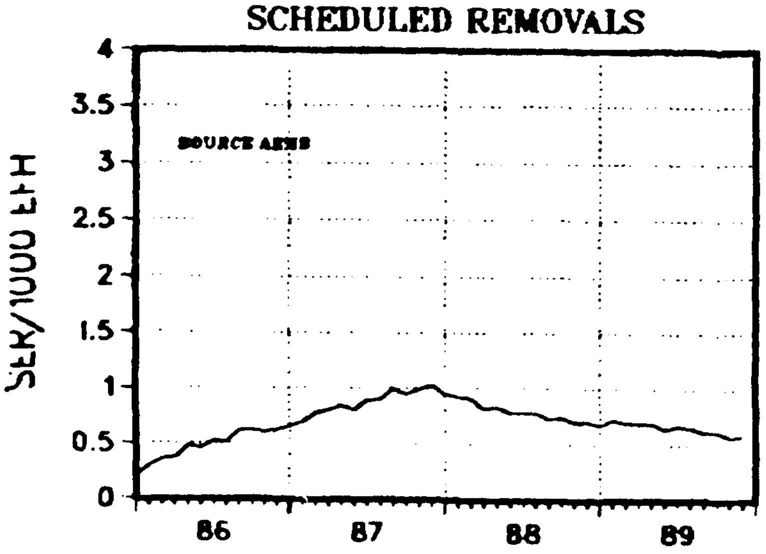
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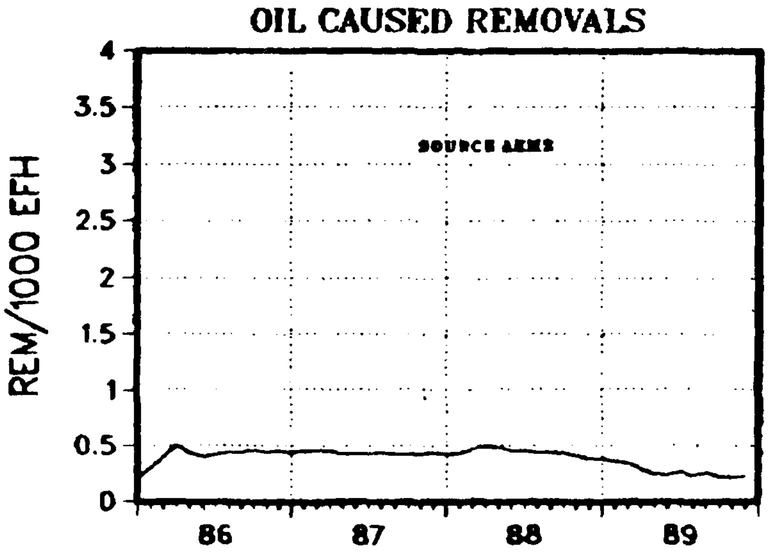
OIL CAUSED REMOVALS

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