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Engine Performance Comparison Associated with Carburetor Icing During Aviation Grade Fuel and Automotive Grade Fuel Operation

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May 1983

Final Report

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16. Abstract

A comprehensive sea-level-static test cell data collection and evaluation effort to review operational characteristics of "off-the-shelf" carburetor ice detection/warning devices for general aviation piston engine aircraft during operation on aviation grade fuel and automotive grade fuel. Presented herin are results, observations and conclusions drawn from over 250 hours of test cell engine operation on 100LL aviation grade fuel, unleaded premium and unleaded regular grade automotive fuel.

Sea-level-static test cell engine operations were conducted utilizing a Teledyne Continental Motors 0-200A engine and a Cessna 150 fuel system to review engine operational characteristics on 100LL aviation grade fuel and various blends of automotive grade fuel as well as carburetor ice detectors/warning devices sensitivity/effectiveness during actual carburetor icing. The primary purpose of test cell engine operation was to observe real-time carburetor icing characteristics associated with possible automotive grade fuel utilization by pistion-powered light general aviation aircraft. In fulfillment of this task, baseline engine operations were established with 100LL aviation grade fuel followed by various blend of automotive grade fuel prior to imposing carburetor icing conditions and assessing operational characteristics.

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As addressed throughout this report, ice accumulation can commence at various times and locations with little or no change, or degradation to engine performance. Hence, the reader should not expect to find explicit engineering data within this report which will pin-point exact cause or time when ice accumulation has commenced

at a specific location. Due to the insidious nature of carburetor icing, data results were best derived by optical (video) observation which was largely utilized during test cell data acquisition on carburetor ice detection device sensitivity/effectiveness.

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EXECUTIVE SUMMARY

This report "Engine Performance Comparison Associated with Carburetor Icing During Aviation Grade Fuel and Automotive Grade Fuel Operation " represents observations, test data and conclusions obtained during sea-level-static test cell engine operation at the Federal Aviation Administration Technical Center. During the accomplishment of this test effort, a comprehensive data collection and evaluation review was made associated with operational characteristics of "off-the-shelf" carburetor ice detection/warning devices for general aviation piston engine aircraft during operation on aviation grade fuel and automotive grade fuel. Various blends of unleaded premium and regular automotive grade fuel obtained from local automotive service stations were utilized for engine performance data collection as compared to 100LL aviation grade fuel. Unleaded automotive fuel rather than standard leaded automotive fuel was selected due to its low lead content and decreasing supply of leaded fuels over the years.

As a result of several hours of Continental 0-200A aircraft engine operation, it was noted that a minor performance change could be seen between aviation and automotive fuels. This change related to horsepower/torque while engine and exhaust temperatures remained the same. Off-the-shelf carburetor ice detection/warning devices operated the same on all fuels tested as did carburetor icing characteristics. It was noted however, that the carburetor had a tendency to commence icing twice as soon with automotive grade fuel as compared to 100LL aviation grade fuel.

INTRODUCTION

PURPOSE.

The Federal Aviation Administration (FAA) Technical Center's propulsion effort is centered on the safety and reliability aspects of propulsion systems for both turbine and piston engines. The detailed planning and objectives of the FAA Technical Center's propulsion program are documented in FAA report (reference 1). Aircraft piston engine safety and reliability is highlighted as an area of concern, particularly induction system problems associated with carburetor icing, induction system moisture ingestion, and carburetor anti-deicing.

The detailed objectives of this specific effort were to: (1) establish test cell engine operation during carburetor ice producing conditions, (2) optically observe real-time carburetor icing operating conditions, and (3) observe/review operational characteristics of "off-the-shelf" carburetor ice detection equipment and engine performance degradation as related to 100LL aviation grade fuel/unleaded automotive grade fuel.

These investigations were completed and reported in another report (reference 2).

In considering the use of automotive gasoline (autogas) in general aviation piston engines, it has long been suspected that the high reid vapor pressure of autogas may increase the tendency of carburetor ice formation. The FAA Office of Airworthiness requested that the investigations noted in reference 2 be expandeed to include an evaluation of the use of autogas relative to its effect on carburetor ice formation. This report documents this expanded effort.

BACKGROUND.

Accident/incident data involving conditions conducive to carburetor/induction system icing as a cause/factor are available from the FAA computer system located in Kansas City, Missouri, which contains both FAA and National Transportation Safety Board (NTSB) data. A review of this data reveals a substantial number of occurrences where carburetor icing was the "most probable cause" of general aviation engine failure while in flight. The term "most probable cause" is used due to difficulty in substantiating the insidious culprit which generally dissipates prior to examination of engine conditions.

The NTSB continues to indicate a number of accidents each year in which carburetor icing was reported or suspected. The NTSB accident/incident data, together with the Technical Center's independent search of FAA's national computer data base, (i.e., Accident/Incidents Data System (AIDS)), were the basis for determining overall scope of the carburetor icing problem. For the purpose of this report, the AIDS was used since it contained NTSB and FAA data and was readily accessible. The AIDS data are compiled from aircraft registry, NTSB records, National Flight Data Center, Flight Standards National Field Office Safety Information tables, and reports submitted by field inspectors. Examples of information that may be obtained are: location, date, aircraft ratings, cause factors, contributing factors, number of fatalities, flying condition, etc. This data bank is accessible through United Computer Systems in Kansas City, Missouri, with current data available from 1976 to present. A more detailed AIDS data breakdown is presented in reference 2, while additional historical data is available from items listed in appendix A bibliography.

The NTSB, FAA, military, Foreign Aviation Agencies, and various pilot organizations have files full of technical reports and published articles dealing with carburetor icing accidents/incidents. The topic has been well researched and published, providing icing probability curves (figure 1) developed by the Canadian Ministry of Transport for pilot education to preclude a dangerous situation. Various individuals have directed their efforts toward developing cockpit instrumentation capable of warning the pilot of actual ice formation, or at least alerting them to the fact that carburetor conditions are conducive to ice formation (depending on atmospheric properties). Other individuals have pursued carburetor modification which would limit engine power loss during carburetor icing and prevent engine stoppage.

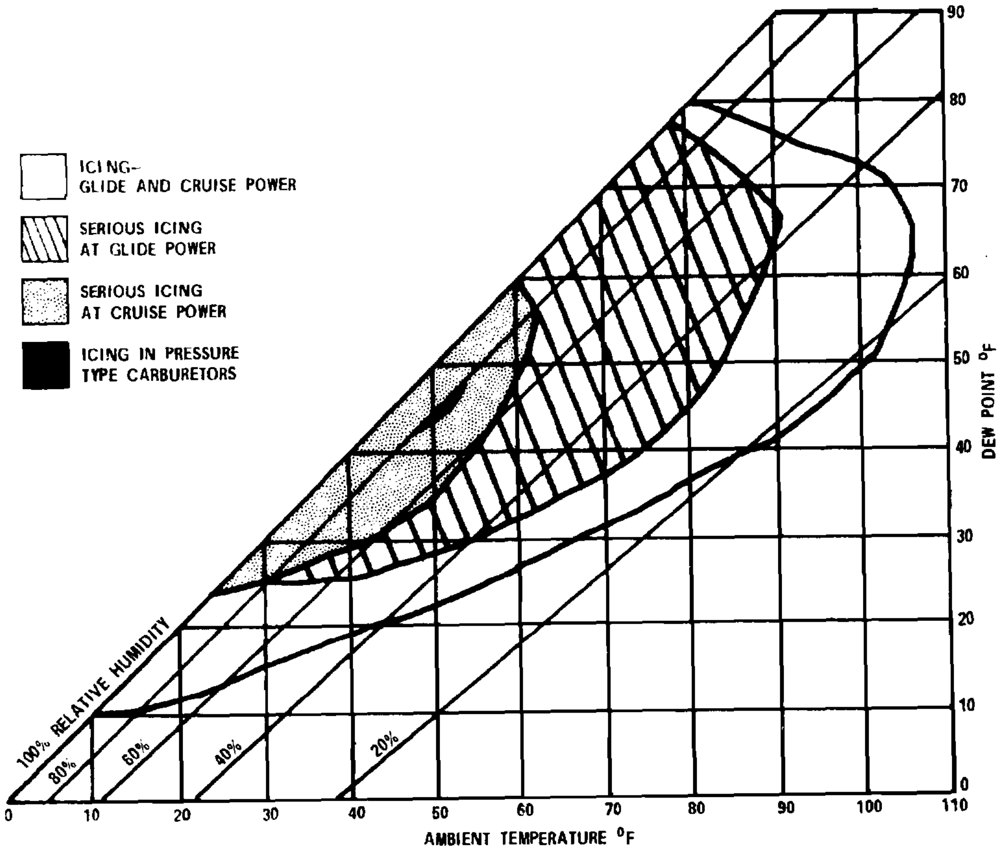


FIGURE 1. CARBURETOR ICING PROBABILITY CHART
MINISTRY OF TRANSPORT - CANADA

With the advent of aviation grade fuel shortages (both regional and spot shortages) plus continued price escalation, numerous individual/aviation organizations have considered aircraft flight operations on fuels other than that originally utilized for aircraft type certification approval. Most requests received by FAA field offices around the country address automotive grade fuel (autogas) usage as a replacement for the aviation grade fuel (avgas) which was originally specified in the aircraft type certificate and flight manual.

An additional review of NTSB accident/incident data also indicated that numerous aircraft operations are taking place with unauthorized autogas. As a result, the FAA Technical Center was requested to initiate an avgas versus autogas program to review work previously accomplished, fuel specification differences, aircraft operational problems/fuel system failure modes, and possible solutions/protection procedures. As part of this program, an analysis of carburetor icing characteristics, engine operational performance degradation, and "off-the-shelf" carburetor ice detection equipment operation were undertaken to ascertain effects associated with autogas usage.

As pointed out in reference 2, engine manufacturers are required to design and construct intake passages to minimize the danger of ice accretion, according to Federal Aviation Regulations (FAR) 33.35(b). Actual engine operation under carburetor icing conditions is not a requirement imposed on the engine manufacturer by the FAR's. In addition, the engine manufacturers point out that carburetor icing is a problem which must be scrutinized on an individual aircraft model installation basis. Therefore, engine manufacturers do little, if any, engine test cell work relative to carburetor icing problems. The final link in the carburetor icing chain is the aircraft manufacturer. As per FAR 23.929 and 23.1093, aircraft manufacturers are required to provide a means of increasing carburetor air temperature by 90° F. Actual aircraft/engine operation in carburetor icing conditions is not imposed by the FAR's and the FAR's remain mute on the topic of ice detection equipment requirements as related to satisfactory engine operation. Some aircraft/engine manufacturers do offer Supplemental Type Certificate (STC) approved carburetor ice detection/warning equipment as optional instrumentation. However, a question arises as to what effect, if any, will be imposed on equipment and carburetor icing tendency during operation on autogas rather than avgas. Of particular interest is the question relative to what would happen to the Canadian Ministry of Transportation carburetor icing probability chart, figure 1, which was originally developed with avgas, if operational performance data were obtained with various blends of autogas. It should be noted, however, that such an effort was beyond the scope of this program.

OBJECTIVE.

Based on the information obtained during the overall background review of carburetor icing problems, a program test plan was developed. Following are the objectives of the plan:

1. Instrument a test engine to obtain necessary performance data indicating performance changes, if any, due to fuel changes/carburetor icing.

2. Review commercial market and attempt to obtain a copy of each carburetor ice detector/warning device utilized on general aviation piston engine aircraft.

3. Establish a standard engine test cycle.

4. Perform a baseline engine performance test run on 100LL avgas.

5. Perform a baseline engine performance test run on unleaded premium autogas.

6. Perform a baseline engine performance test run on unleaded regular autogas.

7. Establish test cell engine operation under known icing conditions and observe operational characteristics of commercial off-the-shelf devices.

8. Determine internal carburetor locations where ice accumulation takes place as a result of avgas versus autogas.

9. Ascertain how ice formation propagates through the carburetor as related to avgas versus autogas.

10. Determine carburetor operation during ice manifestation and note what may result from changing fuel, avgas versus autogas.

11. Determine best location of the carburetor ice detection device to give desired information and note any location changes that may be necessary to accommodate avgas versus autogas.

APPROACH.

Through in-house FAA Technical Center test cell investigations, repeatable carburetor ice producing conditions were established during engine operation on 100LL avgas, unleaded premium autogas and unleaded regular autogas. With strategically positioned borescopes, actual internal carburetor ice formation/propagation was monitored/video recorded while engine performance parameters were recorded during actual engine operation. Figure 2 depicts carburetor instrumentation utilized for testing while table 1 contains a listing of all test parameters measured and recorded during test cell engine operation.

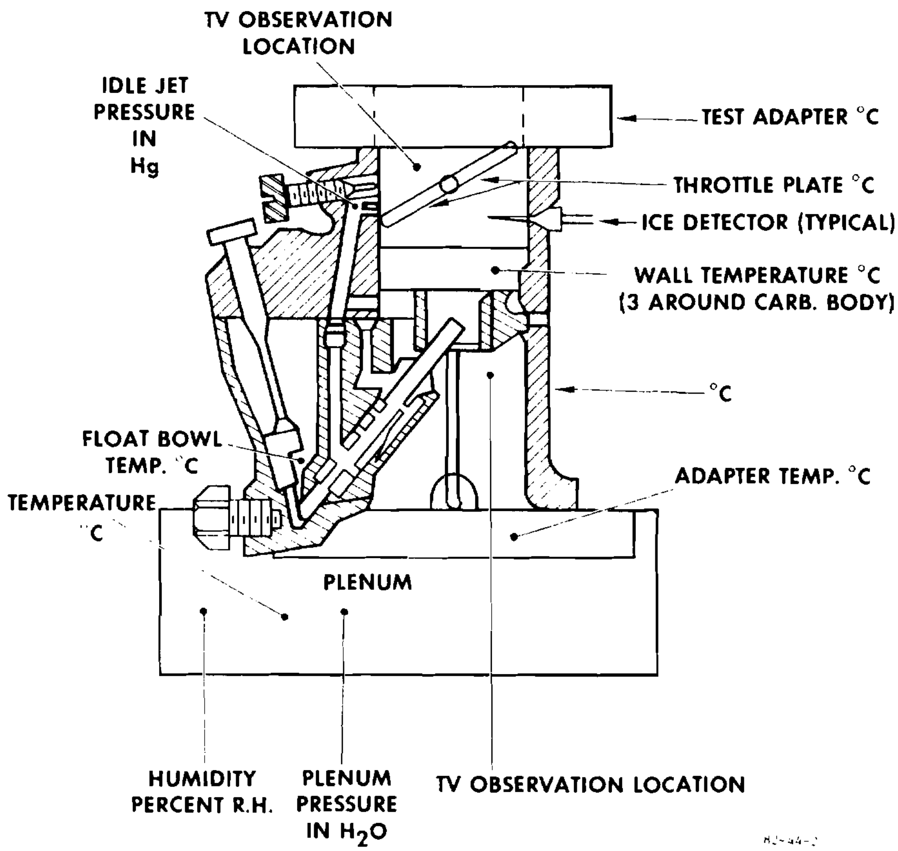


FIGURE 2. CARBURETOR ICE DETECTOR EVALUAITON SYSTEM

TABLE 1. TEST PARAMETERS

Signal Name	Units
#3 Induction Valve Port Temperature	°C
#3 Induction Tube Upper Temperature	°C
#3 Induction Tube Lower Temperature	°C
#4 Induction Valve Port Temperature	°C
Left Fuel Tank Temperature (Autogas)	°C
Right Fuel Tank Temperature (Avgas)	°C
Oil Tank Temperature	°C
Sediment Bowl Temperature	°C
Upper Throttle Plate Metal Temperature	°C
Lower Throttle Plate Metal Temperature	°C
Float Bowl Fuel Temperature	°C
#1 Carburetor Metal Temperature	°C
#2 Carburetor Metal Temperature	°C
#3 Carburetor Metal Temperature	°C
#4 Carburetor Metal Temperature	°C
Carburetor Adaptor Top Temperature	°C
#1 Cylinder Head Temperature	°C
#2 Cylinder Head Temperature	°C
#3 Cylinder Head Temperature	°C
#4 Cylinder Head Temperature	°C
Engine Oil Temperature	°C
Carburetor Adaptor Bottom Temperature	°C
Cowling Air Temperature	°C
Water Temperature	°C
Test Cell Temperature	°C
Air Conditioner Outlet Temperature	°C
Plenum Air Temperature	°C
Supply Air Temperature	°C
#1 Exhause Gas Temperature	°C
#2 Exhaust Gas Temperature	°C
#3 Exhaust Gas Temperature	°C
#4 Exhaust Gas Temperature	°C
Fuel Flow	GPH
Throttle Plate Position	% open
Fuel Pressure	PSIG
Engine Speed	RPM
Horsepower	HP
Torque	FT-LBS
Oil Pressure	PSIG
Carburetor Temperature Probe 1	°C
Cowling Pressure	IN-H_2O
Carburetor Ice Probe 1	VDC
Supply Cooling Air Pressure	PSIG
Plenum Pressure	IN-H_2O
Dew Point (inside plenum chamber)	°C
Ice Indication	VDC
Manifold Pressure	IN-Hg
Idle Jet Pressure	IN-Hg
Barometric Pressure	IN-HgA
Fuel Switch (avgas/autogas)	VDC

BASIC CONSIDERATION

TYPES OF ICE.

Ice may form in the induction system and carburetor of reciprocating engines in the following ways:

1. Impact of water droplets in the induction air on surface whose temperature is below 32° F (0° C).

2. Cooling to below 32° F of the water vapor in induction air by expansion across throttle plate venturi. This expansion process produces a temperature drop which may approach 30° F.

3. As fuel is introduced into the carburetor airstream, water entrained or dissolved in the fuel is cooled to below 32° F.

4. Cooling of moisture-laden induction air to below 32° F, due to fuel evaporation as fuel is introduced into the carburetor airstream.

When a liquid evaporates, a certain amount of heat transfer takes place which cools the surrounding environment. The maximum temperature drop with a stoichiometric mixture in piston engine aircraft carburetors will be approximately 37° F. As such, the total temperature drop through a carburetor may approach 70 F.

FORMATION CHARACTERISTICS.

Based on data obtained during reference 2 testing, it was known that the major ice formation location was the front and back side of the throttle plate. As addressed in the DISCUSSION portion of this report, the throttle plate was the coldest portion of the carburetor and, therefore, most susceptible to ice accumulation. As expected, ice formation locations and patterns around the throttle plate changed with engine speed.

ICING PARAMETERS.

Factors/parameters which are critical for ice formation are carburetor air temperature/ambient air temperature, humidity, and throttle plate angle. Throttle plate angle which relates to engine (rpm) also relates to the amount of ambient air flowing through the engine. This interrelationship has the largest impact on carburetor metal temperature and as such, ice accumulation rate. Fuel temperature and mixture setting (rich/lean) were found to have an insignificant impact on ice formation, location, or rate, as related to the test cell engine installation utilized during testing. Actual flight testing by Newman (reference 3) indicates a detectable tendency for mixture setting to affect icing rate based on five carburetor icing encounters.

OPERATIONAL CHARACTERISTICS.

Most carburetor icing accident reports place final blame as pilot error, due to pilot in command of the aircraft having final authority and responsibility for the safe conduct of flight operations. While this is a true statement from the FAR standpoint, the question remains as to why the pilot allowed conditions to deteriorate to a point of no recovery.

Cockpit instrumentation, depending on aircraft configuration, which provide indications of aircraft/engine performance deterioration are rpm, airspeed/altimeter, exhaust gas temperature (egt), and manifold pressure. As carburetor ice accumulation commences, engine rpm will gradually decay with a fixed pitch propeller and manifold pressure will decay with a constant speed propeller. This decay will be followed by a loss of airspeed if constant altitude is maintained, or a loss of altitude if aircraft trim is allowed to maintain constant airspeed. As noted under the GENERAL OBSERVATIONS portion of this report, ice accumulation generally produces mixture enrichment which leads to a reduction in egt and is accompanied with a rough running engine.

Ice accumulation rate depends on atmospheric conditions, but generally is very steady and persistent. This brings about a steady change to aircraft/engine performance and as such, lends itself to catching the pilot unaware. Due to this steady change, some indications such as egt change are difficult to detect, although not impossible.

In addition to the standard cockput instrumentation required by FAR's, there are optional instruments available on the market shelf which have been approved by the FAA on a no-hazard basis with the issuance of STC's for installation in type certificated aircraft. Such instruments are approved as optional equipment only and flight operations should not be predicated on their use. Appendix B contains a listing of all known devices which are presently available or which will shortly be available as "off-the-shelf" equipment.

TEST CELL EQUIPMENT

ENGINE.

The test engine was a Teledyne Continental Motors zero time factory overhauled 0-200A, serial number 231139-R, naturally aspirated, overhead valved, air cooled, horizontally opposed, direct drive, wet sump aircraft engine, with a bore and stroke of 4.06 inch x 3.88 inch for a total displacement of 201 cubic inches. The compression ratio was 7.0:1 with a firing order of 1-3-2-4.

The wet sump oil system has a 6-quart capacity with a standard gear type pump and no oil cooler. The engine contains hydraulic tappets while the cylinder walls/pistons are spray lubricated. Normal operational oil pressure was 30 to 60 pounds per square inch gage (psig).

The Cessna 150 gravity feed fuel system produced 0.9 pounds per square inch (psi) pressure at the carburetor inlet with a full tank of 13 gallons, 100 low-lead avgas or autogas. Test installation carburetor system was a standard Marvel-Schebler Model MA-35PA, part number 10-5128 which had been especially instrumented to provide desired data parameters for test.

The test installation engine had a dual magneto, radio shielded ignition system where the right magneto fired the upper spark plugs and the left magneto fired the lower plugs. The magnetos were Slick Model 4201 with impulse couplings. Both magnetos drove clockwise, with a one-to-one drive ratio to the crankshaft and timed to 24° before top dead center (BTDC).

COOLING SYSTEM.

The cooling system consisted of an air moving and heat unit, a pressure regulating and shutoff valve, an engine cooling hood, ducting and various pressure, and temperature probes. The air moving and heating unit was self-contained with a 6,000 ft^3/min (CFM) centrifugal blower, 20 Horsepower (HP), 3,600 rpm, 240 volt 3-phase, 60 hertz (Hz) motor. A one million British Thermal Unit (Btu) per hour burner using JP4 fuel with boiler, expansion tank and heat exchanger was also included.

A 24-inch diameter sheet metal duct with temperature and pressure probes was utilized to connect the air moving unit, pressure regulating and shutoff valve, and 18-inch diameter flex duct which attached to the top of engine cooling hood. The pressure regulating and shutoff valve was a sheet metal tee with a set of louvers and regulating slide on the top to allow excess pressure/airflow to escape. The regulating portion had coarse and fine adjustment to allow for easy major settings and daily ambient changes, while the branch portion had shutoff louvers prior to the 18-inch engine ducting.

The engine cooling hood was a sheet metal box on top of the cylinders which converted the velocity of the cooling air into a pressure differential to move air across the cooling fins carrying away engine heat. The box had a total temperature probe and static ports to read cooling air pressure and temperature inside the hood assembly. There were high temperature rubber seals next to each cylinder to force air across the fins, rather than around them. The top of the hood was basically a transition section changing the 18-inch round flex duct to the shape of the cylinder box.

FUEL SYSTEM.

The test installation fuel system utilized a standard factory manufactured Cessna 150 aircraft fuel system from fuel tanks to carburetor inlet with the exception of two slight modifications. The first modification was an installation of two normally closed 115-volt alternating current (a.c.) 9/32-inch orifice solenoid shutoff valves. One each of these valves was placed in the left and right fuel tank supply line just prior to "T" connection in front of standard aircraft fuel line shutoff valve. This modification was implemented to facilitate instantaneous selection of either left or right fuel tank which contained different fuel. During installation of solenoid shutoff valves, an equal length of fuel line was removed so as to maintain as accurate as possible overall system design. For the duration of this test effort, 100LL avgas was always placed in the right fuel tank (when viewed from behind the engine) and test autogas fuel was placed in the left fuel tank.

The second modification encompassed a turbine fuel flow meter installation down stream of the standard aircraft fuel system shutoff valve. This installation location was selected since it would allow continuous fuel flow measurement from either fuel tank. During flowmeter installation, an equal length of fuel line was also removed so as to maintain as accurate as possible overall system design.

Individual left and right fuel tank quick drain valves were removed to facilitate thermocouple installation with Swagelok™ fittings. This installation allowed in-tank fuel temperature data recording from a position 1-inch above fuel tank bottom. In addition, one thermocouple was placed inside the standard aircraft fuel strainer assembly by utilizing cylinder primer line access port. This position provided an actual fuel temperature data point without disrupting fuel line flow. All fuel lines were covered with insulation to reduce ambient temperature impact on fuel. The carburetor instrumentation included two throttle plate temperatures, three metal temperatures, a float bowl fuel temperature, carburetor air inlet temperature (lower borescope adapter, figure 3), and a carburator fuel-air exit temperature (upper borescope adapter, figure 3). Idle jet pressure and inlet fuel pressure were also instrumented. The carburetor was enclosed in a metal box to assist in controlling ambient temperature and simulate engine cowling conditions. There were openings in the box for throttle, mixture control, fuel line, instrumentation wires, tubes and to allow air to exhaust. Two thermocouple probes were also installed in cylinder number 3 induction tube, one each in lower and upper end. Two thermocouples were also installed, one each in cylinder number 3 and cylinder number 4 intake valve port area. After carburetor and engine instrumentation installation was completed, operational testing was accomplished to obtain data for engine performance correlation with performance data obtained during initial engine installation test run checks. No performance change was noted as a result of extensive instrumentation.

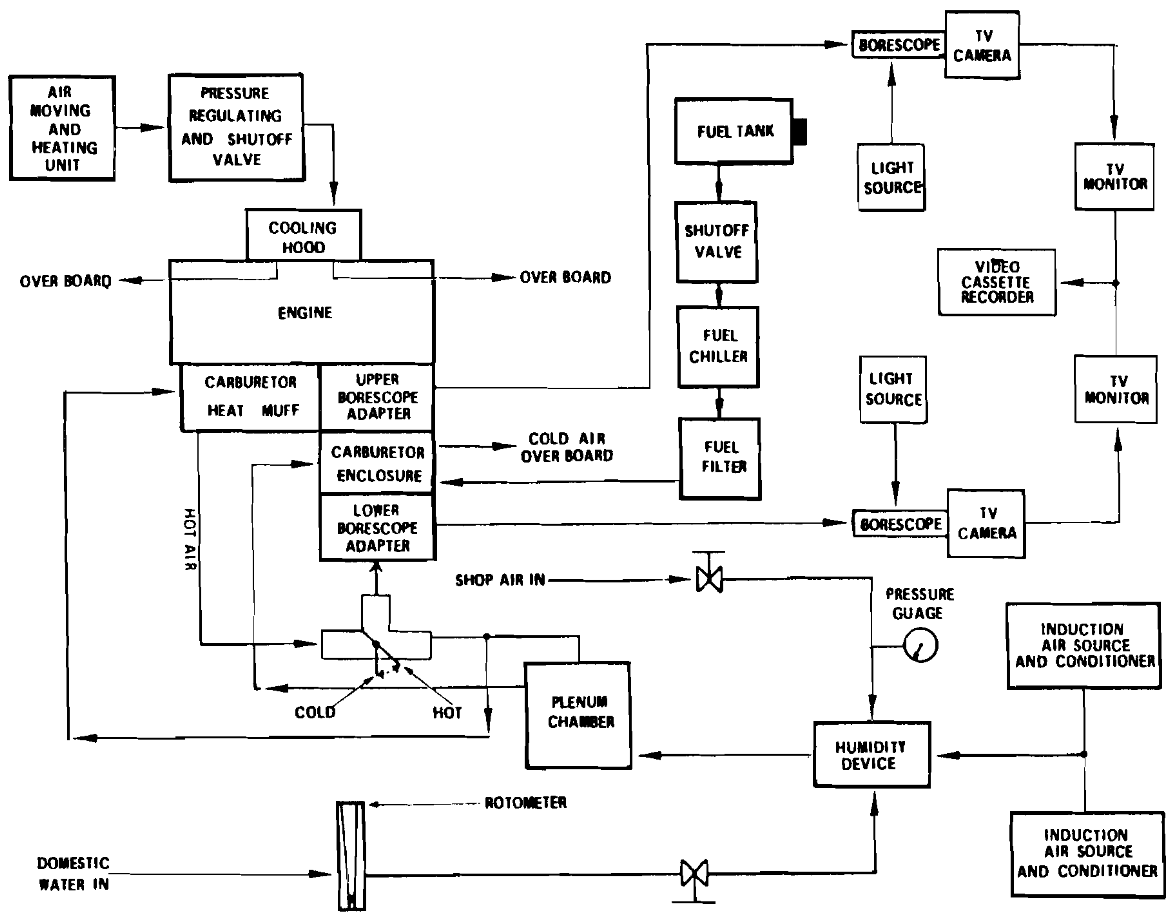


FIGURE 3. TEST SYSTEM SCHEMATIC

INDUCTION AIR SYSTEM.

The inductuon air system consisted of two air sources and conditioners, a humidity device, plenum chamber, carburetor heat valve, heat exchanger, and associated ducting.

The air sources were two 18,000 Btu per hour, 220 volt a.c. air-conditioners ducted together with a 6-inch flex line and a sheet metal tee. There were small sheet metal boxes with thermocouple instrumentation on the air-conditioner outlets that transition to the 6-inch duct. When the engine was not running, the "high-fan" position on air conditioners pressurized the main plenum chamber to about 0.90 inches of water.

A specially designed humidity device which took a stream of water and broke it up with jets of air was used to supply moisture needed to make ice in the carburetor. The device included an air pressure gage and shutoff/regulating valve which controlled the shop air utilized to breakup the water stream, a rotometer and shutoff valve to measure and regulate water flow, and a water discharge tube located in the high pressure air-jet path. This device could easily take ambient air or air-conditioned air to the saturation point by adjusting water flow rate.

The plenum chamber was a 2-foot sheet metal cube with legs, a 6-inch diameter inlet connection from the humidity device and two 3-inch outlets. There was a deflector plate at the 6-inch inlet to arrest any liquid water droplets and deflect them into the sump area. Also included were the temperature probe, pressure tap, dewpoint measuring ports, and sump area drain. The entire plenum was insulated to reduce ambient temperature effects on the conditioned air.

The carburetor heat valve was tee-shaped with a remotely operated hydraulic slave system flapper valve and lever mechanism to allow either normal conditioned air or heated air to enter carburetor inlet. Carburetor heat was used between test points to heat and dry the engine induction system.

The heat exchanger, sometimes called a heater muff, was bolted to the exhaust pipes on the right side of the engine. When heat was selected, induction air would be drawn from the plenum chamber, around the exhaust pipes and into the carburetor inlet. The heater muff inlet and outlet had 3-inch flexible tubing connecting the entire system from plenum to carburetor inlet.

ICE MONITORING SYSTEM.

The ice monitoring system consisted of two fiber optic borescopes, two cold light sources, two television (TV) cameras, one video cassette recorder, two TV monitors, cabling, and various adapters.

There were two 0.340-inch diameter fiber optic borescopes which had a 50-inch working length. One borescope had a forward viewing distal end while the other was side-viewing. Both were capable of 120° articulation in either direction from straight. A cold light source with two easily changed internal lamps, a brightness control knob operating on 115-volt a.c., 2.5 amps, accompained each borescope. Both light sources were attached to a shock-mounted plate to dampen engine vibration and, in addition, the carburetor bottom borescope light source was wired with a remote power switch for control room use while testing optical ice detectors.

Each borescope optical end had a special adapter which allowed attachment to individual standard black and white TV cameras. This assembly was then anchored to the same shock mounted plate utilized for borescope light sources. Each camera also required a separate remote power supply which was located in the control room. The distal end of each borescope was mounted in separate adapters specifically designed to fit below and above carburetor mounting flange and provide physical mounting of borescope probes while the bottom adapter also allowed flexing of the distal end.

A video cassette recorder was used to obtain a pictorial record of pertinent tests or conditions of a test. The video cassette recorder was normally attached to the bottom borescope to record bottom throttle plate view. The recorder could easily and quickly be shifted to the top borescope which provided viewing of either the top throttle plate area or the intake manifold.

Two TV monitors were used to view the test continually and check for ice buildup. The monitors allowed for varying the test conditions and obtaining immediate feedback, relative to which data should be recorded. Figure 3 depicts the overall instrumentation/installation equipment.

DATA ACQUISTION SYSTEM.

The data acquistion system used to collect the data was a NEFF Instrument Corporation Series 620L analog data acquisition and control system. This system consists of a NEFF Series 400 differential multiplexer, a Digital Equipment Corporation PDP 11-04 computer, and a Kennedy Corporation Model 9000 tape transport.

The differential multiplexer was a complete high-speed data acquisition subsystem. It contained a high-speed solid-state analog signal multiplexer that was capable of accepting 256 input channels, a programmable gain differential amplifier, and an analog-to-digital converter. Signals acceptable to the differential multiplexer were thermocouple and analog voltages with full-sacle reading ranging from 5 millivolts to 10.24 volts. Each channel had a 10-Hz filter to reject superimposed and unwanted signal frequencies.

Control of the data acquisition was performed by the PDP11-04 computer which encompassed setting sampling rate (10 kHz max), converting raw data into engineering units as established by operator, displaying eight different parameters on cathode ray tube (CRT) and writing data on Kennedy tape drive at a rate of 1600 bits per second. An alarm capability was installed to warn the engine operator when any parameter reached a critical value.

Thermocouple instrumentation utilized during test operations were calibrated to $\pm 0.5°$ F, while data acquisition/computer system carried data readings to $\pm 0.0001°$ F. This can be observed in the rapid sharp changes depicted in data plots.

ENGINE TEST SEQUENCE

BREAK-IN RUN.

The engine was purchased as a Teledyne Continental Motors factory rebuilt, zero time engine. A 50-hour break-in run was completed prior to the 150 hours of test-cell operation required during reference 2 work effort.

The first 25 hours of operation was conducted with a non-detergent oil type Mil-C-6529 Type II, while the remainder of the testing was conducted with an Ashless Dispersent Aviation oil EE-80. Initially, oil was changed at 25 hours, again at the first 50-hour inspection and every 50 hours of subsequent operation.

Break-in testing started with an 800 to 1000 rpm setting. When oil temperature and cylinder-head temperature (CHT) showed a definite increase, rpm was set to 1200 and a manual data point taken. When oil temperature reached 70° F or greater, rpm was increased to 1800, and after a stabilization time a magneto test was performed. The next series of steps paralleled a normal light plane operation. A full throttle takeoff run of about 5 minutes was accomplished followed by a power reduction to 2050 rpm with a manual data reading taken at each point. Finally, rpm was set at 1950 for a 20- to 30-minute steady-state condition, with data taken every 10 minutes, and then a 1200 rpm cooling condition was set, followed by a decision to either enter a shutdown sequence or initiate another cycle.

The engine start, magneto check and a full power run was labeled Normal Start-Up Test (SUT).

BASELINE TEST 1.

This test was initiated with a SUT. After the full power condition data were taken, rpm was retarded to 1000 and engine allowed to stabilize. Computer data for test parameters listed in table 1 were taken continuously prior to engine start through to engine secure at 1 scan per 15 seconds. Manual data were taken at each test point after engine readings stabilized. Test sequence utilized is tabulated in table 2, but basically consisted of the items previously mentioned above, followed by stabilized test points at each 100 rpm from 1000 to 2800. Manual data recorded during this baseline test sequence for 100LL avgas, unleaded premium autogas, and unleaded regular autogas is presented in appendix C. When a full test was completed, 1200 rpm was selected and cooling air modulated to allow the engine to cool slowly. A 1000 rpm condition was selected, a magneto safety check accomplished, and then mixture control pulled to the OFF-position to stop engine. This latter sequence was labeled Normal Shut-Down Test (SDT).

BASELINE TEST 2.

This test sequence was initiated with engine start and warm-up at 1000 to 1200 rpm until oil temperature reached 75° F. Next came a magneto test at 1800 rpm followed by a power reduction to 1000 rpm for 2 minutes and then proceeded as listed in table 2. The test sequence listed in table 2 was developed which simulated a typical flight profile from takeoff/climb, cruise, en route climb to a higher altitude, cruise, descent for airport, enter traffic pattern, approach, landing, taxi and engine secure. Computer data for test parameters listed in table 1 was taken continuously from engine start through to engine secure at 1 scan per 15 seconds.

Manual data was taken at each test point from takeoff until final return to 1000 rpm. This manual data which was recorded for 100LL avgas, unleaded premium autogas and unleaded regular autogas is presented in appendix D.

TABLE 2. ENGINE TEST SEQUENCE

NORMAL START-UP TEST (SUT)

800 to 1000	1200	1800 MAGNETO CHECK	FULL THROTTLE POWER CHECK

NORMAL SHUT-DOWN TEST (SDT)

1200 cool down	1000 MAG SAFETY CHECK (SHUT COOLING AIR OFF WHEN CHT BELOW 300° F)	PULL MIXTURE OFF

BREAK -IN TEST

SUT	2050	1950	1800	After 1800 either SDT or full throttle run then 2050 and repeat cycle

BASELINE TEST 1

SUT	1000	1100	1200	1300	ETC up to 2800 followed by gradual reduction to 1200 for SDT

BASELINE TEST 2

1000 to warm-up	1200	1800 magneto test	1000 2 minutes	2750 5 minutes	2350 15 minutes	2750 3 minutes	2400 15 minutes
		2000 10 minutes	2300 2 minutes	1500 2 minutes	1000 3 minutes	Pull mixture off	

CARBURETOR ICE WARNING DEVICES.

All carburetor ice warning devices listed in appendix B, with the exception of item b., were tested during carburetor icing conditions with 100LL avgas, unleaded premium autogas and unleaded regular autogas. Tests were conducted with three main parameters in mind. First, it is very difficult to build ice at high rpm (above 2400) in a short period of time. Next, experience had previously shown (reference 2) that throttle angle affects temperature readings in the location of ice detectors mounted in the wall of the carburetor. This means that rpm/throttle angle could affect the ice detection characteristics. Third, ice accumulation will commence at various times and locations with no apparent change or degradation to engine performance. Due to the insidious nature of carburetor icing, data results would best be derived by optical (video) observation.

The optical ice monitoring system gave a very good picture below the throttle plate at all times, while the picture above the throttle plate (which was taken through a 0.5 inch plexiglas plate) provided marginal observation during actual ice accumulation. It was observed that high rpm ice tended to build around the upper throttle plate edge next to carburetor wall which at times was slightly out of the immediate view of the bottom borescope. Relocation of either borescope would not solve this problem. It was also noted that very little, if any, ice formed in the induction manifold at a given test rpm as will be covered in the DISCUSSION portion of this report.

A series of ice detecting tests was performed with each ice warning device utilizing steady state rpm conditions listed in table 2, BASELINE TEST 1, which produced several repeatable ice propagation patterns and rates while operating on various fuel grades. Once a steady-state test point rpm was selected, carburetor heat was applied to remove any existing ice. Once visual ice was gone and throttle plate temperature was above 34° F, heat was turned off. Time was then taken until initiation of ice accumulation and operational characteristics of each warning device observed. Reference 2 should also be reviewed to note detailed operational characteristics of appendix B devices, d and e.

DISCUSSION

ENGINE PERFORMANCE CHANGES DUE TO FUEL TYPE.

This test effort was initiated to review carburetor ice and carburetor ice warning devices operational characteristics change associated with avgas and autogas. As addressed under the TEST CELL EQUIPMENT portion of this report, the test engine was a factory rebuilt zero time 0-200A with approximately 150 hours of test cell operation accumulated by the FAA Technical Center under a separate program. It was concluded at the initiation of this effort that, in order to point out performance changes due to carburetor ice or to evaluate carburetor ice detection/warning devices operation on avgas and autogas, an engine performance comparison due to fuel utilized for testing was a first requirement. As such, instrumentation listed in table 1 was installed so that adequate test parameter data would be obtained. All parameters listed in table 1 were scanned and recorded by computer at 15 second intervals during engine operation. In addition, specific test parameters were hand recorded during some test sequence operation when a special data graph was desired.

Based on previous experience, two baseline test sequences were undertaken as outlined in table 2. Uncorrected test cell performance data taken during baseline test 1 are presented in appendix C. This manually recorded baseline data was taken with rich and lean mixture settings for 100LL avgas, unleaded premium autogas and unleaded regular autogas. Uncorrected test cell performance data taken during baseline test 2 is presented in appendix D. Baseline test 2 simulated a short one-hour flight profile and was only performed with a full rich mixture for total duration. This test sequence was also run with all three grades of fuel.

It should be pointed out at this time that all test cell engine operation was conducted with three grades of fuel: 100LL avgas, unleaded premium autogas, and unleaded regular autogas. Engine performance and carburetor ice detection/warning device testing were all performed on these three grades of fuel. The autogas fuel was obtained from several roadside gasoline stations in four five-gallon containers. No special test fuels were obtained and no special fuel handling procedures instituted. It was desired to obtain performance data on autogas transported to aircraft fuel tanks much in the same way the average pilot would do if utilizing autogas prior to a wide-spread airport delivery network.

After test cell fuel system installation was completed as addressed in the TEST CELL EQUIPMENT portion of this report and pictured in appendix E, a functional test was performed to insure proper operation of all hardware and to measure unusable fuel remaining in left fuel system (autogas fuel tank). It was noted that when the engine ran out of fuel on the left fuel tank, 2500 ml of fuel remained in system.

Whenever a new supply of autogas was brought in, all remaining fuel in left tank was drained from system.

Several meetings were held with various fuel refinery personnel to discuss autogas fuel specifications. The general consensus was that in five years or so, unleaded autogas would be the only grade of fuel available at a roadside gasoline station. Therefore, testing effort was not expended looking at leaded autogas fuel grades.

As part of engine performance analysis related to various fuels, appendix C test cell data were corrected back to standard day dry air conditions and presented in appendix F.

Both horsepower and manifold pressure were corrected as outlined by Obert in reference (4) by utilizing a correction factor (C_f):

$$C_f = \frac{Ps - Pvs}{Po - Pv} \sqrt{\frac{To}{Ts}}$$

where, Ts = standard atmospheric temperature = 520° R
Ps = standard atmospheric pressure = 29.92 in. HgA
Pvs = standard water-vapor pressure in standard atmosphere = zero
To = observed atmospheric temperature during test = °R
Po = observed atmospheric pressure during test = in. HgA
Pv = water-vapor pressure in atmosphere during test (obtained from psychrometric chart using wet and dry bulb temperature during test)

Appendix F performance data are presented for corrected manifold pressure, torque (both measured and computed), corrected horsepower, cylinder head temperature number 1 and exhaust gas temperature number 1. All data were graphed against rpm with both a rich and lean mixture setting for three grades of fuel. It will be noted in appendix F that individual parameter data graphs for each fuel grade are presented first, followed by individual parameter graphs containing all three fuels for both a rich and lean mixture setting.

A review of appendix F data will show a slight change in engine performance data between fuel grades for manifold pressure, cylinder head temperature number 1 and exhaust gas temperature number 1. Such a slight change in data while measured with test cell instrumentation, would not be observed inside the cockpit of an aircraft with existing instrumentation. Horsepower and torque (measured and computed) both show a noticeable change in engine performance above cruise power, depending on grade of fuel being utilized. It will be noted that engine performance on 100LL avgas runs less than that obtained with unleaded premium and better than that obtained with unleaded regular. However, discussions with the Experimental Aircraft Association which has over 700 flight hours in a specially instrumented Cessna 150/Continental O-200A autogas flight test aircraft, indicates that in-flight performance changes were not measurable between the same three fuel grades which they also utilized.

Manual performance data for baseline test 2 sequence are presented in appendix D. Additional computer recorded and processed data are provided in appendix G for 100LL avgas, appendix H for unleaded premium autogas and appendix I for unleaded regular autogas. These three appendix contain engine performance data obtained from three identical test runs to baseline test 2 sequence. It should be pointed out that dew point temperature versus time, appendix I, item I-30, was in a calibration mode during initial start of test sequence, hence the incorrect temperature indication at start.

After completing the various performance test runs on all three grades of fuel anticipated for use when looking at carburetor icing problems, it was concluded that performance degradation due to fuel would not be a problem with this aircraft fuel system/engine combination as installed in the test cell.

ENGINE PERFORMANCE CHANGES DUE TO CARBURETOR ICE.

Once it was determined that overall engine performance would not be changed by fuel grade, an analysis of the induction system was started. The first series of test runs centered around the total induction system temperature distribution at various rpm settings and mixture control impact at cruise power. Figure 4(a), (b), (c), and (d) display the overall induction system temperature distribution for all three grades of fuel. Test point conditions were selected as: 1000-rpm mixture rich, 2300-rpm mixture rich, 2300-rpm mixture lean, and 2750-rpm mixture rich. Figure 4 provides temperature data associated with each grade of fuel as related to induction system position. These positions are as follows:

1. Carburetor air inlet
2. Throttle plate
3. Carburetor fuel-air exit
4. Cylinder #3 induction tube lower end
5. Cylinder #3 induction tube upper end
6. Cylinder #3 intake valve port area

It should be noted that fuel tank temperature for avgas and premium were the same while regular autogas was 12° F higher. This was the result of test runs being performed on different ambient temperature days and not by intent.

As can be seen, the coldest temperature at 1000 rpm occurred at the carburetor exit (position number 3) while at all other rpm conditions the coldest location occurred at the throttle plate (position number 2). Of particular interest is that with fuel and air temperatures at 60° F and above, the throttle plate will still reach freezing conditions.

After reviewing figure 4(a), (b), (c), and (d), it was decided that the most probable location for carburetor ice to form was the throttle plate. This was also concluded during work effort on reference 2.

Another area of interest related to temperature distribution inside the intake valve port area. In order to obtain data associated with this engine area, thermocouples were inserted into the intake port chamber on cylinders numbers 3 and 4. These two cylinders were selected due to easy access and configuration. Cylinder number 3 intake port which was located at the front of the engine was approximately six inches from cylinder number 1 exhaust port. Cylinder number 4 intake port was also located at the front of the engine, however, it was less than one-half inch from cylinder number 2 exhaust port. With this configuration, it was of interest obtaining data relative to temperature impact cylinder number 2 might impose on cylinder number 4.

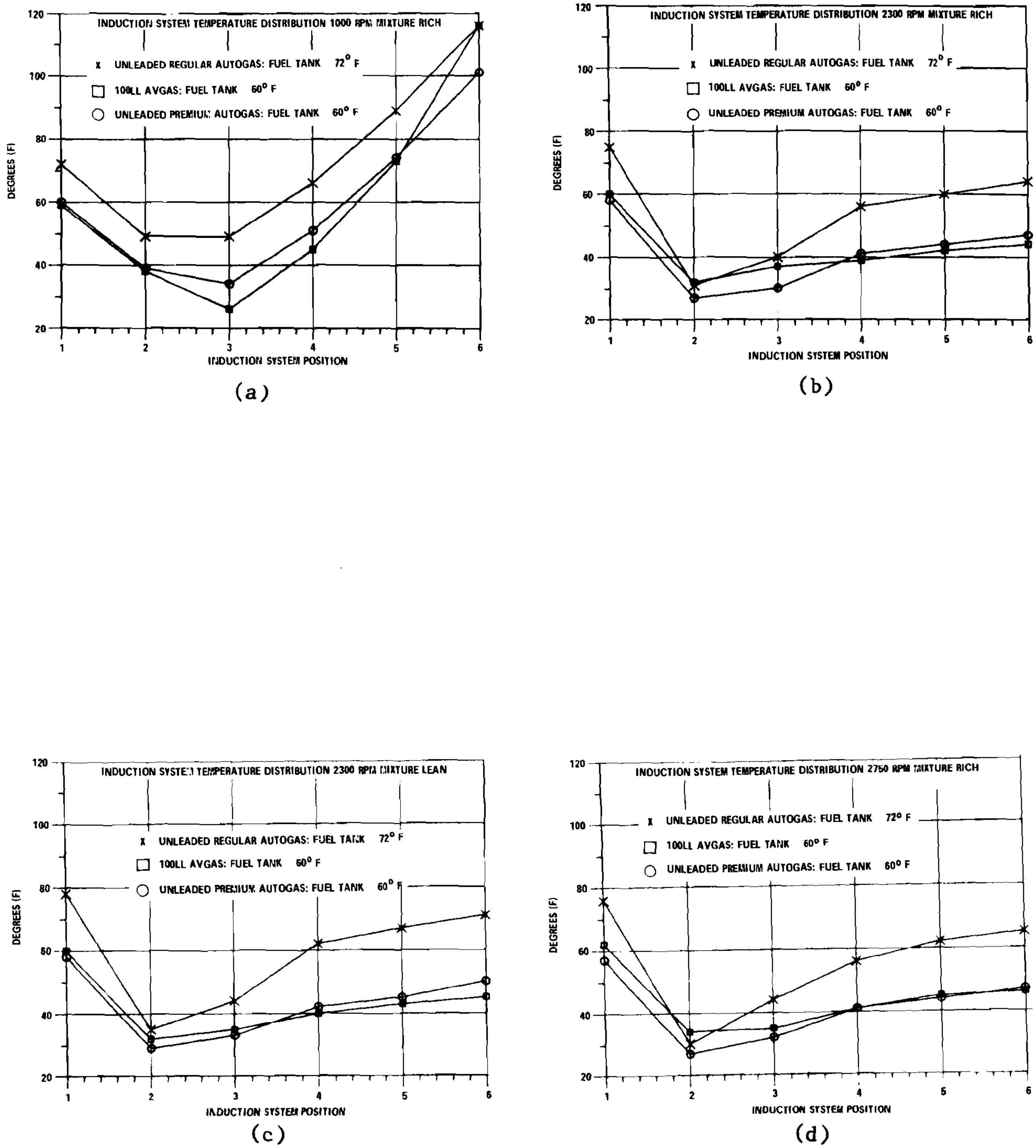


FIGURE 4. INDUCTION SYSTEM TEMPERATURE DISTRIBUTION

Figure 5 represents temperature data distribution for both cylinders number 3 and number 4 up through 2750 rpm. While figure 5 was plotted for 100LL avgas only, the same type of temperature limits and distribution were obtained for all grades of fuel tested.

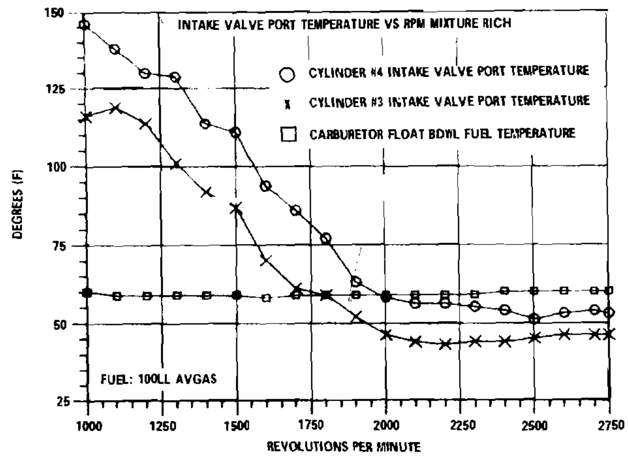


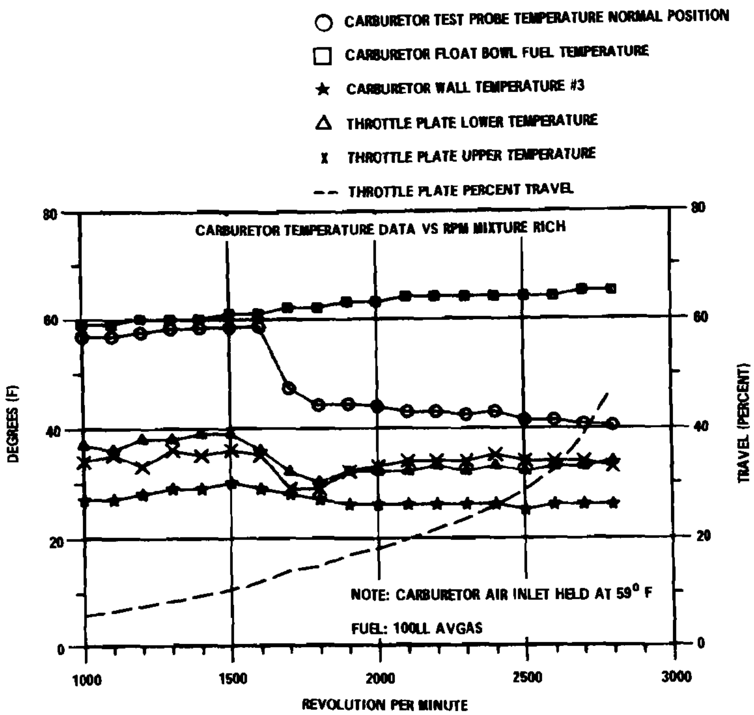
FIGURE 5. INTAKE VALVE PORT TEMPERATURE VERSUS RPM (MIXTURE RICH)

When reviewing carburetor ice detection/warning devices such as listed in appendix B, it will be noted that some devices are throttle plate mounted while others mount in the wall of the carburetor venturi. Experience gained during reference 2 indicated a temperature differential existed between throttle plate and that which was seen by wall mounted device sensors. With this in mind, a series of test runs were made looking at possible temperature differentials.

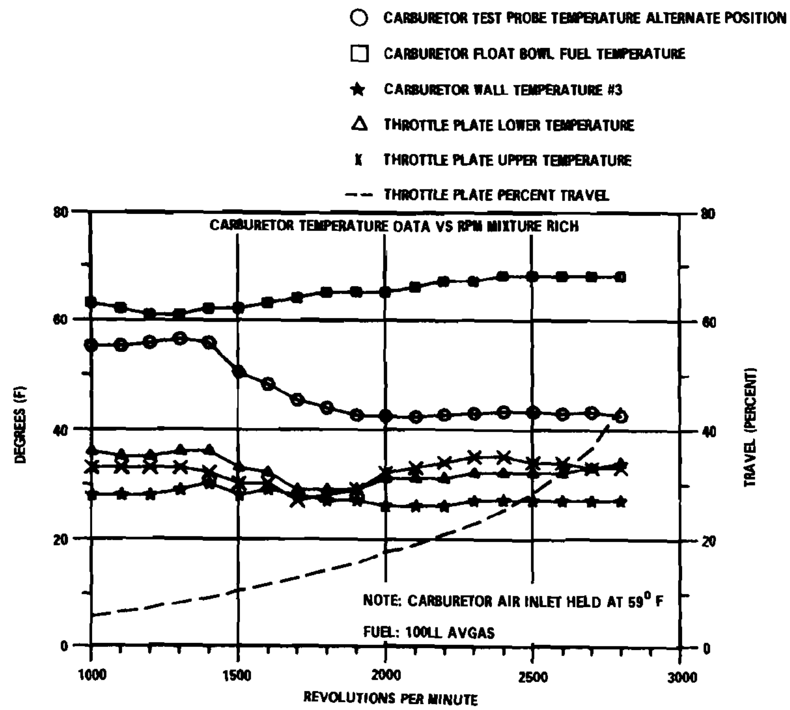
Wall mounted sensors utilize an existing 1/4-inch hole placed in the carburetor venturi by the carburetor manufacturer. However, on some aircraft installations, this location was not accessible and an alternate location has been utilized. Therefore, this alternate sensor location was also tested for possible temperature differentials. This alternate location required the drilling and tapping of a 1/4-inch hole in the carburetor venturi, approximately 40 degrees displaced from original location. Refer to appendix E test cell installation photographs.

Figure 6(a), (b), (c), (d), (e), and (f) represent test data obtained with all three grades of fuel. Two test runs were made on each fuel; one with a carburetor temperature probe in the normal wall position and the other test run with a temperature probe in the alternate position. Carburetor inlet air temperature was maintained at 59° F throughout this test series so as to maintain a constant reference point. A review of all six data graphs will show what temperature differential can exist between wall mounted detector sensor and the actual throttle plate temperature. It can be seen that as engine rpm increased, the differential decreased, however, with the particular test installation utilized, at no time did the wall mounted sensor agree with throttle plate temperature.

After reviewing test cell data utilized for figure 6 an additional series of test runs were accomplished with all three grades of fuel looking specifically at throttle plate temperature. These subsequent test runs were performed with both rich and lean mixture on each fuel with ambient test cell air being inducted into the carburetor.

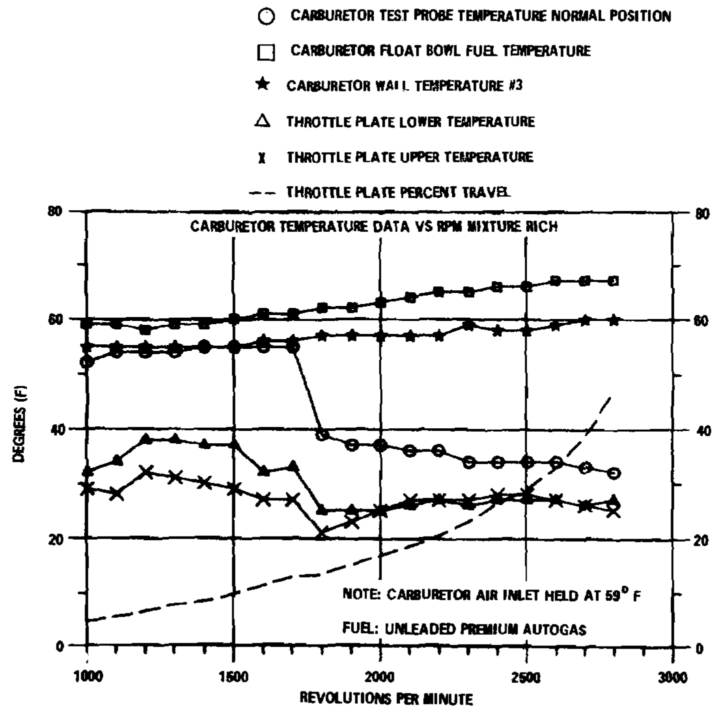


(a)

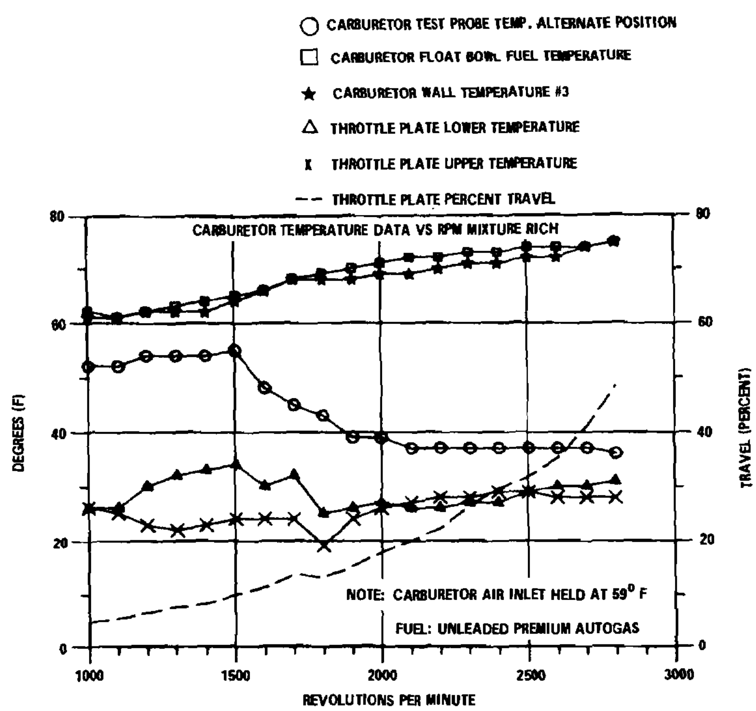


(b)

FIGURE 6. CARBURETOR TEMPERATURE DATA VERSUS RPM (1 of 3 Sheets)

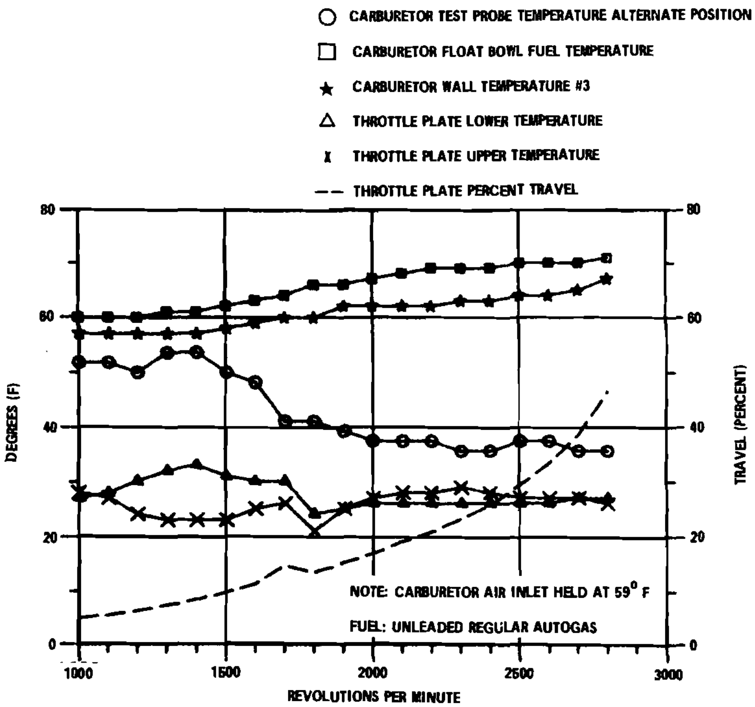


(c)

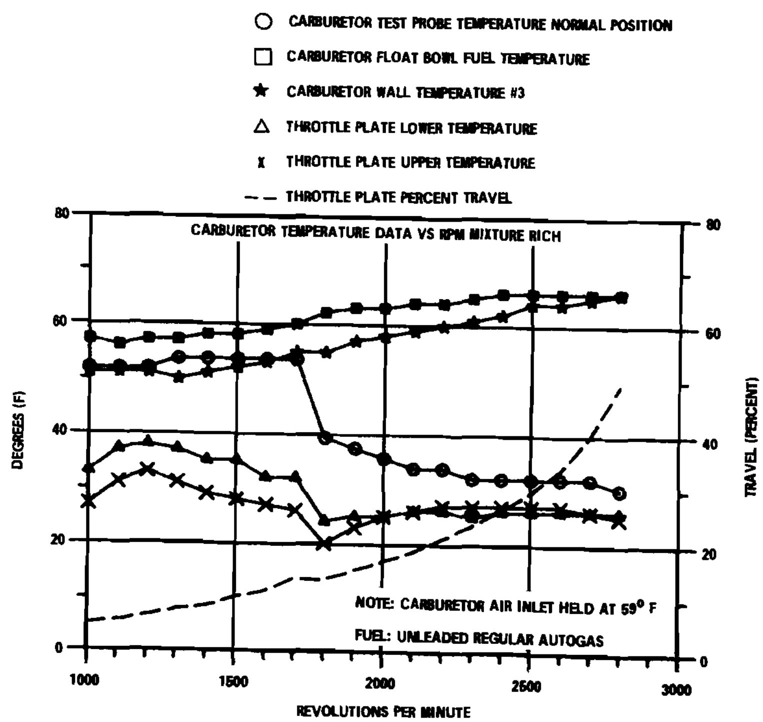


(d)

FIGURE 6. CARBURETOR TEMPERATURE DATA VERSUS RPM (2 of 3 Sheets)



(e)



(f)

FIGURE 6. CARBURETOR TEMPERATURE DATA VERSUS RPM (3 of 3 Sheets)

Figure 7(a) and (b) display the carburetor throttle plate temperatures, rich and lean mixture, for 100LL avgas. Figure 7(c) and (d) display the throttle plate temperature for premium autogas. It can be seen that autogas will cause a slightly lower temperature than avgas. Figure 7(e) and (f) display the same type of data for regular autogas. Even with an elevated fuel and inlet air temperature, the throttle plate reaches freezing temperatures. This appears to be the result of higher volatility autogas which had a Reid Vapor Pressure of 9.8 to 11.6 as compared to the avgas maximum limit of 7.0.

An even better display of fuel effects on throttle plate temperature can be seen in figure 8. This figure provides throttle plate temperature for all three grades of fuel while maintaining constant carburetor air inlet temperature of 59° F. Carburetor float bowl temperature is also provided and all three fuels remained $\pm 2°$ F of the plotted temperature line.

With the effects of various fuel volatility ranges displayed in the data heretofore presented, a final series of test runs was performed relative to time for carburetor ice initiation. In this series of tests, a particular test point rpm was selected, 1600-2400 for premium/100LL and 1400-2400 for regular/100LL. After a stabilized rpm was obtained, carburetor heat was applied to bring throttle plate above freezing to a starting reference temperature, remove any possible hidden ice accumulations, and dry out water content on carburetor surfaces. When all conditions were stable, carburetor heat was removed and time taken until visible ice formation accumulated. This test pattern was repeated at each test point with premium autogas/100LL avgas and again with regular autogas/100LL avgas.

A procedure such as outlined above allowed each autogas grade of fuel to be checked against avgas after a short fuel burn time was allowed to purge opposite fuel out of fuel line and carburetor float bowl. The installation of electric operated solenoid fuel valves in each fuel tank line, as described in TEST CELL EQUIPMENT portion of report and appendix E, provided easy test operation in these tests.

Figure 9(a) and (b) provide results of these test runs. With the exception of premium autogas at 1600 rpm, figure 9(a), the carburetor tends to start icing several minutes sooner with autogas than with 100LL avgas. It should be pointed out that during these icing tests, total carburetor ice accumulation and rate with autogas was no worse than with avgas. Carburetor icing rate is such a variable on any of the three grades of fuel tested, based on rpm and climatic conditions, that none appear any worse than the others.

As listed in table 1, idle jet pressure was monitored during icing testing. It was noted during reference 2 testing that carburetor idle jet pressure was useful in monitoring carburetor performance/sensitivity during ice accumulation and propagation. Figure 10 is an idle jet pressure plot versus rpm with pressure being plotted in inches of mercury vacuum. Figure 10 data were taken from the SUT of one of the ice warning devices test cycle, wherein slight idle jet pressure fluctuations which are evident at 900 and 1300 rpm are attributed to typical engine warm-up characteristics. Pressure fluctuations at 1800 rpm were typical during magneto operational check. This particular test cycle was run with a standard flight propeller and as such, maximum static rpm was 2300 as noted by upper limit of data plot.

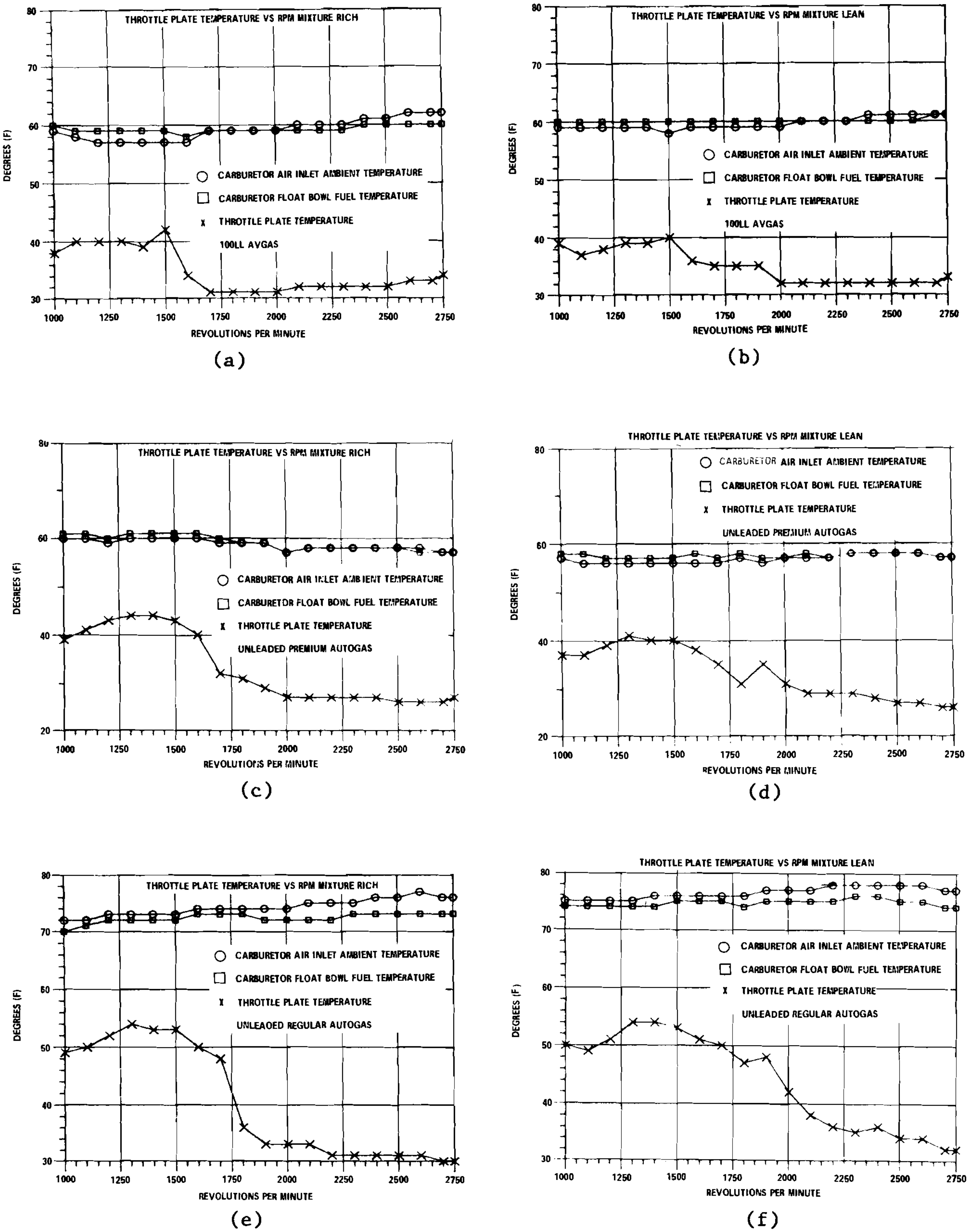


FIGURE 7. THROTTLE PLATE TEMPERATURE VERSUS RPM

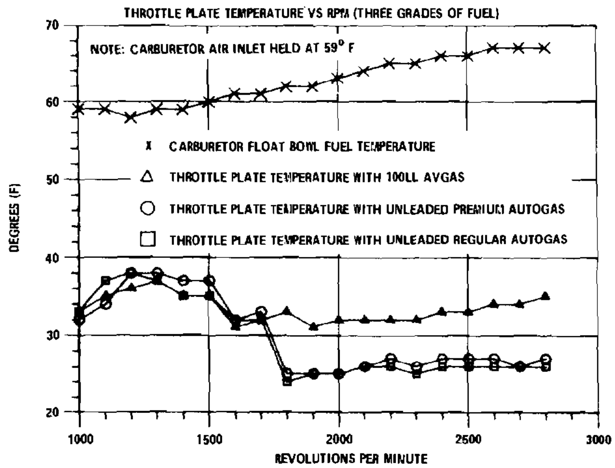
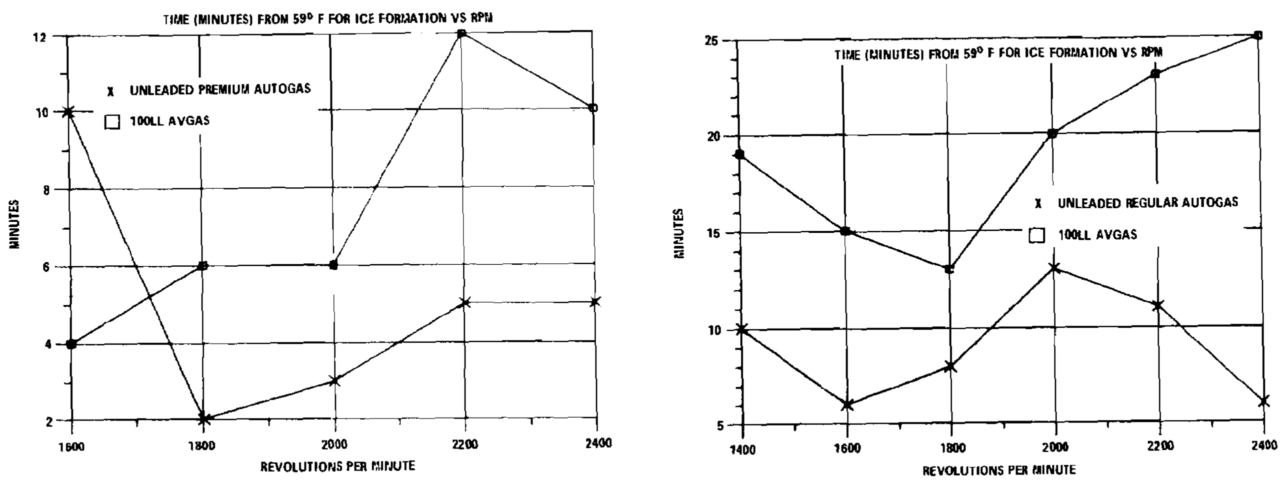


FIGURE 8. THROTTLE PLATE TEMPERATURE VERSUS RPM (THREE GRADES OF FUEL)



(a) (b)

FIGURE 9. TIME (MINUTES) FROM 59° F TO ICE FORMATION VERSUS RPM

Figure 11 reflects idle jet pressure fluctuation during the entire carburetor icing test cycle initiated in figure 10. Large pressure fluctuations were typical during carburetor icing and were detected prior to engine performance change. During some large pressure fluctuations, an idle jet vent was opened to check on possible alteration of engine performance characteristics. Whenever venting was initiated, idle jet pressure would return to near ambient and rpm would increase by 200-300 rpm. Exhaust emission analyzing equipment would better identify changes in engine performance characteristics due to such a venting operation. However, such equipment was not available during testing.

During the aforementioned carburetor icing tests, photographs were taken to provide additional information associated with carburetor ice. Appendix J contains carburetor ice photographs taken during actual engine operation by use of a 35mm camera adapted to one of the fiberoptic borescopes.

CONCLUSIONS

GENERAL OBSERVATIONS.

The following conclusions relate to engine operation under carburetor icing conditions accomplished at sea level conditions only. Engine operation was conducted with a standard flight propeller which gave a static rpm at full throttle of 2300 and a cutoff flight propeller which allowed 2800 rpm at full throttle. It should also be remembered that carburetor ice detectors/warning devices, are STC approved on a non-hazard basis as optional equipment only and flight operations are not to be predicated on their use. Standard cockpit instrumentation will provide adequate information relative to carburetor ice when properly monitored.

1. The static test cell engine installation, without actual aircraft cowling and dynamic flight conditions, allowed an engine heat transfer different from that imposed in-flight. The test cell installation did not allow the lower engine area to dissipate heat as rapidly as in-flight, and hence, represents a conservative condition relative to icing.

2. During test cell engine operation, cooling air across the cylinders was held at four inches of water which is higher than that used in actual aircraft. This would help dissipate engine cylinder head heat at a greater rate.

3. A better understanding of carbureter ice accumulation effects on fuel-air ratio could have been obtained with the use of exhaust emission analyzer equipment.

4. The initial impact on carburetor performance as ice accumulation commenced was a fluctuation of idle jet pressure below normal value. Such fluctuation would appear long before engine performance change commenced. Idle jet pressure became an accurate instrument for early detection of carburetor ice formation and worked equally well, regardless of fuel grade utilized.

5. Carburetor ice accumlation rate varies with rpm and ambient atmospheric conditions At times, ice accumulation was noted within 30 seconds at low rpm. These conditions were true for all grades of fuel tested.

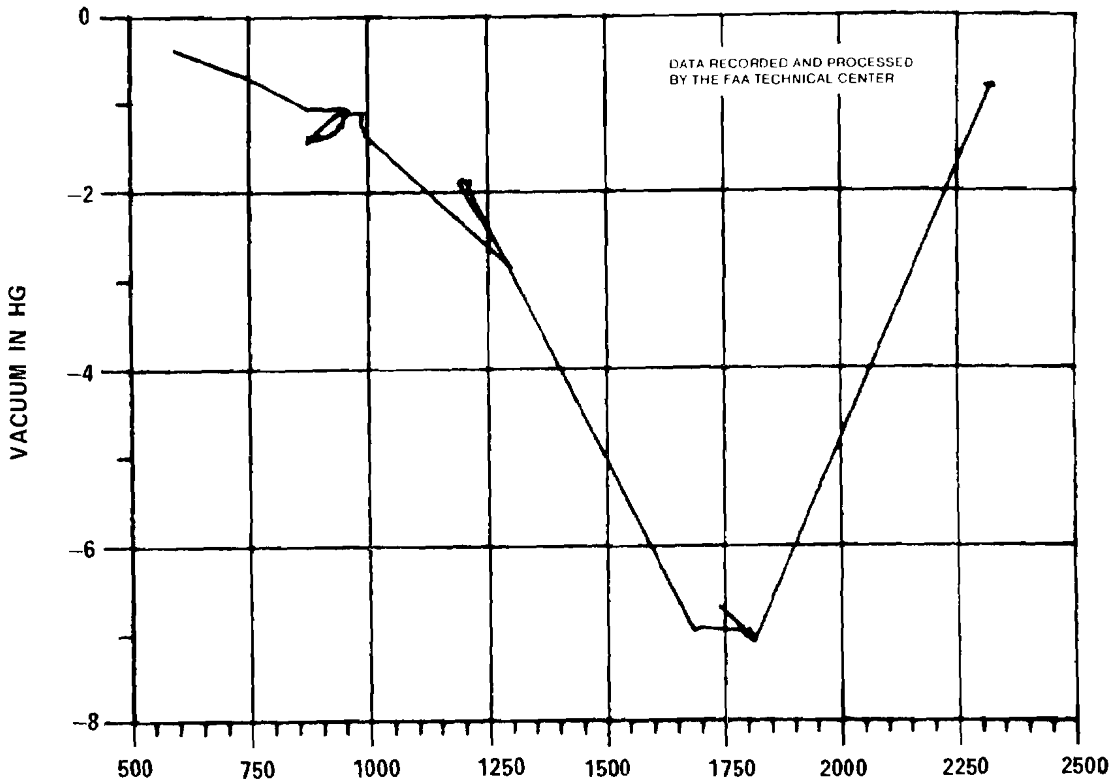


FIGURE 10. IDLE JET PRESSURE VERSUS RPM (NO ICE)

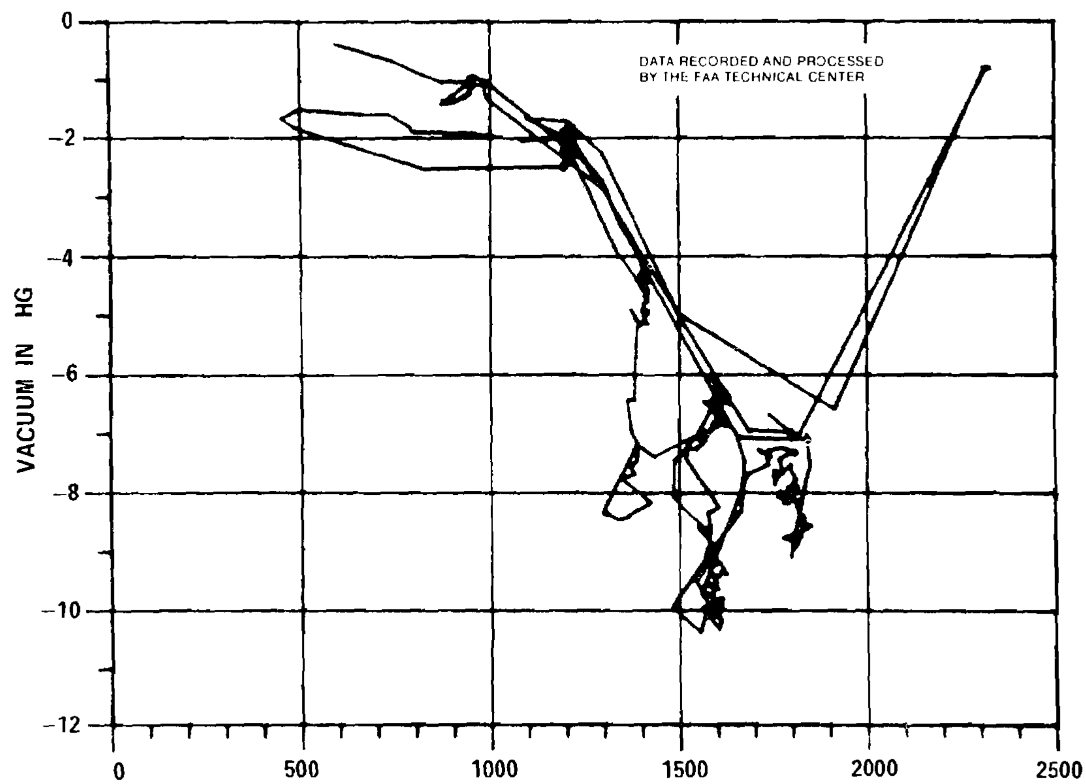


FIGURE 11. IDLE JET PRESSURE VERSUS RPM (WITH ICE)

6. The most conducive condition for this test installation to produce carburetor ice was with an inlet carburetor air temperature of 40° to 65° F. Autogas would favor the upper temperature while avgas favored the lower limit. Testing was not accomplished to attempt to place exact limits to any grade of fuel.

7. During all icing testing, throttle plate and carburetor wall right next to throttle plate were the only locations of ice accumulation.

8. Based on video observations of actual carburetor ice accumulation, the best location for a carburetor ice detector/warning device would be on the throttle plate. Data graphs contained within this report support this fact.

9. Existing throttle plate mounted sensors do not cover the entire throttle plate area. Therefore, ice would build in small amounts on the throttle plate prior to reaching indicator sensor. The amount of ice accumulation was minimal and as noted within this report, the location for ice initiation does change with rpm and climatic conditions.

10. Although there is a temperature differential, wall mounted ice detector/warning devices are useful instruments when used properly as optional equipment for detecting or warning about possible carburetor ice formation.

RELATED FACTS.

1. Surprisingly, little moisture needs to be present in ambient air to initiate carburetor ice/frost formation. This is especially true with autogas.

2. All tested carburetor ice detector/warning devices worked equally well on all grades of fuel tested.

3. Small amounts of ice formation on the manifold side of the throttle plate next to the idle jet holes will have an immediate impact on idle jet pressure (vacuum).

4. Engine change in performance during carburetor icing was similar for all three grades of fuel.

5. Autogas with and without anti-icing additives were tested with no appreciable difference in carburetor icing tendency.

6. Engine performance operation on unleaded premium autogas was slightly better than that achieved on 100LL avgas while unleaded regular autogas provided slightly less performance than 100LL.

7. Cylinder head temperature and exhaust gas temperature as illustrated in appendix F will be just as adequate in removing carburetor ice with autogas as with avgas.

8. Current aircraft certification requirements dictate aircraft must provide a minimum 90° F temperature rise to the induction system air. This will be adequate with autogas grade fuel, even at -15° C (5° F) as indicated on some carburetor ice warning devices.

9. Existing standard cockpit instrumentation is adequate to detect carburetor ice formation with autogas or avgas. Aircraft/engine performance change will provide warning indications with sufficient time to correct deteriorating conditions prior to engine stoppage.

10. Pilot education during student training phase and biennial flight review needs to stress carburetor icing problems, detection indications, and proper corrective procedures as specified by aircraft manufacturer in the approved aircraft flight manuals, especially in aircraft certified by STC for autogas usage.

11. Engine performance changes/data presented within this report relates to the sea-level-static engine installation illustrated in appendix E.

12. Existing carburetors utilize a metal throttle plate which is easily influenced by incoming air. Today's state-of-the-art advancement in composite materials may affect added protection from ice formation if used as throttle plate material. Further protection would be achieved if throttle plate were held at 34° F or above without heating the total induction air mass.

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APPENDIX A

AVGAS-AUTOGAS CARBURETOR ICE BIBLIOGRAPHY

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APPENDIX B

CARBURETOR ICE WARNING DEVICES

APPENDIX B

CARBURETOR ICE WARNING DEVICES

These items are available as "off-the-shelf" optional instrument items.

a. Charles B. Shivers Jr.
8928 Valleybrook Road
Birmingham, Alabama 35206
(telephone 205-833-7968)

This device is a carburetor modification to the throttle plate and accompanied with a cockpit indicator to provide warning of ice accumulation.

b. Boldnor Electronics
Boldnor Farm
Nr. Yarmouth, I.O.W. England
(telephone 098-376-0268)

This device is a thin metal plate positioned between carburetor and induction manifold and accompanied with a cockpit indicator to provide warning of ice accumulation.

c. Dataproducts
New England, Inc.
Barnes Park North

Wallingford, Connecticut 06492
(telephone 203-265-7151)

This device is still under development, however, it will be a throttle plate mounted ice detector accompanied with a cockpit indicator to provide warning of ice accumulation.

d. A.R.P. Industries, Inc.
36 Bay Drive East
Huntington Long Island, New York 11743
(telephone 516-427-1585)

This device is a small light radiation source with a light sensor attached, all of which mounts in an existing 1/4-inch hole located in the carburetor venturi area. The light sensor connects via electric circuit to a cockpit mounted warning light, sensistivity control and optional warning horn.

e. Richter Aero Eqipment, Inc.
15194G Ridge Road
Essex, New York 12936
(telephone 518-963-7080)

This device is a small wire sensing coil of known resistance characteristics which change with temperature. The sensing coil mounts in an existing 1/4-inch hole located in carburetor venturi area. Attached to the coil via electric circuit is a cockpit mounted air temperature gage with color warning area and placard.

APPENDIX C

BASELINE TEST 1 SEQUENCE MANUAL DATA

CARBURETOR ICE TEST DATA

RUN # 1A : TEST # 4 : DATA PAGE # 1 : DATE 6/7/82 :

FUEL 100LL : BAROMETER - In. Hg A 29.88 : PUMP OCTANE ____ :

DRY TEMP 59° F : WET TEMP 56° F : RELATIVE HUMIDITY 84 %:

Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	13:38	13:44	13:49	13:56	14:01	14:07	14:13	14:19	14:25	14:30	14:37	14:42	14:46	14:50	14:55
RPM	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Manifold Press	11.5	11.6	11.9	12.1	12.5	13.2	14.1	15.1	15.5	16.6	17.7	18.7	19.9	20.7	22.0
Torque	16.8	20.0	23.0	30.5	39.3	41.0	47.0	56.0	64.5	65.8	76.0	81.0	88.0	101.0	116.0
Horsepower	3.0	4.7	6.4	7.9	10.1	11.6	15.0	19.2	22.3	24.4	30.0	33.0	37.0	45.0	54.0
CHT #1	206	210	218	230	246	251	256	263	282	296	320	334	334	324	350
#2	209	213	227	244	250	264	274	285	291	292	309	328	345	355	364
#3	199	202	216	228	244	261	264	267	281	286	287	281	287	323	339
#4	198	199	216	231	242	257	261	270	281	285	291	307	331	344	349
EGT #1	398	410	428	458	490	507	526	555	589	624	665	694	694	681	727
#2	299	317	347	378	398	427	446	464	485	496	524	553	586	595	612
#3	328	338	368	388	415	445	456	470	491	510	522	527	538	579	598
#4	325	338	365	389	398	434	441	451	480	487	502	514	539	556	555
Valve Port #4	146	138	130	129	114	111	94	86	77	63	58	56	56	55	54
Valve Port #3	116	119	114	101	92	87	70	61	59	52	46	44	43	44	44
Upper Tube #3	73	72	69	65	60	58	49	47	46	44	42	42	42	42	43
Lower Tube #3	45	45	43	41	40	40	38	38	39	38	38	39	39	39	40
Carburetor Adaptor Upper	26	25	24	23	25	25	26	26	27	26	27	31	37	37	31
Carburetor Adaptor Lower	59	58	57	57	57	57	57	59	59	59	59	60	60	60	61
Throttle Plate Upper	36	36	35	35	35	37	31	29	30	31	32	33	33	33	34
Throttle Plate Lower	38	40	40	40	39	42	34	31	31	31	31	32	32	32	32
Carburetor Temp. Probe	60	59	56	60	57	58	51	48	47	45	45	45	45	44	45
Carburetor Bowl	60	59	59	59	59	59	58	59	59	59	59	59	59	59	60
Sediment Bowl	63	63	63	63	62	62	61	60	60	60	60	60	60	60	60
Fuel Tank AVGAS/AUTOGAS	58/	58/	58/	57/	57/	57/	57/	57/	57/	57/	58/	58/	58/	58/	58/
Test Cell	57	57	57	57	56	57	37	56	57	57	58	59	58	59	59
Water: ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Ice: YES/NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fuel Flow	1.1	1.3	1.4	1.6	1.8	2.0	2.3	3.1	3.2	3.8	4.3	4.7	5.2	5.7	6.3
Mixture (R. or L.)	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

Remarks:

CARBURETOR ICE TEST DATA

RUN # 1A : TEST # 4 : DATA PAGE # 2 : DATE 6/7/82 :

FUEL 100LL : BAROMETER - In. HgA 29.88 : PUMP OCTANE ____ :

DRY TEMP 59° F : WET TEMP 56° F : RELATIVE HUMIDITY 84 %:

Test Point	16	17	18	19
Time	14:59	15:03	15:07	15:12
RPM	2500	2600	2700	2750
Manifold Press	23.3	24.4	25.4	26.4
Torque	118.0	125.0	139.0	149.0
Horsepower	56.0	63.0	72.0	79.0
CHT #1	340	347	382	393
#2	387	392	382	393
#3	355	394	421	431
#4	389	419	443	450
EGT #1	721	741	781	796
#2	653	648	642	758
#3	626	677	709	724
#4	614	638	667	674
Valve Port #4	51	53	54	53
Valve Port #3	45	46	46	46
Upper Tube #3	43	45	45	45
Lower Tube #3	40	41	42	41
Carburetor Adaptor Upper	32	34	35	35
Carburetor Adaptor Lower	61	62	62	62
Throttle Plate Upper	33	33	33	33
Throttle Plate Lower	32	33	33	34
Carburetor Temp. Probe	45	45	45	44
Carburetor Bowl	60	60	60	60
Sediment Bowl	60	60	60	60
Fuel Tank AVGAS / AUTOGAS	58 /	58 /	58 /	58 /
Test Cell	59	59	60	60
Water: ON/OFF	OFF	OFF	OFF	OFF
Ice: YES/NO	NO	NO	NO	NO
Fuel Flow	6.8	7.2	7.6	8.1
Mixture (R. or L.)	R	R	R	R

Remarks:

CARBURETOR ICE TEST DATA

RUN # 1B : TEST # 4 : DATA PAGE # 1 : DATE 6/8/82 :

FUEL 100LL : BAROMETER - In. Hg.A 29.91 : PUMP OCTANE ______ :

DRY TEMP 62° F : WET TEMP 56° F : RELATIVE HUMIDITY 69 %:

Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	13:14	13:19	13:23	13:27	13:29	13:33	13:36	13:41	13:43	13:47	13:51	13:53	13:56	14:00	14:03
RPM	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Manifold Press	11.4	11.4	11.7	12.0	12.4	13.3	14.1	14.5	15.2	16.1	16.9	18.2	19.3	20.4	21.9
Torque	19.0	24.0	26.0	33.0	38.0	41.0	46.0	52.0	59.0	65.0	72.0	81.0	89.0	100.0	111.0
Horsepower	5.0	6.0	7.0	9.0	11.0	13.0	15.0	17.0	21.0	24.0	28.0	33.0	39.0	45.0	53.0
CHT #1	212	216	226	239	258	271	283	290	305	330	342	352	366	380	396
#2	215	218	230	246	256	271	290	305	310	325	334	347	365	374	386
#3	204	210	222	233	252	272	291	296	306	330	340	350	361	376	393
#4	201	207	219	235	252	265	281	296	304	323	331	337	355	369	391
EGT #1	388	404	427	464	512	533	566	580	641	715	744	773	801	819	823
#2	312	320	349	385	409	447	488	504	528	560	566	604	640	658	695
#3	329	340	368	390	429	471	513	502	534	587	605	617	634	659	691
#4	334	335	362	391	407	453	486	489	522	550	539	541	565	584	617
Valve Port #4	135	145	140	135	119	117	107	103	94	89	68	59	59	58	55
Valve Port #3	126	123	118	105	94	90	80	73	71	66	57	48	46	45	45
Upper Tube #3	78	76	74	68	64	61	58	52	50	49	47	44	44	43	44
Lower Tube #3	49	47	46	43	43	43	41	39	39	40	39	39	39	40	40
Carburetor Adaptor Upper	28	26	27	25	25	25	27	26	26	26	26	28	31	35	31
Carburetor Adaptor Lower	59	59	59	59	59	58	59	59	59	59	59	60	60	60	61
Throttle Plate Upper	38	36	35	36	35	37	34	35	35	36	32	32	32	33	33
Throttle Plate Lower	39	37	38	39	39	40	36	35	35	35	32	32	32	32	32
Carburetor Temp. Probe	61	61	60	60	59	61	54	52	50	50	48	46	46	46	46
Carburetor Bowl	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60
Sediment Bowl	62	62	63	63	65	63	65	64	64	64	64	63	63	63	63
Fuel Tank AVGAS / AUTOGAS	58 /	58 /	58 /	58 /	58 /	58 /	58 /	58 /	58 /	58 /	58 /	58 /	59 /	58 /	59 /
Test Cell	58	59	58	58	58	58	58	58	58	58	58	58	58	58	59
Water: ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Ice: YES/NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fuel Flow	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.3	2.5	2.6	3.0	3.5	3.8	4.2	4.7
Mixture (R. or L.)	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

Remarks:

CARBURETOR ICE TEST DATA

RUN # 1B : TEST # 4 : DATA PAGE # 2 : DATE 6/8/82 :

FUEL 100LL : BAROMETER - In. Hg A 29.91 : PUMP OCTANE ______ :

DRY TEMP 62° F : WET TEMP 56° F : RELATIVE HUMIDITY 69 %:

Test Point	16	17	18	19
Time	14:05	14:08	14:13	14:18
RPM	2500	2600	2700	2750
Manifold Press	23.1	24.4	25.6	26.4
Torque	118.0	128.0	135.0	149.0
Horsepower	58.0	64.0	71.0	80.0
CHT #1	395	395	408	416
#2	399	417	434	442
#3	408	424	444	453
#4	409	430	456	462
EGT #1	788	793	812	823
#2	705	725	721	734
#3	701	726	740	750
#4	654	688	699	710
Valve Port #4	53	53	52	53
Valve Port #3	45	45	46	45
Upper Tube #3	43	43	44	44
Lower Tube #3	40	40	41	41
Carburetor Adaptor Upper	32	33	34	35
Carburetor Adaptor Lower	61	61	61	61
Throttle Plate Upper	33	33	32	32
Throttle Plate Lower	32	32	32	33
Carburetor Temp. Probe	46	45	45	44
Carburetor Bowl	60	60	61	61
Sediment Bowl	63	67	61	61
Fuel Tank AVGAS / AUTOGAS	59 /	59 /	59 /	59 /
Test Cell	59	59	59	59
Water: ON/OFF	OFF	OFF	OFF	OFF
Ice: YES/NO	NO	NO	NO	NO
Fuel Flow	5.4	5.9	6.7	7.1
Mixture (R. or L.)	L	L	L	L

Remarks:

CARBURETOR ICE TEST DATA

RUN # 1C : TEST # 4 : DATA PAGE # 1 : DATE 6/7/82 :

FUEL UNLEADED PREMIUM : BAROMETER - In. HgA 29.88 : PUMP OCTANE 91 :

DRY TEMP 59°F : WET TEMP 56°F : RELATIVE HUMIDITY 84 %:

Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	15:27	15:32	15:36	15:40	15:44	15:47	15:52	16:01	16:05	16:12	9:02	9:09	9:13	9:19	9:24
RPM	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Manifold Press	11.5	11.3	11.7	12.1	12.3	13.1	14.0	14.7	15.4	16.6	17.4	18.6	19.8	20.8	22.1
Torque	14.5	19.0	22.0	28.0	34.0	39.0	45.0	50.0	58.0	66.0	74.0	82.0	88.0	98.0	113.0
Horsepower	3.0	5.0	6.0	8.0	10.0	12.0	14.0	17.0	21.0	25.0	28.0	34.0	38.0	43.0	52.0
CHT #1	201	208	220	241	256	262	264	259	265	308	327	340	352	354	350
#2	220	225	239	254	264	274	293	297	298	280	290	303	333	353	377
#3	195	201	213	220	231	256	277	283	281	297	306	318	309	330	335
#4	202	206	219	238	247	263	280	287	292	272	274	282	299	319	358
EGT #1	390	392	416	454	503	505	524	531	539	617	676	709	741	738	729
#2	314	333	366	405	417	441	485	484	495	474	479	499	542	580	627
#3	326	333	358	373	381	438	472	487	491	512	523	551	572	579	590
#4	329	341	358	396	404	441	470	477	487	458	433	445	444	485	559
Valve Port #4	136	121	118	117	109	105	97	88	82	70	62	60	57	56	55
Valve Port #3	101	101	98	87	81	83	76	68	64	59	54	49	47	47	47
Upper Tube #3	74	75	72	66	62	60	56	52	49	47	45	44	44	44	44
Lower Tube #3	51	50	49	47	46	46	45	43	42	42	41	41	41	41	41
Carburetor Adaptor Upper	34	33	31	29	30	31	32	29	27	24	22	25	28	30	30
Carburetor Adaptor Lower	60	60	59	60	60	60	60	59	59	59	57	58	58	58	58
Throttle Plate Upper	40	40	41	42	42	41	39	29	28	28	26	26	26	26	27
Throttle Plate Lower	39	41	43	44	44	43	40	32	31	29	27	27	27	27	27
Carburetor Temp. Probe	61	62	62	62	63	63	54	48	45	42	39	38	37	37	36
Carburetor Bowl	61	61	60	61	61	61	61	60	59	59	57	58	58	58	58
Sediment Bowl	63	64	64	65	65	64	64	63	62	62	59	59	59	60	59
Fuel Tank AVGAS / AUTOGAS	/ 59	/ 59	/ 59	/ 60	/ 60	/ 59	/ 59	/ 59	/ 58	/ 58	/ 57	/ 57	/ 57	/ 57	/ 57
Test Cell	59	59	59	59	60	59	59	58	58	58	55	56	56	56	55
Water: ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Ice: YES/NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fuel Flow	1.1	1.3	1.5	1.6	1.8	2.2	2.3	2.6	3.1	3.7	4.0	4.5	5.0	5.5	6.1
Mixture (R. or L.)	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

Remarks:

CARBURETOR ICE TEST DATA

RUN # 1C : TEST # 4 : DATA PAGE # 2 : DATE 6/8/82 :

FUEL UNLEADED PREMIUM : BAROMETER - In. HgA 29.92 : PUMP OCTANE 91 :

DRY TEMP 59°F : WET TEMP 54°F : RELATIVE HUMIDITY 73 %:

Test Point	16	17	18	19											
Time	9:28	9:35	9:40	9:45											
RPM	2500	2600	2700	2750											
Manifold Press	23.4	24.6	25.8	26.5											
Torque	122.0	139.0	153.0	162.0											
Horsepower	59.0	72.0	80.0	86.0											
CHT #1	334	350	385	397											
#2	396	389	387	401											
#3	357	411	430	439											
#4	396	428	446	451											
EGT #1	716	739	796	805											
#2	664	649	641	667											
#3	627	694	727	728											
#4	620	649	663	672											
Valve Port #4	59	59	59	57											
Valve Port #3	47	47	47	47											
Upper Tube #3	43	44	44	44											
Lower Tube #3	40	41	41	41											
Carburetor Adaptor Upper	32	32	33	32											
Carburetor Adaptor Lower	58	58	57	57											
Throttle Plate Upper	26	26	25	26											
Throttle Plate Lower	26	26	26	27											
Carburetor Temp. Probe	36	35	35	36											
Carburetor Bowl	58	57	57	57											
Sediment Bowl	59	59	58	59											
Fuel Tank AVGAS / AUTOGAS	/ 57	/ 57	/ 57	/ 57	/	/	/	/	/	/	/	/	/	/	/
Test Cell	55	55	55	55											
Water: ON/OFF	OFF	OFF	OFF	OFF											
Ice: YES/NO	NO	NO	NO	NO											
Fuel Flow	6.5	6.9	7.5	7.7											
Mixture (R. or L.)	R	R	R	R											

Remarks:

CARBURETOR ICE TEST DATA

RUN # 1D : TEST # 4 : DATA PAGE # 1 : DATE 6/8/82 :

FUEL UNLEADED PREMIUM : BAROMETER - In. HgA 29.92 : PUMP OCTANE 91 :

DRY TEMP 59°F : WET TEMP 54°F : RELATIVE HUMIDITY 73 %:

Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	10:02	10:06	10:10	10:18	10:26	10:30	10:34	10:38	10:44	10:50	10:54	10:59	11:04	11:07	11:12
RPM	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Manifold Press	11.2	11.2	11.6	12.1	12.4	13.3	14.2	14.7	15.3	16.1	17.0	18.1	19.5	20.6	21.7
Torque	15.0	20.0	28.0	30.0	36.0	39.0	46.0	51.0	59.0	67.0	74.0	82.0	90.0	97.0	106.0
Horsepower	3.0	5.0	7.0	8.0	10.0	12.0	15.0	17.0	21.0	24.0	29.0	34.0	38.0	43.0	49.0
CHT #1	200	213	226	246	263	266	266	278	291	332	343	353	357	379	396
#2	220	225	240	258	264	276	296	308	311	329	336	345	365	378	391
#3	196	204	219	230	242	265	283	294	296	329	341	354	365	379	386
#4	200	206	220	245	252	268	285	295	305	325	330	330	347	357	383
EGT #1	376	394	418	456	529	517	533	566	591	725	751	781	803	825	826
#2	321	336	378	432	422	455	502	521	514	564	562	580	637	657	685
#3	313	329	359	380	397	452	485	506	498	578	605	628	650	671	676
#4	335	333	368	429	400	459	481	502	504	564	545	541	554	563	592
Valve Port #4	137	122	122	118	103	104	94	90	87	83	73	67	64	62	61
Valve Port #3	101	100	99	88	79	80	73	71	65	65	59	53	50	50	49
Upper Tube #3	72	73	72	65	59	57	54	52	50	49	47	46	45	45	45
Lower Tube #3	49	48	47	45	44	43	43	42	42	42	42	42	42	42	42
Carburetor Adaptor Upper	31	31	31	27	27	28	30	28	27	26	27	27	30	33	32
Carburetor Adaptor Lower	57	56	56	56	56	56	55	56	57	56	57	57	57	58	58
Throttle Plate Upper	38	38	37	39	38	38	36	33	28	33	29	28	28	27	27
Throttle Plate Lower	37	37	39	41	40	40	38	35	31	35	31	29	29	29	28
Carburetor Temp. Probe	58	58	58	57	57	58	51	48	45	45	42	40	38	37	37
Carburetor Bowl	58	58	57	57	57	57	58	57	58	57	57	58	57	58	58
Sediment Bowl	61	62	62	62	61	61	61	60	60	60	60	60	60	60	60
Fuel Tank AVGAS/AUTOGAS	57	57	57	57	57	57	57	57	57	57	57	57	57	57	57
Test Cell	55	56	55	56	55	55	56	56	56	55	55	55	56	56	56
Water: ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Ice: YES/NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fuel Flow	1.0	1.1	1.2	1.4	1.5	1.8	2.0	2.2	2.7	2.8	3.0	3.4	3.8	4.2	4.7
Mixture (R. or L.)	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

Remarks:

CARBURETOR ICE TEST DATA

RUN # 1D : TEST # 4 : DATA PAGE # 2 : DATE 6/8/82 :

FUEL UNLEADED PREMIUM : BAROMETER - In. Hg A 29.92 : PUMP OCTANE 91 :

DRY TEMP 60°F : WET TEMP 55°F : RELATIVE HUMIDITY 73 %:

Test Point	16	17	18	19											
Time	11:18	11:22	11:26	11:30											
RPM	2500	2600	2700	2750											
Manifold Press	23.3	24.7	25.9	26.6											
Torque	116.0	133.0	136.0	149.0											
Horsepower	56.0	67.0	72.0	80.0											
CHT #1	393	384	407	405											
#2	399	416	434	446											
#3	395	427	448	450											
#4	418	433	453	463											
EGT #1	795	783	821	816											
#2	715	733	756	757											
#3	675	724	752	753											
#4	655	696	710	714											
Valve Port #4	60	61	62	62											
Valve Port #3	48	49	48	48											
Upper Tube #3	45	45	45	44											
Lower Tube #3	42	42	41	41											
Carburetor Adaptor Upper	33	34	34	34											
Carburetor Adaptor Lower	58	58	57	57											
Throttle Plate Upper	27	26	26	25											
Throttle Plate Lower	27	27	26	26											
Carburetor Temp. Probe	37	37	36	35											
Carburetor Bowl	58	58	57	57											
Sediment Bowl	59	59	59	59											
Fuel Tank AVGAS / AUTOGAS	/ 57	/ 57	/ 57	/ 57											
Test Cell	56	56	56	56											
Water: ON/OFF	OFF	OFF	OFF	OFF											
Ice: YES/NO	NO	NO	NO	NO											
Fuel Flow	5.4	6.0	6.4	6.9											
Mixture (R. or L.)	L	L	L	L											

Remarks:

CARBURETOR ICE TEST DATA

RUN # 3A : TEST # 5 : DATA PAGE # 1 : DATE 6/25/82 :

FUEL UNLEADED REGULAR : BAROMETER - In. HgA 30.06 : PUMP OCTANE 87 :

DRY TEMP 77°F : WET TEMP 63°F : RELATIVE HUMIDITY 45 %:

Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	9:58	10:04	10:08	10:11	10:15	10:18	10:21	10:24	10:27	10:30	10:34	10:37	10:39	10:42	10:44
RPM	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Manifold Press	11.6	11.2	11.5	12.0	12.2	12.9	13.7	14.5	15.2	16.2	17.1	18.0	19.3	20.4	21.9
Torque	13.0	19.0	20.0	28.0	34.0	36.0	42.0	45.0	54.0	59.0	67.0	74.0	79.0	90.0	98.0
Horsepower	3.0	5.0	5.0	8.0	10.0	11.0	13.0	15.0	19.0	22.0	27.0	30.0	34.0	41.0	45.0
CHT #1	210	221	230	241	265	273	275	287	297	296	324	341	351	352	338
#2	229	234	244	259	272	280	296	310	321	310	310	322	336	364	378
#3	212	216	226	237	253	267	287	300	307	297	318	333	337	337	355
#4	214	218	229	245	264	272	287	299	312	304	303	305	310	337	367
EGT #1	395	403	423	454	521	524	528	570	597	612	682	726	739	733	720
#2	327	331	368	408	422	449	475	512	516	494	506	522	543	596	618
#3	339	353	381	404	428	459	493	527	528	518	559	581	588	607	630
#4	347	349	377	416	425	454	474	505	513	486	500	496	492	529	565
Valve Port #4	149	135	134	131	121	117	113	109	100	91	83	79	78	78	75
Valve Port #3	116	117	118	107	101	100	94	92	85	79	73	70	66	64	65
Upper Tube #3	89	90	89	83	79	76	74	72	67	65	64	64	62	60	61
Lower Tube #3	66	66	65	63	62	62	62	61	59	58	58	58	57	56	56
Carburetor Adaptor Upper	49	48	49	45	45	46	46	45	40	35	32	37	38	40	41
Carburetor Adaptor Lower	72	72	73	73	73	73	74	74	74	74	74	75	75	75	76
Throttle Plate Upper	49	51	51	52	51	50	48	47	31	30	31	31	30	30	30
Throttle Plate Lower	49	50	52	54	53	53	50	48	36	33	33	33	31	31	31
Carburetor Temp. Probe	53	60	63	64	65	66	65	65	44	38	36	35	33	32	30
Carburetor Bowl	70	71	72	72	72	72	73	73	73	72	72	72	72	73	73
Sediment Bowl	80	80	78	78	78	78	78	78	77	77	76	76	76	76	76
Fuel Tank AVGAS / AUTOGAS	/71	/71	/72	/72	/72	/72	/73	/73	/73	/74	/74	/74	/74	/74	/75
Test Cell	73	72	73	73	73	74	74	73	74	74	74	74	74	74	75
Water: ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Ice: YES/NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fuel Flow	1.0	1.1	1.2	1.4	1.6	1.8	2.0	2.3	2.9	3.5	4.0	4.3	5.0	5.5	6.0
Mixture (R. or L.)	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

Remarks:

CARBURETOR ICE TEST DATA

RUN # 3A : TEST # 5 : DATA PAGE # 2 : DATE 6/25/82 :

FUEL UNLEADED REGULAR : BAROMETER - In. Hg A 30.06 : PUMP OCTANE 87 :

DRY TEMP 77°F : WET TEMP 63°F : RELATIVE HUMIDITY 45 %:

Test Point	16	17	18	19											
Time	10:46	10:49	10:52	10:54											
RPM	2500	2600	2700	2750											
Manifold Press	23.2	24.2	25.6	26.2											
Torque	106.0	117.0	126.0	132.0											
Horsepower	52.0	59.0	66.0	70.0											
CHT #1	331	354	382	404											
#2	390	388	403	404											
#3	380	408	434	444											
#4	399	421	446	453											
EGT #1	713	749	796	820											
#2	627	629	651	653											
#3	668	706	737	749											
#4	593	619	646	652											
Valve Port #4	77	77	76	76											
Valve Port #3	66	66	65	65											
Upper Tube #3	62	62	62	62											
Lower Tube #3	57	57	56	56											
Carburetor Adaptor Upper	43	44	44	44											
Carburetor Adaptor Lower	76	77	76	76											
Throttle Plate Upper	30	30	30	29											
Throttle Plate Lower	31	31	30	30											
Carburetor Temp. Probe	30	30	29	29											
Carburetor Bowl	73	73	73	73											
Sediment Bowl	76	76	76	77											
Fuel Tank AVGAS / AUTOGAS	/ 75	/ 75	/ 75	/ 75											
Test Cell	75	75	74	75											
Water: ON/OFF	OFF	OFF	OFF	OFF											
Ice: YES/NO	NO	NO	NO	NO											
Fuel Flow	6.5	6.9	7.5	7.8											
Mixture (R. or L.)	R	R	R	R											

Remarks:

CARBURETOR ICE TEST DATA

RUN # 3B : TEST # 5 : DATA PAGE # 1 : DATE 6/25/82 :

FUEL UNLEADED REGULAR : BAROMETER - In. HgA 30.06 : PUMP OCTANE 87 :

DRY TEMP 77°F : WET TEMP 63°F : RELATIVE HUMIDITY 45 %:

Test Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Time	11:08	11:12	11:15	11:18	11:21	11:24	11:27	11:30	11:33	11:37	11:40	11:43	11:45	11:48	11:51
RPM	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
Manifold Press	11.0	11.0	11.4	12.0	12.3	13.1	13.7	14.7	15.3	16.4	16.9	17.9	18.9	20.2	21.6
Torque	13.0	17.0	21.0	26.0	31.0	35.0	39.0	46.0	52.0	60.0	66.0	73.0	81.0	89.0	100.0
Horsepower	3.0	4.0	6.0	7.0	9.0	11.0	13.0	16.0	19.0	23.0	26.0	30.0	35.0	40.0	47.0
CHT #1	216	230	243	263	278	287	291	301	312	336	354	368	380	391	405
#2	229	237	251	269	281	291	302	318	330	339	353	357	369	383	395
#3	212	219	235	251	268	281	295	313	327	342	356	366	379	389	400
#4	216	220	236	255	272	282	292	307	321	337	350	347	352	365	393
EGT #1	399	425	453	515	534	564	568	601	625	721	775	796	824	849	844
#2	315	334	385	431	455	478	502	543	565	592	588	584	601	640	686
#3	338	359	392	427	457	494	523	575	590	649	665	659	677	693	697
#4	350	350	400	451	463	478	500	539	564	597	586	542	553	565	617
Valve Port #4	159	142	143	138	131	125	118	113	107	103	97	88	85	85	83
Valve Port #3	123	121	121	112	107	104	97	94	92	87	81	76	72	71	71
Upper Tube #3	94	94	91	88	84	80	78	74	73	71	69	68	67	67	66
Lower Tube #3	70	70	68	67	66	65	64	64	63	64	63	63	62	62	62
Carburetor Adaptor Upper	51	51	52	48	48	48	47	44	42	39	37	37	41	44	46
Carburetor Adaptor Lower	75	75	75	75	76	76	76	76	76	77	77	77	78	78	78
Throttle Plate Upper	48	47	46	51	50	49	47	47	43	45	40	36	35	34	33
Throttle Plate Lower	50	49	51	54	54	53	51	50	47	48	42	38	36	35	36
Carburetor Temp. Probe	67	68	68	69	70	70	69	69	60	65	53	45	41	39	37
Carburetor Bowl	74	74	74	74	74	75	75	75	74	75	75	75	75	76	76
Sediment Bowl	81	81	81	82	82	82	82	81	81	80	80	80	80	80	80
Fuel Tank AVGAS / AUTOGAS	/ 76	/ 76	/ 76	/ 76	/ 76	/ 77	/ 77	/ 77	/ 77	/ 77	/ 77	/ 77	/ 77	/ 78	/ 78
Test Cell	75	76	76	76	76	77	76	76	76	76	76	76	76	77	75
Water: ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Ice: YES/NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fuel Flow	1.0	1.1	1.2	1.3	1.6	1.8	1.9	2.1	2.5	2.6	2.9	3.4	3.8	4.2	4.5
Mixture (R. or L.)	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

Remarks:

CARBURETOR ICE TEST DATA

RUN # 3B : TEST # 5 : DATA PAGE # 2 : DATE 6/25/82 :

FUEL UNLEADED REGULAR : BAROMETER - In. HgA 30.06 : PUMP OCTANE 87 :

DRY TEMP 77°F : WET TEMP 63°F : RELATIVE HUMIDITY 45 %:

Test Point	16	17	18	19
Time	11:54	11:56	11:58	12:00
RPM	2500	2600	2700	2750
Manifold Press	23.0	24.2	25.5	26.0
Torque	108.0	118.0	126.0	132.0
Horsepower	52.0	59.0	66.0	70.0
CHT #1	399	400	405	408
#2	407	422	435	450
#3	418	436	449	456
#4	420	437	455	468
EGT #1	800	811	815	812
#2	704	721	732	737
#3	724	756	766	764
#4	654	680	689	698
Valve Port #4	81	82	80	79
Valve Port #3	70	70	68	67
Upper Tube #3	65	65	63	63
Lower Tube #3	60	60	58	58
Carburetor Adaptor Upper	46	47	47	47
Carburetor Adaptor Lower	78	78	77	77
Throttle Plate Upper	32	32	31	31
Throttle Plate Lower	34	34	32	32
Carburetor Temp. Probe	34	33	32	32
Carburetor Bowl	75	75	74	74
Sediment Bowl	80	79	79	79
Fuel Tank AVGAS / AUTOGAS	/ 77	/ 77	/ 77	/ 77
Test Cell	76	76	75	75
Water: ON/OFF	OFF	OFF	OFF	OFF
Ice: YES/NO	NO	NO	NO	NO
Fuel Flow	5.3	5.6	6.6	7.1
Mixture (R. or L.)	L	L	L	L

Remarks:

APPENDIX D

BASELINE TEST 2 SEQUENCE MANUAL DATA

CARBURETOR ICE TEST DATA

RUN # 2 : TEST # 4 : DATA PAGE # 1 : DATE 6/9/82 :

FUEL 100LL : BAROMETER - In. Hg A 29.93 : PUMP OCTANE ______ :

DRY TEMP 77°F : WET TEMP 61°F : RELATIVE HUMIDITY 39 %:

Test Point	1	2	3	4	5	6	7	8	9	10
Time	13:35	13:36	13:51	13:52	13:54	14:10	14:18	14:21	14:23	14:25
RPM	2750	2350	2350	2750	2400	2400	2000	2300	1500	1000
Manifold Press	26.0	21.3	21.2	25.9	21.9	21.9	17.2	20.7	12.9	11.2
Torque	125	91	97	137	101	101	70	98	39	16
Horsepower	70	42	45	73	47	48	28	44	12	4
CHT #1	449	400	360	424	390	369	321	326	312	256
#2	406	360	339	384	358	346	334	348	325	255
#3	455	407	385	433	413	395	328	355	326	250
#4	412	391	388	409	400	396	319	356	325	244
EGT #1	867	752	717	850	766	732	651	684	586	436
#2	657	589	580	646	601	585	532	576	486	339
#3	737	660	646	727	675	660	561	619	502	357
#4	616	588	584	617	596	598	521	572	475	356
Valve Port #4	60	66	66	59	65	66	75	66	140	178
Valve Port #3	55	57	56	55	57	56	64	56	115	155
Upper Tube #3	54	55	54	53	55	55	58	55	81	100
Lower Tube #3	50	49	49	49	49	50	49	49	61	70
Carburetor Adaptor Upper	43	37	37	43	38	38	33	37	32	41
Carburetor Adaptor Lower	78	78	77	77	78	78	78	78	77	77
Throttle Plate Upper	42	42	41	42	42	42	41	42	40	43
Throttle Plate Lower	42	40	40	42	41	41	40	41	48	46
Carburetor Temp. Probe	55	57	57	55	57	59	59	59	81	81
Carburetor Bowl	75	76	76	76	76	77	77	77	77	78
Sediment Bowl	76	76	76	76	76	78	78	78	79	80
Fuel Tank AVGAS / AUTOGAS	75 /	75 /	75 /	75 /	75 /	76 /	76 /	76 /	76 /	76 /
Test Cell	76	76	74	75	77	76	77	76	77	77
Water: ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Ice: YES/NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fuel Flow	8.1	5.8	5.8	8.0	6.1	6.1	4.1	5.7	1.8	1.1
Mixture (R. or L.)	R	R	R	R	R	R	R	R	R	R

Remarks:

CARBURETOR ICE TEST DATA

RUN # 1 : TEST # 7 : DATA PAGE # 1 : DATE 7/26/82:

FUEL UNLEADED PREMIUM : BAROMETER - In. HgA 29.92 : PUMP OCTANE 92 :

DRY TEMP 90°F : WET TEMP 75°F : RELATIVE HUMIDITY 50 %:

Test Point	1	2	3	4	5	6	7	8	9	10					
Time	13:39	13:46	13:54	13:58	14:04	14:12	14:22	14:25	14:27	14:31					
RPM	2750	2350	2350	2750	2400	2400	2000	2300	1500	1000					
Manifold Press	26.0	21.2	21.1	26.1	21.8	21.8	17.3	20.6	13.1	10.9					
Torque	126	93	95	132	101	99	66	89	36	15					
Horsepower	67	43	44	70	47	46	27	40	11	4					
CHT #1	391	336	334	407	356	353	305	320	312	273					
#2	398	386	382	411	379	376	352	369	345	279					
#3	420	395	395	446	411	410	347	365	334	274					
#4	422	390	388	444	400	396	336	361	331	272					
EGT #1	800	691	679	837	737	739	615	653	593	453					
#2	671	624	617	662	616	604	556	611	508	359					
#3	734	694	690	760	709	706	602	652	561	393					
#4	657	597	598	661	598	597	543	580	520	387					
Valve Port #4	79	90	90	83	92	88	97	89	145	207					
Valve Port #3	71	76	77	75	77	78	86	78	130	186					
Upper Tube #3	70	73	74	72	75	75	78	75	96	120					
Lower Tube #3	64	67	68	66	68	68	70	68	78	90					
Carburetor Adaptor Upper	54	48	50	55	51	51	44	50	60	62					
Carburetor Adaptor Lower	89	91	92	92	93	93	92	93	92	91					
Throttle Plate Upper	43	45	46	44	46	46	46	47	51	54					
Throttle Plate Lower	44	45	46	45	46	46	47	47	63	57					
Carburetor Temp. Probe	57	57	59	57	59	59	61	59	84	86					
Carburetor Bowl	87	88	89	88	89	90	90	90	90	89					
Sediment Bowl	91	92	94	93	94	95	97	96	97	97					
Fuel Tank AVGAS / AUTOGAS	89	89	91	91	92	92	93	93	93	93					
Test Cell	92	91	93	93	92	93	92	93	94	93					
Water: ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF					
Ice: YES/NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO					
Fuel Flow	7.7	5.5	5.5	7.7	5.8	5.8	3.9	5.4	1.6	0.8					
Mixture (R. or L.)	R	R	R	R	R	R	R	R	R	R					

Remarks:

CARBURETOR ICE TEST DATA

RUN # 1 : TEST # 5 : DATA PAGE # 1 : DATE 6/16/82 :

FUEL UNLEADED REGULAR : BAROMETER - In. Hg A 29.77 : PUMP OCTANE 87 :

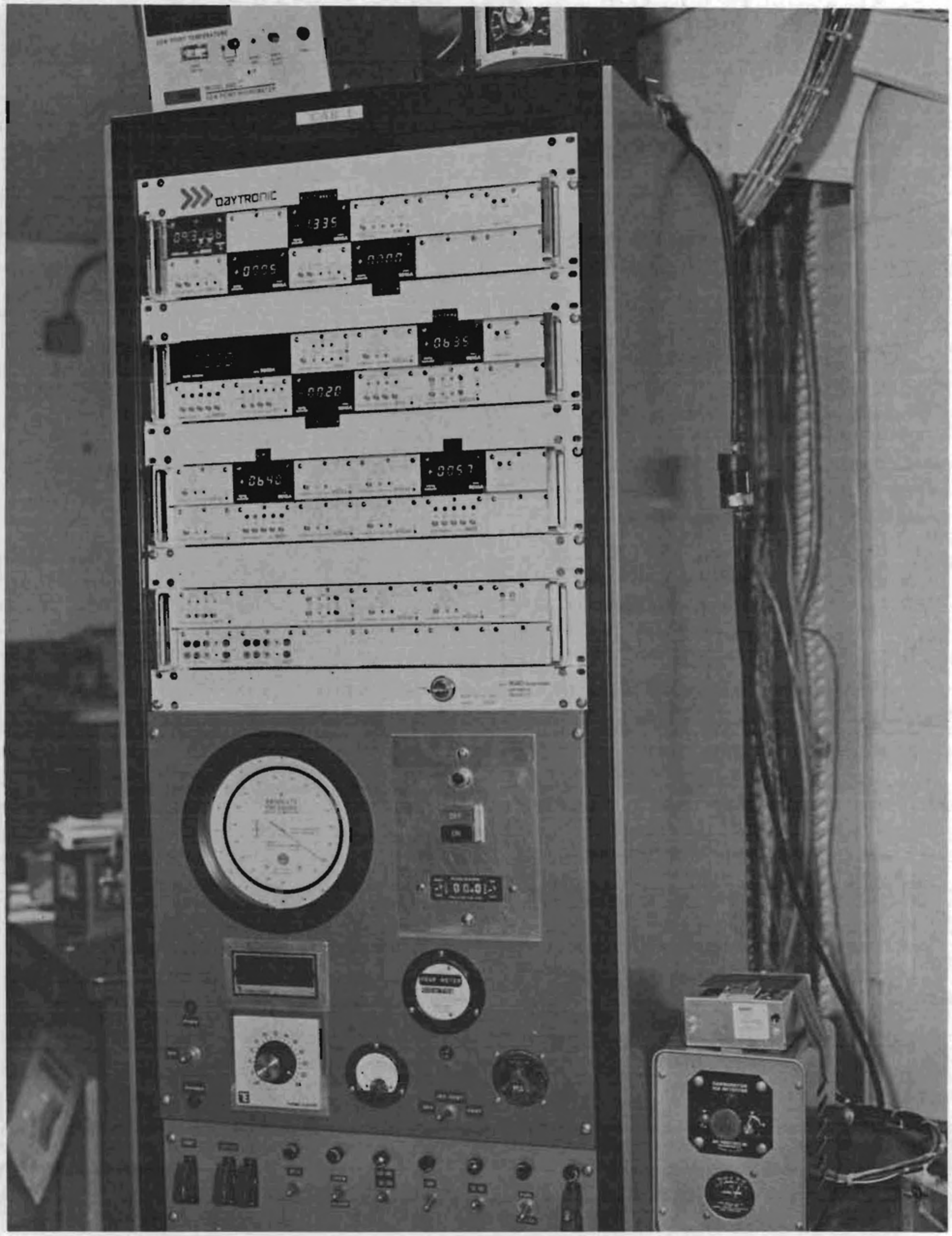
DRY TEMP 82°F : WET TEMP 73°F : RELATIVE HUMIDITY 63 %:

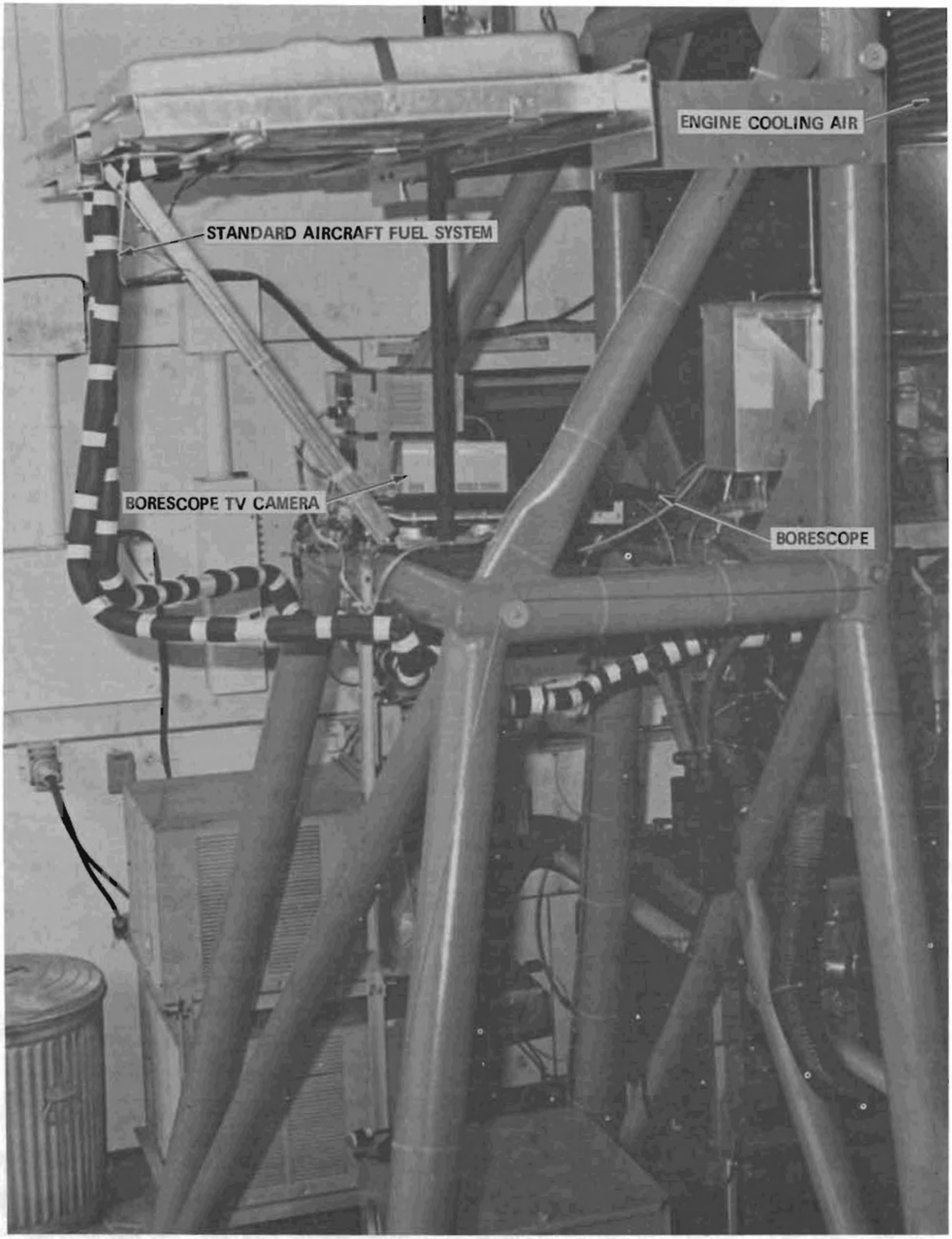
Test Point	1	2	3	4	5	6	7	8	9	10					
Time	13:43	13:50	13:57	14:01	14:07	14:15	14:24	14:28	14:30	14:33					
RPM	2750	2350	2350	2750	2400	2400	2000	2300	1500	1000					
Manifold Press	26.1	21.5	21.3	25.9	22.0	22.0	17.6	20.9	12.9	11.1					
Torque	126	96	96	133	98	97	69	90	37	14					
Horsepower	69	44	44	72	47	46	27	41	12	4					
CHT #1	418	367	353	425	375	372	305	313	302	252					
#2	380	339	334	386	338	336	334	350	328	266					
#3	416	399	397	436	410	411	337	362	330	255					
#4	382	389	390	402	400	398	322	359	325	250					
EGT #1	872	728	716	866	741	740	608	640	555	420					
#2	642	555	536	627	557	537	506	550	487	345					
#3	730	666	662	732	677	677	568	629	517	355					
#4	604	580	592	612	601	601	519	571	492	360					
Valve Port #4	75	84	85	76	85	85	92	85	131	178					
Valve Port #3	70	73	74	71	73	73	80	74	116	138					
Upper Tube #3	67	68	69	67	68	68	71	69	85	103					
Lower Tube #3	62	63	63	63	63	63	64	63	70	77					
Carburetor Adaptor Upper	51	47	47	51	48	48	41	48	48	58					
Carburetor Adaptor Lower	82	83	83	82	83	83	82	83	82	82					
Throttle Plate Upper	35	36	37	35	36	36	38	37	53	56					
Throttle Plate Lower	35	38	38	35	37	38	40	39	61	58					
Carburetor Temp. Probe	46	48	48	46	48	48	54	50	63	57					
Carburetor Bowl	79	80	80	80	81	81	81	81	82	82					
Sediment Bowl	82	83	83	83	83	84	85	84	85	86					
Fuel Tank AVGAS / AUTOGAS	/ 80	/ 81	/ 81	/ 81	/ 82	/ 82	/ 82	/ 82	/ 82	/ 82	/	/	/	/	/
Test Cell	81	81	81	81	81	81	82	82	82	82					
Water: ON/OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF					
Ice: YES/NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO					
Fuel Flow	7.8	5.7	5.7	7.8	6.0	6.0	4.1	5.6	1.6	0.9					
Mixture (R. or L.)	R	R	R	R	R	R	R	R	R	R					

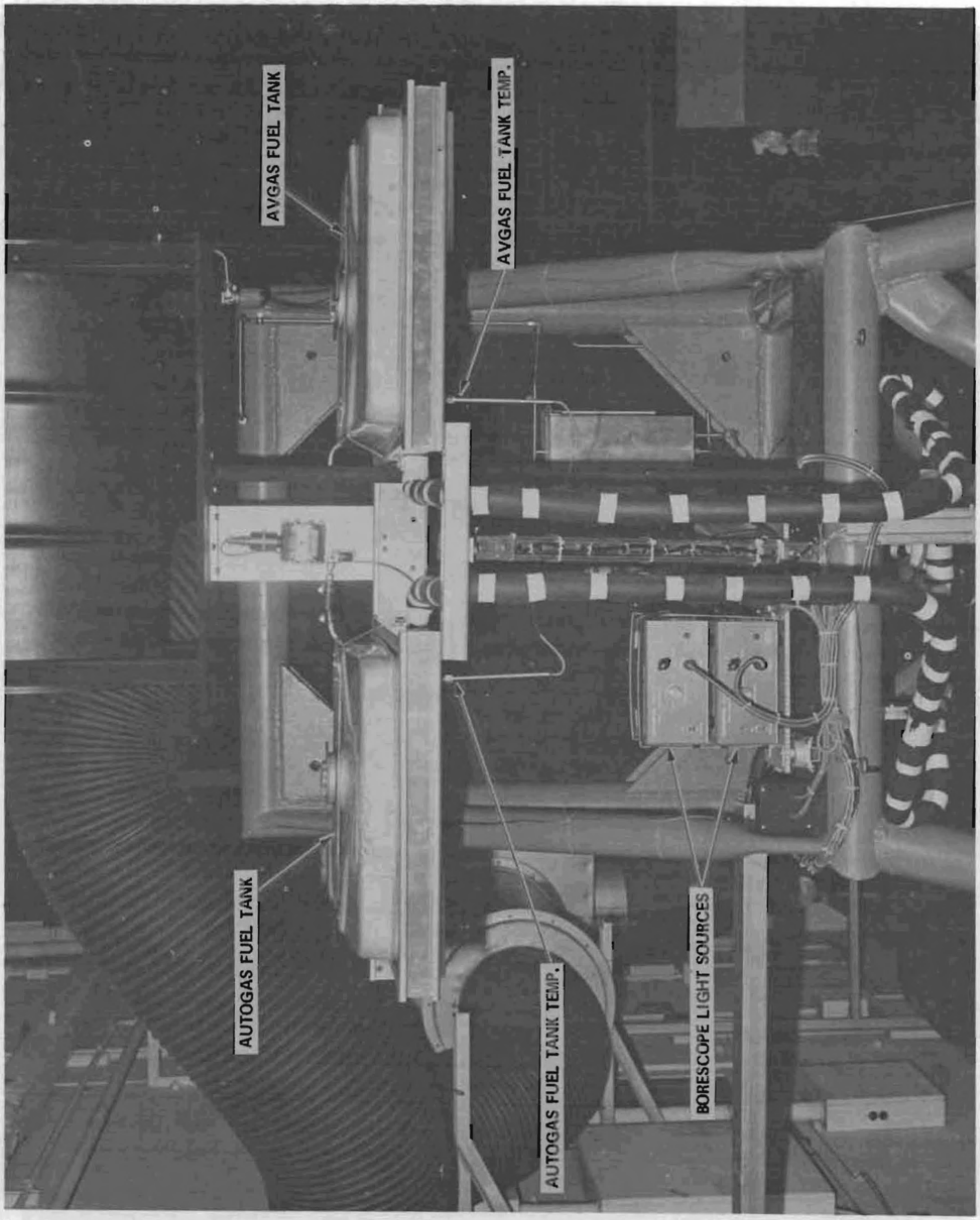
Remarks:

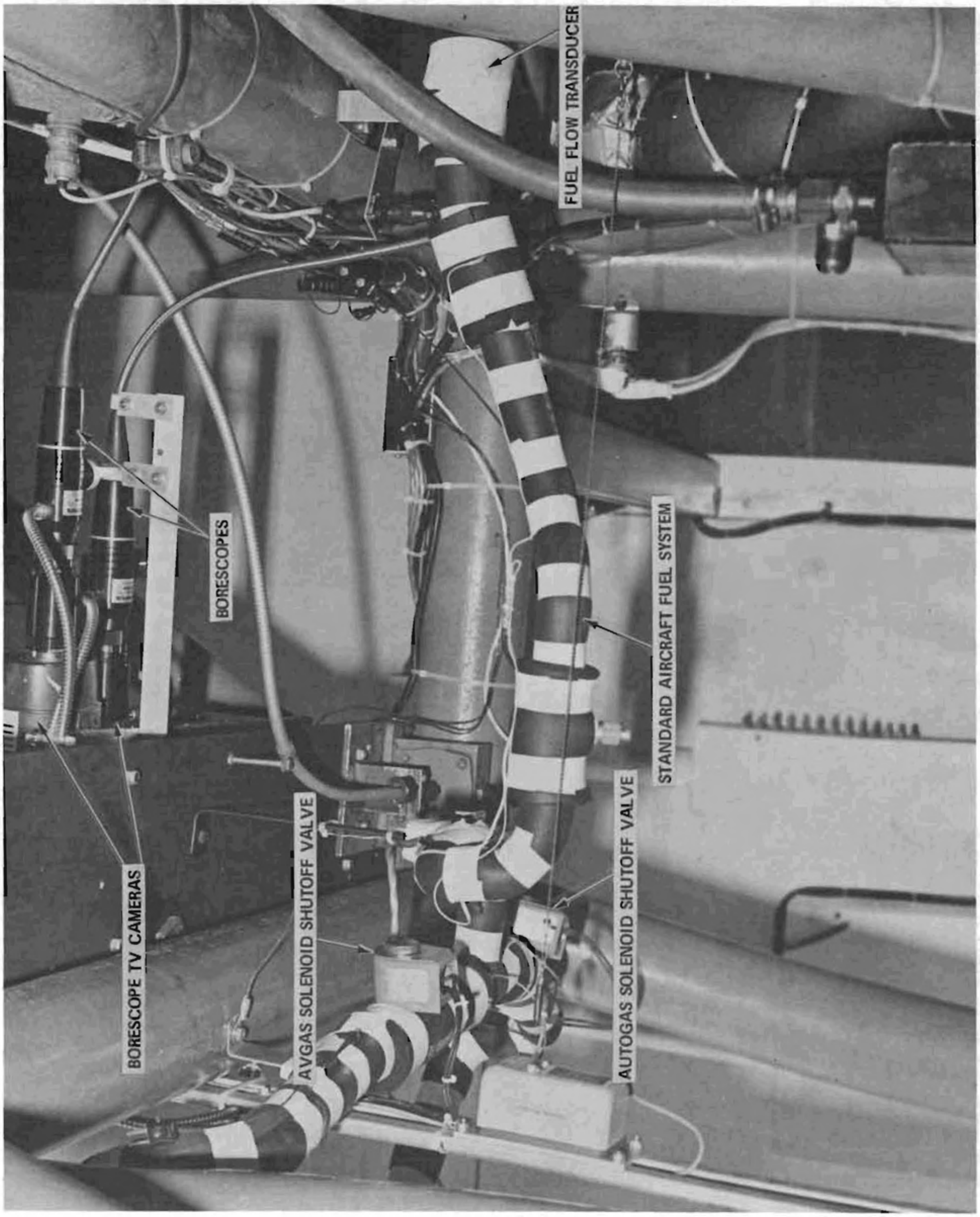
APPENDIX E

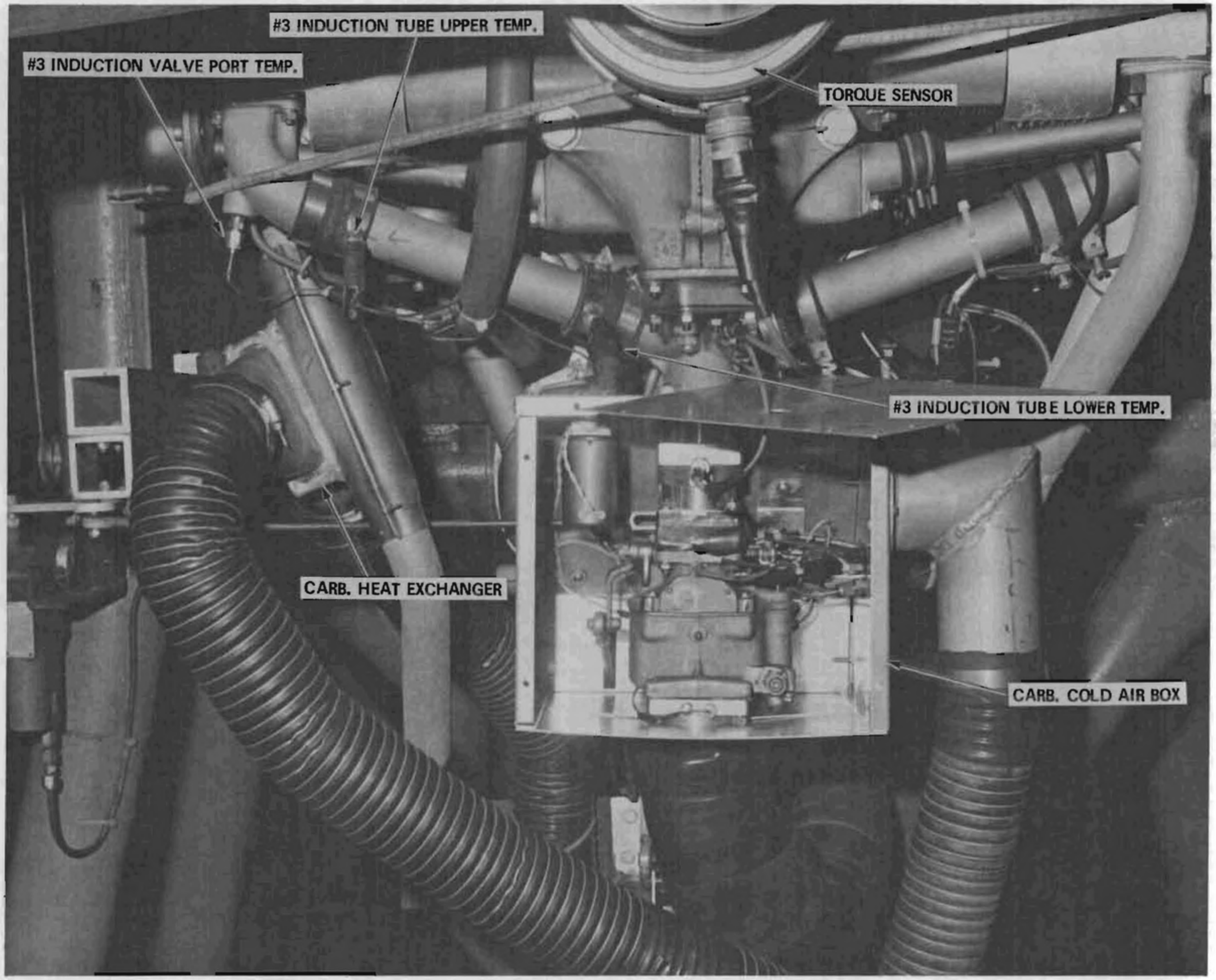
PICTORIAL PRESENTATION OF ENGINE TEST CELL INSTALLATION

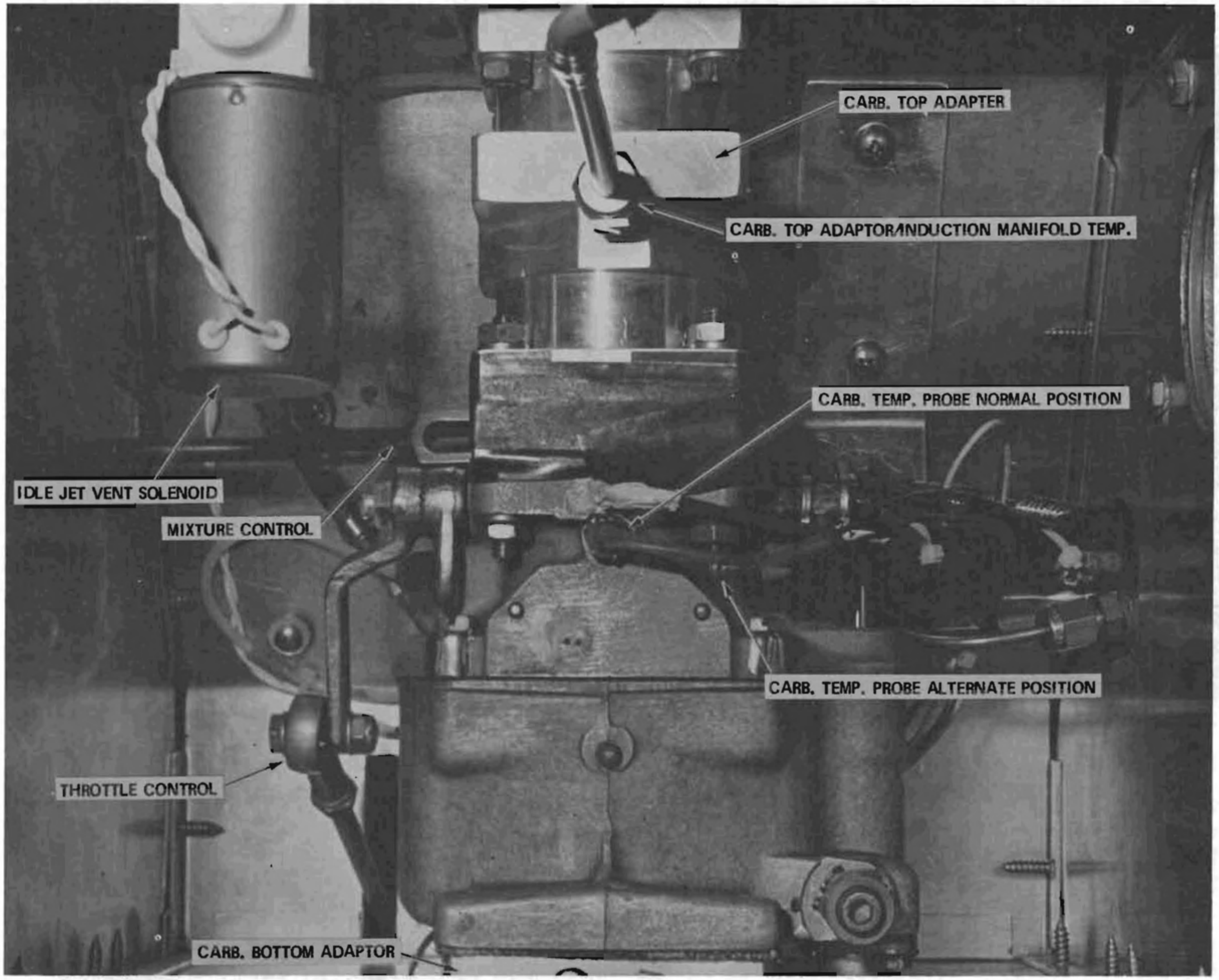

DAYTRONIC


ENGINE COOLING AIR
STANDARD AIRCRAFT FUEL SYSTEM
BORESCOPE TV CAMERA
BORESCOPE


AVGAS FUEL TANK
AVGAS FUEL TANK TEMP.
AUTOGAS FUEL TANK
AUTOGAS FUEL TANK TEMP.
BORESCOPE LIGHT SOURCES


FUEL FLOW TRANSDUCER
BORESCOPES
STANDARD AIRCRAFT FUEL SYSTEM
BORESCOPE TV CAMERAS
AVGAS SOLENOID SHUTOFF VALVE
AUTOGAS SOLENOID SHUTOFF VALVE


#3 INDUCTION TUBE UPPER TEMP.
#3 INDUCTION VALVE PORT TEMP.
TORQUE SENSOR
#3 INDUCTION TUBE LOWER TEMP.
CARB. HEAT EXCHANGER
CARB. COLD AIR BOX


CARB. TOP ADAPTER
CARB. TOP ADAPTOR/INDUCTION MANIFOLD TEMP.
CARB. TEMP. PROBE NORMAL POSITION
IDLE JET VENT SOLENOID
MIXTURE CONTROL
CARB. TEMP. PROBE ALTERNATE POSITION
THROTTLE CONTROL
CARB. BOTTOM ADAPTOR

APPENDIX F

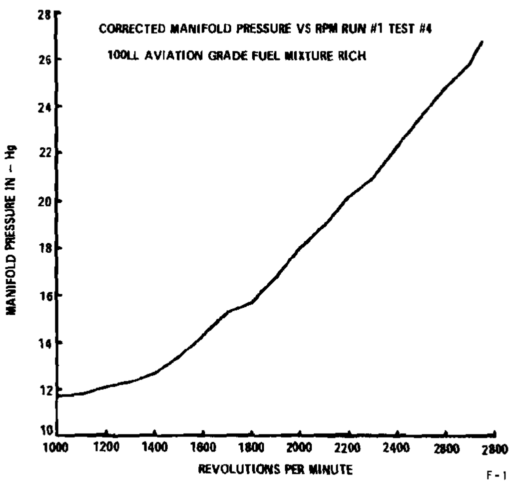
CORRECTED TEST CELL ENGINE PERFORMANCE DATA

100LL AVIATION GRADE FUEL

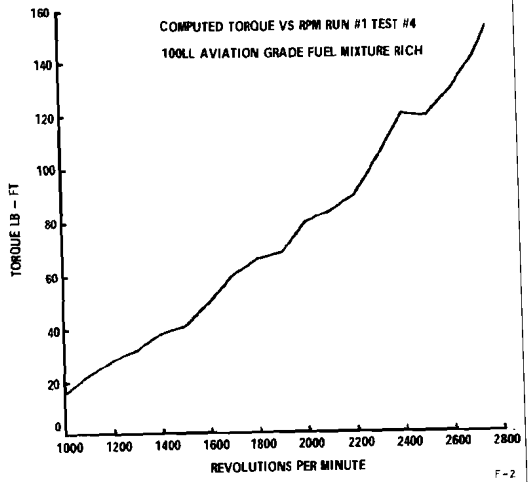
CORRECTED DATA: RUN #1 TEST #4

MIXTURE RICH

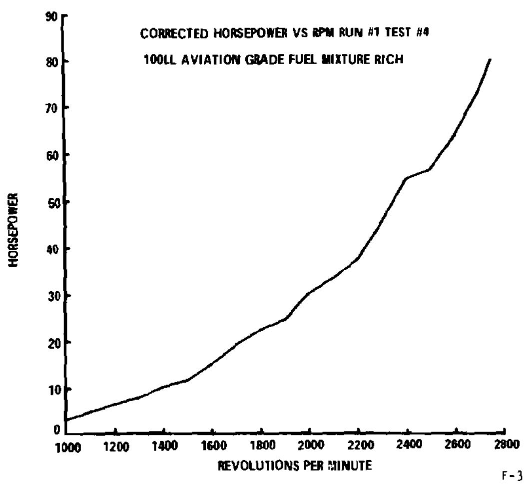
TEST POINT	RPM	M.P.	TORQUE	HP	°F CHT #1	°F EGT #1
1	1000	11.7	16.0	3.0	206	398
2	1100	11.8	22.8	4.8	210	410
3	1200	12.1	28.4	6.5	218	428
4	1300	12.3	32.4	8.0	230	458
5	1400	12.7	38.5	10.3	246	490
6	1500	13.4	41.2	11.8	251	507
7	1600	14.3	50.0	15.2	256	526
8	1700	15.3	60.2	19.5	263	555
9	1800	15.7	66.0	22.6	282	589
10	1900	16.8	68.5	24.8	296	624
11	2000	18.0	80.0	30.4	320	665
12	2100	19.0	83.8	33.5	334	694
13	2200	20.2	89.6	37.6	334	694
14	2300	21.0	104.3	45.7	324	681
15	2400	22.3	119.9	54.8	350	727
16	2500	23.6	119.4	56.8	340	721
17	2600	24.8	129.2	63.9	347	741
18	2700	25.8	142.1	73.1	382	781
19	2750	26.8	153.1	80.2	393	796


CORRECTED MANIFOLD PRESSURE VS RPM RUN #1 TEST #4
100LL AVIATION GRADE FUEL MIXTURE RICH
MANIFOLD PRESSURE IN – Hg
REVOLUTIONS PER MINUTE

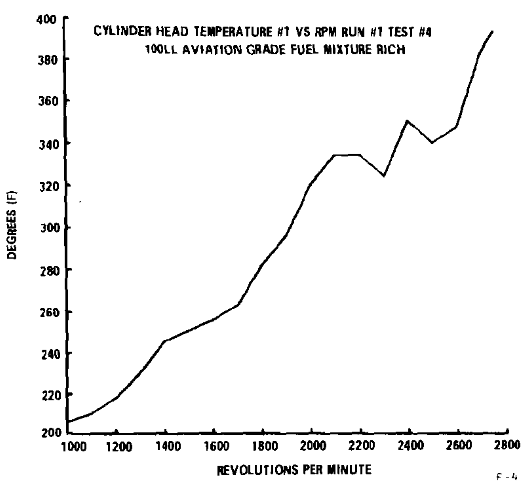
F-1


COMPUTED TORQUE VS RPM RUN #1 TEST #4
100LL AVIATION GRADE FUEL MIXTURE RICH
TORQUE LB – FT
REVOLUTIONS PER MINUTE

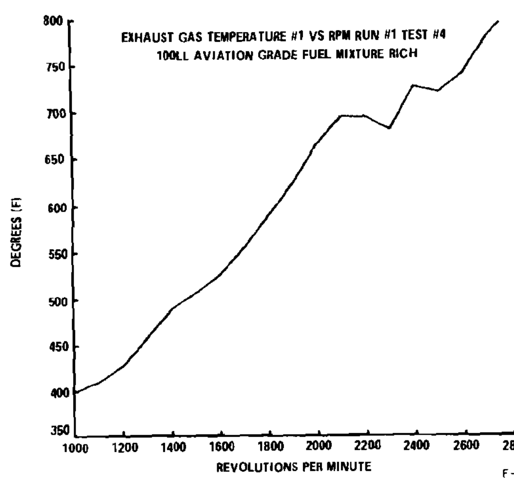
F-2


CORRECTED HORSEPOWER VS RPM RUN #1 TEST #4
100LL AVIATION GRADE FUEL MIXTURE RICH
HORSEPOWER
REVOLUTIONS PER MINUTE

F-3


CYLINDER HEAD TEMPERATURE #1 VS RPM RUN #1 TEST #4
100LL AVIATION GRADE FUEL MIXTURE RICH
DEGREES (F)
REVOLUTIONS PER MINUTE

F-4


EXHAUST GAS TEMPERATURE #1 VS RPM RUN #1 TEST #4
100LL AVIATION GRADE FUEL MIXTURE RICH
DEGREES (F)
REVOLUTIONS PER MINUTE

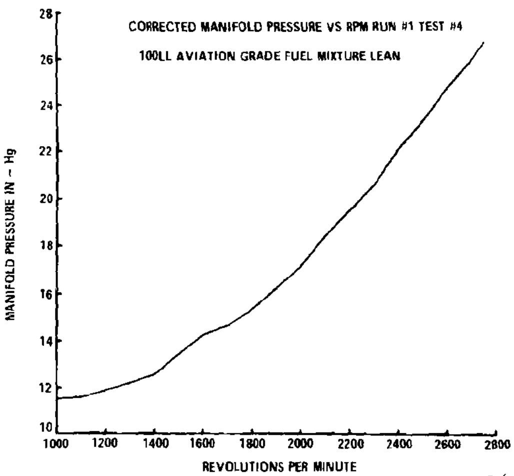
F-5

100LL AVIATION GRADE FUEL

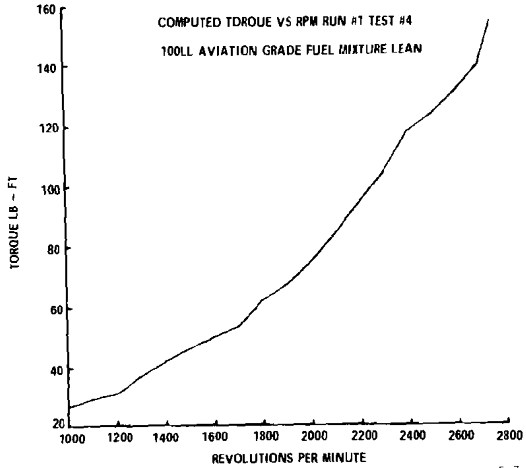
CORRECTED DATA: RUN #1 TEST #4

MIXTURE LEAN

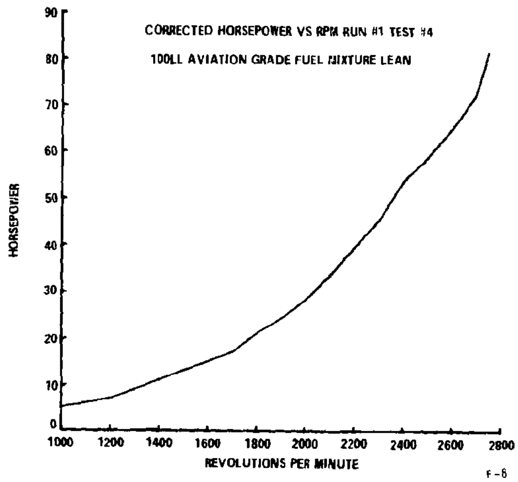
TEST POINT	RPM	M.P.	TORQUE	HP	°F CHT #1	°F EGT #1
1	1000	11.5	26.6	5.1	212	388
2	1100	11.6	29.1	6.1	216	404
3	1200	11.9	31.1	7.1	226	427
4	1300	12.2	36.9	9.1	239	464
5	1400	12.6	41.9	11.2	258	512
6	1500	13.5	46.2	13.2	271	533
7	1600	14.3	50.0	15.2	283	566
8	1700	14.7	53.3	17.3	290	580
9	1800	15.4	62.2	21.3	305	641
10	1900	16.3	67.3	24.4	330	715
11	2000	17.2	74.6	28.4	342	744
12	2100	18.5	83.8	33.5	352	773
13	2200	19.6	94.5	39.6	366	801
14	2300	20.7	104.3	45.7	380	819
15	2400	22.2	117.7	53.8	396	823
16	2500	23.4	123.6	58.9	395	788
17	2600	24.8	131.2	64.9	395	793
18	2700	26.0	140.2	72.1	408	812
19	2750	26.8	155.0	81.2	416	823



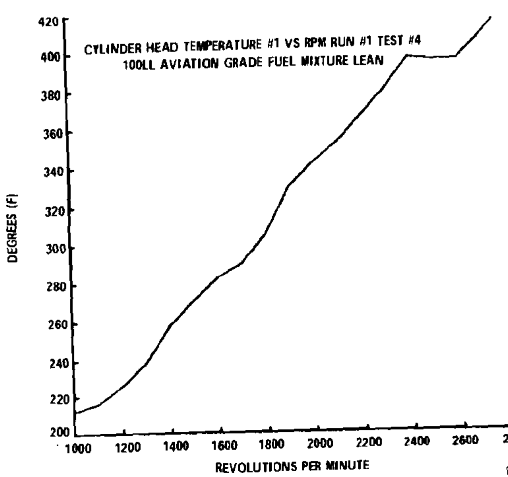
F-6



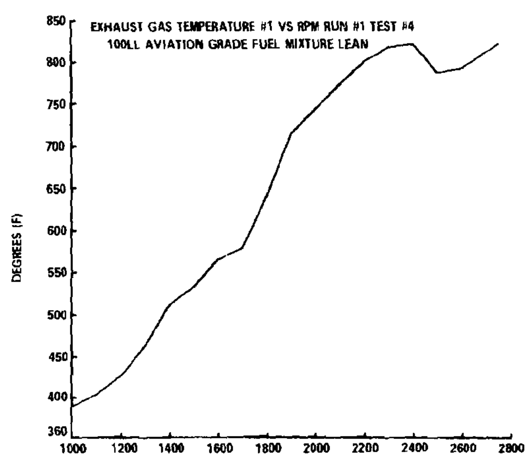
F-7



F-8



F-9



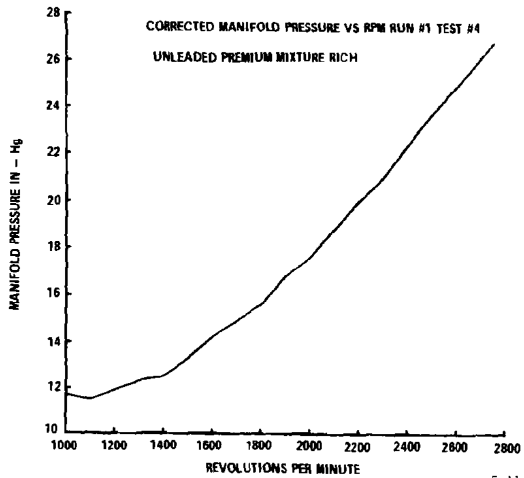
F-10

UNLEADED PREMIUM AUTOMOTIVE FUEL

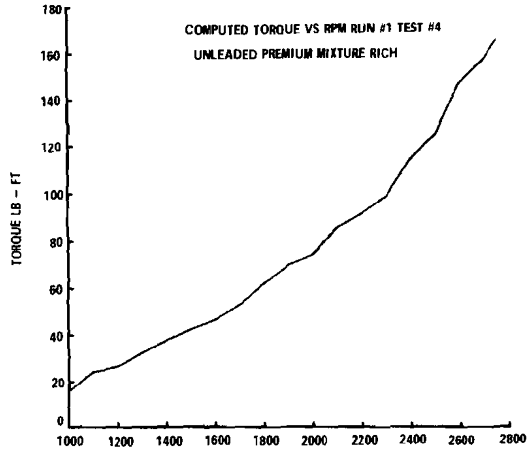
CORRECTED DATA: RUN #1 TEST #4

MIXTURE RICH

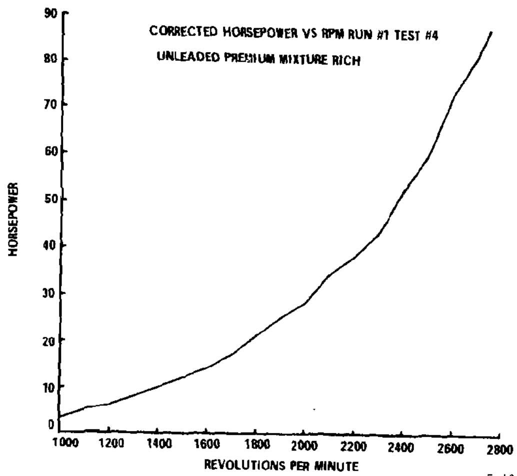
TEST POINT	RPM	M.P.	TORQUE	HP	°F CHT #1	°F EGT #1
1	1000	11.7	16.0	3.0	201	390
2	1100	11.5	24.2	5.1	208	392
3	1200	11.9	26.7	6.1	220	416
4	1300	12.3	32.8	8.1	241	454
5	1400	12.5	38.1	10.1	256	503
6	1500	13.3	42.6	12.2	262	505
7	1600	14.2	46.6	14.2	264	524
8	1700	14.9	53.3	17.3	259	531
9	1800	15.6	62.2	21.3	265	539
10	1900	16.8	70.1	25.4	308	617
11	2000	17.6	74.4	28.3	327	676
12	2100	18.8	86.0	34.4	340	709
13	2200	20.0	91.8	38.4	352	741
14	2300	21.0	99.3	43.5	354	738
15	2400	22.4	115.1	52.6	350	729
16	2500	23.7	125.4	59.7	334	716
17	2600	24.9	147.2	72.8	350	739
18	2700	26.1	157.5	80.9	385	796
19	2750	26.8	166.2	87.0	397	805



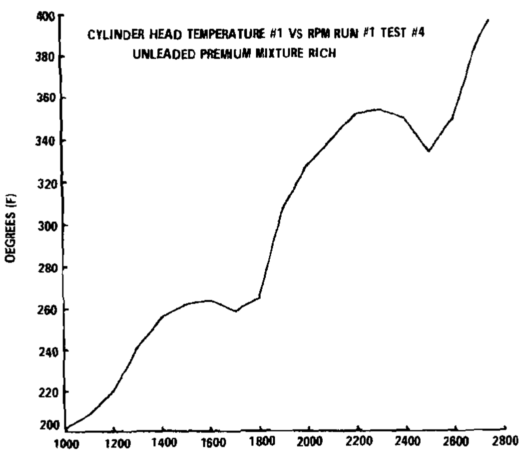
F-11



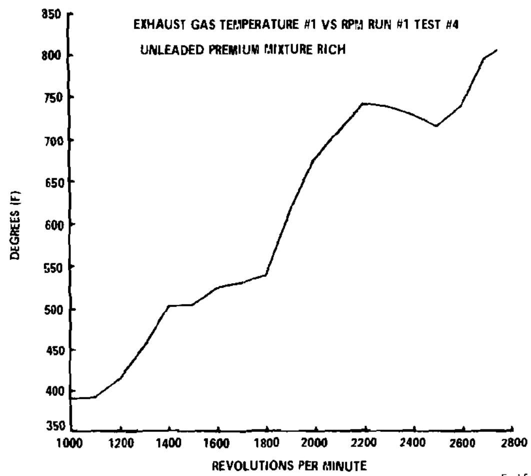
F-12



F-13



F-14



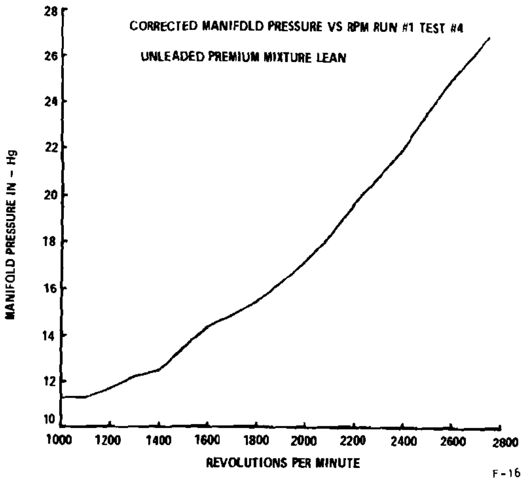
F-15

UNLEADED PREMIUM AUTOMOTIVE FUEL

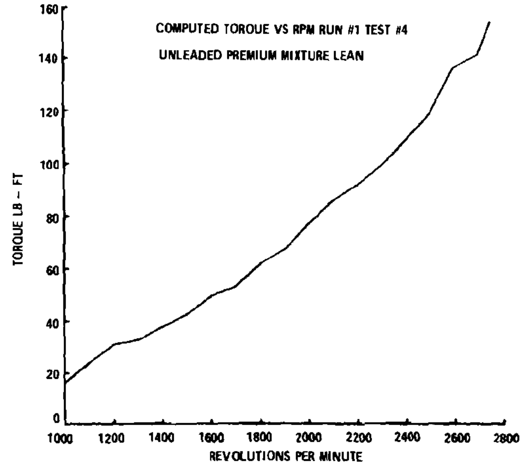
CORRECTED DATA: RUN #1 TEST #4

MIXTURE LEAN

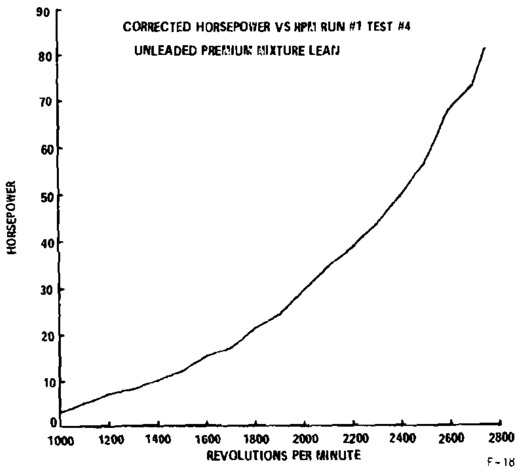
TEST POINT	RPM	M.P.	TORQUE	HP	°F CHT #1	°F EGT #1
1	1000	11.3	15.9	3.0	200	376
2	1100	11.3	24.2	5.1	213	394
3	1200	11.7	31.0	7.1	226	418
4	1300	12.2	32.7	8.1	246	456
5	1400	12.5	38.0	10.1	263	529
6	1500	13.5	42.5	12.1	266	517
7	1600	14.4	49.8	15.2	266	533
8	1700	14.9	53.2	17.2	278	566
9	1800	15.5	62.0	21.3	291	591
10	1900	16.3	67.2	24.3	332	725
11	2000	17.2	77.1	29.4	343	751
12	2100	18.3	86.1	34.4	353	781
13	2200	19.7	91.8	38.5	357	803
14	2300	20.9	99.4	43.5	379	825
15	2400	22.0	108.5	49.6	396	826
16	2500	23.6	119.1	56.7	393	795
17	2600	25.0	137.0	67.8	384	783
18	2700	26.2	141.8	72.9	407	821
19	2750	26.9	154.7	81.0	405	816



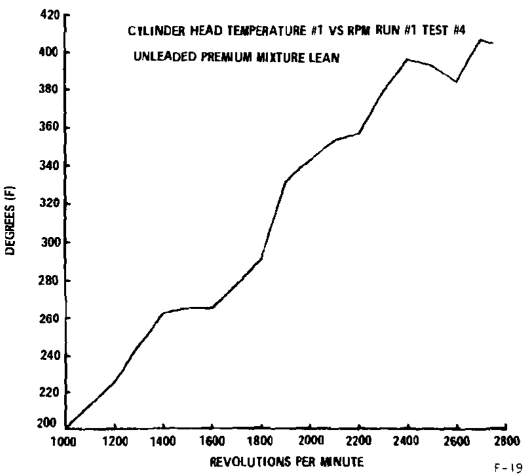
F-16



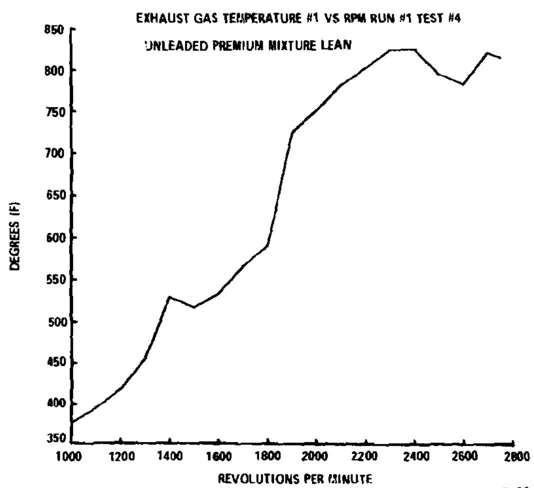
F-17



F-18



F-19



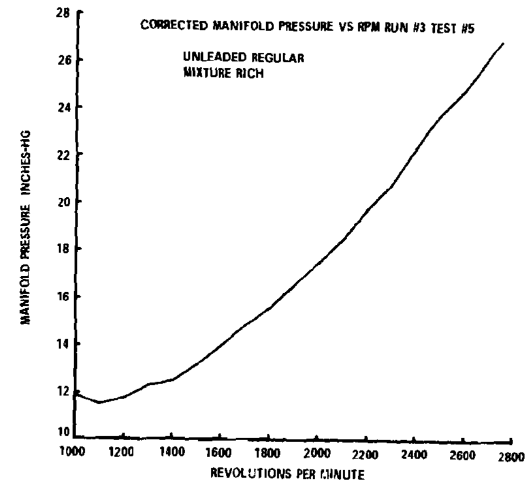
F-20

UNLEADED REGULAR AUTOMOTIVE FUEL

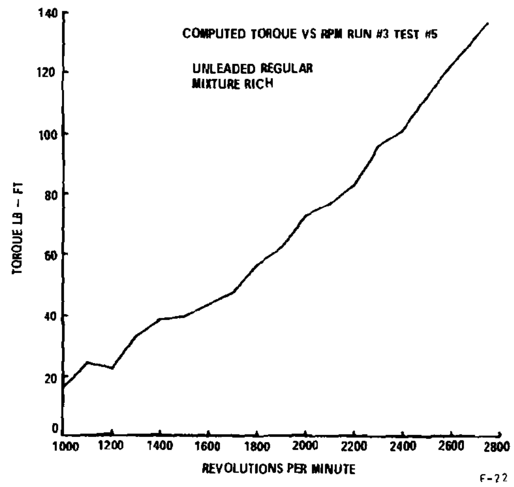
CORRECTED DATA: RUN #3 TEST #5

MIXTURE RICH

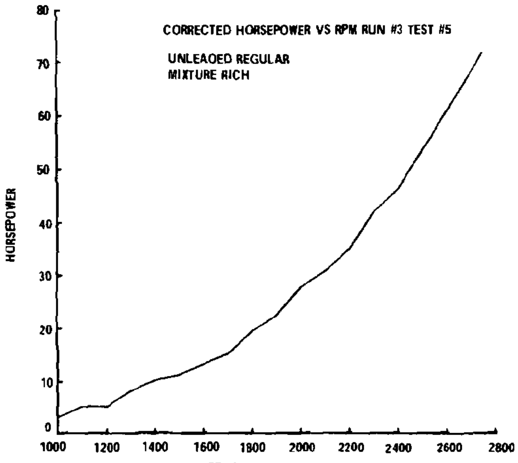
TEST POINT	RPM	M.P.	TORQUE	HP	°F CHT #1	°F EGT #1
1	1000	11.9	16.2	3.1	210	395
2	1100	11.5	24.5	5.1	221	403
3	1200	11.8	22.4	5.1	230	423
4	1300	12.3	33.1	8.2	241	454
5	1400	12.5	38.5	10.3	265	521
6	1500	13.2	39.5	11.3	273	524
7	1600	14.0	43.7	13.3	275	528
8	1700	14.9	47.5	15.4	287	570
9	1800	15.6	56.8	19.5	297	597
10	1900	16.6	62.3	22.6	296	612
11	2000	17.5	72.7	27.7	324	682
12	2100	18.5	76.9	30.8	341	726
13	2200	19.8	83.2	34.9	351	739
14	2300	20.9	96.0	42.0	352	733
15	2400	22.4	100.9	46.1	338	720
16	2500	23.8	112.0	53.3	331	713
17	2600	24.8	122.2	60.5	354	749
18	2700	26.2	131.6	67.7	382	796
19	2750	26.9	137.0	71.8	404	820



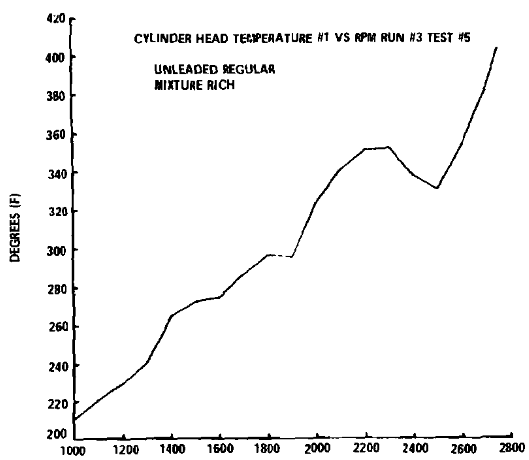
21



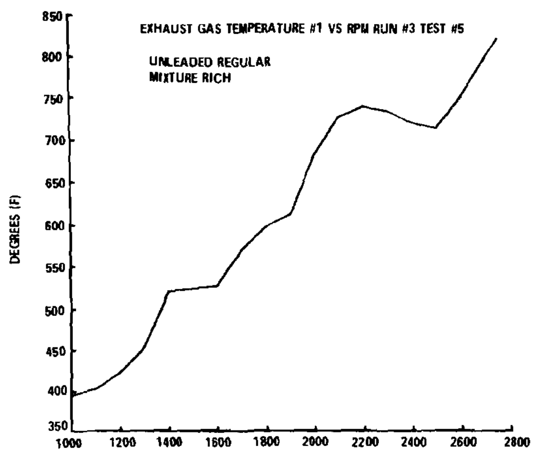
F-22



F-23



F-24



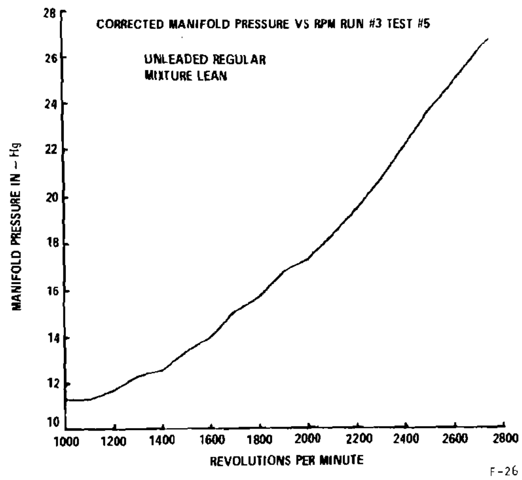
F-25

UNLEADED REGULAR AUTOMOTIVE FUEL

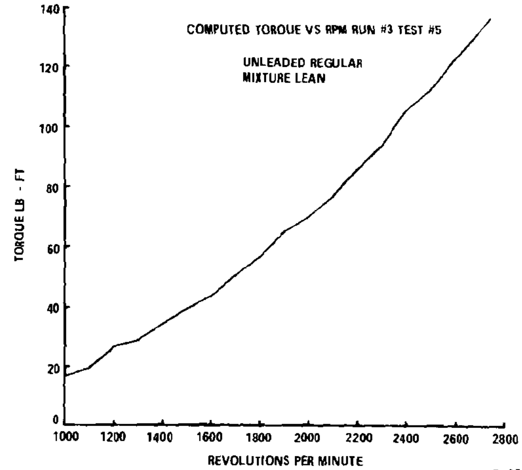
CORRECTED DATA: RUN #3 TEST #5

MIXTURE LEAN

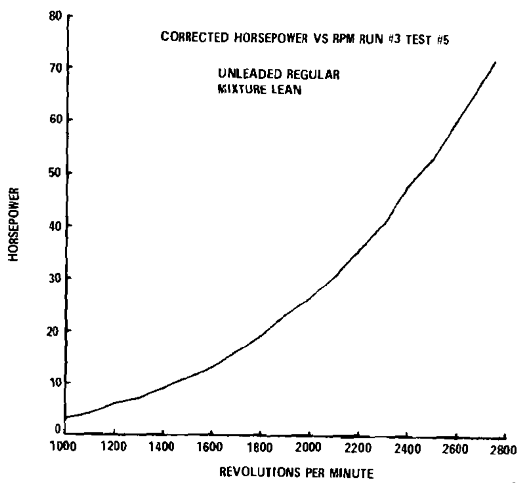
TEST POINT	RPM	M.P.	TORQUE	HP	°F CHT #1	°F EGT #1
1	1000	11.3	16.2	3.1	216	399
2	1100	11.3	19.6	4.1	230	425
3	1200	11.7	26.9	6.2	243	453
4	1300	12.3	29.0	7.2	263	515
5	1400	12.6	34.6	9.2	278	534
6	1500	13.4	39.5	11.3	287	564
7	1600	14.0	43.7	13.3	291	568
8	1700	15.1	50.7	16.4	301	601
9	1800	15.7	56.8	19.5	312	625
10	1900	16.8	65.2	23.6	336	721
11	2000	17.3	70.0	26.7	354	775
12	2100	18.3	76.9	30.8	368	796
13	2200	19.4	85.7	35.9	380	824
14	2300	20.7	93.6	41.0	391	849
15	2400	22.1	105.4	48.2	405	844
16	2500	23.6	112.0	53.3	399	800
17	2600	24.8	122.2	60.5	400	811
18	2700	26.1	131.6	67.7	405	815
19	2750	26.7	137.0	71.8	408	812



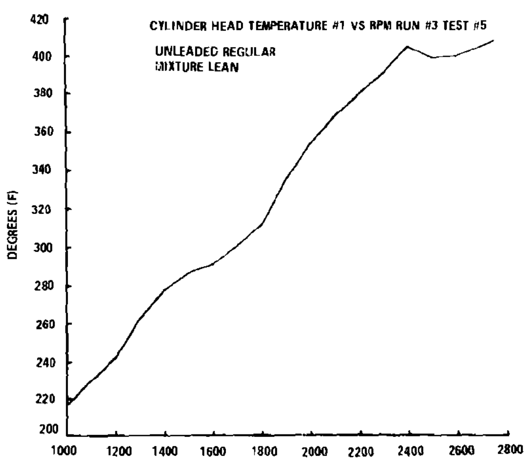
F-26



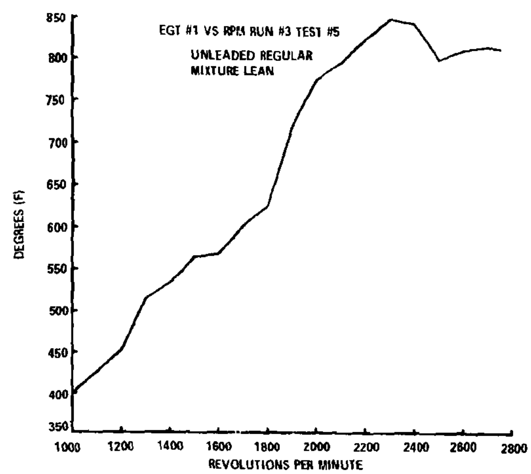
F-27



--28



F-29

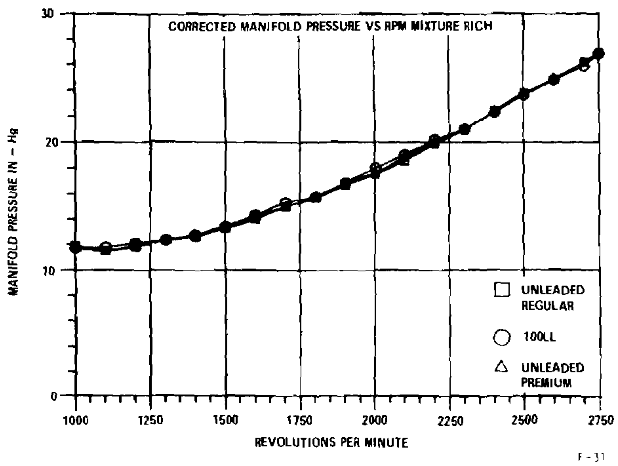


F-30

CORRECTED MANIFOLD PRESSURE (IN. - Hg)

MIXTURE RICH

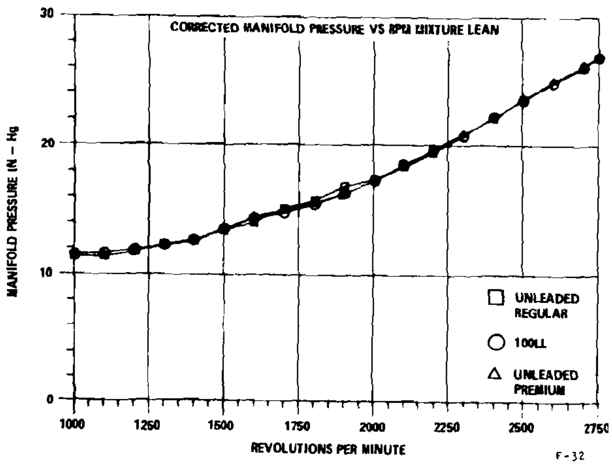
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	11.7	11.7	11.9
2	1100	11.8	11.5	11.5
3	1200	12.1	11.9	11.8
4	1300	12.3	12.3	12.3
5	1400	12.7	12.5	12.5
6	1500	13.4	13.3	13.2
7	1600	14.3	14.2	14.0
8	1700	15.3	14.9	14.9
9	1800	15.7	15.6	15.6
10	1900	16.8	16.8	16.6
11	2000	18.0	17.6	17.5
12	2100	19.0	18.8	18.5
13	2200	20.2	20.0	19.8
14	2300	21.0	21.0	20.9
15	2400	22.3	22.4	22.4
16	2500	23.6	23.7	23.8
17	2600	24.8	24.9	24.8
18	2700	25.8	26.1	26.2
19	2750	26.8	26.8	26.9



CORRECTED MANIFOLD PRESSURE (IN. - Hg)

MIXTURE LEAN

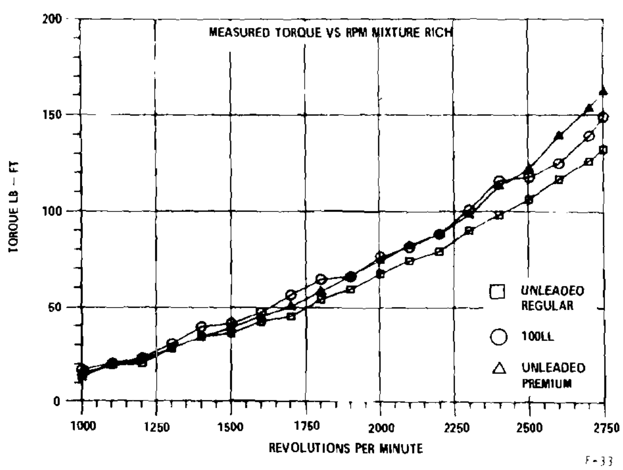
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	11.5	11.3	11.3
2	1100	11.6	11.3	11.3
3	1200	11.9	11.7	11.7
4	1300	12.2	12.2	12.3
5	1400	12.6	12.5	12.6
6	1500	13.5	13.5	13.4
7	1600	14.3	14.4	14.0
8	1700	14.7	14.9	15.1
9	1800	15.4	15.5	15.7
10	1900	16.3	16.3	16.8
11	2000	17.2	17.2	17.3
12	2100	18.5	18.3	18.3
13	2200	19.6	19.7	19.4
14	2300	20.7	20.9	20.7
15	2400	22.2	22.0	22.1
16	2500	23.4	23.6	23.6
17	2600	24.8	25.0	24.8
18	2700	26.0	26.2	26.1
19	2750	26.8	26.9	26.7



MEASURED TORQUE (Lb - Ft)

MIXTURE RICH

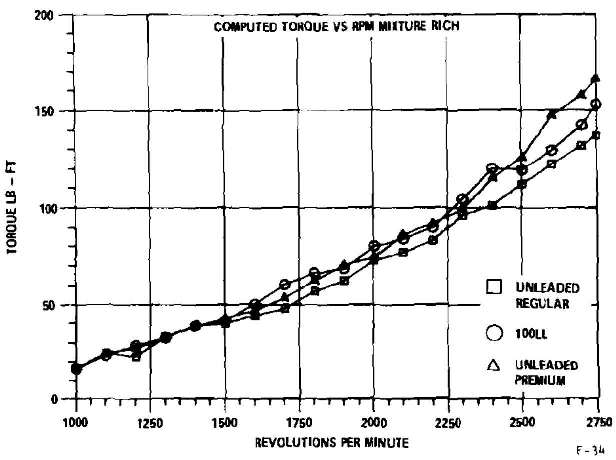
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	16.8	14.5	13.0
2	1100	20.0	19.0	19.0
3	1200	23.0	22.0	20.0
4	1300	30.5	28.0	28.0
5	1400	39.3	34.0	34.0
6	1500	41.0	39.0	36.0
7	1600	47.0	45.0	42.0
8	1700	56.0	50.0	45.0
9	1800	64.5	58.0	54.0
10	1900	65.8	66.0	59.0
11	2000	76.0	74.0	67.0
12	2100	81.0	82.0	74.0
13	2200	88.0	88.0	79.0
14	2300	101.0	98.0	90.0
15	2400	116.0	113.0	98.0
16	2500	118.0	122.0	106.0
17	2600	125.0	139.0	117.0
18	2700	139.0	153.0	126.0
19	2750	149.0	162.0	132.0



COMPUTED TORQUE (Lb - Ft)

MIXTURE RICH

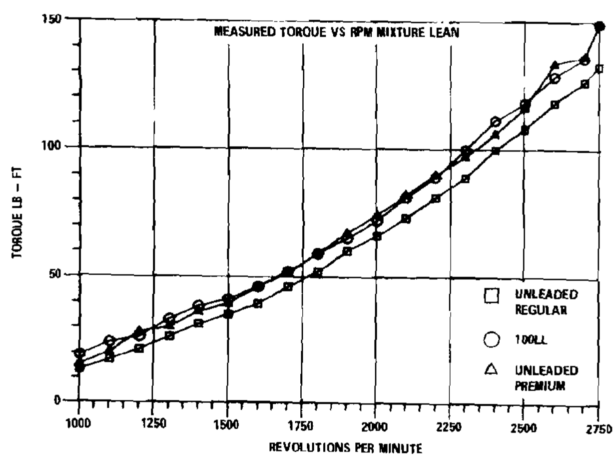
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	16.0	16.0	16.2
2	1100	22.8	24.2	24.5
3	1200	28.4	26.7	22.4
4	1300	32.4	32.8	33.1
5	1400	38.5	38.1	38.5
6	1500	41.2	42.6	39.5
7	1600	50.0	46.6	43.7
8	1700	60.2	53.3	47.5
9	1800	66.0	62.2	56.8
10	1900	68.5	70.1	62.3
11	2000	80.0	74.4	72.7
12	2100	83.8	86.0	76.9
13	2200	89.6	91.8	83.2
14	2300	104.3	99.3	96.0
15	2400	119.9	115.1	100.9
16	2500	119.4	125.4	112.0
17	2600	129.2	147.2	122.2
18	2700	142.1	157.5	131.6
19	2750	153.1	166.2	137.0



MEASURED TORQUE (Lb - Ft)

MIXTURE LEAN

TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	19.0	15.0	13.0
2	1100	24.0	20.0	17.0
3	1200	26.0	28.0	21.0
4	1300	33.0	30.0	26.0
5	1400	38.0	36.0	31.0
6	1500	41.0	39.0	35.0
7	1600	46.0	46.0	39.0
8	1700	52.0	51.0	46.0
9	1800	59.0	59.0	52.0
10	1900	65.0	67.0	60.0
11	2000	72.0	74.0	66.0
12	2100	81.0	82.0	73.0
13	2200	89.0	90.0	81.0
14	2300	100.0	97.0	89.0
15	2400	111.0	106.0	100.0
16	2500	118.0	116.0	108.0
17	2600	128.0	133.0	118.0
18	2700	135.0	136.0	126.0
19	2750	149.0	149.0	132.0

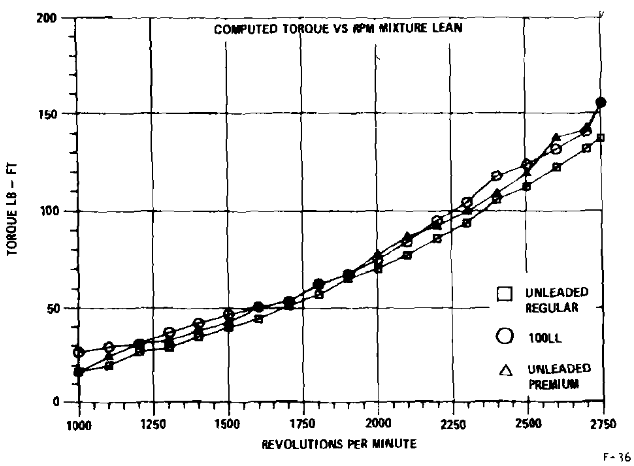


F-35

COMPUTED TORQUE (Lb - Ft)

MIXTURE LEAN

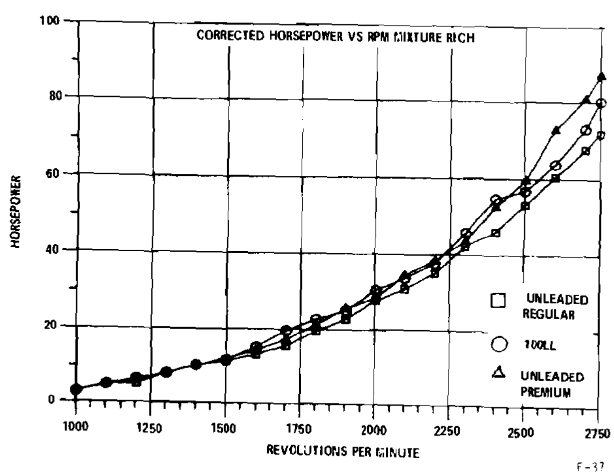
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	26.6	15.9	16.2
2	1100	29.1	24.2	19.6
3	1200	31.1	31.0	26.9
4	1300	36.9	32.7	29.0
5	1400	41.9	38.0	34.6
6	1500	46.2	42.5	39.5
7	1600	50.0	49.8	43.7
8	1700	53.3	53.2	50.7
9	1800	62.2	62.0	56.8
10	1900	67.3	67.2	65.2
11	2000	74.6	77.1	70.0
12	2100	83.8	86.1	76.9
13	2200	94.5	91.8	85.7
14	2300	104.3	99.4	93.6
15	2400	117.7	108.5	105.4
16	2500	123.6	119.1	112.0
17	2600	131.2	137.0	122.2
18	2700	140.2	141.8	131.6
19	2750	155.0	154.7	137.0



CORRECTED HORSEPOWER

MIXTURE RICH

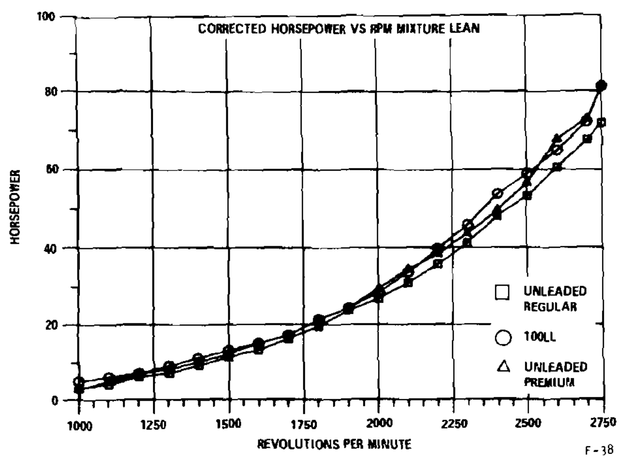
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	3.0	3.0	3.1
2	1100	4.8	5.1	5.1
3	1200	6.5	6.1	5.1
4	1300	8.0	8.1	8.2
5	1400	10.3	10.1	10.3
6	1500	11.8	12.2	11.3
7	1600	15.2	14.2	13.3
8	1700	19.5	17.3	15.4
9	1800	22.6	21.3	19.5
10	1900	24.8	25.4	22.6
11	2000	30.4	28.3	27.7
12	2100	33.5	34.4	30.8
13	2200	37.6	38.4	34.9
14	2300	45.7	43.5	42.0
15	2400	54.8	52.6	46.1
16	2500	56.8	59.7	53.3
17	2600	63.9	72.8	60.5
18	2700	73.1	80.9	67.7
19	2750	80.2	87.0	71.8



CORRECTED HORSEPOWER

MIXTURE LEAN

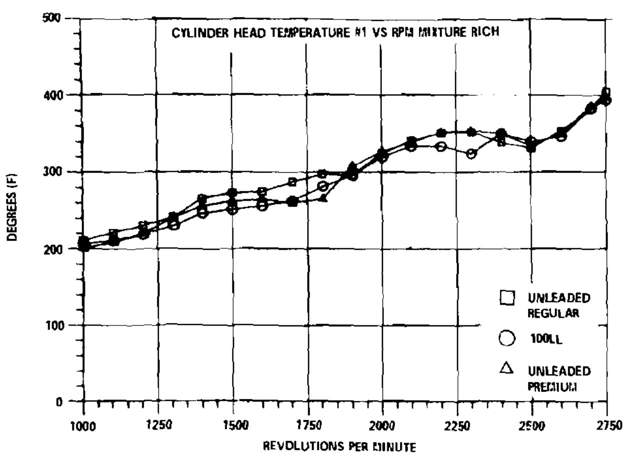
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	5.1	3.0	3.1
2	1100	6.1	5.1	4.1
3	1200	7.1	7.1	6.2
4	1300	9.1	8.1	7.2
5	1400	11.2	10.1	9.2
6	1500	13.2	12.1	11.3
7	1600	15.2	15.2	13.3
8	1700	17.3	17.2	16.4
9	1800	21.3	21.3	19.5
10	1900	24.4	24.3	23.6
11	2000	28.4	29.4	26.7
12	2100	33.5	34.4	30.8
13	2200	39.6	38.5	35.9
14	2300	45.7	43.5	41.0
15	2400	53.8	49.6	48.2
16	2500	58.9	56.7	53.3
17	2600	64.9	67.8	60.5
18	2700	72.1	72.9	67.7
19	2750	81.2	81.0	71.8



CYLINDER HEAD TEMPERATURE #1 (°F)

MIXTURE RICH

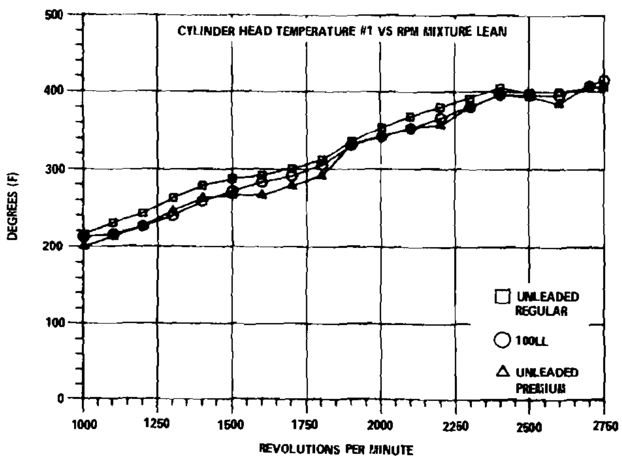
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	206	201	210
2	1100	210	208	221
3	1200	218	220	230
4	1300	230	241	241
5	1400	246	256	265
6	1500	251	262	273
7	1600	256	264	275
8	1700	263	259	287
9	1800	282	265	297
10	1900	296	308	296
11	2000	320	327	324
12	2100	334	340	341
13	2200	334	352	351
14	2300	324	354	352
15	2400	350	350	338
16	2500	340	334	331
17	2600	347	350	354
18	2700	382	385	382
19	2750	393	397	404



CYLINDER HEAD TEMPERATURE #1 (°F)

MIXTURE LEAN

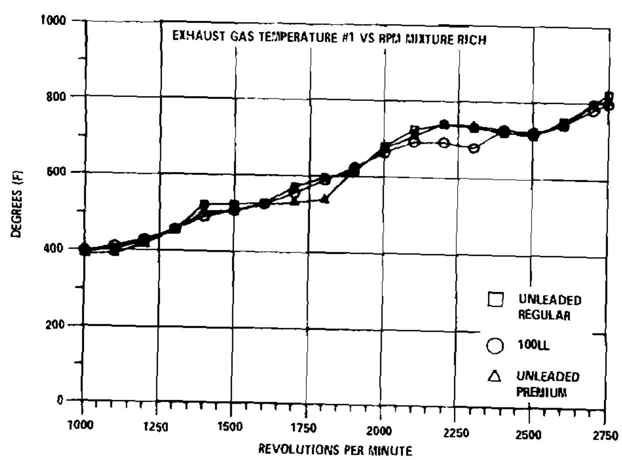
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	212	200	216
2	1100	216	213	230
3	1200	226	226	243
4	1300	239	246	263
5	1400	258	263	278
6	1500	271	266	287
7	1600	283	266	291
8	1700	290	278	301
9	1800	305	291	312
10	1900	330	332	336
11	2000	342	343	354
12	2100	352	353	368
13	2200	366	357	380
14	2300	380	379	391
15	2400	396	396	405
16	2500	395	393	399
17	2600	395	384	400
18	2700	408	407	405
19	2750	416	405	408



EXHAUST GAS TEMPERATURE #1 (°F)

MIXTURE RICH

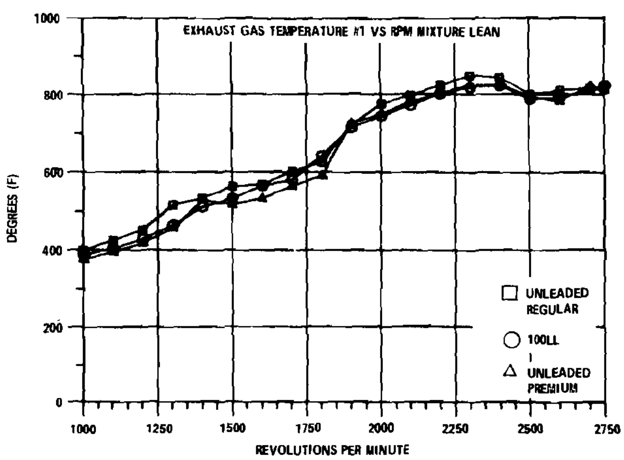
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	398	390	395
2	1100	410	392	403
3	1200	428	416	423
4	1300	458	454	454
5	1400	490	503	521
6	1500	507	505	524
7	1600	526	524	528
8	1700	555	531	570
9	1800	589	539	597
10	1900	624	617	612
11	2000	665	676	682
12	2100	694	709	726
13	2200	694	741	739
14	2300	681	738	733
15	2400	727	729	720
16	2500	721	716	713
17	2600	741	739	749
18	2700	781	796	796
19	2750	796	805	820



EXHAUST GAS TEMPERATURE #1 (°F)

MIXTURE LEAN

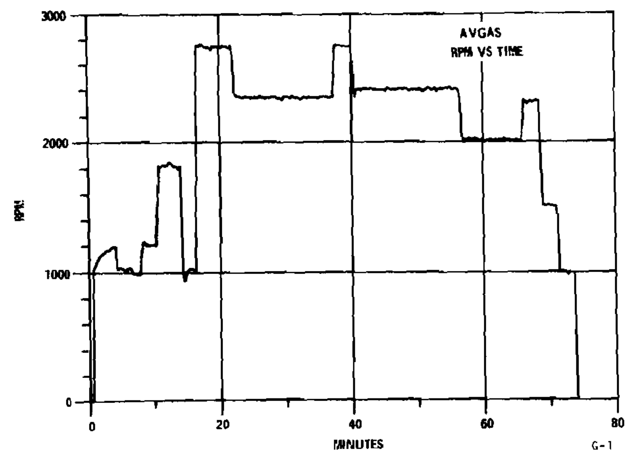
TEST POINT	RPM	100LL	UNLEADED PREMIUM	UNLEADED REGULAR
1	1000	388	376	399
2	1100	404	394	425
3	1200	427	418	453
4	1300	464	456	515
5	1400	512	529	534
6	1500	533	517	564
7	1600	566	533	568
8	1700	580	566	601
9	1800	641	591	625
10	1900	715	725	721
11	2000	744	751	775
12	2100	773	781	796
13	2200	801	803	824
14	2300	819	825	849
15	2400	823	826	844
16	2500	788	795	800
17	2600	793	783	811
18	2700	812	821	815
19	2750	823	816	812

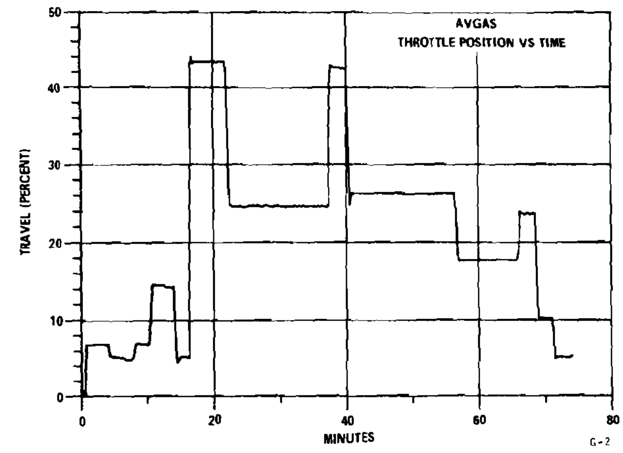


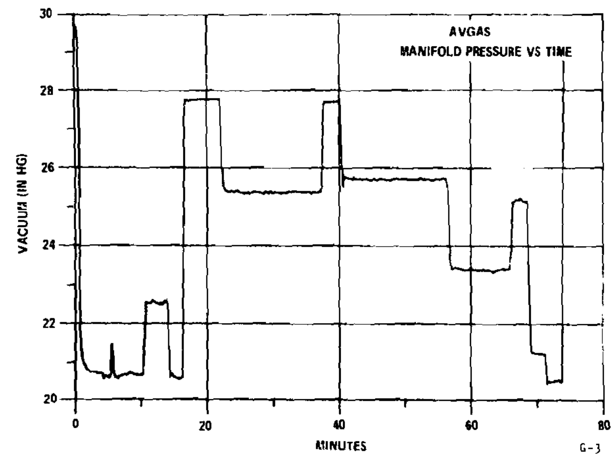
APPENDIX G

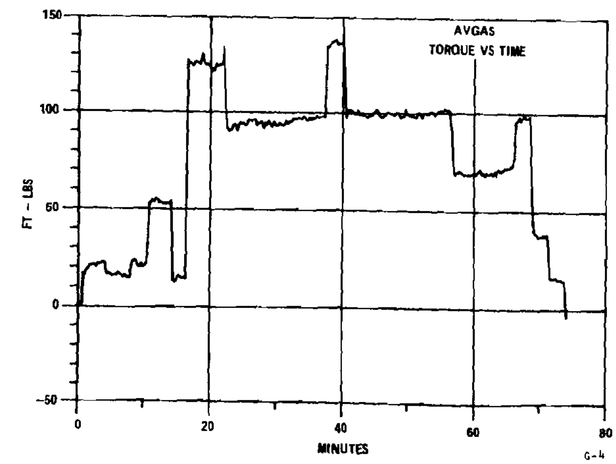
ENGINE PERFORMANCE BASELINE DATA 100LL AVGAS

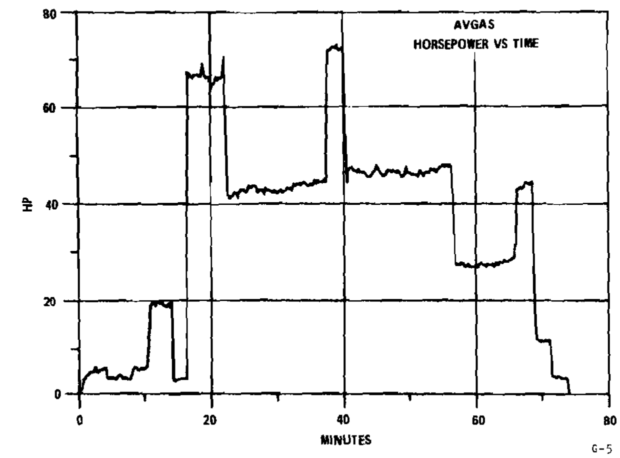
(BASELINE TEST SEQUENCE #1)

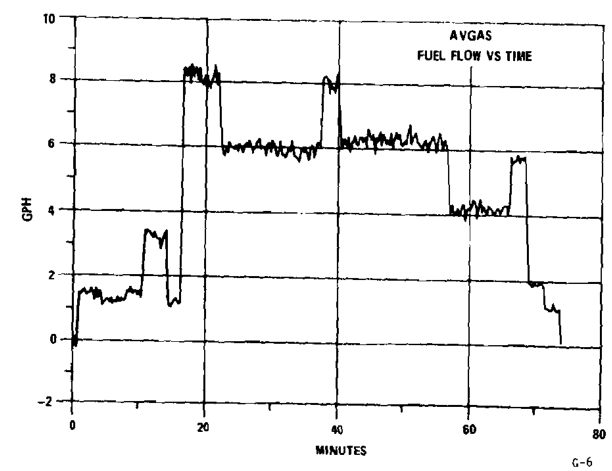

AVGAS
RPM VS TIME
RPM
MINUTES
G-1

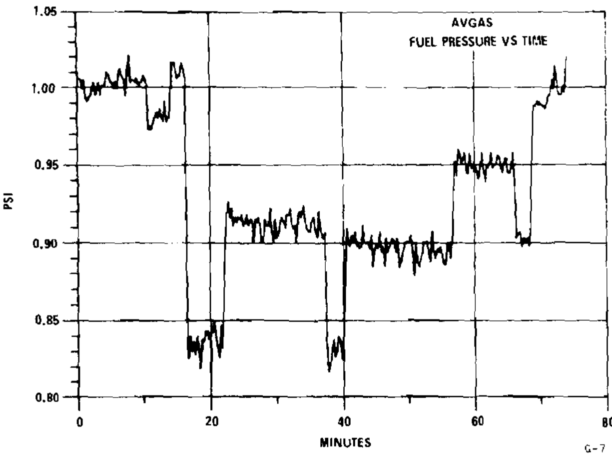

AVGAS
THROTTLE POSITION VS TIME
TRAVEL (PERCENT)
MINUTES
G-2

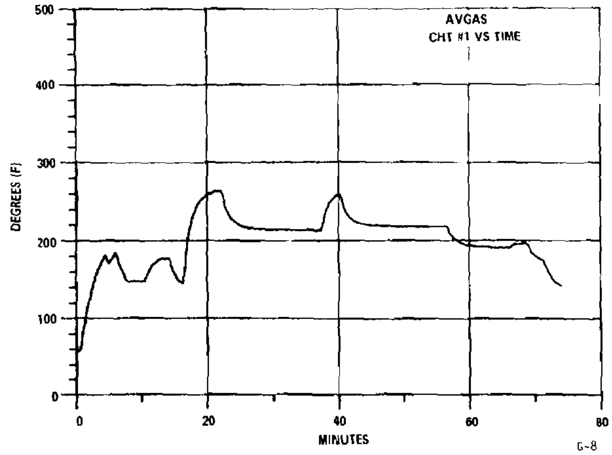

AVGAS
MANIFOLD PRESSURE VS TIME
VACUUM (IN HG)
MINUTES
G-3

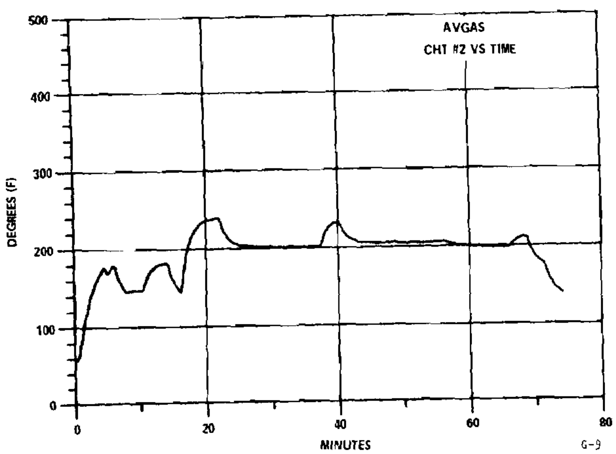

AVGAS
TORQUE VS TIME
FT - LBS
MINUTES
G-4

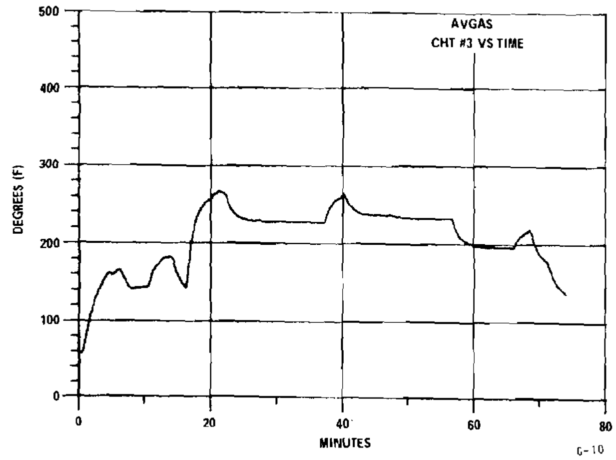

AVGAS
HORSEPOWER VS TIME
HP
MINUTES
G-5

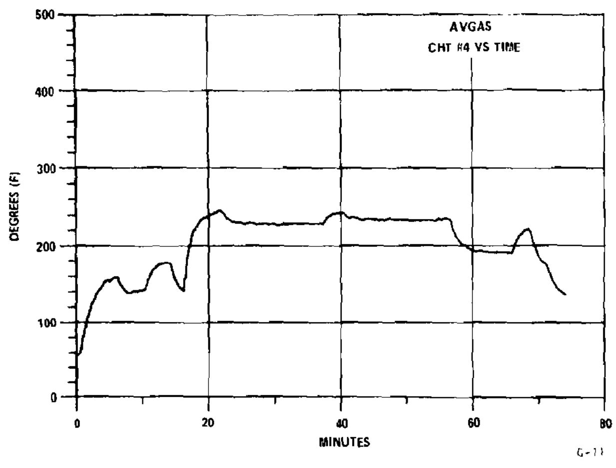

AVGAS
FUEL FLOW VS TIME
GPH
MINUTES
G-6

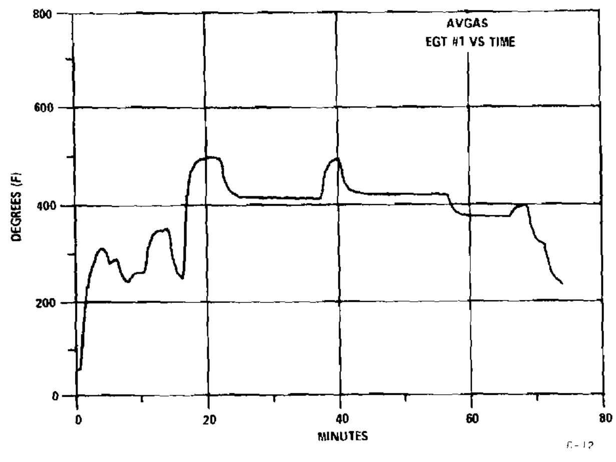

AVGAS
FUEL PRESSURE VS TIME
PSI
1.05
1.00
0.95
0.90
0.85
0.80
0
20
40
60
80
MINUTES
G-7

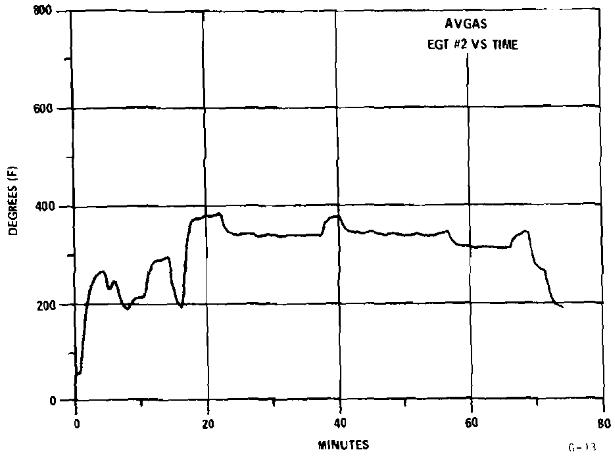

AVGAS
CHT #1 VS TIME
DEGREES (F)
500
400
300
200
100
0
0
20
40
60
80
MINUTES
G-8

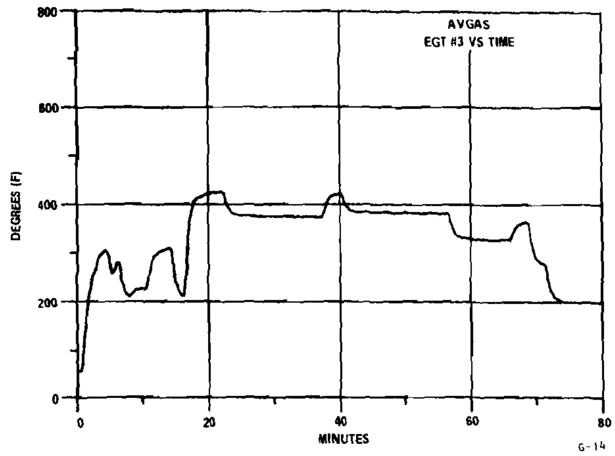

AVGAS
CHT #2 VS TIME
DEGREES (F)
500
400
300
200
100
0
0
20
40
60
80
MINUTES
G-9

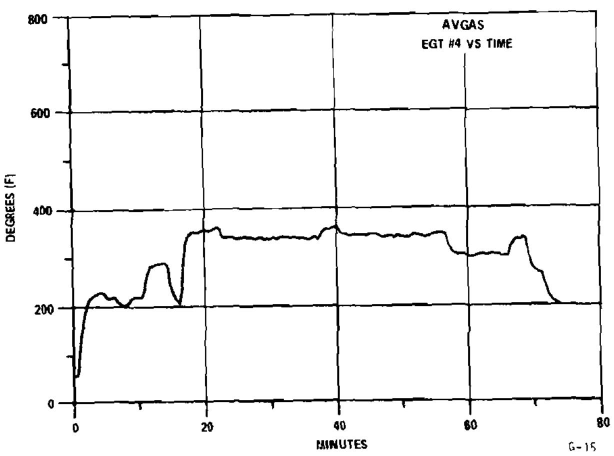

AVGAS
CHT #3 VS TIME
DEGREES (F)
500
400
300
200
100
0
0
20
40
60
80
MINUTES
G-10

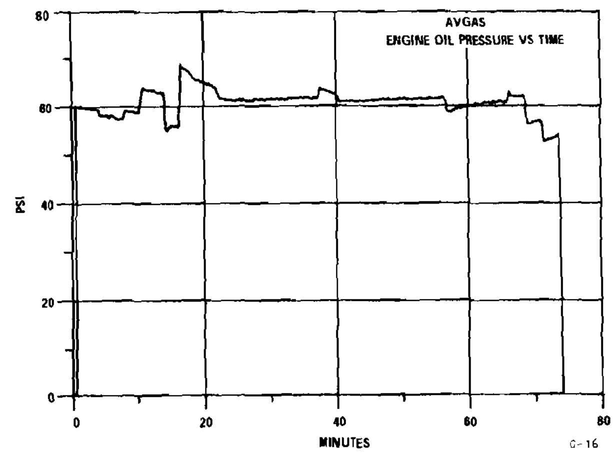

AVGAS
CHT #4 VS TIME
DEGREES (F)
500
400
300
200
100
0
0
20
40
60
80
MINUTES

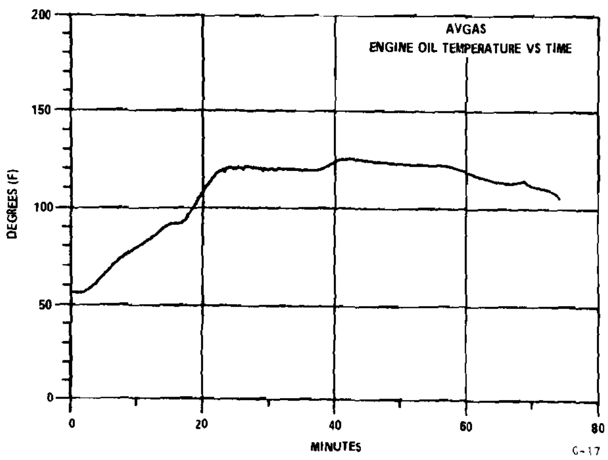

AVGAS
EGT #1 VS TIME
DEGREES (F)
800
600
400
200
0
0
20
40
60
80
MINUTES

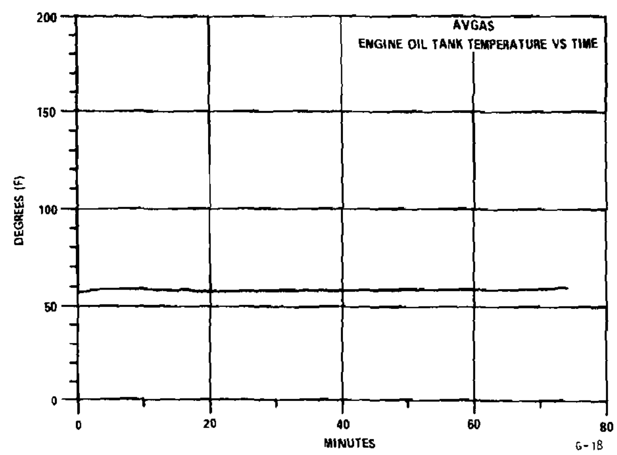

AVGAS
EGT #2 VS TIME
DEGREES (F)
MINUTES
G-13

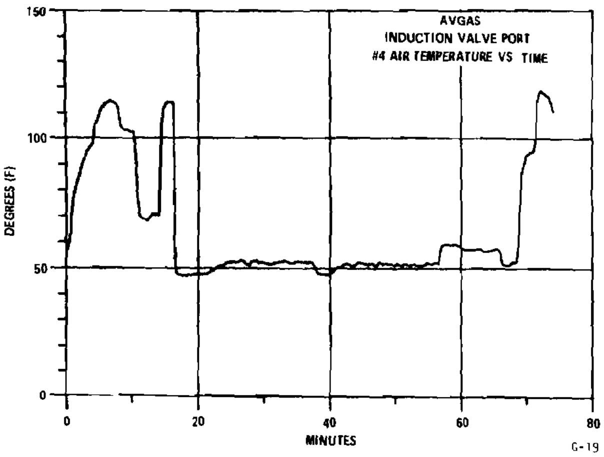

AVGAS
EGT #3 VS TIME
DEGREES (F)
MINUTES
G-14

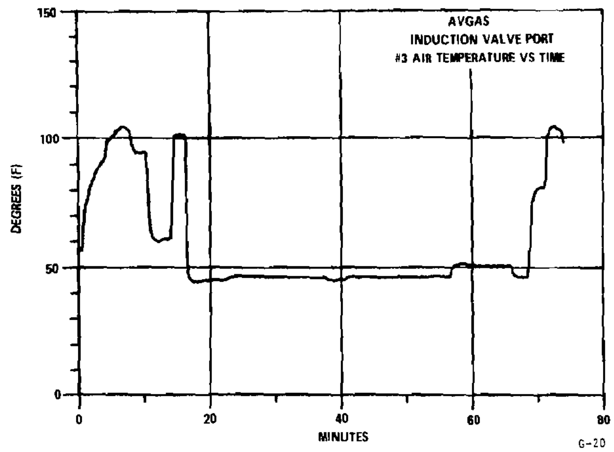

AVGAS
EGT #4 VS TIME
DEGREES (F)
MINUTES
G-15

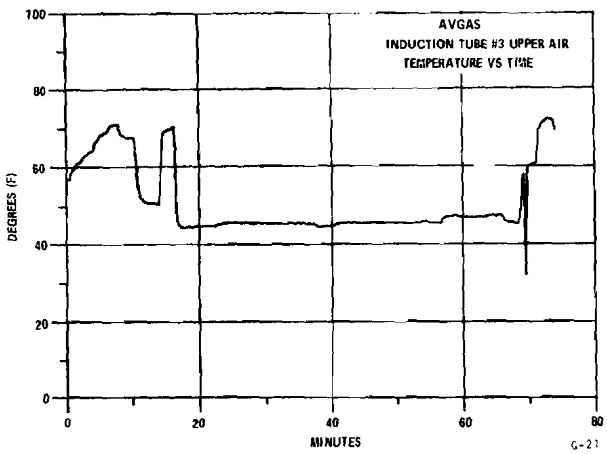

AVGAS
ENGINE OIL PRESSURE VS TIME
PSI
MINUTES
G-16

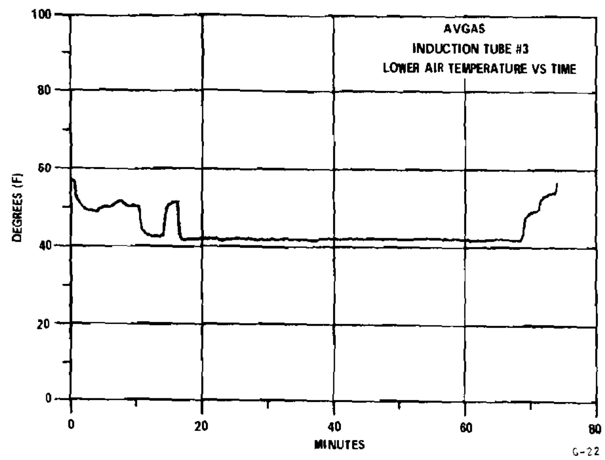

AVGAS
ENGINE OIL TEMPERATURE VS TIME
DEGREES (F)
MINUTES
G-17

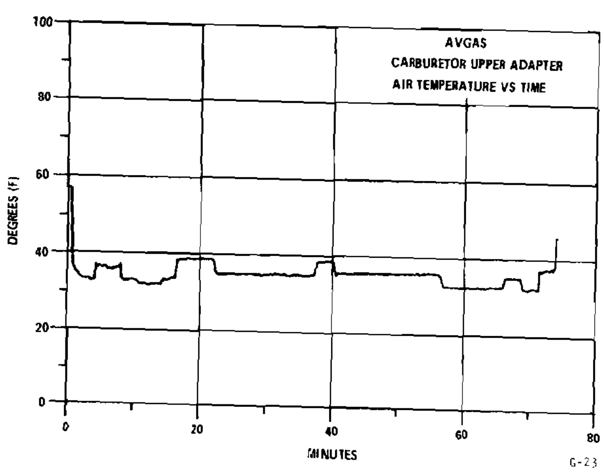

AVGAS
ENGINE OIL TANK TEMPERATURE VS TIME
DEGREES (F)
MINUTES
G-18

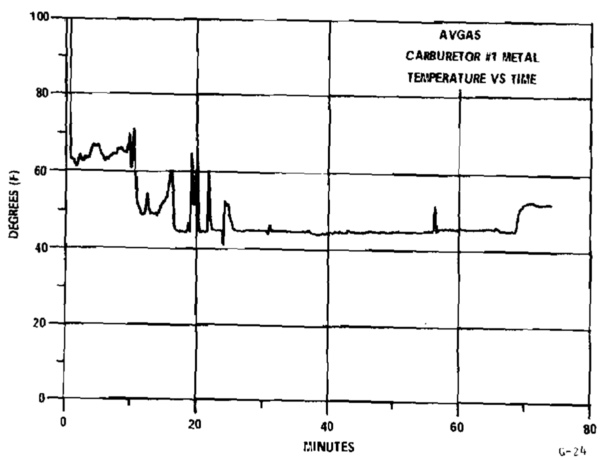

AVGAS
INDUCTION VALVE PORT
#4 AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
G-19

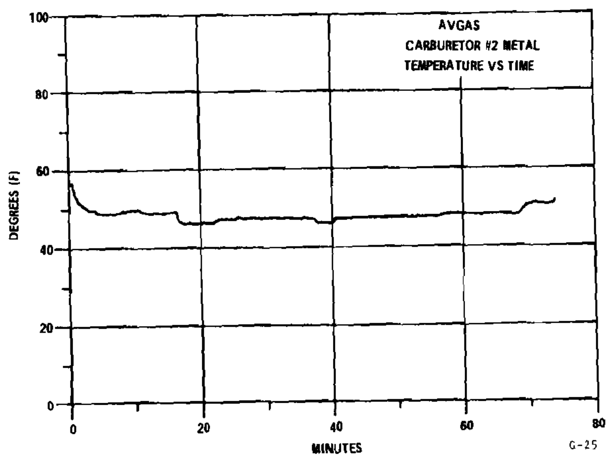

AVGAS
INDUCTION VALVE PORT
#3 AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
G-20

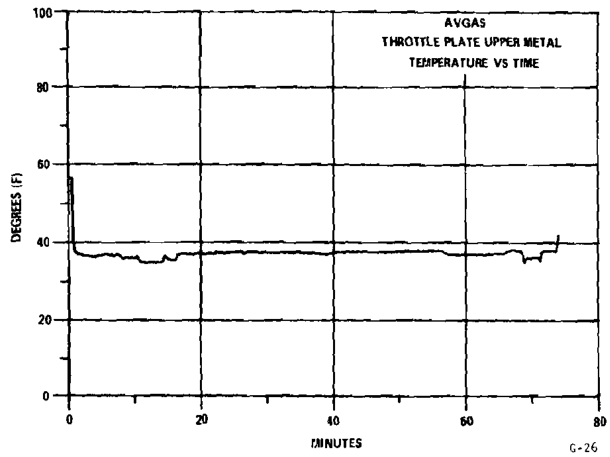

AVGAS
INDUCTION TUBE #3 UPPER AIR
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
G-21

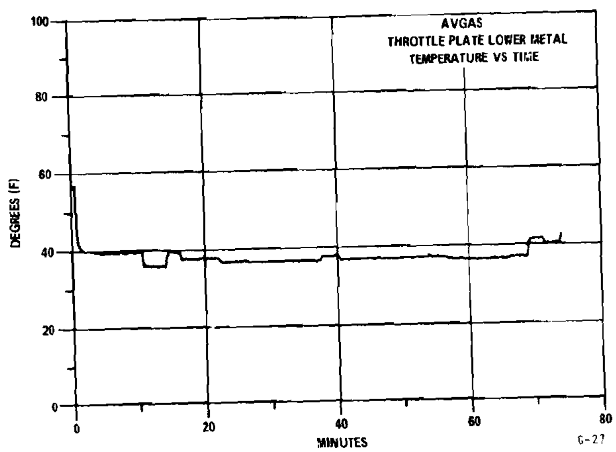

AVGAS
INDUCTION TUBE #3
LOWER AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
G-22

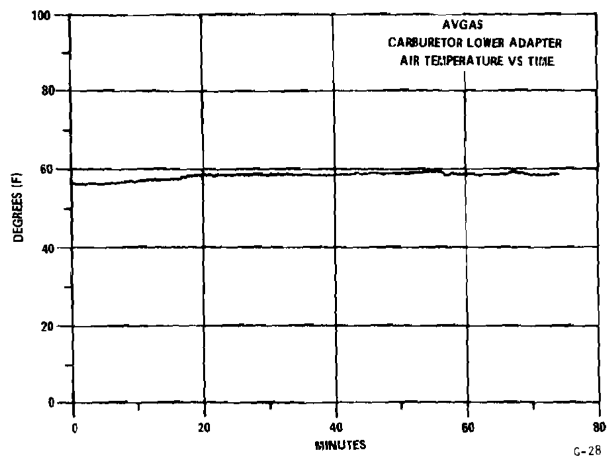

AVGAS
CARBURETOR UPPER ADAPTER
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
G-23

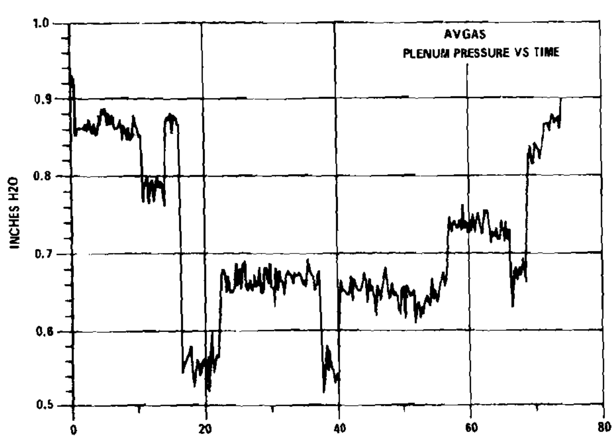

AVGAS
CARBURETOR #1 METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
G-24

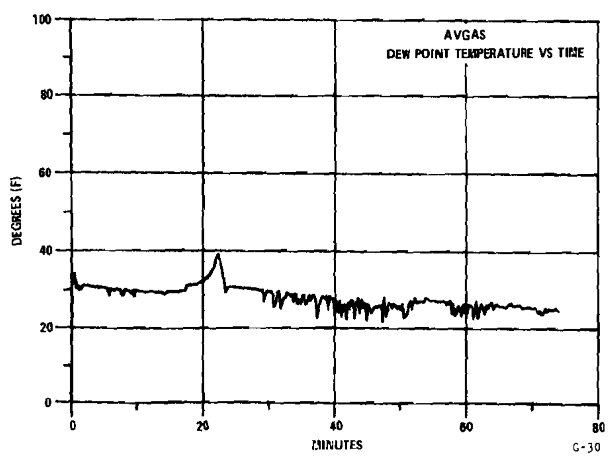

AVGAS
CARBURETOR #2 METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
100
80
60
40
20
0
0
20
40
60
80
G-25

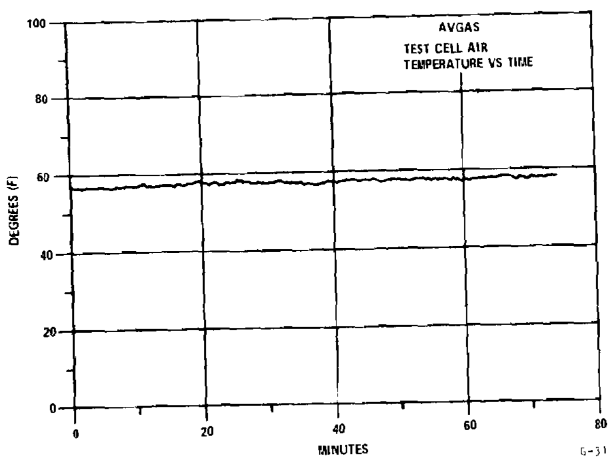

AVGAS
THROTTLE PLATE UPPER METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
100
80
60
40
20
0
0
20
40
60
80
G-26

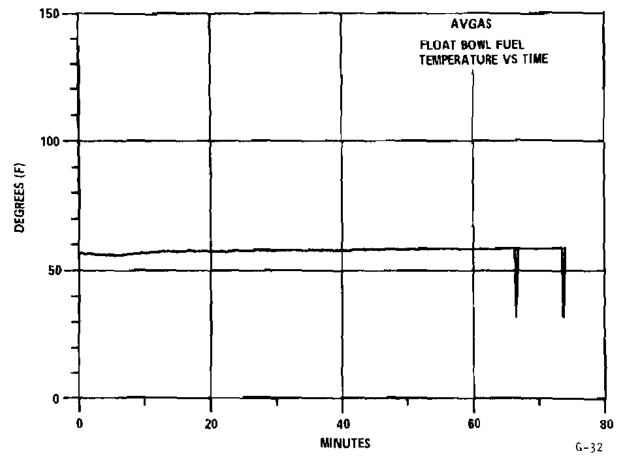

AVGAS
THROTTLE PLATE LOWER METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
100
80
60
40
20
0
0
20
40
60
80
G-27

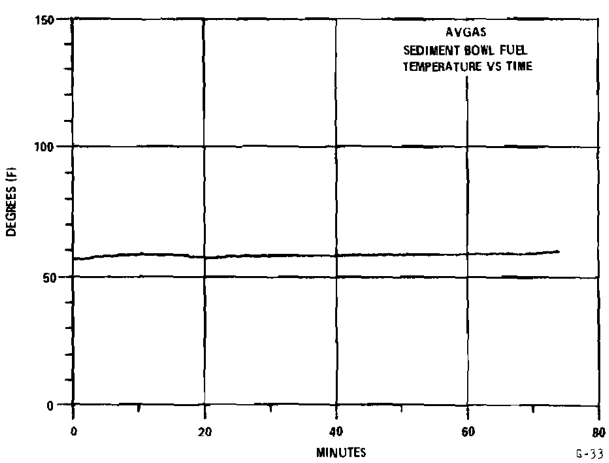

AVGAS
CARBURETOR LOWER ADAPTER
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
100
80
60
40
20
0
0
20
40
60
80
G-28

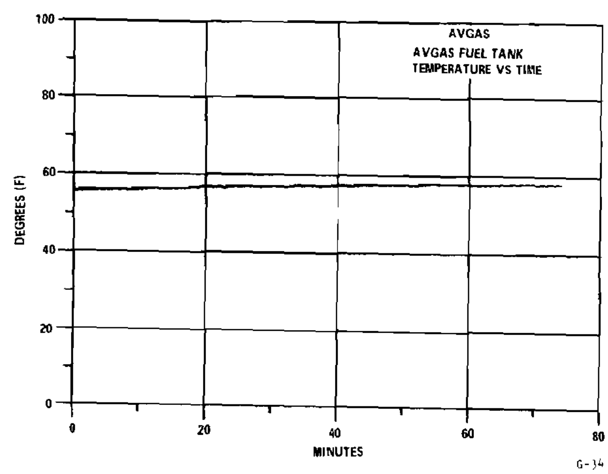

AVGAS
PLENUM PRESSURE VS TIME
INCHES H2O
MINUTES
1.0
0.9
0.8
0.7
0.6
0.5
0
20
40
60
80
G-29

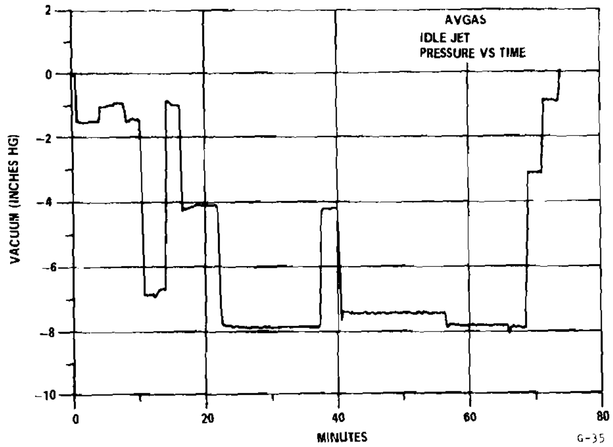

AVGAS
DEW POINT TEMPERATURE VS TIME
DEGREES (F)
MINUTES
100
80
60
40
20
0
0
20
40
60
80
G-30


AVGAS
TEST CELL AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
0
20
40
60
80
100
G-31

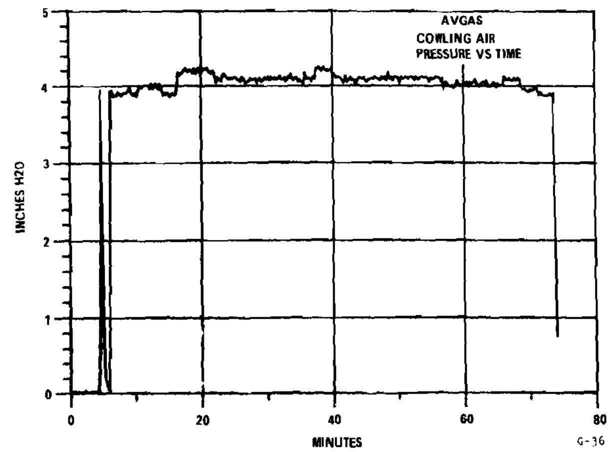

AVGAS
FLOAT BOWL FUEL TEMPERATURE VS TIME
DEGREES (F)
MINUTES
0
50
100
150
20
40
60
80
G-32


AVGAS
SEDIMENT BOWL FUEL TEMPERATURE VS TIME
DEGREES (F)
MINUTES
0
50
100
150
20
40
60
80
G-33

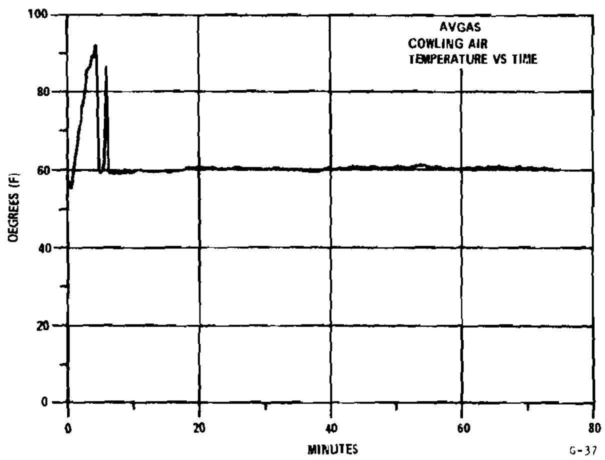

AVGAS
AVGAS FUEL TANK TEMPERATURE VS TIME
DEGREES (F)
MINUTES
0
20
40
60
80
100
G-34



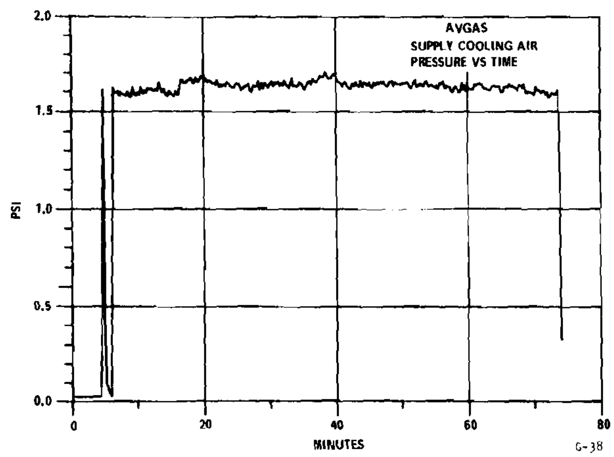
G-35



G-36



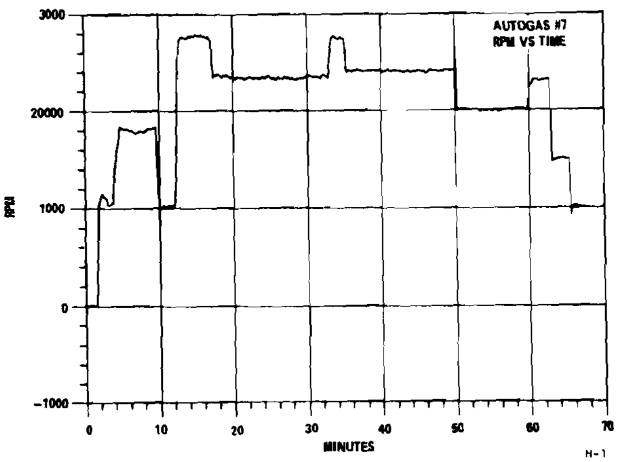
G-37

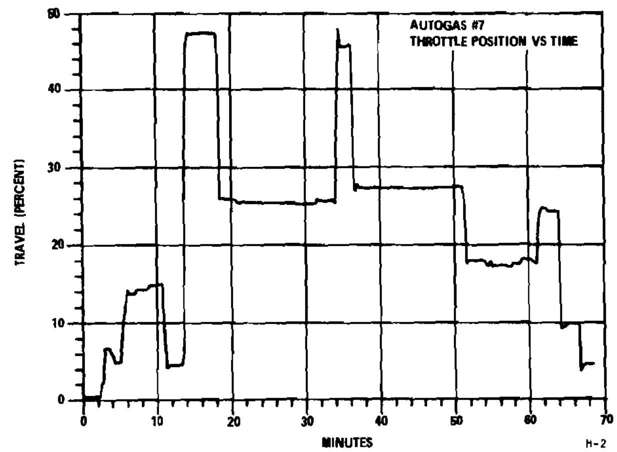


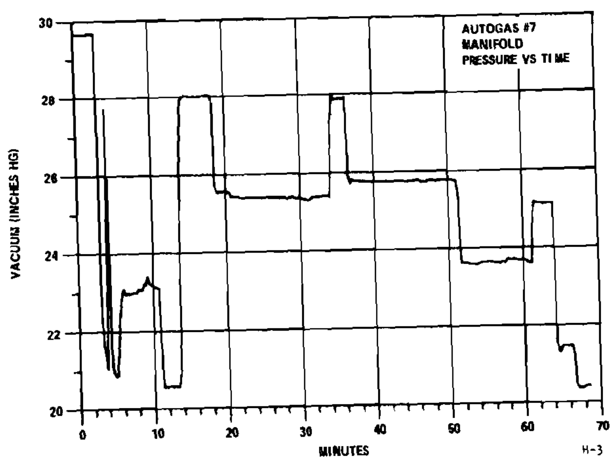
G-38

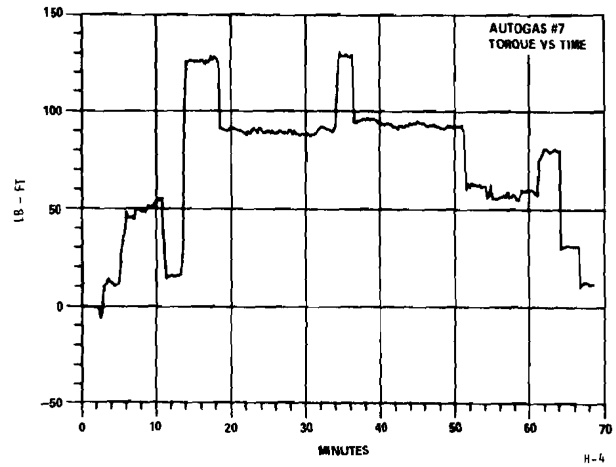
APPENDIX H

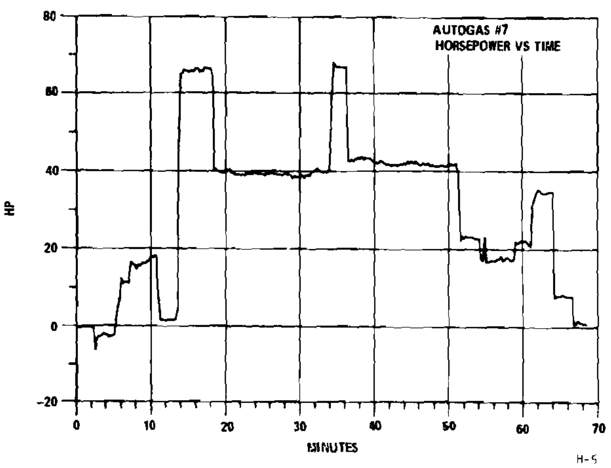
ENGINE PERFORMANCE BASELINE DATA UNLEADED PREMIUM AUTOGAS (BASELINE TEST SEQUENCE #1)

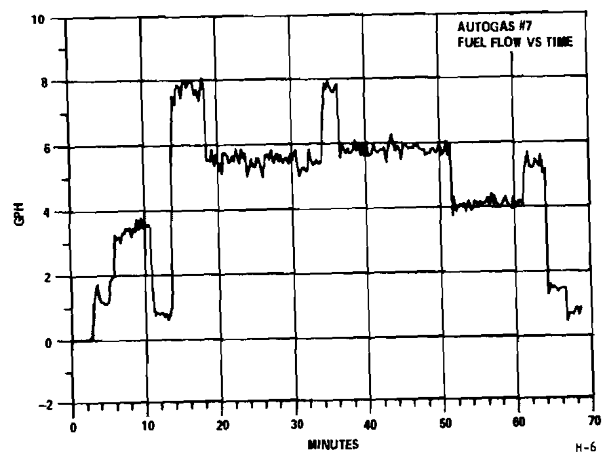

AUTOGAS #7
RPM VS TIME
RPM
MINUTES
H-1

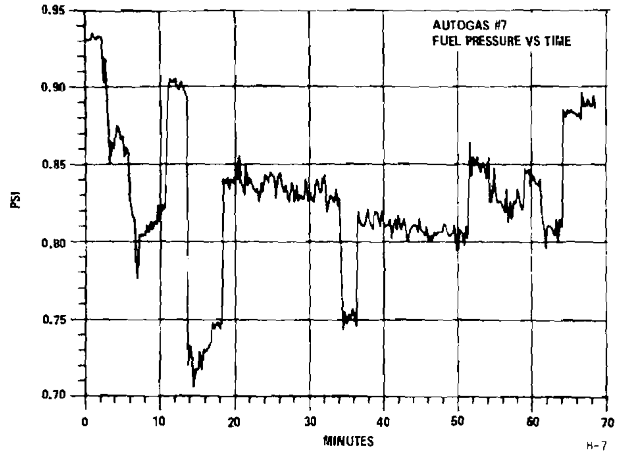

AUTOGAS #7
THROTTLE POSITION VS TIME
TRAVEL (PERCENT)
MINUTES
H-2

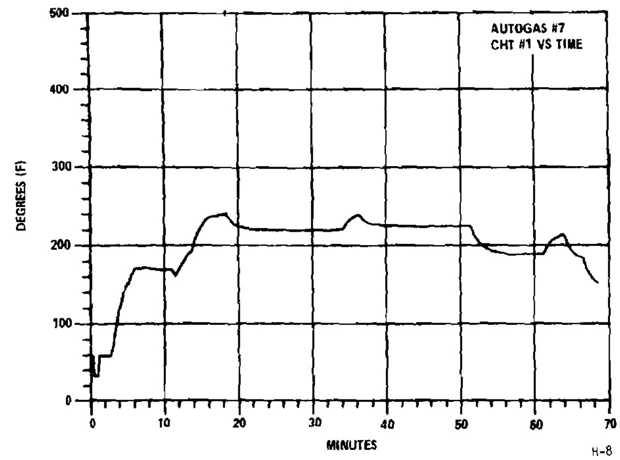

AUTOGAS #7
MANIFOLD
PRESSURE VS TIME
VACUUM (INCHES HG)
MINUTES
H-3

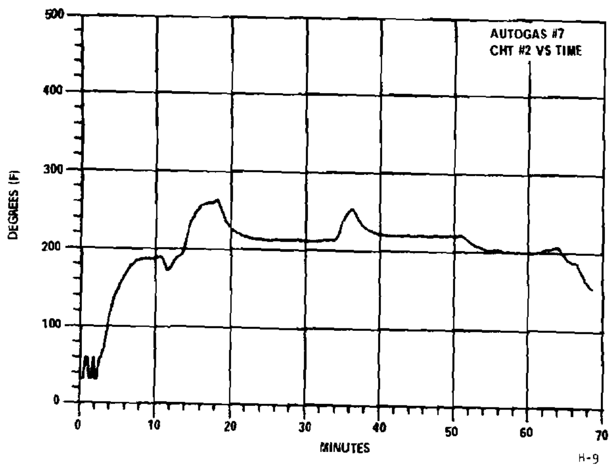

AUTOGAS #7
TORQUE VS TIME
LB - FT
MINUTES
H-4

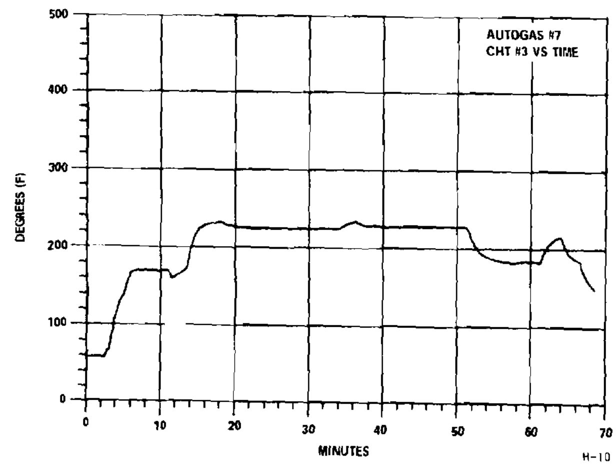

AUTOGAS #7
HORSEPOWER VS TIME
HP
MINUTES
H-5

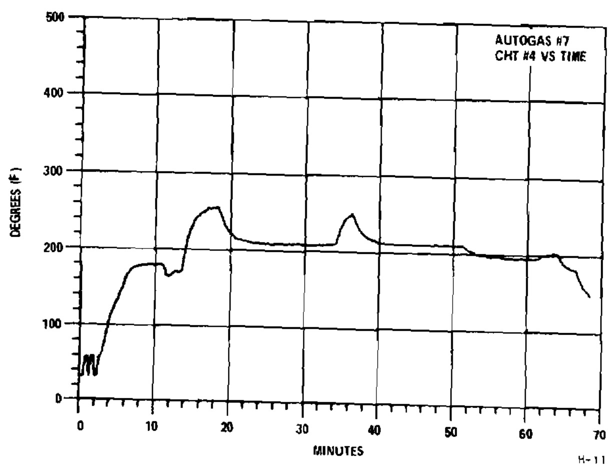

AUTOGAS #7
FUEL FLOW VS TIME
GPH
MINUTES
H-6

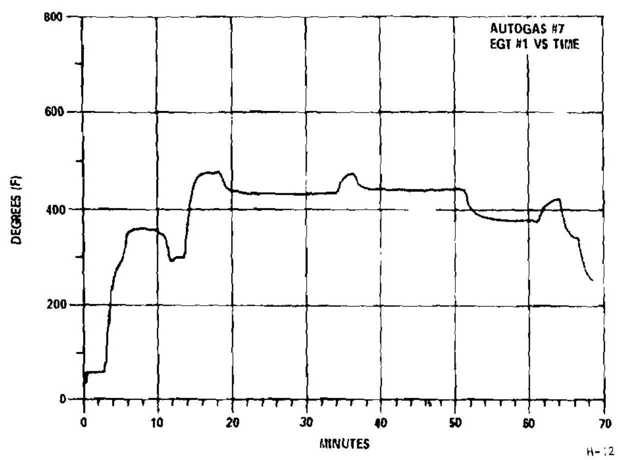

AUTOGAS #7
FUEL PRESSURE VS TIME
PSI
MINUTES
H-7

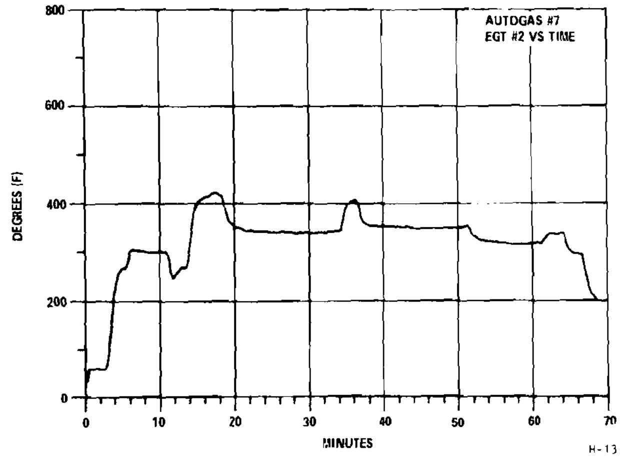

AUTOGAS #7
CHT #1 VS TIME
DEGREES (F)
MINUTES
H-8

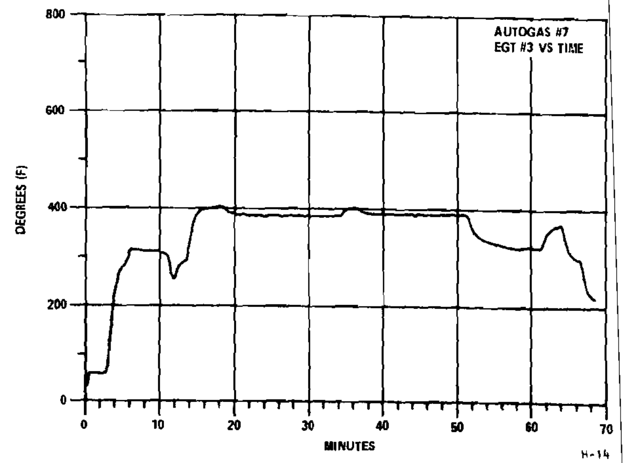

AUTOGAS #7
CHT #2 VS TIME
DEGREES (F)
MINUTES
H-9

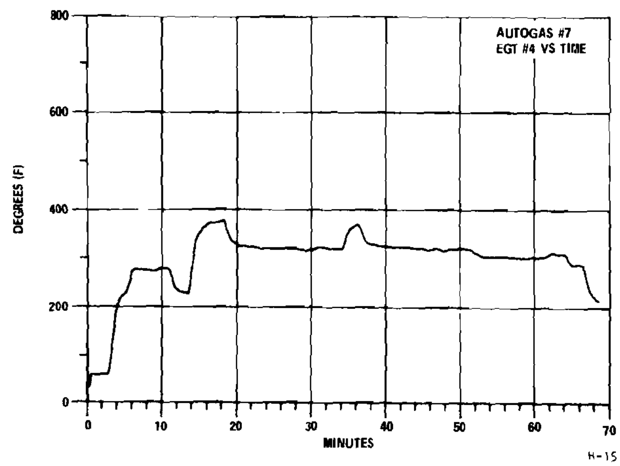

AUTOGAS #7
CHT #3 VS TIME
DEGREES (F)
MINUTES
H-10

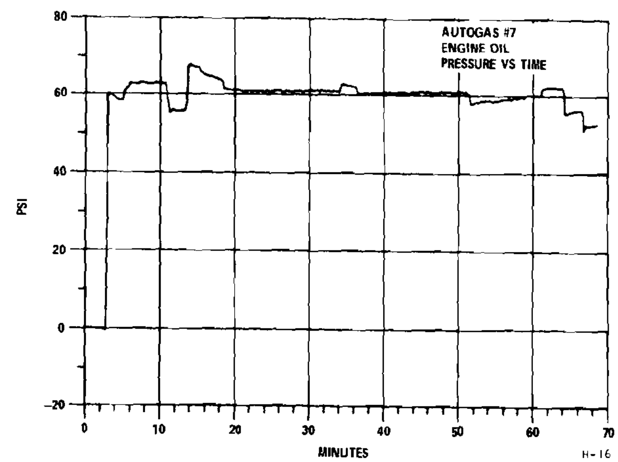

AUTOGAS #7
CHT #4 VS TIME
DEGREES (F)
MINUTES
H-11

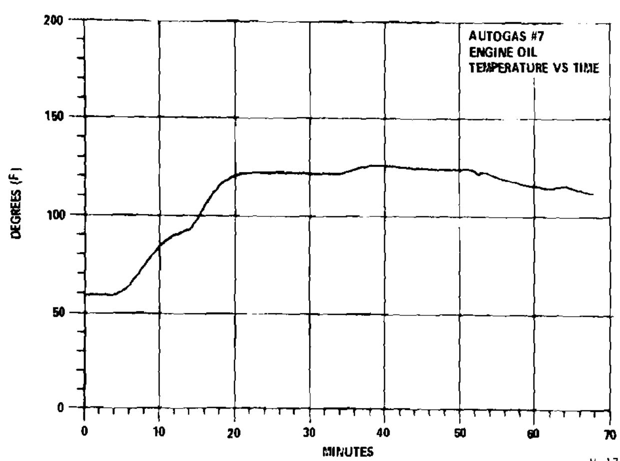

AUTOGAS #7
EGT #1 VS TIME
DEGREES (F)
MINUTES
H-12

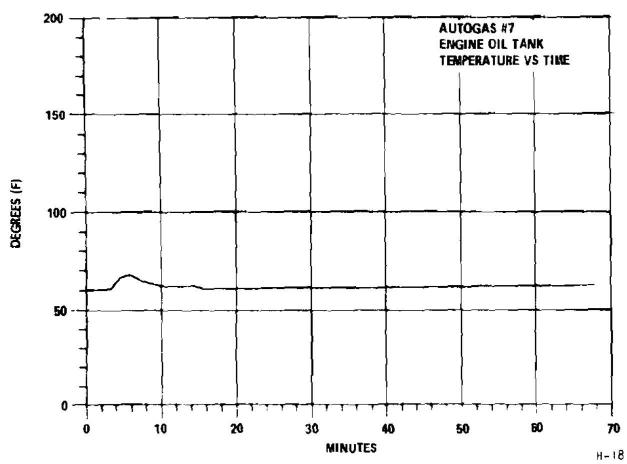

AUTOGAS #7
EGT #2 VS TIME
DEGREES (F)
MINUTES
H-13

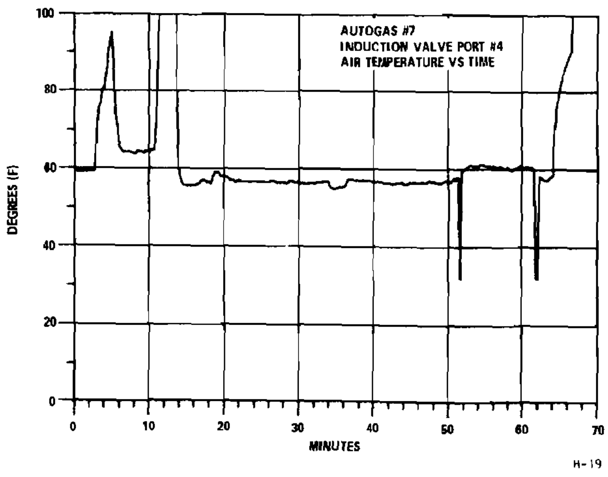

AUTOGAS #7
EGT #3 VS TIME
DEGREES (F)
MINUTES
H-14

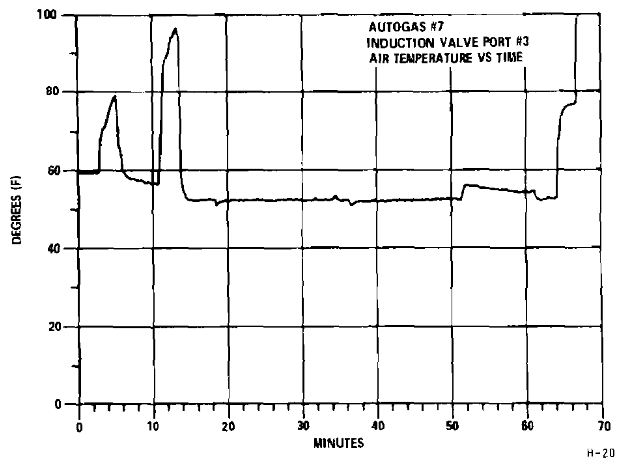

AUTOGAS #7
EGT #4 VS TIME
DEGREES (F)
MINUTES
H-15

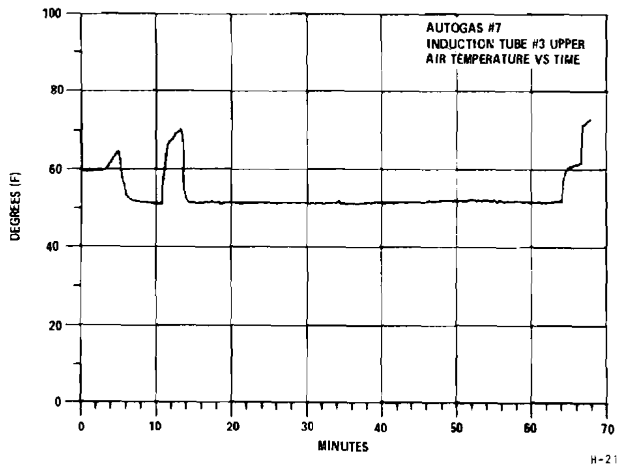

AUTOGAS #7
ENGINE OIL
PRESSURE VS TIME
PSI
MINUTES
H-16

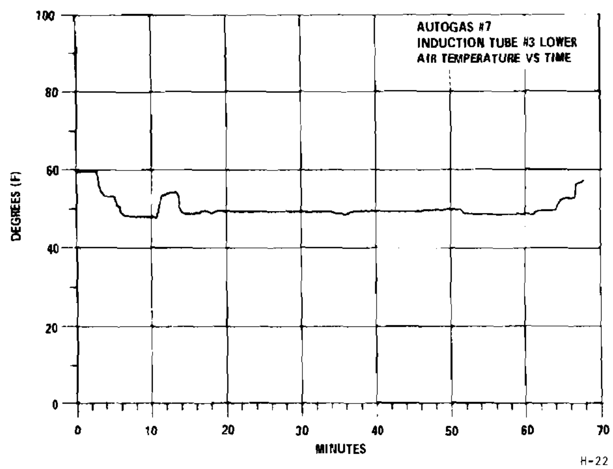

AUTOGAS #7
ENGINE OIL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-17

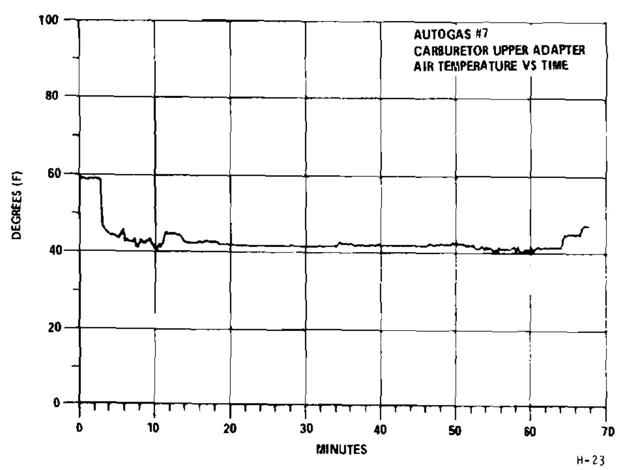

AUTOGAS #7
ENGINE OIL TANK
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-18

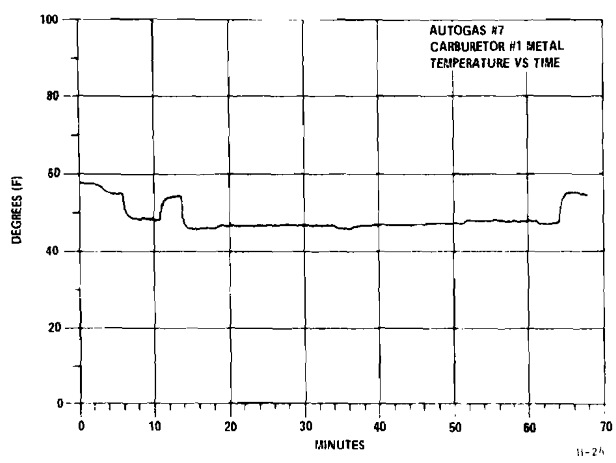

AUTOGAS #7
INDUCTION VALVE PORT #4
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-19

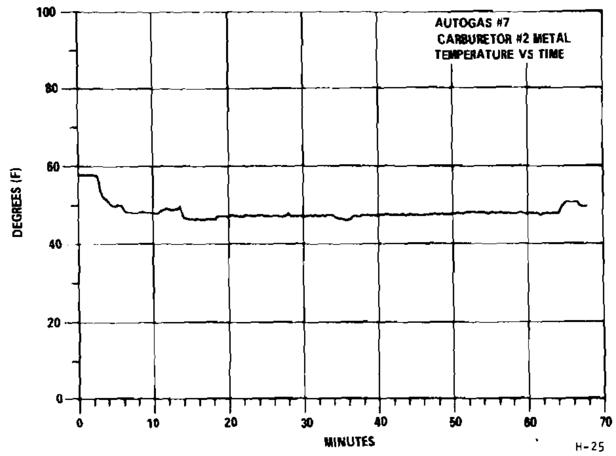

AUTOGAS #7
INDUCTION VALVE PORT #3
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-20

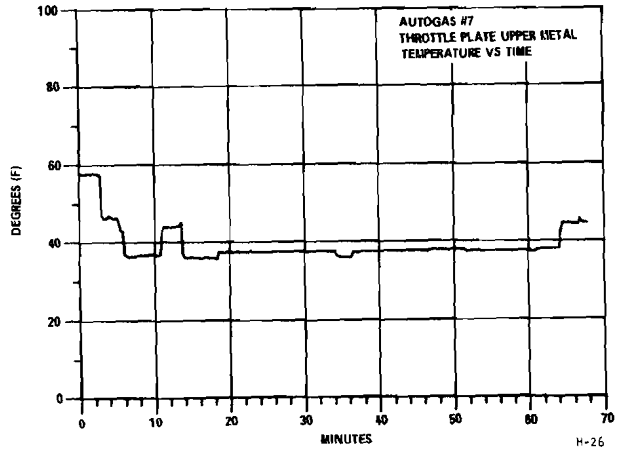

AUTOGAS #7
INDUCTION TUBE #3 UPPER
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-21

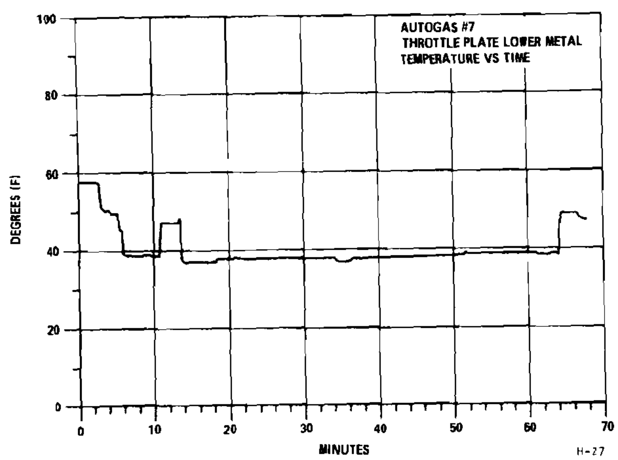

AUTOGAS #7
INDUCTION TUBE #3 LOWER
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-22

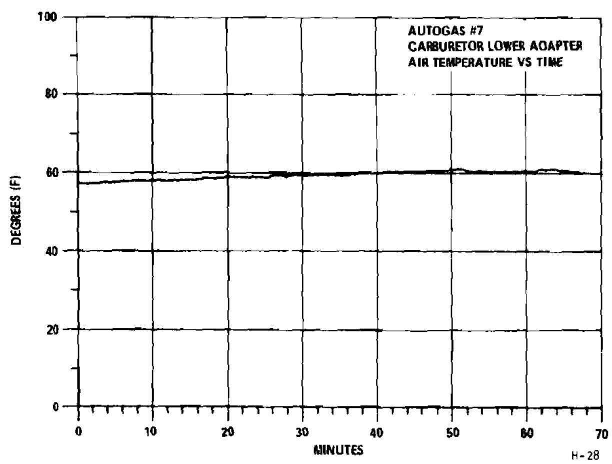

AUTOGAS #7
CARBURETOR UPPER ADAPTER
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-23

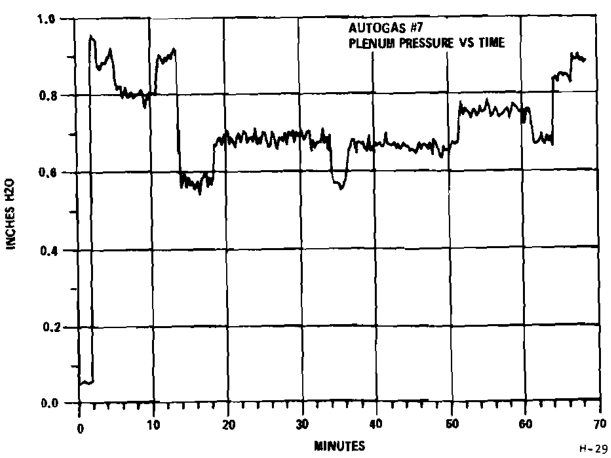

AUTOGAS #7
CARBURETOR #1 METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-24

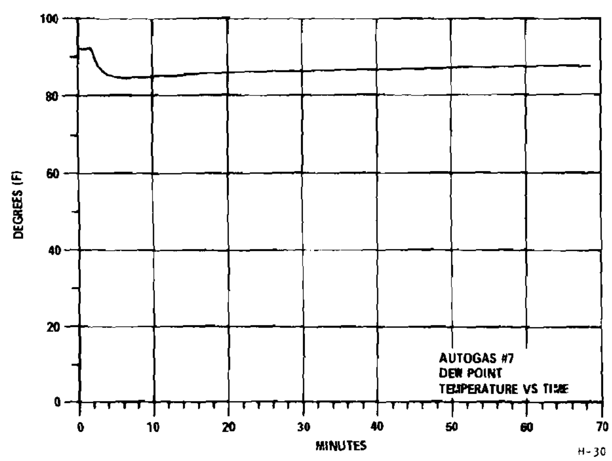

AUTOGAS #7
CARBURETOR #2 METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-25

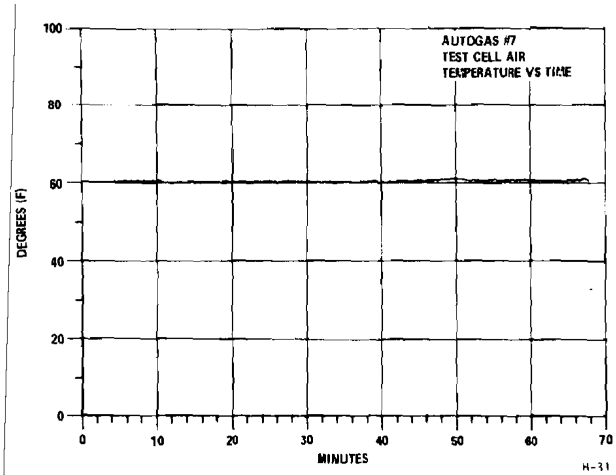

AUTOGAS #7
THROTTLE PLATE UPPER METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-26


AUTOGAS #7
THROTTLE PLATE LOWER METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-27

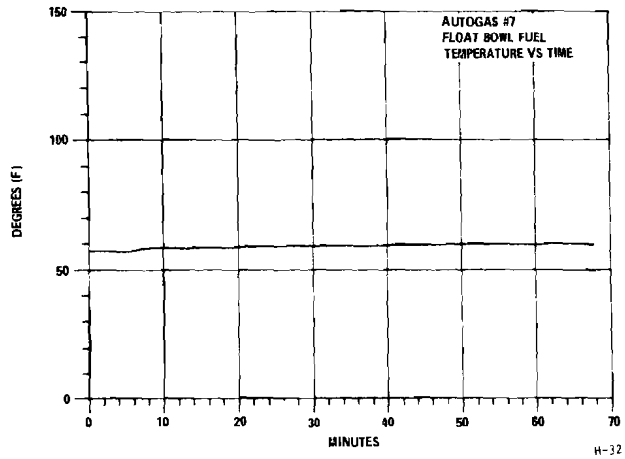

AUTOGAS #7
CARBURETOR LOWER ADAPTER
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-28


AUTOGAS #7
PLENUM PRESSURE VS TIME
INCHES H2O
MINUTES
H-29

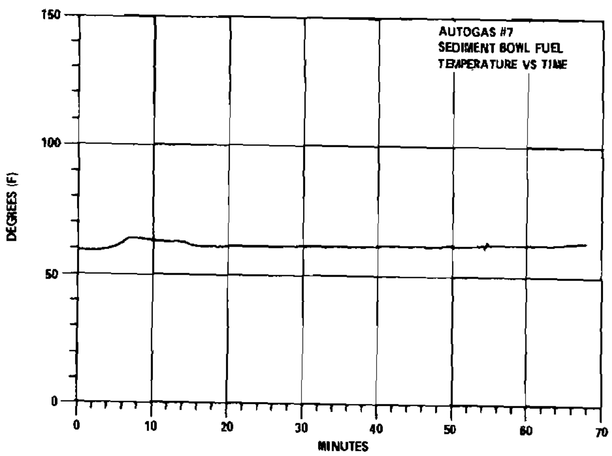

AUTOGAS #7
DEW POINT
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-30



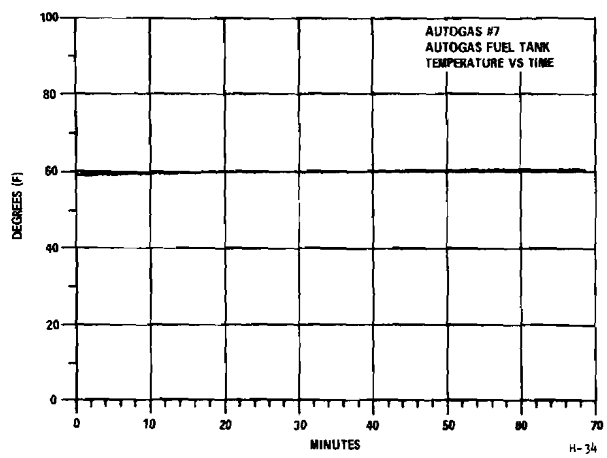
H-31



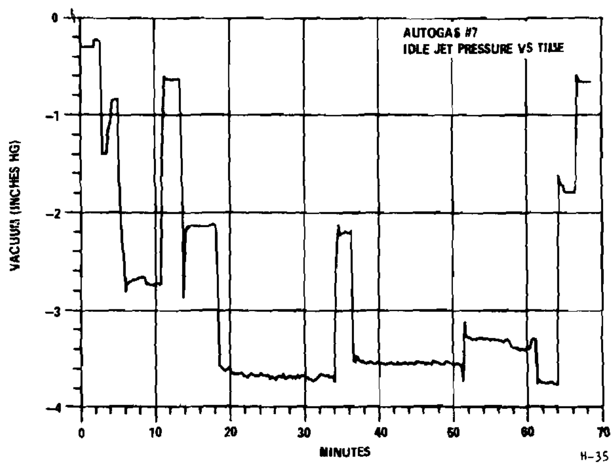
H-32

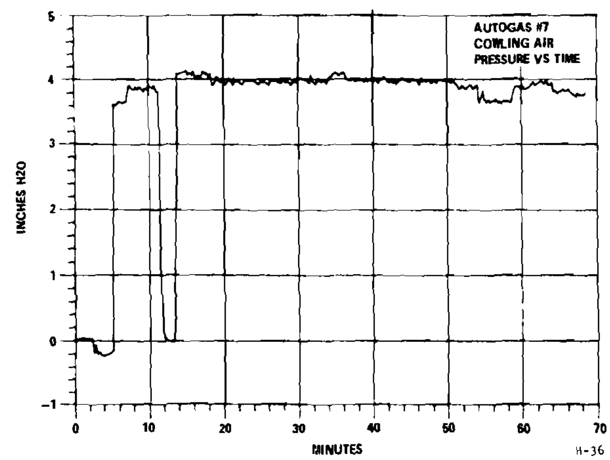


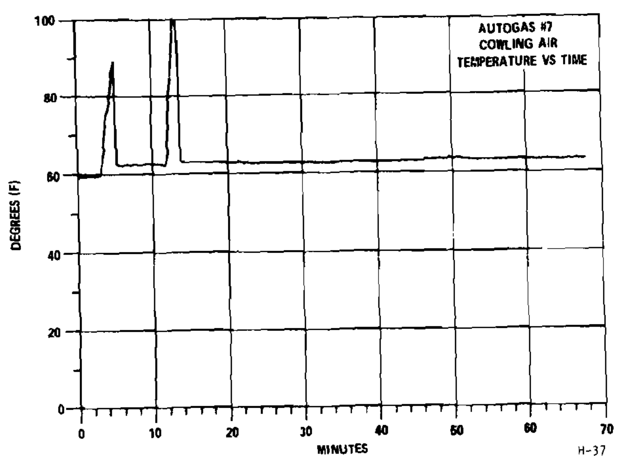
H-33

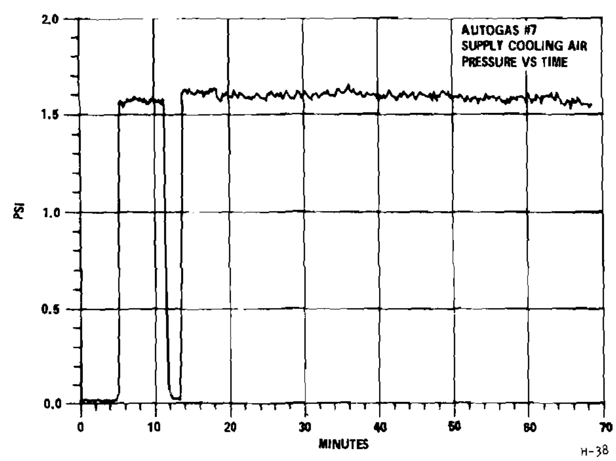


H-34


AUTOGAS #7
IDLE JET PRESSURE VS TIME
VACUUM (INCHES HG)
MINUTES
H-35


AUTOGAS #7
COWLING AIR
PRESSURE VS TIME
INCHES H2O
MINUTES
H-36

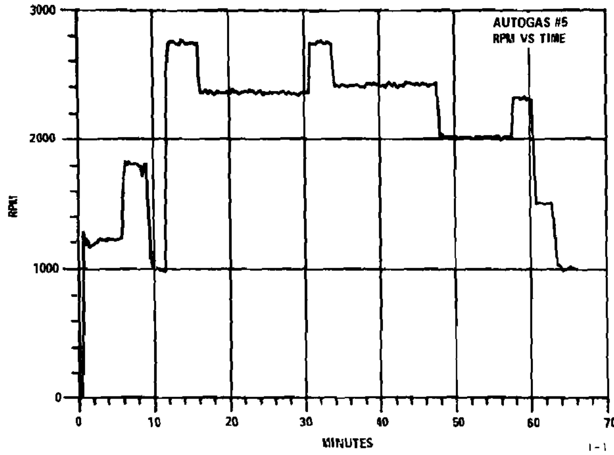

AUTOGAS #7
COWLING AIR
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
H-37

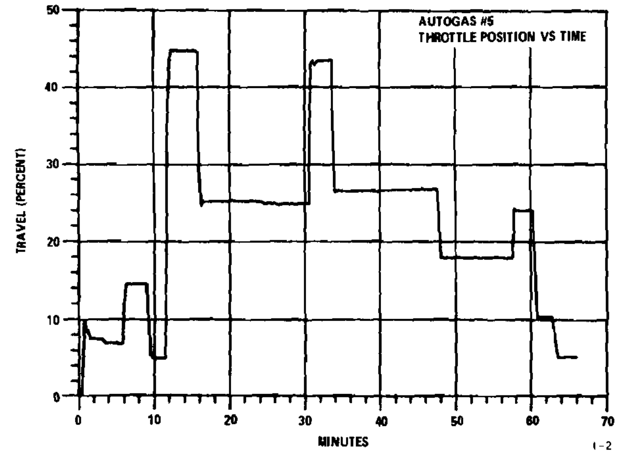

AUTOGAS #7
SUPPLY COOLING AIR
PRESSURE VS TIME
PSI
MINUTES
H-38

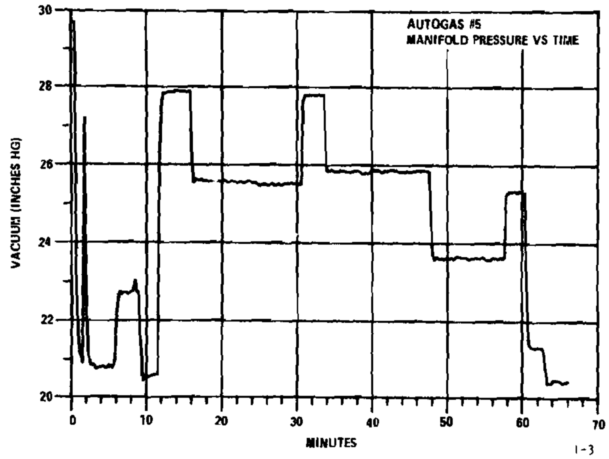
APPENDIX I

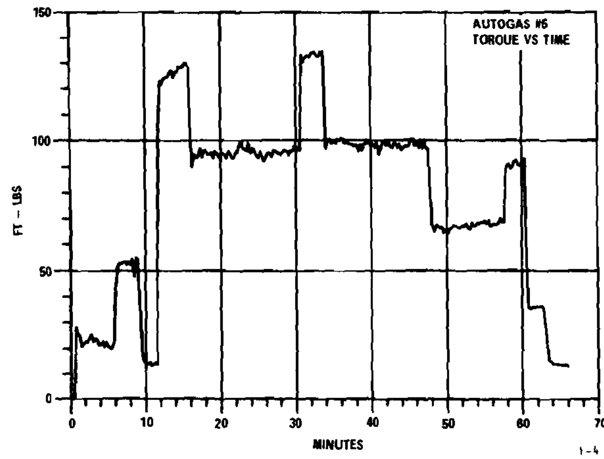
ENGINE PERFORMANCE BASELINE DATA UNLEADED REGULAR AUTOGAS

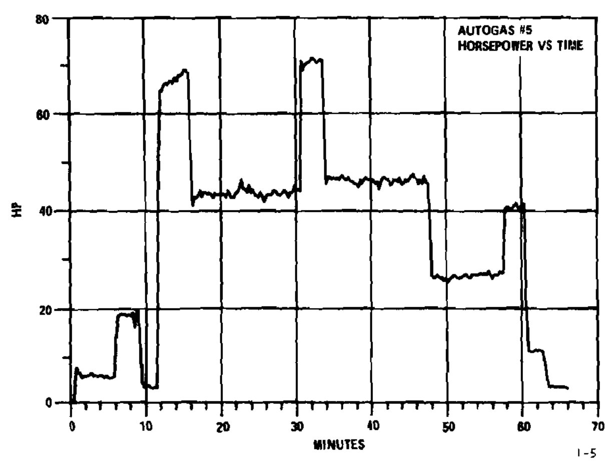
(BASELINE TEST SEQUENCE #1)

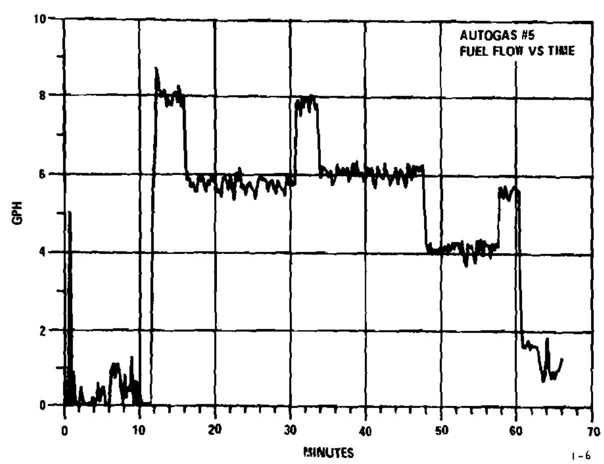

AUTOGAS #5
RPM VS TIME
RPM
MINUTES
0
1000
2000
3000
0
10
20
30
40
50
60
70

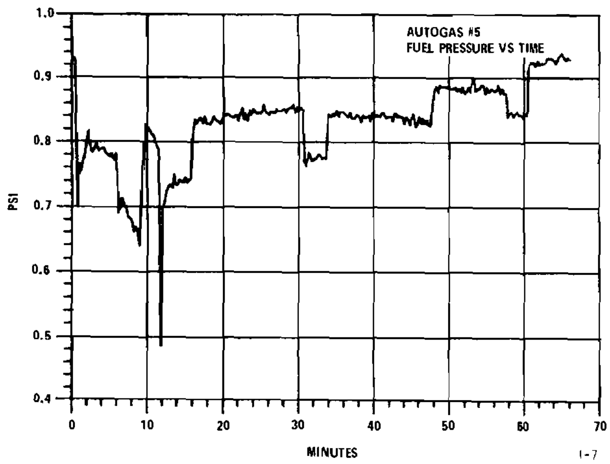

AUTOGAS #5
THROTTLE POSITION VS TIME
TRAVEL (PERCENT)
MINUTES
0
10
20
30
40
50
60
70

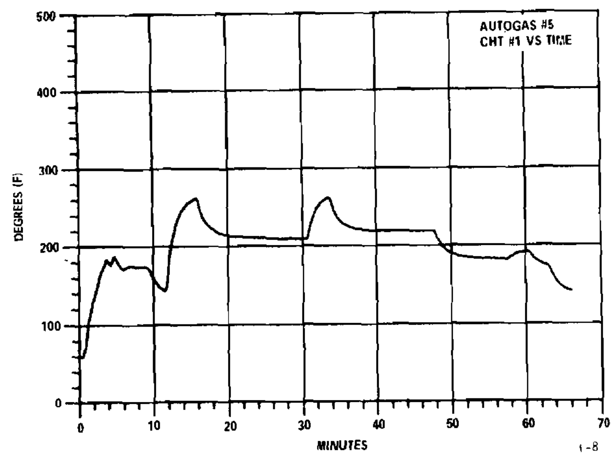

AUTOGAS #5
MANIFOLD PRESSURE VS TIME
VACUUM (INCHES HG)
MINUTES
20
22
24
26
28
30
0
10
20
30
40
50
60
70

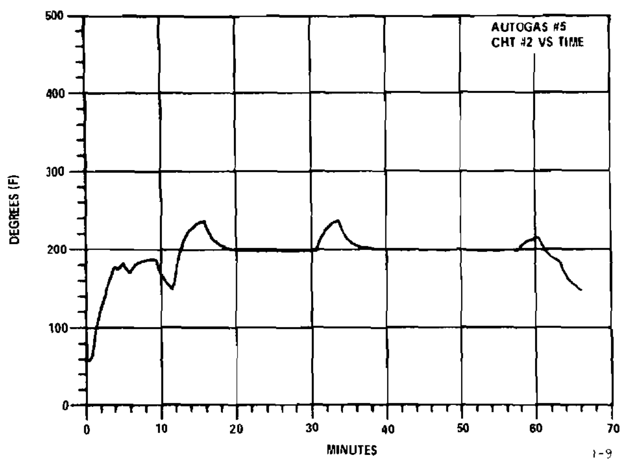

AUTOGAS #6
TORQUE VS TIME
FT - LBS
MINUTES
0
50
100
150
0
10
20
30
40
50
60
70

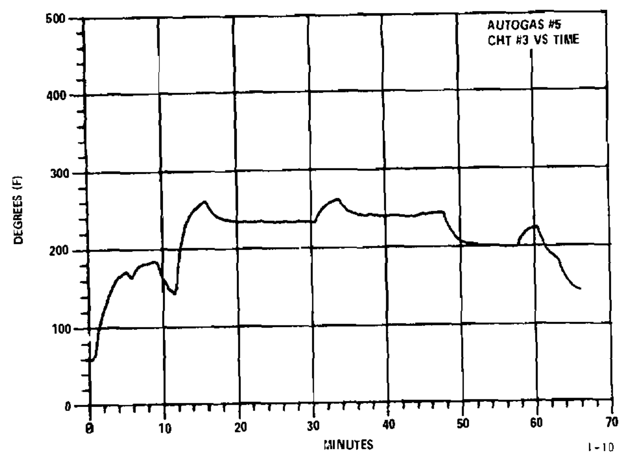

AUTOGAS #5
HORSEPOWER VS TIME
HP
MINUTES
0
20
40
60
80
0
10
20
30
40
50
60
70

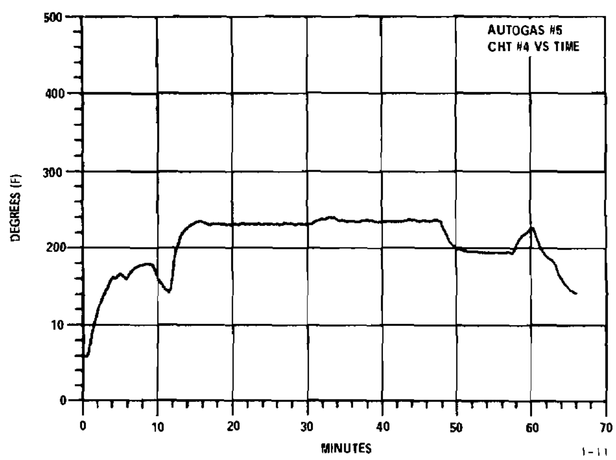

AUTOGAS #5
FUEL FLOW VS TIME
GPH
MINUTES
0
2
4
6
8
10
0
10
20
30
40
50
60
70

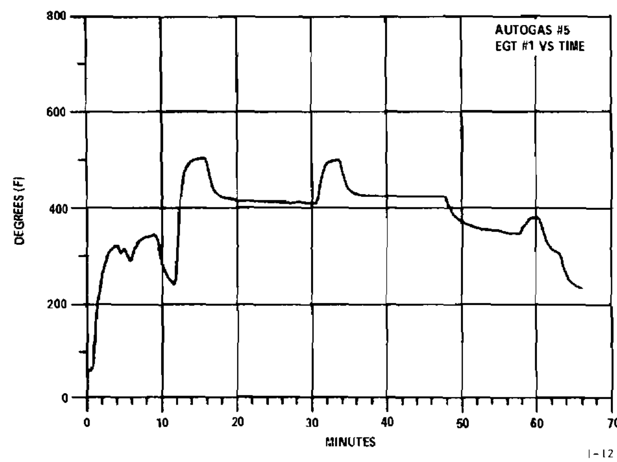

AUTOGAS #5
FUEL PRESSURE VS TIME
PSI
MINUTES
1-7

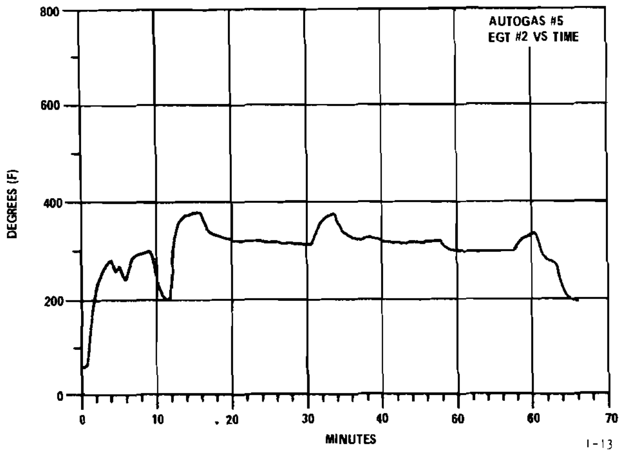

AUTOGAS #5
CHT #1 VS TIME
DEGREES (F)
MINUTES
1-8


AUTOGAS #5
CHT #2 VS TIME
DEGREES (F)
MINUTES
1-9

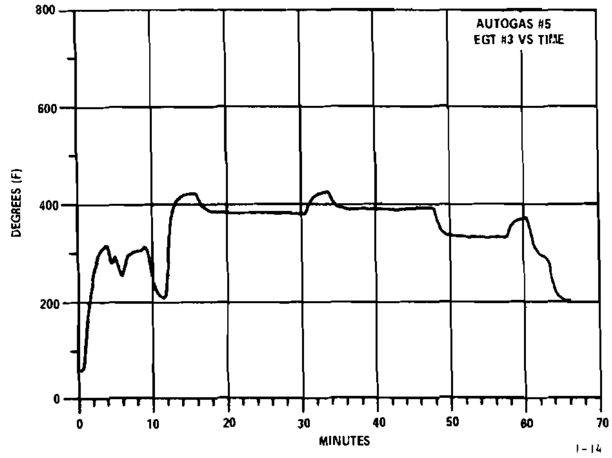

AUTOGAS #5
CHT #3 VS TIME
DEGREES (F)
MINUTES
1-10


AUTOGAS #5
CHT #4 VS TIME
DEGREES (F)
MINUTES
1-11

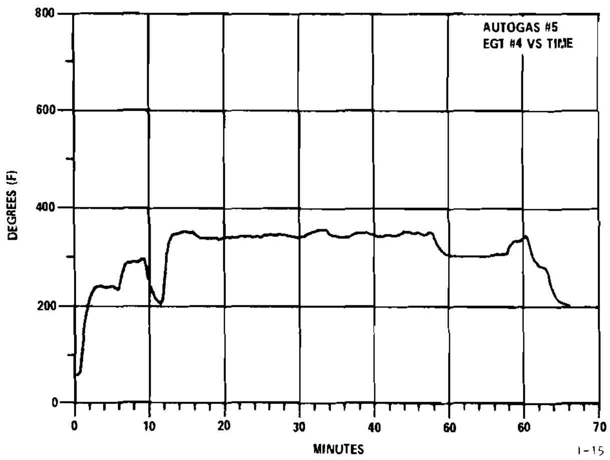

AUTOGAS #5
EGT #1 VS TIME
DEGREES (F)
MINUTES
1-12



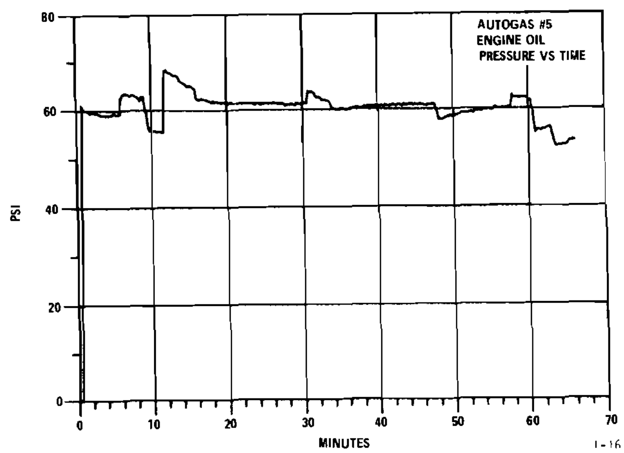
I-13



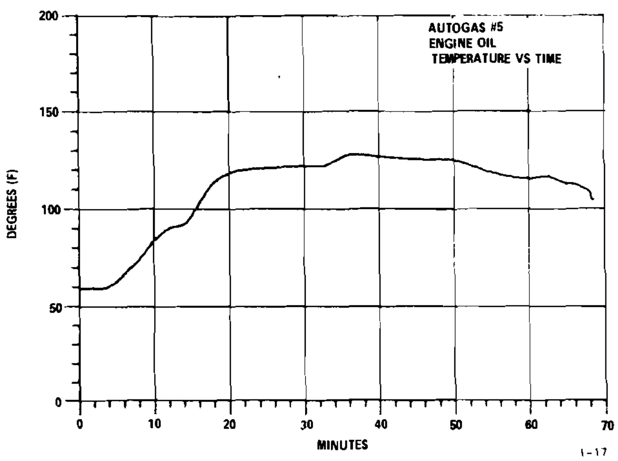
I-14



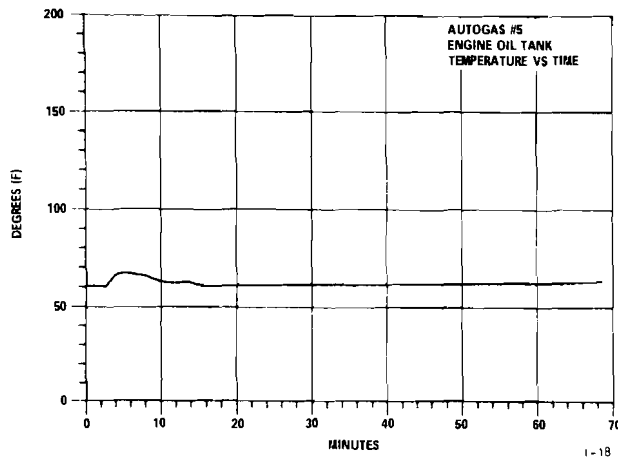
I-15



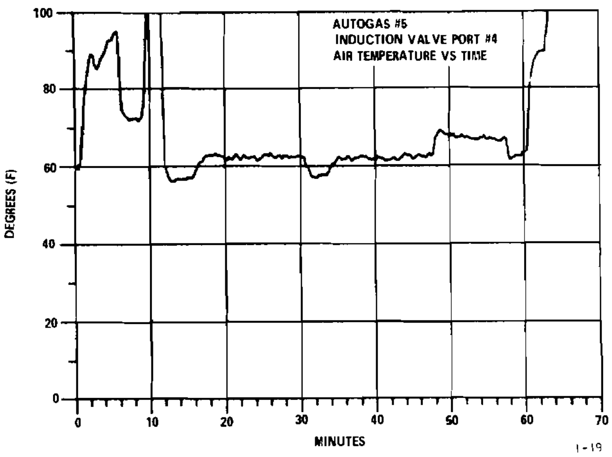
I-16

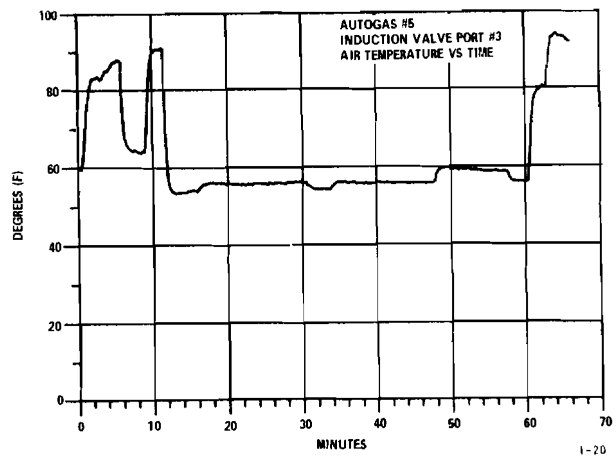


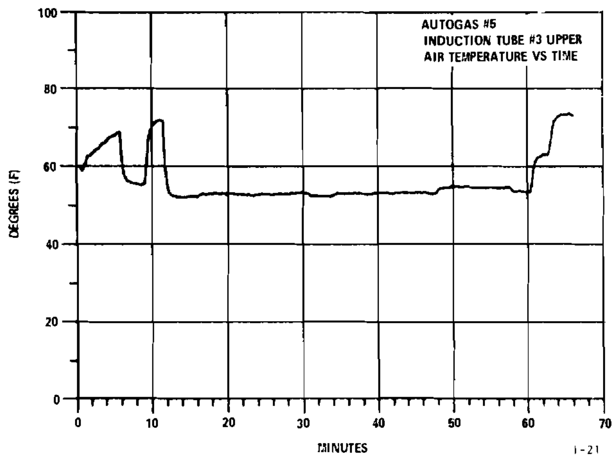
I-17

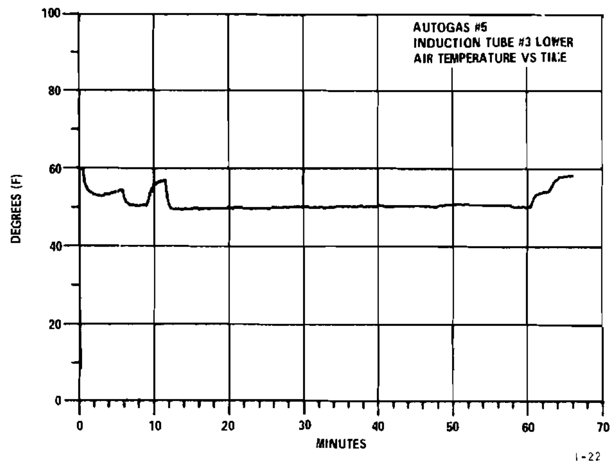


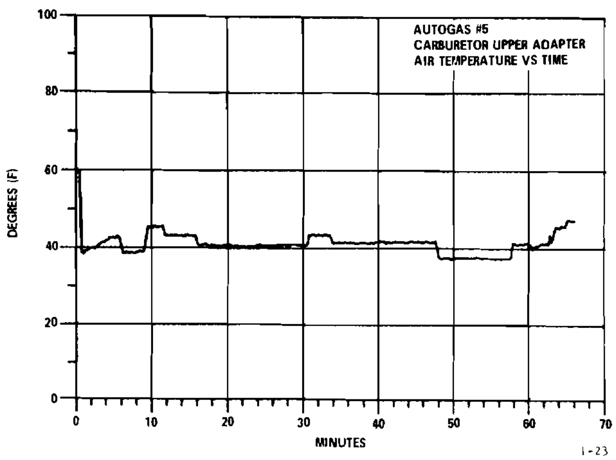
I-18

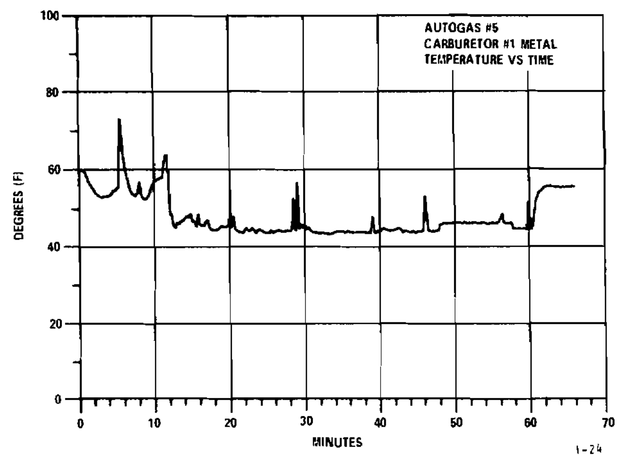

AUTOGAS #5
INDUCTION VALVE PORT #4
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-19

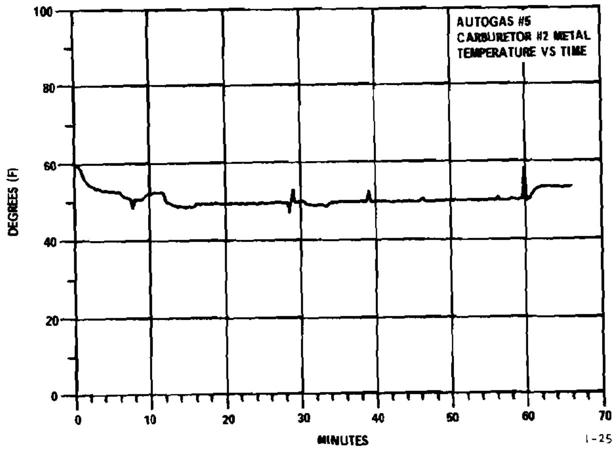

AUTOGAS #5
INDUCTION VALVE PORT #3
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-20

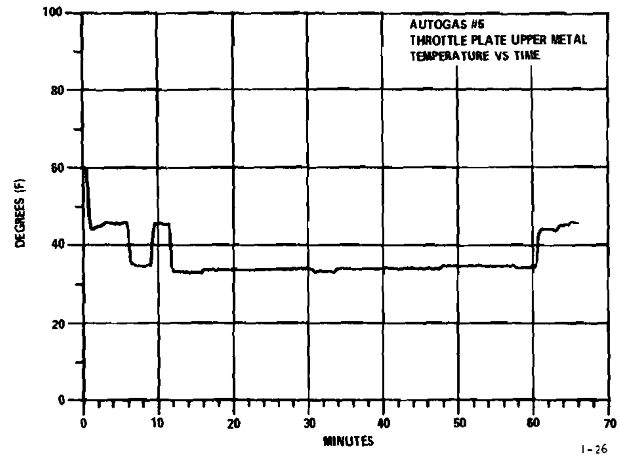

AUTOGAS #5
INDUCTION TUBE #3 UPPER
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-21

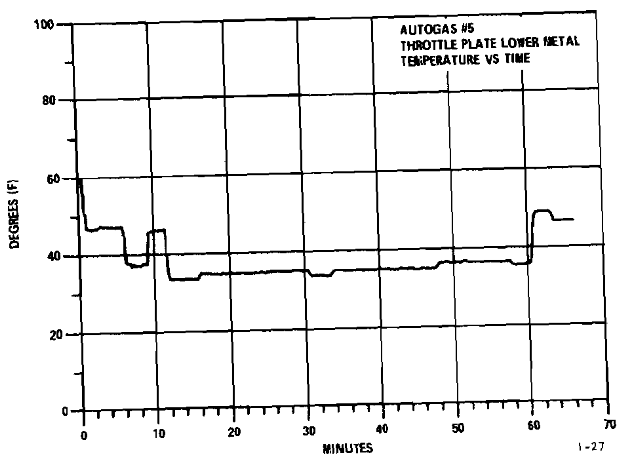

AUTOGAS #5
INDUCTION TUBE #3 LOWER
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-22

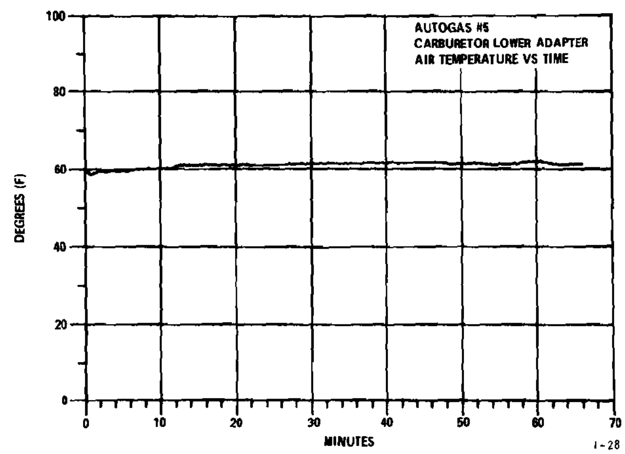

AUTOGAS #5
CARBURETOR UPPER ADAPTER
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-23

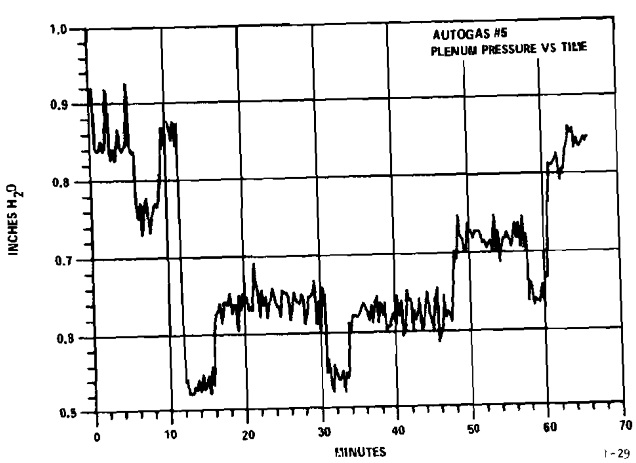

AUTOGAS #5
CARBURETOR #1 METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-24

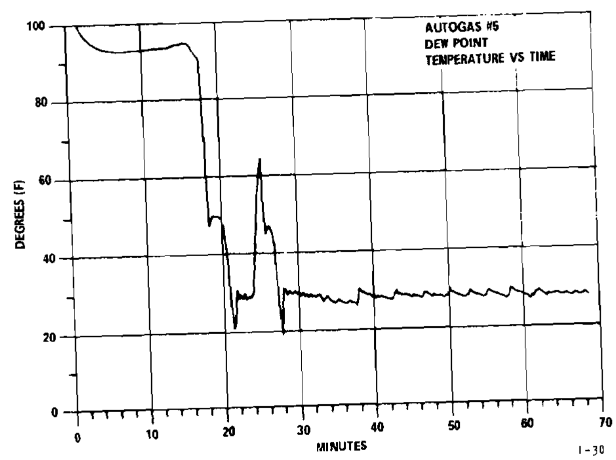

AUTOGAS #5
CARBURETOR #2 METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-25

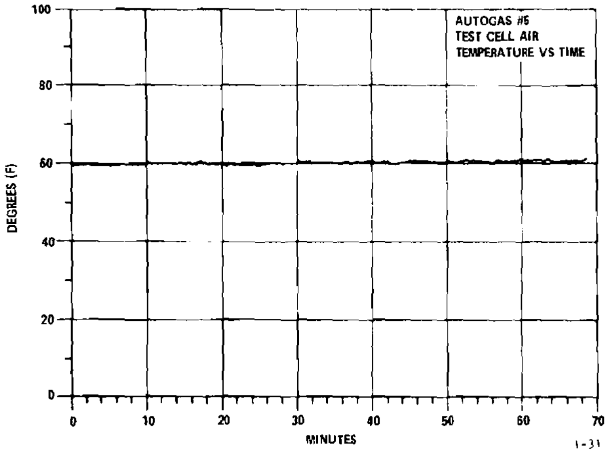

AUTOGAS #5
THROTTLE PLATE UPPER METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-26

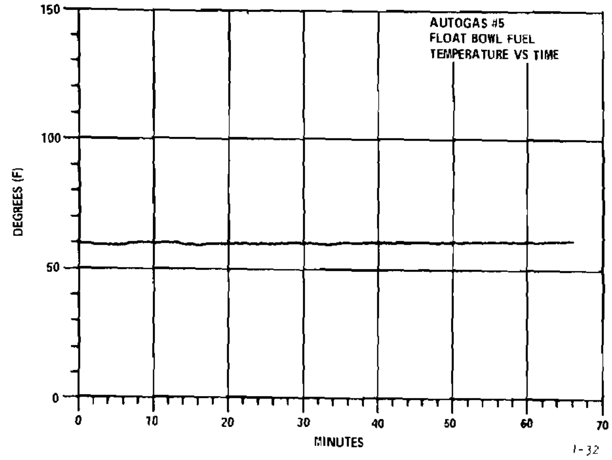

AUTOGAS #5
THROTTLE PLATE LOWER METAL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-27

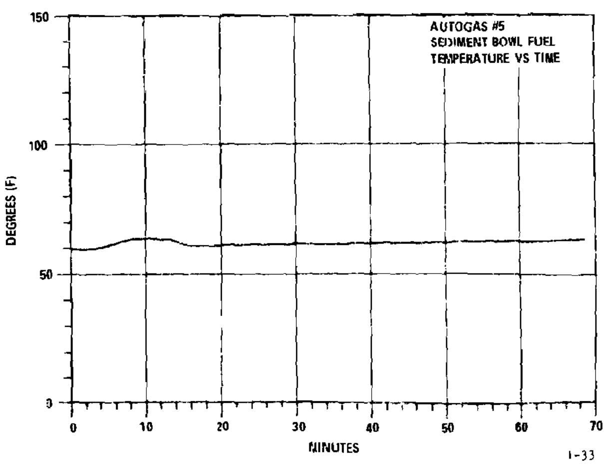

AUTOGAS #5
CARBURETOR LOWER ADAPTER
AIR TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-28

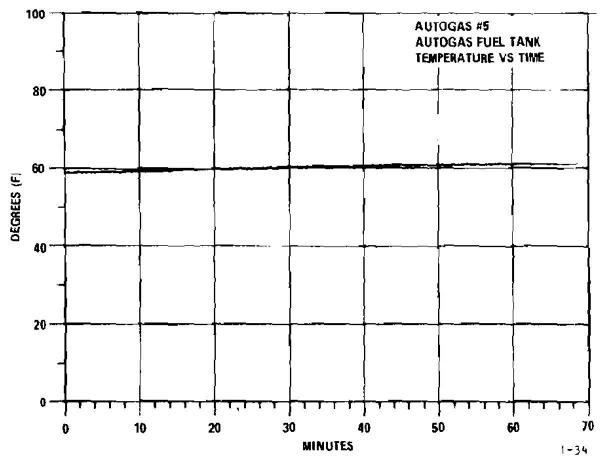

AUTOGAS #5
PLENUM PRESSURE VS TIME
INCHES H2O
MINUTES
I-29

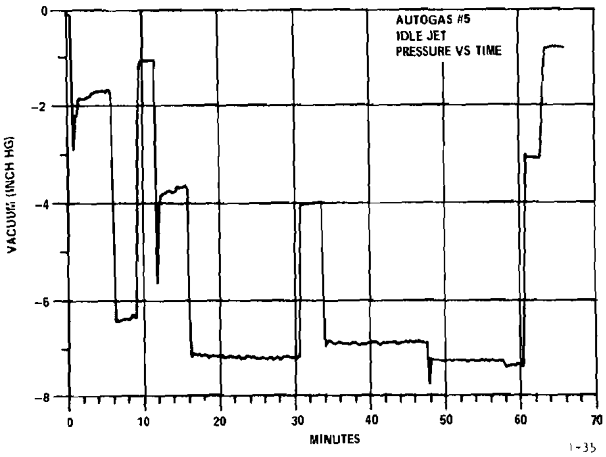

AUTOGAS #5
DEW POINT
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
I-30

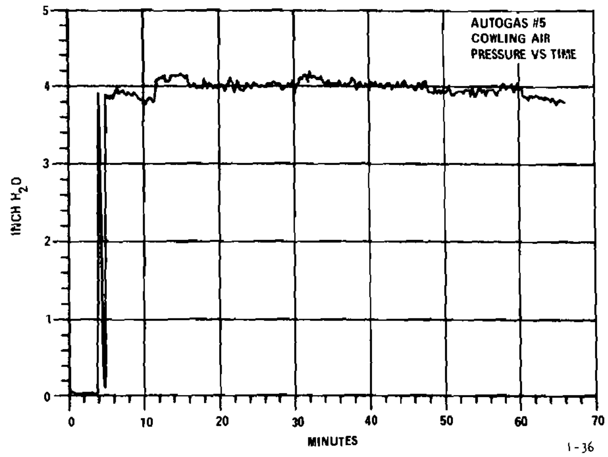

AUTOGAS #5
TEST CELL AIR
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
1-31

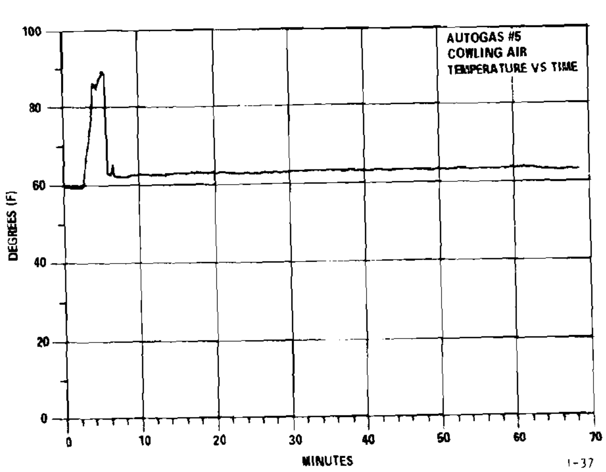

AUTOGAS #5
FLOAT BOWL FUEL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
1-32

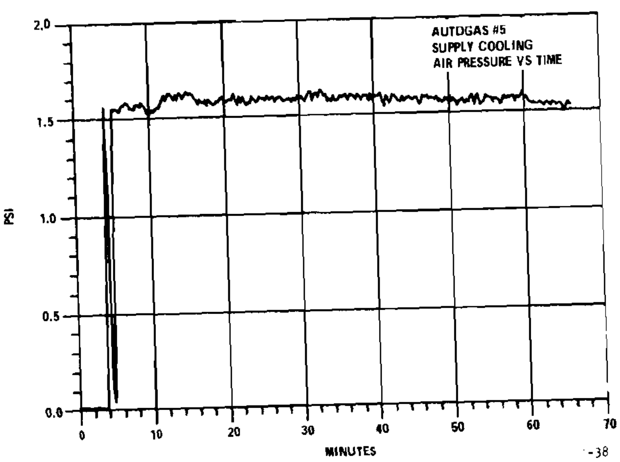

AUTOGAS #5
SEDIMENT BOWL FUEL
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
1-33


AUTOGAS #5
AUTOGAS FUEL TANK
TEMPERATURE VS TIME
DEGREES (F)
MINUTES
1-34


AUTOGAS #5
IDLE JET
PRESSURE VS TIME
VACUUM (INCH HG)
0
-2
-4
-6
-8
0
10
20
30
40
50
60
70
MINUTES
1-35


AUTOGAS #5
COWLING AIR
PRESSURE VS TIME
INCH H_2O
5
4
3
2
1
0
0
10
20
30
40
50
60
70
MINUTES
1-36


AUTOGAS #5
COWLING AIR
TEMPERATURE VS TIME
DEGREES (F)
100
80
60
40
20
0
0
10
20
30
40
50
60
70
MINUTES
1-37


AUTOGAS #5
SUPPLY COOLING
AIR PRESSURE VS TIME
PSI
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
MINUTES
-38


2000 (1885) **AVGAS**


2000 (1900) AUTOGAS

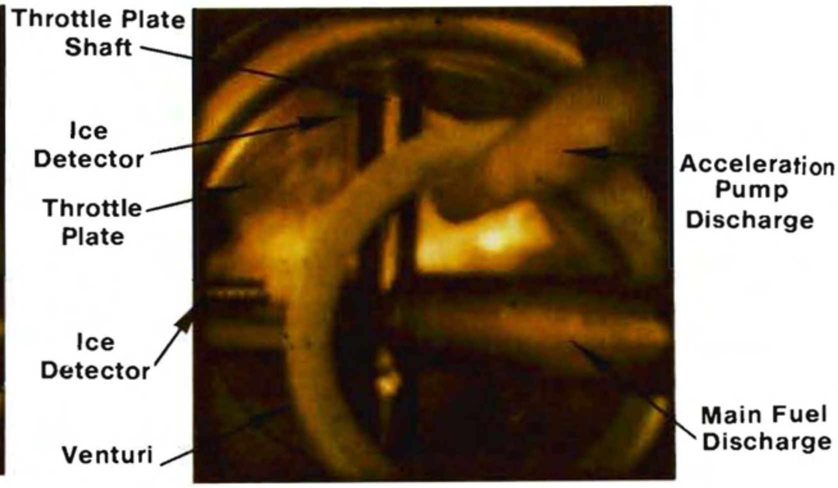

2000 (1890) AUTOGAS


2000 (1800) AUTOGAS


2350 (2295) AUTOGAS


2350 (2258) AUTOGAS

0 RPM



0 RPM

1600 (1430) AVGAS

1600 (1360) AUTOGAS

1800 (1675) AVGAS

1800 (1700) AUTOGAS

APPENDIX J

REAL-TIME CARBURETOR ICE PHOTOGRAPHS