DEVELOPMENT PLAN

THE FAA MODIFIED FUEL PROGRAM

SUBPROGRAM 183-522 FIRE SURVIVABILITY CRITERIA

Systems Research and Development Service
Aircraft and Noise Abatement Division
Airworthiness and Crashworthiness Branch

19 September 1972

BACKGROUND

Civil Aeronautics Board Bureau of Safety Pamphlet No. 7-6-3, "A Study of United States Air Carrier Accidents Involving Fire, 1955-1964," dated 30 March 1966, indicates that there were 13 accidents during this 10-year period where 297 of a total of 328 fatalities occurred as a direct result of fire and its effects and that all 297 fire fatalities would have survived had fire not occurred. From this group of 13 accidents (10 piston, 3 turbine), 342 of the 670 occupants survived.

Five recent survivable air carrier accidents involving fire resulted in 181 fatalities among 431 occupants for a fatality rate of 42%. The NTSB investigation of the Convair 580 accident at New Haven, Conn., 7 June 1971, revealed that 27 of the 28 fatalities survived the initial impact and were caused by fire, smoke, and explosions. Forty-seven of 229 occupants aboard the DC-8-63 involved in a takeoff accident at Anchorage, Alaska, on 27 November 1968, received fatal injuries from post-crash fire and explosion.

From 1964-1969, there were 135 helicopter accidents where fire occurred of which 45% were fatal compared to 28% of the non-fire accidents.

On the basis of approximate aircraft value estimates, hull losses due to fire damage in 1969 were $19.5 million for air carrier aircraft. As larger transports are incorporated in the air carrier fleet, the number of lives exposed to fatal injury by post crash fire following survivable crash is significantly increased.

PROGRAM OBJECTIVES

1. To develop a modified jet fuel which will reduce the likelihood and severity of a post crash fire and thereby increase the time available for safe passenger evacuation and prevent fatalities due to fire.

2. To facilitate the use of modified fuel by the jet air carrier fleet and turbine helicopters by sponsoring the certification of an engine and aircraft components, establishing logistics requirements, and developing a modified fuel specification.

PREVIOUS ACCOMPLISHMENTS

The Federal Aviation Administration has been working on gelled fuels for reducing the crash fire hazard following survivable crash landings since the latter part of 1963 when a contract was awarded to the Western Company, Dallas, Texas, for portable gelled fuel pump and mixer equipment. A follow-on contract was awarded in May 1964 to the Western Company to determine the feasibility of routinely using gelled fuel in regular flight operations. This effort produced a thick gelled fuel known as FAA-1069-1 which had good fire control characteristics and met the basic fuel specification, but engine and aircraft fuel system and ground refueling system compatibility problems were severe. J-47 turbojet engine tests and various other tests at NAFEC with this gelled fuel indicated satisfactory engine performance but the engine had to be purged with standard fuel after each test period and fuel tank modifications were necessary to supply the engine. This gelled fuel also showed deficiencies with respect to storage and vibration stability.

Another contract was awarded to the Western Company in September 1967 for the development of a gelled fuel which will be more compatible with engine and aircraft fuel systems but no significant results were obtained from this effort. In 1968, the U.S. Bureau of Mines developed a rating system under FAA sponsorship to evaluate the relative crash fire hazard characteristic of modified turbine fuels. Also, the Dow Chemical Company and Anheuser-Busch each submitted samples of independently developed gelled fuel to the FAA for testing. The Dow 7038 and Anheuser-Busch fuels showed many significant qualities desired in a crash safe fuel. In 1969, the Douglas Aircraft Company conducted a study under FAA contract to determine the compatibility of the Dow 7038 gelled fuel and several emulsified fuels with a jet transport fuel system. This study showed that the most promising candidate fuels at that time were not compatible with jet transport fuel systems without extensive modification. The study also indicated that emulsified fuels should be eliminated from the crash safe fuels program as showing a lesser potential for development than gels.

In May 1970 a cost analysis study was completed by the Douglas Aircraft Company under FAA contract evaluating the financial aspects of the use of the early Dow 7038 gelled fuel in commercial airline operations. It was estimated that for the first 10-year period, the use of this gelled fuel would increase airline total operating costs by 4.5% due to the gelled fuel and modification costs. In June 1970 contracts were awarded to the Dow Chemical Company and Anheuser Busch for the development of an optimum gelled fuel with a viscosity low enough so as to retain the safety benefits of previous gels and yet be compatible with commercial jet aircraft engines and fuel systems without major modifications being required.

As a result of these contracts, Dow 7129 gelled fuel was developed and offered promise of reducing the estimated 4.5% increase in total operating costs to less than a 2.0% increase since it was 97% less viscous than the 7038 gelled fuel. The viscosity of the new gelled fuel developed by Anheuser-Busch increased more at low temperatures than the 7129 gelled fuel. Accordingly, future efforts were concentrated on further testing of the 7129 fuel.

A 26-hour J-79 engine ground test and CV-880 aircraft fuel system ground test were completed in 1971 using the 7129 gelled fuel and indicated that the engine fuel nozzles should be modified for proper operation. Viscosity drift deficiencies were also identified concurrently with the advent of new modified fuels; AM-1 developed by Continental Oil Co., XD-8103 by Dow Chemical Co., and FM-4 by Imperial Chemical Industries of England. The FAA program was redirected in mid-1972 toward consideration of these new fuels after preliminary testing indicated that crash fire reduction characteristics were excellent at very low additive concentrations of 0.3% by weight.

FY-73 Program

About $263K of FY-72 contract funds will be used to support the following efforts during the first-half of FY-73 to evaluate the XD-8103, AM-1, and FM-4 modified fuels and determine the best candidate:

1.	Interagency Agreement DOT-FA72NA-AP-17 (NATF Lakehurst - RB-66 crash tests)	$155,000
2.	Interagency Agrement DOT-FA71NA-AP-98 Rev. 3/8/72 (NAPTC Philadelphia - simulated altitude combustor tests)	59,000
3.	Contract DOT-FA72NA-727 (Parker Hannifin - fuel nozzle redesign)	11,000
4.	Contract DOT-FA72NA-746 (Rutgers University - fuel mist flame propagation (study)	37,977

The FY-73 contract fund budget contains about $200K in the 183-522 modified fuel program which will be used to conduct J-79 engine ground tests and initiate flight tests during the second-half of FY-73 using modified fuel nozzles and the newly selected fuel. These tests will serve to determine the operational feasibility of the modified fuel concept by the end of FY-73. Planning and test facility preparation requiring about $10K will be initiated in FY-73 to conduct helicopter crash tests in FY-74.

Proposed FY-74 Program

It is proposed in FY-74 to complete the modified fuel program by continuing beyond the feasibility stage established in FY-73 toward a program which will result in gaining approval and acceptance of modified fuel for use in civil aviation. A FY-74 contract fund budget of $1350K is needed to attain this objective through accomplishment of the following program:

1.	Modified fuel aircraft component compatibility tests	$200K
2.	Modified fuel logistics study	100K
3.	Modified fuel engine certification tests	500K
4.	Certificated engine flight endurance tests	500K
5.	Develop modified fuel specification	50K
		$1350K

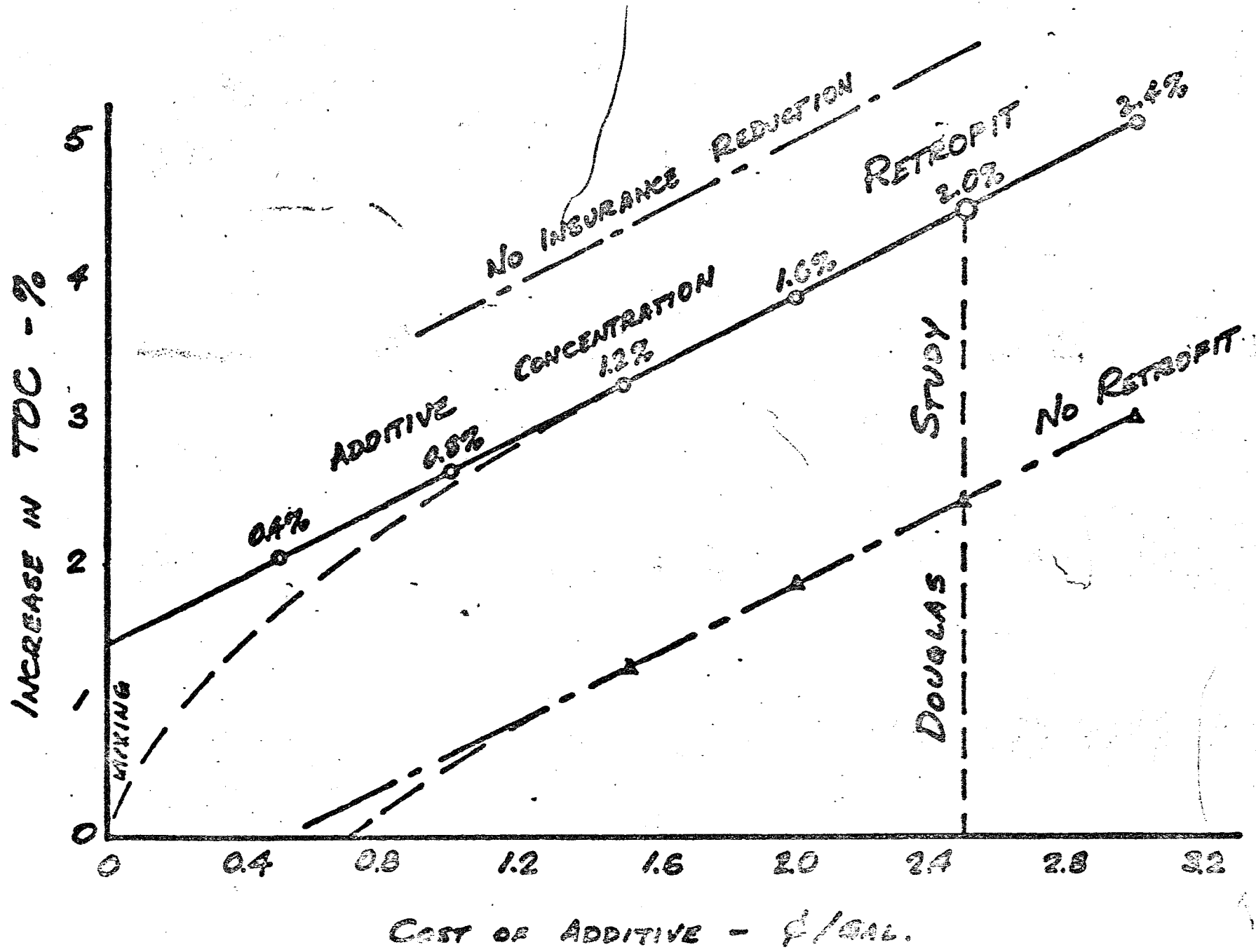
Service Use Considerations

This program is scheduled for completion by December 1975 with the development of a modified fuel specification. This specification, together with certification of an engine and aircraft components on modified fuel by December 1974 and establishment of cost/benefits and logistics requirements by June 1975, will form the basis for potential regulatory action concerning use of modified fuel in air carrier operations leading to the fulfillment of an extensive R&D effort.

The following chart is our rough estimate of the effect of additive cost on total operating cost. If we assume a 20% reduction in insurance costs and no retrofit requirement, it appears that additive concentrations less than 0.4% adding about 0.5 cent to the cost of a gallon of fuel could result in no increase in total operating cost, dependent upon mixing costs.

It appears there is real promise that the first use of modified fuel will be by turbine helicopters in view of the probability that such use may result in reduction of helicopter insurance costs. These costs average about 25% of the total helicopter operating costs compared to about 4% for jet transports. Several helicopter operators have expressed their willingness to voluntarily incur the added expense of modified fuel if it would reduce their insurance costs. One of the main aviation insurance underwriters has indicated that operators using modified fuel will probably obtain lower insurance rates if it is demonstrated in the FAA program that modified fuel will reduce the helicopter fire hazard. Accordingly, helicopter crash tests with the newly selected fuel will also be conducted in FY-74.

FLEET OPERATING COSTS VS. ADDITIVE



DEVELOPMENT PLAN

FY-1972 (Accomplished)

Task I - Aircraft Fuel System Compatibility Tests

Conduct tests under sea level and simulated altitude conditions with a representative wing fuel system to determine the extent of any reduction of usable fuel and any other problems which might be associated with the use of modified fuel. Sea level tests are to be conducted at NAFEC and simulated altitude tests at Naval Air Propulsion Test Center, Philadelphia. These tests were completed in June 1972.

Task II - Engine Compatibility Tests

Sea level tests will be conducted at NAFEC with a representative engine to determine the gross effects of using a modified fuel. Simulated high altitude tests will be conducted by NAPTC Philadelphia to identify specific combustion characteristics of modified fuels. NAFEC will conduct nozzle spray pattern tests of various candidate additives in jet fuel. Parker Hannifin Corporation will redesign and manufacturer 20 J-79 fuel nozzles which will perform properly with the modified fuel selected for flight testing.

Task III - Crash Tests

NAFEC will conduct screening tests with the air gun facility to aid in selecting candidates for further testing. Candidates which perform well in the air gun test will be further tested in 20 gallon catapult crash tests at NAFEC. One or two of fuels selected will be subjected to full scale crash tests at the Naval Air Test Facility, NAS Lakehurst, N.J. These tests will be conducted with USAF RB-66 aircraft as the test articles impacted upon two earth slopes with the wing tank fuel released at about 115 knots in the presence of open flame. These full scale crash tests will include a baseline crash using conventional Jet A fuel to compare the safety advantages of the modified fuel to Jet A.

Task IV - Evaluation of Improved Modified Jet Fuels

NAFEC will conduct tests to evaluate the characteristics and properties of improved modified fuels under various conditions of temperature, shearing, misting, spilling, and storage. Rutgers University will conduct a theoretical study and develop a mathematical model to predict ignition and propagation rates for flames in mists of conventional fuel and modified fuel which might be used in developing improved modified fuels.

FY-1973 (Scheduled)

Task II - Engine Tests

The redesigned J-79 fuel nozzles will be ground testing in a J-79 engine at NAFEC using the best modified fuel available as determined in the full-scale crash test and other screening tests. The test profile will be similar to that of earlier, FY-72 J-79 ground tests at NAFEC. This will constitute preflight qualification. Altitude combustor tests will be conducted at NAPTC, Philadelphia using a redesigned J-79 nozzle in a simulated altitude environment.

Task V - Flight Test

A Convair 880 will be flight tested on the selected modified fuel with one (No. 3) engine fitted with the redesigned fuel nozzles and No. 3 fuel tank containing modified fuel. The CV-880 fuel system is so designed as to allow the selection of a tank containing regular fuel or modified fuel for the operation of No. 3 engine. The purpose of this flight test is to demonstrate the feasibility of using modified fuel in an operational aircraft.

FY-1974 (Proposed)

Task I - Fuel System Tests and Design Modification

A contract will be awarded to an airframe manufacturer to test the selected modified fuel in a representative full-scale fuel system and to develop design changes which will be necessary to accommodate the modified fuel in full-fleet operations. Included will be a study of the logistics requirements of the modified fuel such as filtration, gaging, pumping, storing, transporting, and flow measurement.

Task II - Engine Tests

A contract will be awarded to a commercial large jet engine manufacturer to conduct such tests as may be necessary to obtain a supplemental type certificate for a modern commercial jet engine to operate with regular or modified turbine fuels. This certificated engine model will be used in a flight endurance test to be conducted in a commercial transport.

Task III - Crash Test

NAFEC will conduct a full-scale crash test of a helicopter fueled with modified fuel. This will be a vertical or near vertical drop test to simulate a violent but survivable helicopter crash in the presence of ignition sources. Commercial helicopter operators are expected to be the first users of modified fuel due to the high insurance rates which probably would be reduced if a safer fuel were used.

Task V - Flight Tests

After certification of a modified fuel engine, a contract will be awarded to perform endurance flight tests in a modern transport equipped with the certificated engines. The purpose of the extended flight test is to determine the long-term utility of modified fuel.

Task VII - Modified Fuel Specification

A contract will be awarded to conduct extensive laboratory tests to accurately define the properties and characteristics of modified fuel including its effect on aircraft engines, fuel systems and instrumentation. Based upon this data, an interagency agreement and/or a contract will be awarded for the development of a specification.

COSTS

FY-73 $200K

Engine Tests and Helicopter Crash Tests - $100K

1. Task II - NAFEC J-79 ground tests - $90K 3/73 (If contract nozzle design and combustor tests at Navy Philadelphia indicate no engine modifications)

2. Task III - Helicopter crash tests at NAFEC - $10K 10/73

Flight Tests - $100K

1. Task V - Flight Test CV-880 contingent upon (1) above - $100K 5/73

   NOTE: Assume Army will continue laboratory tests of modified fuel and small engine tests.

FY-74 - $1350K

Assuming the successful completion of FY-73 efforts, a commercial engine and airframe will be qualified and certificated for unrestricted use of modified fuel. A specification will be developed for modified fuels. The following work items are planned.

1. Task I - Conduct extensive component laboratory tests - NAFEC Contract $200K 6/75.

   Define the properties and characteristics of modified fuel to provide a basis for a specification including effect on fuel system, engine and instrumentation.

2. Task I - Engine Logistic Study - Washington Contract $100K
   Determine storage and handling problems and solutions 6/75

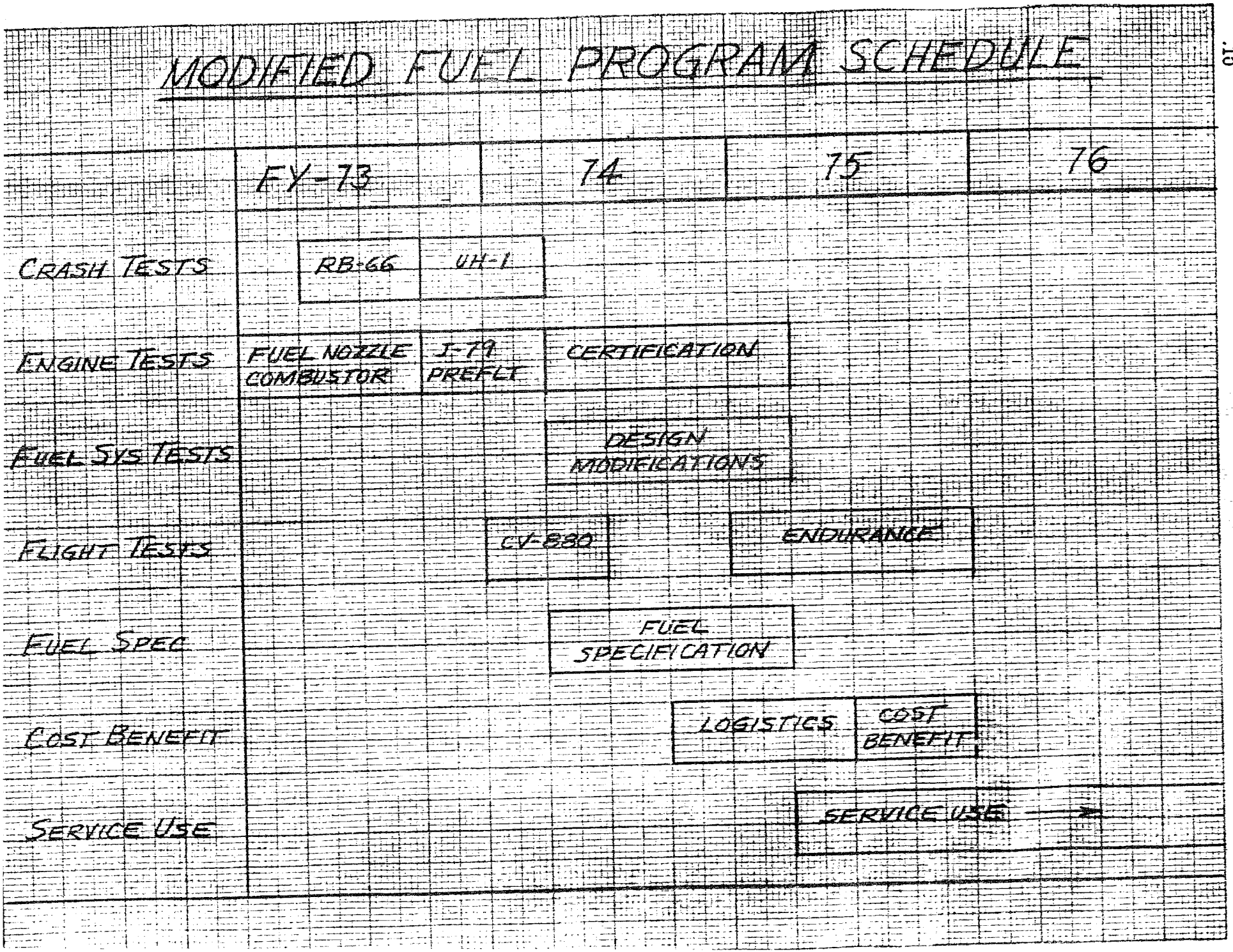
3. Task II - Engine certification tests - NAFEC Contract $500K
   Qualify engine for supplemental type certificate. 12/74

4. Task V - Modified fuel flight endurance tests - NAFEC Contract $500K
   Determine long-term utility of modified fuel in a commercial transport aircraft 6/75

5. Task VII - Develop a specification for modified fuel - Washington Contract $50K

   From research data delineate specifics of any acceptable modified fuel through Mil. Spec. and ASTM specification - 12/75

MODIFIED FUEL PROGRAM SCHEDULE



CONTRACT COST SUMMARY

CONTRACT	CONTRACTOR	DATE	PRODUCT	COST	
FA-WA-4762	The Western Co.	9/63	Gelled fuel mixer	$10,047	
FA64WA-5053	The Western Co.	5/64	1069-1 gelled fuel	91,073	
			FY-64 Total		$101,120
FA67NF-AP-20	Navy NAPTC	1/67	Combustor tests	$41,000	
FA67NF-AP-24	BuMines	6/67	Rating System	53,000	
			FY-67 Total		$94,000
FA68NF-269	The Western Co.	9/67	Aluminum Octoate	$44,170	
FA68NF-273	McDonnell Douglas	10/67	Compatibility Study	57,345	
			FY-68 Total		$101,515
FA68NF-273, Phase V	McDonnell Douglas	5/69	Economic Study	$26,026	
			FY-69 Total		$26,026
FA70NA-496	The Dow Chemical Co.	6/70	7129 gelled fuel	$57,195	
FA70NA-497	Anheuser-Busch, Inc.	6/70	CL-11 gelled fuel	30,771	
FA70NA-517	TWA	6/70	CV-880 wing	21,750	
			FY-70 Total		$109,716
FA71NA-AP-94	Navy NAPTC	4/71	Fuel system tests	$80,300	
FA71NA-AP-98	Navy NAPTC	4/71	Engine component tests	18,700	
		3/71	Crash test instrumentation	24,000	
			FY-71 Total		$123,000
FA72NA-AP-14	Navy NAESU	1/72	Technical assistance	$13,001	
W1-72-2591-1	Marsh & McLennan	3/72	Insurance assistance	2,400	
FA71NA-AP-98, Mod. 1	Navy NAPTC	3/72	Combustor tests	59,000	
FA72NA-AP-17	Navy NATF	3/72	Crash tests	155,000	
NA-P2-1823	General Electric	4/72	Engine inspection	1,923	
FA72NA-746	Rutgers Univ.	6/72	Fuel mist study	37,977	
FA72NA-727	Parker-Hannifin	6/72	Modify fuel nozzle	11,000	
		6/72	Gelled fuel, etc.	44,000	
			FY-72 Total		$324,301
			Total to date		$879,678