



DE83002565

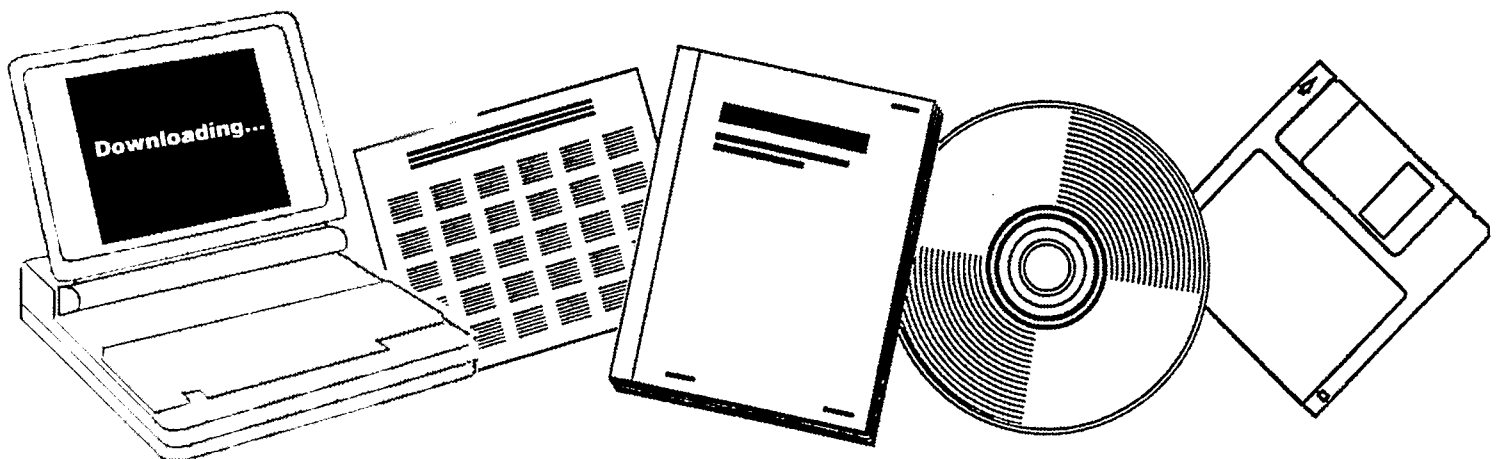
NTIS

One Source. One Search. One Solution.

ALTERNATIVE FUELS FOR MEDIUM-SPEED DIESEL ENGINES (AFFMSDE) PROJECT: A BASELINE PROGRAM PLANNING CONCEPT FOR REVIEW AND REVISION. FINAL REPORT

E:F TECHNOLOGY, INC.
ST. JOHNS, MI

JUN 1982



U.S. Department of Commerce
National Technical Information Service

One Source. One Search. One Solution.

NTIS



Providing Permanent, Easy Access to U.S. Government Information

National Technical Information Service is the nation's largest repository and disseminator of government-initiated scientific, technical, engineering, and related business information. The NTIS collection includes almost 3,000,000 information products in a variety of formats: electronic download, online access, CD-ROM, magnetic tape, diskette, multimedia, microfiche and paper.



Search the NTIS Database from 1990 forward

NTIS has upgraded its bibliographic database system and has made all entries since 1990 searchable on www.ntis.gov. You now have access to information on more than 600,000 government research information products from this web site.

Link to Full Text Documents at Government Web Sites

Because many Government agencies have their most recent reports available on their own web site, we have added links directly to these reports. When available, you will see a link on the right side of the bibliographic screen.

Download Publications (1997 - Present)

NTIS can now provides the full text of reports as downloadable PDF files. This means that when an agency stops maintaining a report on the web, NTIS will offer a downloadable version. There is a nominal fee for each download for most publications.

For more information visit our website:

www.ntis.gov



U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Technical Information Service
Springfield, VA 22161

DE83002565



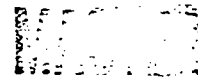
**PORTIONS
OF THIS
DOCUMENT
ARE
ILLEGIBLE**

DE83002565



DOE/CS/50048-T1

**The Alternative Fuels for
Medium-Speed Diesel Engines (AFFMSDE) Project:
A Baseline Program Planning Concept
for Review and Revision**



Prepared by:

**E:F Technology, Inc.
St. Johns, Michigan**

NOTICE

**PORTIONS OF THIS REPORT ARE ILLEGIBLE. It
has been reproduced at the best available
copy to permit the user to a possible avail-
ability.**

FINAL REPORT

under

**U.S Department of Energy
Contract No. DE-AC02-81CS50048.M002**

June 1982

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DOE/CS/50048--T1

DE83 002555

DOE/CS/50048-T1

The Alternative Fuels for Medium Speed Diesel Engines (AFFMSDE) Project:

A Baseline Program Planning Concept for Review and Revision

Prepared by:

E:F Technology, Inc.
St. Johns, Michigan

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It
has been reproduced from the best available
copy to permit the broadest possible avail-
ability.

DISCLAIMER

This report was prepared for the U.S. Department of Energy under contract DE-AC02-81CS50048.M002. It contains information that is proprietary to E:F Technology, Inc. and is not to be distributed outside the Department of Energy without the written consent of E:F Technology, Inc.

FINAL REPORT

under

U.S. Department of Energy
Contract No. DE-AC02-81CS50048.M002

June 1982

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

TABLE OF CONTENTS

	<u>Page</u>
Section 1 - SUMMARY	1
Section 2 - INTRODUCTION	5
2.1 Program Background	5
2.2 Accomplishments	5
2.3 Purpose of This Document	6
2.4 Contents	6
Section 3 - SUGGESTED PROGRAM OBJECTIVES, REQUIREMENTS, AND PRIORITIES DISCUSSION	8
3.1 Objectives	8
3.2 Requirements	8
3.3 Priority Considerations	9
Section 4 - A SUGGESTED MULTI-YEAR RESEARCH, DEVELOPMENT, AND OPERATIONAL DEMONSTRATION PROGRAM PLAN	10
4.1 General Comments and Observations	10
4.1.1 Scope of Objectives Suggested	10
4.1.2 Anticipated Management Problems	10
4.1.3 Planned Information Dissemination	11
4.1.4 Additional Program Components Suggested	12
4.2 Supporting Tasks Component	13
4.3 Planned Information Dissemination Components	13
4.4 The Multi-Year Research, Development, and Operational Demonstration Program Project	14
4.4.1 Basic Logic of Activity Areas	14
4.4.2 Basic Logic of R&D in Stationary Engines	17
4.4.3 Basic Logic of Operational Demonstration	17
4.4.4 Work Areas	19
4.5 The Program Plan Proposed	19
4.5.1 A Concept for Review and Revision	19
4.5.2 R&D Activity Areas	19
4.5.3 An Alternative Fuels Research Motive Power Unit Concept	22
4.5.4 PERT/CPM Chart	23
Section 5 - PROGRAM BENEFITS	26

TABLE OF CONTENTS, Continued

	<u>Page</u>
Section 6 - MANAGEMENT APPROACH	27
Section 7 - BUDGETARY ESTIMATES	29
7.1 Basic Project Budget	29
7.2 Cash Flow Requirements	29
Section 8 - RECOMMENDATIONS	32

LIST OF FIGURES

Figure 1 Electro-Motive Division 2-Cylinder, 567 Cubic Inches/ Cylinder, Normally Aspirated Research Test Engine at Southwest Research Institute in San Antonio, Texas	2
Figure 2 The Rail Motive Power Laboratory at Southwest Research Institute Consisting of a 12-Cylinder Turbocharged General Electric 7FDL Medium-Speed Diesel Engine and an Electro- Motive Division of General Motors 12-Cylinder Turbocharged 645 E3B Medium-Speed Diesel Engine	3
Figure 3 Control Room of the AAR/Southwest Research Institute Rail Motive Power Laboratory	4
Figure 4 Examples of Classes of Alternative Fuels and Some Examples of Such Fuels	15
Figure 5 Presently Proposed Areas of Investigation Comprising the Alternative Fuels for Medium-Speed Diesel Engines (AFFMSDE) Project Activities	16
Figure 6 Progressive Levels of Testing of Alternative Fuel Systems in 2-Cylinder Stationary, Multi-Cylinder Stationary and Rail Operating Environments	18
Figure 7 Proposed Multi-Year Program Planning Concept for the AFFMSDE Program	20
Figure 8 Modified SD45-2 Alternative Fuels Research Motive Power Unit	24
Figure 9 PERT/CPM Chart	25
Figure 10 AFFMSDE Management Structure Suggested by Recent and Proposed SwRI and AAR Initiatives	28

LIST OF FIGURES, Continued

	<u>Page</u>
Figure 11 Basic Budgetary Estimates of the Multi-Year AFFMSDE Program	30
Figure 12 Cash Flow Requirements Estimates of the Multi-Year AFFMSDE Program	31

Section 1

SUMMARY

The major problem that is implicit in this multi-year, essentially voluntarily supported program is the maintenance of voluntary support for what is an ambitious, technically difficult and large-scale program.

It is strongly suggested that the development and formal adoption, by all participants, of a multi-year Program Management Plan might provide a means of focusing attention on this difficult management aspect and thus a means of contributing to developing a commitment to support of the program for its full duration and to achieving the final objectives sought.

Whatever the results of the program activities, they must be accompanied by the effective dissemination of information regarding all program findings. It is recommended that this problem receive specific attention and that a planned approach to information dissemination be developed and maintained.

The reader should remember that during the past four years of the AFFMSDE program, there have been a number of "gluts" in petroleum supply. At this time, another such "glut" is coming to an end. However, in the present circumstances, there are indications that the price of petroleum fuels may not rise significantly for some time in the future because of internal discord in the OPEC producing nations. On the other hand, the inherent instability of the Middle East has never been more apparent than it is today. The potential significance of the proposed program to the U.S. rail industry in this period of uncertainty of continued supply of crude oil from foreign producers is obvious.

The purpose of this document is to provide some suggestions and recommendations for the long-term continuation of the Alternative Fuels for Medium Speed Diesel Engines (AFFMSDE) Program as program support transitions from government to industry.

The Multi-Year Program Management Plan presented here is a suggested baseline concept. If it is subject to review, revision, and expansion in detail by contribution of all program participants, it might provide assistance in developing long-term, planned, commitment to supporting and maintaining continuity of management that these types of program require.

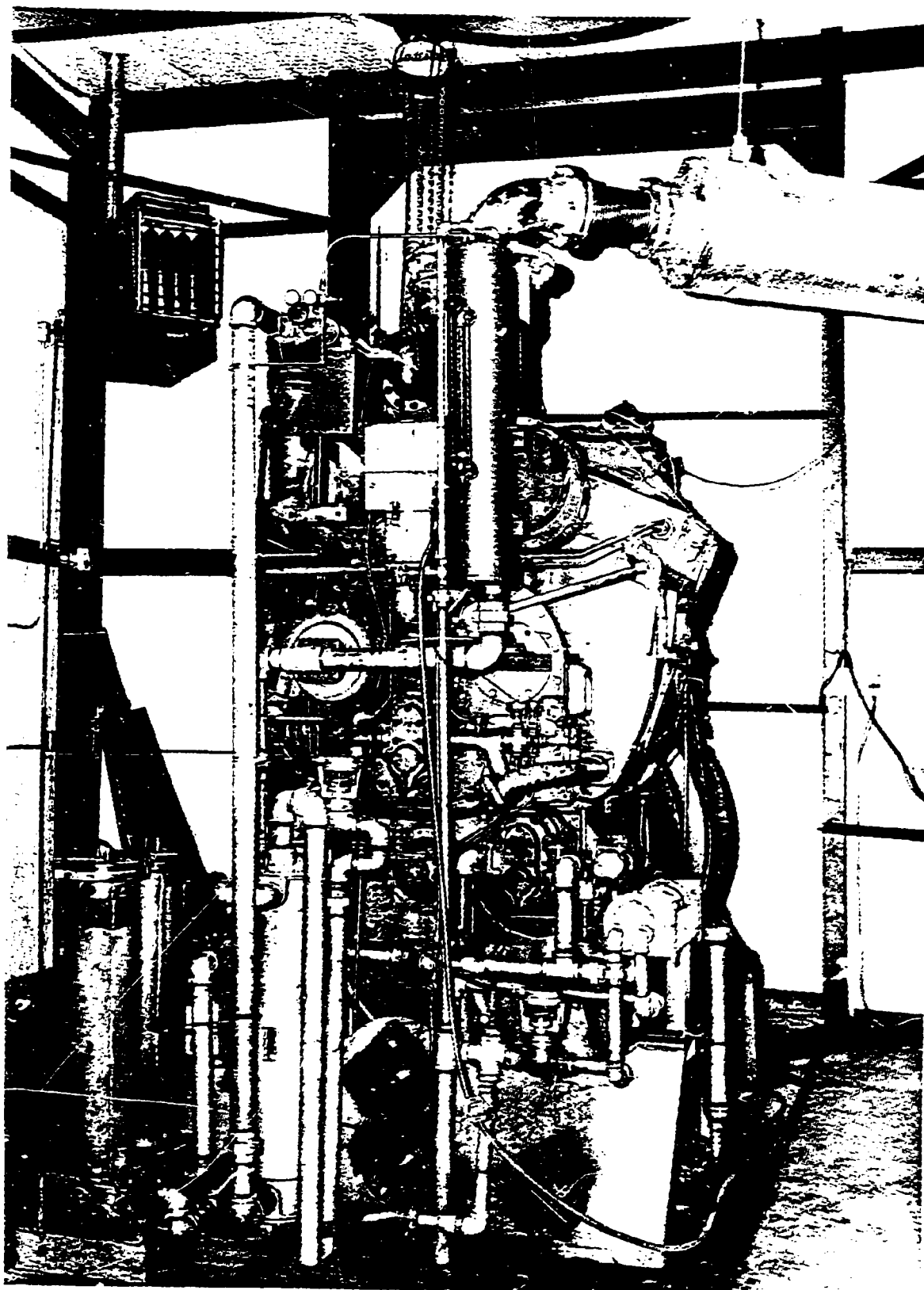


Fig. 1 Electro-Motive Division 2 Cylinder, 567 Cubic Inches/Cylinder, Normally Aspirated Research Test Engine at Southwest Research Institute in San Antonio, Texas.

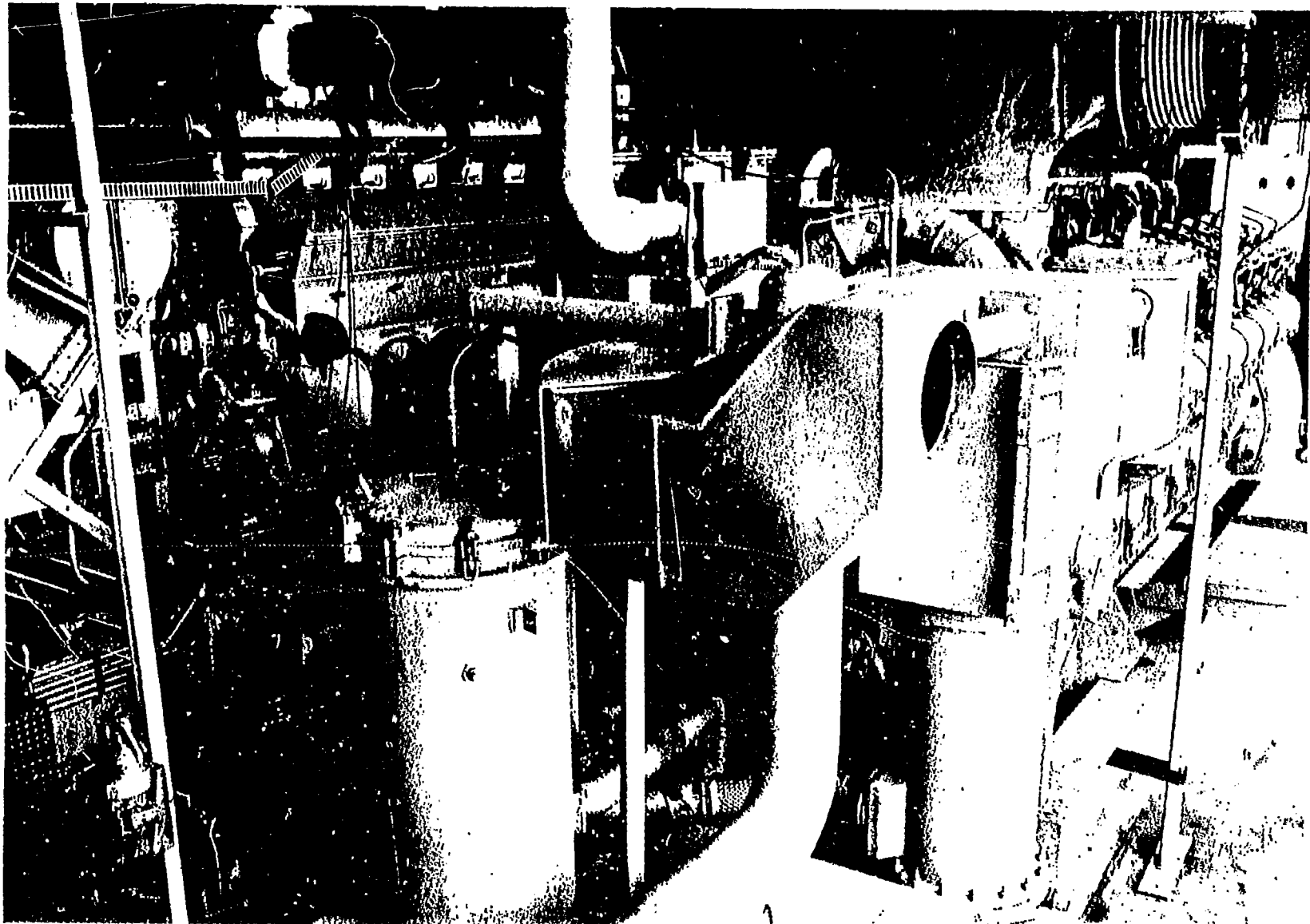


Fig. 2 The Rail Motive Power Laboratory at Southwest Research Institute consisting of a 12 Cylinder Turbocharged General Electric 7FDL medium speed diesel engine and an Electro-Motive Division of General Motors 12 Cylinder, Turbocharged 645 E3B medium speed diesel engine.

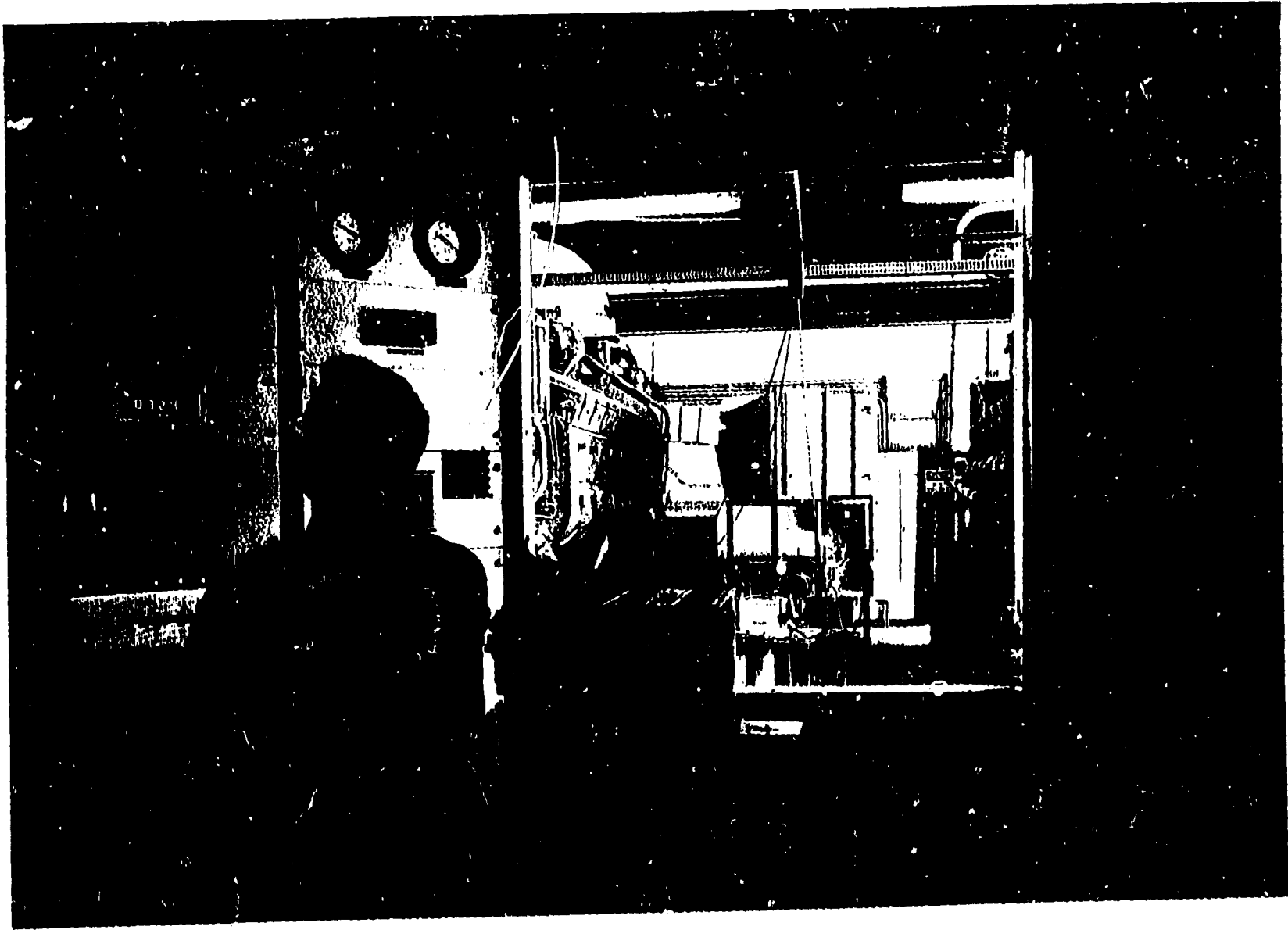


Fig. 3 Control Room of the AAR/Southwest Research Institute Rail Motive Power Laboratory.

Section 2

INTRODUCTION

2.1 Program Background

The Alternative Fuels for Medium-Speed Diesel Engines (AFFMSDE) Program was initially funded by the Non-Highway Transportation Systems Branch of the U.S. Department of Energy in August 1978. The general objective of the program was to identify means of conserving petroleum resources through two strategies. First, through the use of petroleum-based fuels with properties deviating significantly from conventional specification diesel fuels. Secondly, through the use of fossil fuels not derived from petroleum.

In 1979, the Federal Railroad Administration of the U.S. Department of Transportation (DOT/FRA) and the Association of American Railroads (AAR) joined the program effort providing additional financial support.

Member railroads of the AAR contributed two rail diesel engines--a 12-cylinder General Electric (GE) 7FDL turbosupercharged medium-speed engine and a General Motors (GM) Electro-Motive Division 12-cylinder turbosupercharged 645 E3B medium-speed diesel engine--to the project. These engines were delivered to Southwest Research Institute (SwRI) in 1980.

SwRI contributed all facilities, operational support and instrumentation systems equipment needed to complete the installation of these two engines in SwRI's facilities at San Antonio, Texas. This multi-cylinder Rail Motive Power Laboratory is supported by an already existing 2-cylinder GM/EMD Model 567 research engine installation.

2.2 Accomplishments

The characteristics of operation of medium-speed diesel engines on petroleum-based fuels with significant deviation from the Diesel No. 2 specification property limit have been investigated and the findings documented.

The characteristics of operating medium-speed diesel engines on fuel forms representative of synfuels or alternative fuels derived from non-petroleum fossil resources have been studied and the findings have been reported.

A full-scale rail engine research facility has been created. This facility is capable of running 2-cylinder and multi-cylinder engines, fuels, lubri-

cants, additives, and equipment research and development programs using representative medium-speed diesel equipment of contemporary design. This facility is supported by personnel experienced in fuels research and technology, lubricants research and technology, combustion and emissions research, and the design, development, and evaluation of medium-speed diesel engine equipment systems and subsystems.

2.3 Purpose of This Document

Continuing funding support of the AFFMSDE Program by DOE and DOT/FRA is being curtailed. The program will be continued by the Association of American Railroads and its member lines.

The purpose of this document is to provide some suggestions and recommendations for the long-term continuation of this program as this support transition is made from government to industry.

The Multi-Year approach to Program Management Planning presented here is a suggested baseline concept. If it is subjected to review, revision, and expansion in detail by all program participants, it might provide some assistance in developing long-term, planned, support and continuity of management that programs of this type require.

2.4 Contents

This document is a major revision of the "Alternative Fuels for Medium-Speed Diesel Engines: Project Management Master Plan" of April 1979, as prepared by Escher Technology Associates, Inc., in accord with the format recommendations of DOT/FRA. The immediately following section, Section 3, presents suggested program objectives, requirements resulting from these objectives, and a discussion of prioritization of program objectives and requirements. A Program Plan Proposal is presented in Section 4. The proposed program plan embraces three major areas of activities:

- Supporting Tasks
- Planned Information Dissemination
- Research, Development and Operational Demonstration Activities.

The remaining sections are comprised of brief discussions of program products and/or deliverables projected, a suggested basic management approach, generalized budgetary estimates, and principal recommendations from all of the above.

Section 3

SUGGESTED PROGRAM OBJECTIVES, REQUIREMENTS, AND PRIORITIES DISCUSSION

3.1 Objectives

The basic scope of the AFFMSDE Program is concerned exclusively with energy-related aspects of operation of the medium-speed diesel engines in rail motive power units. The program has not been concerned, and it is recommended that it should not be concerned, with improvements related to operational activities in rail motive power unit use. There is an exception to this consideration. This exception is in consideration of the problems of operation using alternative fuel systems as they affect the original equipment manufacturers, operating companies utilizing such systems, and the production, distribution, storage, and delivery of non-petroleum based alternative fuels by manufacturers of such fuels.

The overall objectives of the AFFMSDE Program are:

1. To identify problems, and to develop technical approaches in solution of those problems, associated with rail line operation of medium-speed diesel engines on:
 - diesel fuels derived from petroleum with properties significantly deviating from conventional specification diesel fuels
 - fuels derived from "syncrudes" from coal, oil shale, and tar sands
 - alternative fuels, the use of which may be required because of a lack of adequate supplies of fuels, petroleum, coal, oil shale, and tar sands resources.
2. To identify the nature of, and quantify to the extent appropriate and practical, the problems of operation on alternative fuel systems that will be encountered by original equipment manufacturers and rail line operating companies utilizing such fuel systems
3. To effectively disseminate information resulting from the activities of the AFFMSDE Project.

3.2 Requirements

In order to achieve the overall project objectives, the program of work comprising the AFFMSDE Program Planning Concept presented herein provides an arrangement of activities which meet or fulfill the following requirements:

1. To provide an orderly identification of the problems associated with the operation of medium-speed diesel engines on alternative fuel forms
2. To identify technological approaches to the solution of these problems
3. To evaluate the adequacy of these approaches by operation of two-cylinder stationary, multi-cylinder stationary, and rail motive power equipment systems on such alternative fuel forms
4. To provide an orderly identification of the problems associated with the conversion of medium-speed diesel engines to alternative fuel forms that will be encountered by original equipment manufacturers
5. To provide a similar identification of such problems as they would be encountered by rail line operating companies using such engines converted to operation on such fuel forms
6. To provide an orderly program of planned information dissemination to be executed that will assure the information resulting from the AFFMSDE project will be available to appropriate individuals in those industries that may make use of the investigated fuel forms in medium-speed diesel engines.

3.3 Priority Considerations

It is suggested that all program activities proposed should be evaluated in terms of the following priority considerations:

1. To reduce direct costs of rail operating companies
2. To assure the maximum probability of the ability to continue to operate under the broadest range of fuel availability scenarios possible
3. To conserve petroleum fuel resources
4. To conserve fossil fuel resources.

It must be noted that if priority No. 1 is the only consideration, the resulting program of activities will be of narrow scope and will be concerned only with the near-term. It is suggested that all priorities must be considered and that available resources should be reasonably apportioned between activities that fall in all four priority categories.

Section 4

A SUGGESTED MULTI-YEAR RESEARCH, DEVELOPMENT, AND OPERATIONAL DEMONSTRATION PROGRAM PLAN

4.1 General Comments and Observations

4.1.1 Scope of Objectives Suggested

To date, the scope of work on the AFFMSDE Program has been concerned with types of operations that can generally be classified as being "research" oriented. Tasks accomplished to date have been concerned with identifying the combustion characteristics and the performance of various alternative fuels introduced into medium-speed diesel engine combustion systems using a variety of approaches. Injector systems, emulsifiers, etc., have been constructed to satisfy experimental objectives. This hardware and equipment has not been designed to meet the requirements of operating rail equipment systems.

If the program is to evolve out of research-oriented activities in the fields of combustion and engine performance, the next logical step is the development of selected alternative fuels/engine equipment systems capable of sustained operation with performance, reliability, and maintainability characteristics appropriate to rail operational use.

If the AFFMSDE Program is to continue beyond the developmental phase, the program objective would logically expand to include demonstration of the use of these selected alternative fuel systems in representative rail operating environments.

4.1.2 Anticipated Management Problems

Even if the AFFMSDE Program were to begin to be managed as a pre-planned, adequately funded, and vigorously pursued program, at least five to seven years would be required to accomplish the major objectives briefly discussed above.

The reader should remember that during the past four years of the AFFMSDE Program, there have been a number of "gluts" in petroleum supply. At this time, another such "glut" is coming to an end. However, in the present circumstances, there are indications that the price of petroleum fuels may not rise significantly for some time in the future because of internal discord

within the OPEC producing nations. On the other hand, the inherent instability of the Middle East has never been more apparent than it is today.

Past support of the AFFMSDE Program has been maintained by a cooperative funding approach involving DOE, DOT/FRA, and the AAR. Support of the program is now being assumed by the AAR. It is obvious that future support will depend heavily on the endorsement and participation of the operating rail companies comprising the AAR. It is suggested that success of the overall project depends and requires continuous participation and support by the rail operating companies regardless of the vagaries and vacillating happenings of the World energy market.

The major management problem that is implicit in this multi-year, essentially voluntarily supported program is the maintenance of this voluntary support for what is an ambitious, technically difficult, and a large-scale program. It is strongly suggested that the development and formal adoption, by all participants, of a multi-year Program Management Plan might provide a means of focusing attention to this difficult management aspect and thus a means of contributing to developing a commitment to support of the program for its full duration by the AAR's member lines.

4.1.3 Planned Information Dissemination

To date, the overall objective of the activities performed under the AFFMSDE Program have been concerned with reduction of the levels of uncertainty associated with the use of alternative fuels in rail motive power systems. It is suggested that these objectives should be expanded to include additional technological aspects of energy use in motive power units generally. It is suggested that there are five categories or dimensions of uncertainty:

1. Technological uncertainty
2. Cost uncertainty
3. Demand uncertainty
4. Institutional uncertainty comprised of internal and external institutional uncertainty
5. Uncertainty about externalities outside the institutional system.

To date, the AFFMSDE Program has been concerned almost exclusively with the single consideration of eliminating technological uncertainty associated with the use of alternative fuels. Even in this area of program concentration, the program has progressed only in the "research" phase. Identifying the problems and the solutions to the problems of operating with these fuel systems requires the development of reliable, long-lived and maintainable engine systems operating on selected alternative fuels and the demonstration of the use of these alternative fuels in operating rail environments.

Whatever the results of the program activities, they must be accompanied by the effective dissemination of information regarding all program findings in these areas of uncertainty and the extent to which this uncertainty has been reduced.

It is recommended that information dissemination be identified as a specific task or activity area. An effective information dissemination program should be designed and specific responsibility for its continuous execution provided for in all program-related activities.

4.1.4 Additional Program Components Suggested

At the present time, there is no formally documented, multi-year program plan developed by, and agreeable to, the participants in the AFFMSDE Program. Present activities are almost exclusively research oriented. These activities form the basis from which any multi-year program plan must evolve.

These research activities should evolve through development to operational demonstration if a multi-year program management approach is to be used in the AFFMSDE Program. These activities--research, development, and operational demonstration of alternative fuel systems--form the "core" of a logical program plan.

However, two additional program components are suggested. First, the addition of a "Supporting Tasks" component addressing the many peripheral aspects of the use of alternative fuels, fuel conserving technology, energy recovery technology, systems analysis, and systems economics studies, etc. The second new program component suggested is a planned information dissemination activity as has been discussed.

These three major program components should be restricted to consideration of powerplants in rail motive power units and the servicing and support equipment and personnel systems directly related to motive power unit operation.

Problems related to the operational use of these equipment systems in rail operating environment, and the general problem of energy use and energy conservation in rail operations, should not be within the purview of this program but should fall within the purview of the Energy Steering Committee of the AAR.

4.2 Supporting Tasks Component

It is suggested that some means be developed to carry out individual supporting tasks, on a scheduled and direct basis, into such subject areas as:

- Alternative fuels availability
- Safety in fuel handling, storage, and distribution in rail operations
- Alternative engines and combinations of alternative engines and alternative fuel systems
- Energy conservation opportunities in motive power unit powerplants
- Energy recovery technology in motive power unit powerplants
- Systems economics considerations including the impact of the use of alternative fuels and other technological developments on fuel producers, rail equipment manufacturers, and operating companies. Factors considered should include, among other considerations, the impact on present equity values, the total real costs of conversion, the impact on costs of operation, and rail customer rate impacts.

4.3 Planned Information Dissemination Components

A planned effort should be undertaken to identify the specific information needs of rail operating companies for the information products, in whatever form, to be produced by the AFFMSDE Program. A system for presenting this information in the most effective manner, i.e., written documentation, workshops, seminars, extensive reports, physical demonstrations, etc., should be developed iteratively with the identification of the specific recipients identified within the AAR organizational structure and operating companies. This information should be brought together into a documented information dissemination program compatible with the research, development, and operational dem-

onstration program plan. Responsibility for its execution should be assigned to specific individuals with the appropriate skills and adequate funding support, within the overall program budget, provided.

4.4 The Multi-Year Research, Development, and Operational Demonstration Program Project

4.4.1 Basic Logic of Activity Areas

There are three basically different, but interrelated, types of selection decisions that must be made to establish the approach to be used in this program. The manner in which these decisions are made will determine the effectiveness with which the limited resources available are used to meet the specific objectives of this program. These selection decisions are:

1. The selection of the fuels to be subject to test
2. Selection of the method of use of the fuel in medium-speed diesel engines
3. The extent to which investigation of the fuels is carried in terms of 2-cylinder testing, multi-cylinder testing, and final development and operational demonstration in rail motive power equipment.

The nature of the selection problem becomes apparent if the reader will inspect Figures 4 through 6.

Figure 4 is a representative, but far from complete, identification of examples of six different classes of alternative fuels.

Figure 5, which represents the areas of investigation that have evolved to date in the AFFMSDE Program, contains four methods of use of alternative fuels in diesel engines. These are petroleum-based fuels with properties significantly different from Diesel No. 2 (Area C) and blends and emulsions (Area B). Limiting properties petroleum-based fuels and "stabilized" or "prepared" emulsions could be operated in essentially unmodified medium-speed diesel engines. If the blends and emulsions are prepared "on-line", modifications of some significance are required to the motive power equipment. Dual Fueling and Staged Injection (Areas D and E) represent significant departures in design from conventional injection systems. Further, any two-fuel combination systems, which includes blends and emulsions, dual-fueling and staged injection systems, would require dual fuel storage systems onboard rail motive power equipment.

		Examples:
1.	Limiting Properties Fuels from Petroleum	No. 3 Specification Heavy Oils
2.	Fuels from Non-Petroleum, Fossil Feedstocks	
	Coal Derived	SRC II Methanol
	Oil-Shale Derived	PARAHO Process DFM
	Tar Sands Derived	
3.	Biomass Derived	Ethanol
4.	Vegetable Oils	Castor Corn Cottonseed Peanut Soybean Sunflower
5.	Animal Oils & Fats	
6.	Gaseous Fuels	Methane Ammonia Propane Hydrogen

Fig. 4 Examples of Classes of Alternative Fuels and Some Examples of Such Fuels

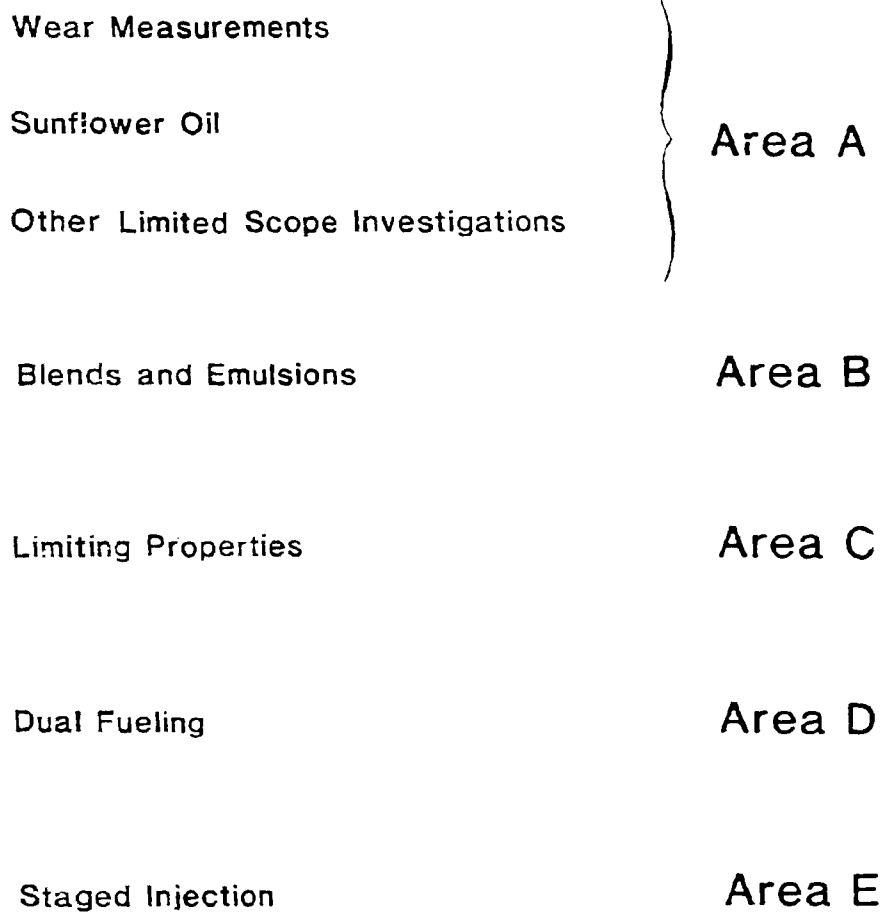


Fig. 5 Presently Proposed Areas of Investigation Comprising the Alternative Fuels for Medium Speed Diesel Engines (AFFMSDE) Project Activities.

Figure 6 illustrates a sequence of 4 steps, the logic of which is obvious, which are progressive steps from research testing through operational demonstration in revenue service. The investigation of any alternative fuel candidates can be carried to any of the four levels of investigation noted on this Figure.

It is also obvious that in the presence of limited resources, including the resource of time, the judicious selection of the fuels to be tested, their method of use, and the level of system testing to which the investigation will be carried is of critical significance in attaining the most effective use of program resources.

4.4.2 Basic Logic of R&D in Stationary Engines

All participants who have been involved in the AFFMSDE Program to date agree that research into combustion performance, fuel delivery systems, engine performance, and emissions characteristics that are of a research nature should be carried out in stationary research engine systems. In order to minimize expenses as well as time requirements, research-oriented efforts should be carried out in the 2-cylinder engine research system and the conclusions reached in this normally aspirated engine system verified by limited running in multi-cylinder, supercharged engines.

Research equipment systems do not require construction in a manner that will assure long-term, reliable operation. If an alternative fuel system is to be investigated as a serious candidate for eventual use in operational demonstration testing, the development of injection systems and support systems for engine operation on selected alternative fuel candidates should also be carried out in stationary engine systems to minimize expense.

4.4.3 Basic Logic of Operational Demonstration

Once the performance, reliability, and maintainability of a specific injection system and supporting systems has been demonstrated in stationary multi-cylinder operation, installation in rail motive power equipment should then logically be undertaken. The objectives of this type of testing should be to verify that the performance, reliability, and maintainability characteristics demonstrated in stationary engine testing are preserved in the high-vibration levels, temperature extremes, etc., environments of rail operating

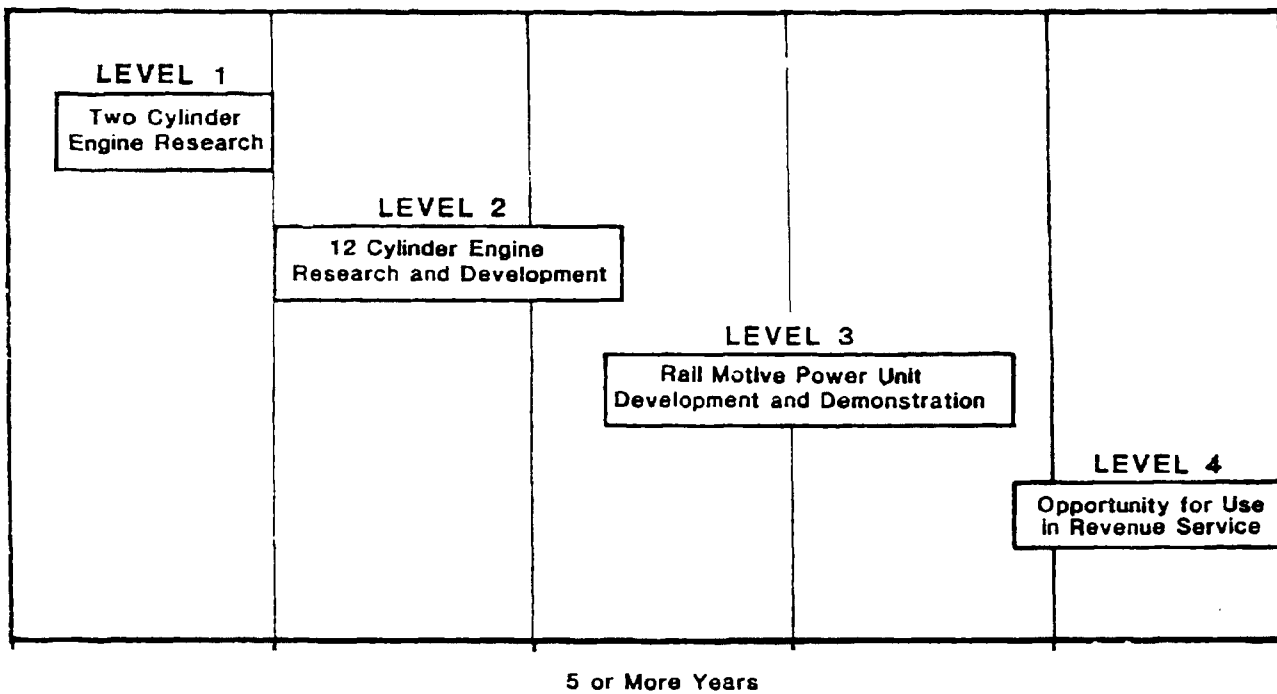


Fig. 6 Progressive Levels of Testing of Alternative Fuel Systems in 2-Cylinder Stationary, Multi-Cylinder Stationary and Rail Operating Environments.

equipment. The number of measurements required to be made in this environment should be significantly reduced from those associated with stationary multi-cylinder testing.

4.4.4 Work Areas

It is proposed that the AFFMSDE Program Plan presented here would consist of three program components:

1. Supporting tasks
2. Information dissemination
3. The multi-year research, development, and operational demonstration program plan.

5 The Program Plan Proposed

4.5.1 A Concept for Review and Revision

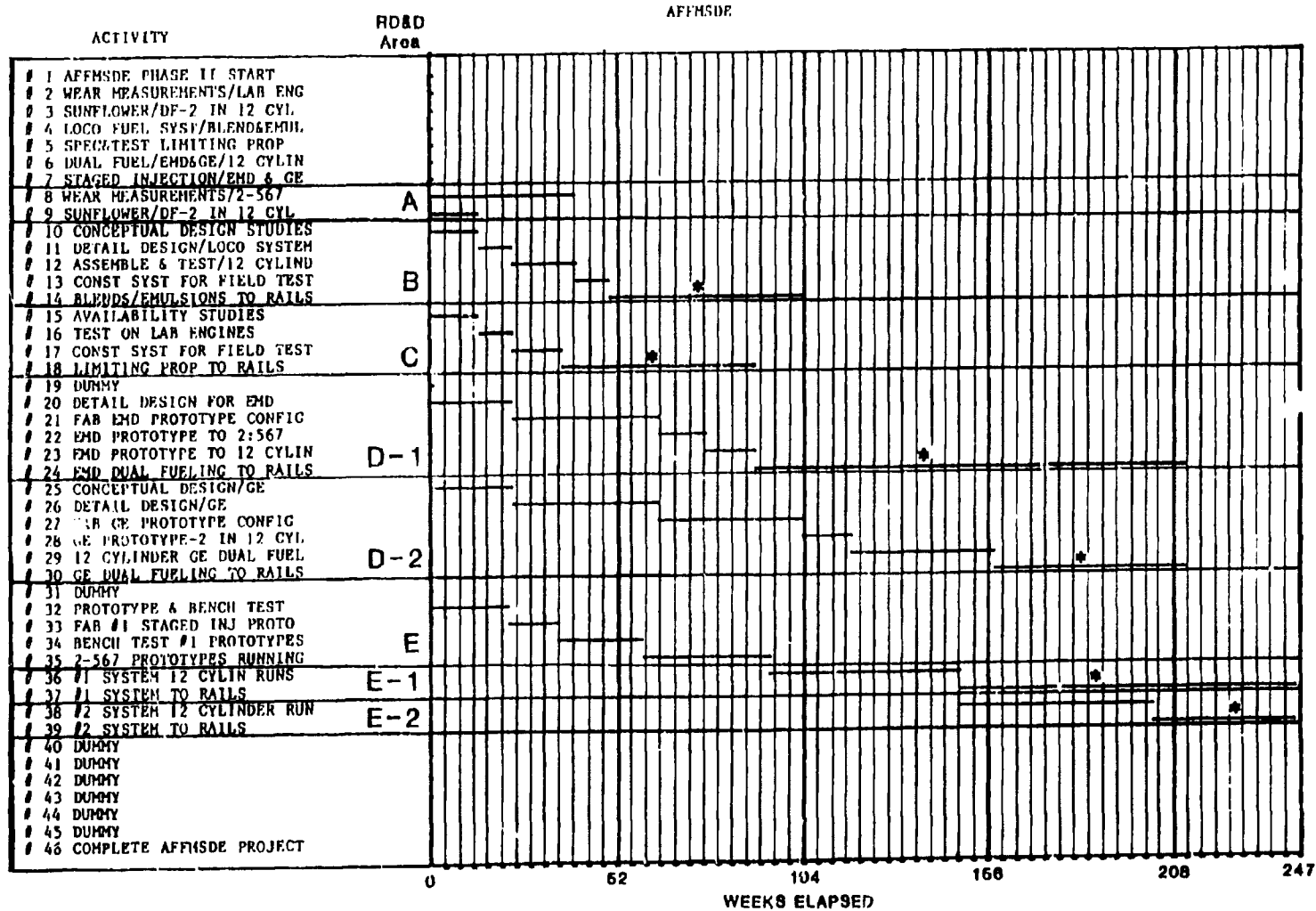
The program planning proposal contained on the following pages is intended to provide only a "baseline" concept. In any program of the duration, complexity, and cost such as is suggested by this program plan, review and revision should be a managed and scheduled process. This planning proposal and this complete document is provided to support two suggested actions. First, the adoption of multi-year, long-range planning as the method of management of the AFFMSDE Program. Secondly, a document upon which the review and revision process can be begun.

4.5.2 RD&D Activity Areas

Figure 7 presents a Gantt chart of the proposed multi-year program. This chart is part of the PERT/CPM planning package--parts of which will be discussed in following pages. The activities column requires discussion in relation to its PERT/CPM origin.

Activities 1 through 7 are "dummy" events used to identify the five "areas" of investigation illustrated in Figure 5.

Activity #1 provides an identification of program start only. Activities #2 and #3 identify two areas of investigation underway at the present time at SwRI. Activities #4 through #7 identify four basic groups of fuel delivery systems investigations as previously discussed and illustrated in Figure 5,



* Operation of Motive Power Units is not Priced or scheduled in detail

Fig. 7 Proposed Multi-Year Program Planning Concept for the AFFMSDE Program.

Actual program activities begin with Activity #8. Activities #40 through #46 are also dummy events used to close out the PERT/CPM presentation and the calculation systems involved in its preparation. Actual program activities are comprised of Activities #8 through #39.

Within each RD&D area, the individual activities provide for the progressive evolution of the investigation of the four basic groups of fuel delivery systems described in Figure 5 through the four "levels" of investigation described in Figure 6, i.e., from 2-cylinder testing through multi-cylinder testing through 2 levels of rail operational demonstration.

Area A Activities

The Area A activities, wear measurements and the investigation of sunflower oil in No. 2 Diesel fuel in 12-cylinder engines is presently underway at SwRI.

Area B Activities

Activities #10 through #14 are sequentially performed to support demonstration operation on selected blends and emulsions in rail motive power units. If the blends and emulsions are "prepared", motive power unit modifications will be minimal. If on-line methods of preparation of blends and emulsions are selected for investigation, major modifications to the motive power unit might be required. The consideration of a requirement for the modification of a conventional motive power unit to serve as an alternative fuel research motive power unit will be discussed separately. !

Area C Activities

Activities #15 through #18 lead sequentially to operational demonstration of diesel fuels with properties significantly deviating from Diesel No. 2. Extensive preparatory work related to this option has already been accomplished in the 2-cylinder and multi-cylinder research investigations at SwRI. Only minimal modifications to motive power equipment would be required to carry out this demonstration.

Areas D-1 and D-2 Activities

Extensive investigations have been carried out in the use of dual-fueling approaches in methanol, ethanol, and SRC-II fuel systems. The development of equipment systems, their evaluation in stationary engine systems, and their eventual evaluation in the rail operations involves significant mechanical design modifications to both the engines and motive power units. The extent of this difference requires separating the equipment manufactured by EMD and GE into two separate areas of investigation. This is provided for in Activities #20 through #24 for the EMD dual-fueling investigations and #25 through #30 for the GE dual-fueling investigations.

Area E Activities

Two-cylinder combustion investigations carried out by SwRI in earlier phases of the program demonstrated that the early injection, up to 115° BTDC, followed by injection of the main alternative fuel charge could provide significant improvement in the combustion of fuels that were otherwise difficult to burn efficiently and with acceptable pressure-rise rates. However, for other program considerations in 2-cylinder testing activities, these investigations were terminated in a relatively early stage. "Staged-injection" is a method of injection of significant interest.

Activities #32 through #35 will provide prototypes of a staged-injection system.

It will then be necessary to take the 2-cylinder design prototype and, with appropriate modifications, evaluate and develop these systems in stationary 12-cylinder engines of both EMD and GE designs. At the completion of these efforts, these systems will be available for operational evaluation in rail motive power units if it is so desired. Activities #36 and #37 provide these two final steps for one manufacturer's design and Activities #38 and #39 provide for the second manufacturer's design, i.e., EMD and GE.

4.5.3 An Alternative Fuels Research Motive Power Unit Concept

While rail motive power unit demonstration of limiting-property petroleum-based fuels and "prepared" blends and emulsions may be carried out with existing motive power equipment with minimum modifications, many of the fuel and delivery systems will require significant modifications for their demonstra-

tion in a rail operating environment. A first option for significantly different fuel forms and dual-fuel systems to be investigated is to use equipment with fuel storage in trailing equipment.

A second option is to construct research motive power units by modifying existing equipment expressly for the requirements of the AFFMSDE Program. One concept of such a modification is illustrated in Figure 8. It should be noted that the tank installation shown can be constructed in such a way as to provide storage capability for a wide range of alternative fuels including liquefied gaseous fuels, blends, slurries, emulsions, etc.

4.5.4 PERT/CPM Chart

It is hoped that the preceding discussions can serve as an introduction to the more complex PERT/CPM presentation on the following page. This presentation contains the same logic of program activity flow depicted in the Gantt chart in Figure 7. It additionally shows the interrelationship of work flow between the activities in each RD&D area previously discussed. Those activities where the design concept of an alternative fuel research motive power unit may find use are illustrated using reproductions of the same unit shown in Figure 8.

Design Concept

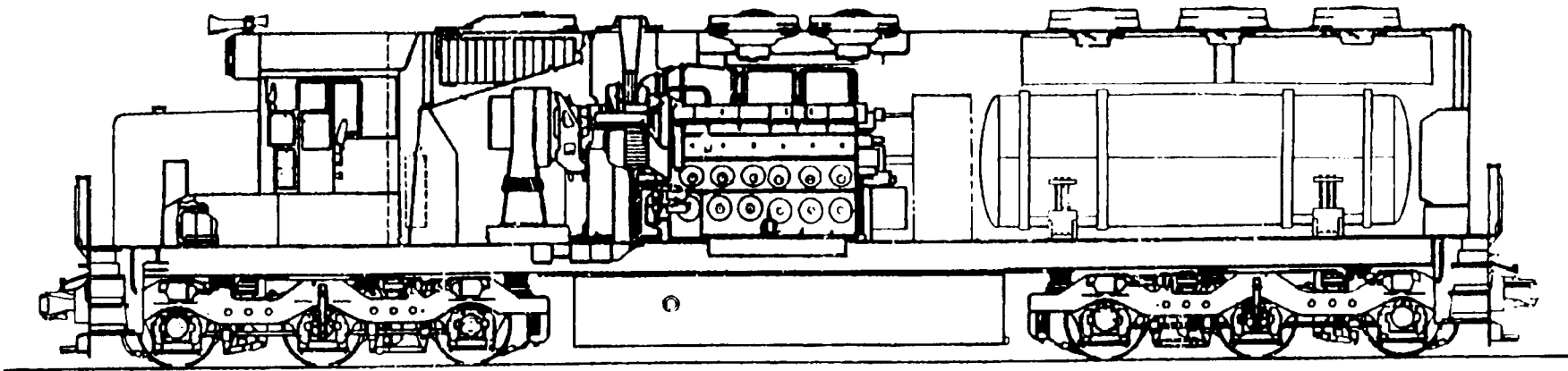
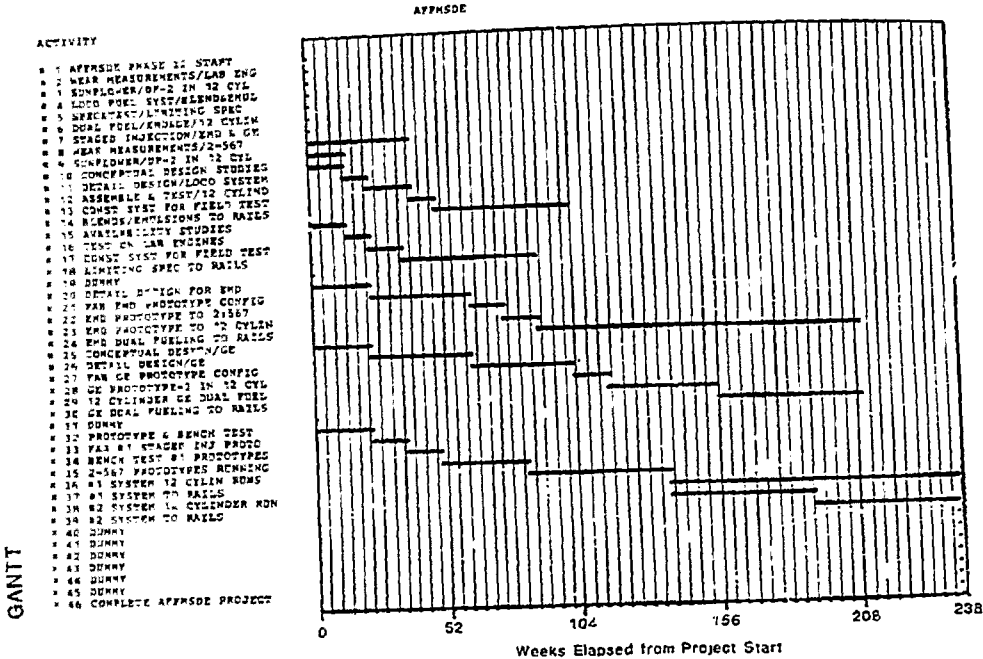


Fig. 8 Modified SD45-2 Alternative Fuels Research Motive Power Unit

ASSOCIATION OF AMERICAN RAILROADS - ALTERNATIVE FUELS FOR ME



GANIT

PROJECT NAME: AFFHSDE

NOTES:

- DL = EXPENDITURE IN THOUSANDS OF DOLLARS/TIME PERIOD
- ML = EXPENDITURE IN THOUSANDS OF MANHOURS/TIME PERIOD
- DUR = DURATION
- EPS = EARLIEST POSSIBLE STARTING TIME (END OF PERIOD)
- EPC = EARLIEST POSSIBLE COMPLETION TIME (END OF PERIOD)
- LAS = LATEST ALLOWABLE STARTING TIME (END OF PERIOD)
- LAC = LATEST ALLOWABLE COMPLETION TIME (END OF PERIOD)
- TS = TOTAL SLACK
- FS = FREE SLACK

ACT	NAME	DL	ML	DUR	EPS	EPC	LAS	LAC	TS	FS
1	AFFHSDE PHASE II START									
2	WEAR MEASUREMENTS/LAB ENG									
3	SUNFLOWER/DF-2 IN 12 CYL									
4	LOCO FUEL SYST/BLNDLEND									
5	SPEC/TEST/LIMITING SPEC									
6	DUAL FUEL/ENGINE/12 CYLIN									
7	STAGED INJECTION/END & CE									
8	WEAR MEASUREMENTS/2-567	1.000	1.000	10	0	30	0	10	0	0
9	SUNFLOWER/DF-2 IN 12 CYL	1.000	1.000	15	0	15	0	15	0	0
10	CONCEPTUAL DESIGN STUDIES	1.000	1.000	13	0	13	0	13	0	0
11	DETAIL DESIGN/LOCO SYSTEM	1.000	1.000	4	13	22	13	22	0	0
12	ASSEMBLY & TEST/12 CYLIND	1.000	1.000	17	22	39	22	39	0	0
13	CONST SYST FOR FIELD TEST	1.000	1.000	6	39	48	39	48	0	0
14	BLEND/EMULSIONS TO RAILS	1.000	1.000	52	48	100	48	100	0	0
15	AVAILABILITY STUDIES	1.000	1.000	13	0	13	0	13	0	0
16	TEST ON LAB ENGINES	1.000	1.000	4	13	22	13	22	0	0
17	CONST SYST FOR FIELD TEST	1.000	1.000	13	22	35	22	35	0	0
18	LIMITING SPEC TO RAILS	1.000	1.000	52	35	87	35	87	0	0
19	DUMMY									
20	DETAIL DESIGN FOR END	1.000	1.000	22	0	22	0	22	0	0
21	FAB END PROTOTYPE CONFIG	1.000	1.000	39	22	61	22	61	0	0
22	END PROTOTYPE TO 21567	1.000	1.000	13	61	74	61	74	0	0
23	END PROTOTYPE TO 12 CYLIN	1.000	1.000	13	74	87	74	87	0	0
24	END DUAL FUELING TO RAILS	1.000	1.000	177	87	204	87	204	0	0
25	CONCEPTUAL DESIGN/GE	1.000	1.000	22	0	22	0	22	0	0
26	DETAIL DESIGN/GE	1.000	1.000	39	22	61	22	61	0	0
27	FAB GE PROTOTYPE CONFIG	1.000	1.000	39	61	100	61	100	0	0
28	GE PROTOTYPE-1 IN 12 CYL	1.000	1.000	13	100	113	100	113	0	0
29	12 CYLINDER GE DUAL FUEL	1.000	1.000	19	113	132	113	132	0	0
30	GE DUAL FUELING TO RAILS	1.000	1.000	52	132	184	132	184	0	0
31	DUMMY									
32	PROTOTYPE & BENCH TEST	1.000	1.000	22	0	22	0	22	0	0
33	FAB #1 STAGED INJ PHOTO	1.000	1.000	13	22	35	22	35	0	0
34	BENCH TEST #1 PROTOTYPES	1.000	1.000	13	35	48	35	48	0	0
35	2-567 PROTOTYPES RUNNING	1.000	1.000	34	48	82	48	82	0	0
36	#1 SYSTEM 12 CYLIN RUNS	1.000	1.000	52	82	134	82	134	0	0
37	#1 SYSTEM TO RAILS	1.000	1.000	104	134	238	134	238	0	0
38	#2 SYSTEM 12 CYLINDER RUN	1.000	1.000	52	134	186	134	186	0	0
39	#2 SYSTEM TO RAILS	1.000	1.000	52	186	238	186	238	0	0
40	DUMMY	0.000	0.000	199	39	238	39	238	0	0
41	DUMMY	0.000	0.000	225	13	238	13	238	0	0
42	DUMMY	0.000	0.000	134	100	238	100	238	0	0
43	DUMMY	0.000	0.000	151	87	238	87	238	0	0
44	DUMMY	0.000	0.000	34	204	238	204	238	0	0
45	DUMMY	0.000	0.000	0	238	238	238	238	0	0
46	COMPLETE AFFHSDE PROJECT	0.000	0.000	0	238	238	238	238	0	0

PERT EVENTS

AFFHSDE

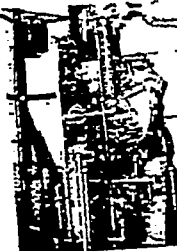
RESULTS OF RESOURCE LEVELING

- NOTES:**
 SS = SCHEDULED START TIME (END OF PERIOD)
 SC = SCHEDULED COMPLETION TIME (END OF PERIOD)

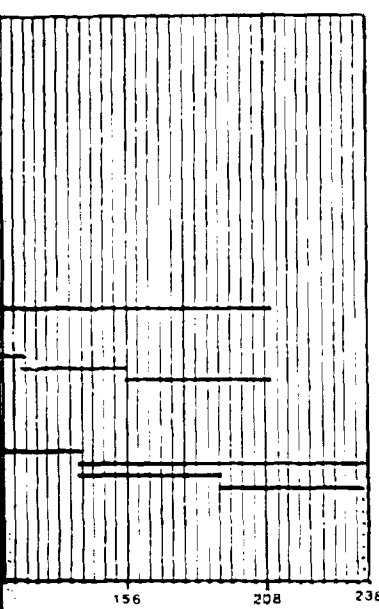
ACT	NAME	SS	SC
1	AFFHSDE PHASE II START		
2	WEAR MEASUREMENTS/LAB ENG		
3	SUNFLOWER/DF-2 IN 12 CYL		
4	LOCO FUEL SYST/BLNDLEND		
5	SPEC/TEST/LIMITING SPEC		
6	DUAL FUEL/ENGINE/12 CYLIN		
7	STAGED INJECTION/END & CE		
8	WEAR MEASUREMENTS/2-567	0	13
9	SUNFLOWER/DF-2 IN 12 CYL	0	13
10	CONCEPTUAL DESIGN STUDIES	13	22
11	DETAIL DESIGN/LOCO SYSTEM	22	39
12	ASSEMBLY & TEST/12 CYLIND	39	48
13	CONST SYST FOR FIELD TEST	39	48
14	BLEND/EMULSIONS TO RAILS	39	100
15	AVAILABILITY STUDIES	13	13
16	TEST ON LAB ENGINES	13	22
17	CONST SYST FOR FIELD TEST	22	35
18	LIMITING SPEC TO RAILS	35	87
19	DUMMY	0	22
20	DETAIL DESIGN FOR END	22	61
21	FAB END PROTOTYPE CONFIG	61	74
22	END PROTOTYPE TO 21567	61	74
23	END PROTOTYPE TO 12 CYLIN	74	87
24	END DUAL FUELING TO RAILS	87	204
25	CONCEPTUAL DESIGN/GE	22	61
26	DETAIL DESIGN/GE	61	100
27	FAB GE PROTOTYPE CONFIG	100	113
28	GE PROTOTYPE-1 IN 12 CYL	113	132
29	12 CYLINDER GE DUAL FUEL	113	132
30	GE DUAL FUELING TO RAILS	132	184
31	DUMMY	0	22
32	PROTOTYPE & BENCH TEST	22	35
33	FAB #1 STAGED INJ PHOTO	35	48
34	BENCH TEST #1 PROTOTYPES	48	82
35	2-567 PROTOTYPES RUNNING	82	134
36	#1 SYSTEM 12 CYLIN RUNS	134	238
37	#1 SYSTEM TO RAILS	134	186
38	#2 SYSTEM 12 CYLINDER RUN	186	238
39	#2 SYSTEM TO RAILS	186	238
40	DUMMY	39	238
41	DUMMY	13	238
42	DUMMY	100	238
43	DUMMY	87	238
44	DUMMY	204	238
45	DUMMY	238	238
46	COMPLETE AFFHSDE PROJECT	238	238

SCHEDULED ACTIVITY START & STOP DATES

AAR/SWF

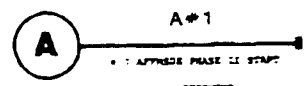


RAILROADS - ALTERNATIVE FUELS FOR MEDIUM SPEED DIESEL ENGINES (AFFMSDE)



...d from Project Start

Representative Configuration
Alternative Fuels Research
Motive Power Unit



AAR/SWRI AFFMSDE PROJECT RESEARCH ENGINES

AFFMSDE
RESULTS OF RESOURCE LEVELING
NOTES:
SS = SCHEDULED START TIME (END OF PERIOD)
SC = SCHEDULED COMPLETION TIME (END OF PERIOD)

ACT	NAME	SS	SC
1	AFFMSDE PHASE II START	-----	-----
2	MEASUREMENTS/LAB ENG	-----	-----
3	EMPLOYER/DP-12 12 CYL	-----	-----
4	LOCO FUEL SYST/LENGERFUL	-----	-----
5	SPEC TEST/LIMITING SPEC	-----	-----
6	DUAL FUEL/EMDAGE/12 CYL/1A	-----	-----
7	STAGED INJECTION/EMD & GE	-----	-----
8	MEASUREMENTS/2-567	0	14
9	EMPLOYER/DP-12 12 CYL	0	13
10	CONCEPTUAL DESIGN STUDIES	0	13
11	DETAIL DESIGN/LOCO SYSTEM	13	22
12	ASSEMBLY TEST/12 CYLIND	22	34
13	CONST SYST FOR FIELD TEST	14	44
14	MEASUREMENTS TO RAILS	44	60
15	AVAILABILITY STUDIES	0	13
16	TEST ON LAW ENGINES	13	22
17	CONST SYST FOR FIELD TEST	22	34
18	LIMITING SPEC TO RAILS	14	44
19	DUMMY		
20	DETAIL DESIGN FOR EMD	0	22
21	FAB ENG PROTOTYPE CONFIG	22	34
22	ENG PROTOTYPE TO 2-567	4	14
23	ENG PROTOTYPE TO 12 CYL	14	44
24	ENG DUAL FUELING TO RAILS	44	60
25	CONCEPTUAL DESIGN/GE	0	22
26	DETAIL DESIGN/GE	22	34
27	FAB GE PROTOTYPE CONFIG	34	44
28	GE PROTOTYPE TO 12 CYL	10	20
29	12 CYLINDER GE DUAL FUEL	113	152
30	GE DUAL FUELING TO RAILS	152	204
31	DUMMY		
32	PROTOTYPE & BENCH TEST	0	22
33	FAB #1 STAGED INC PHOTO	22	34
34	BENCH TEST #1 PROTOTYPES	34	44
35	2-567 PROTOTYPES RUNNING	44	60
36	#1 SYSTEM 12 CYLINDER RUN	42	134
37	#1 SYSTEM TO RAILS	134	234
38	#2 SYSTEM 12 CYLINDER RUN	134	184
39	#2 SYSTEM TO RAILS	186	238
40	DUMMY		
41	DUMMY	13	234
42	DUMMY	100	234
43	DUMMY	47	234
44	DUMMY	204	234
45	DUMMY	218	234
46	COMPLETE AFFMSDE PROJECT	234	234

SCHEDULED ACTIVITY START & STOP DATES



Two Cylinder, Normally Aspirated
EMD 567B Test Engine (2-567)



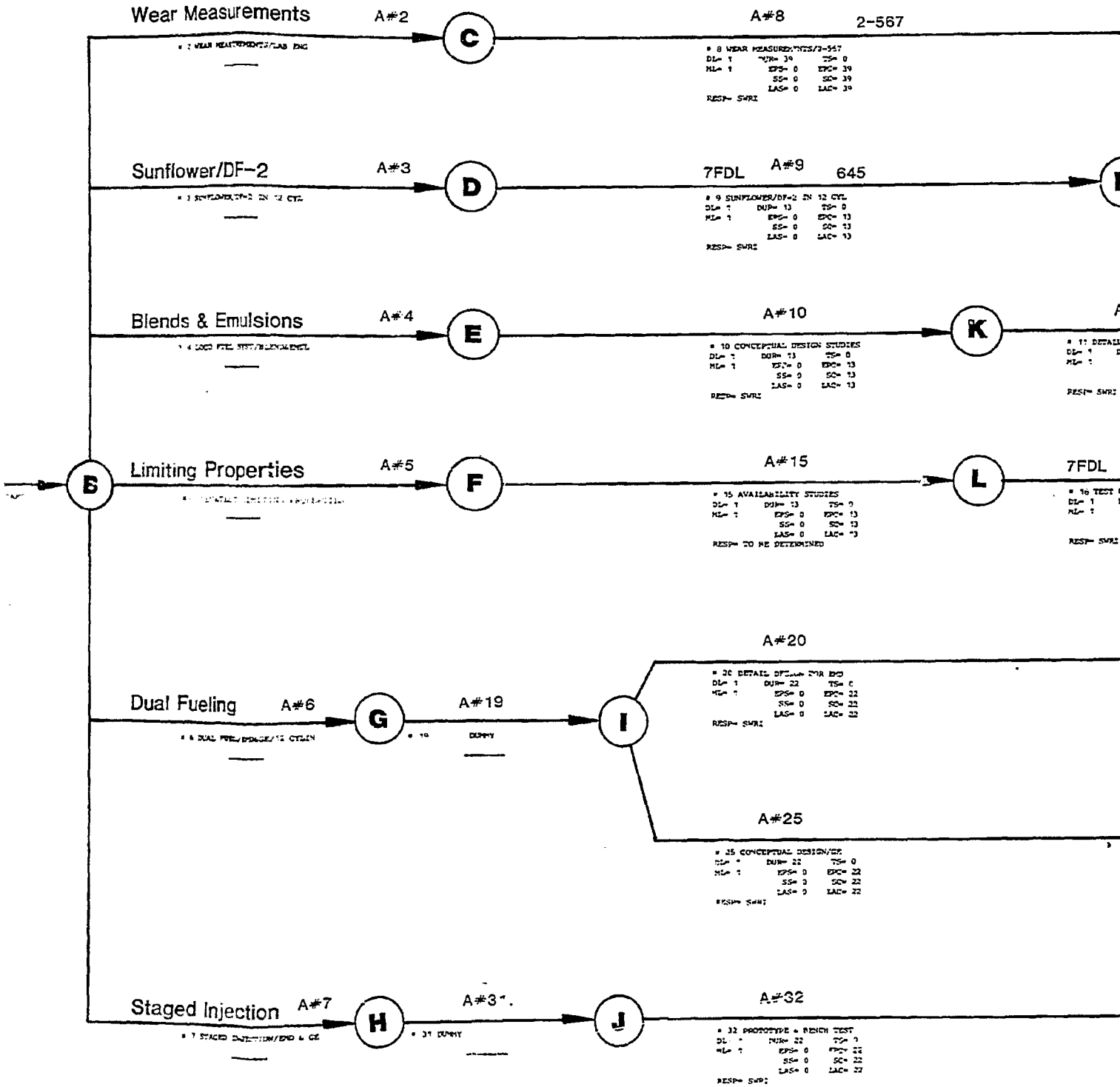
12 Cylinder General Electric
7FDL Engine (7FDL)



12 Cylinder EMD
645 E3B Engine (EMD645)

MSDE) PROGRAM PLAN PROPOSAL

APPROXIMATE ELAPSED TIME



APPROXIMATE ELAPSED TIME

15 Weeks

25 Weeks

A#8 2-567

8 MEAR MEASUREMENTS/2-567
 DEL-1 DUR= 30 TSP= 0
 REL-1 EPS= 0 EPC= 30
 SS= 0 SC= 30
 LAS= 0 LAC= 30
 RESP= SWRZ

7FDL A#9 645

9 SIMFLOW/DP-1 12 CYC
 DEL-1 DUR= 11 TSP= 0
 REL-1 EPS= 0 EPC= 13
 SS= 0 SC= 13
 LAS= 0 LAC= 13
 RESP= SWRZ



A#10

10 CONCEPTUAL DESIGN STUDIES
 DEL-1 DUR= 13 TSP= 0
 REL-1 EPS= 0 EPC= 13
 SS= 0 SC= 13
 LAS= 0 LAC= 13
 RESP= SWRZ



A#11

11 DETAIL DESIGN/LOAD SYSTEM
 DEL-1 DUR= 9 TSP= 0
 REL-1 EPS= 13 EPC= 22
 SS= 13 SC= 22
 LAS= 13 LAC= 22
 RESP= SWRZ



7FDL A#12 645

12 ASSEMBLE & TEST/12 CYCLING
 DEL-1 DUR= 11 TSP= 0
 REL-1 EPS= 22 EPC= 34
 SS= 22 SC= 34
 LAS= 22 LAC= 34
 RESP= SWRZ

A#15

15 AVAILABILITY STUDIES
 DEL-1 DUR= 13 TSP= 0
 REL-1 EPS= 0 EPC= 13
 SS= 0 SC= 13
 LAS= 0 LAC= 13
 RESP= TO BE DETERMINED



7FDL A#16 645

16 TEST ON LAB ENGINES
 DEL-1 DUR= 9 TSP= 1
 REL-1 EPS= 13 EPC= 22
 SS= 13 SC= 22
 LAS= 13 LAC= 22
 RESP= SWRZ



A#17

17 CONST SYST FOR FIELD TEST
 DEL-1 DUR= 13 TSP= 0
 REL-1 EPS= 22 EPC= 35
 SS= 22 SC= 35
 LAS= 22 LAC= 35
 RESP= SWRZ

A#20

20 DETAIL DESIGN FOR ENO
 DEL-1 DUR= 22 TSP= 0
 REL-1 EPS= 0 EPC= 22
 SS= 0 SC= 22
 LAS= 0 LAC= 22
 RESP= SWRZ



A#21

21 FAB ENO PROTOTYPE CONFIG
 DEL-1 DUR= 13 TSP= 0
 REL-1 EPS= 22 EPC= 61
 SS= 22 SC= 61
 LAS= 22 LAC= 61
 RESP= SWRZ

A#25

25 CONCEPTUAL DESIGN/GE
 DEL-1 DUR= 22 TSP= 0
 REL-1 EPS= 0 EPC= 22
 SS= 0 SC= 22
 LAS= 0 LAC= 22
 RESP= SWRZ



A#26

26 DETAIL DESIGN/GE
 DEL-1 DUR= 19 TSP= 0
 REL-1 EPS= 22 EPC= 61
 SS= 22 SC= 61
 LAS= 22 LAC= 61
 RESP= SWRZ

A#32

32 PROTOTYPE & BENCH TEST
 DEL-1 DUR= 22 TSP= 0
 REL-1 EPS= 0 EPC= 22
 SS= 0 SC= 22
 LAS= 0 LAC= 22
 RESP= SWRZ



A#33

33 FAB #1 STAGED INJ PHOTO
 DEL-1 DUR= 13 TSP= 0
 REL-1 EPS= 22 EPC= 35
 SS= 22 SC= 35
 LAS= 22 LAC= 35
 RESP= SWRZ



5 Weeks

35 Weeks

45 Weeks

55 Weeks

GE 7FDL & EMD 645 TEST OPPORTUNITY



645



A#13

13 CONST SYST FOR FIELD TEST
 DL= 1 DUR= 0 TS= 0
 ML= 1 EPS= 39 EPC= 49
 SS= 39 SC= 48
 LAS= 39 LAC= 49
 RESP= SVRI



A#14

Blends & Emulsions Evaluation Opp

14 BLENDS/EMULSIONS TO RAILS
 DL= 1 DUR= 52 TS= 0
 ML= 1 EPS= 48 EPC= 100
 SS= 48 SC= 100
 LAS= 48 LAC= 100
 RESP= TO BE DETERMINED

645
 CYCLING
 DL= 0
 ML= 0
 SS= 0
 LAC= 0

A#18

Limiting Properties Evaluation Opportunity GE & EMD



18 LIMITING PROPERTIES TO RAILS
 DL= 1 DUR= 52 TS= 0
 ML= 1 EPS= 35 EPC= 87
 SS= 35 SC= 87
 LAS= 35 LAC= 87
 RESP= TO BE DETERMINED

645
 CYCLING
 DL= 0
 ML= 0
 SS= 0
 LAC= 0

A#22 2-567



22 END PROTOTYPE TO 21547
 DL= 1 DUR= 13 TS= 0
 ML= 1 EPS= 67 EPC= 74
 SS= 67 SC= 74
 LAS= 67 LAC= 74
 RESP= SVRI



645
 CYCLING
 DL= 0
 ML= 0
 SS= 0
 LAC= 0

A#27



27 END OF MULTICYCLE CONFIG
 DL= 1 DUR= 14 TS= 0
 ML= 1 EPS= 47 EPC= 100
 SS= 47 SC= 100
 LAS= 47 LAC= 100
 RESP= SVRI

645
 CYCLING
 DL= 0
 ML= 0
 SS= 0
 LAC= 0

A#34



34 BENCH TEST #1 PROTOTYPES
 DL= 1 DUR= 13 TS= 0
 ML= 1 EPS= 35 EPC= 48
 SS= 35 SC= 48
 LAS= 35 LAC= 48
 RESP= SVRI

A#35

2-567



35 2-567 PROTOTYPES RUNNING
 DL= 1 DUR= 34 TS= 0
 ML= 1 EPS= 48 EPC= 82
 SS= 48 SC= 82
 LAS= 48 LAC= 82
 RESP= SVRI

645
 CYCLING
 DL= 0
 ML= 0
 SS= 0
 LAC= 0

↑ END OF PROPOSED CY 1982 PROGRAM

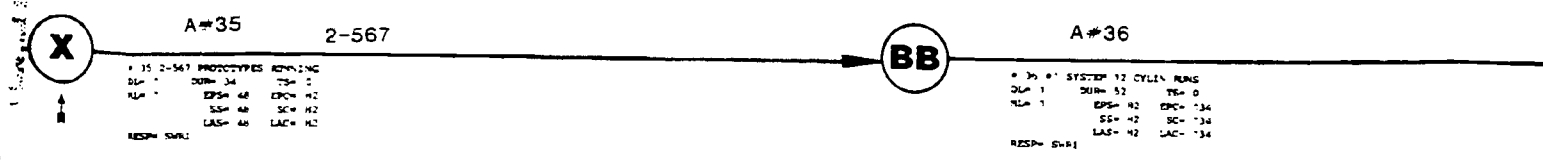
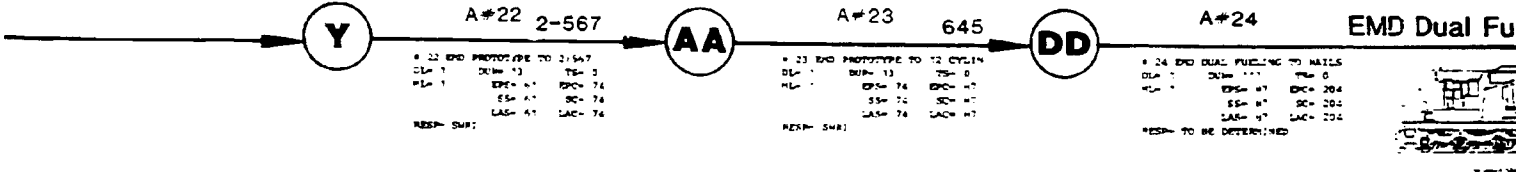
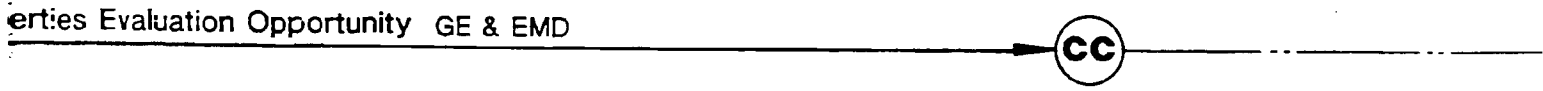
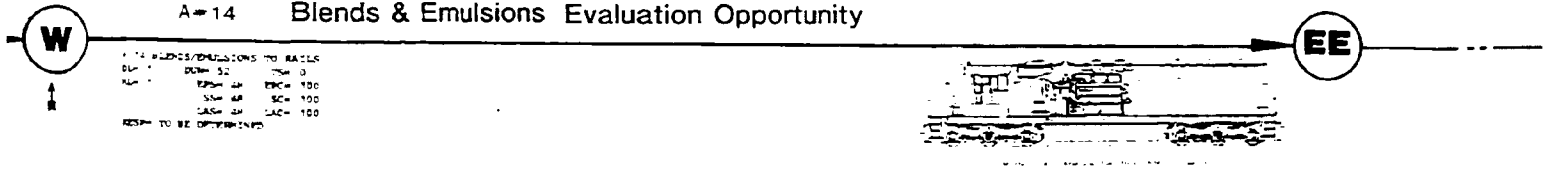
45 Weeks

55 Weeks

85 Weeks

100 Weeks

GE 7FDL & EMD 645 TEST OPPORTUNITY



↑ END OF PROPOSED CY 1982 PROGRAM

100 Weeks

135 Weeks

160 Weeks

EE

4 EMD Dual Fueling Evaluation Opportunity

TUNG TO RAILS
 DLP = 8
 EPS = 204
 SS = 204
 LAC = 204
 RESP =



FF

A#28

7FDL

28 GE PROTOTYPE IN 12 CYL
 DLP = 13 TS = 0
 EPS = 113 EPC = 113
 SS = 113 SC = 113
 LAC = 113 LAC = 113
 RESP = SWI

GG

A#29

7FDL

29 12 CYLINDER GE DUAL FUEL
 DLP = 30 TS = 0
 EPS = 113 EPC = 152
 SS = 113 SC = 152
 LAC = 113 LAC = 152
 RESP = SWI

II

A#30

GE Dual Fueling Evaluation

30 GE DUAL FUELING TO RAILS
 DLP = 52 TS = 0
 EPS = 152 EPC = 204
 SS = 152 SC = 204
 LAC = 152 LAC = 204
 RESP = TO BE DETERMINED



A#37 Staged Injection System #1 Evaluation Op

HH

37 #1 SYSTEM TO RAILS
 DLP = 104 TS = 0
 EPS = 134 EPC = 238
 SS = 134 SC = 238
 LAC = 134 LAC = 238
 RESP = TO BE DETERMINED



Staged Inject

A#38

JJ

38 #2 SYSTEM 12 CYLINDER HIN
 DLP = 52 TS = 0
 EPS = 134 EPC = 186
 SS = 134 SC = 186
 LAC = 134 LAC = 186
 RESP = SWI

38 #2
 DLP = 52
 TS = 0
 EPS = 134
 EPC = 186
 SS = 134
 SC = 186
 LAC = 134
 LAC = 186
 RESP = SWI

240 Weeks

A#40

A 40 DUMPY			
DL#	0	DUM= 100	TS= 0
PL#	0	EPS= 34	EPC= 234
		SS= 34	SC= 234
		LAS= 34	LAC= 234
RESP=			

A#41

A 41			
DL#	0	DUM= 225	TS= 0
PL#	0	EPS= 13	EPC= 234
		SS= 13	SC= 234
		LAS= 13	LAC= 234
RESP=			

A#42

A 42			
DL#	0	DUM= 138	TS= 0
PL#	0	EPS= 100	EPC= 234
		SS= 100	SC= 234
		LAS= 100	LAC= 234
RESP=			

A#43

A 43			
DL#	0	DUM= 751	TS= 0
PL#	0	EPS= 87	EPC= 234
		SS= 87	SC= 234
		LAS= 87	LAC= 234
RESP=			

A#46

A 46 COMPLETE APPROX PROJECT			
DL#	0	DUM= 0	TS= 0
PL#	0	EPS= 234	EPC= 234
		SS= 234	SC= 234
		LAS= 234	LAC= 234
RESP= AAK & SWR			

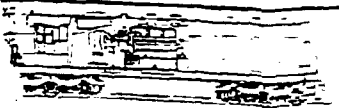


A#44

A 44			
DL#	0	DUM= 34	TS= 0
PL#	0	EPS= 204	EPC= 234
		SS= 204	SC= 234
		LAS= 204	LAC= 234
RESP=			



Fueling Evaluation Opportunity

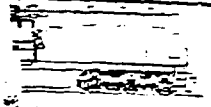


A#45

A 45			
DL#	0	DUM= 0	TS= 0
PL#	0	EPS= 234	EPC= 234
		SS= 234	SC= 234
		LAS= 234	LAC= 234
RESP=			



#1 Evaluation Opportunity



Staged Injection System #2 Evaluation Opportunity



A#39

A 39 #2 SYSTEM DO BALLS			
DL#	1	DUM= 52	TS= 0
PL#	1	EPS= 104	EPC= 234
		SS= 104	SC= 234
		LAS= 104	LAC= 234
RESP= SWR			

Section 5

PROGRAM BENEFITS

- The limits of the properties of petroleum-based fuel that will provide satisfactory operation of medium-speed engines will be determined.
- The characteristics of operation of medium-speed diesel engines on fuel forms representative of synfuels derived from non-petroleum, fossil-based resources will be determined.
- The characteristics of operation of medium-speed diesel engines on fuel forms derived from non-fossil resources will be determined.
- A 2-cylinder and multi-cylinder rail motive power laboratory has been established at SwRI. The facility is supported by personnel experienced in fuels research, lubricants technology, emissions measurements, and combustion research in medium-speed diesel engines and support systems.
- The potential benefits that can be derived from the application of advanced technology to medium-speed diesel engines and the potential benefits and problems associated with the use of alternative engine designs, energy conservation systems, and energy recovery systems will be investigated and documented.
- The strategies or implementation options that can be used to make transition off petroleum-based fuel forms to non-petroleum based fuel forms will be investigated, and documented, from the business operations standpoint of organizations making use of medium-speed diesel engines.
- Fuel injection, and other engine-related equipment systems, capable of providing reliable, safe, and maintainable operation of medium-speed diesel engines on non-petroleum based fuel forms will be brought to a developed hardware status. The problems associated with large-scale production of the designs developed will be identified and the approaches of such manufacturing assessed.
- Onboard fuel storage and delivery systems, and yard fuel storage and delivery systems, capable of reliable, safe, and maintainable operation with non-petroleum based fuel forms will be brought to a developed hardware status. The problems associated with large-scale production of the designs developed will be identified and approaches to such manufacturing assessed.
- The characteristics of operation of medium-speed diesel engines on non-petroleum based alternative fuel forms in full-scale equipment systems will be evaluated.
- The problems, and methods of solution of those problems, associated with the operation of medium-speed diesel engine systems on non-petroleum based fuel forms will be investigated in a practical operating environment. Investigation will be of sufficient scope, in terms of length of period of investigation and scale of equipment used, to assure that the conclusions developed are valid representations of large-scale implementation approaches in real rail business operations.

Section 6

MANAGEMENT APPROACH

The method of approach to the management of the AFFMSDE Program has been established through four years of activity on that program. However, there are two recent changes that may impact this method of management.

First, efforts are presently underway by SwRI under AAR direction to broaden the representation on the Alternative Fuels Steering Committee of the AAR to include representation from the fuels industry.

Secondly, the AAR is understood to be forming an overall energy Steering Committee which will consider the broad aspects of energy use in the rail industry. The problem of alternative fuels, energy conservation, and energy recovery technology in rail motive power equipment is only one aspect of this overall program.

These considerations, combined with the three suggested activity areas previously discussed in this program planning concept document, suggest a project management structure as illustrated in Figure 10.

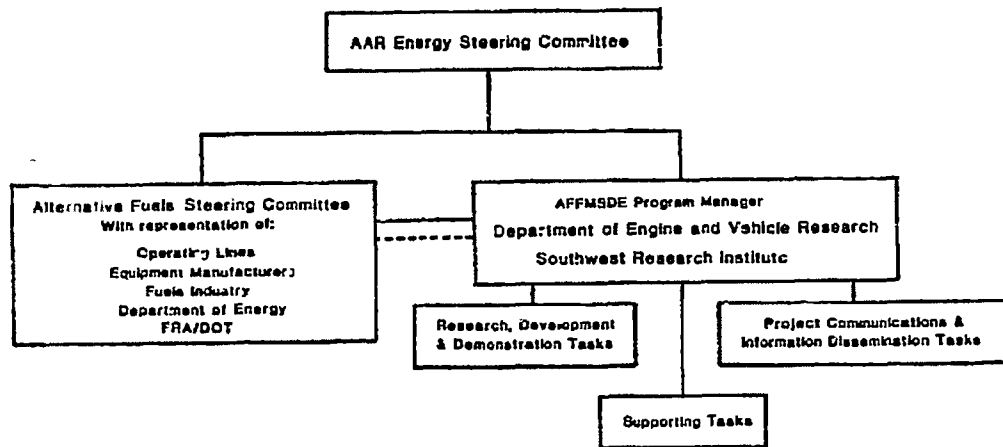


Fig. 10 AFFMSDE Management Structure Suggested by Recent and Proposed SwRI and AAR Initiatives.

Section 7

BUDGETARY ESTIMATES

7.1 Basic Project Budget

Figure 11 presents a basic budgetary estimate for each of the activity areas in terms of total dollars and total manhours required for their completion. This budget does not include funds for the design, construction, or operation of motive power units used in operational demonstrations.

7.2 Cash Flow Requirements

Figure 12 presents the program cash flow requirements over a nominal 5-year program with major milestones indicated. These cash flow estimates do not provide for the design, construction, or operation of motive power equipment in operational rail demonstrations.

DOLLAR AND MANHOUR LEVELS BY TASK

ACTIVITY	RD&D Area	TOTAL DOLLARS	TOTAL MANHOURS
# 1 AFFMSDE PHASE II START		\$0.00	0
# 2 WEAR MEASUREMENTS/LAB ENG		\$0.00	0
# 3 SUNFLOWER/DF-2 IN 12 CYL		\$0.00	0
# 4 LOCO FUEL SYST/BLENDE&EMUL		\$0.00	0
# 5 SPEC&TEST LIMITING PROP		\$0.00	0
# 6 DUAL FUEL/END&GE/12 CYLIN		\$0.00	0
# 7 STAGED INJECTION/EMD & GE		\$0.00	0
# 8 WEAR MEASUREMENTS/2-567	A	\$98,999.90	2,322
# 9 SUNFLOWER/DF-2 IN 12 CYL		\$54,000.10	947
# 10 CONCEPTUAL DESIGN STUDIES	B	\$28,736.90	1,892
# 11 DETAIL DESIGN/LOCO SYSTEM		\$48,939.00	3,216
# 12 ASSEMBLE & TEST/12 CYLIND		\$76,575.00	5,032
# 13 CONST SYST FOR FIELD TEST		\$54,697.00	3,595
* # 14 BLENDS/EMULSIONS TO RAILS		\$0.00	0
# 15 AVAILABILITY STUDIES	C	\$25,000.00	500
# 16 TEST ON LAB ENGINES		\$51,692.00	1,238
# 17 CONST SYST FOR FIELD TEST		\$4,300.00	103
* # 18 LIMITING PROP TO RAILS		\$0.00	0
# 19 DUMMY	D	\$0.00	0
# 20 DETAIL DESIGN FOR EMD		\$105,000.00	2,200
# 21 FAB EMD PROTOTYPE CONFIG		\$50,000.00	1,000
# 22 EMD PROTOTYPE TO 2:567		\$100,000.00	2,100
# 23 EMD PROTOTYPE TO 12 CYLIN		\$339,999.00	5,800
* # 24 EMD DUAL FUELING TO RAILS		\$0.00	0
# 25 CONCEPTUAL DESIGN/GE		\$49,375.00	1,892
# 26 DETAIL DESIGN/GE		\$108,625.00	4,162
# 27 FAB GE PROTOTYPE CONFIG		\$50,000.00	1,000
# 28 GE PROTOTYPE-2 IN 12 CYL		\$350,000.00	2,100
# 29 12 CYLINDER GE DUAL FUEL		\$450,002.00	6,000
* # 30 GE DUAL FUELING TO RAILS		\$0.00	0
# 31 DUMMY	E	\$0.00	0
# 32 PROTOTYPE & BENCH TEST		\$46,097.10	2,580
# 33 FAB #1 STAGED INJ PRGTO		\$27,658.00	1,548
# 34 BENCH TEST #1 PROTOTYPES		\$52,242.00	2,924
# 35 2-567 PROTOTYPES RUNNING		\$749,999.00	4,000
# 36 #1 SYSTEM 12 CYLIN RUNS		\$1,400,000.00	8,000
* # 37 #1 SYSTEM TO RAILS		\$0.00	0
# 38 #2 SYSTEM 12 CYLINDER REN		\$1,400,000.00	8,000
* # 39 #2 SYSTEM TO RAILS		\$0.00	0
# 40 DUMMY		\$0.00	0
# 41 DUMMY		\$0.00	0
# 42 DUMMY		\$0.00	0
# 43 DUMMY		\$0.00	0
# 44 DUMMY		\$0.00	0
# 45 DUMMY		\$0.00	0
# 46 COMPLETE AFFMSDE PROJECT		\$0.00	0

TOTAL DOLLARS \$5,722,000.00
 TOTAL MANHOURS 72,151

* Operation of Motive Power Units is not scheduled or priced in detail

Fig. 11 Basic Budgetary Estimates of the Multi-Year AFFMSDE Program

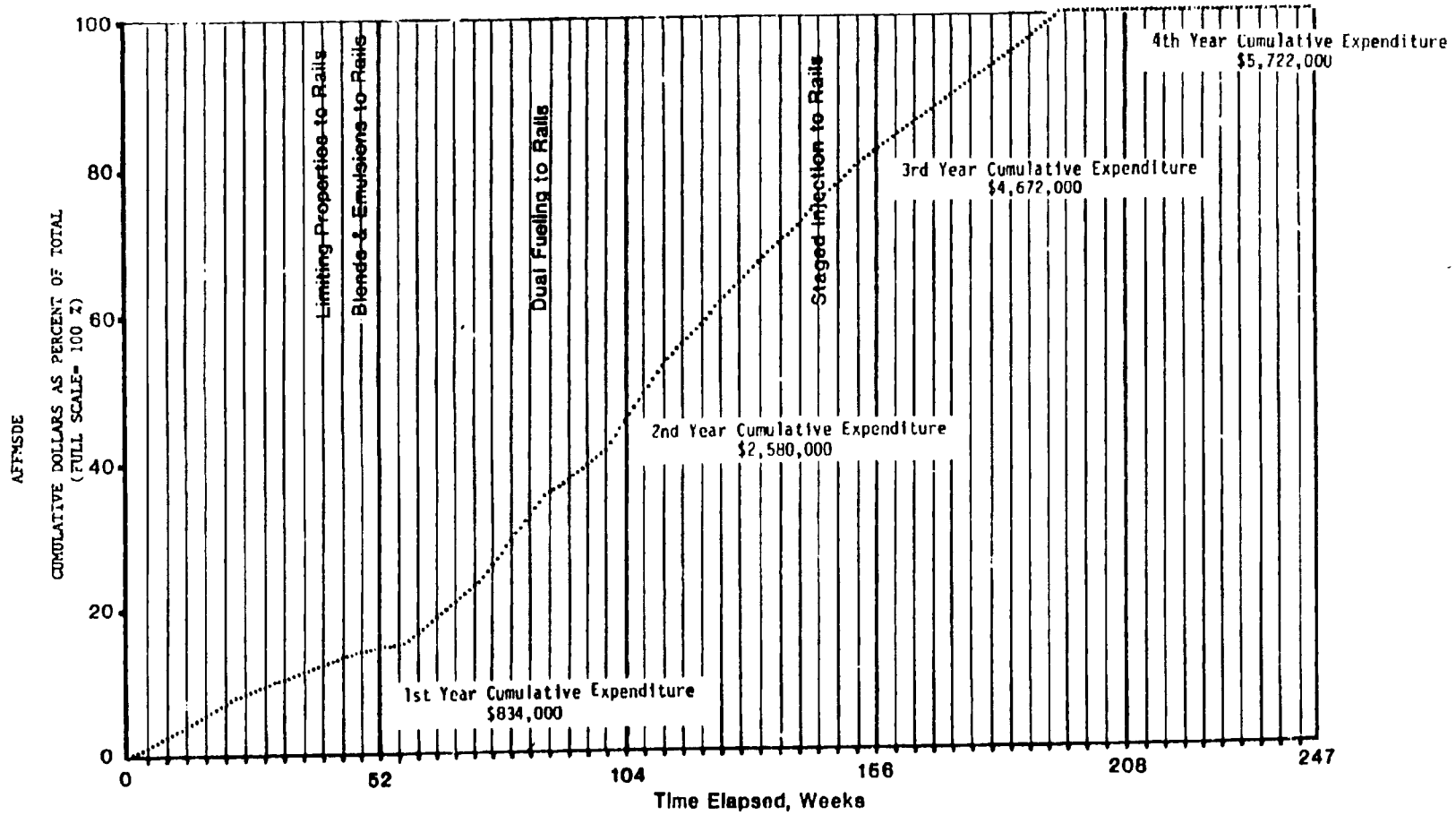


Fig. 12 Cash Flow Requirements Estimates of the Multi-Year AFFMSDE Program

Section 8

RECOMMENDATIONS

1. Planning, Management and Financial Support of the AFFMSDE Program should be carried out on a Multi-Year basis evolving from the present year-to-year approach.
2. Study and analysis tasks covering a broad range of considerations supporting alternative fuels and engine technology tasks should be added to the scope of work of the AFFMSDE program. These tasks should consider such subjects as fuels availability, safety in handling and use, the range of problems that would be encountered by rail operating companies if such fuels were to be used in motive power equipment in revenue service, the impact on original equipment manufacturers, etc.
3. The information needs of the rail operating companies related to the AFFMSDE Program should be studied and specific information requirements, methods of communication, etc. identified. These requirements should form the basis of a planned information dissemination program which should be incorporated into the AFFMSDE Multi-Year Program Plan.

SATISFACTION GUARANTEED

NTIS strives to provide quality products, reliable service, and fast delivery. Please contact us for a replacement within 30 days if the item you receive is defective or if we have made an error in filling your order.

▶ **E-mail: info@ntis.gov**

▶ **Phone: 1-888-584-8332 or (703)605-6050**

Reproduced by NTIS

National Technical Information Service
Springfield, VA 22161

This report was printed specifically for your order from nearly 3 million titles available in our collection.

For economy and efficiency, NTIS does not maintain stock of its vast collection of technical reports. Rather, most documents are custom reproduced for each order. Documents that are not in electronic format are reproduced from master archival copies and are the best possible reproductions available.

Occasionally, older master materials may reproduce portions of documents that are not fully legible. If you have questions concerning this document or any order you have placed with NTIS, please call our Customer Service Department at (703) 605-6050.

About NTIS

NTIS collects scientific, technical, engineering, and related business information – then organizes, maintains, and disseminates that information in a variety of formats – including electronic download, online access, CD-ROM, magnetic tape, diskette, multimedia, microfiche and paper.

The NTIS collection of nearly 3 million titles includes reports describing research conducted or sponsored by federal agencies and their contractors; statistical and business information; U.S. military publications; multimedia training products; computer software and electronic databases developed by federal agencies; and technical reports prepared by research organizations worldwide.

For more information about NTIS, visit our Web site at <http://www.ntis.gov>.

NTIS

**Ensuring Permanent, Easy Access to
U.S. Government Information Assets**



U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Technical Information Service
Springfield, VA 22161 (703) 605-6000
