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EXHAUST EMISSIONS AND OPERATING CHARACTERISTICS OF AN AUTOMOBILE ENGINE DURING COLD START AND WARMUP

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ABSTRACT

Ambient temperature has a marked effect on emissions of the two major pollutants from an automobile engine, namely, unburned hydrocarbons and carbon monoxide. Lower ambient temperatures result in lower cylinder-wall temperatures. This causes an increased quench zone thickness of charge within the combustion chamber thereby increasing the unburned hydrocarbon content of the exhaust. Lower ambient temperatures also mean that the carburetor choke would be closed, at which time a richer than stoichiometric air-fuel mixture is inducted into the engine. This condition prevails during the start and warmup period. The rich mixture promotes increased hydrocarbon and carbon monoxide emissions. Because nitrogen oxide emissions are dependent on peak combustion temperature and since this is insignificantly affected at lower ambient temperatures, no changes in the emissions of NO_x with ambient temperatures were investigated.

The exhaust emissions of an automobile engine during start and warmup were studied on an engine-dynamometer test stand. Tests were conducted in which emissions of carbon

monoxide and hydrocarbons (as n-hexane equivalent) were continuously monitored along with engine load, speed, manifold vacuum, and fuel and air consumption. The engine was run through a predetermined sequence of operation consisting of an idle period followed by application of fixed loads, an idle period and shut down. The tests were run in a range of cold and warm ambient temperatures.

A catalytic converter was then installed on the exhaust system and the engine was run through the same sequence of operations with the same loads and speeds and under similar ambient temperatures. Carbon monoxide and hydrocarbon emissions were continuously monitored as before.

The results obtained confirmed the observations of other investigators that emissions of carbon monoxide and hydrocarbons increased fairly substantially as ambient temperatures dropped. The increase of hydrocarbons was found to be more pronounced, probably because HC emissions are affected by wall quenching as well as rich air-fuel mixture, both of which are predominant at lower ambient temperatures.

The catalytic converter in the present set-up did not reduce emissions to a noticeable degree, especially at start-up and during the warmup period. This was probably because the catalyst surface took some time to warm up and reach operating temperature, and also because secondary air injection to supply additional oxygen for oxidation, was not provided.

In addition, engine warmup rates and the effectiveness of the thermostatically controlled air intake system were checked.

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1. INTRODUCTION

It has been confirmed that the automotive vehicle is a major source of pollution in the atmosphere. In 1965 it was estimated that the automobile accounted for about 60 per cent of the total pollutant emissions in North America[1,2,3*].

Air pollution is the presence of foreign matter (either gaseous or particulate or a combination of both) in the air which is detrimental to the health and/or welfare of man[3].

There are three sources of emittants from most automotive vehicles[4], crankcase ventilation (which has been controlled effectively in post-1964 vehicles). fuel evaporation loss (which has been controlled effectively since post-1971 vehicles) and the exhaust.

The primary remaining emission source from automotive vehicles is the exhaust.

The energy source for automotive vehicles is crude oil from underground which typically contains varying amounts of

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* Superscript numbers indicate references at the end.

sulphur. Most of the sulphur is removed during refining. Thus except for a few engines, the final fuel is one containing hydrocarbons with a small amount of sulphur and lead. The lead (usually in the form of tetraethyl lead) is added to increase the octane rating of the fuel. The chemical equivalent of average gasoline is iso-octane, C_8H_{18}[3]. If perfect complete combustion of this gasoline were assumed, the products of combustion would be carbon dioxide (CO_2) and water (H_2O). Water is not generally considered undesirable and therefore not considered a pollutant. Carbon dioxide is not normally considered a pollutant though it appears that the CO_2 content in the atmosphere[5] has increased 10 per cent since 1900. The CO_2 has the potential of affecting the weather, so it may be ultimately considered a pollutant.

Basically then, except for sulphur dioxide (SO_2) and lead compounds, the components considered as pollutants are the result of imperfect and/or incomplete combustion.

These pollutants are classified as unburned hydrocarbons (HC), carbon monoxide (CO), the oxides of nitrogen (NO_x) and particulates. The HC, CO and particulate emissions, because they are dependant on the combustion process itself, are affected by ambient temperature. The NO_x emissions are primarily a function of maximum combustion temperature and therefore relatively insensitive to ambient conditions.

Carbon monoxide is the most widely distributed and the most commonly occuring air pollutant. Total emissions of CO to the atmosphere exceed those of all other pollutants combined[6]. While CO has not been shown to be detrimental to plant life[7], high concentrations encountered by man can cause physiological and psychological changes and ultimately death.

The importance of hydrocarbons in air pollution lies almost entirely in their role in the formation of photochemical smog[7] when they react with the NO_x in the presence of strong sunlight[8]. Some HC also cause odour[4].

The NO_x, especially nitric oxide (NO) and nitrogen dioxide (NO_2) are toxic.

Particulates emitted from automobiles are composed of various organic and inorganic substances. These include lead, carbon, alkaline earth compounds, iron oxides, tar and oil mist. Of these, lead constitutes the largest weight fraction, at least when the fuel contains lead additives. Partly for this reason and partly because of its toxicity[4], the lead in particulate emissions has received the most attention.

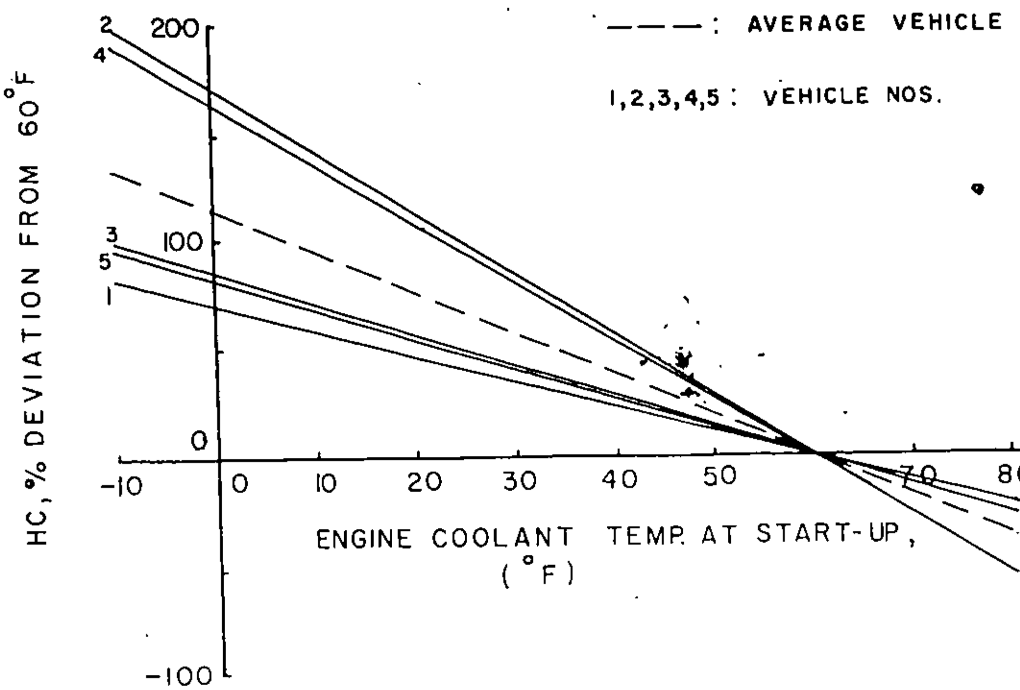
A number of methods of controlling pollutant emissions from automobile exhaust are known. These include fuel changes (switch from leaded to unleaded or low lead gasoline), modifications in the fuel metering system, improved methods of fuel mixing, different designs of the combustion chamber in order to achieve better combustion, air injection into the exhaust manifold to promote oxidation of HC and CO, exhaust gas recirculation - wherein some of the exhaust gas is recirculated into the cylinders to lower peak temperatures and thereby reduce NO_x formation, exhaust thermal reactors and catalytic converters.

The use of the catalytic converter has become popular in the U.S. recently. Located downstream of the exhaust, converters help oxidize the CO and HC to CO_2 and H_2O and reduce NO_2 to N_2. Though it would be desirable for a single converter to do this, it is an extremely difficult proposition in practice. Consequently dual catalytic converters are proposed. The first converter reduces the NO_x while the second one oxidizes CO and HC. Air injection would be provided between the stages. A more detailed description is given in Chapter 2 of this report. Today the converters in the market are used only for oxidizing CO and HC because NO_x reduction catalysts have not yet been introduced for commercial use.

Emission standards and control devices used in Canada have been adopted directly from the U.S. However, the urban driving and climatic conditions in Canada differ markedly from those in many parts of the U.S. The effectiveness and durability of certain emission control devices under Canadian winter temperatures and road conditions have also been questioned[9].

Previous research confirms that HC and CO exhaust emissions increase substantially with decreasing ambient temperatures. Fig. 1.1 from ref. 9 gives graphic displays of percentage deviations of HC and CO from emissions at $60^{o}F$ against engine coolant temperatures at start-up. Average HC emissions increased 100 per cent at $8^{o}F$ when compared with emissions at $60^{o}F$. Average CO emissions were double the $60^{o}F$ value at $20^{o}F$. The cars 1 through 4 were 1973 models of Toyota Corolla, Ford Torino, Chevrolet Vega and Plymouth Satellite, while car 5 was a 1972 Chevrolet Belair.

The Ministry of Transport and Environment Canada Emission Standards did not require the catalytic converter for 1975[10] but cars manufactured and sold in Canada by GM as well as a few



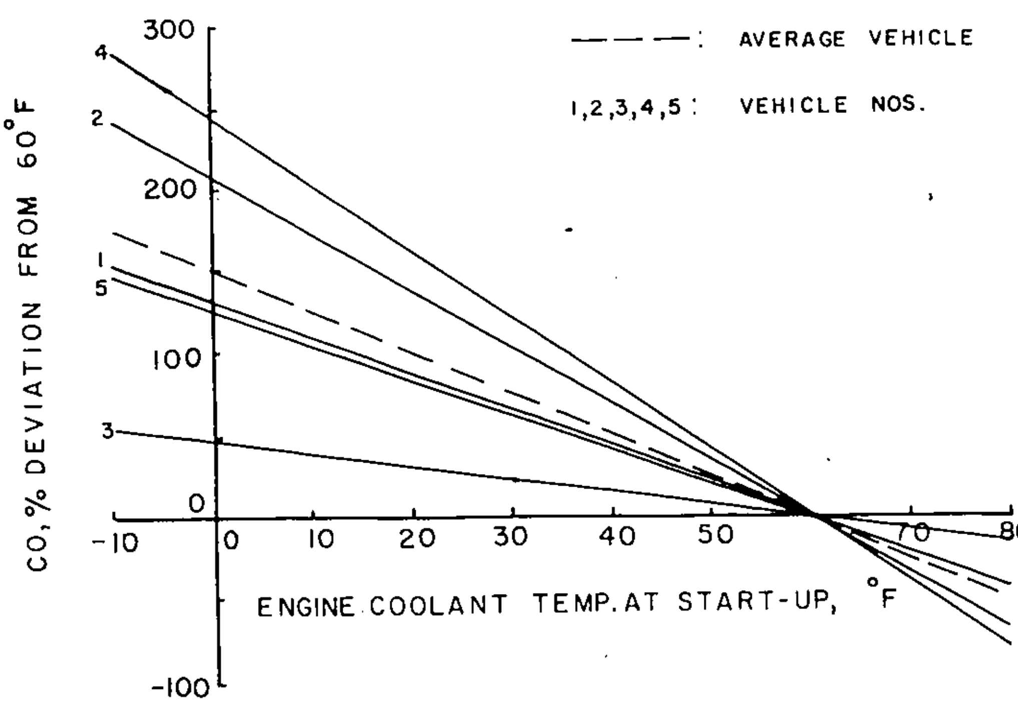


FIG. 1-1. HC AND CO EMISSIONS AS FUNCTION OF TEMPERATURE. (Taken from ref. 9.)

others have the converter. The converter performance in Canadian winters has not been studied in great detail. The purpose of the present investigation was to study emission levels of HC and CO at low temperatures with and without a converter, and to make a comparison with emissions at warm temperatures. In addition, engine warmup rates were also studied.

An engine-dynamometer test facility[11] was used for the tests. Dynamometer simulation of actual driving conditions is an effective method of engine testing. Since the U.S. Federal testing procedure (F.T.P.) is not truly representative of Canadian conditions it was decided to adopt a different procedure for the purposes of this study. Starting sequences and their effects on emissions during warmup were investigated. Exhaust emissions during warmup of an engine, especially after a cold start have been shown to be at the highest level[9,12]; the lower the ambient temperature, the higher the emissions. Engine warmup rates are also adversely affected.

Figure 1-2 from ref. 12 shows the effect of ambient temperature on emissions. These emissions were recorded during the first 3 minutes after start-up. Car A was a 1972 Canadian model with good driveability over a wide range of ambient temperature but with high CO and HC emissions under normal test conditions. Car B was a 1972 California model with poor driveability especially at low temperatures but with better emission controls.

It can be seen that HC and CO emissions and fuel consumption as indicated by the total carbon content in the exhaust increase drastically when temperatures drop, especially

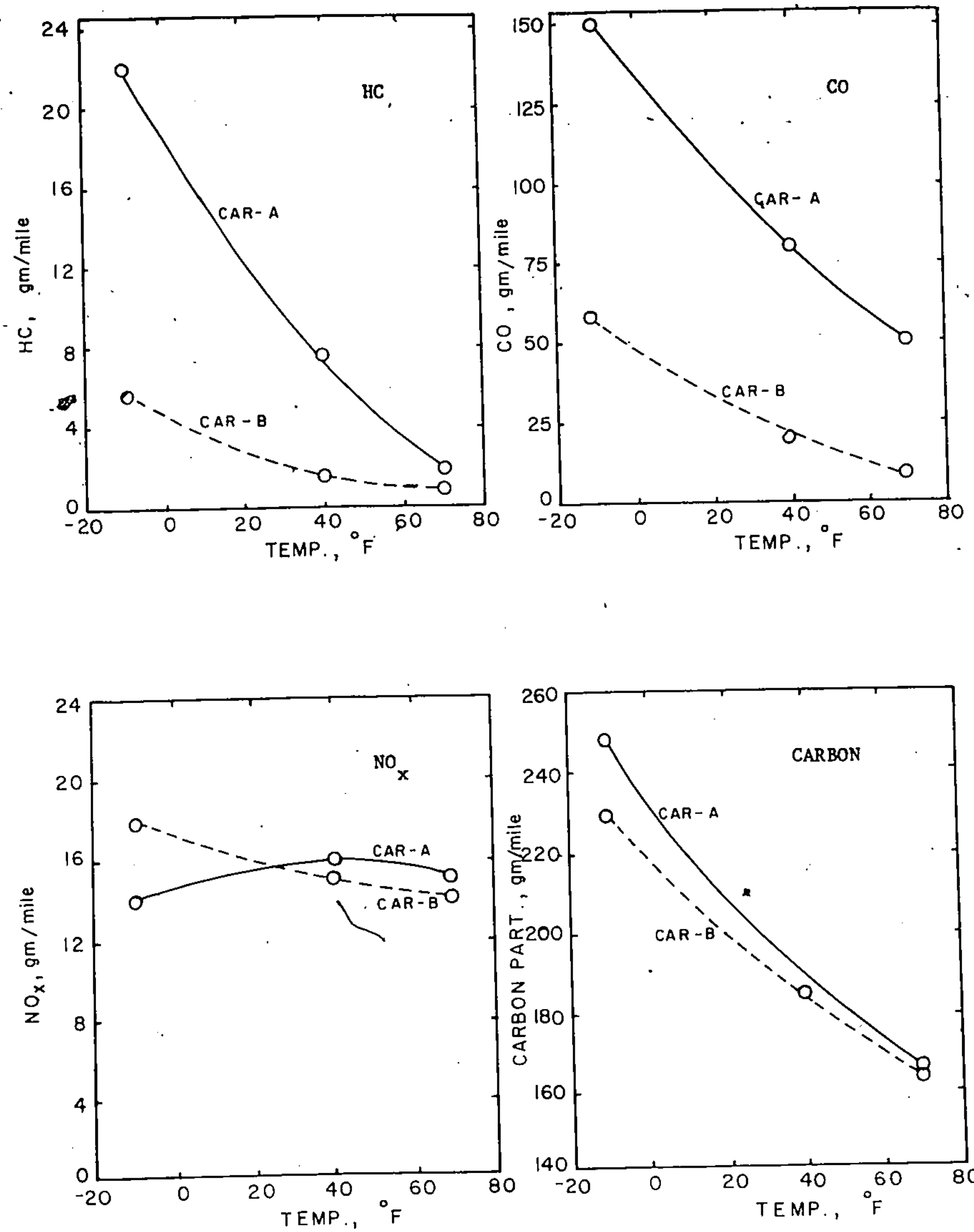


FIG. 1-2. EMISSIONS OF TWO CARS AS FUNCTION OF TEMPERATURE. (Taken from ref. 12.)

for car A. The NO_x emissions are not sensitive to temperatures.

These were the reasons why it was decided to concentrate on an investigation of CO and HC emissions in this study.

2. BACKGROUND THEORY

2.1. MECHANISM OF POLLUTANT FORMATION. A study of the mechanisms of pollutant formation can suggest means of controlling exhaust emissions. The mechanisms of the formation of unburned hydrocarbons, carbon monoxide and the oxides of nitrogen in automobile engines will be described.

2.1.1 Hydrocarbons. There have been three main sources of hydrocarbons from automotive engine operation, namely, unburned exhaust emissions, hydrocarbon evaporative emissions and crankcase ventilation.

Unburned exhaust emissions may arise from three sources[13]; wall quenching, the predominant source[14], incomplete combustion of the charge and exhaust scavenging.

Wall quenching is a combustion phenomena which arises when a propogating flame reaches the vicinity of a wall. The effect of the wall is a slowing down or stopping of the reaction. In general, wall quenching results both from chain breaking reactions and cooling of the layer of charge adjacent to the wall by the cool wall. As a result the flame will not propogate completely to the wall surface. As the flame passes through the combustion chamber, a dark region of unreacted mixture is left adjacent to the wall[15]. The thickness of this region (quench distance) normally varies from 0.002 to 0.005 in. depending on engine operating conditions.

The quench distance is influenced by several variables such as mixture temperature and pressure and equivalence ratio*. The wall surface material including any combustion chamber deposit has an effect[13]. Wall temperature also affects quench distance. When wall temperatures are relatively high the main source of HC emissions is attributed to wall quenching[16]. At lower wall temperatures, this effect is augmented by unreacted fuel which escapes the combustion process due to it not evaporating. Also low ambient temperatures promote lower wall temperatures so that the quench distance is increased thereby increasing HC emissions.

The effect of small crevices in the combustion chamber, such as the top land of the piston[17] and regions around the spark plug ceramic or the crevice left by an imperfectly fitted head-gasket, is to add to the quench effect[13]. In these cases all of the mixture within the crevices remains below its ignition point and leaves the cylinder unreacted.

The largest concentration of unburned HC in the exhaust of automotive engines was found by one investigator[18] to occur under decelerating conditions. The second largest

* Equivalence ratio is defined as the ratio of the actual air-fuel ratio to the stoichiometric air-fuel ratio.

concentration was found to be under idling conditions. He also attributed an abrupt increase in concentration of unburned HC with increase in intake manifold vacuum above 21 in. Hg to an initial failure of the flame to propagate through the mixture.

Incomplete flame propagation may be due to excessively rich or lean mixtures or exhaust gas dilution. Thus any case of incomplete combustion results in high HC emissions. Air-fuel ratio has a significant effect on exhaust HC[19] (see Fig. 2-1). With rich mixtures the quench effect is more predominant. With very lean mixtures the effect of incomplete combustion due to erratic flame propagation and misfire may be the most significant problem.

Poor engine design or large valve overlap may result in some fresh charge escaping to the exhaust. Scavenging in two-cycle gasoline engines can result in very high HC emissions.

The influence of various engine design and operating variables on HC and CO emissions are given in ref. 20.

Hydrocarbon evaporative emissions arise from two sources[13], namely, distillation of the fuel in the carburetor float bowl and evaporation of the fuel in the gas tank and fuel line. Reference 21 gives the various factors influencing these evaporative emissions.

Crankcase ventilation is due to the emission of blow-by gases from the crankcase. These gases were formerly vented into the atmosphere.

These last two sources are no longer of great concern since new cars have control devices which have virtually eliminated them.

2.1.2. Carbon Monoxide. The appearance of carbon monoxide from combustion processes is generally a simple result of oxygen insufficiency[4] on an overall or local basis.

The concentration of CO contained in exhaust products should correspond to a chemical equilibrium state represented by the equation

$$H_2O + CO \rightleftarrows H_2 + CO_2 \quad .$$

At maximum flame temperatures this equilibrium yields significant quantities of CO relative to CO_2 - even for lean mixtures. However, as combustion gases cool from peak flame temperatures to the much lower temperatures characteristic of exhaust products, this equilibrium shifts in a direction favouring oxidation of CO to CO_2. Consequently, for lean or stoichiometric mixtures, only small quantities of CO ultimately appear in the exhaust. For rich mixtures however, due to lack of oxygen[13], significant concentrations of CO persist even in the cool exhaust products.

Lower ambient temperatures result in the choke being operated in a closed position for a longer time so that the mixture is rich and results in higher CO emissions.

CO emissions increase rapidly for rich mixtures as can be seen in Fig. 2.1.

2.1.3. Oxides of Nitrogen. Nitric oxide is the principal oxide of nitrogen formed in combustion process. Upon exposure to additional oxygen in the atmosphere, nitrogen dioxide is usually formed. Most researchers refer to NO_x as the sum of all the oxides of nitrogen.

The formation of nitric oxide (NO) is favoured by the

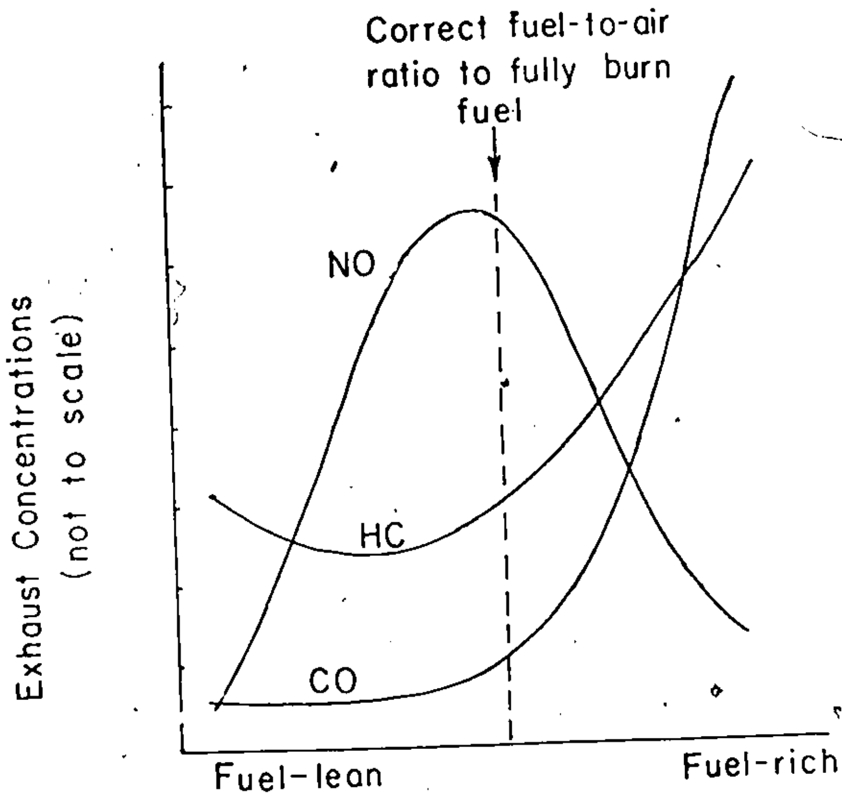


FIG. 2-1. EFFECT OF FUEL-TO-AIR RATIO ON EMISSIONS. EMISSIONS FROM A GIVEN AUTOMOBILE ENGINE VARY WITH THE FUEL-AIR RATIO IN THE COMBUSTIBLE MIXTURE. FUEL LEAN MIXTURES (EXCESS AIR) GIVE LOW HC AND CO EMISSIONS BUT HIGH NO POLLUTION. WITH FUEL RICH MIXTURES THE RELATIVE PROPORTIONS ARE REVERSED. NO SINGLE OPERATING POINT REDUCES ALL THREE POLLUTANTS.

existence of high temperatures. The high temperatures prevailing during the combustion process of the I.C. engine are sufficient to produce significant NO. However, as temperature increases rapidly during the combustion process, formation rates for NO limit the concentration below peak equilibrium levels. Similarly, although equilibrium calculations predict low concentrations of NO at the low temperature of the exhaust, relatively high levels are found in the exhaust since chemical reactions are slow relative to the cooling rate during the expansion of exhaust products[13].

The rate of NO formation depends both on temperature and concentration of oxygen present during combustion. Maximum NO occurs at slightly lean mixtures because of higher combustion temperatures under this condition. See Fig. 2.1.

Due to low ambient temperatures, the peak combustion temperature especially during the warmup period is lower than it would be if the engine would be warmed up in warmer ambient temperatures. Consequently NO formation is slightly reduced. This reduction however offsets the increase in NO formation due to greater air flow after a cold start[22].

Reference 23 gives the influence of engine variables on the formation of the oxides of nitrogen.

2.2. EMISSION CONTROL. The various emission control systems and devices will now be discussed. Control systems for evaporative emissions and crankcase ventilation are not described in detail because since 1971 these emissions have been effectively reduced.

2.3. EVAPORATIVE EMISSION CONTROL. Emissions from the crankcase have been controlled by venting the blow-by gases into the engine, usually into the intake manifold. In some engines, they are led into the air-cleaner, while in other designs, a two-way path leads to the intake manifold and the air-cleaner. Evaporation control is usually by means of a vapour-storing cannister filled with activated charcoal. This absorbs the excess fuel vapour and releases it when fresh air is drawn through.

2.4. EXHAUST EMISSION CONTROL. Exhaust emissions can be controlled by modifying or changing the engine or by installing "add-on" devices in the exhaust system of the engine. Since exhaust emissions are combustion generated, there are three main areas where pollution control can be studied and tackled. These are before, during and after combustion.

2.5. EMISSION CONTROLS BEFORE COMBUSTION. Exhaust emission control by changing or modifying the engine upstream of the cylinder inlet valve was among the first methods tried. There is still considerable work going on in this area. There are three possibilities that have been recognized as important namely, (1) the fuel, (2) the carburetion, and (3) the induction manifold.

2.5.1. The Fuel. Volatility is one of the most important properties of the fuel with regard to exhaust emissions. This is because volatility affects the air-fuel ratio and mixture distribution. The fuel must not be of too high a volatility to cause vapour-lock problems, or possible increase of evaporative emissions especially when the engine is hot-soaked after a hot cycle. It should not be of too low a volatility to cause starting problems and mixture maldistribution[24] and incomplete combustion with consequential increased emissions.

There has been some indication that the use of unleaded fuel reduces HC formation[25]. This may be due to the effect of reduced deposits with unleaded fuel and consequently reduced surface-to-volume ratio. The deposits also tend to absorb raw unburned fuel thereby increasing HC emissions towards the end of the exhaust stroke. However, the consequences of using unleaded fuel are a reduction of the octane number of the fuel and the compression ratio of the engine. This reduces the fuel economy, efficiency and maximum power developed by the engine[26].

2.5.2. <u>The Carburetion</u>. The carburetion system of an internal combustion engine is designed to supply the cylinders with a combustible mixture of an air-fuel ratio pre-determined to provide the best engine performance or economy. Unfortunately the range of air-fuel ratios which give best engine performance do not coincide with those which result in minimum emission of exhaust pollutants. However, the tendency now is to provide lean air-fuel mixture carburetion, if no other emission control systems are fitted to the engine. This is most effective for the control of CO and more effective for the control of HC than NO_x[27]. In order to achieve best results, however, the air and fuel must be homogeneously mixed. Mixture quality is an important parameter in reducing HC and CO emissions[28]. In order to achieve a homogeneous combustible mixture the fuel has to be atomized and vaporized. Fuel vaporization may be enhanced by heating the intake manifold with exhaust gas or cooling water.

Providing a lean mixture for engine operation would necessitate using modified spark plugs, increased spark energy, increasing mixture turbulence, adjusted spark timing and a change of combustion chamber design[29].

An alternative to carburetion is fuel injection for improved emissions from spark ignition engines. Fuel injection, if carried out properly, will reduce HC emissions[30] because the fuel flow variation with air flow can be controlled more precisely. Fuel injection permits easier starting especially from cold, since atomization of fuel does not depend on the cranking speed. Consequently CO and HC emissions from a cold start could be lowered. Electronic fuel injection[31] provides very precise control of fuel distribution to individual cylinders under both steady-state and transient operating conditions. Sensors in the exhaust help maintain the air-fuel ratio for lean running and thus reduce HC and CO, probably at the expense of increased NO_x.

2.5.3. The Induction Manifold. Uniform fuel distribution among the cylinders of the engine will permit lean air-fuel mixtures to be used. This would result in lower HC and CO emissions[32]. Uniform fuel distribution gives lower CO and usually higher NO_x at a given air-fuel ratio. Fuel distribution can be altered by geometric changes in the induction manifold. Improved methods of mixture distribution with mixture homogeneity reduces cyclic cylinder pressure variation, cylinder-to-cylinder and cycle-by-cycle air-fuel ratio variation, and subsequently produces a reduction in HC and CO[28].

2.6. EMISSION CONTROLS DURING COMBUSTION. These emission control systems formed the second stage of progress towards lowering automotive emissions. Among the various possibilities in this area are (1) modification of existing design, (2) changing the existing design, and (3) providing a new design.

2.6.1. Modification of existing design. An early method for reducing HC emissions was to increase the engine idle speed. Increased idle speeds significantly decreases HC[33]. This is due to the throttle not being fully closed during deceleration, causing lower vacuum in the intake manifold. This causes less exhaust gas dilution of the incoming charge and consequently better combustion. Excessive increases in idle speed may nullify the reduced concentration with increased exhaust flow rate and subsequently higher mass emissions.

Retarding the ignition timing decreases the HC concentration[34,19] as a result of decreases in the unburned fuel from the crevites and in the fraction not oxidized in the exhaust system, even though the unburned quench gases and the fraction of the crevice gases not reacted tend to increase the exhaust HC concentration. Spark timing has very little influence on the CO concentration except at very retarded timing when lack of sufficient time to complete CO oxidation leads to increased CO emissions[20]. Nitric oxide can be reduced by retarding the spark. However, retarding the ignition timing lowers the fuel economy.

By increasing the valve overlap, the chances of dilution of the fresh charge by the exhaust gases trapped in the cylinder towards the end of the exhaust stroke, are increased. This results in incomplete flame propagation after ignition. Also, there would be a definite oxygen insufficiency for complete combustion. These two factors would tend to increase HC and CO formation. But because the exhaust gases trapped in the cylinder would have an opportunity to burn more completely, the HC and CO in the exhaust would tend to be lowered. The combined effect of these two factors would result in HC and CO levels in the exhaust to be generally unchanged. However, dilution would reduce the peak combustion temperature in the cylinder so that NO formation would be reduced[35].

Increasing the exhaust back-pressure decreases NO[36]. This is due to increased exhaust gas remaining in the cylinder, thus reducing peak combustion temperature. Hydrocarbons are also reduced as a result of increased back-pressure, since the last exhaust gas to leave the cylinder has a higher HC concentration. Since this is left in the cylinder, it is subsequently burned in the next cycle[13]. But by increasing the back-pressure, the maximum power is reduced.

2.6.2. Changing the existing design. Reducing exhaust emissions by changing the engine design necessitates a study of the following, (1) compression ratio, (2) surface temperature, (3) combustion chamber design and (4) engine design factors.

2.6.2.1. Compression ratio. Reduction in compression ratio was made in numerous 1971-model automobile engines. Lower compression ratios result in reduced HC emissions. This is because of the resulting increase in the clearance volume which traps more residual gas in the cylinder to burn in the next cycle[37]. Also, lower compression ratio engines have higher exhaust temperatures. This higher temperature is useful for promoting oxidation of the HC in the exhaust particularly with a catalytic converter or a thermal reactor. The lower octane requirement for the fuel used in a lower compression ratio engine permits the use of unleaded gasoline which is necessary for catalytic converter operation. But a lower compression ratio engine is less efficient, so for the same power, the fuel consumption is high.

2.6.2.2. Combustion chamber surface temperature. Increased surface temperatures cause lower exhaust HC concentration[38]. This is because of a consequent decrease in the thickness of the quench zone. Surface temperatures may be increased by increasing the coolant temperature by using a higher portion of ethylene glycol in the coolant to raise its boiling point. Rust or scale on coolant surfaces also increase surface temperatures. However, an increase in the average surface temperature will have an adverse effect on the engine octane requirement and volumetric efficiency[30].

2.6.2.3. Combustion chamber design. This is one of the most important factors in the category under discussion. The shape of the combustion chamber plays an important part in controlling exhaust emissions. This is especially true for HC. For instance, one investigator found that a disc-shaped chamber is more efficient in reducing HC and NO than a hemispherical chamber[39]. Reference 40 gives more details on the effect of the combustion chamber shape on NO formation.

Studies have been carried out on the effect of the location of the spark plug for lower emissions. Nitric oxide emissions were not effected by locating the spark plug near the intake or exhaust valves, but the HC emissions were the lowest with the spark plug nearest the exhaust valve and increased with the distance of the spark plug from the exhaust valve[41]. However, the combustion chamber shape and spark plug location must be evaluated experimentally before any new engine design is implemented[39].

An important parameter in combustion chamber design vis-a-vis exhaust emissions is the surface-to-volume ratio (s/v). A lower s/v results in lower HC emissions[37]; CO being unaffected. Lower s/v results in a lower quench surface so that HC concentrations may be lowered[13]. Reduced s/v however, decreases heat loss to the coolant. As a result, NO_x emissions may increase.

2.6.2.4. Engine design factors. These factors are stroke-to-bore ratio (s/b), number of cylinders, and displacement per cylinder. These parameters have to be such as to keep the s/v low in order to reduce HC emissions. The larger the s/b (or longer the stroke) the lower the s/v. The greater the number of cylinders lower the s/v. Also, the larger the displacement per cylinder the lower the s/v. Reference 37 gives more details on the effect of these factors on emissions.

2.6.3. Providing a new design. A new design could be one of the following; (1) providing a new design for the combustion chamber; like the stratified charge or divided combustion chamber, or (2) providing a new design for the engine; like the Rankine or Stirling cycle engine.

2.6.3.1. The stratified charge engine. In an engine of this type[42], a lean mixture is used. The air supply is kept constant while the fuel supply is varied. This reduces power loss due to throttling. To prevent misfire, some means of providing a rich mixture only at the spark plug is made. This supplies energy for igniting the remaining fuel in the combustion chamber, thus sustaining combustion. This is an efficient method of reducing HC and CO because of better combustion, and NO because of lower temperatures in the cylinder. Obert[30] gives a few references on stratified charge engines.

2.6.3.2. The divided combustion chamber engine. This is a major sub-division of the stratified engine. There are discrete main and auxiliary chambers[43]. Among the various types classified under this category is the Honda CVCC engine[44]. This CVCC (compound vortex controlled combustion) engine develops a stratified charge to produce stable combustion of an overall lean mixture. By controlling the fuel mixtures supplied to the main and auxiliary chambers, and by geometrical design of the combustion chamber, the mixture formed immediately before ignition is such as to result in low HC, CO and NO_x emissions, and improved fuel economy, compared with conventional engines. Reference 43 gives other types of divided combustion chamber engines.

2.6.3.3. Other types of engines. Various types of engines for low pollution have been investigated. These include the gas turbine, Rankine and Stirling cycle engines, and rotary engines with suitable modifications[45,46]. The diesel engine is a viable alternative to the gasoline engine as far as pollution is concerned.

2.7. EMISSION CONTROLS AFTER COMBUSTION. These devices which form the third stage in the progress towards lowering automotive emissions, are fitted to the engine exhaust system. There are three main such devices used; these are, (1) exhaust gas recirculation, (2) thermal reactors and (3) catalytic converters.

2.7.1. Exhaust gas recirculation. While all the emission control systems or devices discussed so far were fairly effective in controlling HC and CO emissions, most of them tended to increase NO_x emissions. Among the methods favoured for NO_x reduction are by spark retard and charge dilution. Spark retard, as discussed earlier, reduces NO_x emissions to some extent, but not sufficiently enough to meet stringent NO_x emission standards. Charge dilution is achieved by mixing the intake air with some inert gas, usually exhaust gas. This gas will help reduce the peak combustion temperature in the cylinder. This reduces NO_x emissions[47,48]. Since the amount of nitrogen oxides, especially NO produced in the cylinder from atmospheric nitrogen and oxygen is an exponential function of combustion temperature, even a moderate decrease in combustion temperature will result in a significant decrease in NO production[27].

Exhaust gas is tapped, preferably from the exhaust pipe between the exhaust manifold and the muffler. The flow control valve, which controls the flow of recirculated exhaust, is actuated by the carburetor throttle in some engines[27]. In some designs, a variable orifice valve is operated by the pressure differential between the intake manifold and the exhaust back pressure[49]. Good cylinder-to-cylinder distribution is essential for maximum benefit[13].

The E.G.R. system is an effective way of reducing NO_x emissions and it has been tested for durability[50]. There is an excessive intake system deposit buildup, and increased oil sludging[13]. There is also a loss of power and increased cycle-by-cycle variation in the charge[51] which results in lower flame speeds and more erratic running of the engine. This results in the loss of driveability of the automobile.

2.7.2. Thermal reactors. Carbon monoxide and unburned hydrocarbons are the products of incomplete and/or insufficient combustion, during the process that takes place in the cylinder. If there is some means of completing the combustion so that the unwanted pollutants are removed, the engine exhaust would be a lot cleaner. In present designs of engine combustion chambers and ignition systems, this is not possible.

The thermal reactor is a device fitted to the exhaust pipe, ~~provided to~~ complete the oxidization of HC and CO to H_2O and CO_2. This is done by injecting air into the exhaust[13]. This promotes oxidation of CO to CO_2 through the equation,

$$2CO + O_2 \rightarrow 2CO_2$$

To achieve successful burning (the oxidation process involves burning of the exhaust gases), flammability considerations require that the initial temperature plus the temperature from the release of the chemical energy (because the reaction involving the oxidation of CO is exothermic), must be greater than about 1800°F[52.53].

The NO_x emissions may increase if (a) high exhaust temperatures result, due to oxidation of CO and HC by added air or (b) injected air enters the cylinder through the exhaust valve (due to valve overlap) and leans the mixture to increase the peak temperature[54].

For a high degree of oxidation of HC and CO, a high exhaust temperature with sufficient injected air and residence time (time required to complete the oxidation) are needed. If a flame is generated, the heat generated by the combustion of the HC and CO must keep the reaction going.

Carbon monoxide provides most of the combustion generated heat because of its abundance in the exhaust gas stream. Hence thermal reactors are developed most easily for rich carburetion situations. The basic factors governing the combustion of HC and CO in the exhaust[55] are (a) composition of the reacting mixture, (b) residence time and (c) temperature and pressure of the mixture. These are in turn affected by the basic engine variables such as spark-timing, air-fuel ratio etc. It is also necessary to optimize the air injection rate for lowest HC and CO.

Minimum HC and CO are obtained with rich mixtures. Also if too much air is injected, quenching of the exhaust will increase HC to levels higher than those without air injection.

Air injection rate depends on the exhaust temperature, especially for low CO emissions, so ambient temperature and warmup rate are important.

At leaner mixtures, since air injection would cool the exhaust, heat conservation would be necessary. Proper insulation of the reactor core has to be provided. In one design described in the literature[56], reacted exhaust gases are recirculated around the core to maintain a layer of hot gases between the core and the outer casing. The inner core is designed to provide adequate mixing of the air injected into the exhaust system.

Also, to sustain a flame, the oxygen essential for burning must be added and mixed with the exhaust gases before the temperature drops below the flammability limit. So the injected air should be preheated.

Fuel economy of an engine using a thermal reactor system is a problem, especially with small engines[53]. This is due to the necessity of using a rich mixture for proper oxidation. Other reactor systems are given in ref.53.

2.7.3. Catalytic converters. The reaction of oxidizing[57] CO and HC can be speeded up by the use of catalysts. When mixtures of CO and O_2 (or H_2 and O_2) are brought into contact with a smooth platinum surface at 500-700 K, they react at a rate which is proportional to the partial pressure of O_2 and inversely proportional to the partial pressure of CO (or H_2). The reaction velocity increases rapidly with temperature. With the platinum at 750-1050 K, the velocity is practically independent of temperature; being limited largely by the rate at which the gases come into contact with the surface. With an excess of O_2, the velocity is proportional to the pressure of O_2.

Catalysts are substances which change the rate of chemical reaction without themselves being permanently depleted. They may or may not actually enter into the reaction and if they are consumed at all, the rate of consumption is small[3].

Catalysts are useful in speeding up a combustion reaction, but catalyst activity can be easily impaired by

a) chemical reaction with the gas stream, or/and

b) physical coating.

Catalyst loss usually results from attrition.

Catalysts have been considered for purifying automotive exhaust for a long time. Till the early 1960s, researchers were looking for catalysts to reduce all the emissions from the exhaust. The problems of catalyst deactivation by impurities in the gasoline and high temperatures in the exhaust were also hindrances to the use of the catalytic converter.

Catalytic converters are generally of two types, namely, granular and monolithic (honeycomb). Granular types may be cylindrical (pelleted) or spherical, with the diameter of the circular cross-section about 1/16 to 1/4 in. The granules are usually built up from a porous refractory inorganic oxide like alumina, silica, etc., called the catalyst support. Covering the surface of the pore walls a few molecules thick, is the layer of the active catalytic ingredient called the promoter. Promoters decrease the pore volume of the support, which is why the quantity of promoter used should be small. Pore wall surface areas of 100-300 acres are not uncommon[58].

The monolithic type is a one-piece ceramic substrate with a corrugated wire mesh support[59] which is coated with the promoter in the same manner as the granular type. The monolithic types have less attrition problems, faster thermal response and easier packaging when compared to the granular type[60]. They also have a lower pressure drop, are smaller in size, and use the catalytic component more effectively[61]. They have disadvantages too because they

(a) have internal failures due to faster thermal response, and

(b) undergo more rapid deactivation by trace poisons due to low internal surface area which makes the active sites more accessible to lead and other poisons[60].

The catalyst support must have certain design features before it can be accepted for an automobile exhaust system. These include low back-pressure at the outlet, resistance to attrition and high exhaust temperatures and must present a high surface area and controlled porosity, for efficient conversion of pollutants.

<u>Catalyst reactions</u>.

$$2CO + O_2 \rightarrow 2CO_2$$

$$2H_aC_b + (2b+a/2)O_2 \rightarrow 2bCO_2 + aH_2O$$

$$2NO + CO \rightarrow N_2 + CO_2$$

$$2NO + 2H_2 \rightarrow N_2 + 2H_2O$$

While the first two equations represent the oxidation of the CO and HC respectively, the last two represent the reduction of NO by CO and H_2. All these reactions are thermodynamically feasible at the temperatures prevailing in the engine exhaust[4].

Catalyst location. The location of the catalytic converter should be such as to fit adequately in the automobile exhaust system. The warmup characteristics also depend on the proper location.

Air injection. Catalytic converters of the oxidizing type may use air injection to complete the combustion[13]. Or, they may operate without air, utilizing excess oxygen from lean engine mixtures if good heat conservation is achieved. Since this is not possible, present day engines equipped with a converter are fitted with an air pump for secondary air injection into the exhaust manifold.

Catalyst degradation. Durability is a major problem with the catalytic converter. Fig. 2.2 (from ref. 62) gives an indication of the gross change in catalytic activity due to overheating (no special effort was made to control the feed gas composition, catalyst temperature, E.G.R. rate, or space velocity).

A study by Englehard Industries[63] indicated that effective control of HC and CO for 50,000 miles was achieved with a monolithic catalytic converter in the absence of system or engine malfunction. The gradual increase in the HC emissions, which was found to occur, was found to be primarily due to thermal

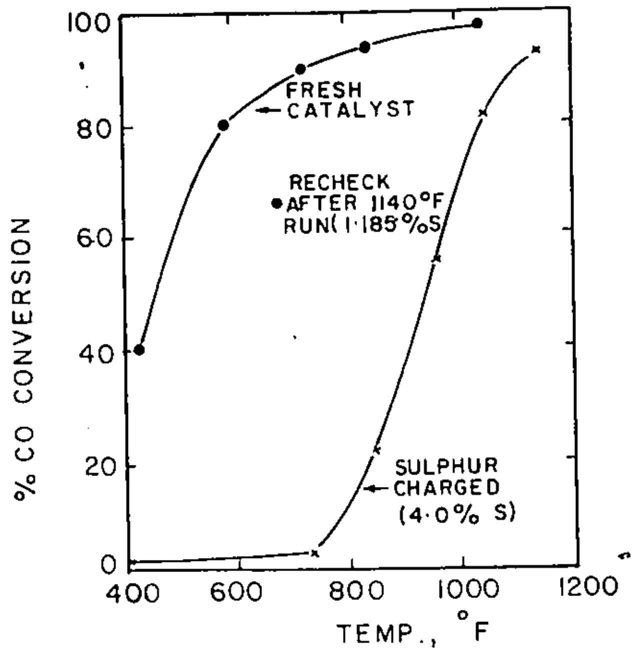


FIG. 2-2. EFFECT OF LAB SULPHUR CHARGING ON CO REACTIVITY OF A CU-CR CATALYST (HOURLY SPACE VELOCITY 15,000)
(Taken from ref. 65.)

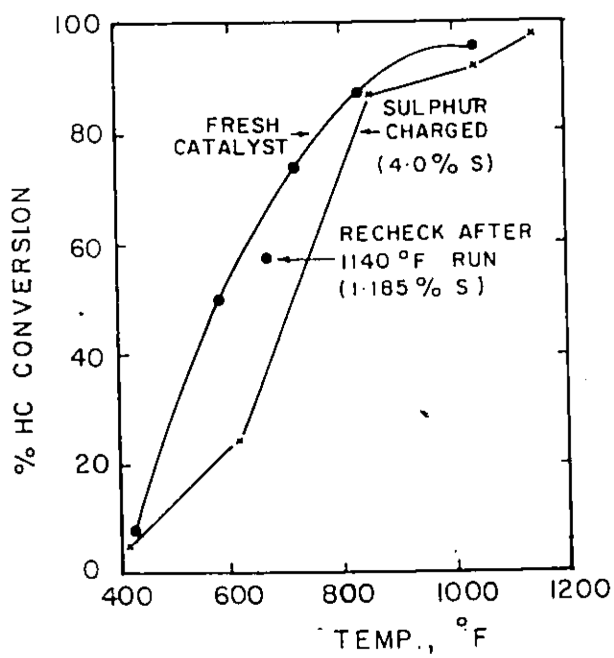


FIG. 2-3. EFFECT OF LAB SULPHUR CHARGING ON HC REACTIVITY OF A CU-CR CATALYST (HOURLY SPACE VELOCITY 15,000)
(Taken from ref. 65.)

effects.

However, the presence of lead and sulphur in the gasoline presents a different picture. Fig. 2.3 shows the loss of efficiency of HC and CO conversion after 25,000 miles of steady-state aging, with increasing lead content in the fuel[64]. From this figure, it can be concluded that unleaded or low leaded gasoline (lead below 0.5 g/gal) has to be used.

Figs 2.4 and 2.5 show the effect of distributing sulphur uniformly throughout the catalyst beads, as compared to a fresh catalyst. The CO reactivity is dramatically decreased (Fig. 2.4) but the reduction of activity of HC conversion is not so dramatic (Fig. 2.5). The single point in the two figures indicates that the CO and HC reactivity had partially recovered at 680°F (65% conversion for CO) when the sulphur content was decreased from 4.0 to 1.85 per cent[65].

Phosphorus compounds added to the gasoline as lead scavengers, valve-seat anti-wear agent or detergent also cause deterioration of the catalyst[66].

Sulphuric acid emission. Installation of oxidizing catalysts in automobile exhaust systems has led to an increase in the particulate matter emitted. This increase was found to be most noticeable when the engine used lead-free gasoline. This particulate matter was found to consist of aqueous sulphuric acid (H_2SO_4). This is because fuel sulphur emerges from the engine as sulphur dioxide, SO_2. The catalytic converter oxidizes most of the SO_2 to sulphur trioxide, SO_3, thus

$$2SO_2 + O_2 \rightarrow 2SO_3$$

and the SO_3 easily reacts with the moisture in the exhaust to

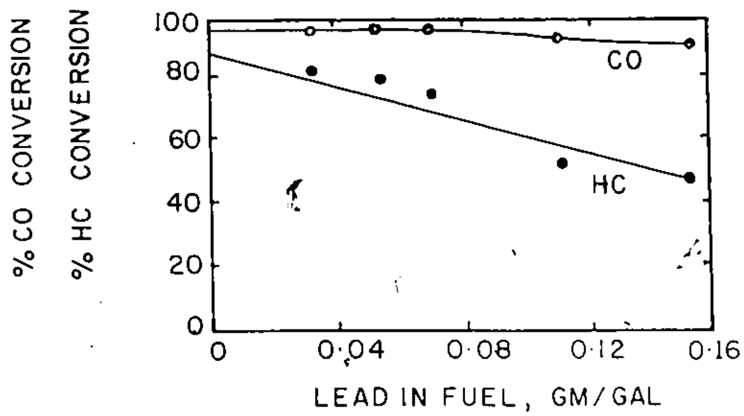


FIG. 2-4. DYNAMOMETER CONVERSIONS AFTER 25,000 MILES OF STEADY STATE AGING. (Taken from ref. 64.)

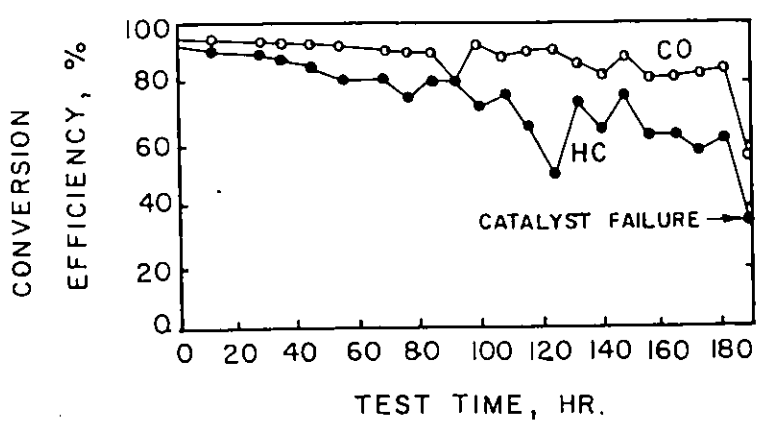


FIG. 2-5. DYNAMOMETER CATALYST EFFICIENCY TEST. (Taken from ref. 62.)

form sulphuric acid, thus

$$SO_3 + H_2O \rightarrow H_2SO_4$$

About 40% of the gross particulate emission is H_2SO_4, depending on the humidity. The rest is primarily water. Without the catalyst, the H_2SO_4 is less than 1/50 as much as with the catalyst; the bulk of the fuel sulphur being emitted as sulphur dioxide[67].

Catalyst warmup. Another problem with a catalytic converter is that it will not come into operation until it reaches its operating temperature. This temperature, called the "light-off" temperature, is usually above 1000°F and the converter takes some time to reach it. Consequently, when the engine is started after a cold-soak, when emissions are the highest, the converter is not in operation. Improved methods for fast catalyst warmup have to be provided. Increasing the exhaust temperature by modifying the engine spark timing, using the heat of reaction of the oxidation of CO and HC,(especially the former because it is more abundant), locating the converter as close to the exhaust manifold as possible to prevent heat loss, and use of auxiliary heating devices to warm up the converter; these are some of the methods that have been used or tried[53].

Fig. 2.6 shows the single and dual bed catalytic converter and explanations are also given.

2.8. CONTROL TECHNIQUES ON ENGINE UNDER TEST. Specific emission control techniques employed on the engine tested are described in detail in Appendix A.

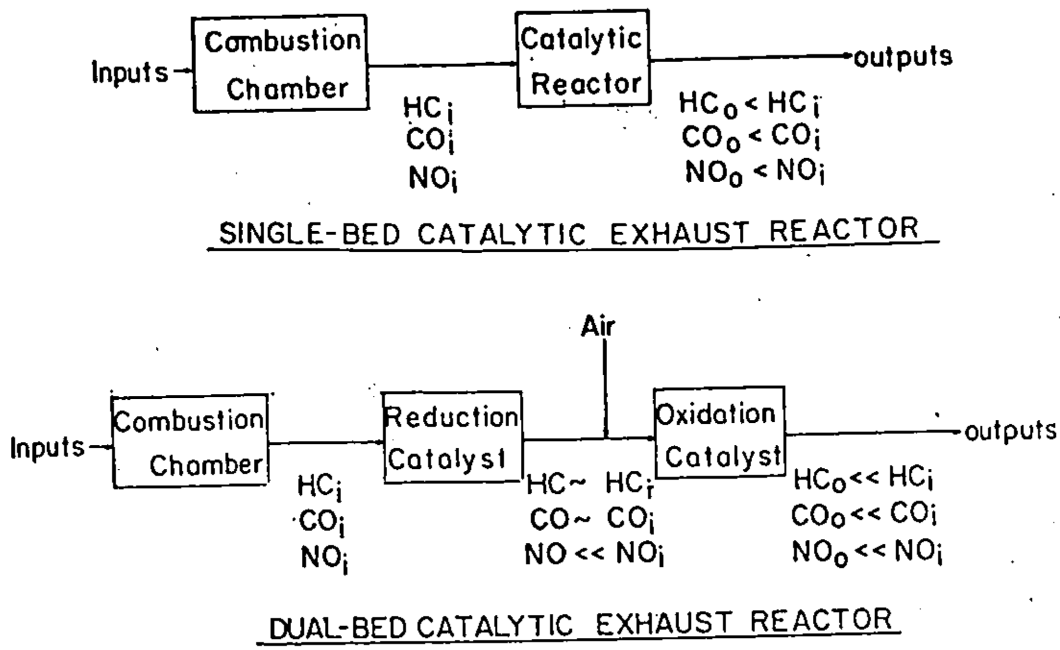


FIG. 2-6. SINGLE- AND DUAL-BED CATALYTIC EXHAUST REACTOR. (Taken from ref. 4.)

WITH A SINGLE-BED REACTOR EXTREMELY CLOSE CONTROL OF INPUT CONDITIONS TO THE COMBUSTION CHAMBER, ESPECIALLY AIR-FUEL RATIO, IS REQUIRED.

WITH A DUAL-BED REACTOR, CLOSE CONTROL OF THE AIR-FUEL RATIO IS NOT REQUIRED. ONLY, MIXTURE TO THE ENGINE MUST BE RICH TO ENSURE REDUCTION CONDITIONS IN THE FIRST REACTOR. SECONDARY AIR ADDED BETWEEN THE TWO REACTORS HELPS THE CATALYTIC OXIDATION OF HC AND CO IN THE SECOND REACTOR.

3. EXPERIMENTAL SET-UP : EQUIPMENT USED

The engine laboratory was designed to meet the following objectives:

1. Engine emission study, under cold and hot ambient conditions,

2. Evaluation of exhaust emission control system performance,

3. Study of engine performance for low emissions,

4. Fuel consumption tests, and

5. Engine temperature measurements.

3.1. THE TEST LABORATORY. The laboratory consists of an engine test cell and an adjoining instrument and control room.

The test cell consists of the engine and dynamometer mounted on a test bed plate; the engine being connected to the dynamometer through a driveshaft with two universal joints. The engine exhaust is connected to a pipe leading to the outside. A fuel tank mounted at a higher elevation supplies fuel to the engine carburetor. The closed-loop system heat-exchanger is mounted below the cell, along with the coolant pump and coolant drum. Fig. 3.1 shows a plan drawing of the engine cell.

The instrument and control room houses the strain-gauge indicator, the temperature recorder, the exhaust gas analyzer and recorder, the fuel and air-flow meters, and the carburetor throttle control system. The engine can be controlled from this room without having to enter the cell at any time during a test run. Fig. 3.2 shows a plan drawing of the instruments in the control room.

3.2. THE VENTILATION SYSTEM. For cold weather operation the cold-air duct above the engine cell was brought into use. The cold air is drawn from outside by means of a fan. The air is directed into the cell through louvres on the roof of the cell. Except for slight losses in the piping, the temperature of the air in the cell was the same as that of the outside air. On one occasion, the difference between the outside air temperature and the engine cell temperature was found to be about 3°F. The air from the cell is exhausted from below by means of an exhaust fan.

3.3. THE COOLING SYSTEM. An existing[11] cooling water system was used. Because of low temperatures in the cell during the cold temperature tests, the closed-loop cooling system was used. To lower the freezing point of water, it was mixed with ethylene glycol, in the ratio of approximately 1:1. A schematic diagram is shown in Fig. 3.3.

The reservoir tank has a capacity of about 40 gallons. The coolant is pumped into the heat exchanger and cooled before it enters the dynamometer. Another branch enters the cooling column. Hot coolant from the engine is passed into the

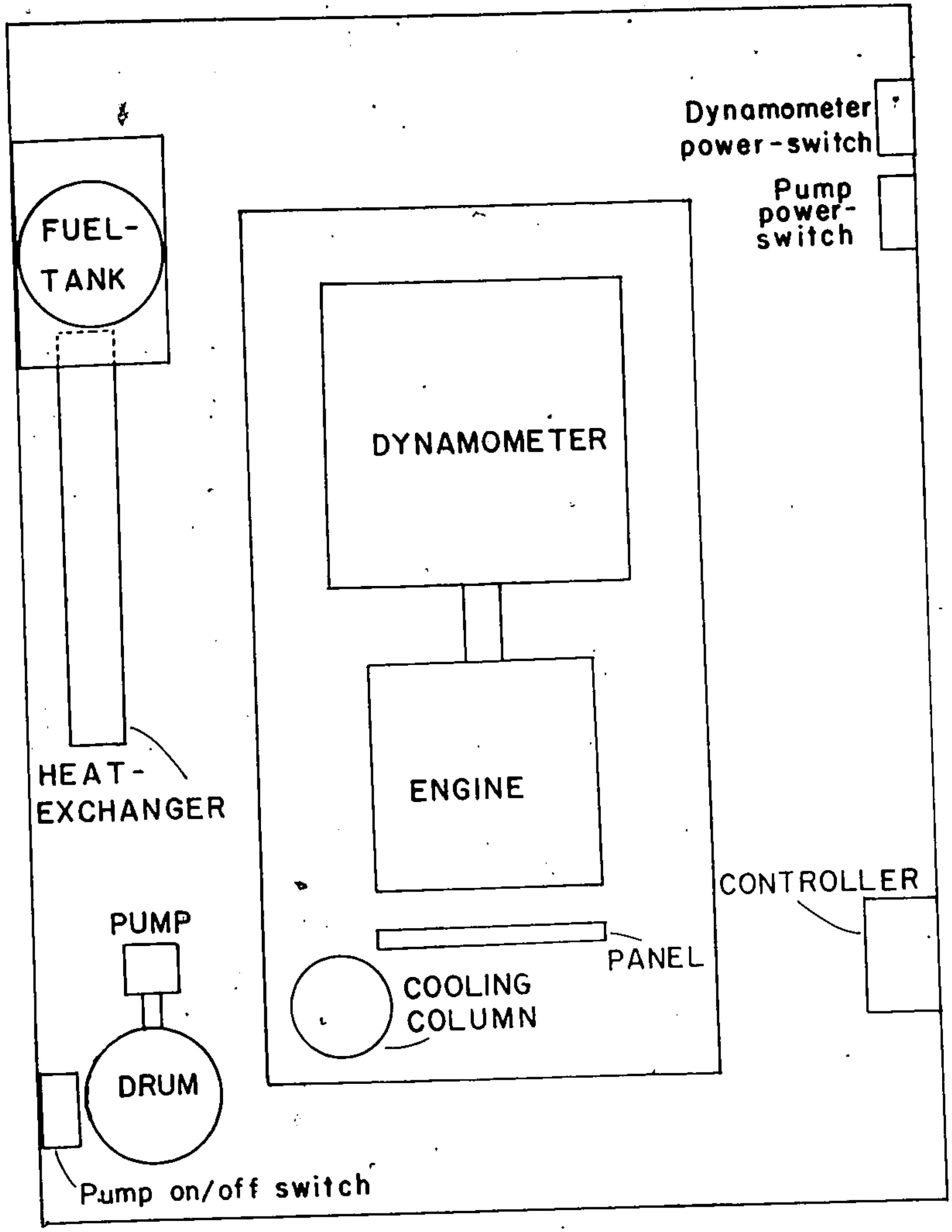


FIG. 3-1. A PLAN DRAWING OF THE ENGINE CELL.

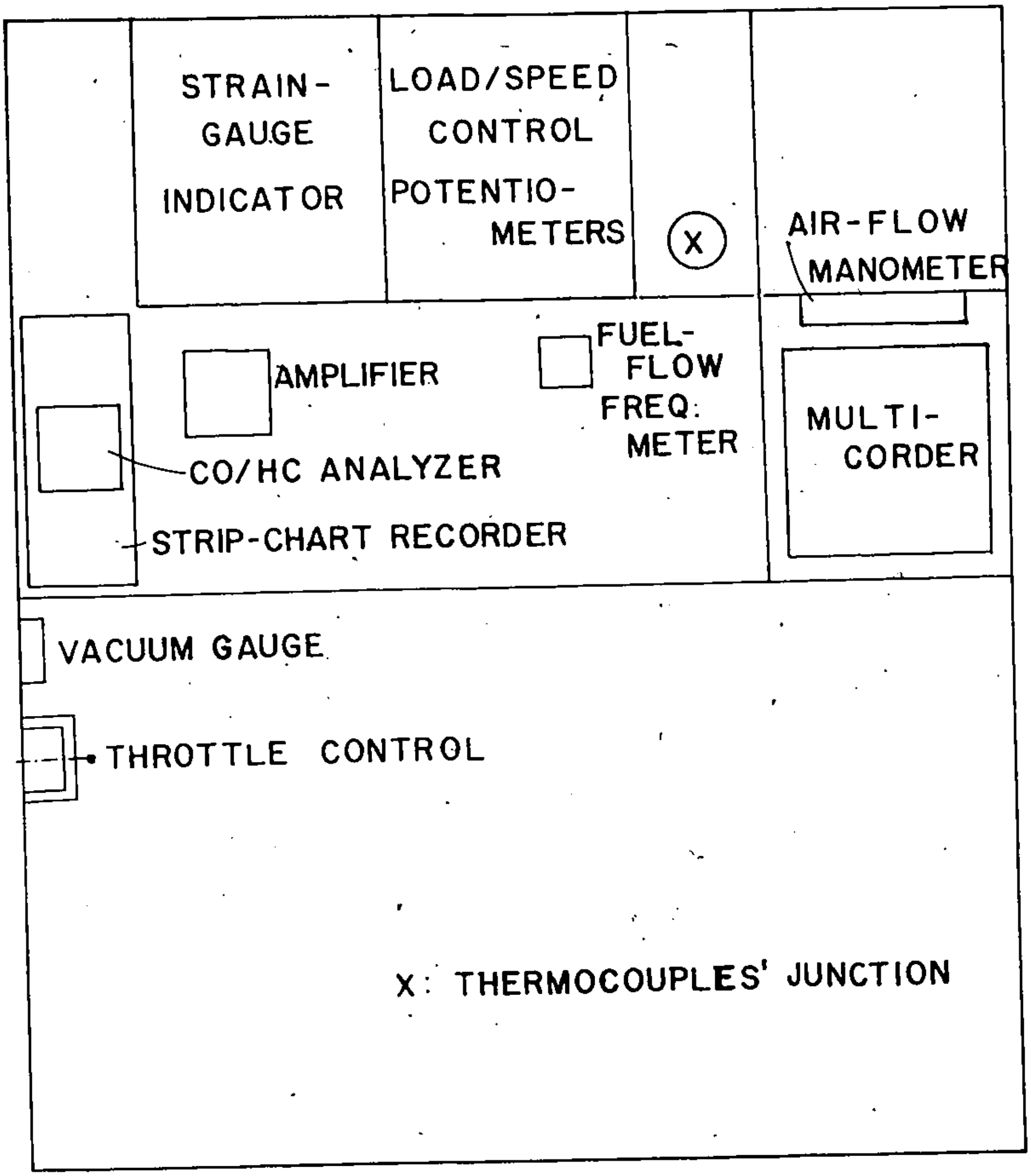


FIG. 3-2. A PLAN DRAWING OF THE INSTRUMENTS IN THE CONTROL ROOM.

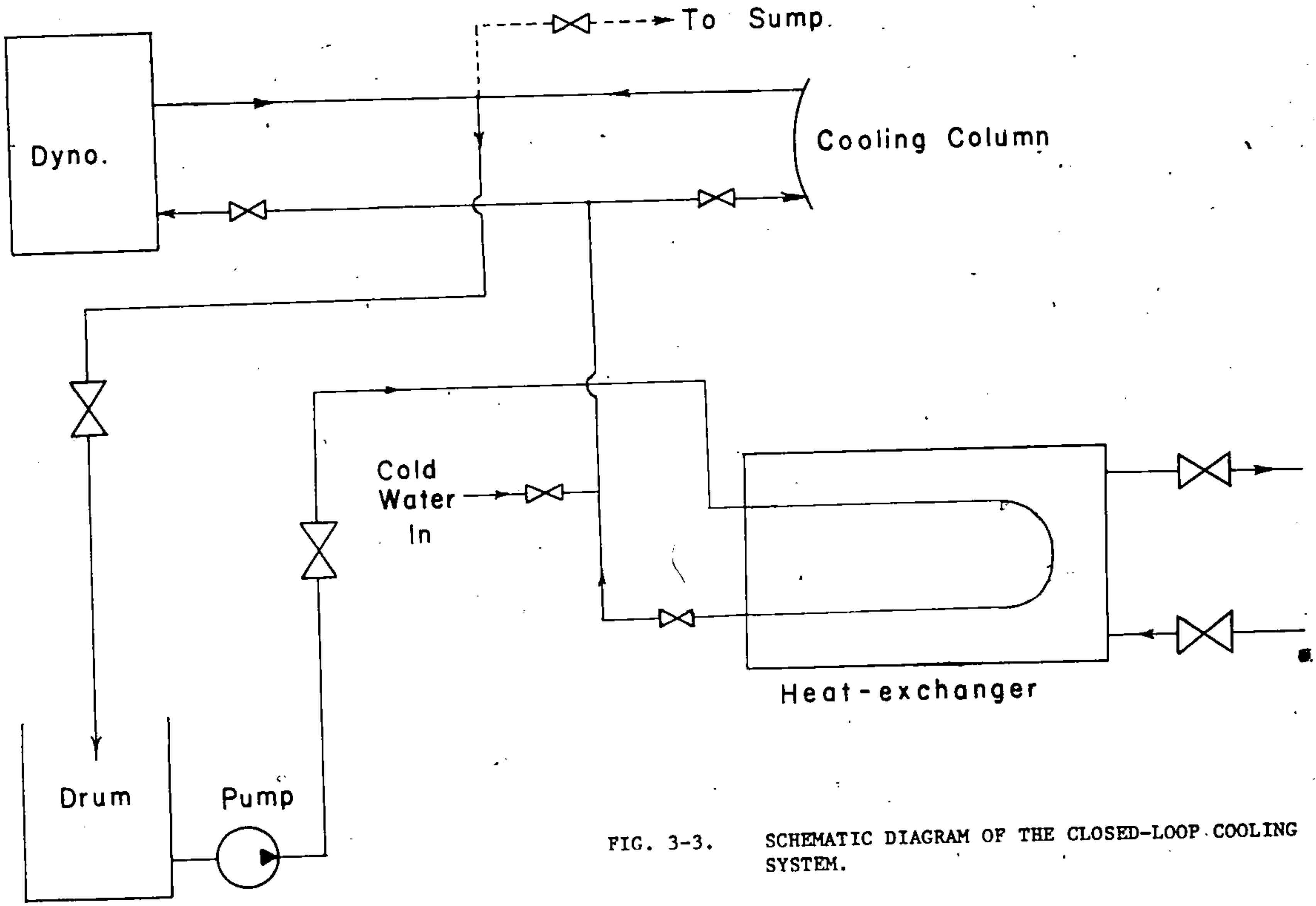


FIG. 3-3. SCHEMATIC DIAGRAM OF THE CLOSED-LOOP COOLING SYSTEM.

cooling column. Hot coolant from the engine is passed into the column and returned to the reservoir tank along with the water from the dynamometer.

The heat-exchanger is of counter-flow shell-and-tube design. The coolant in this heat-exchanger is a separate ethylene glycol mixture which is cooled by atmospheric air in the ventilation system.

A cooling column is used in place of a radiator. The engine coolant is circulated through the column (as in a radiator) by the engine coolant pump and the temperature is maintained by sensitive modulating thermostats that assure engine operating temperature within the limits specified by the engine manufacturer. The hot coolant in the column is cooled by mixing with the cold fluid which is introduced into the column at a mid-point. Thermostats at the inlet of the cooling column control the temperature of the fluid entering the engine[68].

3.4. <u>THE ENGINE</u>. A Chevrolet V-8, water-cooled, 350 cubic inch, 1971 model automotive engine was used for the test runs. Detailed specifications are given in Appendix A. The engine does not have an air pump for air injection at the catalytic converter inlet. The carburetor is adjusted for a high idle speed.

The fuel used to run the engine was Shell Ultra unleaded gasoline. This fuel was selected for compatibility with the catalytic converter. One drum of 45 gallons of fuel was used for the entire test program.

The ignition switch of the engine was connected through terminals provided in the controller (see section 3.7.3) for safety, so that the engine could not be started without excitation to the dynamometer.

A warning device was installed to give a buzzing sound and a flashing red light if the oil pressure went below 2 psi and/or if the cooling water temperature rose above 205°F.

3.5. THE DYNAMOMETER. This was a Dynamatic eddy-current absorption type. The eddy-current dynamometer in the simplest form consists of a disc which driven by the engine under test, turns in a magnetic field. The strength of the field is controlled by varying the current through a series of coils located on both sides of the disc. The revolving disc acts as a conductor cutting the magnetic field. Currents are induced in the disc, and since no external circuit exists, the induced currents heat the disc[30].

The development of braking torque in the eddy-current type dynamometer is due to two reacting magnetic fields. One is the eddy-current reactive field due the rotor. The other is the field set up by the field magnet (stator)[69].

The dynamometer is water-cooled.

Detailed specifications are given in Appendix B.

3.6. THE CATALYTIC CONVERTER. This was a GM 260 cubic inch type designed by A.C. Spark Plug Division. The platinum- and palladium-based catalyst material is deposited on a thin layer of spherical or cylindrical alumina (aluminum oxide) pellets, about 1/8 in. diameter. These pellets are packed in a stainless steel container. The pellets provide a surface area of more than 2.25 x 10^6 square feet (or more than the area of 50 football fields). The total platinum/palladium loading is about 0.05 troy ounces. See Fig. 3.4.

The catalytic converter was located about 3 feet from the exhaust manifold, approximating the under-floor mounting in a typical Chevrolet car with a V-8 engine. The converter was mounted on an angle bracket located alongside the engine-dynamometer test-stand in the engine cell.

3.7. INSTRUMENTATION. The instruments used during the test program will now be described. These instruments were used to determine the air-fuel ratio, the engine torque, speed, manifold vacuum, the HC and CO emissions and various temperatures.

3.7.1. Measurement of Air Flow. The air flow rate was measured by a Go-Power M-5000 Air-flow meter. This instrument is based on the principle of flow through a nozzle. The air is drawn through a long-radius flow nozzle into a pulse-damping drum. From the drum, the air flows through a flexible hose into the engine carburetor. All the air entering the carburetor must therefore flow through the nozzle. The pressure drop across the nozzle is measured in inches of water by a manometer. Charts provided by the manufacturer give the mass flow rate of air corresponding for the nozzle size selected, as a function of the pressure difference measured. This flow rate is calibrated at 60°F and 29.92 in. Hg (standard conditions). The manual provides correction factor charts for test temperature, pressure and humidity[70].

Because the smaller diameter nozzles did not give accurate

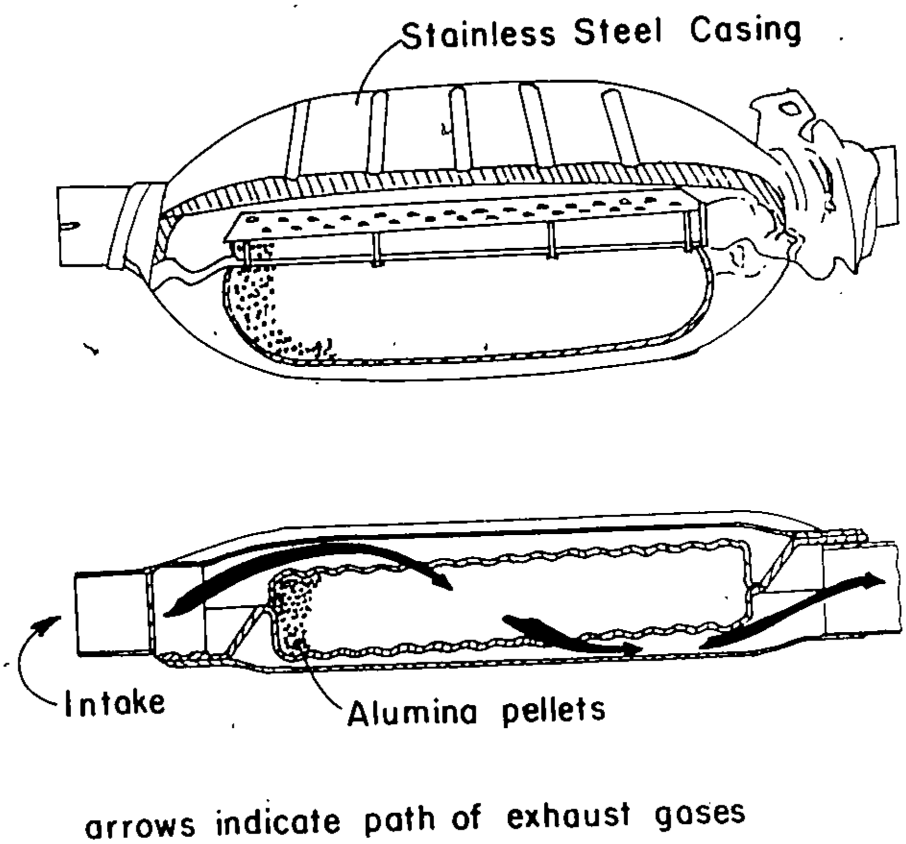


FIG. 3-4. THE GM 260-CUBIC INCH SIZE CATALYTIC CONVERTER.

readings, they were calibrated. This procedure is described in Appendix C.

3.7.2. Measurement of Fuel-flow. The fuel flow rate was measured by a Cox Instruments' Vortex Flow-meter. This is a transducer which detects the fluid flow and gives a frequency signal proportional to the volumetric flow. The signal is generated by the interuption of an infrared light beam. These frequency signals are picked up and amplified and the frequencies are displayed over given intervals on an Hewlett-Packard frequency-counter. There are charts provided, relating the frequency in hertz (hz) to the fuel flow rate in pounds per hour (ppr or lb/hr) for gasoline.

3.7.3. Speed and Load Control Potentiometer. Speed and load control of the dynamometer is provided by the control of current through the magnet (stator) of the dynamometer. The speed control potentiometer operates such that the speed of the rotor (essentially the same as the engine output shaft speed) is kept constant, while the excitation(and the braking torque) is varied to hold the speed relatively constant. The load control potentiometer holds the excitation current (the current flowing through the rotor) and thus the braking torque, relatively constant. Thus the load is kept constant.

The controller (Mark III Type 4 Controller of Dynamatic Corp.) located in the engine cell houses the necessary electronic circuit to control the amount of excitation in the dynamometer brake unit[71].

3.7.4. The Load Cell and Strain-gauge Indicator. The load cell (of BLH Electronics Inc.) is an electronic transducer which translates changes in force or weight into changes in voltage. This change in voltage produces a repeatable deflection or indication in the read-out instrumentation, which can be calibrated directly in terms of the load applied to the cell.

Hermetically sealed within the load cell are one or more sets of strain-guages bonded to a steel element. The strain-gauges are electrically connected to form a balanced Wheatstone bridge. The deflection of the strain-gauge filament creates a change in its resistance, thereby unbalancing the bridge. As a result, for a given input voltage, the output voltage of the bridge varies proportionally with the load, and the change can be read on appropriate instrumentation[72].

The control room has a Daytronic Corp. Model 901 Strain-gauge indicator. This is a precision null-balance servo instrument. It supplies DC excitation to the bridge. It has a gauge giving the load calibrated to read foot-pounds (ft-lb) of braking torque. Zero and span controls, polarity reversing switch and an adjustable signal damping filter are provided[73].

The strain-gauge indicator was calibrated to correct the meter readings with actual loads. Details are given in Appendix D.

3.7.5. Engine Speed. The dynamometer rotor speed (and the engine speed) is sensed by an alternator. A tachometer, Standard model SG-6, which is connected to the alternator, indicates the engine speed in revolutions per minute (R.P.M.).

3.7.6. Manifold Vacuum. The engine intake manifold vacuum was measured by a vacuum gauge mounted in the control room. This gauge gives the vacuum in inches of mercury (in. Hg).

3.7.7. Temperature Measurement and Recording. During the tests, the following temperatures were measured:

(i) Engine exhaust, when the engine was run without a catalytic converter,

(ii) Catalytic converter inlet, } when the engine was

(iii) Catalytic converter outlet, } run with the converter

(iv) Water outlet,

(v) Inlet air,

(vi) Air-cleaner air,

(vii) Intake manifold, and

(viii) Pre-heated air, when the engine was run during separate tests to study the performance of the engine intake system.

The temperatures were measured by thermocouples mounted at appropriate locations. The thermocouples for the first three items mentioned above are chromel-alumel while those for the remaining five are copper-constantan. The cold junction of the thermocouples was kept in an ice-bath in a sealed vacuum flask. Crushed ice was used for better contact with the junction wires. The output of the thermocouples is in millivolts to be converted to a read-out on a recorder. The recorder used for the purpose of recording the temperatures continuously was a Watanabe Multicorder model MC611L. This is a servo-type, potentiometric, transistorized recorder[74], with 6 channels. Each channel has a separate pen. The pens are filled with differently coloured ink for easy identification.

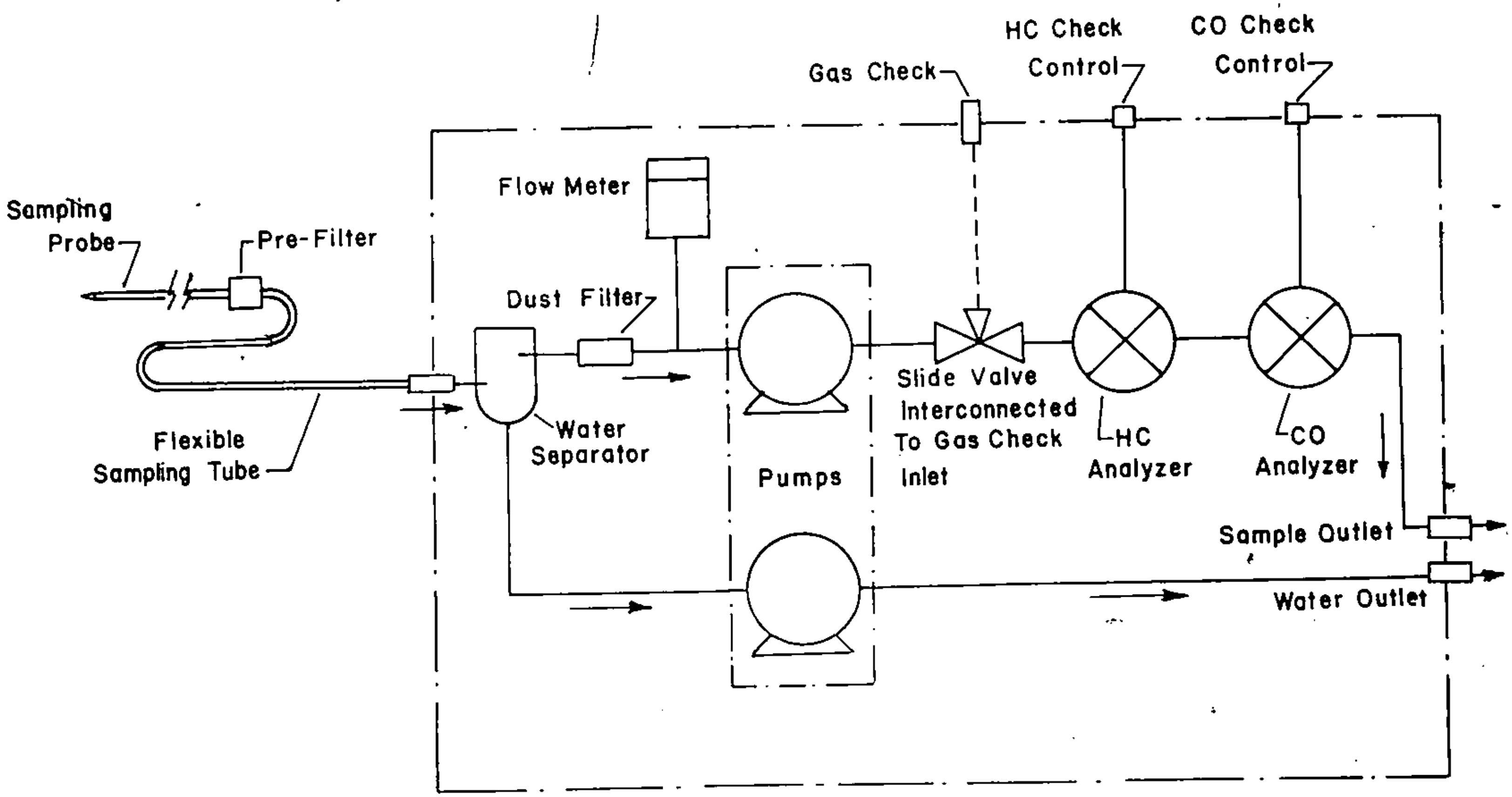


FIG. 3-5. SCHEMATIC DIAGRAM OF THE EXHAUST GAS SAMPLING SYSTEM.

3.7.8. Exhaust Gas Sampling. The sampling system for continuous measurement of the exhaust components consists of a sampling probe, a needle valve to control the sampling flow, an inline filter and the sampling line connected to the analyzer. Fig. 3.5 shows the sampling system.

The sampling probe is fixed to the engine exhaust system in such a way as to minimize induction of ambient air. A 1/4 in. OD stainless steel tube is placed parallel to the flow, facing the upstream direction of the exhaust line.

A needle valve is used to shut off the sampling line when emission measurements are not made. An inline filter is used to trap particulate matter. An easily replaceable 7 micron filter is used as the filtering element.

Because the main tests were carried out in cold ambients, the sample gas was not cooled. It was found to be cool enough for the analyzer to handle. Also, the moisture trap using silica gel and phosphorus pentoxide was bypassed because of air leakage into the system from the U-tubes. The analyzer moisture pump was able to handle the moisture in the sample gas and the readings were not found to be erraneous because of bypassing the moisture trap.

3.7.9. The CO/HC Analyzer. The analyzer used during the tests was of the non-dispersive infrared (NDIR) type manufactured by Olson-Horiba, model Mexa-300. It measures CO in moles per cent (%) and HC as n-hexane equivalent, in parts per million (ppm).

Infrared analyzers are based on the principle that heteroatomic gases absorb infrared energy at distinct and (more or less) separated wavelengths, with the absorbed energy raising the temperature and pressure of the gas.

Consider the simplified diagram in Fig. 3.6. The analyzer contains a reference cell (filled with atmospheric air), a sample cell through which the gas mixture flows, and a detector cell (filled with the specific gas to be measured (analysis gas). The detector cell is divided into two compartments by a pressure-responsive diaphragm[30].

Let the sample cell be filled first with room air, like the reference cell. Infrared energy passing through these two cells into the detector will be absorbed only in the regions where the detector has absorption bands. The detector diaphragm remains stationary (zero reading) since the same amount of energy is recieved by the gas on each side of the diaphragm. Now if the sample cell is charged with the sample gas, infrared energy proportional to the concentration of sample gas will be absorbed in the sample cell. Therefore less energy will reach the sample side of the detector (relative to that recieved through the reference cell) thus lowering the pressure in the sample side of the detector. Movement of the diaphragm is then amplified electronically and fed to an indicator and recorder[75].

The instrument is usually calibrated by sample gas of known concentration. Some doubt exists when testing unknown mixtures as to whether or not unknown gases are contributing to the signal (by absorbing energy in bands close to the sample gas).

For testing gases like CO and HC, the detector unit must be sensitized (filled) with the gas to be tested. Sturgis et al[76]

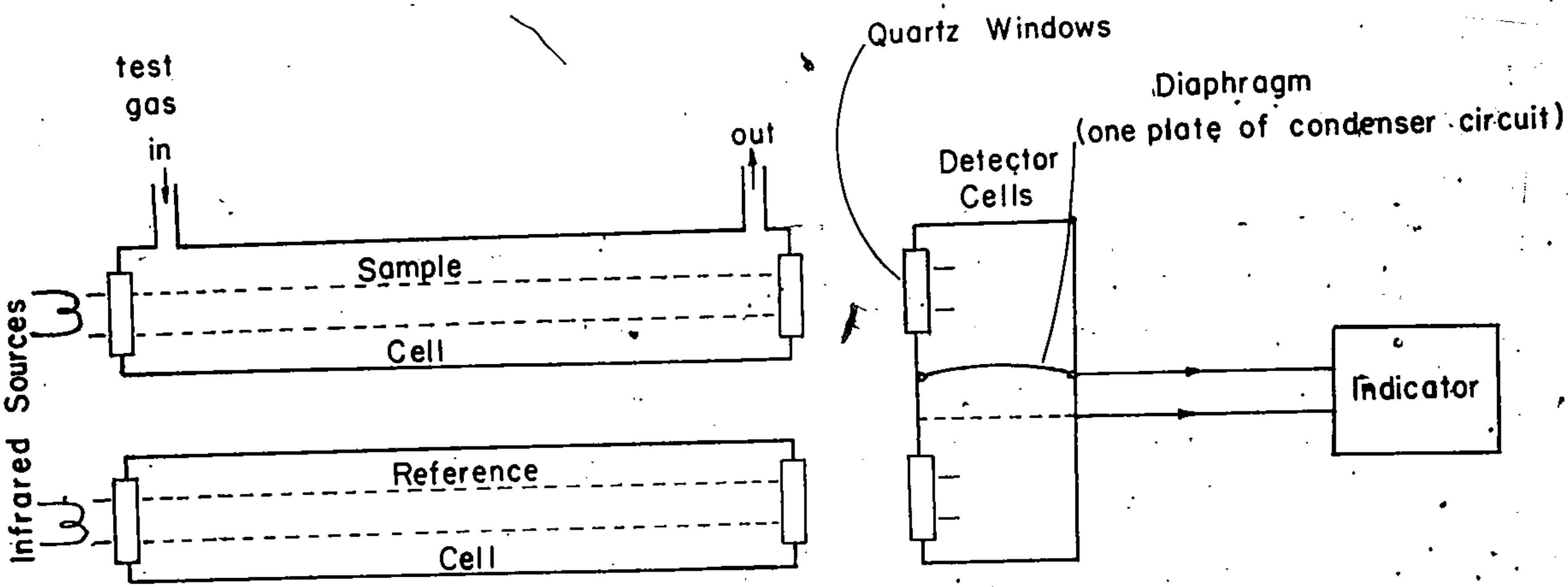


FIG. 3-6. DIAGRAM OF NONDISPERSIVE, INFRARED GAS ANALYZER (NDIRA). (Taken from ref. 30.)

stated that the response of an NDIR analyzer to methane was poor and when sensitized with n-hexane (equivalent hexane), the analyzer was unresponsive to acetylenes and aromatics, and with a lower response to olefins than to the corresponding paraffins. The authors recommended that the detector cell be filled with a mixture of acetylene, ethylene and benzene for best response to hydrocarbons.

The specifications and calibration procedure for the analyzer are given in Appendix E.

3.7.10. Continuous Recording of CO/HC Levels. The CO/HC levels were continuously recorded on a Hewlett-Packard strip-chart recorder, model 7100B. The recorder is a two-pen type. Two isolated self-balancing servo-mechanisms move the pens depending on the voltage signals recieved from the analyzer (which has the necessary devices to do so). A multi-speed motor drive moves the chart[77].

3.8. ALTERNATIVE EQUIPMENT. The following section deals in brief with some alternative equipment that (a) are in general use, (b) could have been used, and/or (c) recommended for future use.

3.8.1. Choke Monitor. The performance of the engine during warmup depends to a large extent on the choke. Since CO emissions are highest when the choke is closed, the rate of opening of the choke should be monitored. This gives an idea of the speed at which the engine is warming up. Modern engine design practice recommends a quick release choke to reduce emissions. But these chokes greatly impair warmup driveability when gasolines of conventional volatility is used[78].

3.8.2. Other Emission Test Methods. In most cases the NDIR analysis of the exhaust gases tends to undermeasure the hydrocarbon content. So other methods of exhaust gas analysis have been used.

3.8.2.1. Flame ionization method. This method is based on the fact that a flame of pure hydrogen (or hydrogen diluted with nitrogen) contains a negligible amount of ions while the addition of even traces of organic compounds produces a large amount of ionization. A metered amount of H_2, air and exhaust gas is burned together. Positive and negative ions will be formed in pairs. In one type of analyzer, an ion-collector is positive relative to the burner. Measuring the flow of electrons (current) between the burner and the collector gives the amount of hydrocarbons. The unit is calibrated by metering known quantities of HC. Flame ionization is not too selective to the type of HC present, unlike infrared analyzers. But the flame ionizer is responsive to oxygen in the exhaust gas[30].

The magnitude of this oxygen effect depends on the instrument, instrument operating parameters, O_2 concentration in the sample and composition of the individual hydrocarbons in the sample. Oxygen influence was increased[79] markedly when pure H_2 was used, without a diluent. Uniformity of response was improved when helium was used as the diluent in place of nitrogen.

Ref. 79 gives a procedure to improve the response speed and HC analysis, by slight modification of the commercial instruments as well as adherence to specific operating conditions.

3.8.2.2. Gas chromatography. This is a physical method of separating a mixture into its constituents. The separated constituents are measured by a thermal conductivity detector (TCD - for weakly ionizable gases) or hydrogen flame ionization detector (FID - for hydrocarbons). The FID is about twice as sensitive as the TCD. Both methods require calibration by testing known mixtures under similar flow conditions[30].

3.8.2.3. Orsat apparatus. This apparatus is convenient for measuring CO_2, CO and O_2. This is a chemical method, where the gases are absorbed by chemicals. Potassium hydroxide absorbs CO_2, pyrogallic acid absorbs O_2 and cuprous chloride absorbs CO. The Orsat will ignore the water vapour in the sample. Chemical analysis, though accurate, is time consuming, which is why other methods are popular[30].

3.8.3. Sampling of Catalytic Converter inlet and outlet. An additional sampling device to measure the CO and HC levels before the exhaust gas enters the converter would give us an idea about the converter performance. Endurance testing of the catalyst, effects of contaminants in the fuel on the converter, and catalyst evaluation could also be carried out.

3.8.4. Catalytic Converter and Back-pressure. The effect of the catalytic converter on the engine back-pressure can be evaluated by using pressure gauges. Also the pressure variation across the converter could also be studied. The monolithic and pelleted type converters could be compared, with this parameter in mind.

4. EXPERIMENTAL PROCEDURE

4.1. THE FEDERAL TESTING PROCEDURE. The federal testing procedure for 1973 and later model cars, is based on a driving cycle which is essentially a reproduction of an actual time-speed history of an automobile driven over a 7.5-mile "typical" metropolitan route. It requires 22 min. 51 sec. for the test.

As a practical necessity "driving" is done on a chassis dynamometer. Power absorption and inertial effects of the dynamometer are set to approximate the power requirements and the inertia of a vehicle driven on the road; these dynamometer characteristics are adjusted to the vehicle weight.

The car is started after soaking for 12 hours in a 60°-86°F ambient. The cycle involves various idling, accelerations, decelerations and cruise modes of operations.

Emission measurements are either made continuously during the tests or are made upon bag samples collected during the tests. The single bag system was used to test 1972 through 1974 vehicles. The three bag system applies for 1975-76 vehicles. The sampling technique is called the Constant Volume System (CVS) because a constant flow of gas is maintained through the system. Air is used to dilute the exhaust gas to avoid the condensation of vapour which could dissolve some pollutants and reduce the measured values.

The methods of measurement of the pollutant are also specified. For CO and CO_2 it is the NDIR, for HC it is the FID, and for NO_x it is the chemiluminescence technique. The emissions are expressed in terms of the weight (in grams) of the pollutant per unit distance (in miles) driven by the automobile[4,13].

4.2. DEFECTS IN THE FTP. (a) The FTP requires that the vehicle be tested on a chassis dynamometer; hence it is also called the "vehicle test". It was reported[80] that a chassis dynamometer test exhibits poor repeatability, mainly due to the variability of the vehicle. Daily tests on a single vehicle over a 5 month period have shown that engine CO and HC emissions exhibit standard deviations of 18% and 23% over their respective means. The length of time involved in the testing is also high. Only 6 development tests per day were carried out on a 2-shift basis.

(b) The length of the driving distance (7.5 miles of "simulated urban driving") and the time (approximately 23 min.) was based on the driving patterns in the U.S., specifically California, where automobile pollution is a major problem, because of the photochemical smog. Driving patterns in Canada are not the same. Driving conditions are also not the same. This is mainly due to the weather.

(c) The daily minimum temperatures in the month of January in most of Canada, fall below 0°F more often than in the U.S.

Temperatures in the winter months often go below -20°F, and temperatures below -40°F can be reached[81]. Thus the cold start ambient temperature range of 60°-86°F in Canada is not truly representative of Canadian weather where temperatures below 32°F are often experienced for at least 6 months of the year.

4.3. <u>JUSTIFICATION IN USING THE PRESENT SET-UP</u>. The present set-up uses an engine-dynamometer system. The engine-dynamometer system has been known to produce fairly repeatable results. Deviations from mean CO and HC have been given as 0.69% and 0.75% respectively[80]. Test runs of over 20 runs per day over 2 shifts have been carried out. The engine-dynamometer system permits flexibility of operation, easy control of external variables and repeatability of results.

The set-up includes a cooling column in place of an automobile coolant radiator. For a stationary engine, this is a more efficient form of cooling, because cooling is achieved by mixing hot and cold coolant in the column. With the cooling column it is easy to maintain a constant engine temperature. In a radiator, heat transfer is by convection. It will not be very effective on an engine-dynamometer system because proper air flow through the radiator cannot be provided.

The tests involved warmup studies so a simple cycle was followed, to study the warmup period involving an idle period followed by fixed loads applied to the engine.

The cycle was as follows: Cold soak followed by a test sequence consisting of (1) start-up, fast idle and warmup, (2) load condition 1, (3) load condition 2 (an increased load condition, (4) return to load condition 1, (5) idle, and

(6) shut down.

Slightly different procedures were followed for tests under cold and warm temperature start-up conditions. Idling time for low temperature start-up was 2 min. whereas for warm temperature start-up the time was 30 sec. to 1 min.

4.4. THE DRIVING CYCLE. This will now be described in detail.

1. Allow the engine to cold-soak for about 8 to 12 hours.

2. Start the engine with no load and let it fast idle at about 1800 R.P.M. for the time specified, depending on whether the ambient temperature is cold or warm. Letting the engine warmup at idle after start-up is a normal practice in winter. The time of 2 min. for cold ambients was essentially an arbitrary choice, after a couple of earlier test runs with a 3 minute warmup time were tried. The engine was found to be warm enough for loading at the end of 2 min. The R.P.M. invariably rose to about 2100 at the end of the warmup period.

3. Load the engine by operating the load control potentiometer and opening the throttle. This took about 30 sec. The load ranged between 95 and 165 ft-lb. With a majority of the tests the load was about 135 ft-lb. The R.P.M. was stabilized at 1600. The manifold vacuum, depending on the load, varied between 8 to 12 in. Hg.

This signifies a gradual acceleration to a cruising speed of about 55 MPH in about 5 minutes after start-up. At 55 MPH, the R.P.M. of the road wheel of an automobile is about 650, assuming the tire diameter is about 28.5 in. for a G78-15 tire. For a GM Chevelle, with a 350 cu.in. engine and a 2.73:1 rear axle reduction ratio, the output shaft of the transmission will turn at about 1700 R.P.M. Corresponding to a road speed of 55 MPH, the required theoretical road horse-power (rhp) is 25, based on the formula[30]

$$\text{rhp} = \frac{V}{375}(0.0148W + 0.000128AV^2)$$

where V = the vehicle speed in MPH,

W = the curb weight of the automobile and the weight of equipment and passengers, assumed 4000 lb, and

A = the frontal area of the vehicle, assumed 28 ft².

Now, the value of the load on the engine (in ft-lb) varies between 96 and 152 at the end of 5 minutes. The mean value of the load is estimated to be about 128 ft-lb. The engine brake-horsepower is about 40.

This load condition, called load condition 1, was applied upto the end of the 9th minute after start-up.

4. After 9 minutes of running, put an additional load on the engine. This load was about 250 ft-lb. This was achieved by increasing the throttle opening so that the speed was kept the same, at 1600 R.P.M. The manifold vacuum was around 4 in. Hg.

This load condition, called load condition 2, by a similar reasoning, could be taken to represent a gradient driving at about 33 MPH.

Load condition 2 was applied for 3 minutes.

5. After 12 minutes of running, apply load condition 1 again. This was done by closing the throttle until the load and manifold vacuum were about the same as in condition 1. This load

was maintained for 3 minutes.

6. After 15 minutes of running, bring the engine to idle. This was done by pushing the throttle cable all the way in. This enabled the engine and the system to stabilize. Also, it was desired to keep the dynamometer water outlet temperature within safe limits.

This slow idling, at about 700 R.P.M. was maintained for 5 minutes.

7. The end of the cycle was reached after 20 min. of running. Usually the engine was shut down immediately though it was allowed to run a few minutes longer in a few cases.

4.5. INITIAL EXPERIMENTS. Before the actual tests were carried out, some preliminary work was undertaken to check the various systems.

4.5.1. The Engine. The engine was tuned to manufacturer's specifications. The engine compression was checked and found to vary between 160 and 170 psi, which is within the 20 psi variation as recommended by the manufacturer. New spark plugs were fitted and gapped to the specifications given in the manual. Distributor dwell was also checked and found to be correct. The engine high tension wiring was replaced because of spark leakage from some of the old wires. The ignition timing was checked. The warning device for low oil pressure and/or high water temp temperature was checked and found to work satisfactorily.

4.5.2. The Dynamometer. When operating the unit with the closed-loop cooling system it was found that as soon as the inlet temperature (to the dynamometer) reached 90°F, the engine would shut down. The problem was traced to the low pressure cut-off switch. This switch, according to the manual[69], will cut off excitation if the water pressure falls below 11 psi. The drop in pressure was probably due to a surge of water when the water temperature switch opened. This switch normally opens when the outlet water temperature reaches 168°F. Since the problem of the engine shutting down, especially during a test run, caused back-firing due to burning of the fuel in the exhaust manifold, it was decided to disconnect the pressure switch, after which no problems of engine shut down occured.

4.5.3. The Air- and Fuel-Flow Meters. These meters were separately checked for accuracy. The air-fuel ratios were found to be fairly reasonable, except for idle running when the air-fuel ratios obtained were lower than expected. The selection of the proper nozzle of the air-flow meter depended on the load applied to the engine. The 1.75 in. nozzle was best suited for most of the tests carried out in this program. The 1.183 in. nozzle caused exessive manometer deflection even when load condition 1 was applied, so it was used to determine air flow rates at idle only.

4.5.4. The Sampling Line. The exhaust sampling system was first connected as described in ref. 11, but without the Dyna-pump, manometer and rotameter. The system was checked for leaks. It was found that air was being drawn in from the U-tube caps, especially at the first U-tube.

Another problem at one stage was that the analyzer was found to indicate abnormally high values of HC. This was quite prominent after the engine stopped suddenly during a run. The problem was traced to the silica gel in the U-tubes. When the engine shuts down suddenly during a run, high quantities of unburned fuel pass into the exhaust. The sample line picks this up and the silica gel absorbs it. This is why, in subsequent runs, high levels of HC were indicated by the analyzer.

It was also found that the analyzer sample pump and the Dynapump, which was later introduced, were not sufficient to draw sample gas from the exhaust due to losses in the U-tubes. Consequently it was decided to by-pass the U-tubes. The water separator in the analyzer was found to be capable of handling the moisture in the sample line.

The cooler and water trap in the sample line were also eliminated because of leaks and pumping losses. Also, due to cold ambient temperatures when the first part of the test program was carried out, the sample gas was sufficiently cooled before it reached the analyzer.

4.5.5. The Analyzer. The analyzer was calibrated before every test according to the procedure laid down by the manufacturer (outlined in Appendix E). The calibration was done at the high range of the meter. This was because the CO and HC levels were high at start-up, and the low range of the meter could not indicate these levels.

4.5.6. The Thermocouples and Temperature Recorder. The thermocouples were checked for accuracy by submerging the probes in boiling water and verifying with a mercury thermometer. The corresponding deflection on the recorder indicated calibration outputs.

4.6. THE ACTUAL TESTS. The actual tests were started towards the end of winter. Experiments were carried out early in the morning or late at night, especially for the low temperature tests.

The time was noted during tests with a stop-watch. The readings which were recorded manually were noted in the following format:

TIME	FUEL FLOW	AIR FLOW	MANIFOLD VACUUM	SPEED	LOAD	REMARKS
sec, min.	Hz	in.water	in.Hg	rpm	ft-lb*	

The engine cell temperature was indicated by a thermometer directly above the engine. The wet- and dry-bulb temperatures were indicated by a psychrometer and the room barometric pressure by a barometer, both placed on the wall on the left of the engine. These temperature and pressure values were noted before and after a test run.

Before the engine ignition switch was turned on, the various systems were brought into operation. This procedure is outlined in Appendix E.

4.6.1. Low Temperature Tests without the Converter. Initial tests were carried out without the converter for two reasons:

(a) the converter was not immediately available, and

(b) the engine could be run with unleaded gasoline to

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* strain-gauge indicator values.

remove all traces of leaded fuel that might have remained in the system.

The engine gave no trouble when starting from cold. Occasionally, the battery-charger was used to bring the battery to full charge.

The major problem of running the engine in cold ambients was the freezing of water vapour in the exhaust sample line. This was particularly severe when the ambient temperatures were below 20°F. As a result, the sampling line would be blocked and the analyzer would not indicate any pollution levels in the engine exhaust. This invariably happened within 3 to 4 minutes after start-up.

The water vapour condensed after a test run, would freeze during the cold soaking period. This caused the blocking of the sampling line. To prevent this the sampling line was disconnected after a test run and kept in the warmer instrument room and reconnected before the next test run began.

4.6.2. <u>Low Temperature Tests with the Converter</u>. A quick method of switching over to the converter was utilized. The exhaust flexible piping was connected to the converter by means of U-clamps and bolted down to the bracket. The switch-over took barely a few minutes. The outlet from the converter was also connected by flexible piping to the exhaust ventilation system.

No modifications to the engine were carried out; the spark timing, carburetor adjustments and valve overlap were kept the same. The tune-up was kept unchanged.

One of the problems encountered was the moisture content of the exhaust. The effect of the converter was to produce more moisture. There was no apparent effect of sulphuric acid either on the piping or the analyzer.

4.6.3. Warm Temperature Tests. For these tests the ventilation system was adjsuted to supply mixed air at the desired temperature. Room temperatures (in the test cell) were in the range of 70° to 80°F.

For warm temperature running, all systems were maintained the same. The closed-loop cooling system was the only potential trouble area. However, it worked satisfactorily during the test runs. Dynamometer water inlet temperatures did not cross the 100°F mark.

The major problem of running the engine in warm ambients was the vapour lock in the fuel line. This invariably resulted in the sudden stalling of the engine during a test run. The fuel pump had to be primed a few times before the engine would start again.

One of the first indications that the engine was low on fuel was when the fuel flow frequency-counter showed high (and absurd) fluctuations in the flow. This was because air was being sucked into the fuel line and since the flow-meter picks up frequency changes in any fluid (whether air or gasoline) the values would be indicated on the frequency-counter.

The fuel level was maintained at a certain level before a test run was made. Also, the fuel line was primed by blowing into the fuel tank so that the line was always filled with fuel before the engine ignition switch was turned on.

4.6.4. <u>Testing the Engine Air-intake System</u>. The engine is fitted with a "Thermac" Air-cleaner assembly. The system is depicted in Fig. 4.1. According to the GM manual on emission control systems[82], the thermostatically controlled air cleaner is designed to maintain a minimum temperature of approximately 100°F for the air entering the carburetor. Maintaining this minimum temperature permits good driveability with leaner carburetor air-fuel mixture which helps reduce exhaust emissions.

The temperatures of the inlet air, pre-heated air (by the exhaust) and the air cleaner air were recorded during separate test runs following the same cycle, in warm ambient temperatures. Fig. 4.2 shows the locations of the thermocouples for this particular set of experiments.

From the figure, m_1 is the mass of air, at temperature T_1, entering the air-flow meter nozzle. The mass of the air entering the pre-heater unit is m_2 and the temperature at the pre-heater outlet is T_2 while m_3 is mass of the remaining air at temperature T_1. The hot air of mass m_2 mixes with the cooler air of mass m_3 so that the air entering the carburetor is of mass m_1 at a temperature T_3. We now have

$$m_1 = m_2 + m_3 \qquad \ldots \; 4.1$$

The heat given up by the heated air, of mass m_2 is assumed to be equal to the heat taken by the cooler air, of mass m_2, so

$$m_3(T_3 - T_1)c_p = m_2(T_2 - T_3)c_p \qquad \ldots \; 4.2$$

For the sake of simplicity, we assume that the specific heat of air does not change appreciably over the temperature range that the air-preheater was operated. Thus, cancelling the c_p term and rearranging eq. 4.2 we get

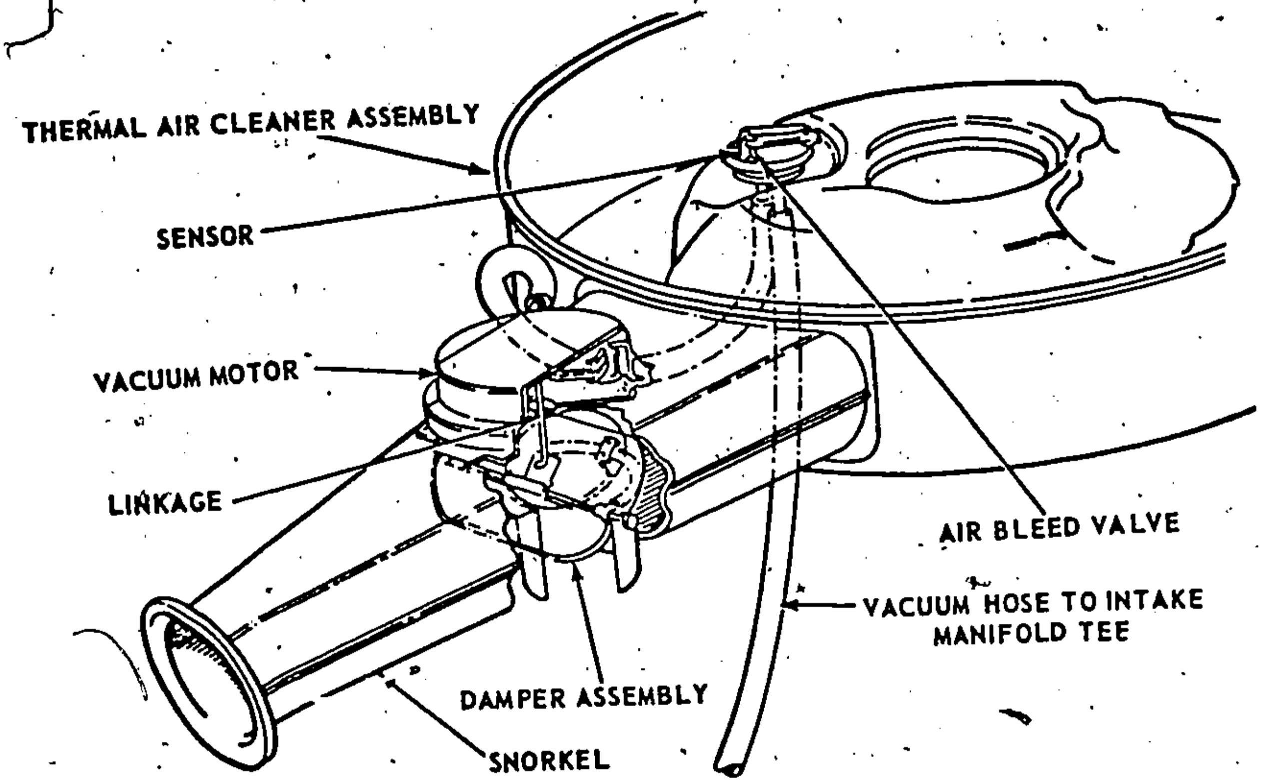

FIG. 4-1. THE GM "THERMAC AIR CLEANER" SYSTEM

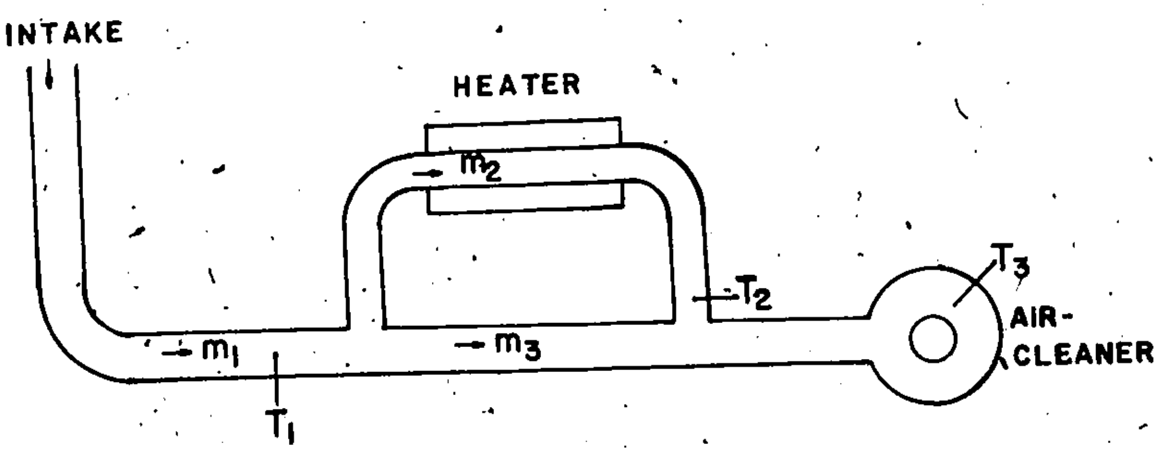

FIG. 4-2. SCHEMATIC DIAGRAM SHOWING THE THERMOCOUPLE LOCATION FOR THE STUDY OF THE AIR INTAKE SYSTEM OF THE ENGINE.

$$m_3 = m_2(T_2 - T_3)/(T_3 - T_1) \qquad \ldots\ 4.3$$

From eq. 4.1 we have

$$m_1 = m_2 + m_2(T_2 - T_3)/(T_3 - T_1)$$

$$= m_2[1 + (T_2 - T_3)/(T_3 - T_1)]$$

$$= m_2(T_3 - T_1 + T_2 - T_3)/(T_3 - T_1)$$

$$= m_2(T_2 - T_1)/(T_3 - T_1)$$

$$m_2 = m_1(T_3 - T_1)/(T_2 - T_1) \qquad \ldots\ 4.4.$$

Thus eq. 4.4 gives the mass of air entering the air pre-heater, for different temperatures of the inlet air, pre-heated air and the air entering the air cleaner.

This experiment was carried out 6 times and the values of m_2 were calculated.

4.7. <u>OTHER PROBLEMS, DIAGNOSIS AND REMEDIES</u>. During a test run, the multicorder and strip chart recorder gave some trouble. One of the pens in the multicorder kept hunting all the time. The defect was found to be in the machine. But, because the temperature curve drawn by that particular pen was not unduly off the mark, it was not corrected. Also, it was feared that the experiment would be held up. Another problem encountered in both recorders was the ink drying up in one or more pens during a test run. This would usually be discovered after the test run was well under way, resulting in gaps in the recording. The pens were pumped to force the ink to flow. Some times, the pen or pens had to be cleaned after the test run was made. This is why there are incomplete data in some of the tables.

5. PRESENTATION OF DATA

In all, 56 runs were made; 16 with and 40 without the catalytic converter. Table 5-1 gives the breakdown of the run numbers corresponding to the temperature range at start-up of the engine.

The calculated data are presented in Tables 5-2 through 5-40. The fuel flow values have been converted from Hz to lb/hr. The air flow values have been converted from in. of water to lb/hr. The corrected air flow (indicated as "corr. air flow") is the product of the air flow rate and the correction factor. The correction factor includes the following:

(a) Correction for temperature,

(b) Correction for pressure, and

(c) Correction for humidity.

The temperatures were calculated from tables for the particular type of thermocouple used. These tables give the relation between the millivolt output given by the recorder, and the temperature[83].

The Tables 5-2 through 5-40 contain certain symbols which

TEMPERATURE RANGE (°F)	RUN NUMBERS	
	WITH CONVERTER	WITHOUT CONVERTER
0 - 5		
6 - 10		
11 - 15		16*
16 - 20		14*
21 - 25		18
26 - 30		1*
31 - 35	25, 27	11, 19*, 20, 22†
36 - 40	24, 26*, 28	2*, 8*, 12, 13, 21
41 - 45	23	6*, 9*, 10*
46 - 50	32	
51 - 55		
56 - 60		
61 - 65		
66 - 70		
71 - 75	36 to 40	7*, 41 to 47, 48*
76 - 80	33*, 34, 35†	50* to 53*, 56*
81 - 85		54*, 55*
	* Incomplete recording of data † Engine stopped before cycle was completed due to lack of fuel Other runs were not recorded at all	

Table 5-1. Run numbers corresponding to ambient temp. at start-up

are explained below;

* Indicates that the particular instrument or pen stopped working during a test run.

\- Indicates that the particular reading(s) was (were) not taken and/or the particular calculation (s) was (were) not made.

x Indicates that the engine stopped prematurely during a test run.

Figures 5-1a through 5-40a show the temperature plots obtained by the multicorder. In these figures, the expression 'START' indicates that the engine was started up. The expression 'CHANGE OF LOAD CONDITION' indicates that a load was either put on or taken off. The load conditions are described in Chap. 4. The expression 'END OF CYCLE' indicates that the 20 minute period was over. In most cases the engine was shut off a few seconds after the end of the 20 minutes running period, while in others, the engine was allowed to run a few minutes longer. In two instances, the term 'SHUT DOWN' has been used. This indicates that the engine stopped during the cycle, and the test had to be discontinued.

Figures 5-1b through 5-4b show the plots obtained by the strip-chart recorder for CO and HC emission levels produced by the engine. The same expressions have been used here to indicate the various events during the driving cycle.

Figures 5-1c through 5-32c show the plots of the variables calculated in Tables 5-2 through 5-40, against the time after start-up. These are air-fuel ratio, CO and HC emissions, manifold vacuum, exhaust temperature (for runs without the catalytic converter), catalytic converter inlet and outlet temperatures (for runs with the catalytic converter) and the inlet air temperature. In these figures the expression 'LOAD CONDITION 1' which was the first load condition applied to the engine, and 'LOAD CONDITION 2', which was the second, are described in Chap. 4. The only variation is in Fig. 5.31c, for run # 47 where 'LOAD CONDITION 3' indicates that the same load as in 'LOAD CONDITION 2' was applied but at a higher speed of 1860 R.P.M. Similarly, 'LOAD CONDITION 4' indicates that the same load as in 'LOAD CONDITION 1' was applied but at the same higher speed, of 1860 R.P.M.

6. ANALYSIS OF RESULTS

6.1. DISCUSSION OF THE TEST RUNS. A stage by stage discussion of the results obtained during the tests will now be given.

6.1.1. Fast Idle. There are distinct differences in the way in which the engine operates when started from cold and w warm ambient temperatures so these will be discussed separately.

6.1.1.1. Cold ambient conditions. Certain changes in engine performance occur with cold temperature start-up. Low temperatures increase friction loads. In addition, the carburetor is choked, a condition that results in three basic changes in engine operation, namely

(1) Enrichment of the air-fuel mixture as a result of increased pressure differential across the fuel jet; test results in Tables 5-2 through 5-10 show that the air-fuel rat ratios during the fast idle period are about 50% richer than those occuring later during the various load conditions,

(2) Increase in the engine air-flow as a result of an

increase in the demand to overcome friction loads as well as the result of enrichment beyond a best power setting; test results, for example in Table 5-7, show that the air-flow is 63.4% greater during fast-idle than during the slow idle period (towards the end of the cycle), and

(3) Poor distribution of the air-fuel ratio between cylinders[84].

As the engine warms up friction loads reduce so the R.P.M. starts to increase (from 1800 at end of the first 15 seconds, to 2030 after 2 minutes as shown in Table 5-7), as no external load is applied. The air-fuel ratio gets leaner at the same time. In Table 5-5 for example, we see that the air-fuel ratio increases 23% during the fast idle period.

The HC and CO levels are high, as we can see for instance in Table 5-10. This is because the air-fuel ratio is richer than stoichiometric, air-flow is high and the low ambient temperatures promote cooler combustion chamber walls so that the quench thickness is somewhat greater. The presence of the catalytic converter does not appear to alter the situation to a noticeable degree. Comparing emission levels indicated in Tables 5-11 and 5-16, we see that they are practically the same during the fast-idle period. This is mainly because the catalyst must reach a certain temperature (called "light-off temperature") before significant conversion can take place[85]. Unless some means for quick warmup of the catalyst is provided during the initial warmup period of the engine, it would not be very effective in reducing the HC and CO levels.

6.1.1.2. <u>Warm ambient conditions</u>. Comparing the test results in Tables 5-6 and 5-30 we see that with a warm temperature start-up the air-fuel ratio is about 20% leaner and the engine air-flow about 15% lower than the corresponding values during a cold temperature start-up, within the first 30 seconds. We also see that it takes only about half the time to reach the same exhaust temperature with a warm temperature start-up compared with a cold temperature start-up indicating that the engine warms up approximately twice as fast when the ambient temperature rises from 12°F to 74°F.

At start-up CO and HC emissions peak to maximum values which are lower than those obtained in cold temperature start-up. The emission levels, especially those of HC, start to fall off at a faster rate in warm ambient temperatures.

6.1.2. Load Condition 1. From test results we see that the air-fuel ratios, exhaust temperatures and temperatures of the air cleaner, inlet manifold and cooling water are about the same for both cold and warm temperature tests, at the time load condition 1 is applied. This indicates that the engine is running under practically similar conditions in both types of tests. The average brake specific fuel consumption is 0.57 lb per bhp per hour in the cold temperature tests and 0.56 lb per bhp per hour in the warm temperature tests.

The HC and CO emission levels now reach a minimum value. In both cold and warm temperatures, the minimum values are the same. Since the engine is running at a steady speed, the emissions are also more or less constant.

6.1.3. Load Condition 2. While keeping the speed constant the load was increased by increasing the throttle opening. The manifold vacuum decreased from about 10 in. Hg to about 2.1/2 in. Hg. In Table 5-30, for example, we see that the air-fuel ratio decreases 21% (or the air-fuel mixture becomes richer). This trend can be seen in Figs. 5-1c through 5-32c. The exhaust temperature increases slightly; so also does the engine air intake temperature. The air cleaner and inlet manifold temperatures drop. This is due to changes in the air preheating system which will be discussed in section 6.5.1. The average brake specific fuel consumption is about 0.53 lb per bhp per hour.

Test results show that HC emissions increase by a factor of about 5. The CO emissions show a greater proportionate increase (over 15 times). These increases are based on emissions just before load condition 2 was applied.

In the case of HC we can view this result arising from effects of several factors, some of which tend to reduce emissions while others tend to increase them. Apparently the opposing effects result in an increase in HC emissions.

A factor tending to increase HC concentration as load is increased is reduced residence time within the exhaust system. The residence time of the exhaust gas in the very hot section of the exhaust system is an important factor affecting the amount of exhaust after-reaction. Residence time may be defined as:

$$t \text{ (in min.)} = \frac{\text{volume of hot exhaust system, ft}^3}{\text{volume flow of exhaust gas, ft}^3\text{/min}}$$

If the load is doubled, volume flow is approximately doubled and residence time reduced by 50%. The net effect is the same as if exhaust system volume were reduced by 50% at a given exhaust volume. Exhaust given exhaust volume flow. Exhaust volume and residence time effects are discussed in ref. 13.

An increased air-flow rate would increase the concentration of HC as a result of increases in the unburned fuel from the quench zone and from the crevices, and in the fractions of unburned HC exhausted from the combustion chamber, even though the fractions of quench and crevice gases not oxidized in the chamber decreases. The largest part of the increase in exhaust HC concentration due to increasing the air-flow rate was caused by the increase in unburned fuel from the crevices[34].

Another reason why the HC would increase is due to the richness of the air-fuel mixture[20].

Factors which tend to reduce HC emissions include quench thickness, exhaust temperature and combustion chamber surface temperature. The quench thickness decreases as the cylinder pressure and temperature increase[86]. Mean cylinder pressure increases linearly with load. Hence increases in load would tend to reduce concentration of HC. Also as load is increased exhaust temperatures would be higher; this would increase exhaust after-reaction[13], reducing HC emissions. Increasing the combustion chamber surface temperature(as indicated by the coolant temperature, which is near its maximum value) also tends to reduce HC emissions[38].

In the case of CO, the increase in emissions is substantial. This is probably due to the large increase in the richness of the air-fuel mixture which is the most predominant factor. One must also keep in mind that CO is an intermediate compound in HC oxidation. Thus relatively good HC oxidation in the exhaust would produce some CO which has not completely oxidized[13].

The catalytic converter does not appear to reduce emissions during this part of the cycle. This can be seen by comparing data in Tables 5-8 and 5-15 which show that CO and HC emission levels are about the same as they are without a converter. The only plausible explanation is that there is insufficient oxygen for the catalyst to catalyze the oxidation reaction. The only remedy appears to be air injection into the exhaust manifold. This would increase the overall air-fuel ratio and enable the oxidation reaction to take place in the catalytic converter.

6.1.4. Return To Load Condition 1. By reverting back to the first load condition (this is done by merely closing the throttle), the operating conditions are the same as described in 6.1.2. The air cleaner and inlet manifold temperatures rise again; exhaust temperatures drop off slightly. The air-fuel ratio is slightly leaner than that in the previous case because the engine is warmer so it can run leaner at the same power and speed.

The CO and HC levels drop back to the minimum values as soon as the load is reduced. This is because of the effects of the leaner air-fuel ratios and lower air-flow rate.

6.1.5. Idle. As soon as the engine is brought to idle, the exhaust temperature drops rapidly. The air cleaner temperature is now steady at the value determined by the thermostat in the "Thermac" system (in the vicinity of 100°F). The engine intake air temperature starts to drop. The inlet manifold temperature rises because of the thermal inertia of the engine block. The air-fuel ratio keeps fluctuating, mostly on the rich side. Manifold vacuum drops slightly. The engine speed drops to a minimum value depending on the idle screw setting, and then steadies.

The CO and HC levels are maintained low. The effect of richer air-fuel ratios which tend to increase emissions is probably balanced by decreased air-flow rate. However, HC emissions for operation without a catalyst, show a fluctuation.

6.1.6. Shut Down. As soon as the engine ignition is switched off, the exhaust temperature falls very sharply. All other temperatures begin to drop except that of the inlet manifold, which rises due to the thermal inertia of the engine.

As soon as the ignition is switched off, there is a small mass of fuel which flows through the engine and the exhaust system. This is due to the inertia of the fuel mass and the fact that the throttle plate is slightly open, despite the solenoid which closes it. As a result, there is an instantaneous peak in the unburned HC. The amount is much higher without the converter. Because the CO emissions stop as soon as the ignition is switched off, there is no peaking of the CO.

6.2. EFFECT OF AMBIENT TEMPERATURE ON MAXIMUM EMISSIONS.

From the data given in Tables 5-2 through 5-40, the maximum values of CO and HC emissions were studied with respect to ambient temperature at start-up.

[illegible] Carbon [illegible]oxide. [illegible] gives [illegible]

[illegible] reached [illegible] the [illegible]

6.2.1. EFFECT OF TEMPERATURE ON CO EMISSIONS. Figure 6-1 gives a plot for the maximum CO emission values reached after start-up against temperature. The graph clearly indicates the effect of ambient temperature on these maximum CO emissions. Maximum CO emissions increased about 25% when start-up temperatures were lowered to 30°F from 75°F without the converter. The same comparison with the converter showed an increase of about 40% at the lower ambient temperature.

The large amount of scatter in the points especially at lower ambient temperatures can be attributed to the choke action. The rate of choke opening and the time the choke starts to open need not be the same every time the engine runs through a cycle. The mechanical linkages could stick temporarily: choke action is known to not be completely repeatable over similar conditions[30].

A separate calculation was made to determine average composite mass emissions as opposed to the emission concentrations actually measured. These were averaged out over the 20-minute cycle in order that they might be related to the grams per mile emissions as actually reported by other authors performing EPA-type tests. The calculation procedure for determining mass emissions from the emission concentrations that were measured is outlined in Appendix G.

Based on the procedure mentioned above, the average CO mass emissions were found to be 1.43 times greater at 23°F than at 75°F.

This compares reasonably well with the results of Ashby et al[89] who ran tests on various automobile engines similar to

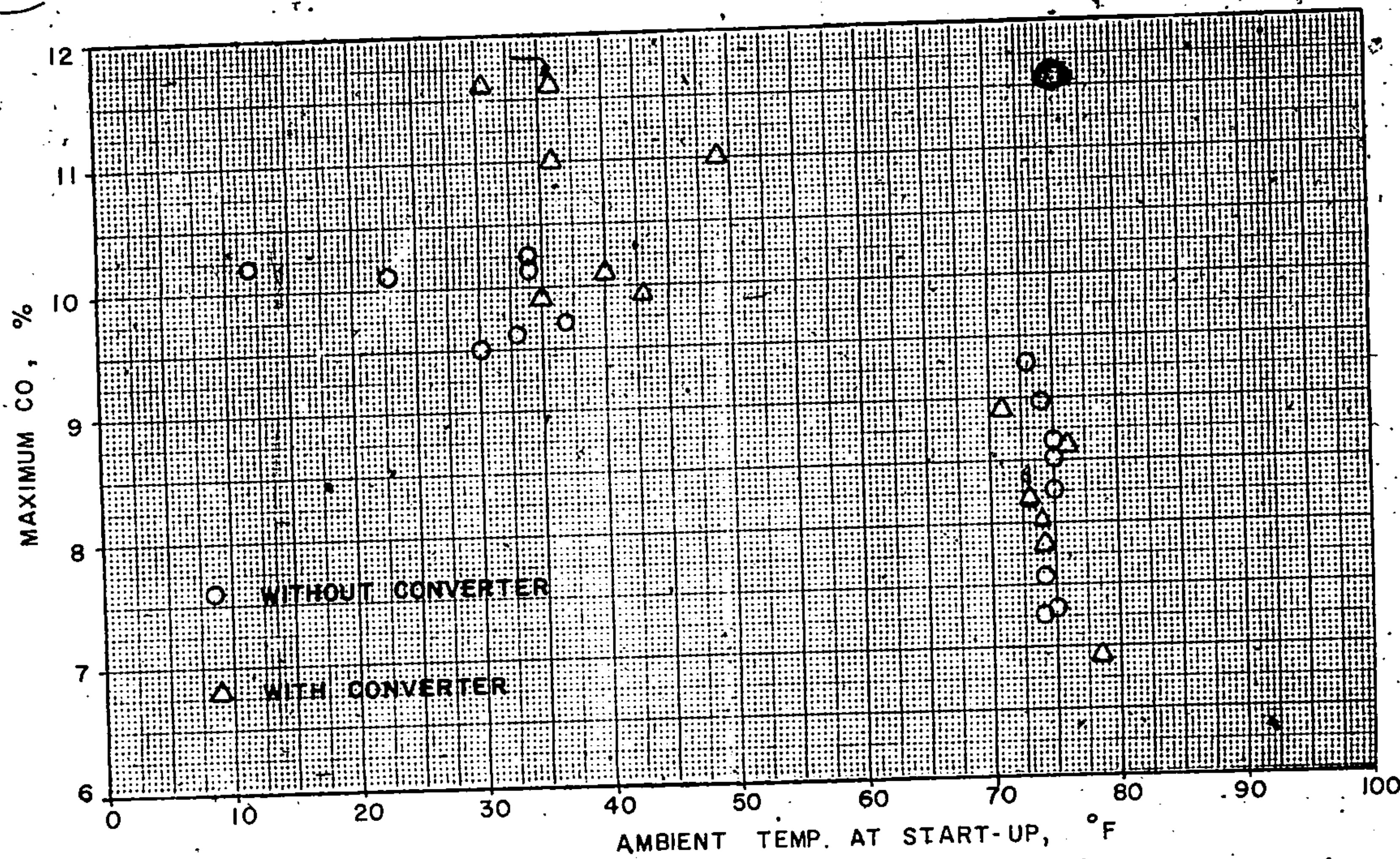

FIG. 6-1. EFFECT OF TEMPERATURE ON MAX. CO EMISSIONS.

the one under study, based on the 1975 CVS schedule and obtained CO mass emissions (in grams per mile) that were 1.55 times greater at 20°F than at 75°F.

The results of Polak[87] based on the 1975 FTP on various types of engines show an increase of 1.52 times the 60°F value at 20°F.

Miles and Homfeld[22] obtained a 65% increase in average CO mass emissions at 20°F over those at 70°F.

A similar comparison of mass emissions at ambient temperatures of 31°F and 74°F was made for two tests with a converter. It was found that composite mass CO emissions at 31°F were 32.5% greater than at 74°F. Ashby et al obtained the following results:

	Average mass CO emissions in grams per mile at 20°F	Average mass CO emissions in grams per mile at 75°F	Increase over 75°F value
Without catalyst	87.0	56.0	1.55 times
With catalyst	28.0	5.6	4.10 times

Thus they obtained a greater proportionate increase with decreasing ambient temperature with the converter than without. The smaller proportionate increase obtained in this work would indicate that the converter appears to work reasonably well at high and low ambient temperatures, at least in this test program. However, mass emissions and concentration levels of both CO and HC for tests with the catalytic converter were fairly high at all ambient temperatures. Emission levels of carbon monoxide and hydrocarbons obtained from runs with the converter were found to be unreliable because the engine set-up was not optimized for the use of the converter. For example, comparing runs with and without the converter at 74°F, CO emissions were actually 40% higher and the HC emissions about 5% higher with the converter. This is contrary to what one would expect. Ashby et al for instance obtained a 10-fold decrease in CO emissions at 75°F with the converter (see table on p 81).

6.2.2. <u>EFFECT OF TEMPERATURE ON HC EMISSIONS</u>. Figure 6-2 gives a plot for the maximum HC emissions reached after start-up against the ambient temperature. The effect of these maximum emissions is some what similar to that of CO. However there appears to be a greater increase in maximum HC emissions as the ambient temperature drops; maximum HC emissions at 30°F increased to a level that was 3.0 times the level at 75°F without the converter and 3.8 times the level at 75°F with the converter.

The scatter of points in the graph is more pronounced in this figure than in Fig. 6-1. This probably indicates that the HC emissions are more adversely affected by the operation of the choke and by mixture maldistribution than CO emissions.

The average composite mass HC emissions as described in the previous section (6.2.1.) and the procedure for which is outlined in Appendix G were found to be 1.58 times greater at 23°F than at 75°F.

This compares with Ashby et al who obtained average mass HC emissions that were 1.63 times greater at 20°F than at 75°F.

Polak's results show an increase of 1.51 times the 60°F value at 20°F whereas Miles and Homfeld obtained a 53% increase in average HC emissions at 20°F compared to 70°F.

Thus we see that results obtained for both CO and HC mass emissions compare reasonably well with those of other investigators.

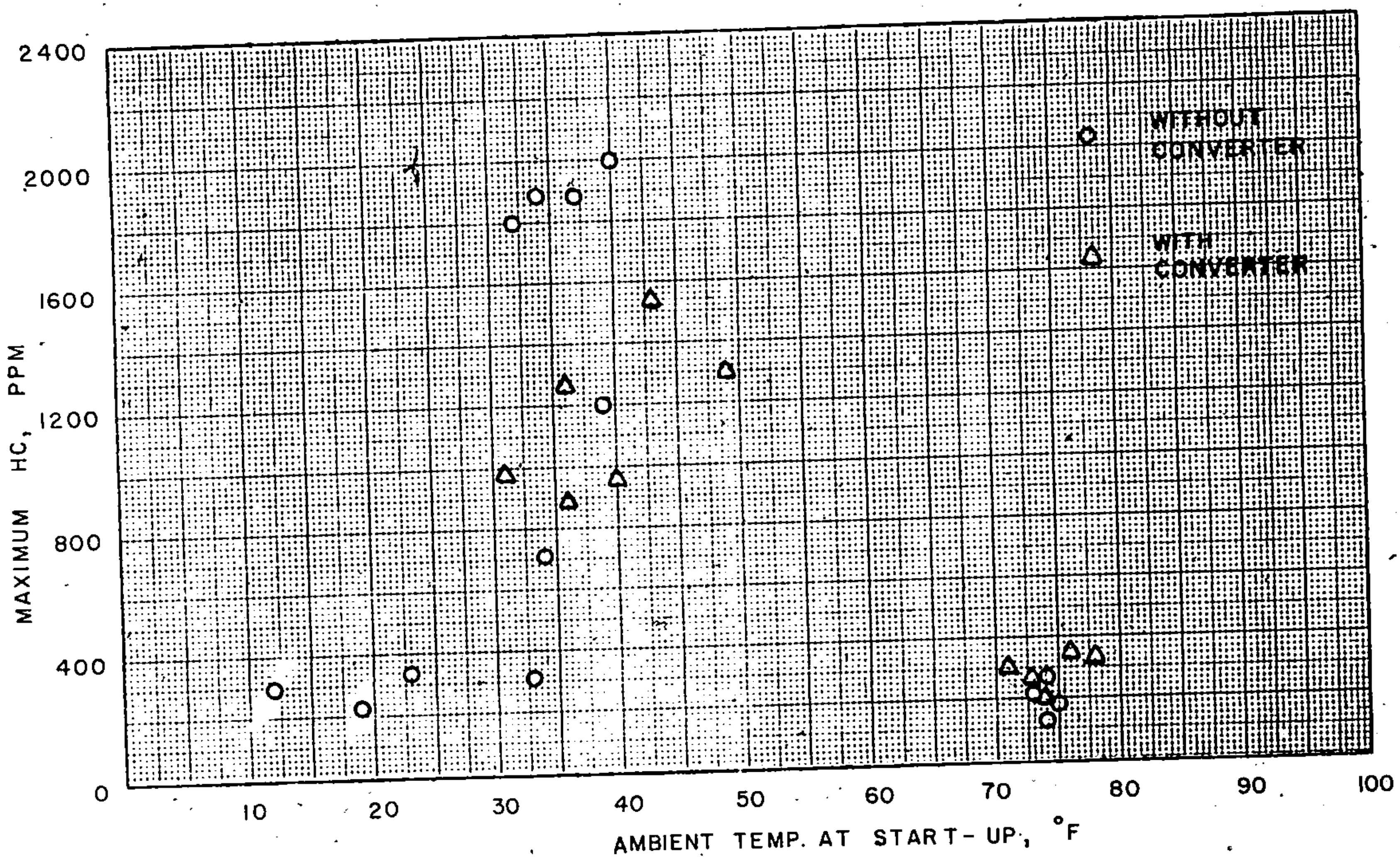

FIG. 6-2. EFFECT OF TEMPERATURE ON MAX. HC EMISSIONS.

6.3. TIME TAKEN FOR EMISSIONS TO REDUCE TO A MINIMUM. Figures 6-3 and 6-4 give plots for the time taken for emissions (CO and HC respectively) to reduce to a minimum level. This time would depend essentially on the load and air-fuel ratio at that instant. The plot gives a rough idea, for similar loads, for cold ambient start-up. It appears that HC emissions take a little longer to reach a minimum. This means that the factors which affect the reduction in quench distance have yet to come into play. This is evident both with and without the converter. The presence of the converter seems to be most effective only at higher ambient temperatures, for both CO and HC. This is only a tentative conclusion. However more tests would have to be carried out as there really is insufficient information to be conclusive in this statement.

6.4. EFFECT OF BED INLET TEMPERATURE ON CATALYST PERFORMANCE. Figures 6-5 through 6-17 give plots of the CO and HC emissions as a function of the catalytic converter bed inlet temperature. As it can be expected, the emissions reach a minimum value as the bed inlet temperature reaches a certain value.

A peculiar feature can be noted in these plots. In low ambient temperatures the emission levels reduce to a minimum at inlet bed temperatures ranging from 600° to 700°F, whereas in warm ambient temperatures the temperature range is lower (200° to 300°F). The curves for inlet bed temperatures versus time after start-up are essentially similar for both types of ambients so this further proves that emissions reduce to minimum values at a faster rate in warm ambient temperatures than in cold. Also, the catalytic converter reaches the light-off

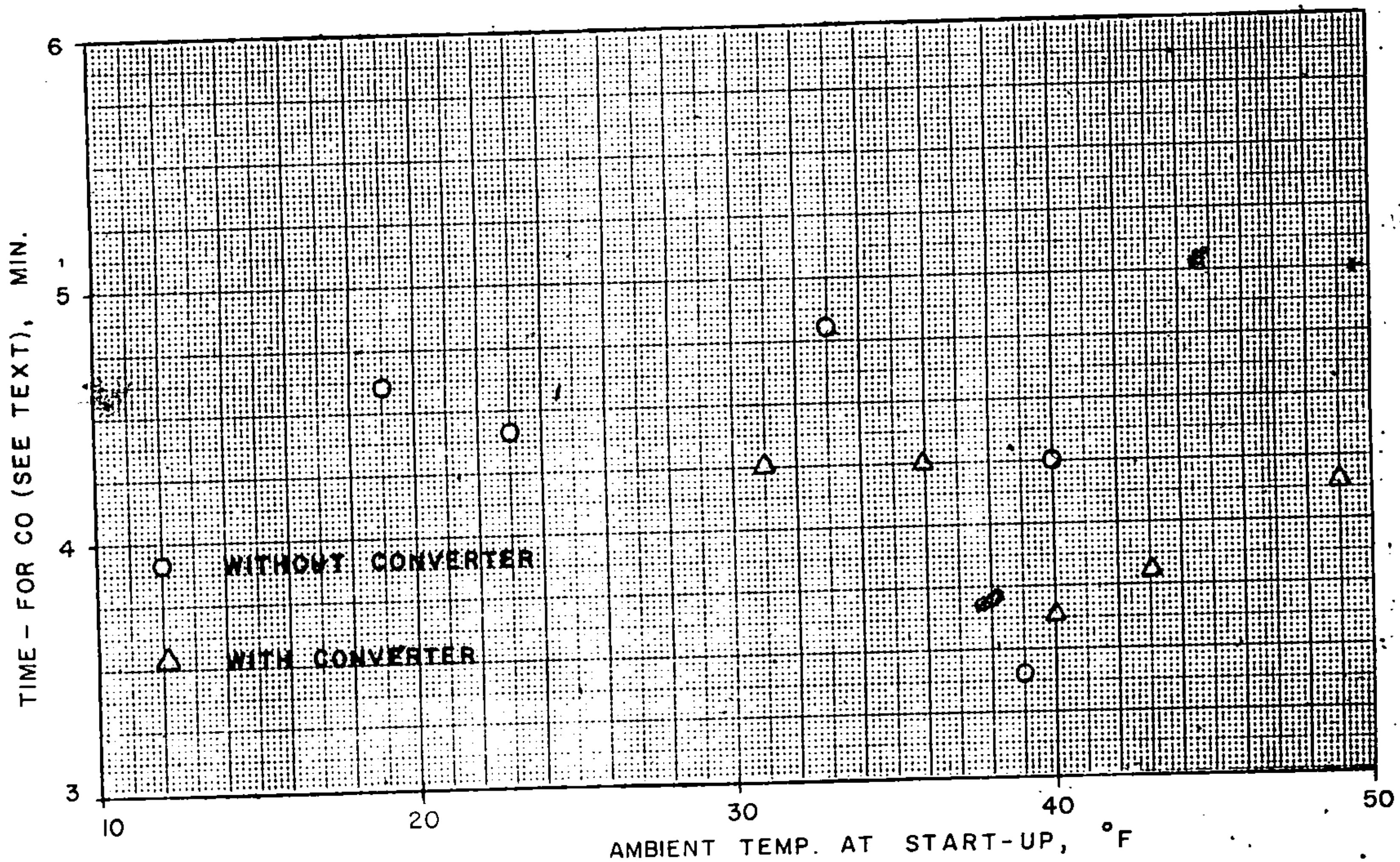

FIG. 6-3. EFFECT OF TEMPERATURE ON TIME REQUIRED FOR CO EMISSIONS TO REACH MIN. LEVEL.

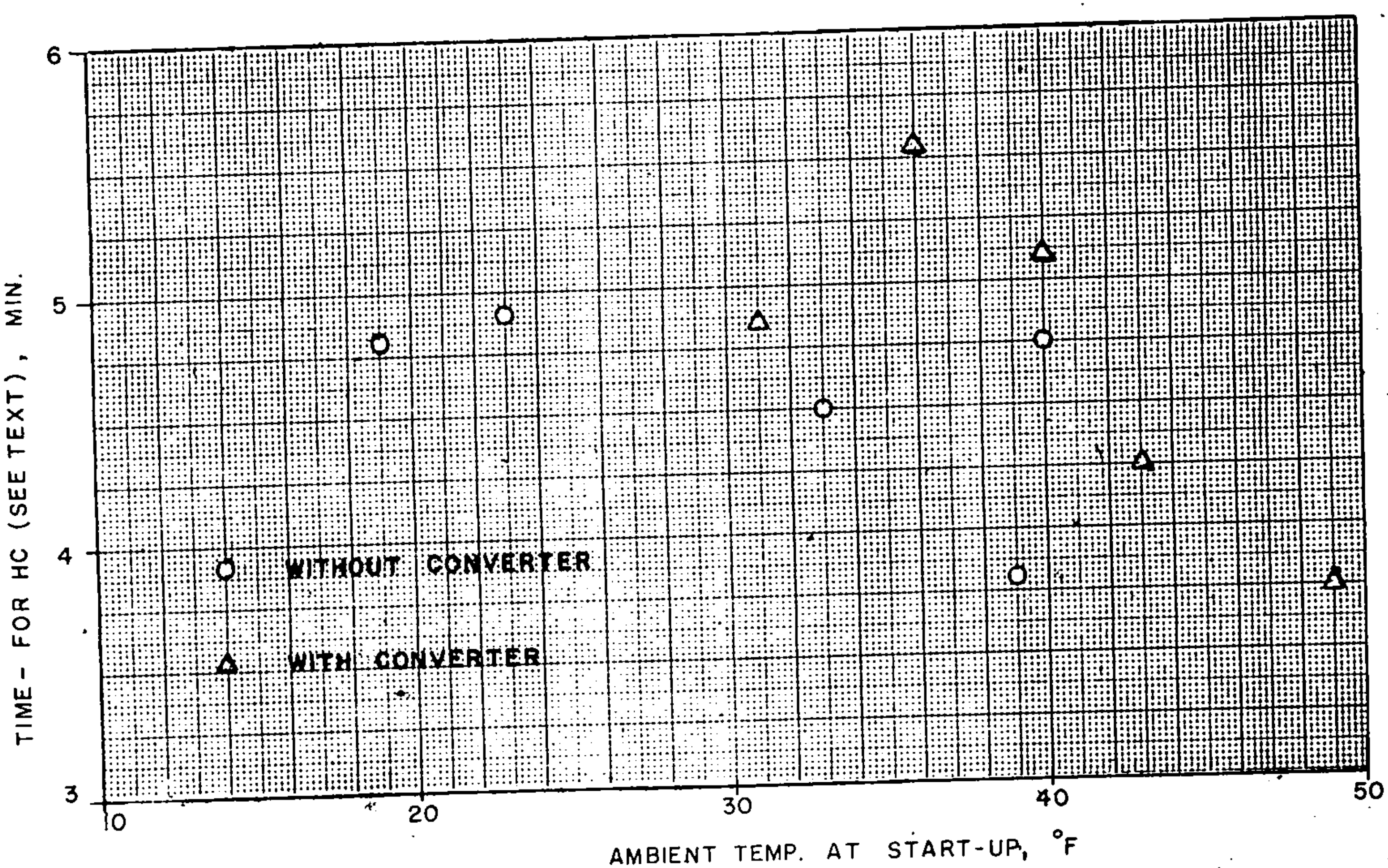

FIG. 6-4. EFFECT OF TEMPERATURE ON TIME REQUIRED FOR HC EMISSIONS TO REACH MIN. VALUE.

temperature quicker in warm ambient temperatures.

6.5. AIR INTAKE SYSTEM STUDIES. From the temperature plots (Figs. 5-1a through 5-40a) the time required for warmup was estimated. The temperature of the air at the air cleaner rises gradually from start-up, reaches a peak and then drops off to an approximately steady state level, during the first 9 minutes of the cycle. It may be argued that this is the temperature the "Thermac system" tries to maintain during the first part of the cycle. When the air cleaner temperature rises it reaches this temperature and probably because of thermal inertia, shoots up further and peaks before dropping off. By extending the steady state line backward till it meets the line which is rising one can approximate the time taken for the air in the air cleaner to reach the steady state temperature. This is considered a good indication of, and thus defined as the "warmup time". As an example see Fig. 5-5a. The location of the steady state temperature on the print-out of the air cleaner temperature is indicated by point A in the figure.

The warmup time has been plotted against the ambient temperature (Fig. 6-18). Although there appears to be some scatter in the points, one can see that there is an approximately linear relationship between the warmup time and the ambient temperature. The warmup time appears to be fairly insensitive to the loads considered. These loads were not substantially different from each other.

The time required to warm up the engine, as estimated from Fig. 6-18, increases about 90% when the ambient temperature decreases from 75°F to 20°F.(see section 6.1.1.2). Warmup time

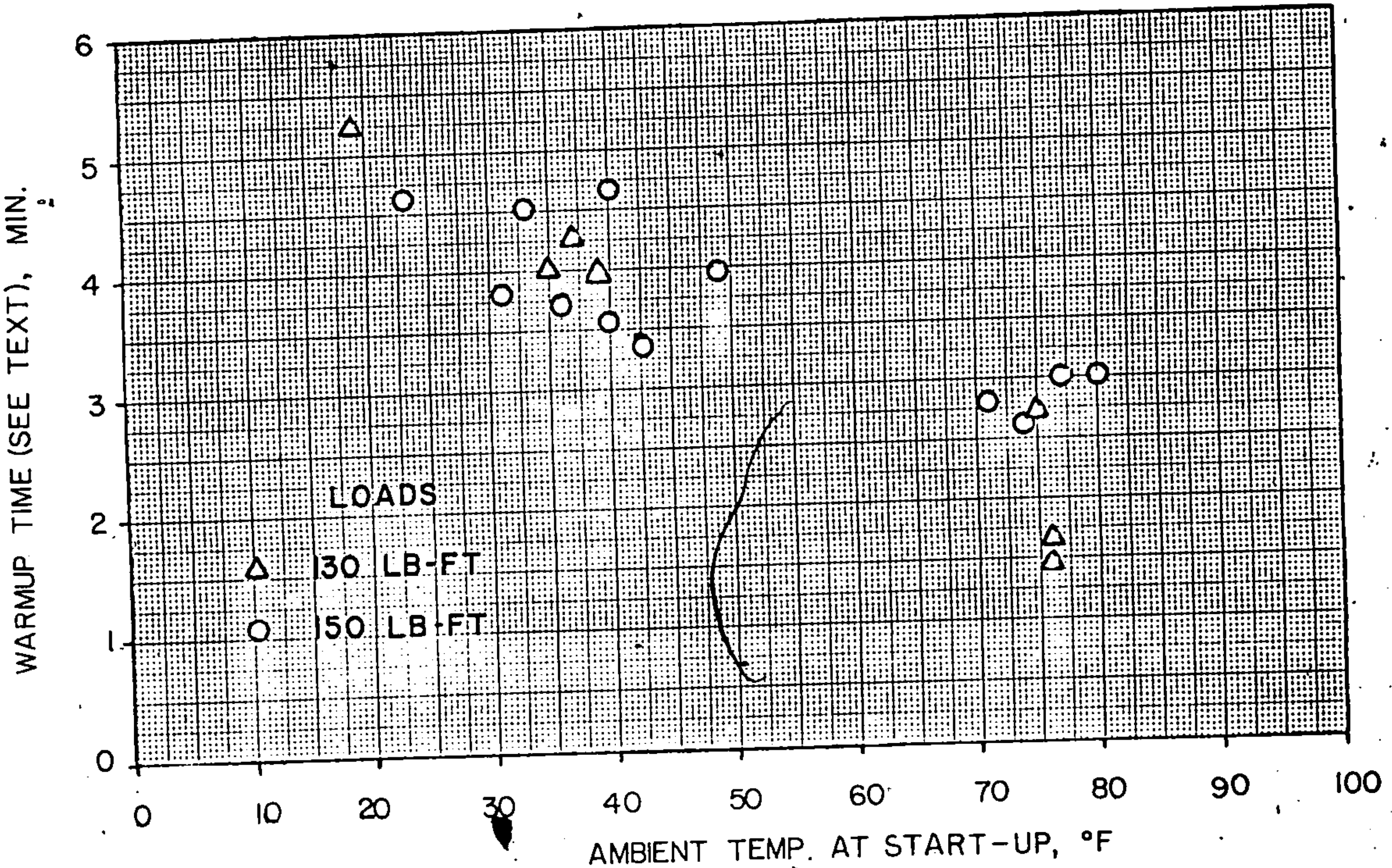

FIG. 6-18. EFFECT OF TEMPERATURE ON ENGINE WARMUP TIME

increases about 13.5% when the ambient temperature decreases from 40°F to 25°F.

A recent paper[94] studied the effect of cold temperature on some driveability malfunctions like stall, idle roughness, backfire, hesitation, stumble, and surge. The authors assigned a malfunction severity rating for each category, during each part of the driving cycle. They found that the majority of the warmup problems (like hesitations, stalls, stumbles, and backfires on acceleration after warmup) occured during the cold-start and driveaway portion of the test cycle. The average demerit rating at 40°F decreased by 16.8% when compared with those at 25°F.

Thus we see that the cold-start and driveaway performance of an automobile depends to a large extent on the time required for the engine to warm up.

A more direct comparison of warmup time with other investigators was not made because of lack of available data.

6.5.1. <u>The Air Preheater</u>. From calculations of the mass flow rates through the air-intake and the manifold heater, it appears that most of the air is flowing through the main intake at start- and warmup. This is because the temperature differential across the intake air and the air cleaner ([T_3 - T_1] in Fig. 4-2) is almost zero at start-up and during the first 45 seconds of the cycle. In actual fact the air is mostly flowing through the heater; but during the first 45 seconds of the cycle, the exhaust gases are not warm enough to heat the air and cause a high temperature differential between T_3 and T_1. As the exhaust gases get warmer, T_3 starts increasing in greater proportion to T_1 and so more and more air passes through the heater. This proceeds until a balance is reached between the temperature rise due to the manifold heating and the temperature drop due to the cold intake air. The mass of the air passing through starts to drop off gradually until it reaches a minimum value after 9 minutes of running. When the load condition 2 is applied, the air entering air cleaner is warm enough so that the heater system gets shut off and most of the air passes through the main air passage. When load condition 1 is applied again, the heater comes into operation again. But because $(T_3 - T_1)$ is large enough, only a small fraction of the air passes through it. This is maintained throughout the idle period as well.

7. CONCLUSION

The conclusions derived from the analysis of the results described in Chap. 6, will now be given. Included also are suggestions for future work.

The test runs made were quite effective to investigate warmup characteristics of a representative North American automobile engine. A suitable sequence of operations was deemed necessary for proper study. The engine-dynamometer system, which was used in the experimental work, was determined to have advantages over a chassis dynamometer due to better control of certain operating parameters such as load, speed, throttle position and coolant temperature. Useful results of start-and warmup characteristics of the engine were obtained.

There was some difficulty in obtaining repeatable results. The catalytic converter test results were particularly suspect.

7.1. TEST RUNS. Emission levels from the engine over a range of ambient temperatures were checked. Tests with a catalytic converter fitted to the exhaust system of the same engine were also carried out over approximately the same range of ambient temperatures.

Ambient temperature was found to have a strong influence on CO and HC emissions. This conclusion has been obtained by a number of investigators in the past[9,12,22,81,87,89,90].

Highest emissions were found to occur during the warmup period of the engine test cycle. The warmup period of the test cycle used in this study is the initial fast idle period before a load was put on the engine: this period was for the first two minutes after start-up in the cold temperature test and the first one minute after start-up in the warm temperature test. Increased emissions during the warmup period were obtained both on mass as well as on concentration basis. The increase in the mass emissions during warmup at 23°F compared to 75°F is given below:

HC	CO
150%	85.5%

Some comparison might be made with the results of some other investigators. They used a differently defined warmup sequence. Their results are given below; they are for approximately the same range of temperatures, i.e. between 20°F and 75°F:

HC	CO
99%*	86%*
	126%†

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* Miles and Homfeld[22]: these figures give the total gram difference accounted for in the first 2 "cycles" of the 1972 EPA schedule. A cycle is defined as the portion of the schedule between idle periods. There are 18 cycles in the schedule. The car was a 4000 lb model with a 350 cu. in. displacement engine.

Consequently it could be concluded that the test sequence used in this study is as good as that chosen by other researchers, to indicate warmup trends.

The increase in average concentration emissions over the same range of temperatures (23°F - 75°F) was not so pronounced, during the warmup period. The percentage increases are given below:

HC	CO
22.5%	6.0%

The main causes for the increase in the concentration emissions of both CO and HC at the lower ambient temperatures are the enrichening of the air-fuel mixture due to the choke action, and increased quench thickness.

Robertson[90] presented a graph of the choke-off time versus the ambient temperature. The temperature range in his graph is between -30°F and +30°F and this graph indicates a choke off time of about 6 minutes at 20°F. Thus during the warmup period of the engine test cycle the choke does not open fully. This explains the higher increase in HC concentration.

The mass emissions at warmup increase substantially because of increased intake air flow. It was found that the air flow rate at 23°F was about 80% higher than at 75°F, during the warmup period. This is because idling during warmup requires more power to overcome increased friction in colder ambient temperatures.

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† Ashby et al[89] (continued from p 92): this figure gives the difference between the grams per mile (cold start) emissions of CO, the test being carried out by the 1975 FTP.

The ratio of average mass emissions during warmup to the composite mass emissions averaged over the entire 20-minute cycle was computed. These ratios are given below:

	HC	CO
at 23°F	4.21	4.20
at 75°F	2.73	3.22

As a comparison, the ratio of mass emissions collected in the first bag of the 23-minute cycle of the 1972 FTP to the composite emissions, as given by Grinberg and Morgan[12], are given below. These ratios are at 70°F:

HC	CO
5.20	3.90

In their case, the warmup time was for 125 seconds which corresponded to 9.1% of the total test time. The corresponding figures for our test (at 75°F) were 60 seconds and 5% respectively. Even then, our results compare quite favourably with theirs. Another point to note in our results is that the ratios increase as the ambient temperatures decrease. This is what Grinberg and Morgan obtained, as indicated below:

	HC	CO
at 40°F	7.03	6.50
at -10°F	7.35	5.95

This conclusion may be justified within experimental error.

The results of warmup sequences show that the test cycle used in this work compares favourably with that employed in the U.S. Federal Testing Procedure.

Both HC and CO emissions took at least 2 minutes longer to reach a minimum level in cold ambient temperatures. At 19°F the minimum levels of both CO and HC were reached after about 4.1/2 minutes while at 75°F they took 2.1/2 minutes. Minimum levels were practically the same for CO and HC emissions in both cold as well as warm ambient temperatures.

There was some difficulty in obtaining repeatable results although test conditions were maintained as close as feasible to each other. Test runs were identical, warmup rates (depending on whether the test temperature was warm or cold) were the same and the loads and speeds were unchanged.

The results obtained from test runs based on a test procedure completely different from the U.S. Federal Test Procedure are thus found to be comparable to a large extent with those obtained from tests on engines run by following the F.T.P.

Thus the results are quite useful in studying emission levels and warmup rates of an automobile engine mounted on an engine dynamometer test stand. It must be borne in mind that the tests made by other investigators refered to in this chapter were made on a chassis dynamometer test stand.

The comparable results thus justify using an engine-dynamometer system as well as following a different test sequence.

7.2. THE CATALYTIC CONVERTER. The emission results obtained after the catalytic converter was installed in the exhaust system of the engine were found to be generally unreliable. At start-up and during the warmup period of the test cycle, there was no noticeable reduction in HC and CO emissions. This was probably due to the fact that the catalyst did not reach the activation (light-off) temperature for significant conversion of the exhaust carbon monoxide and unburned hydrocarbons to carbon dioxide and water.

One investigator[89] found that catalyst equipped engines showed a greater proportionate increase in HC and CO emissions when ambient temperatures decreased than engines without the catalytic converter.

The inactivation time of the converter during the warmup of the engine could be reduced by preheating the catalyst bed[53].

There is another problem with using the catalytic converter. Air injection into the exhaust stream at the converter inlet should be provided for efficient conversion. Oxygen is necessary for significant oxidation of HC and CO. Since air injection was not available for these experiments, HC and CO emissions were high.

Another reason why the HC and CO emissions were higher than expected was because the engine set-up was not optimized for use with the converter.

The catalytic converter however did appear to reduce by about 30 seconds, the time required for emission levels to reach a minimum value. It also helped dampen fluctuations in HC emission levels during the slow idle period. The reason for this is not clearly known. Too, the peak HC at shut down was found to be lower with a converter.

7.3. <u>AIR INTAKE SYSTEM</u>. The operation of the thermostatically controlled air intake system was studied under various ambient temperatures and engine operating conditions. Warmup time was found to be lower for higher ambient temperatures.

The cold-start and driveaway performance of an automobile was found to depend to a large extent on the engine warmup time.

The operation of the "Thermac Air Cleaner" assembly was also checked. It was found that air flow through the exhaust manifold heater dropped to a minimum when the warmup time had been reached. The device was found to be fairly effective in bringing up the carburetor air temperature rapidly to a sufficiently high value so that fuel vaporization was more complete.

7.4. <u>SUGGESTIONS FOR FUTURE WORK</u>. Through experience with the tests undertaken, certain recommendations can be made which should be investigated if further work in this area is to be carried out.

7.4.1. <u>Test Procedures</u>,

<u>The driving cycle</u>. The 2 minute warmup period after a cold start in winter (which was used in the tests) was an arbitrary choice. This period should probably be extended if lower ambient temperatures than those used here are encountered. Particular engine transmission combinations might suggest other load conditions than those used here. The 5 minute idle at the end of the second application of load condition 1 would rarely be encountered in practice. This was included in the cycle mainly to prevent overheating of the coolant in the dynamometer.

<u>Tests with engine block-heaters</u>. In Canada, block-heaters are often installed in order to heat the engine block during an overnight soak in cold ambient temperatures as it helps achieve a

quick start and warmup. The effect of using block-heaters on engine emissions could be studied. By keeping the engine block warm, the HC emissions at start and warmup would be lowered because of a possible reduction in cylinder quench thickness.

Tests using fuels of other types. By modifying the fuel composition, the volatility could be increased. Usually additives are added to the fuel. The effect of such fuels on the warmup characteristics, emission levels and fuel consumption could be investigated.

Tests on the Catalytic converter. These include converter performance and endurance tests, effects of contaminants and sulphate emissions and effect of the catalytic converter on engine back pressure, exhaust flow rate, cycle-by-cycle variation in emission levels.

7.4.2. Equipment. By installing new equipment, certain additional tests could be carried out.

Providing a choke monitor to determine the time the choke starts to open, its rate of opening and the time taken for it to open fully.

Providing a low pressure cut-off switch in the water line into the dynamometer which will cut off excitation if the water pressure goes below 2 or 3 psi and not 11 psi as is the case at present. Bypassing the switch is preferable because water pressure does not fall below 5 psi during a test run.

Providing the engine ammeter and oil pressure gauges in the control room for easy accessibility especially when the engine is in operation.

Providing a device to keep the sampling line warm in cold temperature tests so that the moisture from the exhaust does not freeze during a test run. Passing the sampling line through a warmed brine bath or providing a heater are two ways of tackling the problem.

7.4.3. Engine. Certain modifications to the engine itself could produce interesting results.

By adjusting the thermostat setting of the cooling column to ensure that the cooling water circulates in the engine at a higher temperature, the effects on emissions could be studied. This is significant since surface temperature of the engine has an effect on HC formation.

By tuning the engine for optimum operation with the catalytic converter the effects of the various parameters could be investigated. These include valve timing, ignition timing, carburetor setting, etc.

By providing air injection, either at the exhaust ports or at the inlet to the catalytic converter, the emission levels could be investigated.

7.5. AIR QUALITY IN WINTER. A great deal of evidence has has been presented substantiating the fact that engine exhaust emissions increase with decreasing ambient temperatures for at least the warmup period of the dynamometer emission test cycle. The question which must now be answered is whether or not these increases are observed in the atmosphere as monitored degradation in air quality.

Robertson[90] discussed the comparison of air quality in winter and summer, considering established health levels and meterological influences on a region and/or automotive usage changes with the variation in the seasons.

He concluded that none of the three major pollutants, HC, CO and NO_x appear to dramatically change seasonably as suggested by the exhaust emission tests on automobiles locally per region or nation-wide.

The largest influencing factor to air pollution abatement is the weather. The temperature of an area significantly influences the formation of oxidants and the dispersion of pollutants. Temperature variation can also change the reaction rate. Laboratory experiments have shown that an increase in ambient temperature increases the rate of NO_x and HC oxidation. Photochemical reactions are substantially reduced thus causing less concern at lower ambient temperatures.

Studies carried out by several authors have indicated that wind velocity and atmospheric instability or vertical temperature profile are two key meterological parameters in pollutant abatement. High pollution levels occur over large areas for prolonged periods of time when there are relatively light winds at the surface and aloft as well as inversion conditions in the lower layers of the atmosphere.

Low wind speeds limit the dilution and transport of pollutants horizontally. Inversion layers limit vertical transport, stagnating lower regions from the higher wind speeds which occur at greater altitudes. Inversions usually occur due to stable air conditions which are determined by the rate of decrease of temperature with altitude. When the temperature decreases at a rate greater than 5.4°F per 1000 feet, the air is considered to be unstable.

In the winter months, long nights and short days would tend to support increased duration of inversion. However, in cold weather climates, the climatic conditions prevent persistent inversions from occuring. Across Canada, the average temperature in January is about 50°F lower than in July. The amount of solar radiation received per day in January is, on an average, approximately one-fifth of that received in July due to the fewer hours of sunlight in the winter months. On an average, wind speeds are 50% higher in January than in July.

Thus the three principal meterological factors, namely, low temperatures, fewer hours of sunlight, and high wind speeds naturally abate any increases in the air quality in winter due to their influence in the environment on pollutants not only from the automobile but from all other sources as well.

Other reasons are contributed by man. Every year, newer and better cars are introduced into the road; cars are maintained better in order to make them run more efficiently in winter; less automobile driving is done in winter than in summer. Also the probability that the engine would cool down to ambient temperature before restart could be less than expected. Nation-wide use of block-heaters has also improved the situation[90].

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A. THE ENGINE

A.1. SPECIFICATIONS[91].

Manufacturer and designation	General Motors of Canada Ltd., Chevrolet Division.
Type	Automotive V-8
Displacement	350 cu. in.
Power	245 HP at 4800 R.P.M.
Torque	350 ft-lb at 2800 R.P.M.
Bore x stroke	4 in. x 3.48 in.
Compression ratio	8.5:1
Firing order	1-8-4-3-6-5-7-2
Valve lifter	Hydraulic
Compression	160 psi at cranking speed, throttle wide open. Maximum variation 20 psi between cylinders.
Spark plug gap	0.035 in.
Distributor:	
Point dwell	29° - 31°
Point gap	0.016 in. (used), 0.019 in. (new)

Condenser	0.18 - 0.23 microfarads
Timing (with Auto. Trans.)	6° btdc at idle speed with vacuum advance disconnected and plugged.
Air cleaner	"Thermac" system, paper element type. Also acts as a flame arrestor.
Idle speed	550 R.P.M.
Carburetor	2 bbl, with 2 venturi and separate fuel feed for each; down draught, with temperature-sensing choke[92].
Ignition coil	Primary resistance 1.77 - 2.05Ω at 75°F. Secondary resistance 3000 - 20,000Ω at 75°F.

A.2. EMISSION CONTROL SYSTEMS ON ENGINE. The engine is fitted with emission control systems which were in use on Canadian models in 1971. The U.S. Federal Emission control standards did not include NO_x control at that time.

A.2.1. Factors Considered in Engine Design for Low Emissions. These factors have been considered by the manufacturers when designing the engine described here.

(a) Size and shape of the combustion chamber which helps control the travel of the flame as it moves through the chamber.

(b) Ratio of the combustion chamber volume to wall surface, which affects the quenching action and amount of unburned HC.

(c) Compression ratio, which affects both the combustion temperature and the octane rating of the fuel that must be used.

(d) Valve arrangement, timing and overlap, which determine the volumetric efficiency and scavenging action of the engine that is important for control of NO_x.

(e) Carburetor and manifold arrangement and carburetor adjustments to provide proper air-fuel mixture.

(f) Exhaust manifolds, pipes and mufflers that allow free flow and help assure complete combustion.

(g) Spark plug gap and timing settings that provide the most effective burning action under all circumstances.

The ultimate aim is to burn the fuel as completely as possible, but without excessive combustion temperatures.

The engine that was tested has the emission control systems explained below. Each system performs the specific function described.

A.2.2. Positive Crankcase Ventilation System. The engine is fitted with a 'closed' type positive crankcase ventilation system to meet the requirements for controlling crankcase vapour emissions, to protect crankcase oil from dilution, and to reduce sludge formation.

Air drawn into the crankcase via the air cleaner mixes with the crankcase vapours. These vapours are then drawn up through a vacuum- and spring-controlled ventilating valve (PCV) into the intake manifold, where they mix with the air-fuel mixture and are then burned in the combustion process.

The PCV valve is designed to close by spring pressure when the engine is not running. When the engine starts, the manifold vacuum pulls the valve open against spring pressure. The valve remains open allowing the crankcase fumes to enter the intake manifold as long as there is engine vacuum. Thus the valve action varies with the engine condition; restricting the flow at idle or slow engine speeds, increasing it as the engine speed increases. The valve would be forced shut if a backfire occurs, preventing ignition of fumes in the crankcase.

When the engine conditions are such that more vapours are created than the PCV valve can handle, the excess vapour flows back through the air cleaner and carburetor and thence into the engine, instead of being released into the atmosphere.

A.2.3. Controlled Combustion System. This system, also called the CCS, was introduced by GM in 1968 to reduce unburned HC and CO in the exhaust. A newer combustion chamber design, cooling system thermostats in the 190°-220°F range for quicker warmup, special carburetor calibrations and adjustments and ignition adjustments and spark advance controls closely related to various driving conditions; these are some of the features of the CCS.

The CCS uses the "Thermac Air Cleaner", shown in Fig. 4.1. The thermostatically controlled air cleaner unit is designed to maintain a minimum temperature of approximately 100°F for the air entering the carburetor. Maintaining this minimum temperature permits good driveability with a leaner carburetor air-fuel mixture which helps reduce exhaust emissions.

As seen in Fig. 4.1, the vacuum motor, controlled by the temperature-sensor, and operated by the engine vacuum, operates the damper assembly to control the air flow, providing either preheated air from a shroud around the exhaust manifold or unheated air from the atmosphere.

When the temperature of the air entering the air cleaner is below 85°F, most of the air passes through the exhaust manifold heating system and mixes with the rest of the cool air which passes right through, to maintain a safe minimum temperature in the air cleaner.

As the temperature in the air cleaner begins to rise above 85°F, the damper begins to open, thus allowing less air to pass through the exhaust manifold preheater system. When the temperature in the air cleaner rises above 130°F, the damper is fully opened and all the incoming air passes through to the air cleaner.

The CCS uses lean carburetor adjustments with the idle mixture screw limiters that are factory adjusted. Idle speeds adjustments are higher and ignition timing retarded as compared to earlier models. An idle-stop solenoid is fitted to prevent engine dieseling (continuing to run) when the ignition is turned off. The solenoid allows the throttle to close beyond the normal idle position when the ignition is turned off.

Other special ignition timing systems used in the CCS include a centrifugal advance that starts at a higher speed, and a vacuum advance system that is switched off at idle.

The retarded spark setting at idle speeds makes the engine run hotter at idle and low speed conditions. To protect the engine against overheating, it is equipped with a temperature-sensitive thermostatic vacuum switch. The switch is mounted in the engine cooling system. An excessive coolant temperature causes an advancement of the timing to speed up the engine and reduce the heat rejected to the coolant.

A.2.4. Evaporation Emission Control System. This system is used to reduce emission of gasoline vapours from the engine fuel system. The engine under test does not have this because it does not have the same type of fuel tank as the 1971 automobile. Vapours from the carburetor fuel bowl are absorbed by a vapour-storing canister containing activated charcoal. This occurs mostly when the engine is not running. When the engine is operated, fresh air is drawn up through the canister, and along with the vapours, are drawn into the carburetor, to be burned with the rest of the charge, in the cylinder. With this system, external carburetor vapour and idle vents are sealed. Some venting action is provided by the purge port through which the vapours are drawn from the canister.

A.2.5. Combination Emission Control System. This is used in the automobile fitted with the CCS; with the distributor vacuum advance eliminated in the low forward gears which are in use for long periods of time during city driving. The vacuum advance control is acomplished by means of a solenoid (CEC solenoid) which is energized by grounding a switch at the transmission.

B. THE DYNAMOMETER

B.1. SPECIFICATIONS.

Type	Eddy Current absorption
Rating	450 HP, from 1600 to 6000 R.P.M.
Cooling system data:	
Type of cooling	Water cooled, equipped with strainer and solenoid valve, constant flow valve to maintain line pressure, water modulating valve to regulate water flow into the unit.
Water flow rate	35 gallons per minute, maximum
Pressure range	35 to 100 psi
Inlet temperature	Less than 90°F
Water pressure switch	Set at 11 psi
Water temperature switch	Set at 165°F at discharge (range 162°-168°F)
Strain gauge Indicator:	
Transducers	4 arm strain gauge, 120-2000Ω

Excitation	16 to 5 Volts DC, to maintain 50 milliamps bridge current
Power requirement	105-125 Volts, 60 Hz, 35 W
Load cells;	
Bridge type	Single, 350Ω (±5Ω)
Excitation	12 Volts AC/DC (20 Volts AC/DC maximum)
Rated output	3 MV/V input
Controller:	
Type	Silicon controlled rectifier
Power requirement	575 Volts AC, 60 Hz, single phase

C. AIR-FLOW NOZZLE CALIBRATION

The smaller nozzles of the Go-power air-flow meter did not appear to give accurate values of air flow based on the manufacturer's data. This was assumed to be the reason why values of air-fuel ratio in the earlier work[11] were lower than expected. Consequently, the nozzles were recalibrated as follows.

The nozzles were mounted on a calibration rig set up for determining the velocity of flow by means of the velocity traverse method. The unit was connected as shown in Fig. C.1.

Air was drawn through the system by means of a fixed speed blower. Flow rate was controlled by means of dampers in the exhaust of the blower. The deflection of fluid in the flow-meter manometer gave a mass flow rate according to the GO-power charts.

The velocity of flow at the section was determined by a pitot tube traverse.

Because of the boundary-layer effect, there is a variation in the velocity of the fluid flowing in a tube, across the

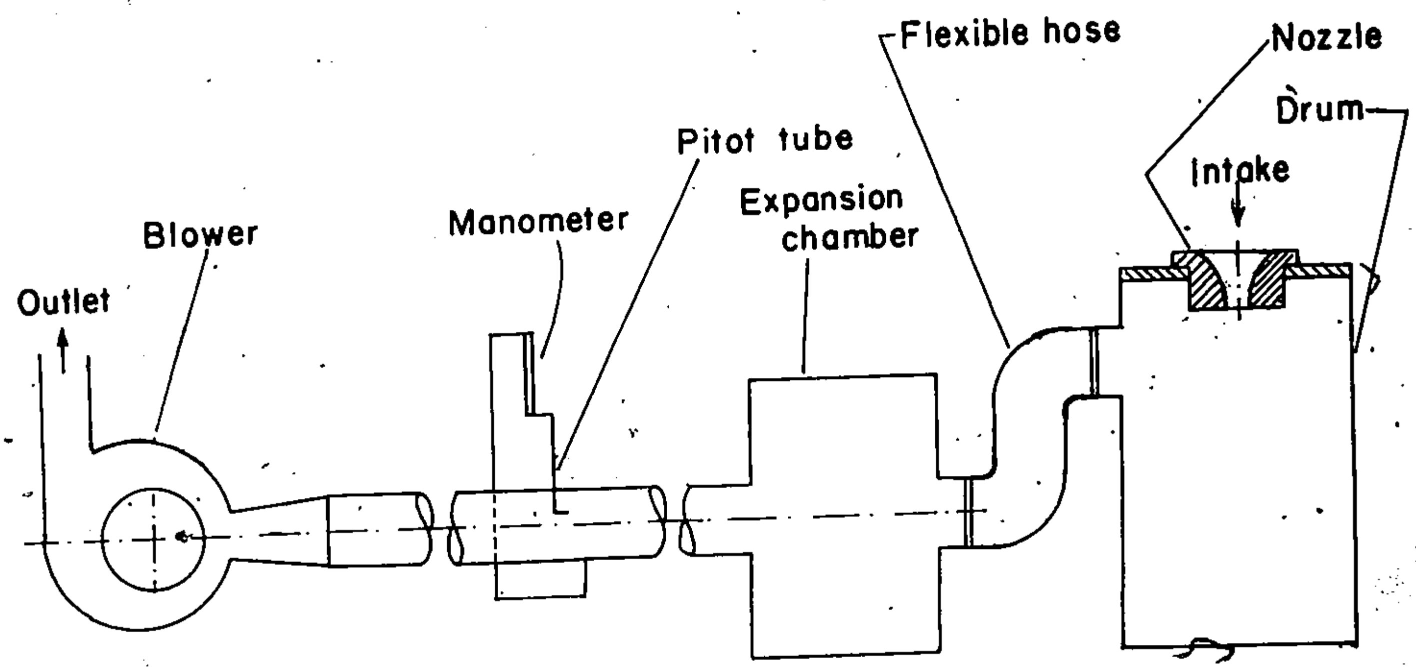


FIG. C-1. SCHEMATIC DIAGRAM OF THE AIR-FLOW METER NOZZLE CALIBRATION RIG.

cross-section. Fig. C.2 shows the profiles of velocity in laminar and turbulent flows in a circular tube. The laminar fl flow profile is assumed to be parabolic[93]. The profile for turbulent flow is more complicated.

If we connect a pitot tube as shown in Fig. C.3, there will be a pressure drop between points 1 and 2. Point 1 is at any arbitrary location across the cross-section of the tube.

We have, by Bernoulli's theorem, assuming no friction losses,

$$p_1/w_{air} + v_1^2/2g = p_2/w_{air} + v_2^2/2g \qquad \ldots C.1$$

But due to the boundary-layer phenomenon, velocity v_2 is zero, so simplifying eq. C.1, we get,

$$v_1^2/2g = (p_2 - p_1)/w_{air}$$

$$v_1 = \sqrt{[(p_2 - p_1)2g/w_{air}]}$$

$$= \sqrt{(2\Delta p/\rho_{air})} \qquad \ldots C.2$$

because $w_{air} = \rho_{air} \cdot g$

By means of the pitot tube probe, the pressure difference between any point on the cross-section of the pipe, and the wall was determined. The pressure difference was read directly by means of a manometer, which is calibrated to give the pressure difference in millimeters of water.

Thus by traversing the pitot tube across the diameter of the tube, pressure differences and hence the velocities for different points were obtained. The bulk velocity at the cross-section of the tube was calculated by using the formula

$$V_{bulk} = \int V \, dA / \int dA \qquad \ldots C.3$$

The value of the integral $\int V \, dA$ was determined by Simpson's

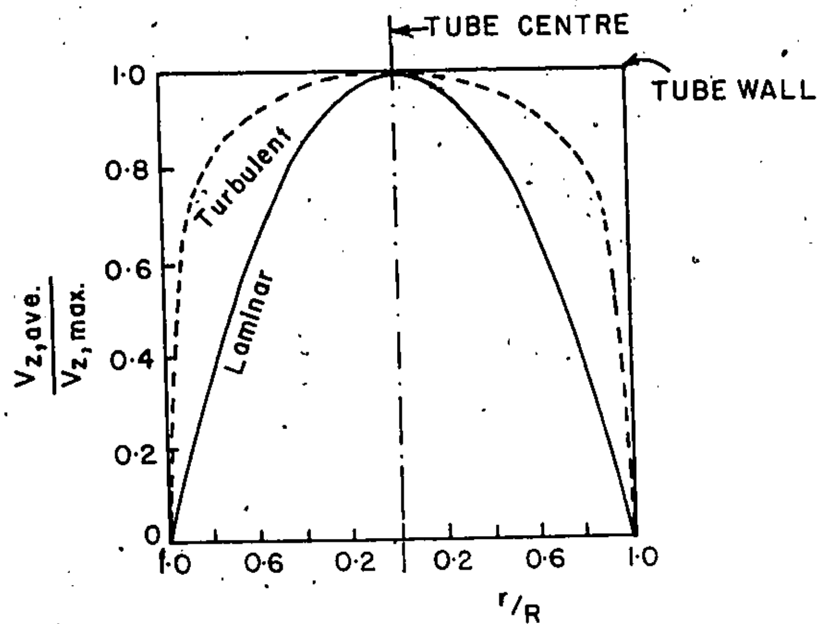


FIG. C-2. QUALITATIVE COMPARISON OF LAMINAR AND TURBULENT VELOCITY DISTRIBUTIONS. (Taken from ref. 93.)

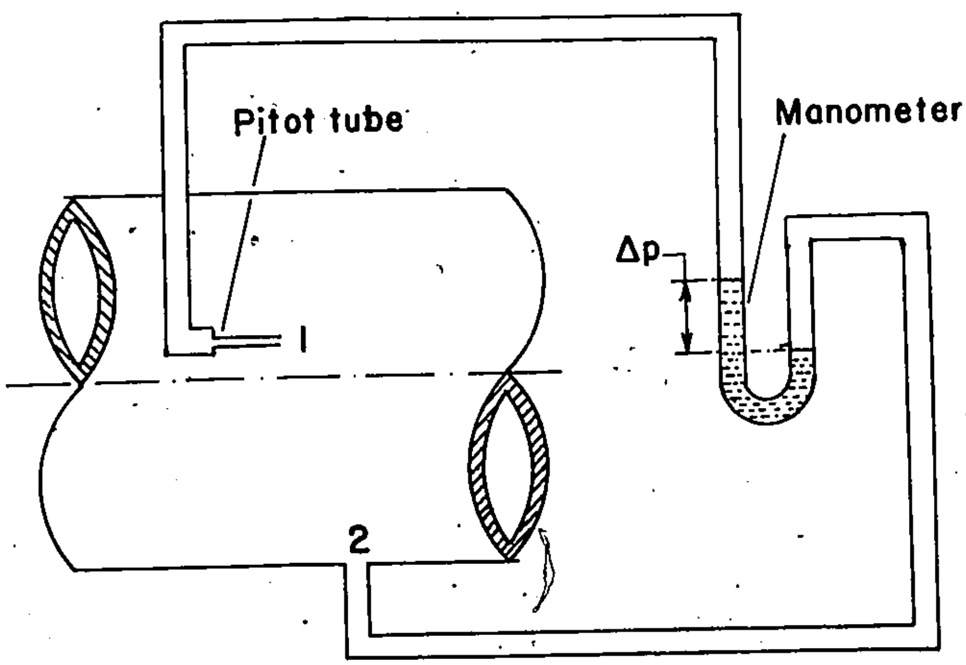


FIG. C-3. SCHEMATIC DIAGRAM SHOWING THE PITOT TUBE AND MANOMETER CONNECTIONS.

rule. The mass flow rate was then determined from the equation

Mass flow rate = Bulk velocity x Cross-sectional area x density of the air (at temp. and press) ... C.4

The mass flow rate was then corrected for standard temperature (60°F) and pressure (29.92 in. Hg) to conform to the Go-power charts.

The different values of the mass flow rate were then plotted for different values of the Go-power manometer readings and compared with the plots given by Go-power.

It was found that the accuracy reduced with the nozzle size; that is, the 0.5 in. nozzle was the least accurate, the 0.75 in. one next and the 1.183 in. one the most accurate. The 1.75 in. nozzle was found to be fairly accurate without any calibration.

Fig. C.4 gives the plots for the 1.183 in. nozzle; for the calibrated and Go-power values.

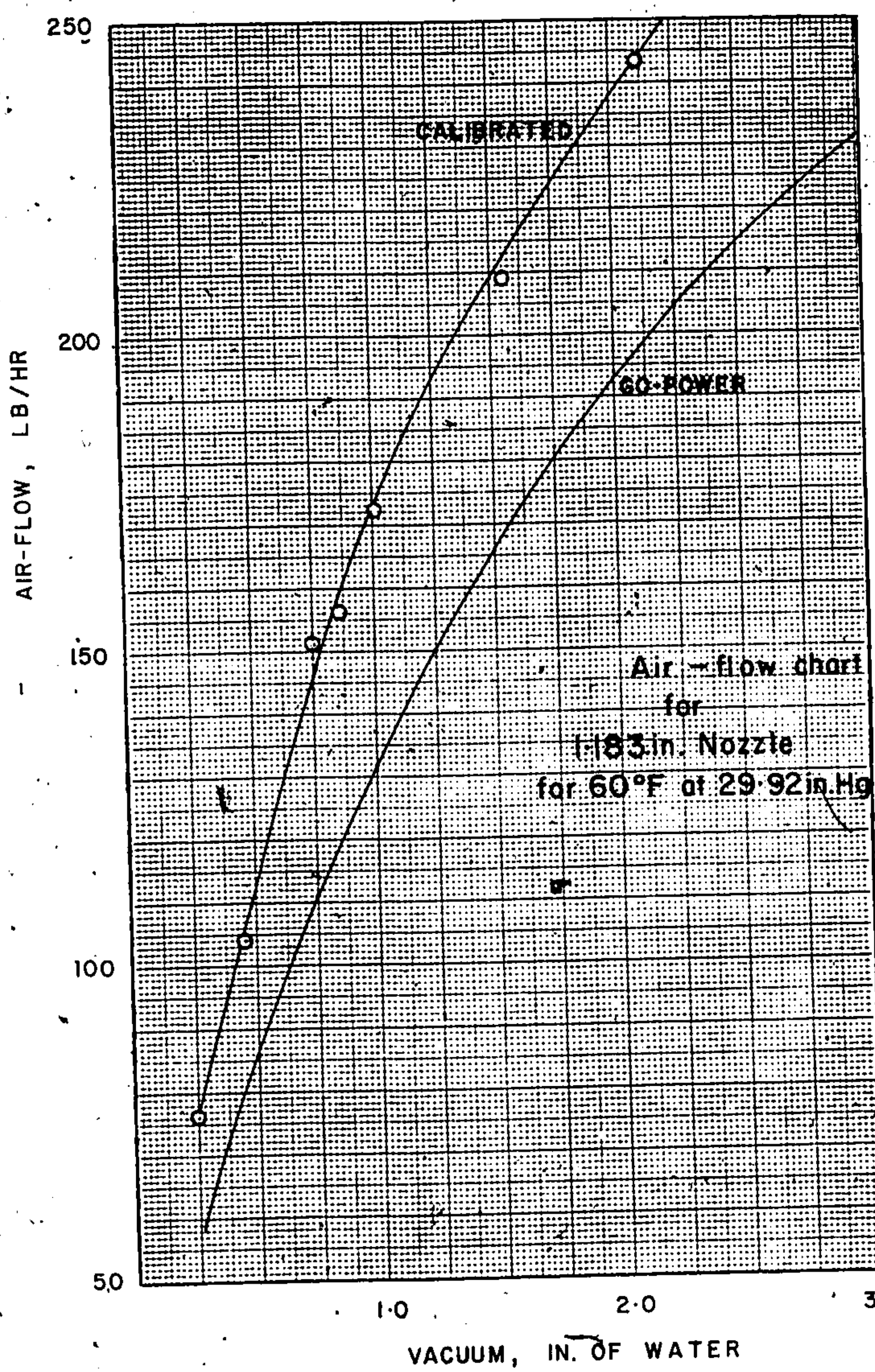


FIG. C-4. CALIBRATION FOR 1.183 in. "GO POWER" NOZZLE.

D. STRAIN-GAUGE INDICATOR CALIBRATION

Due to a factory error in the calibration of the strain-gauge indicator, it was found necessary to calibrate it at a true reading of 50 per cent of the actual readings.

This was done by manually loading the dynamometer load cells and checking the deflection on the gauge. The actual torque was the product of the load (due to the weight) and the torque arm. The strain-gauge indicator was then adjusted such that the gauge showed half the actual torque with the first weight on the torque-arm. Adjustment was done by rotating the coarse- and fine-span screws. Subsequent values of actual torque and the gauge readings were noted for higher weights on the load cells. The readings were verified by unloading the load cells in the reverse order to which they were loaded.

The zero of the gauge was adjusted by the 'Normal zero' screw. After the calibration, the 'Push to calibrate' button was pressed; the gauge showed a reading of 724 ft-lb. This was standardized for the entire test program as a calibration for the strain-gauge indicator.

A plot of the actual torque and the strain-gauge indicator readings is given in Fig. D.1.

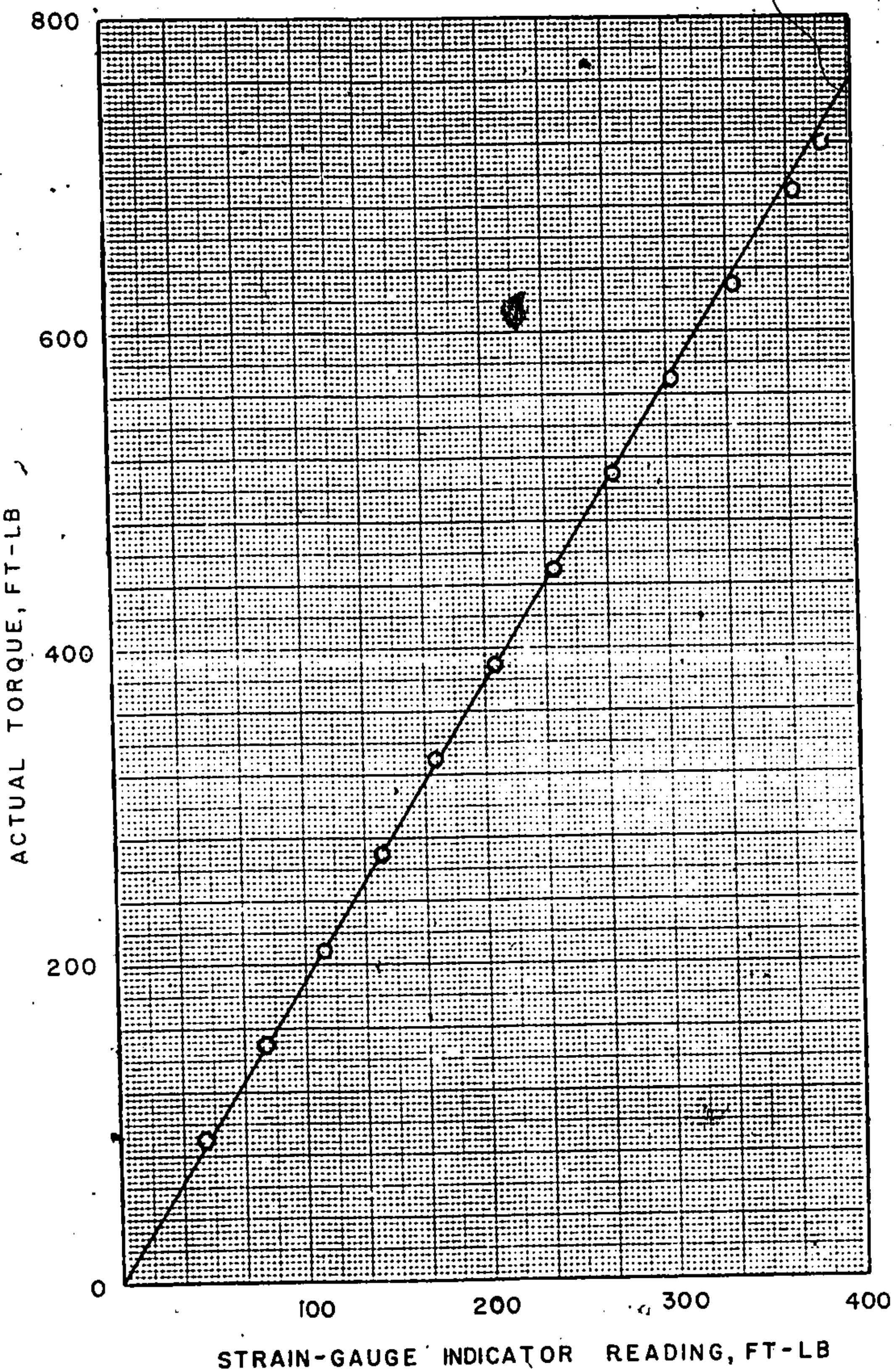


FIG. D-1. STRAIN-GAUGE INDICATOR CALIBRATION.

E. THE MEXA-300 ANALYZER

E.1. SPECIFICATIONS.

Measuring method	Infrared analyzer, non-dispersive method, positive filter, double light sources
Operating range	Low:- 0.0-2.0% CO, 0-400 ppm HC (n-hexane) High:- 0-10% CO, 0-2000 ppm HC
Response time	90% of the reading in 7 sec. (including built-in sampling lag time
Read out	Two meters, with a 3 in. scale length each, for CO and HC
Power requirements	115 Volts AC, 60 Hz, single phase
Sampling system	Complete with flow meter, water separator, particulate filter and pump; with pre-filter

Electrical output points are provided for recording CO and HC concentrations simultaneously.

E.2. CALIBRATION. The analyzer requires a zero calibration, a basic span calibration and a daily span calibration. These calibrations have to be carried out in order to obtain accurate readings.

E.2.1. Zero Calibration. This was done every day before the start of the experiment. The procedure is as follows: Switch on the sample pump. While keeping the tip of the exhaust probe in clean air, adjust the HC and CO ZERO controls so that both meters indicate a zero reading.

E.2.2. Basic Span Calibration. This was carried out every week. A CO-HC mixed span gas was used. The quantities of CO and HC as n-hexane equivalent are marked on the cylinder label. The procedure is as follows:

(a) Place the PUMP switch in the OFF position.

(b) Press the nozzle of the calibration gas cylinder against the GAS CHECKER inlet at the bottom of the front panel of the instrument. This automatically feeds the gas into the analyzer unit.

(c) First the HC meter reading and then the CO meter reading will move up the scale. Continue to press the nozzle of the cylinder against the inlet till the meter readings have stabilized. Now remove the nozzle and adjust the SPAN control for CO to bring the CO meter reading to the point corresponding to the concentration printed on the label of the cylinder. Similarly, adjsut the SPAN control for HC.

(d) Turn on the pump and check to see that the meter readings return to zero.

(e) Immediately after the gas calibration, press and hold in the CO CHECK control (see Fig. E.1). The CO meter should indicate a reading within the black range (marked on the meter face) in about 3 seconds. The HC meter will indicate a reading, but should be ignored.

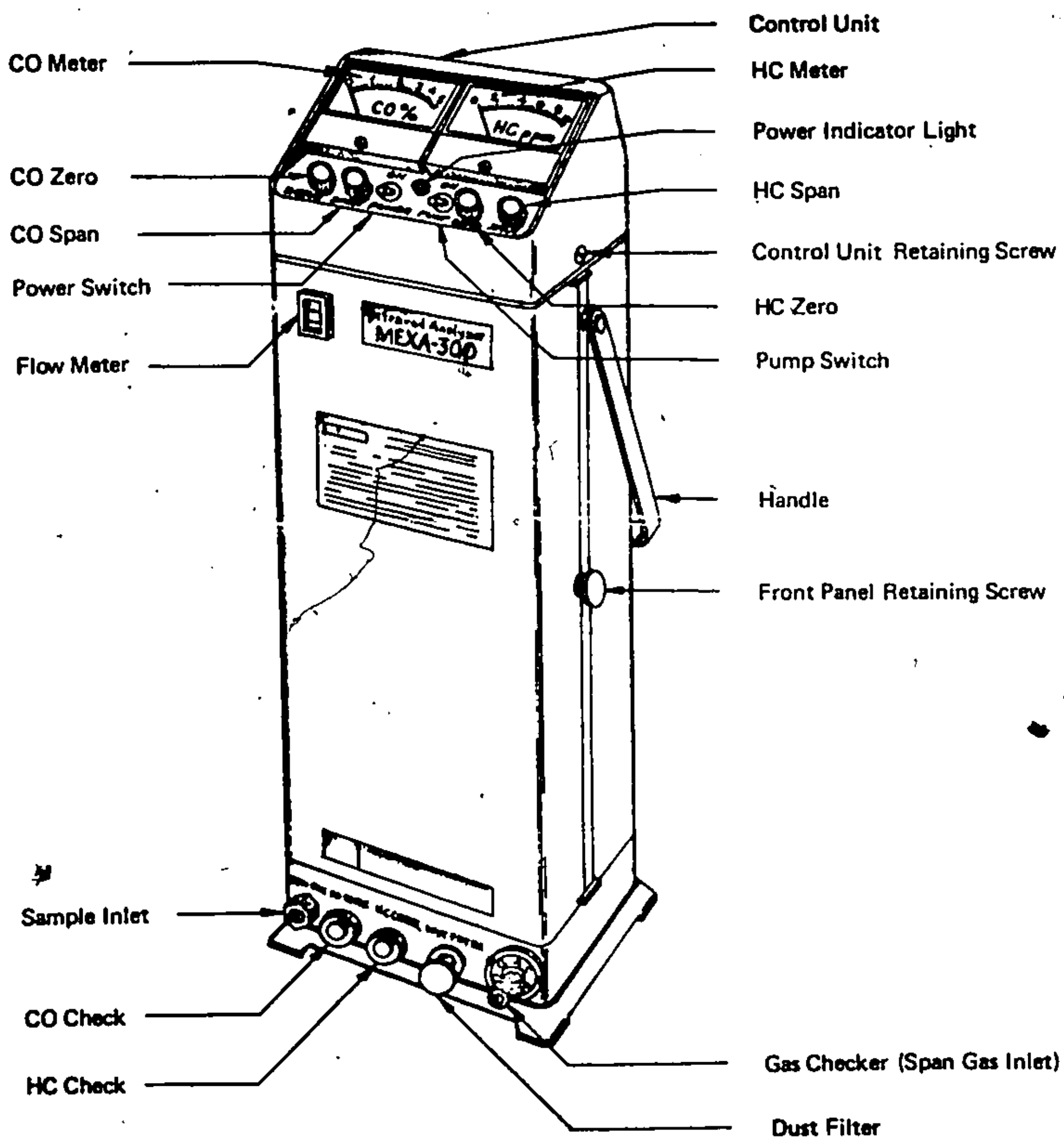


FIG. E-1. THE MEXA-300 ANALYZER

(f) Release the CO CHECK control and check to see that the meter reading returns to zero immediately.

(g) Perform the same checks as in (e) and (f) with the HC CHECK control.

(h) If either the CO or HC meters fail to indicate a value within the black range, make appropriate adjustments given in the manual[75].

E.2.3. Daily Span Calibration. This was done every day, after the zero calibration, as follows:

(a) Switch off the pump.

(b) Press and hold in the CO CHECK. After the meter reading has stabilized in about 3 seconds, adjust the SPAN control so that the CO meter indicates a value within the black range, and release the CO CHECK control; the meter should go back to zero.

(c) Perform the same span check on the HC meter using the HC CHECK control.

Insert the sample probe into the exhaust system of the engine and start the pump. The instrument is now ready for sample measurement.

F. PROCEDURES

F.1. START-UP.

(a) Check fuel level in the fuel tank and coolant level in the drum.

(b) Switch on the dynamometer power switch and the pump power switch.

(c) Switch on the pump.

(d) The cooling column drain control knob, water supply valve and the thermostat are pre-set so these need not be adjusted every day.

(e) Check to see if the green light on the panel in the instrumentation room, marked 'A.C.LINE ON' is lit up.

(f) Let the load control potentiometer remain at zero. Set the speed control potentiometer to 6.5 to obtain the start-up characteristics desired.

(g) Push the black button marked 'EXCITATION ON'. The green light marked 'EXCITATION ON' will light up.

(h) Switch on the CO/HC analyzer, the amplifier, the frequency counter, the strip-chart recorder and the multicorder.

Switch on the strain-gauge indicator to 'STAND-BY'.

(i) After about half an hour, calibrate the HC/CO analyzer (see Appendix E) and switch on the analyzer pump. Switch the strain-gauge indicator to 'RUN'. Depress the 'PUSH TO CALIBRATE' button of the strain-gauge indicator to see if the gauge shows a value of 724 ft-lb. If it does not indicate the value, make appropriate adjustments as given in the manual. Switch on the drive for the two recorders and adjust the zeros for them.

(j) Turn the engine ignition key on. The warning buzzer and light will come on. Start the engine. The warning buzzer and light will go off a few seconds after the engine turns. Start the stop watch. The engine will now run at about 1800 R.P.M. with a nominal load.

The engine is loaded by adjusting the speed control potentiometer, for the first load condition.

The engine is now in working condition to conduct the tests.

F.2. <u>SHUT DOWN</u>.

(a) Turn off the ignition key to stop the engine.

(b) An alternate way is to push the red button marked 'EXCITATION OFF'. The green light marked 'EXCITATION ON' will go out. The warning buzzer and light will come on. To switch them off, the ignition key will have to be turned off.

(c) If the engine is switched off by switching off the dynamometer excitation, the black button marked 'EXCITATION ON' must be pressed in order to circulate the cooling water which gets shut off when the excitation is turned off.

(d) Switch off the drives for the recorders and then their power switch.

(e) Switch off the amplifier, the frequency counter and the strain gauge indicator. Switch off the CO/HC analyzer pump and then its power switch.

(f) After about 15 minutes switch off the water supply, the water pump power and the dynamometer power switches.

G. CALCULATION OF MASS EMISSIONS

The mass emissions of carbon monoxide hydrocarbons were estimated, on an approximate basis, with the help of formulas given in Chapter 10 of ref. 13.

In the case of the CVS-1 cycle, the mass emissions were calculated by using the exhaust flow rate, the density of the pollutant and the concentration. Thus for the case of the hydrocarbons, the formula would be

$$HC_{mass} = V_{mix} \times \rho_{HC} \times \frac{HC_{conc} \text{ (in ppm C)}}{10^6}$$

In this equation, the HC_{mass} is the mass emissions of the hydrocarbons. If the V_{mix} is in ft^3/hour the HC_{mass} is in grams per hour. The V_{mix} is the total wet exhaust volume (exhaust gas plus the dilutent air) corrected to 528 R and 760 mm Hg. In our case, we do not have any air dilution of the exhaust sample. Also, we do not know the volume flow rate of the exhaust gases. But for all practical purposes, the volume flow rate of the intake air and fuel should be equal to the exhaust flow rate, and since the fuel flow compared to the air flow is quite small (on a volume basis), the exhaust flow rate is assumed to be equal to the volume flow rate of the intake air, which is then the V_{mix} in our case. Thus the intake flow rate is corrected to 528 R and 760 mm Hg. The value of ρ_{HC}, the density of the hydrocarbons as $CH_{1.86}$ at 528 R and 760 mm Hg is taken as 16.33 g/ft³. The HC_{conc} should be in parts per million carbon, so the ppm n-hexane equivalent is to be multiplied by 6.

In the case of carbon monoxide the formula is

$$CO_{mass} = V_{mix} \times \rho_{CO} \times \frac{CO_{conc}\ (\text{in } \%)}{100}$$

Here the density of CO is taken as 32.97 g/ft³ at 528 R and 760 mm Hg.

By using these formulas the mass emissions for each value of the concentration of the HC and CO have been calculated. Since the air flow rate and the temperatures of the intake air and exhaust are known, the average mass emissions during the warmup period and the entire 20-minute cycle have been estimated by the Simpson's rule.

H. CALCULATED DATA FROM TEST RUNS

TABLES 5-2 THROUGH 5-40.

DATE OF RUN & TIME:- 22 - 3 - 1975 / 0900 HRS
RUN # :- 11.
HOURS OF COLD SOAK:- 24.

ROOM TEMPERATURE AT START:- $32^{o}F$
BAROMETER PRESSURE:- 29.54 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- $44^{o}F$

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURE °F WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	47.7	197.5	205.0	4.24	19	1700	0	>10.0	1300	712	-	34.0	34.0	34.0	38.0
30 "	46.0	"	"	4.40	"	"	"	"	1425	820	-	"	"	"	42.0
45 "	45.0	"	"	4.49	"	"	"	"	1600	874	-	"	"	"	45.0
60 "	42.5	"	"	4.76	"	"	"	"	1800	915	-	"	"	"	50.0
75 "	"	"	"	"	"	"	"	"	1400	958	-	"	"	36.0	52.5
90 "	39.0	"	"	5.18	"	2000	"	"	"	979	-	N.A.	N.A.	N.A.	N.A.
105 "	N.A.	N.A.	N.A.	N.A.	N.A	N.A.	N.A.	N.A.	N.A.	990	-	"	"	"	"
120 "	"	"	"	"	"	"	"	"	"	1000	-	"	"	"	"
2½ min	"	"	"	"	"	"	"	"	"	1068	-	"	35.0		"
3 "	30.0	250.0	256.0	8.54	13	1600	103	4.0	150	1148	-	52.5	35.5	62.0	81.0
3½ "	26.0	"	"	9.85	"	"	"	0.6	50	1223	-	64.0	36.0	70.0	88.0
4 "	22.0	"	"	11.60	"	"	"	0.3	40	1244	-	75.0	37.0	80.0	92.0
4½ "	20.8	"	"	12.30	"	"	"	0.2	25	1254	-	86.0	"	88.0	100.0
5 "	20.5	260.0	266.5	13.0	"	"	"	"	"	1258	-	183.0	38.0	95.0	102.0
6 "	20.6	262.5	269.0	13.05	"	"	"	"	< 25	1268	-	188.0	"	101.0	92.0
7 "	20.8	264.0	270.5	13.00	12½	"	"	"	"	1285	-	177.0	41.0	104.0	"
8 "	"	267.5	274.0	13.20	"	"	"	"	"	1287	-	172.5	"	107.0	90.0
9 "	40.0	417.5	421.0	10.50	4½	"	247	2.6	75	1330	-	84.0	46.0	86.0	65.0
9½ "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10 "	40.5	417.5	421.0	10.40	4½	1600	247	2.6	75	1350	-	145.0	47.5	81.0	55.0
11 "	"	420.0	424.0	10.50	"	"	"	"	"	1352	-	185.0	48.0	"	"
12 "	"	"	"	"	"	"	"	"	"	1354	-	"	50.0	"	"
12½ "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13 "	25.0	329.0	332.0	13.20	9½	1600	143	0.2	< 25	1352	-	185.0	50.0	107.0	90.0
14 "	25.1	342.5	345.0	13.75	8½	"	"	"	"	1340	-	"	"	120.0	"
15 "	"	"	"	"	8	"	"	"	"	"	-	"	"	122.0	"
15½ "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16 "	25.1	342.5	345.0	13.75	8	1600	143	0.2	< 25	1340	-	185.0	50.0	125.0	"
17 "	10.0	76.0	76.6	7.66	18	750	0	"	"	1150	-	188.0	49.0	141.0	"
18 "	7.7	"	"	10.10	"	"	"	"	"	1012	-	177.5	46.0	147.0	"
19 "	8.0	"	"	9.74	"	"	"	"	"	951	-	186.0	45.0	150.0	"
20 "	7.8	"	"	9.90	"	"	"	"	"	915	-	177.5	44.0	152.0	"

TABLE 5-2. CALCULATED DATA FROM TEST RUNS.

DATE OF RUN & TIME:- 25 - 3 - 1975 / 1230 HRS
RUN # :- 12.
HOURS OF COLD SOAK:- 14.

ROOM TEMPERATURE AT START:- 40°F
BAROMETER PRESSURE:- 29.38 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 49°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURE °F EXH. OUT	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	37.0	197.5	198.5	5.36	19	1700	0	9.0	250	657	-	40.0	40.0	40.0	45.0
30 "	33.8	192.5	193.5	5.74	"	"	"	10.0	1500	785	-	"	41.0	"	47.0
45 "	33.0	"	"	5.87	"	"	"	>10.0	1800	870	-	"	"	"	51.5
60 "	32.6	"	"	5.94	"	"	"	"	"	912	-	"	42.5	"	56.0
75 "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90 "	32.0	192.5	193.5	6.05	19	1700	0	>10.0	2000	955	-	40.0	43.0	44.5	63.0
105 "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
120 "	28.4	192.5	193.5	6.83	19	1700	0	>10.0	1000	986	-	44.5	44.5	54.0	72.0
2½ min	25.0	"	"	7.75	"	"	"	9.5	250	1023	-	49.0	"	59.5	77.0
3 "	22.8	237.5	238.5	10.50	8½	1600	152	"	"	1100	-	49.5	47.0	67.5	85.0
3½ "	26.0	325.0	327.0	12.50	"	"	"	"	"	1230	-	46.5	"	75.0	89.0
4 "	27.0	320.0	322.0	11.90	"	"	"	0.4	50	1272	-	"	49.0	81.0	96.0
4½ "	25.8	317.5	319.5	12.20	"	"	"	0.2	20	1283	-	51.5	"	89.0	*102.5
5 "	26.2	332.5	334.5	12.75	"	"	"	"	< 20	1294	-	167.0	51.5	96.0	100.0
6 "	26.6	342.5	344.5	12.95	8	"	"	"	"	1315	-	168.5	54.0	101.0	97.0
7 "	26.5	345.0	347.5	13.10	"	"	"	"	"	1326	-	72.0	"	106.5	96.0
8 "	41.9	427.5	430.0	10.25	2½	"	252	2.8	75	1337	-	94.0	56.0	83.0	91.5
9 "	42.0	430.0	432.0	10.30	"	"	"	2.9	"	1348	-	184.5	58.0	82.0	91.0
9½ "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10 "	41.9	428.0	430.0	10.25	2½	1600	252	2.9	75	1350	-	178.0	59.0	82.0	91.0
11 "	"	"	"	"	"	"	"	3.0	"	1352	-	"	"	"	"
12 "	25.2	342.5	344.0	13.65	9	"	143	0.2	< 20	"	-	"	"	119.5	104.5
12½ "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13 "	26.5	352.5	354.0	13.45	7½	1600	157	0.2	< 20	1352	-	178.0	59.0	121.5	96.0
14 "	27.0	355.0	356.5	13.20	"	"	"	"	"	"	-	"	"	124.0	"
15 "	26.9	"	"	13.30	"	"	"	"	"	"	-	180.0	"	127.0	"
15½ "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16 "	7.5	76.0	76.4	10.20	18	750	0	0.2	< 20	1071	-	179.0	58.5	145.0	"
17 "	7.8	"	"	9.80	"	"	"	"	"	980	-	178.0	56.0	149.0	"
18 "	8.0	"	"	9.55	"	"	"	"	"	944	-	"	54.0	155.0	"
19 "	"	"	"	"	"	"	"	"	"	912	-	177.0	52.0	156.0	"
20 "	"	"	"	"	"	"	"	"	"	891	-	176.0	51.5	157.0	"

TABLE 5-3.

DATE OF RUN AND TIME:- 25 - 3 - 1975 / 2300 HRS
RUN # :- 13.
HOURS OF COLD SOAK:- 11.

ROOM TEMPERATURE AT START:- 39°F
BAROMETER PRESSURE:- 29.50 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 48°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURE °F WATER OUT	TEMPERATURE °F INLET AIR	TEMPERATURE °F INLET MANI-FOLD	TEMPERATURE °F AIR-FILTER
15 sec	37.8	200.0	205.5	5.44	19	1700	0	10.0	350	726	-	39.0	39.0	32.0	43.0
30 "	35.5	202.5	208.0	5.85	"	"	"	>10.0	500	827	-	36.0	40.0	34.5	46.0
45 "	33.8	"	"	6.15	"	"	"	"	600	875	-	34.5	41.5	36.5	50.5
60 "	32.5	"	"	6.40	"	"	"	"	625	912	-	"	"	39.0	55.0
75 "	31.9	"	"	6.50	"	"	"	"	1000	943	-	38.0	42.0	42.5	59.5
90 "	31.0	"	"	6.70	"	"	"	"	1200	964	-	42.5	"	45.0	64.0
105 "	28.9	"	"	7.20	"	"	"	"	700	980	-	48.5	42.5	48.0	67.5
120. "	26.6	"	"	7.80	"	"	"	"	300	"	-	51.5	43.0	50.5	71.0
2½ min	26.5	285.0	293.0	11.00	10	1600	133	9.0	200	1028	-	61.0	43.5	57.0	78.5
3 "	26.4	"	"	11.10	"	"	"	1.4	75	1176	-	70.0	44.5	66.0	87.5
3½ "	24.5	"	"	11.95	"	"	"	0.4	40	1234	-	78.5	46.0	71.0	95.0
4 "	24.0	"	"	12.20	"	1550	"	0.2	25	1251	-	88.5	47.5	84.0	100.5
4½ "	23.4	300.0	307.5	13.10	"	"	"	"	"	1261	-	95.0	48.5	90.5	"
5 "	24.0	307.5	315.0	"	9½	"	"	"	"	1277	-	73.0	49.5	93.0	99.0
6 "	24.5	317.5	326.0	13.30	"	"	"	"	"	1298	-	75.5	50.5	101.5	96.5
7 "	24.4	322.5	331.0	13.50	"	"	"	"	"	1305	-	73.0	51.5	107.0	95.5
8 "	24.3	"	"	13.60	"	"	"	"	"	1307	-	93.0	52.5	112.0	"
9 "	24.4	"	"	13.50	"	"	"	"	"	1309	-	176.0	53.0	116.5	"
9½ "	38.4	422.5	430.5	11.20	3½	1600	247	1.0	75	1336	-	171.0	55.0	99.0	73.0
10 "	41.8	425.0	434.0	10.40	"	"	"	2.6	"	1342	-	180.0	56.0	90.5	66.5
11 "	41.9	427.5	436.0	"	"	"	"	2.8	"	1344	-	178.0	57.0	87.5	64.0
12 "	42.0	428.0	437.0	"	"	"	"	"	"	1358	-	"	58.0	87.0	"
12½ "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13 "	23.4	315.0	321.0	13.70	10	1600	133	0.2	25	1342	-	180.0	57.0	120.0	103.5
14 "	24.0	322.5	338.0	"	"	"	123	"	"	1336	-	178.0	"	123.0	96.5
15 "	"	"	"	"	"	"	"	"	"	1333	-	"	"	125.0	95.0
15½ "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16 "	7.0	76.0	77.4	11.05	18	750	0	0.2	25	1059	-	178.0	55.0	142.5	95.0
17 "	7.2	"	"	10.70	"	"	"	"	"	996	-	176.0	52.5	147.5	"
18 "	7.9	"	"	9.80	"	"	"	"	"	943	-	"	50.5	148.0	"
19 "	"	"	"	"	"	725	"	"	"	912	-	"	49.5	152.0	"
20 "	8.0	"	"	9.70	"	"	"	"	"	890	-	"	48.5	"	"

TABLE 5-4.

DATE OF RUN & TIME:- 26 - 3-1975 / 0900 HRS
RUN # :- 14.
HOURS OF COLD SOAK:- 9½.

ROOM TEMPERATURE AT START:- 19°F
BAROMETER PRESSURE:- 30.02 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 28°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURE °F EXH. OUT	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	34.0	200.0	214.5	6.30	19	1750	0	6.5	200	701	-	19.0	19.0	13.0	22.5
30 "	33.0	"	"	6.50	"	"	"	9.2	225	814	-	15.5	"	17.0	27.0
45 "	32.0	202.5	217.5	6.80	"	"	"	9.8	"	861	-	12.5	"	21.0	32.0
60 "	31.2	"	"	6.95	"	"	"	>10.0	"	893	-	12.0	20.0	24.0	36.5
75 "	30.0	200.0	214.5	7.15	"	"	"	"	"	925	-	"	"	26.0	41.0
90 "	29.4	"	"	7.30	"	"	"	"	"	946	-	19.0	20.5	30.5	46.0
105 "	29.0	"	"	7.40	"	"	"	"	"	967	-	28.5	21.5	33.0	49.0
120 "	28.7	"	"	7.75	"	"	"	"	"	988	-	33.0	22.0	36.5	54.0
2½ min	34.5	260.0	279.0	8.10	10	1600	133	8.5	100	1052	-	44.0	23.5	44.0	63.0
3 "	32.0	292.5	314.0	9.80	"	"	"	4.0	75	1125	-	58.0	24.5	53.5	70.5
3½ "	29.3	292.0	313.0	10.70	"	"	"	3.2	"	1200	-	69.5	25.0	62.5	78.5
4 "	26.5	287.5	307.0	11.60	"	"	"	0.9	40	1253	-	78.5	26.0	72.0	85.0
4½ "	24.5	290.0	310.0	12.65	"	"	"	0.2	25	1275	-	85.0	27.5	78.5	91.5
5 "	24.0	"	"	12.90	"	"	"	0.1	20	1280	-	170.5	28.5	86.0	95.0
6 "	24.2	302.5	322.5	13.30	"	"	"	*	*	1296	-	174.5	30.5	95.0	96.0
7 "	24.1	"	"	13.30	"	"	"			1312	-	167.0	31.0	102.5	"
8 "	24.3	307.5	327.5	13.50	9½	"	"			1317	-	65.0	33.0	108.5	95.0
9 "	24.2	310.0	330.5	13.60	"	"	"			1327	-	59.5	"	113.0	94.0
9½ "	39.5	406.0	430.5	10.90	4½	"	247			1349	-	170.5	34.0	88.0	66.0
10 "	39.4	"	"	10.95	"	"	"			1371	-	108.5	36.5	78.5	49.0
11 "	39.7	410.0	435.0	11[illegible]	"	"	"			1379	-	172.5	37.5	76.0	47.0
12 "	39.3	411.0	435.5	11.10	"	"	"			1382	-	170.0	"	75.0	"
12½ "	28.0	285.0	302.0	10.80	10½	"	133			1360	-	175.0	"	125.5	106.5
13 "	23.0	307.5	325.5	14.15	10	"	"			1348	-	172.5	"	117.0	96.0
14 "	24.0	315.0	334.0	13.95	9¾	"	"			1336	-	174.5	"	119.5	91.5
15 "	24.1	"	"	13.90	"	"	"			"	-	175.0	37.0	125.5	90.0
15½ "	-	-	-	-	-	-	-			-	-	-	-	-	-
16 "	7.8	76.0	80.1	10.30	18½	760	0			1062	-	172.5	34.0	134.0	89.5
17 "	"	"	"	"	"	"	"			999	-	150.5	33.0	144.5	89.0
18 "	8.0	"	"	10.00	"	"	"			957	-	172.5	30.5	146.5	"
19 "	"	"	"	"	"	"	"			930	-	142.0	29.0	148.0	"
20 "	8.1	"	"	9.90	"	"	"			908	-	"	"	"	"

TABLE 5-5.

DATE OF RUN & TIME:- 27 - 3 - 1975 / 0830 HRS
RUN # :- 16.
HOURS OF COLD SOAK:- 9.

ROOM TEMPERATURE AT START:- 12°F
BAROMETER PRESSURE:- 30.32 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 22°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURE °F EXH. OUT	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	33.5	210.0	231.0	6.90	19	1750	0	9.43	290	717	-	12.0	12.5	7.0	16.0
30 "	32.8	205.0	226.0	"	"	"	"	9.65	265	812	-	7.0	13.0	8.5	21.5
45 "	32.1	"	"	7.05	"	"	"	9.80	241	823	-	5.0	"	14.5	26.0
60 "	31.0	"	"	7.30	"	"	"	10.15	229	908	-	"	14.0	18.0	31.0
75 "	30.9	"	"	7.33	"	"	"	10.20	"	929	-	"	14.5	21.5	34.5
90 "	30.2	"	"	7.50	"	"	"	"	231	957	-	7.0	15.0	25.0	40.0
105 "	30.0	"	"	7.52	"	"	"	"	229	982	-	14.0	15.5	28.5	44.5
120 "	"	"	"	"	"	"	"	"	227	998	-	21.5	"	31.0	49.0
2½ min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 "	34.2	290.0	316.0	9.25	13½	1600	143	*	*	1082	-	44.5	18.0	44.5	64.0
3½ "	28.5	285.0	311.0	10.90	"	"	"			1140	-	54.0	19.0	51.5	69.5
4 "	25.1	"	"	12.40	"	"	"			1215	-	67.5	19.5	60.5	76.0
4½ "	22.0	"	"	14.10	"	"	"			1246	-	78.5	20.5	69.5	80.5
5 "	24.5	292.5	318.0	13.00	10	"	"			1257	-	85.0	21.0	76.5	87.0
6 "	25.0	"	"	12.70	"	"	"			1289	-	26.0	23.5	89.5	94.0
7 "	"	300.0	326.5	13.10	"	"	"			1322	-	31.0	26.0	98.0	"
8 "	"	307.5	335.0	13.40	"	"	"			1332	-	169.0	27.5	104.5	"
9 "	"	315.0	342.0	13.70	"	"	"			1354	-	173.0	28.5	111.0	"
9½ "	40.0	402.5	435.0	10.90	5	"	247			1374	-	46.0	30.5	89.5	60.5
10 "	39.4	"	"	11.05	"	"	"			1392	-	106.5	"	76.5	49.0
11 "	30.0	350.0	378.0	12.60	7	"	"			1408	-	65.0	34.0	75.0	44.5
12 "	29.0	"	"	13.05	"	"	"			1392	-	181.0	"	94.0	64.0
12½ "	-	-	-	-	-	-	-			-	-	-	-	-	-
13 "	39.0	416.0	450.0	11.50	5	1600	247			1395	-	173.0	35.5	78.0	49.0
14 "	41.0	417.5	451.0	11.00	3¾	"	257			"	-	172.0	36.0	75.0	44.5
15 "	22.6	307.5	332.0	14.70	11	"	133			1364	-	"	35.5	119.5	102.5
15½ "	-	-	-	-	-	-	-			-	-	-	-	-	-
16 "	23.0	315.0	340.0	14.80	10½	1600	133			1354	-	175.0	35.5	121.5	89.5
17 "	7.1	76.0	82.0	11.55	19	740	0			1090	-	172.0	32.0	136.0	84.0
18 "	7.2	"	"	11.40	"	"	"			1013	-	"	30.5	144.0	"
19 "	7.5	"	"	10.90	"	"	"			970	-	"	28.5	148.5	"
20 "	7.8	"	"	10.60	"	"	"			943	-	144.0	27.5	150.0	"

TABLE 5-6.

DATE OF RUN & TIME:- 28 - 3 - 1975 / 1030 HRS
RUN # :- 18.
HOURS OF COLD SOAK:- 13.

ROOM TEMPERATURE AT START:- 23°F
BAROMETER PRESSURE:- 30.12 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 33°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURE °F EXH. OUT	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	30.2	205.0	219.0	7.25	19	1800	0	9.00	338.0	705	-	23.0	23.5	21.0	28.0
30 "	30.0	"	"	7.30	"	1900	"	9.50	307.0	812	-	"	"	23.0	31.0
45 "	29.5	"	"	7.45	"	1950	"	9.70	300.0	860	-	"	24.0	25.5	37.0
60 "	29.4	"	"	7.48	"	2000	"	9.85	295.0	897	-	"	24.5	30.0	41.5
75 "	29.0	"	"	7.55	"	2030	"	9.95	284.0	923	-	"	25.5	31.5	46.0
90 "	"	"	"	"	"	"	"	9.98	269.0	944	-	"	26.0	36.0	51.0
105 "	28.8	"	"	7.60	"	"	"	10.00	261.0	971	-	30.0	26.5	39.0	55.0
120 "	"	"	"	"	"	"	"	10.10	"	987	-	34.5	27.5	43.0	60.0
2½ min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 "	29.5	267.5	286.0	9.70	12½	1600	152	6.00	123.0	1150	-	52.5	30.0	60.0	78.0
3½ "	26.8	"	"	10.70	"	"	123	2.57	61.5	1203	-	66.5	31.0	69.0	85.5
4 "	23.8	265.0	283.5	11.90	"	"	"	0.28	15.3	1246	-	77.5	31.5	77.5	91.0
4½ "	22.1	260.0	277.0	12.50	"	"	"	0.14	"	1266	-	86.5	32.0	86.5	97.0
5 "	22.0	"	"	12.60	"	"	133	"	"	1277	-	176.0	34.5	95.0	99.0
6 "	23.8	295.0	314.0	13.20	10½	"	"	"	"	1300	-	182.0	37.0	101.5	97.0
7 "	23.9	300.0	319.0	13.45	"	"	"	"	"	1310	-	176.0	38.0	104.0	95.0
8 "	"	310.0	330.0	13.80	"	"	"	"	"	1321	-	69.0	39.0	114.5	94.0
9 "	24.0	"	"	13.75	"	"	"	"	"	1326	-	60.0	"	118.5	"
9½ "	37.0	412.5	438.0	11.80	5	"	247	3.36	61.5	1361	-	180.0	41.5	95.0	68.0
10 "	40.4	413.5	439.0	10.85	"	"	"	3.21	"	1367	-	182.0	42.0	89.0	58.0
11 "	40.0	415.0	440.0	11.00	"	"	"	2.86	"	1388	-	"	44.0	85.0	55.0
12 "	40.5	416.0	441.0	10.90	"	"	"	3.43	"	"	-	181.0	48.5	"	"
12½ "	25.8	280.0	296.5	11.50	9½	"	133	0.21	15.3	1378	-	186.0	"	129.0	123.0
13 "	24.5	315.0	333.0	13.60	"	"	"	0.14	"	1367	-	181.0	"	123.0	104.0
14 "	24.6	325.0	343.0	13.95	"	"	"	"	"	1361	-	183.0	"	125.0	93.0
15 "	24.2	326.0	343.5	14.20	"	"	"	"	"	1355	-	182.0	"	129.0	92.0
15½ "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16 "	7.2	76.0	80.3	11.15	18½	800	0	0.14	15.3	1087	-	182.0	44.0	146.0	92.0
17 "	"	"	"	"	"	775	"	"	16.0	1023	-	158.0	41.5	152.0	"
18 "	8.0	"	"	10.05	"	750	"	"	15.0	971	-	182.0	39.0	154.0	"
19 "	"	"	"	"	"	725	"	"	17.0	940	-	152.0	38.0	156.0	89.0
20 "	"	"	"	"	"	"	"	"	18.0	920	-	148.0	37.0	"	87.0

TABLE 5-7.

DATE OF RUN & TIME:- 31 - 3 - 1975 / 1445 HRS
RUN # :- 19.
HOURS OF COLD SOAK:- 76 (APPROX).

ROOM TEMPERATURE AT START:- $34^{\circ}F$
BAROMETER PRESSURE:- 29.65 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:-

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURE °F EXH. OUT	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	33.6	202.5	207.5	6.18	19	1700	0	9.24	854.0	-	-	-	-	-	-
30 "	33.0	"	"	6.30	"	"	"	9.56	1490.0						
45 "	32.8	"	"	6.35	"	"	"	9.80	1645.0						
60 "	32.5	"	"	6.40	"	"	"	9.86	1800.0						
75 "	"	"	"	"	"	"	"	9.92	1890.0						
90 "	31.0	"	"	6.70	"	"	"	10.00	1780.0						
105 "	30.0	"	"	6.90	"	1900	"	10.05	1350.0						
120 "	29.5	"	"	7.05	"	"	"	10.15	722.0						
2½ min	27.0	267.5	274.0	10.20	12½	1600	143	5.70	307.0						
3 "	23.[illegible]	"	"	11.50	"	"	"	3.62	184.5						
3½ "	23.0	"	"	11.90	"	"	"	0.58	92.2						
4 "	21.5	"	"	12.75	"	"	"	0.22	61.5						
4½ "	21.1	"	"	13.00	12	"	"	0.14	46.1						
5 "	"	285.0	292.5	13.80	"	"	"	"	30.7						
6 "	24.5	322.5	329.5	13.45	9½	"	123	"	"						
7 "	25.0	330.0	336.5	13.50	9	"	"	"	15.4						
8 "	24.6	"	"	13.70	"	"	"	"	"						
9 "	24.8	332.5	339.0	"	"	"	"	"	"						
9½ "	40.2	422.5	430.0	10.70	3¾	"	251	3.91	97.0						
10 "	39.8	427.5	435.0	10.90	"	"	"	3.71	"						
11 "	"	428.0	436.0	10.95	3½	"	257	3.78	"						
12 "	"	"	"	"	"	"	"	3.84	"						
12½ "	22.1	285.0	289.0	13.10	10	"	139	0.22	23.0						
13 "	23.2	327.5	333.0	14.30	9	"	"	0.14	15.4						
14 "	23.3	329.0	334.0	"	"	"	137	"	"						
15 "	"	"	"	"	"	"	"	"	"						
15½ "	-	-	-	-	-	-	-	-	-						
16 "	7.0	76.0	77.6	11.10	18½	750	0	0.14	15.4						
17 "	8.0	"	"	9.70	"	"	"	"	"						
18 "	"	80.0	81.7	10.20	"	725	"	"	"						
19 "	7.8	"	"	10.50	"	"	"	"	61.5						
20 "	7.9	"	"	10.35	"	"	"	"	92.2						

TABLE 5-8.

DATE OF RUN & TIME:- 1 - 4 - 1975 / 0900 HRS
RUN # :- 20.
HOURS OF COLD SOAK:- 18.

ROOM TEMPERATURE ~~AT~~ START:- 33°F
BAROMETER PRESSURE:- 29.72 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 43°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURE °F WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	38.5	155.0	161.5	4.20	19	n.a.	0	7.75	305.0	656	-	33.0	33.0	28.0	33.0
30 "	-	-	-	-	-	-	-	8.50	245.0	743	-	31.0	"	28.5	34.5
45 "	22.4	150.0	156.0	6.96	"	1450	0	9.15	260.0	787	-	29.0	"	30.0	37.5
60 "	21.8	"	"	7.15	"	1500	"	9.33	"	811	-	28.5	33.5	31.5	40.0
75 "	21.5	"	"	7.25	"	1520	"	9.42	"	832	-	"	34.0	34.0	43.5
90 "	20.8	"	"	7.50	"	1560	"	9.47	252.0	848	-	"	34.5	36.0	47.0
105 "	20.5	"	"	7.60	"	1565	"	9.55	"	866	-	33.0	"	39.0	51.5
120 "	20.2	"	"	7.80	"	"	"	9.60	245.0	887	-	44.0	35.0	41.0	54.0
2½ min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 "	30.5	275.0	286.0	9.40	12	1600	152	6.40	183.5	1075	-	54.0	36.5	54.0	71.0
3½ "	28.8	280.0	291.0	10.10	"	"	"	4.35	122.0	1149	-	63.0	37.5	63.0	79.5
4 "	26.0	277.5	288.0	11.10	11½	"	133	0.87	15.3	1213	-	72.0	39.0	74.0	87.0
4½ "	23.0	"	"	12.50	"	"	"	0.25	"	1245	-	74.0	40.0	87.0	96.0
5 "	22.9	"	"	12.55	"	"	"	0.18	"	1255	-	96.0	41.0	91.5	100.5
6 "	23.0	300.0	311.0	13.50	"	"	"	"	"	1277	-	104.5	43.5	98.0	96.0
7 "	"	302.5	312.5	13.60	10½	"	"	"	"	1298	-	186.5	46.0	104.5	93.5
8 "	"	305.0	315.5	13.70	"	"	"	"	"	1309	-	173.5	47.0	112.0	"
9 "	"	"	"	"	"	"	"	"	"	1312	-	131.0	48.0	116.0	"
9½ "	42.0	427.5	440.0	10.50	2½	"	247	3.78	91.8	1341	-	184.5	48.5	98.0	77.0
10 "	41.8	432.5	446.0	10.65	"	"	"	3.92	"	1352	-	122.5	50.0	88.0	65.0
11 "	42.0	430.0	443.0	10.50	2	"	257	3.78	"	1363	-	170.5	52.5	85.0	60.5
12 "	"	431.0	444.0	10.55	"	"	"	4.00	"	1368	-	181.5	54.0	"	"
12½ "	22.0	263.0	272.5	12.40	10	"	133	0.29	15.3	1352	-	174.5	55.0	125.5	113.0
13 "	23.0	302.5	313.0	13.60	"	"	123	0.18	"	1341	-	178.5	"	121.5	104.5
14 "	23.2	315.0	326.5	14.05	"	"	"	"	"	1336	-	177.5	"	124.0	94.0
15 "	23.-	"	"	13.95	"	"	"	"	"	1331	-	"	"	126.0	90.5
15½ "	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16 "	7.75	80.0	83.0	10.70	19	760	0	0.18	15.3	1138	-	178.5	53.0	144.0	89.0
17 "	8.0	76.0	78.9	9.85	18½	750	"	"	"	1075	-	177.5	51.0	150.5	"
18 "	"	"	"	"	18	735	"	"	"	1022	-	176.5	49.5	153.5	"
19 "	"	"	"	"	"	725	"	"	26.7	969	-	"	48.0	154.5	"
20 "	"	"	"	"	"	"	"	"	30.5	927	-	"	47.0	"	"

TABLE 5-9.

DATE OF RUN & TIME:- 1 - 4 - 1975 / 2230 HRS
RUN # :- 21.
HOURS OF COLD SOAK:- 11.

ROOM TEMPERATURE AT START:- 37°F
BAROMETER PRESSURE:- 29.80 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 44°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURE °F WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	34.3	230.0	237.0	6.90	19	-	0	9.43	465.0	697	-	37.0	37.0	30.0	37.0
30 "	33.5	227.0	234.0	7.00	"	1725	"	9.78	590.0	825	-	32.5	"	"	39.0
45 "	33.0	"	"	7.10	"	1700	"	9.58	1675.0	877	-	32.0	37.5	32.5	43.0
60 "	"	"	"	"	"	1750	"	"	1890.0	910	-	31.0	"	36.0	47.0
75 "	32.5	"	"	7.20	"	"	"	9.68	1860.0	947	-	"	38.0	39.0	51.0
90 "	32.0	"	"	7.30	"	1900	"	9.72	1490.0	963	-	32.5	38.5	41.5	55.0
105 "	30.2	"	"	7.75	"	2000	"	"	915.0	984	-	34.0	39.0	45.0	60.0
120 "	29.5	"	"	7.95	"	2050	"	9.43	465.0	999	-	39.0	"	47.5	64.0
2½ min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 "	24.8	251.0	258.5	10.35	15	1600	105	3.48	155.0	1110	-	60.0	40.5	61.0	79.5
3½ "	21.2	247.0	254.0	12.00	"	"	"	0.65	77.5	1184	-	66.5	41.5	71.0	86.5
4 "	19.2	245.0	251.0	13.20	"	"	90	0.29	46.5	1216	-	76.5	43.0	80.0	93.0
4½ "	18.8	"	"	13.40	"	"	96	0.22	38.8	1227	-	84.0	44.0	88.5	97.5
5 "	"	257.0	264.0	14.00	"	"	"	0.18	31.0	1238	-	183.0	45.0	93.0	101.5
6 "	18.6	256.0	263.0	14.10	"	"	90	0.14	23.3	1258	-	184.0	46.0	99.5	96.0
7 "	"	"	"	"	"	"	"	"	17.0	1270	-	170.0	47.0	106.0	93.0
8 "	18.8	257.0	264.0	14.00	"	"	"	"	"	1275	-	141.5	47.5	111.0	91.0
9 "	18.6	"	"	14.20	"	"	"	"	"	1281	-	91.0	48.5	115.5	"
9½ "	"	258.0	265.0	14.25	"	"	"	"	"	1282	-	180.0	49.5	119.0	"
10 "	"	"	"	"	"	"	"	"	"	1283	-	97.5	"	120.0	"
11 "	"	259.0	266.5	14.35	14¾	"	"	"	"	1285	-	125.0	50.0	123.0	"
12 "	"	"	"	"	"	"	"	"	"	1287	-	168.0	51.0	125.0	90.0
12½ "	"	"	"	"	"	"	"	"	"	1289	-	176.0	"	127.0	"
13 "	"	260.0	268.0	14.40	"	"	"	"	"	1291	-	*	"	128.0	"
14 "	"	261.0	268.5	14.45	"	"	"	"	"	"	-		"	129.0	"
15 "	"	"	"	"	"	"	"	"	"	"	-		"	130.5	88.5
15½ "	-	-	-	-	-	-	-	-	-	1089	-		"	139.5	86.5
16 "	7.0	75.0	77.2	11.00	19	800	0	0.18	23.3	1036	-		50.0	143.5	"
17 "	7.5	76.0	78.4	10.45	"	"	"	"	31.0	984	-		49.5	148.0	"
18 "	8.0	"	"	9.80	"	"	"	"	46.5	940	-		48.5	150.0	"
19 "	7.8	"	"	10.05	"	750	"	"	31.0	920	-		47.5	"	"
20 "	8.0	"	"	9.80	18¾	"	"	"	77.5	890	-		47.0	"	"

TABLE 5-10.

DATE OF RUN & TIME:- 2 - 4 - 1975 / 0930 HRS
RUN # :- 22.
HOURS OF COLD SOAK:- 10.

ROOM TEMPERATURE AT START:- 34°F
BAROMETER PRESSURE:- 29.88 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- -

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT (TEMPERATURE °F)	CAT. CONV. OUT (TEMPERATURE °F)	WATER OUT (TEMPERATURE °F)	INLET AIR (TEMPERATURE °F)	INLET MANI-FOLD (TEMPERATURE °F)	AIR-FILTER (TEMPERATURE °F)
15 sec	48.0	227.0	236.0	4.90	19	1700	0	9.58	480.0	678	-	34.0	35.0	28.0	34.0
30 "	50.2	"	"	4.70	"	"	"	9.96	511.0	780	-	30.0	"	30.5	37.5
45 "	52.0	"	"	4.55	"	"	"	10.10	558.0	843	-	28.0	"	31.5	41.0
60 "	51.0	"	"	4.65	"	"	"	10.20	589.0	875	-	"	"	35.0	45.5
75 "	49.5	"	"	4.75	"	"	"	10.25	712.0	924	-	"	"	37.5	51.0
90 "	30.0	225.0	233.5	7.80	"	"	"	"	589.0	933	-	30.0	36.0	41.0	57.0
105 "	27.5	"	"	8.50	"	2000	"	10.15	511.0	954	-	33.0	36.5	45.0	61.5
120 "	30.1	"	"	7.85	"	2050	"	9.86	341.0	970	-	37.5	"	49.0	65.0
2½ min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 "	26.4	253.0	261.0	9.95	15	1600	105	3.77	124.0	1097	-	56.0	38.5	63.0	80.0
3½ "	24.0	250.0	259.0	10.80	"	"	96	1.15	62.0	1161	-	65.0	40.5	72.5	88.0
4 "	22.0	"	"	11.80	"	"	"	0.44	31.0	1198	-	75.0	41.0	80.0	93.5
4½ "	21.2	"	"	12.20	"	"	"	0.33	23.2	1203	-	83.5	42.0	88.0	99.0
5 "	20.2	259.0	268.0	13.25	"	"	"	0.29	19.4	1208	-	177.5	43.0	92.5	"
6 "	19.8	257.0	266.5	13.45	"	"	"	"	15.5	1224	-	181.5	44.0	100.0	94.5
7 "	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
8 "															
9 "															
9½ "															
10 "															
11 "															
12 "															
12½ "															
13 "															
14 "															
15 "															
15½ "															
16 "															
17 "															
18 "															
19 "															
20 "															

TABLE 5-11.

DATE OF RUN & TIME:- 5 - 4 - 1975 / 1130 HRS
RUN # :- 23.
HOURS OF COLD SOAK:- 19.

ROOM TEMPERATURE AT START:- 43°F
BAROMETER PRESSURE:- 29.83 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 57°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURE °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	33.5	210.0	214.5	6.40	19	1800	0	9.06	822.0	102	202	43.0	44.0	38.0	43.0
30 "	33.2	205.0	209.5	6.30	"	1750	"	9.58	1365.0	124	339	"	"	"	44.5
45 "	32.9	"	"	6.35	"	1735	"	9.73	1458.0	128	471	"	"	40.5	47.5
60 "	32.8	"	"	6.40	"	"	"	9.84	1535.0	132	552	"	"	43.0	52.0
75 "	32.0	"	"	6.55	"	1800	"	9.86	1490.0	139	602	"	"	44.5	56.5
90 "	31.2	"	"	6.70	"	1950	"	9.90	1162.0	157	668	"	"	47.5	61.0
105 "	30.2	"	"	6.95	"	2050	"	9.80	745.0	182	682	45.0	45.0	52.0	65.5
120 "	28.1	"	"	7.45	"	"	"	9.50	480.0	240	695	47.5	46.0	55.0	69.0
2½ min	-	-	-	-	-	-	-	3.63	194.0	382	793	59.0	46.5	63.0	78.0
3 "	28.8	300.0	307.0	10.65	10½	1600	152	1.90	117.0	495	915	65.5	47.5	73.5	88.0
3½ "	25.8	"	"	11.90	"	"	133	0.36	38.8	645	968	78.0	49.0	83.5	97.5
4 "	24.4	302.5	310.0	12.70	10	"	"	0.18	31.0	738	985	88.0	50.5	92.0	104.0
4½ "	24.1	317.5	325.0	13.50	"	"	"	"	23.3	809	1000	96.5↑	52.0	95.5	97.5
5 "	24.2	321.5	328.5	13.60	"	"	"	"	19.4	852	1015	98.5↓	52.5	100.0	98.5
6 "	"	327.5	334.5	13.80	9¾	"	"	"	"	903	1037	105.0↓	54.5	107.0	96.0
7 "	"	"	"	"	"	"	"	"	15.5	944	1052	68.0↓	56.5	113.5	95.0
8 "	"	"	"	"	"	"	"	"	"	972	1062	70.0↑	58.0	119.0	"
9 "	"	"	"	"	"	"	"	"	13.6	986	1070	177.0↑	60.0	123.0	"
9½ "	41.0	427.5	436.0	10.65	3¾	"	247	3.74	81.6	1012	1092	163.0↓	60.5	111.5	87.0
10 "	41.2	"	"	10.60	3½	"	"	3.85	93.2	1021	1112	188.5↓	61.5	*	74.5
11 "	"	428.0	436.5	"	"	"	"	3.79	"	1070	1133	182.0↓	63.5		70.0
12 "	41.4	"	"	10.55	"	"	"	"	"	1098	1153	"	65.5		"
12½ "	24.2	321.5	327.5	13.55	9¾	"	133	0.72	19.4	1105	1126	"	67.0		111.5
13 "	23.9	327.5	334.0	14.00	"	"	"	0.36	"	"	1100	"	"		106.0
14 "	"	331.0	338.0	14.15	"	"	"	0.27	15.5	1077	1083	185.0↑	"		92.0
15 "	"	"	"	"	"	"	"	"	"	1056	1074	185.0	67.5		90.0
15½ "	7.2	78.0	79.8	11.10	19	800	0	"	11.6	1030	915	191.0	68.5		89.0
16 "	7.4	"	"	10.80	"	750	"	"	"	1014	788	187.0	69.0		"
17 "	7.5	"	"	10.60	"	"	"	"	"	993	697	183.0	68.5	158.0	91.0
18 "	7.7	"	"	10.35	"	"	"	"	"	979	640	182.0	67.0	161.0	91.5
19 "	8.0	"	"	9.95	"	"	"	"	"	957	595	"	65.5	163.0	92.5
20 "	7.9	"	"	10.10	"	"	"	"	"	923	566	180.5	64.5	"	94.0

TABLE 5-12.

DATE OF RUN & TIME:- 6 - 4 - 1975 / 2100 HRS
RUN # :- 24.
HOURS OF COLD SOAK:- 33.

ROOM TEMPERATURE AT START:- $40^{o}F$
BAROMETER PRESSURE:- 29.74 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- -

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	40.7	205.0	210.5	5.15	19	1700	0	9.40	535.0	57	411	40.0	39.0	34.0	40.0
30 "	39.7	"	"	5.40	"	"	"	9.80	596.0	123	438	"	"	"	42.0
45 "	38.1	"	"	5.55	"	"	"	9.98	642.0	129	532	"	"	36.5	46.5
60 "	36.3	"	"	5.80	"	"	"	10.10	788.0	134	598	"	"	39.0	51.0
75 "	35.5	"	"	5.95	"	1750	"	"	950.0	136	646	"	"	41.0	55.5
90 "	34.4	"	"	6.15	"	1900	"	"	744.0	138	687	"	39.5	44.5	59.5
105 "	31.6	"	"	6.65	"	2000	"	9.94	558.0	140	705	42.0	40.0	47.5	64.0
120 "	30.0	"	"	7.00	"	2050	"	9.62	397.0	178	712	47.0	"	51.5	68.5
2½ min	30.1	290.0	297.5	11.00	11	1600	152	5.19	176.0	321	817	57.0	"	59.5	77.0
3 "	28.4	285.0	292.0	10.30	"	"	"	1.89	61.2	483	913	68.5	41.5	69.5	87.5
3½ "	24.6	"	"	11.90	"	"	133	0.09	23.0	619	954	77.0	43.0	78.0	94.0
4 "	23.9	"	"	12.20	"	"	124	0.07	15.3	726	976	88.0	44.5	88.0	101.0+
4½ "	23.2	302.5	309.0	13.30	10½	"	"	"	13.4	785	997	96.5+	46.0	93.5	101.0+
5 "	23.4	"	"	13.20	"	"	"	"	11.5	835	1005	67.0+	47.0	96.0	98.5
6 "	23.6	312.5	319.0	13.50	"	"	119	"	7.6	891	1029	70.5+	48.0	101.5	96.0
7 "	"	315.0	321.5	13.60	10¼	"	"	"	"	928	1039	"	50.5	108.0	95.0
8 "	"	317.5	324.0	13.70	"	"	"	"	"	955	1045	66.0+	51.5	114.0	"
9 "	"	"	"	"	"	"	"	"	"	968	1050	182.5+	53.0	120.5	"
9½ "	39.1	425.0	432.5	11.10	3¾	"	247	5.16	61.2	992	1092	102.0+	54.0	107.0	82.0
10 "	40.9	427.5	435.5	10.55	"	"	"	"	68.9	1013	1124	182.0+	55.0	96.0	70.5
11 "	"	428.5	437.0	10.70	"	"	"	"	"	1071	1145	177.0+	57.0	91.5	66.0
12 "	"	430.0	438.0	10.75	"	"	"	"	"	1102	1155	178.5+	59.5	91.0	65.0
12½ "	23.9	330.0	336.0	14.05	9	"	133	0.09	11.5	1105	1116	183.5+	60.0	133.0	122.5
13 "	24.8	342.5	349.0	14.10	"	"	"	0.07	3.8	1102	1106	179.5+	"	126.0	105.5
14 "	25.0	"	"	13.95	"	"	"	"	"	1075	1092	182.5	61.0	127.0	95.0
15 "	"	"	"	"	8¾	"	"	"	"	1060	1081	186.5	"	134.0	92.5
15½ "	10.0	82.5	84.3	8.50	19¼	780	0	"	"	1028	919	190.5	61.5	142.0	91.5
16 "	7.0	78.0	79.6	11.40	"	"	"	"	"	1013	817	179.5	63.0	149.5	92.5
17 "	7.2	"	"	11.10	19	750	"	"	"	992	692	185.0	61.0	155.0	91.5
18 "	7.5	"	"	10.60	18¾	"	"	"	"	968	630	179.5+	60.0	159.0	92.5
19 "	7.8	"	"	10.30	18½	740	"	"	"	948	592	140.0+	58.0	160.5	95.0
20 "	"	"	"	"	"	"	"	"	"	913	566	166.5+	57.5	162.0	96.0

TABLE 5-13.

DATE OF RUN & TIME:- 7 - 4 - 1975 / 0900 HRS
RUN # :- 25.
HOURS OF COLD SOAK:- 12.

ROOM TEMPERATURE AT START:- 35°F
BAROMETER PRESSURE:- 29.71 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- -

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	TEMPERATURES °F CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	32.8	200.0	205.5	6.45	19	1800	0	9.00	1100.0	52	268	35.0	35.0	29.0	35.0
30 "	37.2	"	"	5.45	"	1700	"	9.46	1483.0	113	391	"	"	"	36.5
45 "	36.4	"	"	5.65	18½	1730	"	9.62	1590.0	121	503	"	"	32.0	39.5
60 "	35.6	"	"	5.75	"	"	"	9.69	1810.0	124	560	"	"	35.0	44.0
75 "	34.0	"	"	6.05	"	"	"	9.79	1825.0	146	615	"	"	37.0	49.0
90 "	33.0	"	"	6.25	19	1800	"	9.86	1660.0	176	658	37.5	36.0	39.5	53.5
105 "	32.5	"	"	6.30	"	1950	"	9.90	1230.0	211	687	41.0	"	43.0	57.0
120 "	30.8	"	"	6.65	"	2000	"	9.72	680.0	254	709	45.5	36.5	46.5	60.0
2½ min	28.0	250.0	256.5	9.15	14	1600	133	6.53	283.0	361	778	54.5	37.0	53.5	69.0
3 "	25.9	"	"	9.90	13½	"	124	3.77	176.0	467	850	64.0	38.0	61.0	77.0
3½ "	22.8	"	"	11.25	"	"	105	0.15	61.2	558	902	74.0	39.5	70.0	84.5
4 "	21.0	"	"	12.20	13	"	96	0.09	40.8	644	929	84.0	40.5	80.0	91.5
4½ "	20.7	"	"	12.40	"	"		0.07	30.6	717	950	91.5	41.5	87.5	98.0
5 "	20.4	267.5	274.0	13.40	12¾	"	"	0.05	30.2	765	961	178.0+	42.5	91.5	96.5
6 "	20.7	"	"	13.25	"	"	"	"	20.4	828	982	180.0+	44.0	97.5	93.5
7 "	20.8	270.0	277.0	13.30	12½	"	"	"	15.3	865	992	174.5+	46.5	104.0	91.5
8 "	"	272.5	279.0	13.40	"	"	"	"	13.4	897	999	100.0+	47.0	110.5	91.0
9 "	"	275.0	282.0	13.55	12½	"	"	"	7.8	915	1003	71.5+	49.0	117.0	"
9½ "	36.2	417.5	424.0	11.70	3¾	"	247	3.41	61.2	934	1056	183.0+	50.0	103.5	85.0
10 "	39.6	"	"	10.70	"	"	"	3.34	71.4	963	1101	125.5+	50.5	92.0	68.0
11 "	40.0	419.0	425.0	10.65	"	"	"	3.52	76.5	1019	1130	185.0+	52.0	87.5	61.0
12 "	"	421.0	427.0	10.70	"	"	"	3.62	"	1077	1140	181.5+	54.0	87.0	60.0
12½ "	25.0	264.0	269.0	10.75	11	"	133	0.14	13.4	1084	1111	177.5+	55.5	112.5	82.5+
13 "	22.6	300.0	306.0	13.50	10½	"	"	0.11	7.8	"	1082	180.5+	56.0	100.0	98.0+
14 "	22.7	307.5	314.0	13.85	10½	"	"	0.09	3.9	1061	1061	180.5+	57.0	123.0	96.5
15 "	"	310.0	316.5	13.95	10	"	"	"	"	1034	1053	179.5+	57.5	127.5	91.0
15½ "	10.8	82.5	84.5	8.45	19	800	0	"	"	1006	918	184.5+	58.0	137.0	89.0
16 "	7.0	76.0	77.5	11.10	"	"	"	"	"	987	823	177.5+	"	144.0	"
17 "	7.5	"	"	10.40	18¾	750	"	"	"	966	663	168.5+	57.5	150.0	"
18 "	8.0	"	"	9.70	18½	"	"	"	"	947	623	176.5+	55.5	154.5	89.5
19 "	"	"	"	"	"	740	"	"	"	924	582	148.0+	54.0	156.0	90.0
20 "	8.2	"	"	9.45	"	"	"	"	"	894	555	149.5+	53.0	156.5	91.0

TABLE 5-14.

DATE OF RUN & TIME:- 8 - 4 - 1975 / 0900 HRS
RUN # :- 26.
HOURS OF COLD SOAK:- 24.

ROOM TEMPERATURE AT START:- 36°F
BAROMETER PRESSURE:- 29.82 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 50°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	38.2	204.0	210.5	5.65	19	1750	0	10.32	542.0	58	278	36.0	37.0	30.5	36.0
30 "	34.6	"	"	6.10	18¾	1735	"	10.80	572.0	119	435	35.5	"	31.5	37.0
45 "	33.4	"	"	6.30	"	"	"	11.00	662.0	128	530	35.0	"	32.0	40.5
60 "	33.0	"	"	6.40	"	"	"	11.05	872.0	130	599	34.0	37.5	36.0	46.5
75 "	32.8	"	"	6.45	"	"	"	"	902.0	133	642	"	"	38.0	50.0
90 "	32.0	201.5	208.0	6.50	19	1800	"	11.00	1165.0	146	674	"	"	42.0	55.5
105 "	31.2	"	"	6.65	19½	1950	"	10.92	1265.0	176	703	38.0	38.0	45.0	60.0
120 "	30.0	"	"	6.95	20	2050	"	10.78	1054.0	222	723	42.0	38.5	48.0	64.5
2½ min	29.0	267.5	275.5	9.00	12¼	1600	152	6.11	211.0	364	802	53.0	39.5	56.5	69.0
3 "	27.0	"	"	10.20	"	"	143	3.32	120.5	494	888	63.5	40.5	65.5	81.0
3½ "	25.0	"	"	11.00	12¼	"	115	0.08	30.1	610	914	74.5	41.5	74.5	89.0
4 "	22.4	"	"	12.30	"	"	"	0.04	24.1	696	962	85.5	42.5	83.5	95.5
4½ "	22.0	277.5	286.0	13.00	11¾	1580	"	0.02	18.8	760	972	94.0	43.5	91.0	101.0
5 "	"	285.0	293.0	13.30	"	"	"	"	15.0	809	988	170.0+	44.5	93.0	96.5
6 "	"	290.0	298.0	13.55	11½	"	"	"	"	866	1004	174.0+	46.5	102.0	*
7 "	"	292.5	300.5	13.70	"	"	"	"	13.0	903	1020	140.0+	48.5	109.0	
8 "	22.1	295.0	303.5	"	11¼	"	"	"	"	930	1025	94.0+	50.0	114.0	
9 "	"	"	"	"	11	"	"	"	11.0	946	1030	73.5+	51.5	119.0	
9½ "	37.0	417.5	428.0	11.60	4	"	247	3.47	60.2	964	1078	177.0+	52.0	106.0	
10 "	39.5	"	"	10.85	"	"	"	3.32	"	993	1115	183.0+	52.5	94.0	
11 "	"	419.0	430.0	10.90	"	"	"	3.51	67.8	1062	1141	183.0+	55.5	90.0	
12 "	40.0	"	"	10.75	"	"	"	3.77	"	1093+	1152	177.0+	57.5	"	
12½ "	21.9	260.0	267.5	12.20	11	"	124	0.08	18.8	1093+	1106	182.5+	58.5	128.0	
13 "	22.1	295.0	303.0	13.75	"	"	"	0.06	15.0	1091	1078	179.0+	"	124.0	
14 "	22.4	302.5	311.0	13.90	"	"	"	0.04	13.0	1062	1062	182.0	"	127.0	
15 "	"	"	"	"	"	"	"	"	"	1035	1051	"	59.5	130.5	
15½ "	7.0	76.0	78.4	11.20	19	780	0	"	"	1004	885	180.5+	60.5	141.0	
16 "	7.2	"	"	10.90	"	"	"	"	"	988	790	187.0+	"	147.5	
17 "	7.5	"	"	10.45	"	750	"	"	"	964	685	172.0+	59.5	153.0	
18 "	7.8	"	"	10.05	"	"	"	"	"	946	621	167.0+	58.5	157.0	
19 "	"	"	"	"	18¾	"	"	"	"	924	583	134.5+	57.5	158.0	
20 "	8.0	"	"	9.80	"	"	"	"	"	903	532	147.0+	55.5	159.0	

TABLE 5-15.

DATE OF RUN & TIME:- 9 - 4 - 1975 / 0800 HRS
RUN # :- 27.
HOURS OF COLD SOAK:- 22.

ROOM TEMPERATURE AT START:- 31°F
BAROMETER PRESSURE:- 29.91 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- -

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	37.2	205.0	214.5	5.75	19	1800	0	10.70	511.0	76	262	31.0	32.0	31.0	31.0
30 "	35.2	202.5	211.5	6.00	"	1750	"	11.10	604.0	113	413	"	32.5	26.0	32.0
45 "	33.6	"	"	6.30	"	"	"	11.40	640.0	120	521	"	33.0	"	35.5
60 "	33.2	"	"	6.40	"	1775	"	11.52	723.0	126	589	"	33.5	29.0	40.0
75 "	32.6	200.0	209.0	6.50	"	"	"	11.60	874.0	142	638	"	34.0	31.0	45.0
90 "	32.5	"	"	6.55	19½	1850	"	"	978.0	196	675	33.0	34.5	34.0	49.5
105 "	31.0	"	"	6.85	"	1950	"	11.52	857.0	251	702	37.0	35.0	38.0	54.0
120 "	30.2	"	"	7.00	~20	"	"	11.35	549.0	300	713	42.5	35.5	41.5	58.5
2½ min	31.5	288.0	300.0	9.55	12	1600	162	5.80	181.0	435	825	52.0	"	49.5	67.5
3 "	28.2	287.5	298.0	10.60	11	"	152	3.02	90.3	570	905	62.0	37.0	59.5	77.5
3½ "	26.1	285.0	297.0	11.40	"	"	133	0.15	26.4	681	957	72.5	39.0	69.5	85.0
4 "	23.9	"	"	12.45	"	"	"	0.09	15.1	756	989	83.0	39.5	78.5	93.0
4½ "	23.5	292.5	305.0	13.00	10½	"	"	0.08	11.3	814	994	94.0	40.5	87.0	98.0
5 "	24.0	301.5	314.0	13.10	10¼	1570	"	"	7.5	862	1010	126.5+	41.5	89.5	95.5
6 "	23.5	310.0	323.0	13.75	10	"	"	"	3.4	925	1025	118.0+	43.5	97.0	93.0
7 "	"	314.0	327.0	13.90	"	"	"	"	"	952	1036	72.0+	46.0	103.5	91.5
8 "	"	"	"	"	"	"	"	"	"	962	1041	67.5+	47.0	109.0	90.5
9 "	"	315.0	328.0	13.95	9¾	"	"	"	"	973	1049	106.0+	48.0	114.0	"
9½ "	40.1	415.0	431.0	10.75	3¾	1580	251	3.91	60.3	994	1094	138.5+	49.5	97.0	79.5
10 "	"	"	"	"	"	"	"	3.77	"	1020	1122	188.0+	51.0	88.0	67.0
11 "	"	417.5	434.0	10.80	"	"	"	3.84	"	1073	1141	180.0+	53.0	84.0	58.5
12 "	"	420.0	436.0	10.90	"	"	"	3.95	"	1105	1152	180.0+	55.5	83.0	"
12½ "	23.5	327.5	340.0	14.50	9	"	133	0.15	3.4	"	1110	183.0+	56.0	126.0	109.0
13 "	24.0	"	"	14.20	"	"	"	0.12	"	1099	1094	177.0+	"	120.5	102.5
14 "	"	330.0	343.0	14.30	"	"	"	"	"	1071	1081	179.0+	56.5	"	94.0
15 "	"	"	"	"	"	"	"	"	"	1052	1073	181.0	"	124.0	88.5
15½ "	7.0	82.5	85.9	12.25	19½	800	0	"	"	1020	897	186.0+	57.0	135.0	87.5
16 "	7.2	76.0	79.0	10.95	19¼	"	"	"	"	1002	798	177.0+	57.5	142.5	"
17 "	"	"	"	"	19	750	"	"	"	978	688	177.0+	56.0	148.5	85.0
18 "	7.6	"	"	10.40	"	"	"	"	"	962	622	165.0+	55.0	152.0	86.0
19 "	8.0	"	"	9.90	"	"	"	"	"	936	589	140.5+	54.0	154.0	"
20 "	"	"	"	"	"	"	"	"	"	904	554	136.0+	53.0	155.0	"

TABLE 5-16.

DATE OF RUN & TIME:- 10 - 4 - 1975 / 0830 HRS
RUN # :- 28.
HOURS OF COLD SOAK:- 24.

ROOM TEMPERATURE AT START:- 36°F
BAROMETER PRESSURE:- 29.85 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 48°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	34.5	202.5	219.0	6.35	19	1800	0	10.70	572.0	58	283	36.0	36.0	30.0	36.0
30 "	39.0	"	"	5.65	"	1750	"	11.15	636.0	86	443	"	"	31.0	37.0
45 "	36.8	"	"	5.95	18¾	"	"	11.40	"	110	534	"	"	32.0	41.0
60 "	35.9	"	"	6.10	"	"	"	11.50	734.0	120	599	"	37.0	36.0	45.0
75 "	34.8	"	"	6.30	"	1800	"	11.52	880.0	125	648	"	"	38.0	50.0
90 "	33.5	"	"	6.55	19½	1900	"	11.58	780.0	141	680	"	38.0	41.0	55.0
105 "	31.0	"	"	7.10	20	1950	"	11.30	745.0	174	699	40.5	"	45.0	60.0
120 "	29.9	"	"	7.35	"	2050	"	11.05	541.0	244	712	45.0	"	49.0	63.5
2½ min	30.4	267.5	275.5	9.05	13	1600	152	6.48	195.0	390	818	54.5	40.5	56.5	73.5
3 "	26.3	265.0	273.0	10.40	12¾	1580	143	3.88	121.0	507	882	64.0	41.0	65.5	82.0
3½ "	23.8	"	"	11.45	12½	"	124	0.15	30.1	605	930	76.0	42.0	74.5	89.5
4 "	22.0	"	"	12.40	"	1560	115	0.11	18.8	691	951	87.0	43.0	83.5	95.0
4½ "	21.2	285.0	293.0	13.80	12	"	"	0.08	15.1	760	967	96.5+	44.0	90.0	101.0
5 "	21.5	"	"	13.60	"	"	"	"	11.3	803	978	169.0+	45.0	92.0	95.0
6 "	"	"	"	"	"	"	"	"	7.5	856	993	171.0+	47.5	101.0	[illegible].0
7 "	"	287.5	296.0	13.80	"	"	"	"	"	893	1004	84.5+	49.0	107.0	92.0
8 "	"	"	"	"	"	"	"	"	"	919	1009	65.5+	50.0	115.0	91.5
9 "	"		"	"	"	"	"	"	"	937	1014	73.5+	52.0	119.0	"
9½ "	39.5	415.0	427.0	10.80	4	1575	247	4.03	75.0	961	1078	176.0+	52.5	100.0	81.0
10 "	"	"	"	"	"	"	"	3.88	"	988	1109	185.0+	54.0	92.0	68.0
11 "	"	417.5	429.5	10.85	"	"	"	3.81	"	1051	1133	178.5+	56.5	89.0	64.0
12 "	"	418.5	430.5	10.90	"	"	"	4.03	"	1088	1146	179.0+	59.0	88.0	62.0
12½ "	20.8	267.5	275.0	13.20	12	"	115	0.15	11.3	"	1099	179.0+	59.5	124.5	90.0
13 "	21.2	285.0	293.0	13.80	"	"	"	0.13	7.5	"	1067	179.0+	"	121.0	103.0
14 "	"	287.5	296.0	13.95	"	"	"	"	"	1067	1040	179.0	"	125.0	92.0
15 "	"	"	"	"	"	"	"	"	"	1009	1035	180.0+	"	129.5	90.0
15½ "	11.0	76.0	78.4	7.15	19	780	0	"	"	990	882	187.0+	"	140.0	89.5
16 "	7.5	"	"	10.45	"	775	"	"	"	988	781	178.0+	60.0	145.0	89.0
17 "	7.8	"	"	10.05	18¾	760	"	"	"	961	680	179.0+	59.0	151.0	88.0
18 "	"	"	"	"	"	750	"	"	"	940	615	179.0+	57.5	154.0	87.0
19 "	8.0	"	"	9.80	18½	740	"	"	"	914	578	155.0+	56.5	155.0	"
20 "	"	"	"	"	"	735	"	"	"	882	552	151.0+	56.0	156.0	"

TABLE 5-17.

DATE OF RUN & TIME:- 16 - 4 - 1975 / 0745 HRS
RUN # :- 32.
HOURS OF COLD SOAK:- 24.

ROOM TEMPERATURE AT START:- 49°F
BAROMETER PRESSURE:- 29.83 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 62°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	34.0	197.5	200.0	5.90	19½	1850	0	10.40	904.0	62	326	49.0	49.0	43.0	49.0
30 "	31.8	"	"	6.30	"	"	"	10.70	1300.0	104	425	"	49.5	44.0	"
45 "	31.4	"	"	6.40	"	1900	"	10.92	1220.0	107	509	"	50.0	46.0	51.0
60 "	31.0	"	"	6.45	"	1950	"	11.00	1092.0	123	568	"	"	49.0	53.5
75 "	29.8	"	"	6.75	"	2050	"	"	633.0	134	615	"	50.5	51.0	56.0
90 "	29.0	192.5	195.0	"	20	"	"	10.78	481.0	143	644	50.5	51.0	55.0	58.0
105 "	28.0	"	"	7.00	"	"	"	10.40	361.0	161	673	55.0	52.0	58.0	61.5
120 "	26.5	"	"	7.35	"	"	"	9.85	271.0	194	698	58.0	53.0	61.5	64.0
2½ min	28.6	282.5	286.0	10.00	11	1600	152	1.88	100.0	304	879	66.0	53.5	67.0	70.0
3 "	27.0	"	"	10.60	"	"	143	0.53	52.6	472	928	79.0	55.0	79.0	76.0
3½ "	25.0	275.0	278.5	11.10	"	"	"	0.06	30.1	614	974	89.0	56.0	89.0	82.5
4 "	24.2	"	"	12.20	"	"	137	0.04	22.6	721	989	100.0↑	57.0	98.0	89.0
4½ "	"	"	"	"	10½	"	133	"	18.8	785	1005	172.5↓	58.0	106.5	95.0
5 "	"	315.0	318.0	13.15	10	"	"	"	15.0	828	1016	59.0↑	59.0	"	96.5
6 "	"	"	"	"	"	"	"	"	"	875	1037	156.5↑	60.0	109.5	90.0
7 "	"	317.5	320.5	13.25	"	"	"	"	11.3	912	1047	186.5↓	62.5	114.0	"
8 "	"	320.0	323.0	13.35	"	"	130	"	7.5	941	1052	178.0↓	64.0	118.0	89.0
9 "	"	321.5	324.0	13.40	"	"	"	"	"	955	1058	176.5↓	65.0	122.0	"
9½ "	34.8	427.5	431.0	12.40	3½	"	251	4.40	67.8	970	1100	186.5↑	65.5	109.5	82.5
10 "	44.2	430.0	434.0	9.80	3	"	"	"	"	996	1125	178.0↑	66.0	102.0	79.0
11 "	43.8	"	"	9.90	"	"	257	4.68	"	1039	1148	180.5↑	68.5	95.0	74.0
12 "	44.2	"	"	9.80	"	"	"	4.52	71.5	1071	1159	182.5	70.0	94.0	73.0
12½ "	23.5	250.0	252.0	10.70	11½	"	133	0.11	15.0	"	1121	"	70.5	136.0	89.5
13 "	"	272.5	274.5	11.70	11	"	126	0.08	11.3	1076	1090	"	71.0	159.5	119.0
14 "	23.2	312.5	316.0	13.60	10½	"	115	0.06	7.5	1065	1071	192.0↑	71.5	134.0	98.0
15 "	"	314.0	317.5	13.70	"	"	"	"	"	1034	1066	188.0↓	"	133.0	89.5
15½ "	7.5	76.0	77.0	10.30	19½	800	0	"	"	1013	889	"	"	146.0	88.0
16 "	"	"	"	"	19	780	"	"	"	997	783	182.5↓	"	152.0	"
17 "	7.8	"	"	9.90	"	760	"	"	"	965	666	"	70.0	158.5	"
18 "	"	"	"	"	18¾	750	"	"	"	933	601	180.0	68.5	160.5	89.5
19 "	8.0	"	"	9.65	"	"	"	"	"	907	568	"	66.0	161.5	"
20 "	"	"	"	"	18½	735	"	"	"	870	544	"	65.5	162.5	"

TABLE 5-18.

DATE OF RUN & TIME:- 18 - 4 - 1975 / 0845 HRS
RUN # :- 34.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 78°F
BAROMETER PRESSURE:- 29.70 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 85°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	-	-	-	-	-	-	-	6.90	330.0	91	275	79.0	78.0	73.5	78.0
30 "	32.0	307.5	295.0	9.25	10½	1600	172	2.79	150.0	136	564	82.5	"	"	79.0
45 "	-	-	-	-	-	-	-	3.47	135.0	181	693	83.5	78.5	77.0	82.5
60 "	31.8	305.0	292.5	9.20	10	1600	172	3.31	116.0	209	773	85.0	79.0	82.5	87.0
75 "	-	-	-	-	-	-	-	2.41	90.0	258	829	88.0	79.5	88.0	91.0
90 "	30.0	300.0	287.5	9.60	9¾	1600	156	0.75	45.0	314	874	91.0	80.0	93.0	95.5
105 "	-	-	-	-	-	-	-	0.15	22.5	401	908	92.5	80.5	98.0	101.0
120 "	27.0	295.0	283.0	10.50	9¾	1600	156	0.09	15.0	509	934	96.5	81.0	103.0	105.5
2½ min	26.2	307.5	295.0	11.25	9	"	141	0.08	7.5	677	964	104.0	82.5	113.0	114.0
3 "	25.5	352.5	337.0	13.15	8½	"	"	0.07	3.8	763	990	115.0	84.0	"	"
3½ "	26.0	353.5	337.5	13.00	"	"	"	"	"	827	1011	188.5+	84.5	108.0	105.5
4 "	"	355.0	339.0	13.05	"	"	"	"	"	869	1027	178.5+	85.5	110.0	100.0
4½ "	25.8	"	"	13.10	"	"	133	"	"	890	1041	190.0+	87.0	113.0	99.0
5 "	"	"	"	"	"	"	"	"	"	922	1048	206.0+	"	115.0	98.5
6 "	26.0	"	"	13.00	8¼	"	"	"	"	953	1064	202.0+	89.0	119.0	98.0
7 "	26.2	"	"	12.95	"	"	"	"	"	985	1075	200.5+	90.5	123.0	"
8 "	"	"	"	"	"	"	"	"	"	1012	1082	201.0	92.0	126.0	"
9 "	26.5	"	"	"	"	"	"	"	"	1017	1085	"	93.0	129.5	"
9½ "	42.0	431.0	411.0	9.80	2¼	"	247	5.13	82.5	1038	1107	202.5	93.5	121.5	97.5
10 "	43.4	429.0	408.0	9.45	"	"	"	5.20	90.0	1046	1122	"	94.0	119.5	97.0
11 "	43.6	"	"	9.35	"	"	"	5.16	"	1078	1136	203.0	95.5	119.0	"
12 "	45.5	"	"	9.00	"	"	"	5.13	"	1094	1138	204.0	96.5	"	"
12½ "	28.0	277.5	256.0	9.45	9¾	"	137	0.15	9.9	1095	1117	"	97.5	154.0	119.0
13 "	24.8	337.5	321.0	12.95	9	"	"	0.13	7.5	1094	1096	202.0	"	159.0	138.0
14 "	25.0	338.5	322.5	12.90	"	"	"	0.11	3.8	1072	1083	"	"	143.0	110.5
15 "	"	340.0	324.0	12.95	"	"	"	"	"	1051	1082	"	"	143.5	106.0
15½ "	7.8	76.0	72.4	9.30	18½	750	0	"	"	1017	890	209.5	"	158.0	"
16 "	"	"	"	"	"	725	"	"	"	1003	784	201.0	"	164.0	"
17 "	"	"	"	"	18½	720	"	"	"	975	667	200.5	96.5	170.0	"
18 "	8.0	"	"	9.05	"	710	"	"	"	953	607	200.0	94.5	173.0	"
19 "	"	"	"	"	18	700	"	"	"	937	564	199.5	93.0	174.0	107.0
20 "	"	"	"	"	"	"	"	"	"	890	534	199.0	92.0	175.0	"

TABLE 5-19.

DATE OF RUN & TIME:- 19 - 4 - 1975 / 0845 HRS
RUN # :- 35.
HOURS OF COLD SOAK;- -

ROOM TEMPERATURE AT START:- 76°F
BAROMETER PRESSURE:- 28.97 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- -

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	24.8	127.5	118.5	4.80	15	1550	0	8.59	337.0	93	272	77.5	77.0	75.0	76.0
30 "	"	267.5	248.5	10.00	12	1600	133	*	225.0	124	401	78.0	"	71.5	77.0
45 "	-	-	-	-	-	-	-		130.0	162	584	"	"	74.0	79.0
60 "	28.0	264.0	245.5	8.75	12	1600	133		120.0	173	675	79.0	"	77.5	82.0
75 "	-	-	-	-	-	-	-		105.0	184	739	82.0	77.5	82.0	85.5
90 "	27.0	260.0	242.0	8.95	12	1600	128		89.7	206	788	83.5	78.0	86.0	89.0
105 "	-	-	-	-	-	-	-	0.85	48.6	255	827	86.5	78.5	91.0	93.5
120 "	24.2	257.5	239.5	9.90	11¾	1600	118	0.19	29.9	322	856	87.5	79.0	96.0	98.0
2½ min	23.2	252.5	234.0	10.10	11½	"	115	0.11	15.0	474	896	94.5	79.5	105.0	104.0
3 "	23.0	267.5	248.0	10.70	11¼	"	"	0.09	11.2	606	923	101.0	80.0	112.5	111.0
3½ "	22.8	307.5	286.0	12.55	10¾	"	108	"	"	692	946	200.0+	82.0	111.0	"
4 "	23.0	"	"	12.45	"	"	"	"	7.5	750	962	169.0+	82.5	108.5	102.0
4½ "	23.2	"	"	12.30	"	"	"	"	3.6	793	978	188.0+	83.0	110.0	100.0
5 "	23.4	"	"	12.20	"	"	"	"	"	827	988	182.0+	85.0	112.0	98.5
6 "	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
7 "															
8 "															
9 "															
9½ "															
10 "															
11 "															
12 "															
12½ "															
13 "															
14 "															
15 "															
15½ "															
16 "															
17 "															
18 "															
19 "															
20 "															

TABLE 5-20.

DATE OF RUN & TIME:- 20 - 4 - 1975 / 1545 HRS
RUN # :- 36.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 73°F
BAROMETER PRESSURE:- 29.70 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- -

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	-	-	-	-	-	-	-	7.40	262.0	117	348	73.0	73.5	67.5	73.0
30 "	25.8	192.5	186.5	7.30	17	1600	75	7.91	210.0	128	471	76.5	"	"	74.0
45 "	-	-	-	-	-	-	-	8.18	188.0	155	540	77.5	74.0	70.0	75.0
60 "	23.5	230.0	222.0	9.50	14½	1600	115	7.46	157.0	168	631	80.0	"	73.0	77.0
75 "	-	-	-	-	-	-	-	4.75	120.0	177	697	82.0	74.5	76.5	79.0
90 "	22.4	228.5	220.5	9.85	14½	1600	103	4.45	113.0	196	747	86.0	"	80.0	83.0
105 "	-	-	-	-	-	-	-	3.39	90.0	226	782	89.5	75.0	84.0	86.0
120 "	20.5	227.5	219.5	10.70	14½	1600	103	2.07	60.0	275	811	92.0	75.5	88.5	88.5
2½ min	18.1	221.0	212.0	11.70	"	"	"	0.15	15.0	404	852	95.0	76.5	97.0	95.0
3 "	17.5	"	"	12.10	"	"	97	0.11	11.3	515	880	102.0	77.5	105.0	101.5
3½ "	"	"	"	"	14	"	"	"	7.5	610	896	123.5+	78.5	112.0	107.0
4 "	17.3	260.0	248.0	14.35	13½	"	96	"	3.8	675	912	180.0+	79.5	"	"
4½ "	"	"	"	"	"	"	"	"	"	724	928	198.5+	80.5	110.0	102.0
5 "	17.5	"	"	14.20	"	"	"	"	"	761	938	184.0+	81.5	112.0	100.5
6 "	21.6	325.0	309.0	14.30	10	"	147	"	"	827	996	190.0+	82.0	114.0	99.0
7 "	"	327.5	311.0	14.40	9¾	"	"	"	"	887	1020	191.5+	84.0	118.5	98.0
8 "	21.8	328.0	312.0	14.35	"	"	"	"	"	928	1033	193.5	86.0	122.0	"
9 "	"	"	"	"	"	"	"	"	"	954	1038	"	"	125.0	100.0
9½ "	32.0	422.5	401.0	12.55	3½	"	247	5.35	67.5	975	1078	195.5+	"	116.0	98.0
10 "	38.6	"	"	10.40	"	"	"	5.58	75.0	999	1097	195.5+	86.5	112.5	96.0
11 "	38.0	"	"	10.60	"	"	"	5.54	82.5	1044	1112	196.5+	88.5	112.0	95.0
12 "	"	"	"	"	"	"	"	5.61	"	1070	1123	197.5+	90.5	112.5	"
12½ "	24.8	265.0	251.0	10.10	10	"	135	0.21	11.3	"	1091	195.5	92.0	155.0	116.5
13 "	21.2	330.0	313.0	14.75	9¾	"	130	0.15	7.5	"	1070	194.5	"	150.0	126.0
14 "	21.5	333.5	315.5	14.70	"	"	"	"	3.8	1054	1063	"	"	138.5	111.0
15 "	"	"	"	"	"	"	"	"	"	1036	"	"	"	"	109.0
15½ "	4.0	65.0	61.5	15.40	18¾	760	0	"	"	1001	867	202.0+	92.5	154.0	108.0
16 "	2.5	"	"	-	18½	742	"	"	"	986	787	193.5	92.0	160.0	107.0
17 "	4.2	"	"	-	18¼	720	"	"	"	964	651	"	90.5	166.0	"
18 "	4.5	"	"	-	"	715	"	"	"	954	592	191.5	89.5	168.5	"
19 "	4.0	"	"	-	18	700	"	"	"	928	554	"	88.5	170.0	"
20 "	4.5	"	"	-	"	"	"	"	"	894	526	191.0	87.5	"	"

TABLE 5-21.

DATE OF RUN & TIME:- 21 - 4 - 1975 / 1000 HRS
RUN # :- 37.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 71°F
BAROMETER PRESSURE:- 30.14 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 83°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	CAT. CONV. IN (TEMPERATURES °F)	CAT. CONV. OUT (TEMPERATURES °F)	WATER OUT (TEMPERATURES °F)	INLET AIR (TEMPERATURES °F)	INLET MANI-FOLD (TEMPERATURES °F)	AIR-FILTER (TEMPERATURES °F)
15 sec	23.8	192.5	191.5	8.05	18	-	75	8.0	300.0	100	357	73.0	71.0	65.5	71.0
30 "	23.2	197.5	196.0	8.45	17½	1600	"	8.66	240.0	137	464	79.0	"	65.0	"
45 "	-	-	-	-	-	-	-	8.94	210.0	167	535	80.5	"	66.5	71.5
60 "	22.4	187.5	186.0	8.30	17½	1620	152	8.76	195.0	183	592	84.0	"	69.0	74.0
75 "	-	-	-	-	-	-	-	7.54	16[illegible].0	194	644	88.5	71.5	71.0	76.0
90 "	26.0	287.5	274.5	10.95	11	1620	150	2.87	97.6	218	740	91.0	72.0	76.0	79.0
105 "	-	-	-	-	-	-	-	0.30	60.0	257	814	94.5	73.0	82.0	82.0
120 "	25.5	287.5	274.5	11.15	10½	1620	142	0.10	30.0	321	865	97.5	74.0	88.5	86.0
2½ min	23.0	280.0	277.5	12.05	"	"	"	0.08	18.8	480	920	103.0	75.0	98.5	93.0
3 "	"	"	"	"	10½	"	"	"	15.0	627	950	112.0	76.0	107.0	100.5
3½ "	22.5	"	"	12.30	"	"	"	"	13.0	719	971	152.0+	77.0	114.5	107.0
4 "	23.0	342.5	338.0	14.70	9½	"	135	"	11.5	783	989	186.0+	78.0	116.5	111.0
4½ "	"	337.5	333.0	14.50	"	"	"	"	7.4	828	1005	205.5+	79.0	111.0	103.0
5 "	23.1	341.0	336.0	14.55	"	"	"	"	"	865	1018	190.0+	80.0	112.0	100.5
6 "	23.4	342.5	338.5	14.45	"	"	"	"	"	915	1039	201.5	81.5	116.5	98.5
7 "	"	"	"	"	"	"	"	"	"	948	1052	202.5	83.0	119.0	98.0
8 "	23.5	"	"	14.40	9½	"	"	"	"	973	1058	199.5	84.0	122.5	97.5
9 "	"	"	"	"	"	"	"	"	"	984	1063	201.5	85.0	126.0	98.5
9½ "	40.8	430.0	424.0	10.40	3	"	251	5.12	67.0	1005	1097	203.5	85.5	116.5	97.5
10 "	39.8	428.5	422.0	10.60	"	"	"	5.27	"	1026	1119	"	86.5	114.5	95.0
11 "	44.4	430.0	424.0	9.60	"	"	"	4.82	"	1068	1138	"	87.5	"	94.0
12 "	42.2	"	"	10.05	2½	"	"	5.05	"	1089	1145	"	88.5	"	"
12½ "	21.9	260.0	255.0	11.60	11	"	133	0.15	11.5	"	1110	"	90.0	154.0	109.0
13 "	20.8	317.5	311.0	14.25	10½	"	124	0.11	7.4	"	1081	202.5	"	157.5	125.0
14 "	21.0	322.5	315.0	15.00	"	"	122	"	"	1074	1064	"	"	140.5	110.0
15 "	21.5	"	"	14.65	"	"	118	"	"	1039	1058	"	"	"	107.5
15½ "	8.0	76.0	74.4	9.30	19	760	0	"	"	1005	865	205.5	"	154.0	106.0
16 "	6.4	"	"	11.60	18½	"	"	"	"	989	761	201.5	"	161.0	"
17 "	6.6	"	"	11.30	"	735	"	"	"	970	654	"	88.5	166.0	"
18 "	6.1	"	"	12.20	"	725	"	"	"	948	592	199.5	87.5	168.5	"
19 "	6.9	"	"	10.80	"	"	"	"	"	928	552	"	86.5	170.0	"
20 "	7.0	"	"	10.60	"	720	"	"	"	899	530	"	85.5	"	"

TABLE 5-22.

DATE OF RUN & TIME:- 22 - 4 - 1975 / 0915 HRS
RUN # :- 38.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 78 °F
BAROMETER PRESSURE:- 30.28 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 85 °F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURE °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	23.3	192.5	191.5	8.20	18	1630	75	7.28	300.0	104	360	75.0	74.0	69.0	74.0
30 "	22.0	"	"	8.70	"	"	"	7.84	218.0	129	472	77.0	"	68.5	"
45 "	-	-	-	-	-	-	-	7.39	192.0	164	550	79.0	74.5	69.5	74.5
60 "	24.8	296.5	294.5	11.90	11	1630	162	2.04	110.0	183	689	81.0	"	74.0	77.5
75 "	-	-	-	-	-	-	-	2.00	90.0	205	775	84.0	75.0	81.0	81.0
90 "	26.5	292.5	290.0	10.95	10¾	1630	155	0.94	60.0	249	834	86.0	76.0	85.5	83.5
105 "	-	-	- -	-	-	-	-	0.15	37.5	315	875	89.5	76.5	91.5	87.0
120 "	24.8	287.5	285.0	11.50	10½	1610	143	0.08	30.0	400	902	92.5	77.0	96.0	91.5
2½ min	22.8	285.0	283.0	12.40	"	"	136	0.04	26.2	584	939	97.5	78.5	105.5	100.0
3 "	22.7	"	"	12.45	10½	"	"	"	22.5	689	965	105.5	79.5	113.0	107.0
3½ "	"	342.5	339.0	14.95	9½	"	130	"	15.0	766	981	189.5+	81.0	119.5	113.0
4 "	23.0	"	"	14.75	"	"	"	"	13.0	817	1002	175.0+	"	111.0	104.5
4½ "	"	345.0	341.0	14.85	"	"	"	"	"	854	1018	187.0+	81.5	112.0	101.0
5 "	"	346.5	342.0	14.90	"	"	"	"	"	885	1029	203.0+	83.0	113.0	100.0
6 "	"	350.0	345.0	15.00	"	"	"	"	"	932	1044	199.5+	85.0	117.0	97.5
7 "	"	"	"	"	9	"	"	"	"	960	1058	198.0	86.0	121.5	"
8 "	23.2	"	"	14.90	"	"	"	"	"	981	1066	197.0	87.0	125.0	100.0
9 "	"	"	"	"	"	"	"	"	"	997	1069	197.5	88.0	128.0	"
9½ "	40.5	430.0	424.0	10.45	3¾	"	251	4.97	67.5	1013	1102	198.5	89.0	119.5	"
10 "	39.5	427.5	421.0	10.65	"	"	"	5.12	75.0	1029	1119	199.5	"	117.0	97.5
11 "	44.5	"	"	9.45	"	"	"	4.82	"	1066	1134	200.0	90.5	116.0	96.0
12 "	42.0	430.0	424.0	10.10	"	"	"	5.05	"	1087	1140	201.5	91.5	116.5	"
12½ "	23.0	265.0	260.0	11.30	11	"	135	0.11	22.5	"	1108	200.0	92.5	150.5	108.0
13 "	21.2	322.5	317.0	14.95	10	"	128	0.08	15.0	1086	1082	198.0	"	159.5	132.0
14 "	21.5	330.0	324.0	15.05	"	"	124	"	13.0	1066	1071	"	"	149.5	111.0
15 "	"	"	"	"	"	"	"	"	"	1039	1063	198.5	"	"	109.0
15½ "	7.8	76.0	74.4	9.55	19	770	0	"	"	1002	885	206.0	"	154.5	108.0
16 "	"	"	"	"	18¾	735	"	"	"	992	775	198.0	"	161.5	107.5
17 "	7.9	"	"	9.40	18½	725	"	"	"	965	655	"	91.5	167.0	"
18 "	6.4	"	"	11.65	"	720	"	"	"	950	593	196.5	90.5	169.5	"
19 "	6.8	"	"	10.95	"	715	"	"	"	923	553	"	89.0	171.0	"
20 "	5.9	"	"	12.60	"	710	"	"	"	892	527	"	88.5	"	"

TABLE 5-23.

DATE OF RUN & TIME:- 23 - 4 - 1975 / 0930 HRS
RUN # :- 39.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 74°F
BAROMETER PRESSURE:- 30.21 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 85°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F: CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	24.0	195.0	193.0	8.05	18	1625	75	7.35	270.0	96	338	74.0	74.0	69.0	74.0
30 "	23.0	192.5	190.5	8.30	17¾	"	"	8.04	210.0	128	464	76.0	"	68.5	"
45 "	-	-	-	-	-	-	-	8.20	188.0	154	538	77.0	74.5	69.5	75.0
60 "	23.0	285.0	282.0	12.25	11½	1625	150	5.35	165.0	164	601	78.5	"	72.5	77.0
75 "	-	-	-	-	-	-	-	2.45	94.0	172.	724	79.5	75.0	78.5	80.5
90 "	26.2	285.0	282:0	10.75	11¼	1625	150	1.66	75.0	198	801	83.0	75.5	84.0	83.5
105 "	-	-	-	-	-	-	-	0.45	45.0	249	846	86.0	76.0	88.5	87.0
120 "	23.9	285.0	282.0	11.80	11	1625	142	0.41	30.0	318	881	90.0	77.0	94.0	91.0
2½ min	22.8	277.5	274.0	12.00	"	"	138	0.21	26.2	450	925	97.0	78.5	104.0	99.0
3 "	22.2	"	"	12.35	10¾	"	"	"	23.1	639	951	102.0	"	112.0	105.5
3½ "	22.0	315.0	310.0	14.10	10½	"	"	"	18.8	711	972	198.0+	80.5	119.5	112.0
4 "	22.5	332.5	327.0	14.55	10	1610	130	"	15.0	775	994	170.0+	81.0	111.0	105.5
4½ "	22.8	336.5	331.5	"	9¾	"	126	"	"	812	1008	186.5+	82.0	112.0	102.5
5 "	"	"	"	"	"	"	"	"	"	839	1021	193.5+	83.0	114.0	101.0
6 "	"	337.5	332.5	14.60	"	"	"	"	"	892	1042	196.0+	85.0	118.0	99.0
7 "	23.1	"	"	14.40	"	"	"	"	"	929	1050	193.5	86.0	121.5	"
8 "	23.3	"	"	14.25	"	"	"	"	"	951	1058	194.5	87.5	125.0	100.0
9 "	23.6	338.5	333.5	14.10	"	"	"	"	"	959	1063	"	88.0	128.0	101.0
9½ "	36.8	430.0	421.0	11.50	3¾	"	253	5.20	66.6	974	1092	"	"	121.5	"
10 "	38.0	"	"	11.10	3½	"	"	5.40	75.0	995	1113	196.0	90.0	117.0	99.0
11 "	41.0	"	"	10.50	"	"	"	5.35	82.5	1034	1135	"	91.5	116.0	96.5
12 "	35.9	"	"	11.70	"	"	"	5.42	"	1058	1142	198.0	92.0	"	"
12½ "	19.0	250.0	244.0	12.80	11½	"	126	0.28	22.5	1057	1108	196.0	94.0	159.0	115.0
13 "	18.9	315.0	307.5	16.20	10¾	"	118	0.26	15.0	1055	1079	195.5	93.5	153.5	129.0
14 "	19.0	317.5	310.0	16.30	"	"	"	"	"	1034	1065	"	94.0	142.0	111.5
15 "	19.2	"	"	16.15	"	"	"	"	"	1008	1060	"	"	"	110.5
15½ "	8.3	76.0	74.0	8.95	19	760	0	"	"	979	881	202.0	"	156.5	109.5
16 "	7.8	"	"	9.50	18½	"	"	"	"	960	775	194.5	"	163.0	"
17 "	"	"	"	"	18¼	725	"	"	"	939	662	"	92.0	168.0	"
18 "	"	"	"	"	"	700	"	"	"	921	598	193.5	91.5	171.0	"
19 "	6.2	"	"	11.95	"	695	"	"	"	897	566	"	91.0	"	"
20 "	"	"	"	"	18	690	"	"	"	868	538	"	89.0	"	"

TABLE 5-24.

DATE OF RUN & TIME:- 25 - 4 - 1975 / 1100 HRS
RUN # :- 40.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- $74^{o}F$
BAROMETER PRESSURE:- 29.94 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- $85^{o}F$

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F CAT. CONV. IN	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	17.0	135.0	132.0	7.80	20½	1600	0	8.85	300.0	74	265	75.0	74.0	70.0	74.0
30 "	17.6	"	"	7.55	"	"	"	"	218.0	107	366	77.0	"	69.5	"
45 "	17.0	"	"	7.80	"	"	"	"	188.0	118	439	78.5	"	70.0	"
60 "	15.8	"	"	8.40	"	"	"	8.75	172.0	124	486	79.5	74.5	71.5	74.5
75 "	-	-	-	-	-	-	-	7.74	157.0	133	533	84.0	"	73.0	76.0
90 "	19.8	312.5	306.0	15.45	10	1600	160	1.20	67.5	140	692	87.0	"	77.0	79.0
105 "	-	-	-	-	-	-	-	0.90	52.5	154	799	89.5	75.0	81.5	82.0
120 "	26.5	306.0	299.5	11.30	9¾	1600	156	0.26	30.0	200	860	93.0	76.0	88.0	85.5
2½ min	25.0	300.0	293.0	11.75	9½	"	150	0.56	15.0	383	923	99.0	77.0	103.5	94.0
3 "	23.6	"	"	12.40	9¾	"	146	0.37	11.0	589	958	103.0	78.5	108.0	101.5
3½ "	23.0	296.5	289.5	12.60	9	"	"	"	7.5	700	980	127.0+	80.0	116.0	108.0
4 "	"	"	"	"	8¾	"	136	"	3.7	775	997	181.5+	"	121.0	113.5
4½ "	23.5	358.0	349.0	14.85	"	"	"	"	"	828	1018	201.0+	81.5	112.0	105.0
5 "	24.0	360.0	351.0	14.60	"	"	"	"	"	865	1032	184.0+	82.0	"	101.0
6 "	23.5	"	"	14.95	"	"	"	"	"	918	1057	194.0	84.5	116.0	99.0
7 "	"	"	"	"	"	"	"	"	"	955	1066	192.5	86.0	121.0	"
8 "	23.3	"	"	15.05	"	"	"	"	"	981	1078	194.5	87.0	123.5	101.0
9 "	"	"	"	"	"	"	"	"	"	1000	1079	"	88.0	128.0	103.0
9½ "	39.0	437.5	426.0	10.90	2¾	"	253	4.98	60.0	1013	1100	196.0	89.0	121.0	101.0
10 "	39.9	436.5	425.0	10.65	"	"	"	5.12	67.5	1029	1120	197.0	89.5	116.0	99.0
11 "	39.6	"	"	10.75	2½	"	"	"	71.0	1066	1135	197.5	91.5	115.0	97.5
12 "	"	440.0	427.5	10.80	"	"	"	5.29	75.0	1100	1142	198.0	93.0	"	"
12½ "	36.5	280.0	271.0	7.45	9½	"	142	0.64	11.0	1113	1124	198.5	94.0	146.0	111.5
13 "	21.9	345.0	334.0	15.25	8½	"	135	0.56	7.5	"	1100	197.0	"	159.0	132.5
14 "	22.4	352.5	341.0	"	"	"	133	0.37	3.7	1071	1087	"	"	140.0	112.0
15 "	20.8	"	"	16.40	"	"	"	"	"	1050	1079	"	"	"	110.0
15½ "	8.5	76.0	73.4	8.65	19	790	0	"	"	1021	902	203.0	"	153.5	109.5
16 "	8.0	"	"	9.15	18½	750	"	"	"	1002	799	197.0	"	161.5	"
17 "	"	"	"	"	"	725	"	"	"	981	674	194.5	93.0	167.5	"
18 "	6.6	"	"	11.10	18¼	720	"	"	"	965	604	"	91.5	171.0	"
19 "	7.8	"	"	9.40	"	715	"	"	"	942	566	"	90.5	171.5	"
20 "	8.1	"	"	9.05	18	700	"	"	"	910	538	"	89.5	"	"

TABLE 5-25.

DATE OF RUN & TIME:- 26 - 4 - 1975 / 1100 HRS
RUN # :- 41.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 73°F
BAROMETER PRESSURE:- 30.00 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 84°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURES °F WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	16.5	142.5	137.0	8.30	20½	1600	38	9.28	210.0	646	-	73.0	73.5	69.0	73.0
30 "	16.2	"	"	8.45	"	"	"	9.05	180.0	758	-	78.0	"	"	"
45 "	16.0	"	"	8.55	"	"	"	8.92	165.0	801	-	78.5	"	69.5	73.5
60 "	15.8	"	"	8.65	"	"	"	8.45	150.0	832	-	81.0	"	71.0	75.0
75 "	-	-	-	-	-	-	-	1.47	75.0	880	-	82.5	74.0	72.5	76.0
90 "	26.6	300.0	287.0	10.80	10½	1600	156	1.51	60.0	1049	-	86.0	74.5	78.0	79.0
105 "	-	-	-	-	-	-	-	1.21	22.5	1112	-	89.0	75.0	83.0	82.5
120 "	26.0	296.5	284.0	10.90	10	1600	147	0.83	15.0	1154	-	90.0	76.0	88.5	85.0
2½ min	23.8	293.5	281.0	11.80	"	"	142	0.26	11.0	1197	-	94.0	77.5	98.0	93.5
3 "	23.5	"	"	11.95	"	"	"	0.23	7.5	1219	-	102.0	78.5	107.5	101.0
3½ "	22.8	290.0	278.0	12.20	9½	"	136	"	"	1245	-	160.0+	80.0	116.0	108.0
4 "	22.3	353.0	337.0	15.10	8¾	"	133	"	3.8	1261	-	179.0+	81.0	120.5	114.0
4½ "	23.8	355.0	339.0	14.25	"	"	"	"	"	1285	-	197.5+	82.5	112.0	104.5
5 "	23.6	"	"	14.35	"	"	"	"	"	1304	-	185.5+	83.0	112.5	101.5
6 "	23.8	"	"	14.25	"	"	"	"	"	1326	-	196.0+	85.0	116.5	99.0
7 "	23.9	"	"	14.20	"	"	"	"	"	1331	-	193.5	86.5	120.5	"
8 "	"	"	"	"	"	"	"	"	"	1334	-	195.5	88.0	124.0	100.5
9 "	"	"	"	"	8½	"	"	"	"	1339	-	"	89.5	127.0	101.5
9½ "	40.4	429.0	408.5	10.10	3¾	"	247	5.28	60.0	"	-	196.5	"	122.0	101.0
10 "	39.5	431.0	410.0	10.40	"	"	"	5.40	82.5	"	-	197.5	90.0	117.5	98.0
11 "	43.5	"	"	9.45	"	"	"	4.97	"	1348	-	"	91.0	116.5	97.0
12 "	43.8	"	"	9.40	"	"	242	5.13	"	1353	-	198.5	93.0	117.5	"
12½ "	27.9	270.0	256.5	9.20	10½	"	135	0.45	15.0	1362	-	197.5	94.0	143.5	106.5
13 "	22.8	332.5	316.0	13.85	9½	"	126	0.23	7.5	1347	-	196.5	93.5	158.0	131.0
14 "	22.0	335.0	318.0	14.45	"	"	"	"	3.8	1342	-	"	"	140.5	116.0
15 "	21.7	"	"	14.65	"	"	"	"	"	"	-	"	94.0	141.0	113.0
15½ "	8.8	76.0	71.9	8.15	18¾	780	0	"	11.0	1187	-	204.0	"	153.0	108.0
16 "	9.5	"	"	7.55	"	750	"	"	15.0	1107	-	196.5	93.5	161.0	"
17 "	10.6	"	"	6.88	18½	725	"	"	30.0	1028	-	195.5	91.0	168.0	"
18 "	10.4	"	"	6.90	18¼	715	"	"	52.5	991	-	195.0	89.5	170.0	"
19 "	8.8	"	"	8.15	"	710	"	"	45.0	965	-	194.0	88.0	171.5	"
20 "	9.0	"	"	8.00	18	"	"	0.26	75.0	943	-	193.5	87.0	172.0	"

TABLE 5-26.

DATE OF RUN & TIME:- 28 - 4 - 1975 / 0900 HRS
RUN # :- 42.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 75 °F
BAROMETER PRESSURE:- 29.78 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 86 °F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURES °F WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	24.8	135.0	131.0	5.30	20½	1600	27	8.40	180.0	648	-	76.5	76.0	72.0	75.0
30 "	22.3	"	"	5.85	"	"	"	8.60	165.0	768	-	79.5	"	71.0	"
45 "	21.0	"	"	6.20	"	"	"	8.63	158.0	811	-	80.5	"	"	"
60 "	19.8	"	"	6.60	"	"	38	8.14	150.0	840	-	83.0	"	72.5	76.0
75 "	-	-	-	-	-	-	-	1.50	135.0	861	-	86.0	"	73.5	77.0
90 "	26.8	280.0	270.0	10.10	11½	1600	143	1.66	67.5	1046	-	88.0	76.5	78.0	79.5
105 "	-	-	-	-	-	-	-	1.06	60.0	1104	-	90.0	77.5	84.0	83.0
120 "	25.0	277.5	268.0	10.70	"	1600	143	0.45	41.3	1135	-	94.0	78.0	88.0	86.0
2½ min	22.8	272.5	263.0	11.50	11	"	133	0.07	18.8	1185	-	100.0	78.5	98.5	94.0
3 "	21.8	268.5	259.0	11.90	"	"	130	"	15.0	1215	-	111.0	80.5	108.0	101.0
3½ "	21.5	"	"	12.05	"	"	"	"	11.3	1234	-	118.0	82.0	116.0	108.0
4 "	21.7	327.5	314.5	14.50	10	1610	124	"	7.5	1263	-	179.5+	"	119.0	113.5
4½ "	"	328.5	315.5	14.55	"	"	"	"	"	1269	-	202.0+	84.0	113.0	104.5
5 "	22.0	"	"	14.35	"	"	"	"	"	1285	-	183.5+	85.0	114.0	101.0
6 "	[illegible]	330.0	316.0	"	"	"	"	"	"	1306	-	189.0+	87.0	118.0	100.0
7 "	"	331.0	317.0	14.40	"	"	"	"	"	1317	-	192.0	88.0	121.5	99.0
8 "	22.3	"	"	14.20	"	"	"	"	"	1328	-	193.0	89.0	125.5	100.5
9 "	22.1	"	"	14.35	"	"	"	"	"	1333	-	"	90.5	129.0	101.0
9½ "	39.0	437.5	417.5	10.70	3	1620	251	5.20	71.8	1338	-	194.0	"	121.5	"
10 "	41.0	440.0	420.0	10.25	"	"	"	5.42	75.0	1344	-	195.5	91.5	117.0	99.0
11 "	46.1	"	"	9.10	"	"	"	5.05	78.6	1360	-	"	92.5	116.0	98.5
12 "	42.3	"	"	9.95	"	"	"	5.35	82.5	1363	-	"	95.0	117.0	"
12½ "	21.7	280.0	266.0	12.25	10	"	136	0.23	15.0	1374	-	197.0	95.5	132.0	111.0
13 "	22.3	342.5	325.0	14.60	8¾	"	133	0.07	7.5	1364	-	196.0	96.0	151.5	127.0
14 "	22.8	345.0	327.5	14.35	"	"	"	"	"	1360	-	195.5	95.0	140.0	112.0
15 "	"	346.0	328.5	14.40	"	"	"	"	"	"	-	[illegible]	96.0	141.0	110.0
15½ "	8.8	76.0	71.8	8.15	18½	725	0	"	97.5	1183	-	201.5	"	152.0	109.0
16 "	"	"	"	"	"	"	"	"	15.0	1104	-	197.0	96.5	161.5	108.5
17 "	10.2	"	"	7.05	18½	720	"	"	"	1030	-	193.0	94.0	167.5	"
18 "	9.3	"	"	7.75	18	710	"	"	30.0	988	-	"	92.5	170.5	"
19 "	8.8	"	"	8.15	17¾	700	"	"	90.0	946	-	"	91.0	171.5	"
20 "	10.0	"	"	7.18	"	"	"	"	82.5	929	-	"	90.5	172.5	"

TABLE 5-27.

DATE OF RUN & TIME:- 29 - 4 - 1975 / 1130 HRS
RUN # :- 43.
HOURS OF COLD SOAK:- - -

ROOM TEMPERATURE AT START:- 75°F
BAROMETER PRESSURE:- 29.93 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 86°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURES °F WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	20.2	197.5	187.5	9.30	20	2100	38	7.09	158.0	755	-	77.0	75.0	72.0	75.0
30 "	24.0	"	"	7.80	"	"	"	7.32	134.0	871	-	81.0	76.0	"	76.0
45 "	22.5	"	"	8.35	"	"	"	7.19	126.0	935	-	82.0	"	73.5	77.0
60 "	22.0	"	"	8.55	"	"	"	6.80	106.0	953	-	87.0	"	77.0	79.5
75 "	-	-	-	-	-	-	-	4.39	94.5	988	-	91.5	76.5	79.5	82.0
90 "	22.8	267.5	253.5	11.10	12	1600	135	1.87	63.0	1072	-	95.0	"	84.0	85.0
105 "	-	-	-	-	-	-	-	1.29	47.4	1122	-	97.0	77.0	88.0	88.0
120 "	22.0	262.5	249.0	11.30	12	1600	130	0.72	34.5	1152	-	99.0	78.0	94.0	91.0
2½ min	21.5	260.0	246.0	11.45	11¾	1610	124	0.25	15.7	1191	-	105.5	79.5	103.5	99.0
3 "	21.0	257.5	244.0	11.60	"	"	"	0.22	11.8	1210	-	111.0	80.0	112.0	105.5
3½ "	20.7	262.5	249.0	12.05	11¼	"	118	"	"	1231	-	209.0+	82.0	119.0	112.5
4 "	21.2	315.0	297.5	14.05	11	"	115	0.20	3.8	1247	-	178.0+	83.0	114.0	110.0
4½ "	"	"	"	"	10¾	1595	"	"	"	1263	-	190.5+	84.0	"	105.5
5 "	"	"	"	"	"	"	"	"	"	1277	-	186.5+	85.0	116.0	103.0
6 "	21.5	"	"	13.85	"	"	"	"	"	1295	-	193.0+	86.0	119.0	101.0
7 "	21.7	"	"	13.75	"	"	"	"	"	1306	-	191.0+	88.0	123.5	"
8 "	"	"	"	"	"	"	"	"	"	1317	-	193.5	89.0	127.0	"
9 "	22.0	316.5	299.5	13.60	10½	"	"	"	"	1320	-	"	90.0	130.0	103.5
9½ "	41.5	423.5	398.0	9.60	3¾	1600	244	4.85	78.8	1330	-	"	91.0	123.5	103.0
10 "	39.3	"	"	10.10	"	"	"	5.04	82.7	1333	-	195.5	"	119.0	100.0
11 "	43.3	"	"	9.20	"	"	"	4.89	"	1344	-	196.0	94.0	118.0	99.0
12 "	39.0	"	"	10.20	"	"	"	5.10	86.5	1349	-	196.5	95.0	"	"
12½ "	21.2	275.0	258.0	12.15	9	"	137	0.43	15.7	1365	-	195.5	96.0	155.5	116.0
13 "	21.8	338.5	317.5	14.60	"	"	133	0.22	3.8	1349	-	194.5	95.0	147.5	127.0
14 "	22.1	342.5	321.0	14.50	"	"	130	"	"	1344	-	195.0	96.0	141.0	112.5
15 "	23.0	345.0	323.5	14.05	"	"	"	"	"	1343	-	195.5	"	"	111.0
15½ "	11.3	76.0	71.0	6.30	19	780	0	"	23.6	1146	-	202.0	96.5	155.5	110.5
16 "	10.0	"	"	7.10	18½	750	"	"	7.6	1082	-	195.0	95.5	162.0	"
17 "	11.3	"	"	6.30	"	725	"	"	"	1024	-	193.5	94.5	167.5	110.0
18 "	12.5	"	"	5.70	"	"	"	"	35.4	988	-	193.0	92.5	171.0	"
19 "	15.6	"	"	4.55	"	720	"	"	78.8	951	-	"	91.0	"	"
20 "	10.8	"	"	6.60	18¼	710	"	"	94.5	930	-	"	90.0	172.5	"

TABLE 5-28.

DATE OF RUN & TIME:- 30 - 4 - 1975 / 1000 HRS
RUN # :- 44.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 75°F
BAROMETER PRESSURE:- 30.17 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 86°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURES °F WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	20.8	135.0	129.0	6.20	21½	1740	19	8.06	205.0	661	-	77.0	75.0	72.0	75.0
30 "	26.2	142.5	135.0	5.15	"	1770	"	8.42	174.0	783	-	79.5	"	71.0	"
45 "	23.4	"	"	5.75	"	1780	"	"	158.0	829	-	81.0	76.0	72.0	"
60 "	19.8	"	"	6.80	"	1800	"	8.28	134.0	861	-	83.0	76.5	74.0	76.5
75 "	-	-	-	-	-	-	-	5.61	118.0	903	-	87.0	77.0	75.0	77.5
90 "	21.1	300.0	286.5	13.60	10½	1600	156	1.33	71.8	1051	-	90.0	"	79.5	79.5
105 "	-	-	-	-	-	-	-	1.03	55.2	1125	-	92.5	"	84.0	84.0
120 "	26.0	300.0	286.5	11.00	10	1600	152	0.81	47.3	1167	-	95.0	77.5	90.0	86.0
2½ min	24.5	296.5	282.5	11.50	9¾	"	143	0.29	31.5	1205	-	101.0	79.5	100.0	94.0
3 "	23.4	290.0	277.0	11.80	"	"	"	"	23.6	1229	-	112.0	81.0	110.0	103.0
3½ "	23.1	"	"	12.00	9½	1590	"	0.27	19.7	1247	-	177.5+	82.0	117.0	110.0
4 "	20.7	356.0	339.0	16.40	8½	"	135	0.25	15.8	1269	-	177.0+	84.0	116.0	113.0
4½ "	23.5	"	"	14.45	"	"	"	"	"	1290	-	192.5+	85.0	112.0	104.5
5 "	"	"	"	"	"	"	"	"	"	1298	-	184.5+	85.5	112.5	101.0
6 "	23.8	"	"	14.25	"	"	"	"	"	1320	-	191.5	88.0	116.5	100.0
7 "	"	"	"	"	"	"	"	"	"	1333	-	191.0	90.0	121.0	101.0
8 "	"	"	"	"	"	"	"	"	"	1341	-	192.0	90.5	125.0	102.0
9 "	24.0	"	"	14.15	"	"	"	"	"	1349	-	"	92.0	128.0	103.5
9½ "	39.2	431.0	410.0	10.45	2½	"	251	5.25	86.6	"	-	194.5	92.5	120.5	102.0
10 "	39.4	"	"	10.40	"	"	247	5.36	90.7	"	-	"	95.0	119.0	101.0
11 "	44.3	"	"	9.30	"	"	"	5.04	"	1360	-	195.5	95.5	118.0	100.0
12 "	42.0	"	"	9.78	"	"	"	5.25	94.5	"	-	"	96.0	119.0	"
12½ "	20.8	263.0	249.0	11.95	10¾	"	133	0.43	27.6	1412	-	193.5	96.5	161.5	119.0
13 "	21.5	312.5	296.0	13.80	9¾	"	125	0.29	15.8	1352	-	193.0	97.0	146.5	122.5
14 "	21.7	315.0	298.0	13.75	"	"	"	"	"	1349	-	"	96.5	141.0	112.0
15 "	22.0	316.5	300.0	13.65	"	"	"	"	"	"	-	"	97.0	141.5	110.0
15½ "	-	76.0	71.8	-	19	780	0	"	19.7	1138	-	200.0	"	155.5	"
16 "	-	"	"	-	18¾	750	"	"	15.8	1083	-	192.5	"	162.5	109.5
17 "	-	"	"	-	18½	730	"	"	23.6	1026	-	191.5	95.5	167.5	"
18 "	-	"	"	-	"	700	"	"	31.5	988	-	"	93.0	171.0	"
19 "	-	"	"	-	18¼	"	"	"	"	951	-	"	92.0	171.5	"
20 "	-	"	"	-	18½	"	"	"	39.4	931	-	"	90.5	"	"

TABLE 5-29.

DATE OF RUN & TIME:- 1 - 5 - 1975 / 0930 HRS
RUN # :- 45.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 74°F
BAROMETER PRESSURE:- 30.09 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 85°F.

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURES °F WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	24.8	197.5	189.5	7.65	20½	2100	37	7.37	276.0	743	-	76.0	74.0	69.5	74.0
30 "	23.0	"	"	8.25	"	"	"	7.55	158.0	868	-	80.0	"	"	"
45 "	21.8	"	"	8.70	20	"	"	7.48	138.0	916	-	81.0	75.0	72.0	76.0
60 "	21.2	"	"	8.95	"	"	"	7.05	122.0	952	-	85.0	75.5	75.0	77.0
75 "	-	-	-	-	-	-	-	5.75	105.0	976	-	87.0	"	77.0	80.0
90 "	25.0	292.5	280.5	11.25	10½	1600	152	1.49	63.0	1087	-	92.5	"	83.0	84.0
105 "	-	-	-	-	-	-	-	0.86	47.3	1149	-	90.0	76.0	88.0	87.0
120 "	25.4	292.5	280.5	11.05	10	1600	143	0.58	31.5	1199	-	92.5	77.0	94.0	90.0
2½ "	23.5	"	"	11.95	"	"	141	0.29	15.8	1219	-	98.5	79.0	104.0	98.5
3 "	"	290.0	277.0	11.80	9¾	"	"	0.27	11.8	1241	-	99.0	80.0	111.5	106.0
3½ "	22.8	"	"	12.15	"	"	139	0.25	7.9	1254	-	195.5+	82.0	120.0	113.0
4 "	"	350.0	335.0	14.70	8½	"	135	"	3.9	1273	-	148.0+	"	113.0	111.0
4½ "	23.7	352.0	336.5	14.20	"	"	"	"	"	1291	-	186.0+	84.0	112.0	104.5
5 "	23.5	"	"	14.35	"	"	133	"	"	1300	-	194.5+	84.5	113.5	102.0
6 "	23.7	"	"	14.20	"	"	"	"	"	1320	-	196.5+	86.0	117.0	100.0
7 "	23.9	"	"	14.10	"	"	"	"	"	1332	-	193.5	88.0	121.5	101.0
8 "	"	"	"	"	"	"	"	"	"	1337	-	194.5	89.0	125.0	102.5
9 "	24.1	"	"	13.95	"	"	"	"	"	1341	-	"	90.0	128.0	103.0
9½ "	37.9	437.5	418.0	11.00	2½	"	253	5.19	70.9	"	-	195.0	90.5	121.0	102.5
10 "	40.5	"	"	10.30	"	"	"	5.40	78.8	1343	-	195.5	92.0	117.5	100.0
11 "	36.3	"	"	11.50	"	"	"	5.32	82.7	1354	-	196.5	94.0	117.0	99.5
12 "	36.0	"	"	11.60	"	"	"	"	86.5	1357	-	197.0	94.5	"	"
12½ "	20.2	287.5	274.0	13.55	9	"	144	0.36	15.8	1370	-	196.5	95.0	159.0	117.0
13 "	21.2	357.5	340.0	16.05	8	"	133	0.29	7.9	1357	-	193.0	94.5	145.0	124.0
14 "	21.8	358.5	341.0	15.65	"	"	135	"	3.9	"	-	"	95.0	139.0	112.5
15 "	22.2	360.0	342.0	15.40	"	"	"	"	"	"	-	194.5	96.0	140.0	111.0
15½ "	6.0	71.0	67.1	11.20	19	770	0	"	15.8	1148	-	200.0	"	155.5	"
16 "	-	"	"	-	18¾	750	"	"	7.9	1087	-	193.0	94.5	163.0	"
17 "	-	"	"	-	"	"	"	"	71.0	1024	-	192.0	93.5	168.0	"
18 "	-	"	"	-	18½	725	"	"	118.0	979	-	190.5	92.0	171.0	"
19 "	-	"	"	-	18½	710	"	"	63.0	952	-	"	90.0	172.0	"
20 "	5.2	"	"	12.90	"	"	"	"	43.3	929	-	"	89.0	"	"

TABLE 5-30.

DATE OF RUN & TIME:- 2 - 5 - 1975 / 1005 HRS
RUN # :- 46.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 74°F
BAROMETER PRESSURE:- 29.96 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 86°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURES °F WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	26.9	197.5	187.0	6.95	20¼	2100	38	7.05	126.0	759	-	76.0	74.0	70.0	74.0
30 "	24.8	"	"	7.55	"	"	"	7.26	"	870	-	78.5	"	"	"
45 "	24.0	"	"	7.80	20	"	"	"	117.0	913	-	80.5	75.5	72.0	75.0
60 "	22.3	"	"	8.40	"	"	"	6.98	106.0	950	-	83.0	76.0	75.0	77.0
75 "	-	-	-	-	-	-	-	4.60	93.6	976	-	87.0	76.5	77.0	79.5
90 "	25.4	285.0	269.5	10.60	11	1600	148	1.51	50.7	1092	-	"	"	83.0	83.0
105 "	-	-	-	-	-	-	-	0.97	39.0	1138	-	89.0	77.0	87.5	86.0
120 "	24.8	285.0	269.5	10.85	10½	1600	143	0.61	27.3	1166	-	"	"	93.0	89.5
2½ min	23.0	280.0	264.5	11.50	"	1580	135	0.29	15.6	1198	-	89.5	79.5	102.5	97.5
3 "	22.3	277.5	262.0	11.75	10¼	1590	"	0.11	11.8	1227	-	96.0	80.0	111.0	105.5
3½ "	22.5	278.5	263.0	11.70	"	"	"	"	"	1252	-	196.0+	82.0	119.0	111.5
4 "	"	337.5	317.5	14.10	9½	"	128	0.07	"	1262	-	168.0+	83.0	116.0	112.0
4½ "	23.1	338.5	318.5	13.80	"	"	124	"	7.8	1284	-	184.0+	84.0	113.0	104.5
5 "	23.0	"	"	13.85	"	"	"	"	"	1292	-	192.0+	85.0	114.0	101.5
6 "	23.3	"	"	13.65	9¼	"	"	"	3.9	1312	-	192.5	86.0	117.0	100.0
7 "	24.5	"	"	13.00	"	"	"	"	"	1322	-	190.0	88.0	121.5	"
8 "	24.8	"	"	12.85	"	"	125	"	"	1332	-	191.0	90.0	126.0	101.5
9 "	24.2	"	"	13.15	"	"	"	"	"	1337	-	"	90.5	128.5	102.5
9½ "	45.0	427.5	400.0	8.90	2½	1600	245	5.11	74.3	"	-	193.0	"	121.5	101.5
10 "	43.3	"	"	9.25	"	"	"	4.93	78.2	1343	-	193.5	91.5	117.0	99.5
11 "	37.2	"	"	10.75	"	"	244	5.39	86.0	"	-	"	93.0	"	"
12 "	36.9	"	"	10.85	"	"	"	5.46	93.6	1346	-	194.5	95.0	"	"
12½ "	21.8	275.0	257.0	11.80	10	"	135	0.43	15.6	1364	-	"	"	154.5	117.0
13 "	21.4	338.5	316.5	14.80	9	"	128	0.27	7.8	1354	-	193.5	95.5	146.5	123.5
14 "	21.5	"	"	14.70	"	"	"	0.25	3.9	1348	-	193.0	95.0	140.0	112.0
15 "	22.5	"	"	14.05	"	"	"	"	"	"	-	"	95.5	"	110.0
15½ "	8.2	76.0	70.6	8.65	18¾	780	0	0.29	15.6	1140	-	199.5	96.0	154.5	109.5
16 "	10.8	"	"	6.55	"	740	"	"	7.8	1082	-	193.0	"	162.0	109.0
17 "	9.0	"	"	7.85	18¼	715	"	"	46.8	1018	-	191.0	93.0	167.0	"
18 "	8.8	"	"	8.05	18	700	"	"	31.5	971	-	190.0	91.5	170.0	"
19 "	9.5	"	"	7.45	17¾	685	"	"	"	938	-	"	90.5	171.0	"
20 "	7.5	"	"	9.45	"	"	"	"	93.6	913	-	"	90.0	"	"

TABLE 5-31.

H32

DATE OF RUN & TIME:- 4 - 5 - 1975 / 1615 HRS
RUN # :- 47.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 75°F
BAROMETER PRESSURE:- 29.70 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 89°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	EXH. OUT	CAT. CONV. OUT	TEMPERATURES °F WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	23.5	142.5	133.0	5.65	21	1650	19	8.13	197.0	674	-	76.0	75.0	72.0	75.0
30 "	26.5	"	"	5.00	"	1700	"	8.35	181.0	776	-	77.0	"	71.5	75.5
45 "	24.2	"	"	5.50	20¾	1730	"	8.25	169.0	818	-	79.0	75.5	72.0	76.0
60 "	20.1	"	"	6.60	"	"	"	7.91	146.0	845	-	81.0	76.5	73.0	77.5
75 "	-	-	-	-	-	-	-	5.04	126.0	903	-	82.0	"	75.0	79.5
90 "	25.5	292.5	272.0	10.65	10½	1600	150	1.58	78.8	1061	-	84.0	77.0	79.5	82.0
105 "	-	-	-	-	-	-	-	1.37	63.0	1120	-	"	"	84.0	85.0
120 "	25.8	292.5	272.0	10.55	10½	1600	147	0.90	51.2	1149	-	88.0	"	88.5	88.5
2½ min	24.0	287.5	268.0	11.15	10	"	135	0.25	31.5	1199	-	90.0	79.5	99.0	96.0
3 "	23.0	285.0	265.0	11.50	"	"	"	0.20	23.6	1225	-	96.0	81.0	108.0	103.5
3½ "	22.8	"	"	11.60	9¾	"	"	"	"	1242	-	133.0+	82.0	116.0	111.0
4 "	22.5	345.0	320.0	14.20	8¾	"	129	0.19	15.8	1263	-	174.5+	84.0	118.0	116.0
4½ "	23.1	"	"	13.85	"	"	"	0.18	"	1279	-	192.5+	85.0	111.0	105.5
5 "	23.2	"	"	13.80	"	"	"	"	"	1295	-	181.5+	85.5	111.5	103.0
6 "	23.1	"	"	13.85	"	"	"	"	"	1317	-	187.5+	88.0	116.0	101.0
7 "	23.0	"	"	13.90	"	"	"	"	"	1325	-	189.0	90.5	120.5	102.0
8 "	23.2	"	"	13.80	"	"	"	"	"	1332	-	190.0	"	124.5	103.5
9 "	23.8	"	"	13.45	"	"	"	0.14	"	1338	-	"	92.5	128.0	104.5
9½ "	42.5	440.0	407.0	9.60	2½	"	249	5.19	94.5	1335	-	192.5	"	119.0	103.5
10 "	41.5	"	"	9.80	"	"	247	5.36	"	1338	-	"	95.0	117.0	101.0
11 "	36.2	"	"	11.25	"	1610	"	5.33	"	1342	-	"	96.0	"	"
12 "	36.5	"	"	11.15	"	"	"	5.58	103.0	1343	-	"	98.5	118.0	101.5
12½ "	43.0	500.0	460.0	10.70	3	1860	"	6.05	106.0	1349	-	191.0	98.0	116.5	103.5
13 "	43.5	"	"	10.60	"	"	"	6.19	110.0	"	-	192.5	100.0	116.0	"
14 "	43.0	"	"	10.70	"	"	"	6.12	"	1355	-	195.0	101.0	116.5	104.5
15 "	37.0	445.0	408.0	11.05	"	1600	"	5.69	106.0	1349	-	193.0	103.0	121.0	105.5
15½ "	21.2	310.0	284.5	13.45	9	"	143	0.32	31.5	1378	-	"	103.5	152.5	118.0
16 "	21.8	355.0	326.0	14.95	8	1610	"	0.18	19.7	1368	-	192.5	"	142.0	118.5
17 "	23.0	"	"	14.15	"	1620	133	"	15.8	1365	-	"	102.0	140.0	113.5
18 "	24.9	382.5	349.5	14.05	9¾	1860	123	"	"	1376	-	"	103.5	141.0	113.0
19 "	26.6	380.0	347.0	13.05	"	1870	"	"	"	1377	-	"	"	142.0	"
19½ "	6.3	76.0	69.5	11.60	18½	770	0	"	94.5	1183	-	200.0	104.5	155.5	"
20 "	8.0	"	"	8.70	18¼	750	"	"	23.8	1104	-	193.0	103.5	165.0	"

TABLE 5-32.

DATE OF RUN & TIME:- 5 - 5 - 1975 / 0920 HRS
RUN # :- 48.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 74°F
BAROMETER PRESSURE:- 29.87 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 85°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	CO %	HC ppm. HEXANE EQUIV.	TEMPERATURES °F EXH. OUT	CAT. CONV. OUT	WATER OUT	INLET AIR	INLET MANI-FOLD	AIR-FILTER
15 sec	16.2	142.5	135.5	8.35	21	1600	19	8.70	213.0	652	-	74.0	75.0	*	74.0
30 "	16.4	135.0	128.0	7.80	"	1680	"	8.92	189.0	780	-	76.5	"		74.5
45 "	16.0	"	"	8.05	"	1700	"	8.74	173.0	823	-	77.0	"		75.0
60 "	"	"	"	"	"	1740	"	8.63	158.0	849	-	81.0	"		76.0
75 "	-	-	-	-	-	-	-	6.40	126.0	888	-	82.0	75.5		78.5
90 "	26.5	277.5	263.0	9.90	10½	1600	152	1.73	75.0	1045	-	84.0	76.0		81.0
105 "	-	-	-	-	-	-	-	1.62	63.0	1113	-	85.5	76.5		84.0
120 "	25.5	276.5	262.0	10.30	10	1600	144	1.08	47.2	1150	-	87.0	77.0		87.0
2½ min	23.8	275.0	261.0	10.95	"	"	140	0.29	23.6	1205	-	94.0	78.5		94.5
3 "	23.0	270.0	256.0	11.15	9¾	"	138	0.22	15.8	1226	-	100.0	80.0		102.5
3½ "	22.5	"	"	11.40	"	"	"	"	11.8	1252	-	118.0+	81.0		109.0
4 "	"	342.5	323.5	14.40	8¾	"	133	"	7.9	1269	-	177.5+	82.0		115.0
4½ "	23.2	345.0	326.0	14.05	"	"	127	0.19	"	1284	-	202.0+	84.0		107.0
5 "	23.9	347.5	328.5	14.75	"	"	"	"	"	1297	-	181.5+	84.5		103.5
6 "	23.4	"	"	14.05	"	"	"	"	"	1321	-	190.5+	87.0		101.0
7 "	"	"	"	"	"	"	"	"	"	1332	-	190.0	89.0		101.5
8 "	23.8	"	"	13.80	"	"	"	"	"	1337	-	192.0	90.0		102.5
9 "	24.8	346.5	327.0	13.20	8½	"	"	"	"	1348	-	"	91.5		103.0
9½ "	26.0	360.0	348.0	13.00	10¾	1875	117	"	"	1364	-	191.0	92.5		103.5
10 "	26.9	"	"	12.60	"	"	"	"	"	1370	-	"	94.0		104.5
11 "	26.3	372.5	350.0	13.30	"	1885	"	"	"	1377	-	193.0	95.0		105.5
12 "	26.5	"	"	13.20	10½	"	"	"	"	1381	-	"	96.0		106.0
12½ "	23.9	346.5	325.0	13.60	8½	1590	129	"	"	1364	-	195.5	97.0		107.0
13 "	26.0	"	"	12.50	"	"	"	"	"	1359	-	194.0	96.5		107.5
14 "	26.3	"	"	12.35	"	"	"	"	"	1356	-	"	97.0		108.0
15 "	26.5	347.5	326.0	12.30	"	"	"	"	"	[illegible]	-	194.5	"		108.5
15½ "	8.0	76.0	71.1	8.90	18¾	775	0	0.25	23.6	1166	-	200.0	98.0		"
16 "	8.1	"	"	8.80	18½	755	"	"	11.8	1098	-	192.0	97.0		"
17 "	6.1	"	"	11.65	18¼	725	"	0.29	"	1029	-	191.0	95.0		"
18 "	3.5	"	"	[illegible]	17¾	695	"	"	23.6	979	-	190.5	93.0		109.0
19 "	8.7	"	"	8.20	"	"	"	"	"	950	-	"	91.5		"
20 "	6.1	"	"	11.65	"	"	"	"	55.1	928	-	190.0	90.0		"

TABLE 5-33.

DATE OF RUN & TIME:- 15 - 5 - 1975 / 0830 HRS
RUN # :- 50.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 76°F
BAROMETER PRESSURE:- 29.82 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 88°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	TEMPERATURES °F EXH. OUT	WATER OUT	INLET AIR	AIR-FILTER	HEATED AIR
15 sec	22.4	142.5	136.0	6.05	20½	1650	18	644	-	76.0	76.0	79.5
30 "	20.0	"	"	6.80	21	1700	"	777	-	"	"	89.0
45 "	19.5	"	"	7.00	21¼	1750	"	819	-	"	"	100.0
60 "	17.6	"	"	7.75	"	1775	"	830	-	76.5	77.5	112.0
90 "	27.0	330.0	314.0	11.65	8½	1600	162	1041	-	77.0	81.5	125.5
120 "	27.8	336.5	321.0	"	8	1580	165	1159	-	78.0	87.0	161.5
2½ min	25.4	"	"	12.60	"	"	"	1211	-	80.0	93.5	194.0
3 "	22.4	285.0	271.5	12.10	9¾	"	139	1221	-	82.5	100.0	200.0
3½ "	"	"	"	"	"	"	"	1243	-	83.5	109.0	220.5
4 "	22.5	340.0	323.0	14.35	9	"	130	1259	-	84.5	115.0	254.0
4½ "	22.7	"	"	14.25	"	"	"	1275	-	86.0	105.5	326.5
5 "	23.0	"	"	14.15	"	"	"	1286	-	87.0	102.0	379.5
6 "	23.2	"	"	13.95	"	"	"	1307	-	88.0	100.0	449.0
7 "	22.5	"	"	14.35	"	"	"	1318	-	90.0	101.0	500.0
8 "	23.0	"	"	14.15	"	"	"	1323	-	92.0	102.0	528.5
9 "	23.3	"	"	13.85	"	"	"	1329	-	92.5	102.5	547.0
9½ "	41.0	430.0	408.0	9.95	2½	"	247	"	-	94.0	102.0	389.0
10 "	35.6	"	"	11.45	"	"	244	"	-	97.0	101.0	334.5
11 "	45.1	"	"	9.05	"	"	"	1339	-	99.5	"	168.5
12 "	39.8	"	"	10.25	"	"	"	"	-	102.0	102.0	139.0
12½ "	24.3	292.5	277.0	11.40	8	"	143	1365	-	103.0	110.5	*
13 "	24.0	355.0	335.0	13.95	"	"	136	1361	-	102.0	120.5	
14 "	23.0	"	"	14.60	7¾	"	"	1355	-	"	112.0	509.0
15 "	23.5	"	"	14.25	"	"	"	1350	-	101.0	110.5	557.0
15½ "	6.2	76.0	72.0	11.60	18¾	770	0	1136	-	"	110.0	519.0
16 "	9.9	"	"	7.25	18½	750	"	1078	-	100.5	"	441.5
17 "	10.2	"	"	7.05	"	735	"	1016	-	98.5	"	366.0
18 "	9.0	"	"	8.00	18¼	725	"	978	-	96.0	"	398.0
19 "	6.5	"	"	11.05	18	710	"	946	-	94.0	"	379.5
20 "	7.0	"	"	10.25	"	"	"	925	-	92.0	"	"

TABLE 5-34.

DATE OF RUN & TIME:- 15 - 5 - 1975 / 1430 HRS
RUN # :- 51.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 77°F
BAROMETER PRESSURE:- 29.74 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 91°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	TEMPERATURES °F EXH. OUT	WATER OUT	INLET AIR	AIR-FILTER	HEATED AIR
15 sec	16.0	135.0	128.5	8.05	20¾	1700	18	678	-	77.0	77.0	81.5
30 "	15.4	"	"	8.35	"	1730	"	799	-	"	"	92.5
45 "	15.0	"	"	8.60	21	1750	"	848	-	"	"	103.0
60 "	14.2	"	"	9.05	"	1770	"	879	-	"	78.0	115.0
90 "	27.6	311.0	295.5	10.70	9¼	1600	150	1026	-	78.0	82.0	135.0
120 "	25.8	"	"	11.45	9	"	143	1153	-	80.0	88.0	162.5
2½ min	25.0	"	"	11.80	8¾	"	"	1196	-	82.5	96.0	188.0
3 "	24.0	307.5	292.5	12.20	"	"	"	1222	-	84.5	103.0	209.0
3½ "	23.9	"	"	12.25	"	"	142	1244	-	87.0	110.0	224.0
4 "	27.0	357.5	339.5	12.60	8	"	133	1270	-	89.0	109.5	283.5
4½ "	27.3	360.0	341.5	12.50	"	"	130	1286	-	91.5	103.0	358.0
5 "	"	"	"	"	"	"	"	1300	-	93.0	"	414.0
6 "	"	357.5	339.5	12.45	"	"	"	1322	-	96.0	"	488.0
7 "	26.0	"	"	13.05	"	"	"	1335	-	98.0	104.0	526.0
8 "	"	"	"	"	"	"	"	1343	-	100.0	105.0	545.0
9 "	"	"	"	"	"	"	"	1346	-	102.0	106.0	553.0
9½ "	43.0	437.5	414.5	9.65	2	"	241	1351	-	103.0	106.5	542.0
10 "	43.3	436.5	413.5	9.55	"	"	"	1335	-	104.5	107.0	326.0
11 "	42.9	"	"	9.65	"	"	"	1339	-	106.0	"	187.0
12 "	"	"	"	"	"	"	"	"	-	107.0	"	149.5
12½ "	25.3	330.0	312.0	12.30	9	"	124	1358	-	"	112.0	381.0
13 "	25.5	335.0	316.5	12.40	"	"	"	1351	-	"	"	449.0
14 "	27.3	336.5	318.0	11.65	"	"	"	1346	-	"	"	524.0
15 "	28.9	337.5	318.5	11.00	"	"	"	"	-	"	"	528.0
15½ "	9.0	76.0	71.6	7.95	18¼	750	0	1132	-	"	"	483.0
16 "	8.0	"	"	8.95	"	720	"	1079	-	106.0	"	422.5
17 "	7.0	"	"	10.25	17¾	690	"	1011	-	102.0	"	363.0
18 "	7.2	"	"	9.95	17¼	670	"	968	-	100.0	"	340.5
19 "	7.5	"	"	9.60	17	650	"	937	-	97.0	"	354.5
20 "	"	"	"	"	"	"	"	905	-	96.0	"	358.0

TABLE 5-35.

DATE OF RUN & TIME:- 15 - 5 - 1975 / 2115 HRS
RUN # :- 52.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 80°F
BAROMETER PRESSURE:- 29.72 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 94°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	TEMPERATURES °F EXH. OUT	WATER OUT	INLET AIR	AIR-FILTER	HEATED AIR
15 sec	18.6	135.0	127.0	6.85	20¾	1680	18	687	-	80.0	80.0	83.0
30 "	18.0	"	"	7.05	21	1720	"	807	-	"	80.5	94.0
45 "	17.4	"	"	7.30	"	1780	"	847	-	80.5	82.0	106.0
60 "	16.8	"	"	7.55	"	"	"	876	-	81.0	83.0	118.0
90 "	-	315.0	296.0	-	-	1600	-	1029	-	81.5	86.0	135.5
120 "	29.0	"	"	10.20	9	"	143	1159	-	82.0	93.0	162.0
2½ min	27.3	312.5	293.5	10.75	8¾	"	142	1204	-	85.5	99.5	189.0
3 "	26.7	307.5	289.0	10.80	"	"	"	1236	-	87.0	107.5	208.5
3½ "	27.0	"	"	10.70	8½	"	"	1252	-	88.0	114.0	223.0
4 "	26.8	359.0	336.0	12.55	7¾	"	133	1279	-	90.0	116.0	282.5
4½ "	27.5	"	"	12.20	"	"	"	1295	-	92.0	108.0	350.0
5 "	"	"	"	"	"	"	"	1311	-	94.0	106.0	403.0
6 "	27.8	"	"	12.10	"	"	"	1332	-	96.0	"	480.5
7 "	28.6	357.5	334.0	11.70	"	"	"	1340	-	99.0	108.0	527.0
8 "	28.4	"	"	11.75	"	"	"	1349	-	101.0	108.5	552.0
9 "	28.6	"	"	11.70	"	"	"	1356	-	102.0	110.0	567.0
9½ "	47.0	443.5	414.0	8.60	2	"	247	1340	-	103.0	"	373.0
10 "	47.8	440.0	411.0	"	"	"	244	1343	-	106.0	108.5	251.0
11 "	42.9	"	"	9.85	"	"	"	1345	-	107.5	"	169.0
12 "	42.0	441.5	413.0	"	"	"	"	"	-	110.0	110.0	141.0
12½ "	24.0	307.5	286.0	11.90	10¼	"	133	1368	-	"	113.5	421.5
13 "	23.0	"	"	12.40	"	"	115	1356	-	109.0	117.0	329.0
14 "	24.1	"	"	11.85	10½	"	"	1345	-	108.0	116.5	526.0
15 "	"	"	"	"	"	"	"	1343	-	106.0	"	553.5
15½ "	7.8	76.0	70.0	9.00	18¼	750	0	1127	-	"	"	476.0
16 "	7.0	"	"	10.00	"	"	"	1071	-	"	"	426.5
17 "	7.5	"	"	9.35	17¾	700	"	1013	-	103.0	"	373.0
18 "	6.3	"	"	11.10	17½	675	"	968	-	101.0	"	384.0
19 "	6.5	"	"	10.75	17¼	665	"	936	-	99.0	"	381.0
20 "	"	"	"	"	"	660	"	913	-	97.5	"	379.0

TABLE 5-36.

DATE OF RUN & TIME:- 16 - 5 - 1975 / 0900 HRS
RUN # :- 53.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 76°F
BAROMETER PRESSURE:- 29.76 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 89°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	TEMPERATURES °F EXH. OUT	WATER OUT	INLET AIR	AIR-FILTER	HEATED AIR
15 sec	18.0	140.0	133.0	7.40	20¾	1650	0	662	77.0	76.5	76.5	79.5
30 "	18.6	"	"	7.15	"	1700	"	784	77.5	76.0	77.0	90.0
45 "	18.0	142.5	135.0	7.55	21	1730	"	820	78.0	"	77.5	99.5
60 "	17.5	"	"	7.75	"	"	"	852	78.5	76.5	79.0	113.0
90 "	29.8	302.5	286.5	9.65	10	1600	152	1060	79.0	77.5	82.5	132.5
120 "	28.4	300.0	285.0	10.00	9½	"	150	1148	82.0	79.0	90.0	161.0
2½ min	26.7	295.0	280.0	10.50	9¼	"	143	1201	101.0	81.0	97.0	185.0
3 "	25.4	292.5	277.0	10.90	"	"	"	1227	106.0	83.5	105.0	203.5
3½ "	25.7	290.0	275.0	10.70	9	"	"	1243	143.5	85.5	113.0	216.0
4 "	26.5	352.5	333.0	12.55	8¼	"	130	1265	171.0+	86.0	117.5	255.5
4½ "	"	"	"	"	"	"	"	1286	192.0+	88.0	108.0	328.0
5 "	26.0	"	"	12.80	"	"	"	1302	180.0+	90.0	104.5	386.0
6 "	"	"	"	"	"	"	"	1324	190.0	92.0	104.0	464.0
7 "	26.7	"	"	12.50	"	"	"	1334	188.0	94.5	105.0	515.5
8 "	27.1	"	"	12.30	"	"	"	1343	190.0	96.0	106.0	542.0
9 "	26.9	"	"	12.40	"	"	"	1348	189.0	98.0	107.0	558.0
9½ "	46.5	437.5	412.5	8.90	2¼	"	245	1339	"	99.0	"	378.5
10 "	43.8	"	"	9.45	"	"	244	1343	190.0	101.0	106.0	252.0
11 "	40.5	436.0	411.0	10.15	"	"	"	1345	"	104.0	"	165.0
12 "	40.6	"	"	10.10	"	"	"	"	"	107.0	107.0	136.5
12½ "	22.8	322.5	303.0	13.50	9¾	"	130	1361	189.5	"	115.5	419.5
13 "	23.0	325.0	305.0	13.25	"	"	118	1353	188.0	105.5	114.5	356.0
14 "	23.3	"	"	13.10	"	"	"	1351	188.5	"	113.0	526.5
15 "	"	"	"	"	"	"	"	1348	"	104.0	112.0	551.5
15½ "	7.5	77.0	71.8	9.60	18½	750	0	1126	199.5	"	112.5	494.5
16 "	"	"	"	"	18	725	"	1076	188.0	102.5	"	433.0
17 "	8.1	"	"	8.90	17¾	700	"	1018	186.5	100.0	"	364.5
18 "	8.2	"	"	8.75	"	690	"	968	"	97.0	"	365.0
19 "	7.9	"	"	9.10	"	"	"	944	"	94.5	"	379.0
20 "	8.0	"	"	9.00	"	"	"	920	"	93.0	"	"

TABLE 5-37.

DATE OF RUN & TIME:- 22 - 5 - 1975 / 1700 HRS
RUN # :- 54.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 87°F
BAROMETER PRESSURE:- 29.83 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 96°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	TEMPERATURES °F EXH. OUT	WATER OUT	INLET AIR	AIR-FILTER	HEATED AIR
15 sec	24.8	163.5	151.8	6.10	20½	1630	0	718	87.5	87.0	87.0	92.5
30 "	23.0	"	"	6.60	"	"	"	854	88.0	"	"	104.0
45 "	23.5	"	"	6.45	"	1650	"	915	87.0	"	"	117.0
60 "	22.5	"	"	6.75	"	"	"	950	87.5	88.0	88.0	129.5
90 "	26.9	266.0	246.5	9.15	13	1600	105	1041	89.0	88.5	91.0	150.0
120 "	24.8	265.0	246.0	9.90	"	"	"	1126	93.5	90.0	98.0	174.5
2½ min	24.1	263.5	244.0	10.10	12¾	"	"	1166	96.0	91.0	104.0	196.0
3 "	23.9	263.0	243.5	10.20	12½	"	"	1193	107.0	93.0	112.0	212.0
3½ "	-	-	-	-	-	-	-	-	-	-	-	-
4 "	-	-	-	-	-	-	-	-	-	-	-	-
4½ "	19.8	247.0	228.5	11.55	15¾	1600	65	1211	177.5+	96.0	113.0	337.0
5 "	18.5	246.0	227.5	12.30	"	"	"	1218	176.5+	96.5	111.0	371.0
6 "	19.2	245.0	226.5	11.80	"	"	"	1232	"	98.0	110.0	423.0
7 "	19.8	"	"	11.45	"	"	"	1243	177.5	99.0	"	450.0
8 "	20.0	"	"	11.30	"	"	"	1248	"	100.0	"	463.0
9 "	18.3	242.0	223.0	12.20	"	"	61	1253	"	101.0	"	486.0
9½ "	18.6	"	"	12.00	"	"	56	1256	"	"	111.0	476.0
10 "	22.5	"	"	9.95	"	"	"	"	178.0	"	"	484.0
11 "	24.8	"	"	9.00	"	"	60	1260	"	102.0	111.5	482.5
12 "	23.4	"	"	9.55	"	"	56	1264	178.5	"	112.0	"
12½ "	21.0	"	"	10.60	"	"	61	"	"	103.0	112.5	"
13 "	20.8	"	"	10.70	"	"	56	1266	"	"	113.0	480.5
14 "	19.2	"	"	11.65	"	"	65	"	"	104.0	"	476.0
15 "	18.0	"	"	12.40	"	"	"	1268	"	"	"	473.5
15½ "	7.2	77.0	70.5	9.75	17½	690	0	1073	185.5	"	"	420.0
16 "	"	"	"	"	"	670	"	1023	179.5	"	"	384.0
17 "	6.2	"	"	11.30	16¾	635	"	988	177.0	103.5	113.5	348.5
18 "	7.8	"	"	9.00	"	"	"	933	"	102.0	114.0	321.5
19 "	7.0	"	"	10.10	"	"	"	907	"	101.5	114.5	324.0
20 "	6.4	"	"	11.00	"	"	"	891	"	101.0	115.0	320.5

TABLE 5-38.

DATE OF RUN & TIME:- 23 - 5 - 1975 / 0930HRS
RUN # :- 55.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 81°F
BAROMETER PRESSURE:- 29.88 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 90°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	TEMPERATURES °F EXH. OUT	WATER OUT	INLET AIR	AIR-FILTER	HEATED AIR
15 sec	22.8	163.5	154.5	6.80	21	1650	18	648	81.0	81.0	81.0	84.0
30 "	22.2	"	"	6.95	"	1700	"	782	"	"	82.0	94.0
45 "	22.5	"	"	6.90	"	1740	"	832	"	81.5	83.0	107.0
60 "	21.2	"	"	7.30	21¼	1760	"	867	80.0	82.0	84.0	115.5
90 "	23.7	242.5	228.5	9.25	15½	1650	96	993	79.5	82.5	87.5	136.5
120 "	22.8	251.0	236.5	10.35	14½	"	"	1083	79.0	83.5	92.0	160.0
2½ min	22.5	253.0	238.0	10.60	14	1640	"	1147	90.0	84.5	98.5	181.0
3 "	22.0	"	"	10.80	"	"	"	1184	107.0	86.5	105.0	200.5
3½ "	23.2	"	"	10.25	"	1630	"	1205	113.5	87.5	111.5	214.0
4 "	21.5	"	"	11.10	"	"	"	1226	171.0+	88.5	118.0	218.0
4½ "	20.9	-	-	-	-	-	-	-	-	-	-	-
5 "	21.5	271.5	255.0	11.90	14	1630	79	1248	175.0+	91.0	111.5	350.5
6 "	20.2	264.0	248.0	12.30	"	"	75	1272	179.0+	93.0	110.0	435.5
7 "	18.9	266.0	249.5	13.20	14¼	"	"	1282	181.0	94.0	"	482.5
8 "	20.0	"	"	12.50	"	"	"	1290	"	95.5	"	510.0
9 "	19.5	"	"	12.80	"	"	"	1299	"	97.0	"	529.0
9½ "	18.9	264.0	247.0	13.10	"	"	"	1301	"	98.0	"	532.0
10 "	18.7	"	"	13.20	14½	"	"	"	178.0	98.5	111.0	535.0
11 "	19.1	"	"	12.90	"	"	"	"	"	99.0	111.5	543.0
12 "	20.0	"	"	12.35	"	"	"	1306	182.5	99.5	"	546.0
12½ "	19.1	"	"	12.90	"	"	"	1309	"	100.0	"	548.0
13 "	18.7	"	"	13.20	"	"	"	"	181.0	100.5	112.0	"
14 "	"	262.5	245.0	13.10	"	"	"	1306	180.0	101.0	112.5	545.5
15 "	"	"	"	"	14¾	"	"	"	181.0	101.5	"	544.5
15½ "	7.1	77.0	71.5	10.10	18	700	0	1112	187.5	"	"	488.0
16 "	7.0	"	"	10.20	17¾	685	"	1046	182.5	"	113.0	453.5
17 "	5.2	"	"	13.75	17½	675	"	993	178.5	100.0	"	422.0
18 "	5.0	"	"	14.30	"	650	"	956	"	99.0	113.5	398.5
19 "	5.5	"	"	13.00	17¼	"	"	916	"	98.0	"	392.0
20 "	"	"	"	"	17	"	"	903	"	97.0	"	380.0

TABLE 5-39.

DATE OF RUN & TIME:- 26 - 5 - 1975 / 1050 HRS
RUN # :- 56.
HOURS OF COLD SOAK:- -

ROOM TEMPERATURE AT START:- 77°F
BAROMETER PRESSURE:- 29.78 in. Hg
ROOM TEMPERATURE AT SHUT DOWN:- 88°F

TIME AFTER START UP	FUEL FLOW LB/HR	AIR FLOW LB/HR	CORR. AIR FLOW LB/HR	AIR-FUEL RATIO	MANI-FOLD VAC. IN.HG	SPEED R.P.M.	TORQUE LB-FT	TEMPERATURES °F EXH. OUT	WATER OUT	INLET AIR	AIR-FILTER	HEATED AIR
15 sec	23.4	218.0	200.0	8.55	20	2100	38	756	77.0	77.0	77.0	83.5
30 "	"	"	"	"	"	"	"	884	"	"	77.5	97.5
45 "	23.0	217.0	199.0	8.65	"	"	"	921	"	"	78.5	112.0
60 "	22.5	216.0	198.0	8.80	"	"	"	961	78.0	78.5	80.0	126.5
90 "	22.8	219.5	201.0	8.85	16½	1600	79	989	78.5	79.0	84.0	149.0
120 "	20.8	216.0	197.5	9.50	"	"	75	1053	80.0	79.5	89.0	167.5
2½ min	18.9	214.5	195.5	10.35	16¼	"	69	1106	83.0	80.0	94.5	186.5
3 "	18.7	"	"	10.45	16	1580	68	1133	104.0	81.5	100.5	201.0
3½ "	18.0	214.0	195.0	10.85	"	"	"	1159	112.0+	82.5	106.0	213.0
4 "	18.3	239.0	218.0	11.90	15¾	"	"	1175	172.5+	83.5	112.0	228.0
4½ "	18.5	242.5	221.0	11.95	"	"	"	1201	165.5+	84.0	109.0	292.0
5 "	19.0	244.0	222.5	11.70	"	"	"	1212	176.5+	85.0	106.0	330.0
6 "	18.9	245.0	223.5	11.80	15½	"	"	1229	182.5+	87.0	104.0	399.0
7 "	19.2	"	"	11.65	"	"	"	1244	184.5+	88.0	"	442.0
8 "	"	"	"	"	"	"	"	1254	183.5	89.0	"	475.0
9 "	18.1	"	"	12.35	"	"	"	1260	182.5	89.5	104.5	492.0
9½ "	17.5	"	"	12.75	"	"	"	1262	181.5	90.0	"	504.0
10 "	17.3	245.5	224.0	12.95	"	"	"	1263	182.5	90.5	105.0	509.0
11 "	17.5	"	"	12.80	"	"	"	1265	"	91.0	"	516.0
12 "	17.8	"	"	12.60	"	"	"	1266	"	91.5	"	521.0
12½ "	16.8	"	"	13.35	"	"	"	1268	"	92.5	106.5	524.0
13 "	17.3	"	"	12.95	"	"	"	1270	183.0	93.0	"	526.0
14 "	17.8	"	"	12.60	"	"	"	1272	"	93.5	107.0	531.0
15 "	18.1	246.0	224.0	12.40	"	"	"	1273	"	94.0	107.5	532.0
15½ "	17.8	"	"	12.60	"	"	"	1268	"	"	"	"
16 "	12.0	72.0	65.4	5.45	18½	740	0	1100	185.0	"	"	483.0
17 "	9.0	"	"	7.30	18¼	720	"	1005	179.5	93.5	"	451.0
18 "	6.3	"	"	10.40	18	700	"	958	185.0	92.0	"	421.0
19 "	7.5	"	"	8.75	17½	680	"	931	184.5	91.0	"	409.0
20 "	8.5	"	"	7.70	"	675	0	909	186.0	90.0	"	392.0

TABLE 5-40.

I. TEMPERATURE-TIME HISTORY RECORDED ON THE MULTICORDER

FIGURES 5-1a THROUGH 5-40a.

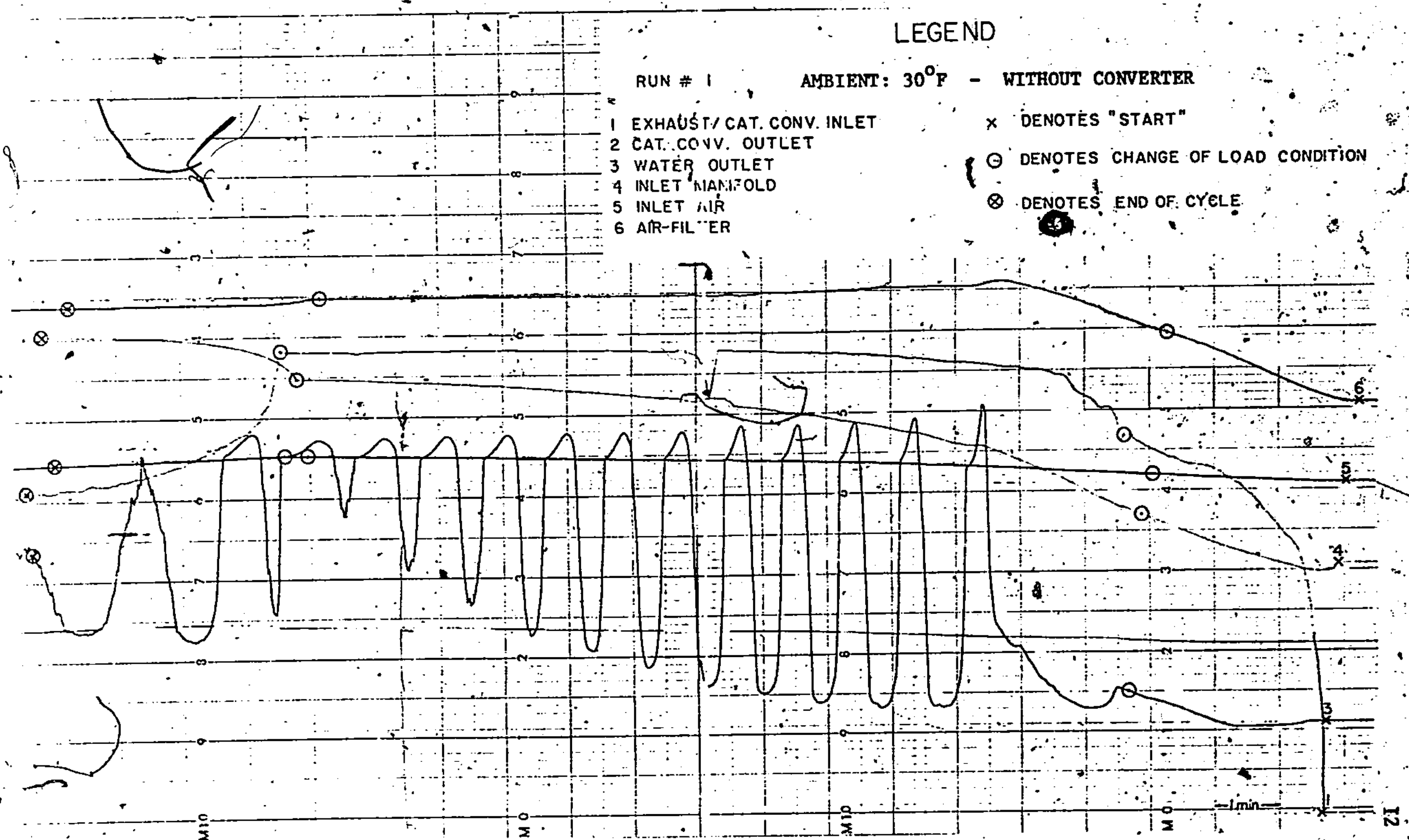


FIG. 5-1a. TEMPERATURE - TIME HISTORY RECORDED ON THE MULTICORDER

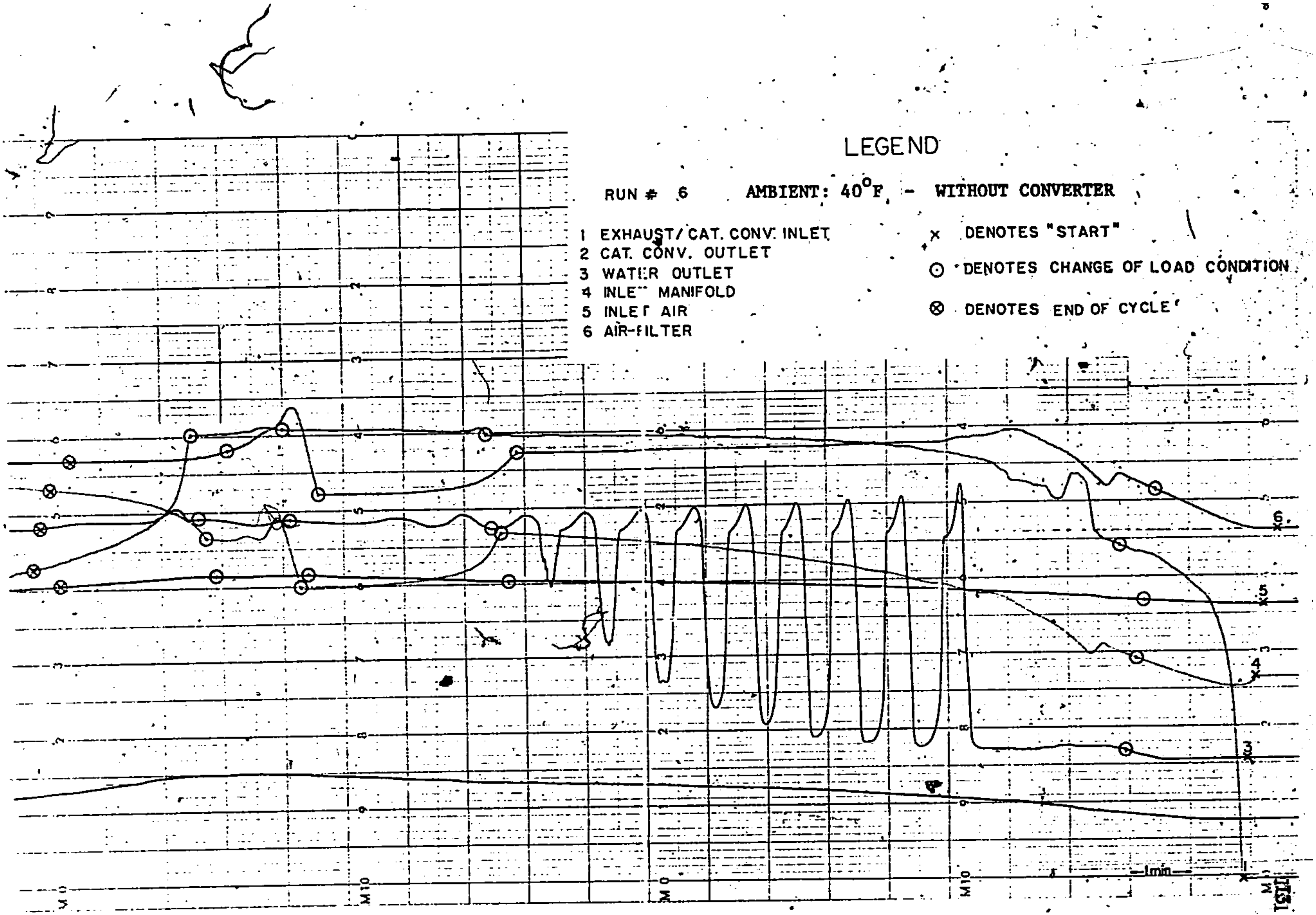

LEGEND
RUN # 6 AMBIENT: 40°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
x DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-2a.

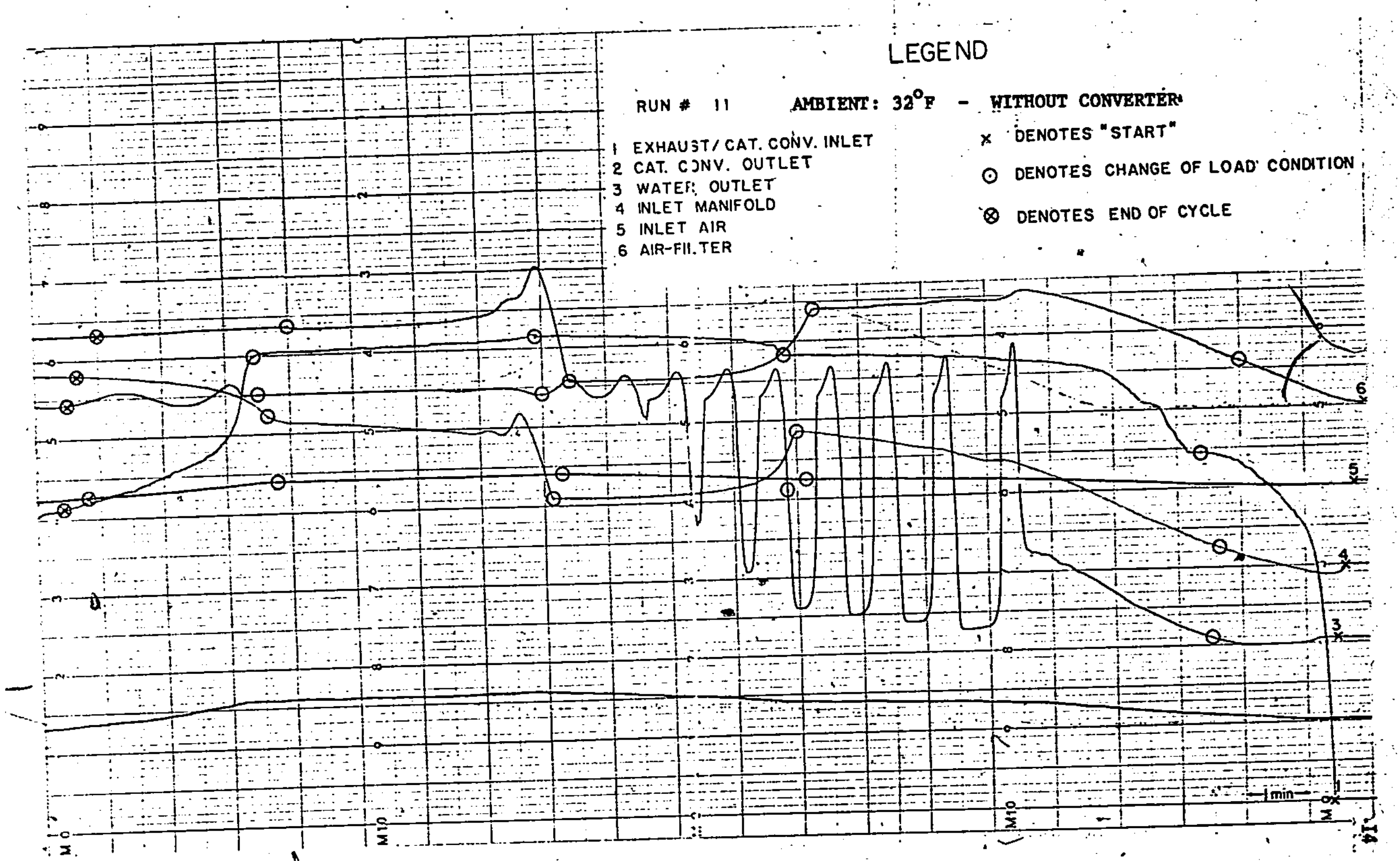

LEGEND
RUN # 11 AMBIENT: 32°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
x DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min

FIG. 5-3a.

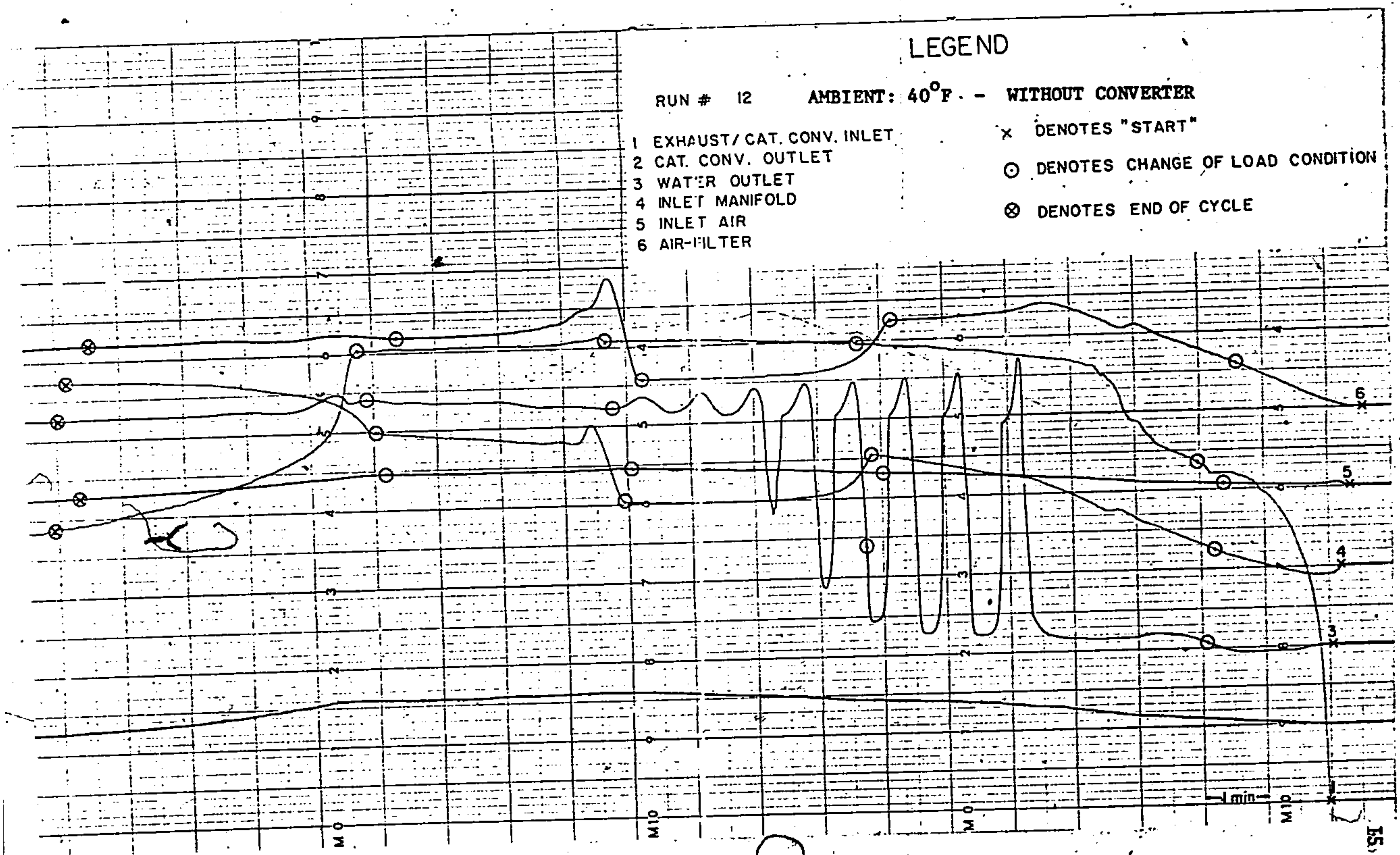
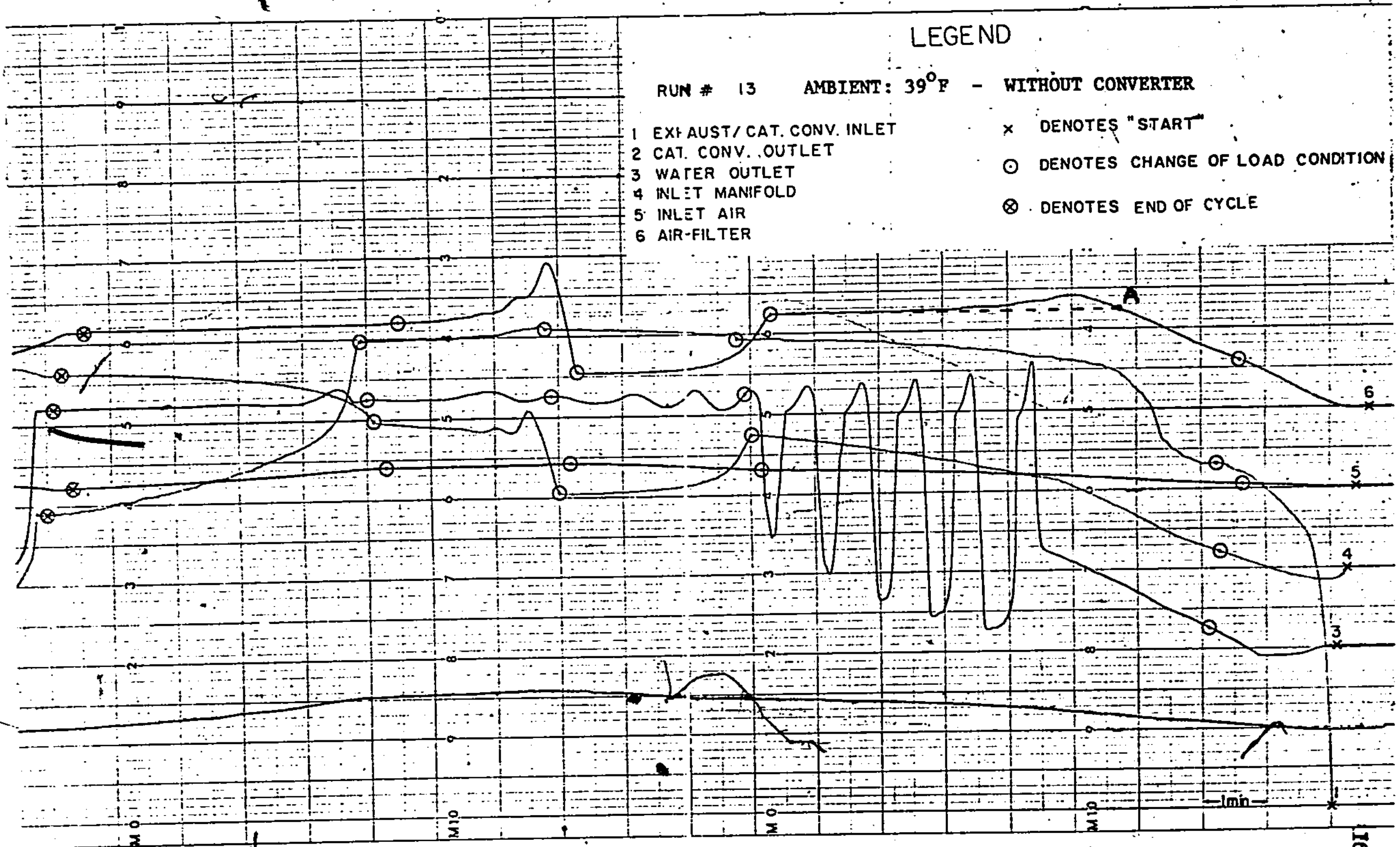
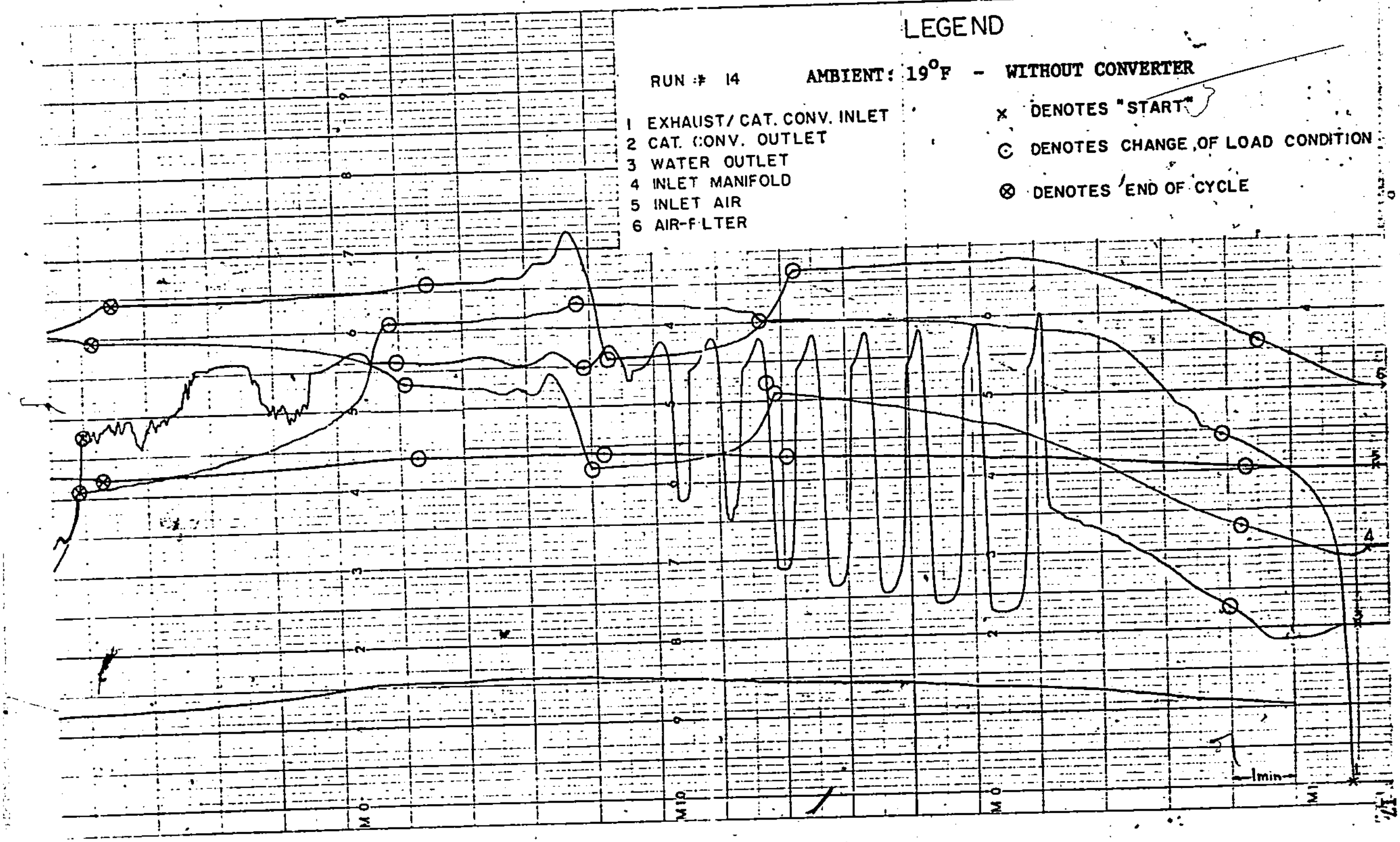

LEGEND
RUN # 12
AMBIENT: 40°F. - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
x DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min
M0
M10
M0
M10
15

FIG. 5-4a.



LEGEND
RUN # 13 AMBIENT: 39°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
A
1min

FIG. 5-5a.



LEGEND
RUN # 14
AMBIENT: 19°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
C DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-6a.

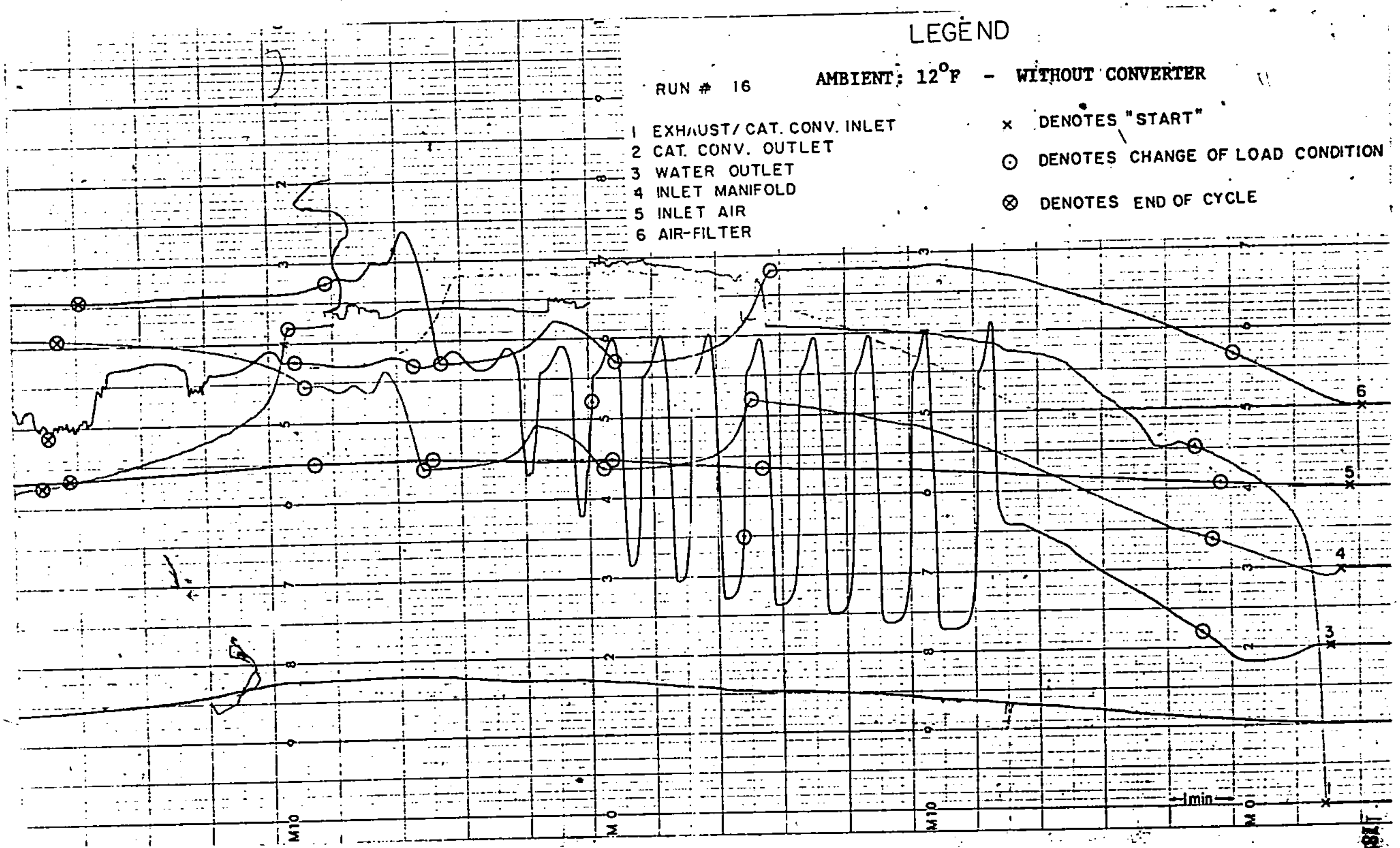

LEGEND
RUN # 16
AMBIENT: 12°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min
M10
M0
M10
M0

FIG. 5-7a.

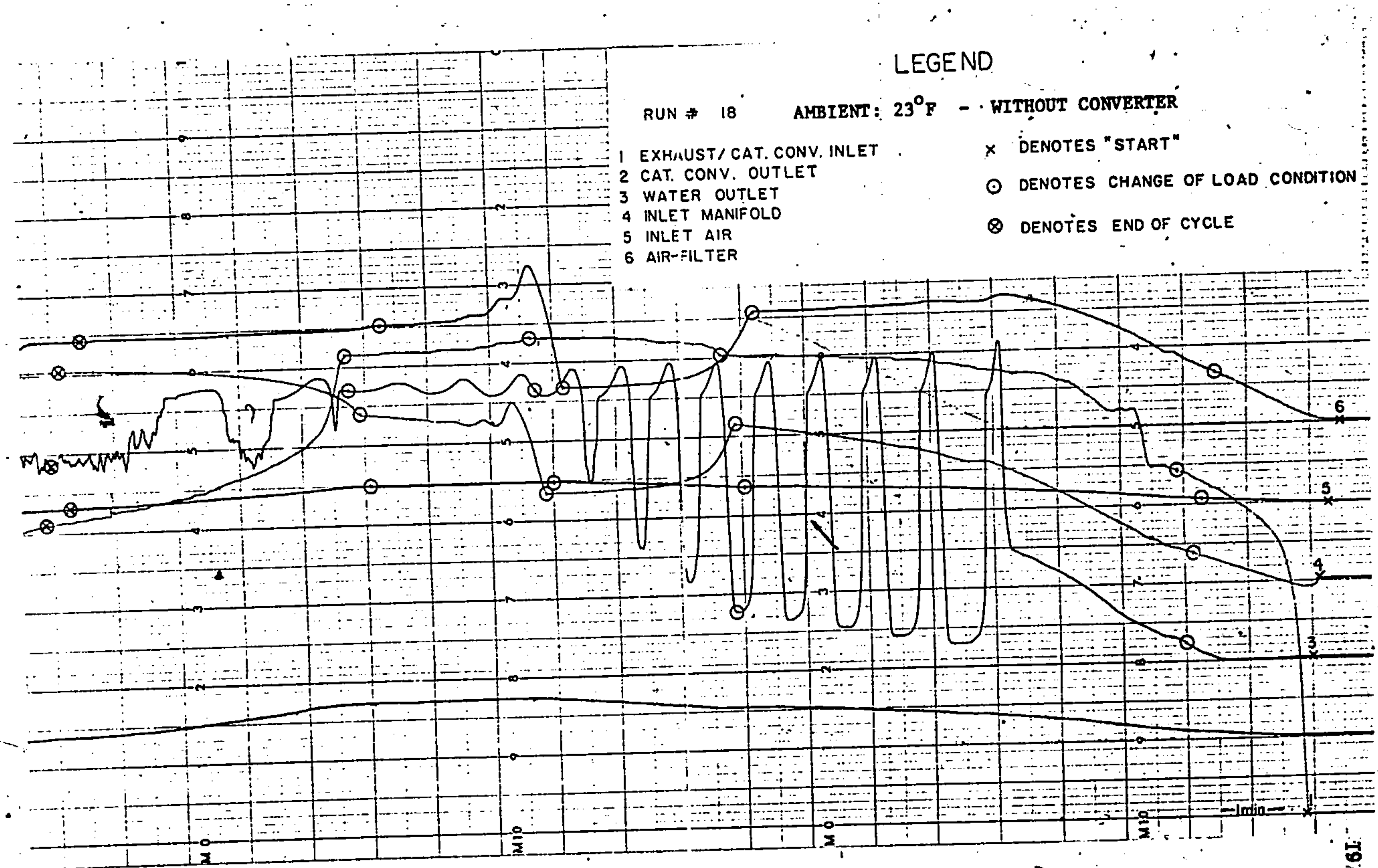
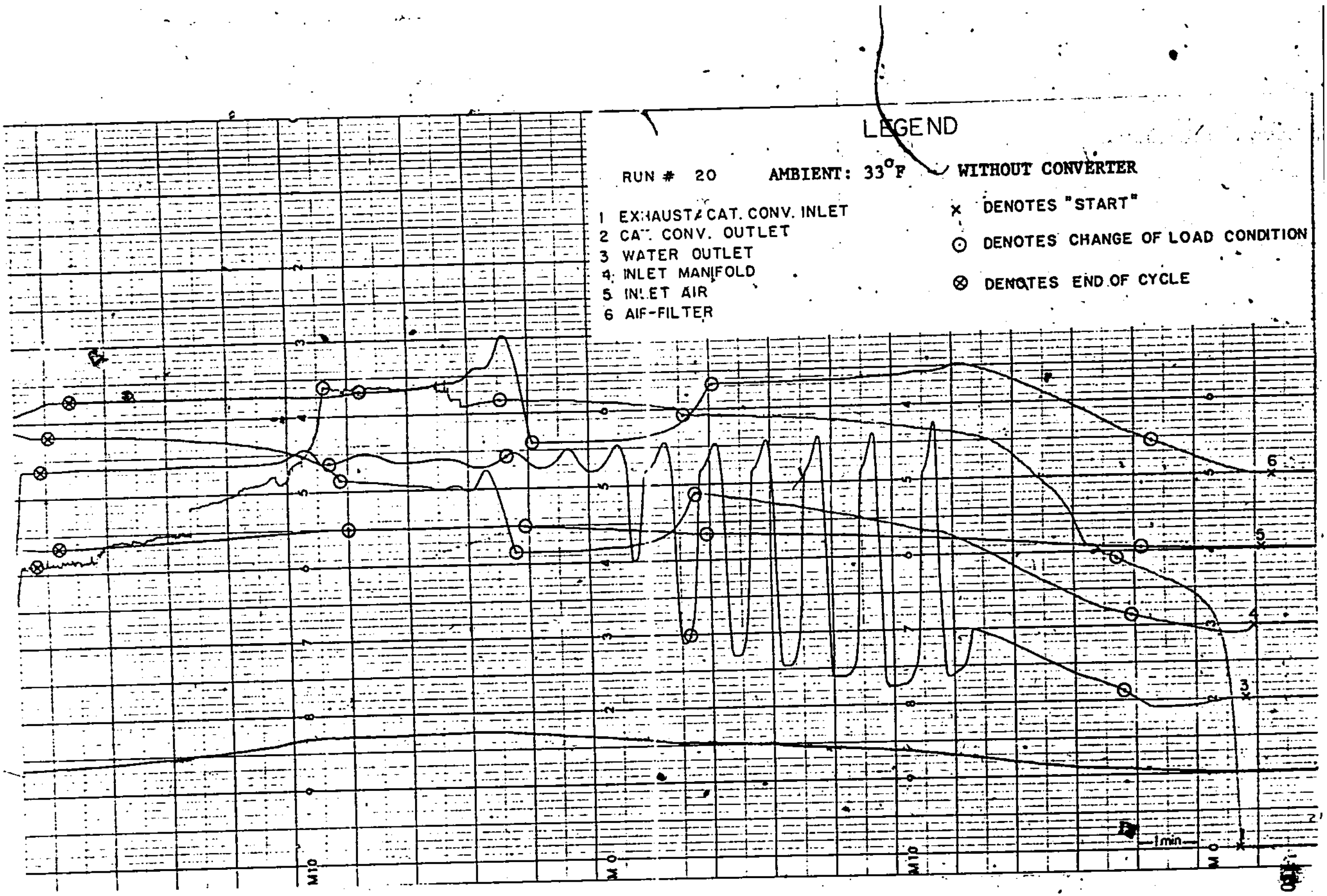
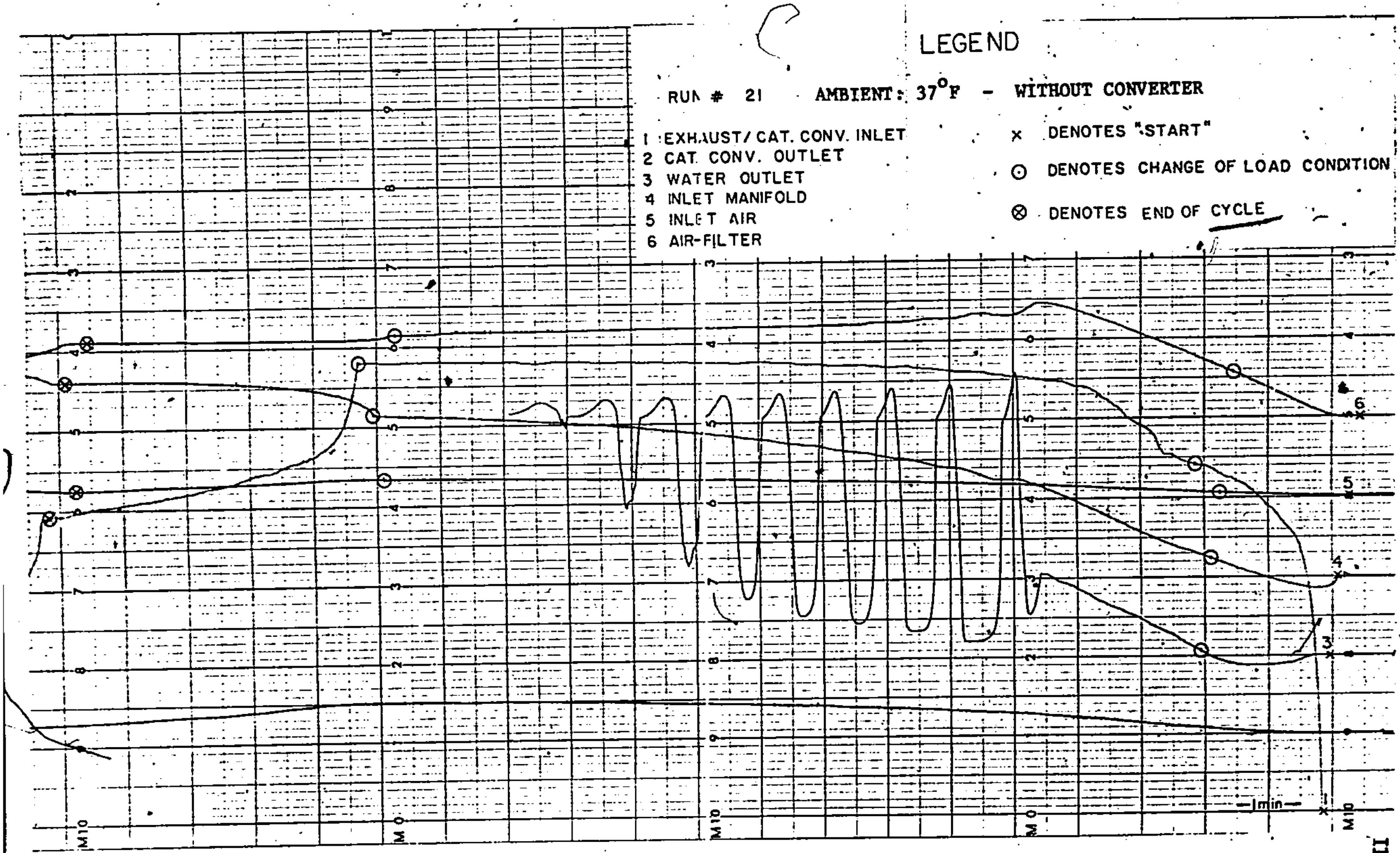

LEGEND
RUN # 18
AMBIENT: 23°F - WITHOUT CONVERTER
1 EXHAUST/ CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
—1min—
M0
M10

FIG. 5-8a.



LEGEND
RUN # 20
AMBIENT: 33°F
WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIF-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min

FIG. 5-9a.



LEGEND
RUN # 21 AMBIENT: 37°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min
M10
M0

FIG. 5-10a.

LEGEND

RUN # 22 AMBIENT: 34°F - WITHOUT CONVERTER

1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER

× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊕ DENOTES "SHUT DOWN"

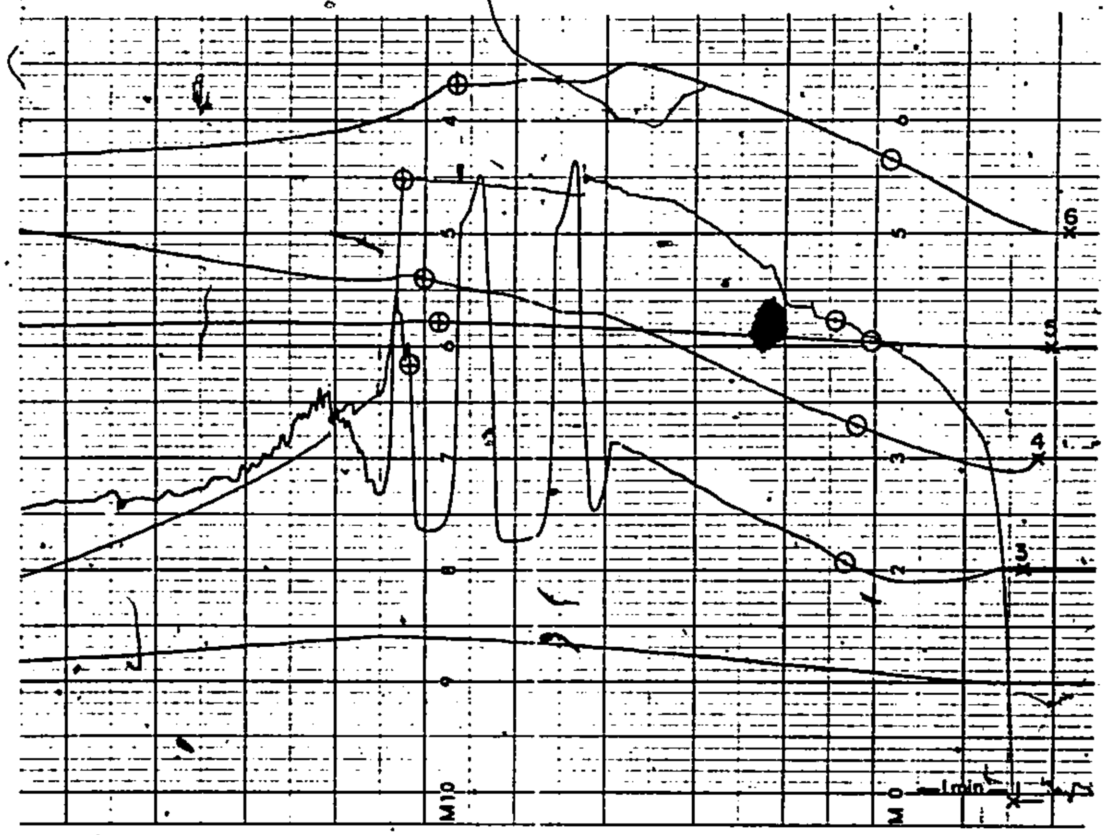


FIG. 5-11a.

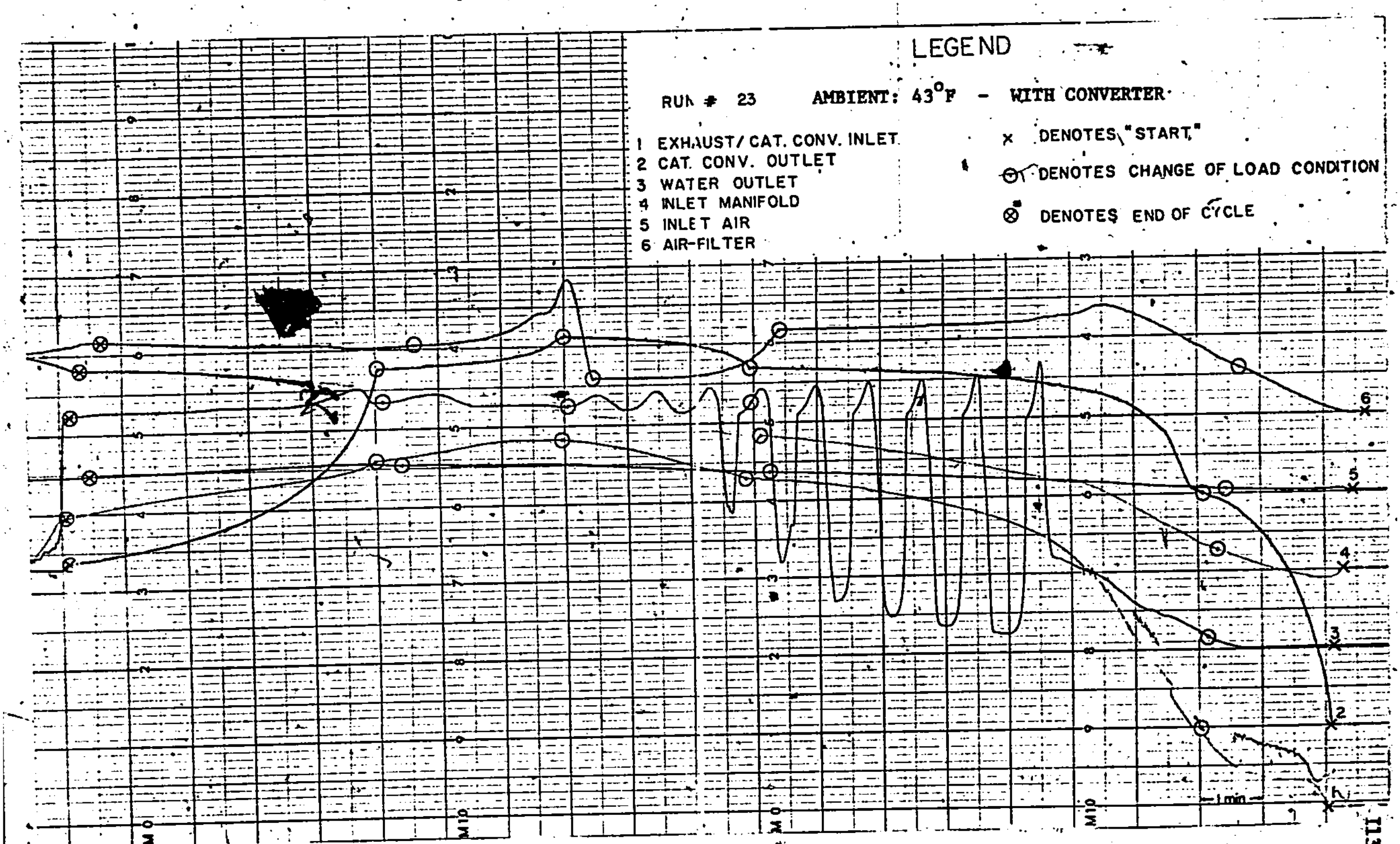

LEGEND
RUN # 23
AMBIENT: 43°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min

FIG. 5-12a.

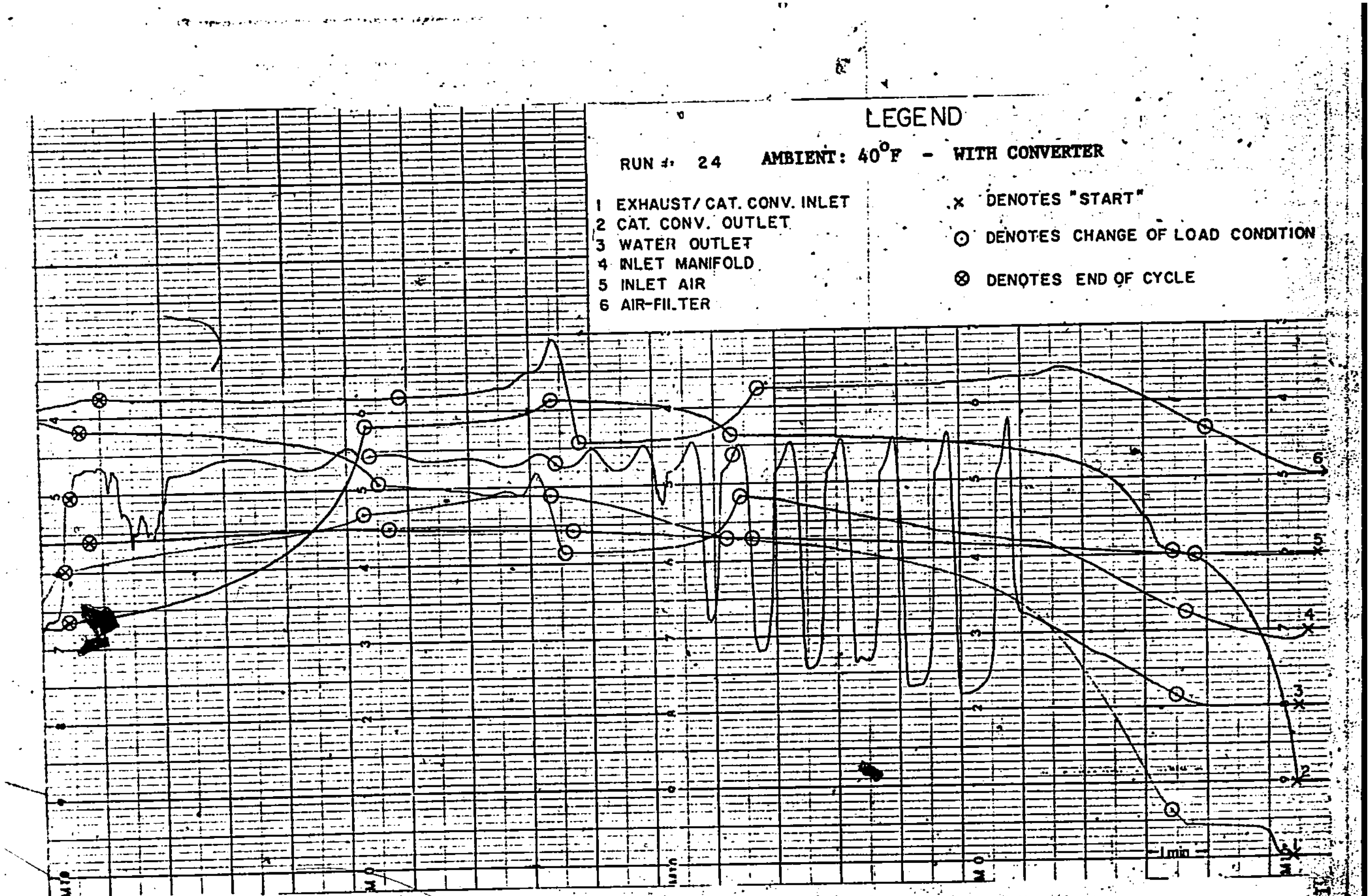

LEGEND
RUN #: 24 AMBIENT: 40°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min
114

FIG. 13a.

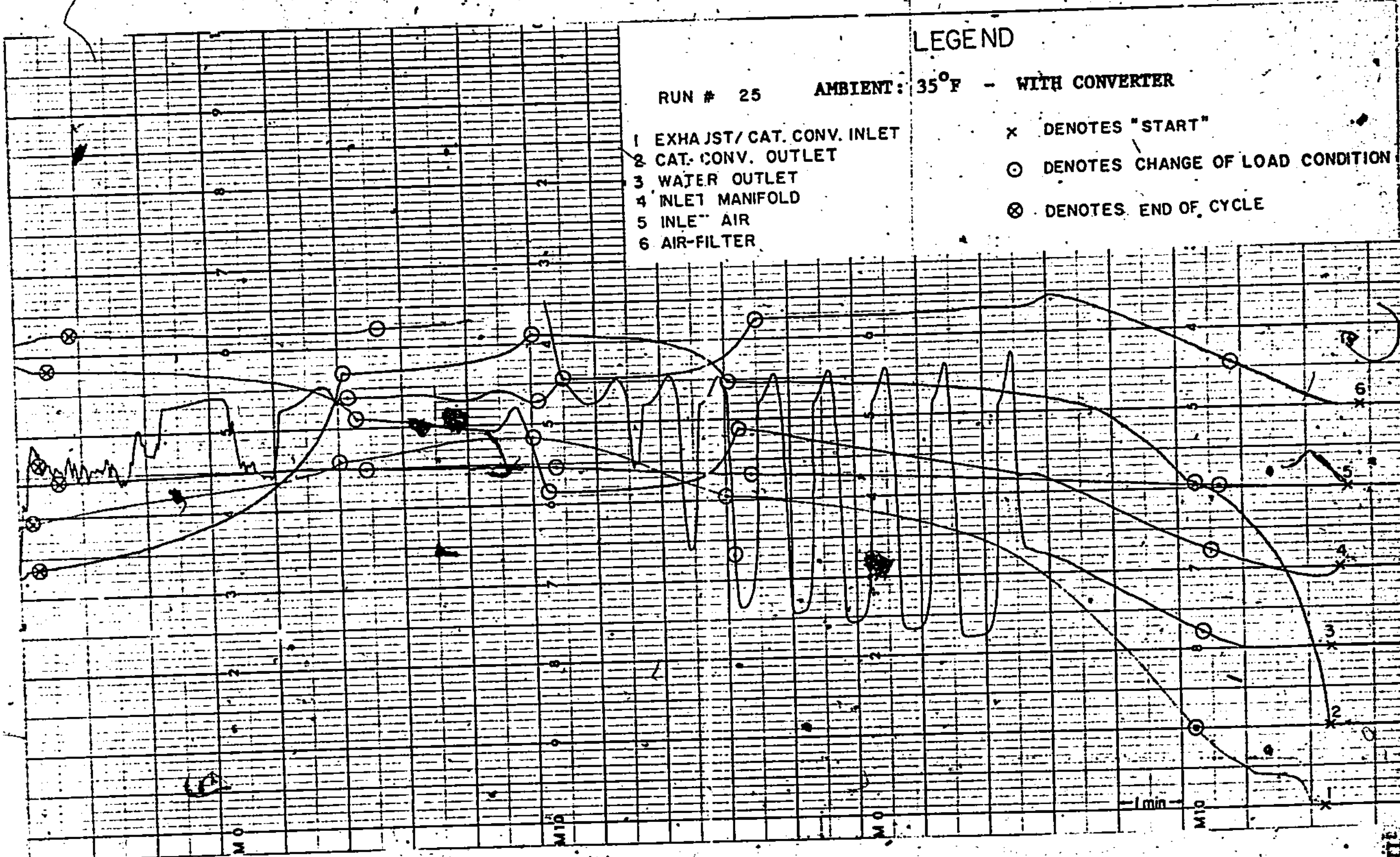

LEGEND
RUN # 25
AMBIENT: 35°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min

FIG. 5-14a.

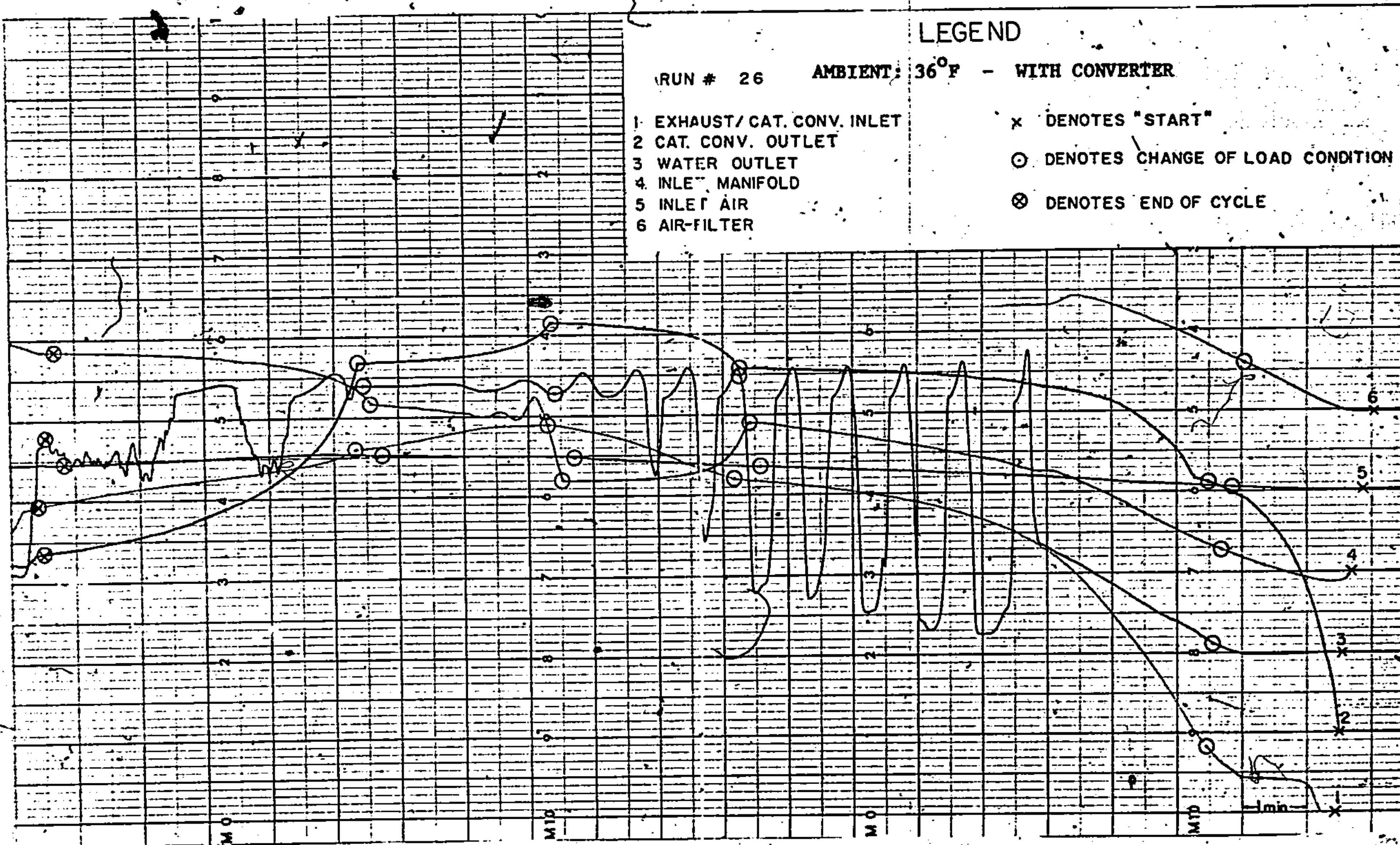

LEGEND
RUN # 26
AMBIENT: 36°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-15a.

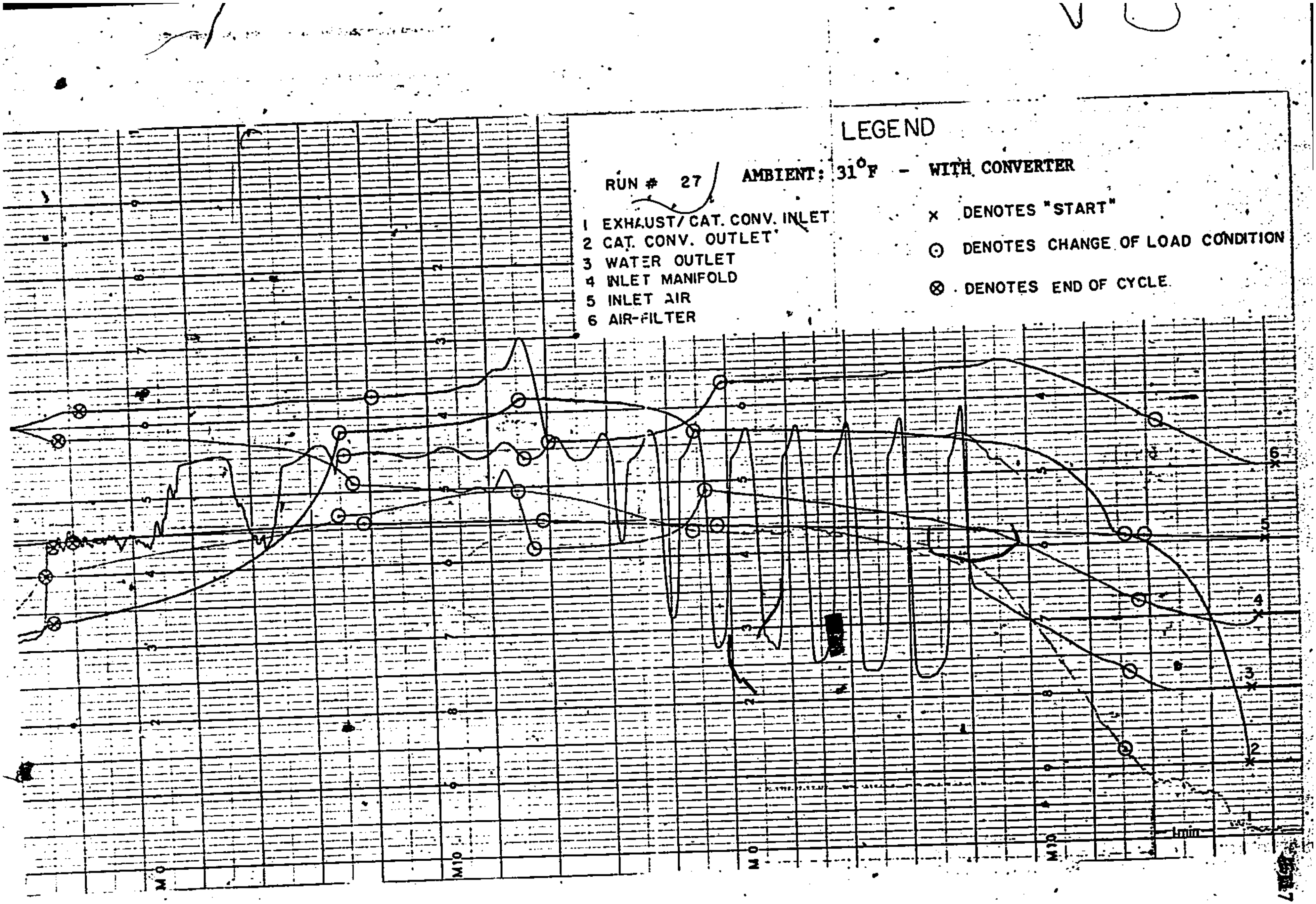

LEGEND
RUN # 27
AMBIENT: 31°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-16a.

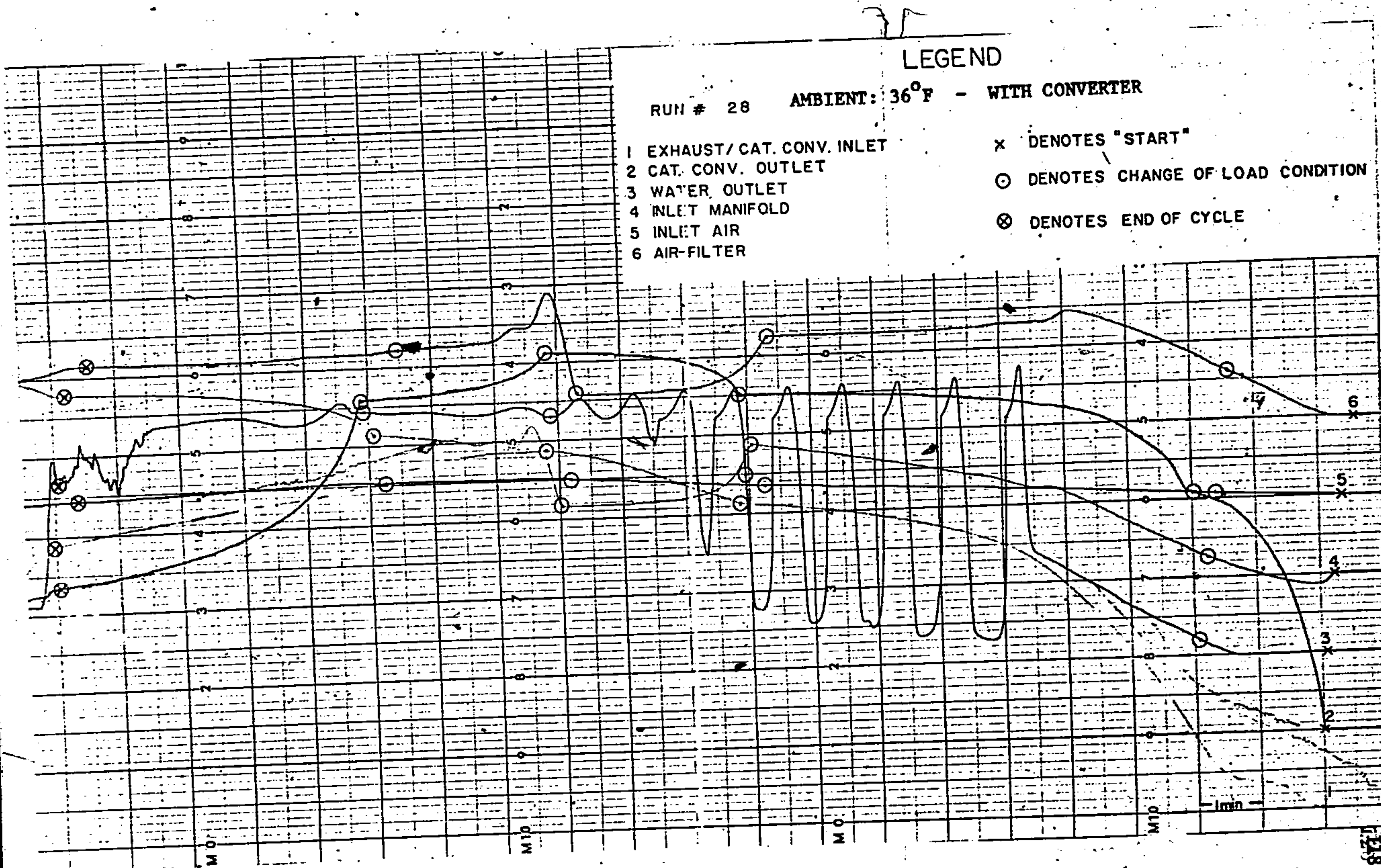

LEGEND
RUN # 28 AMBIENT: 36°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-17a.

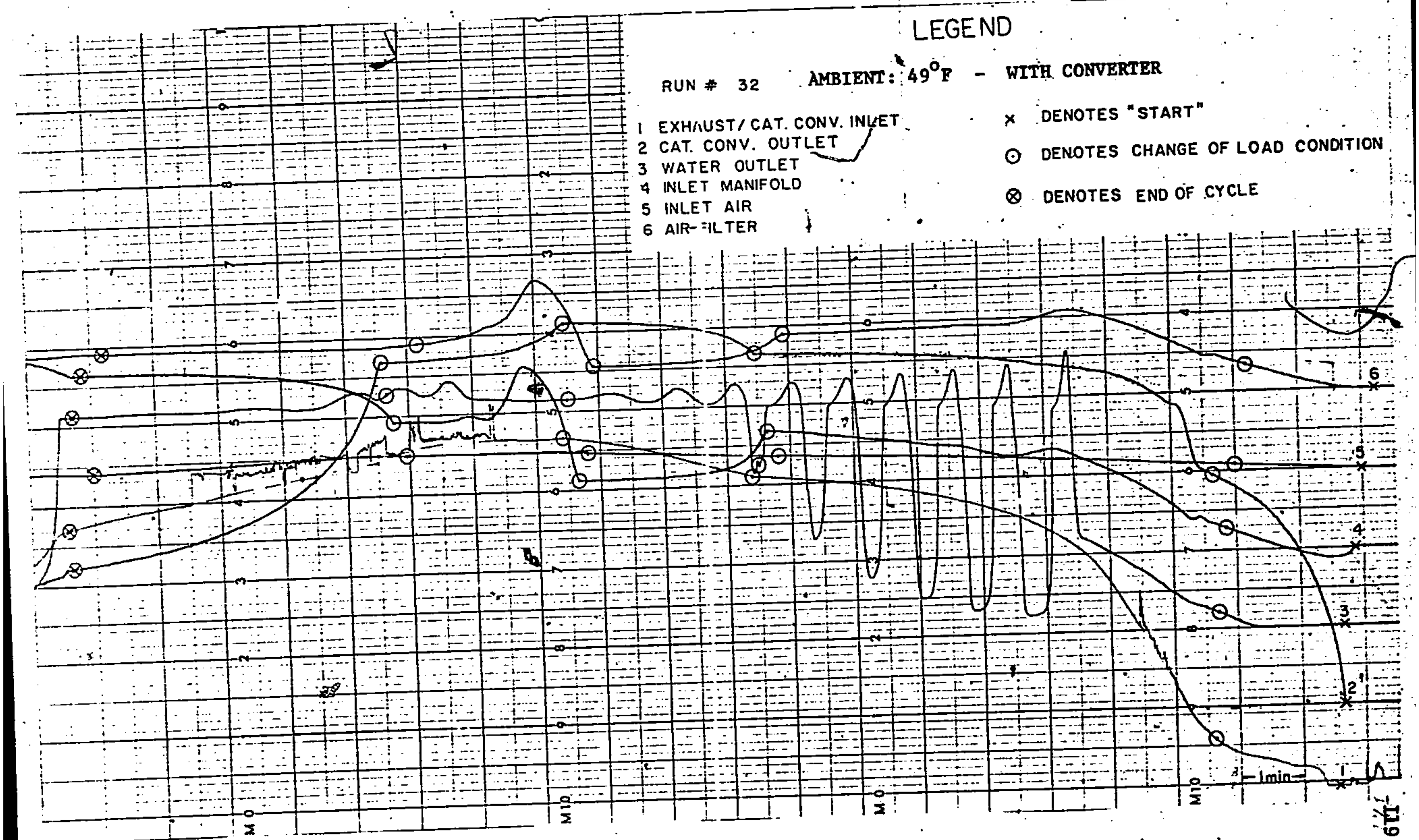

LEGEND
RUN # 32
AMBIENT: 49°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-18a.

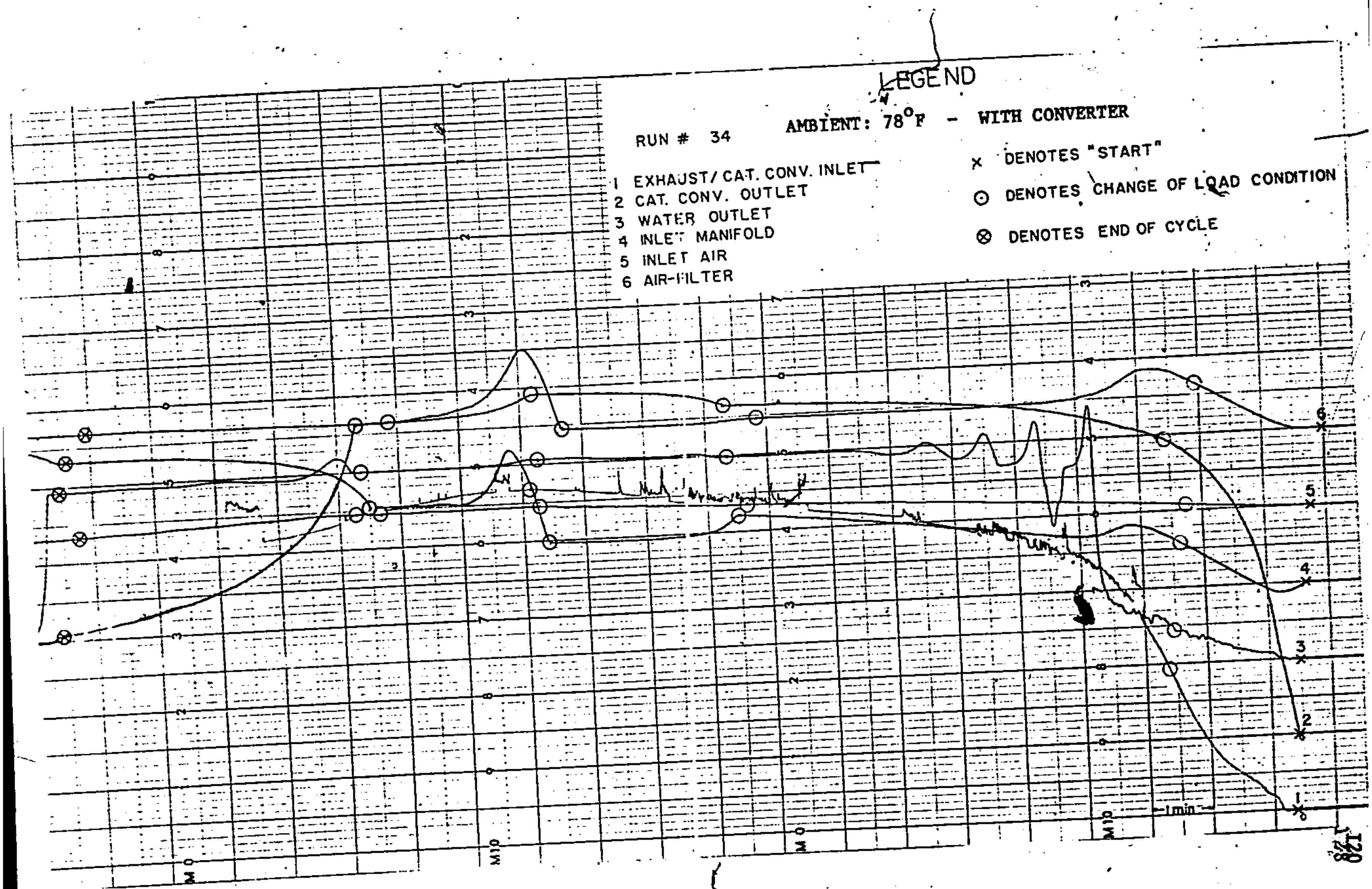

LEGEND
RUN # 34
AMBIENT: 78°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
x DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min
120

FIG. 5-19a.

LEGEND

RUN # 35 AMBIENT: 76°F – WITH CONVERTER

1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER

× DENOTES "START"

○ DENOTES CHANGE OF LOAD CONDITION

⊕ DENOTES "SHUT DOWN"

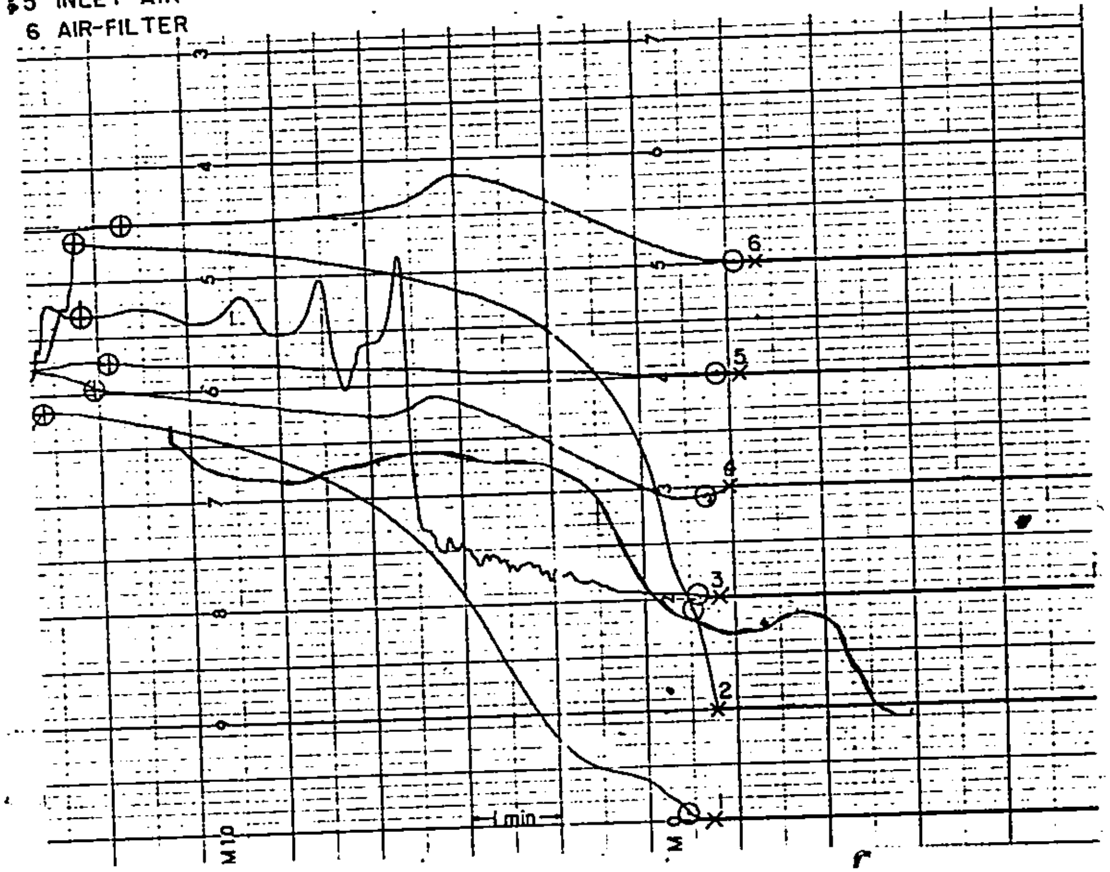
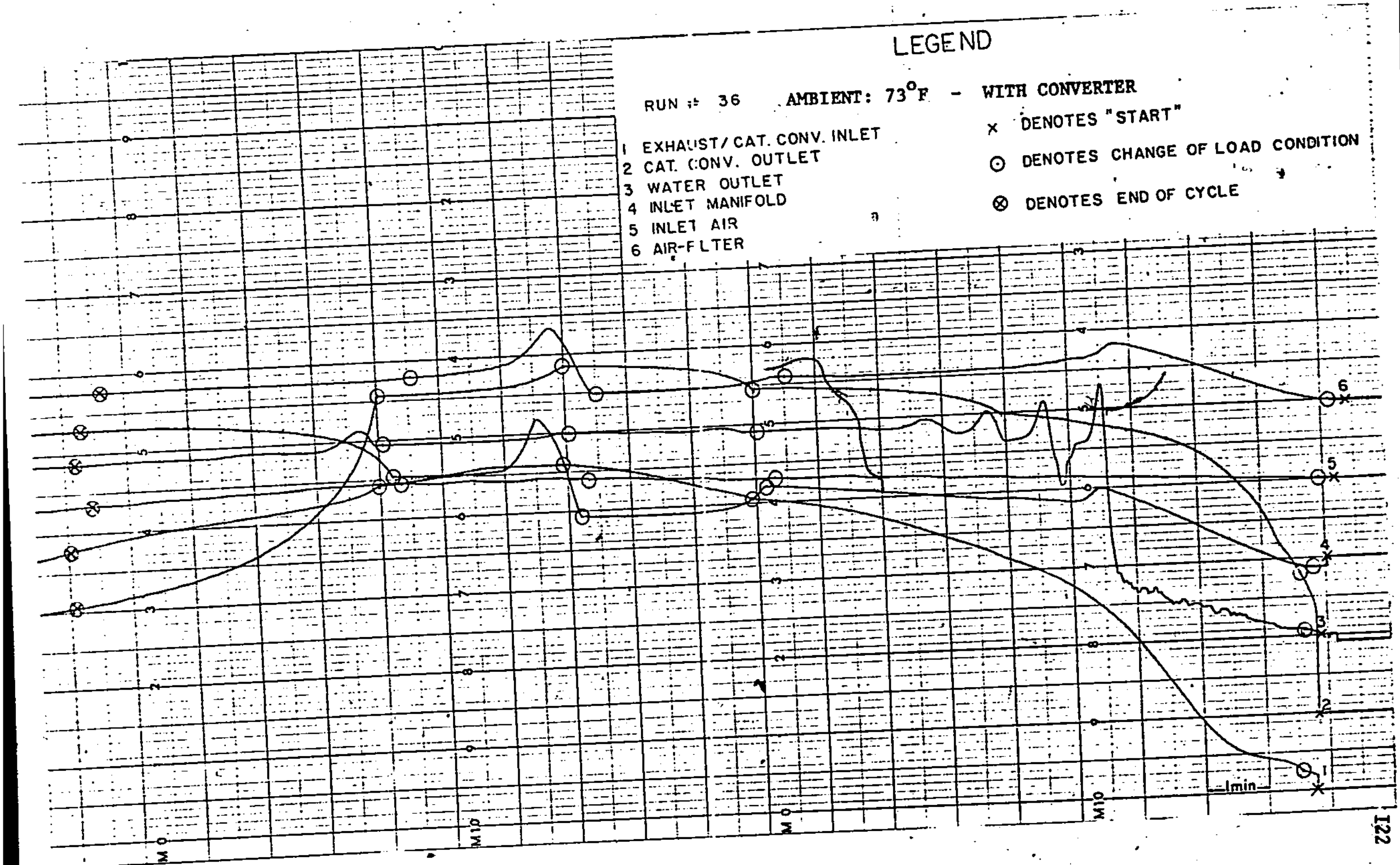


FIG. 5-20a.



LEGEND
RUN # 36 AMBIENT: 73°F - WITH CONVERTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
1min

FIG. 5-21a.

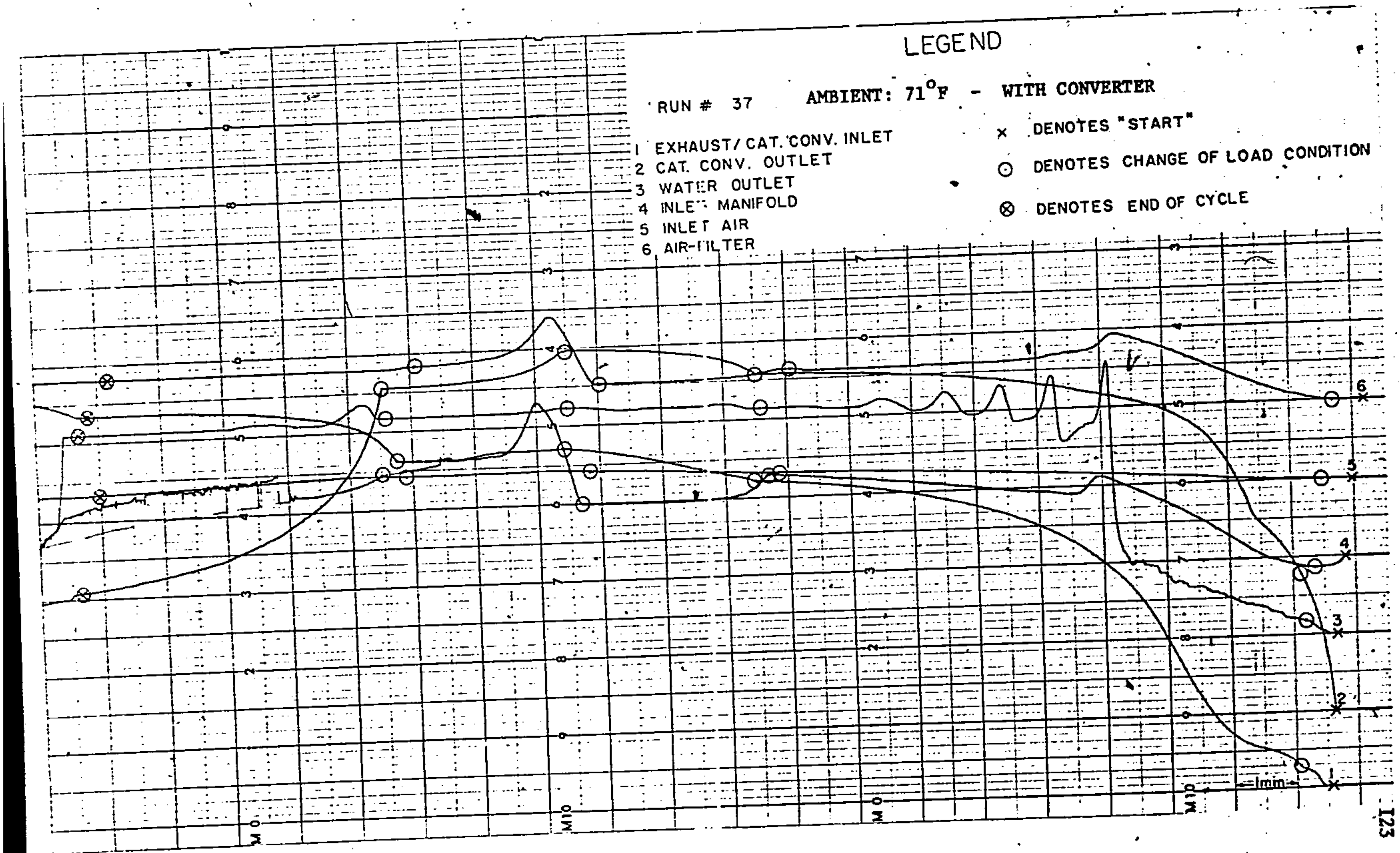
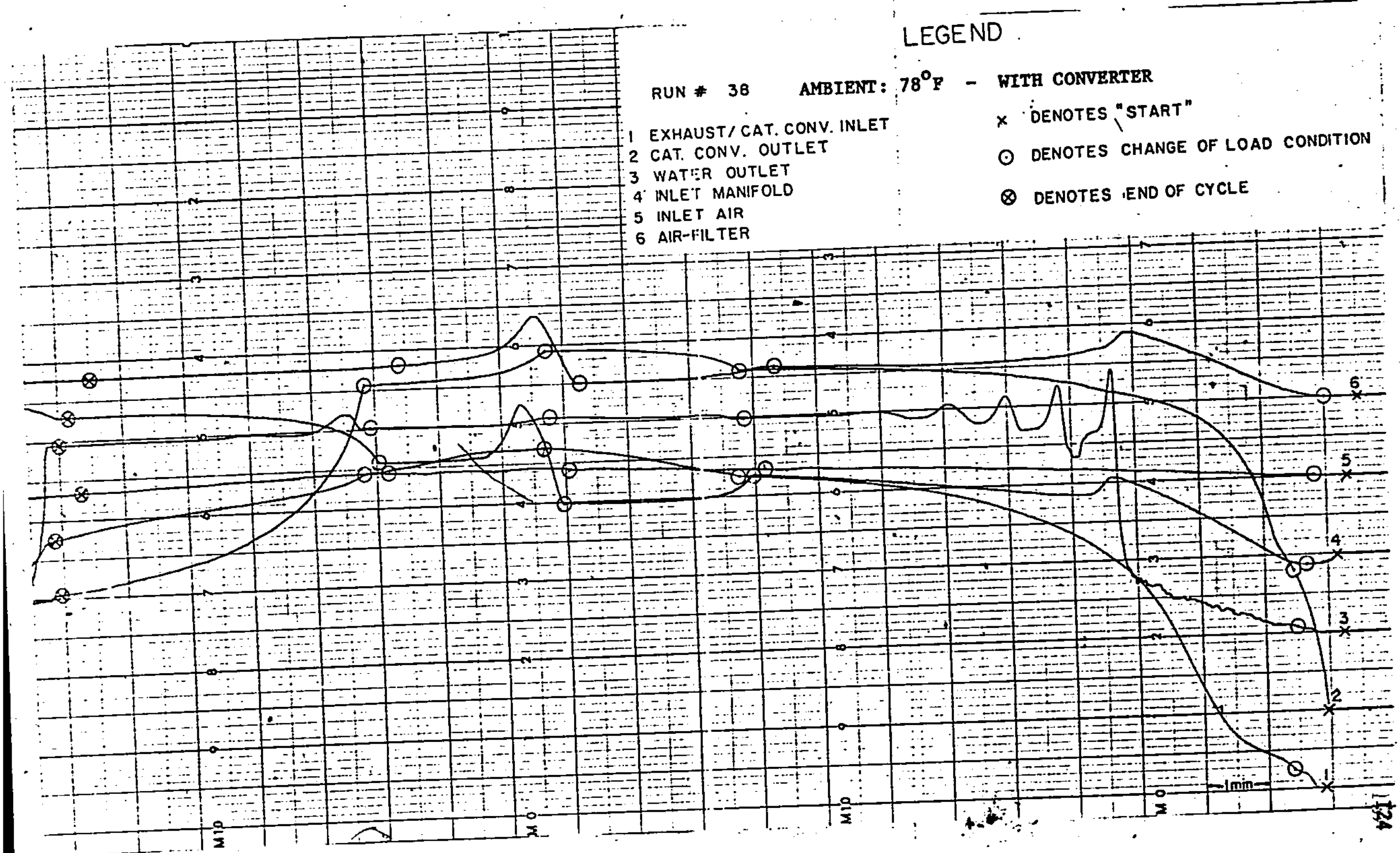

LEGEND
RUN # 37
AMBIENT: 71°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1mm

FIG. 5-22a.



LEGEND
RUN # 38 AMBIENT: 78°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1mm

FIG. 5-23a.

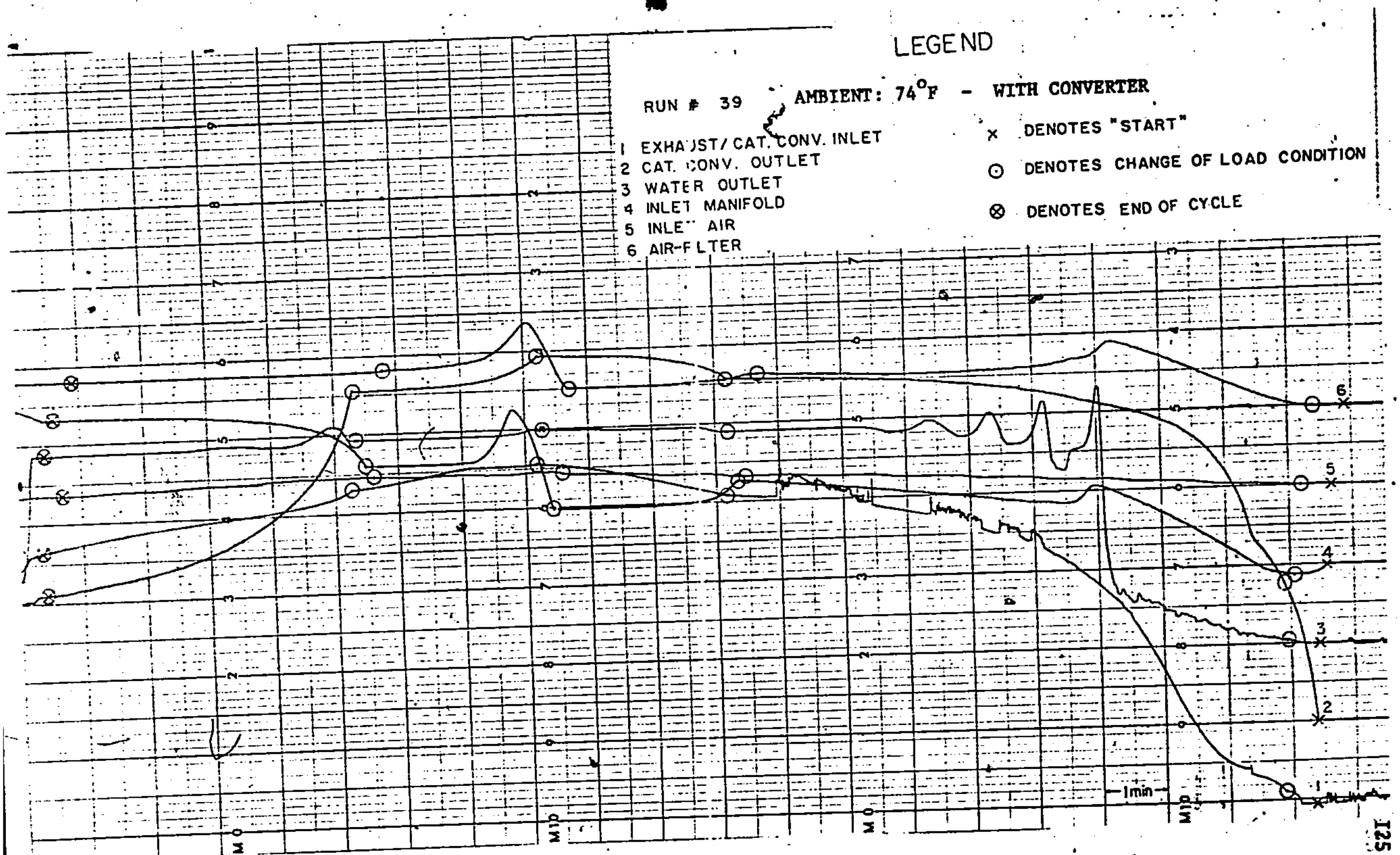

LEGEND
RUN # 39
AMBIENT: 74°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min
I25

FIG. 5-24a.

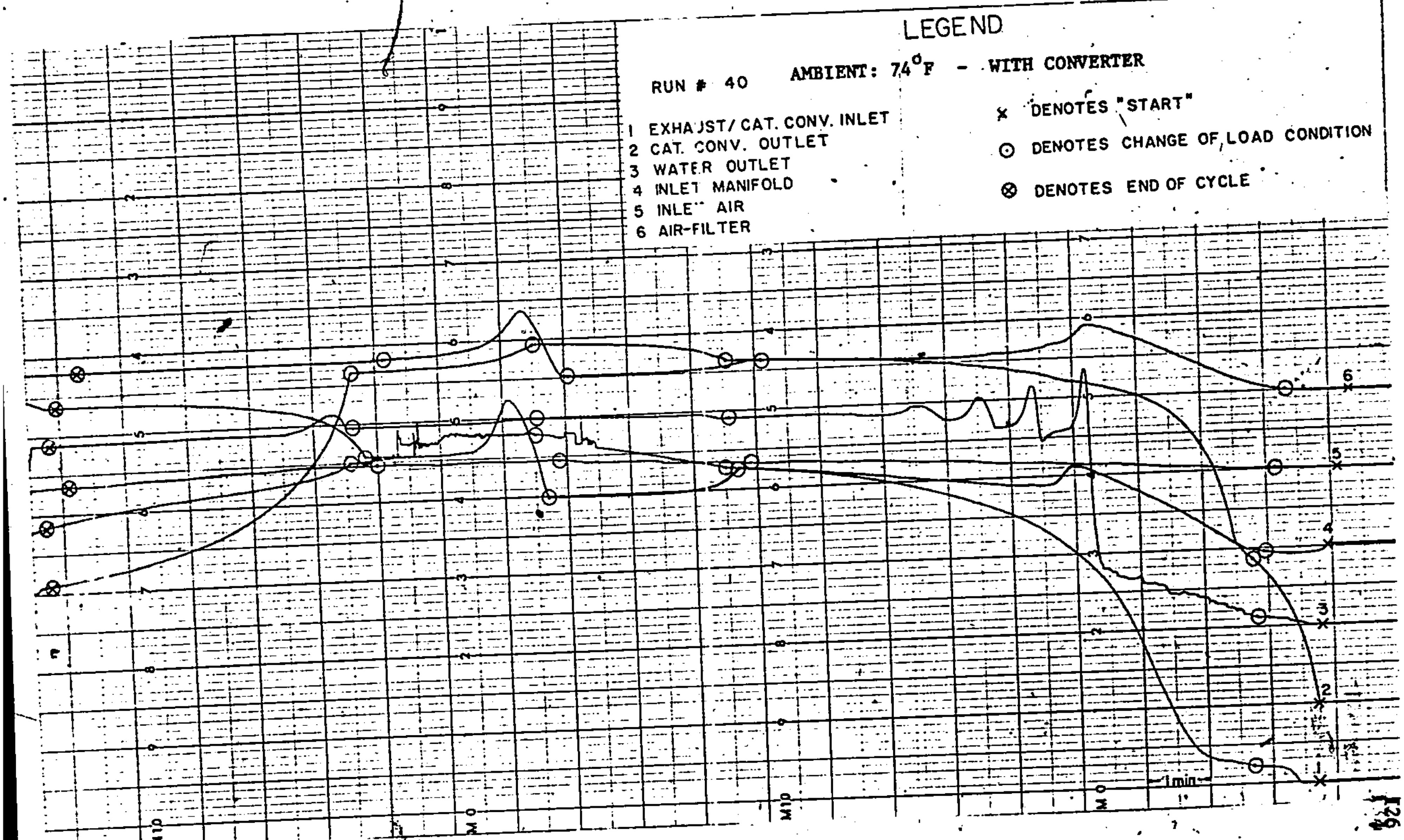

LEGEND
RUN # 40
AMBIENT: 74°F - WITH CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-25a.

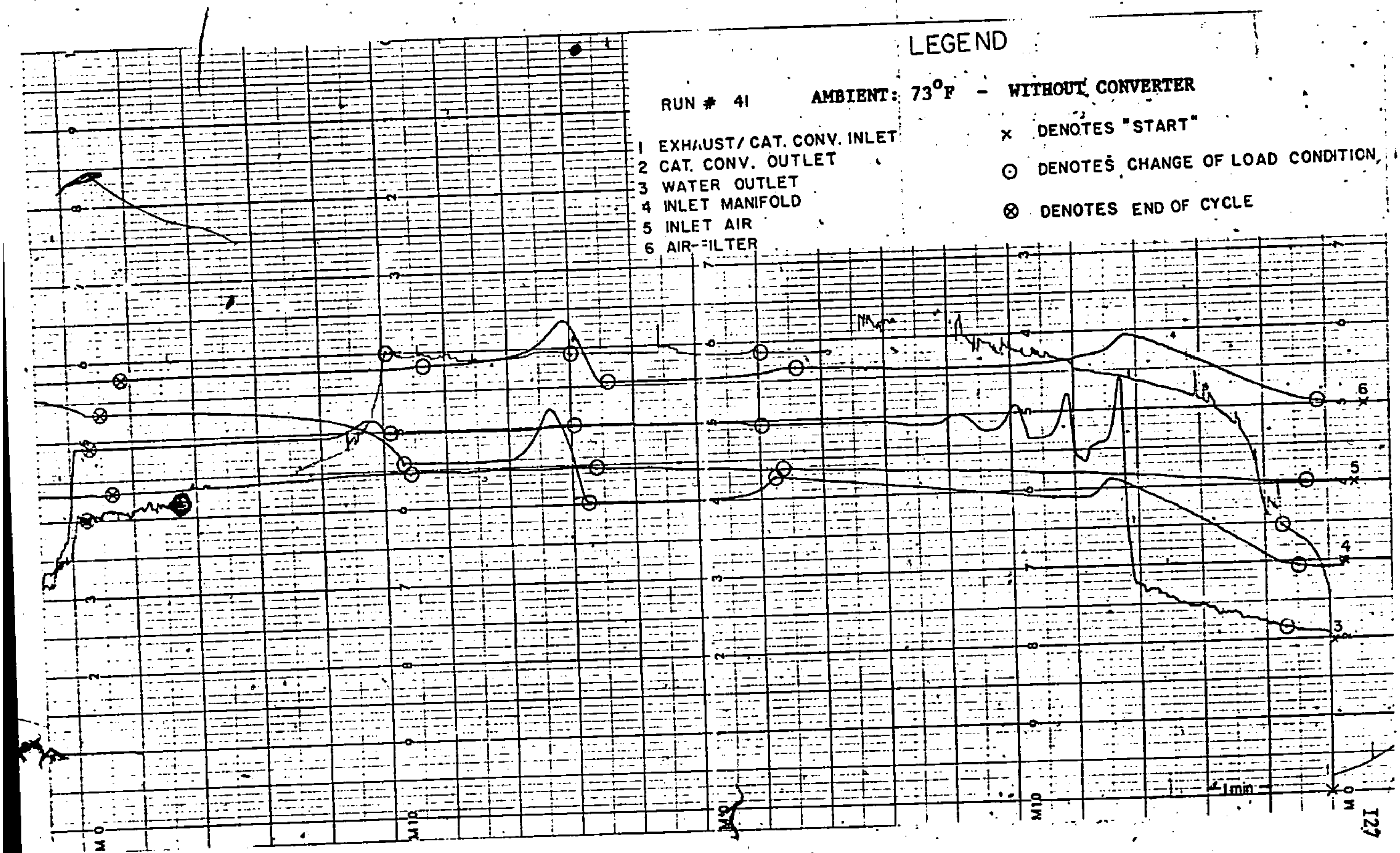
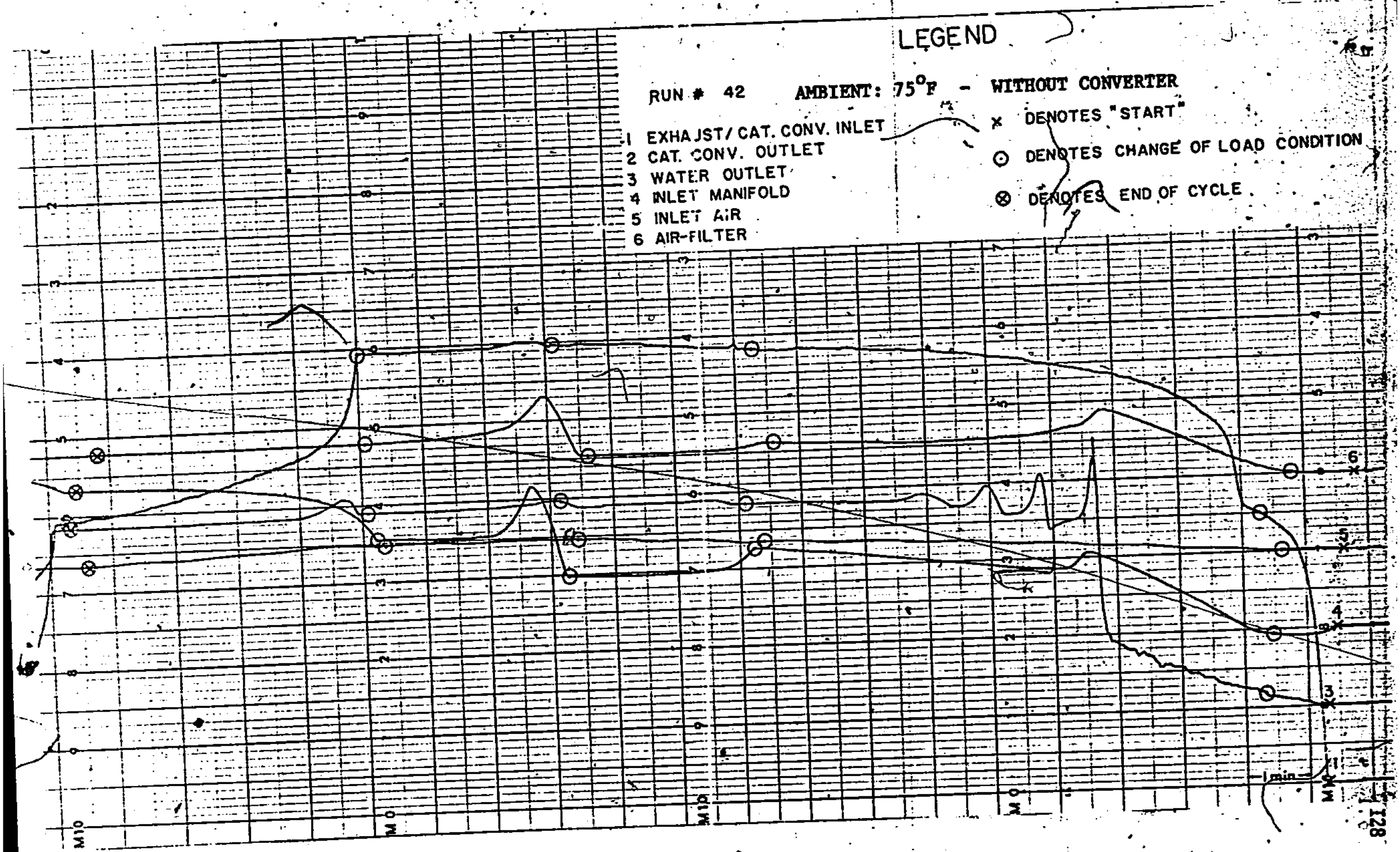

LEGEND
RUN # 41
AMBIENT: 73°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min

FIG. 5-26a.



LEGEND
RUN # 42 AMBIENT: 75°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min
I28

FIG. 5-27a.

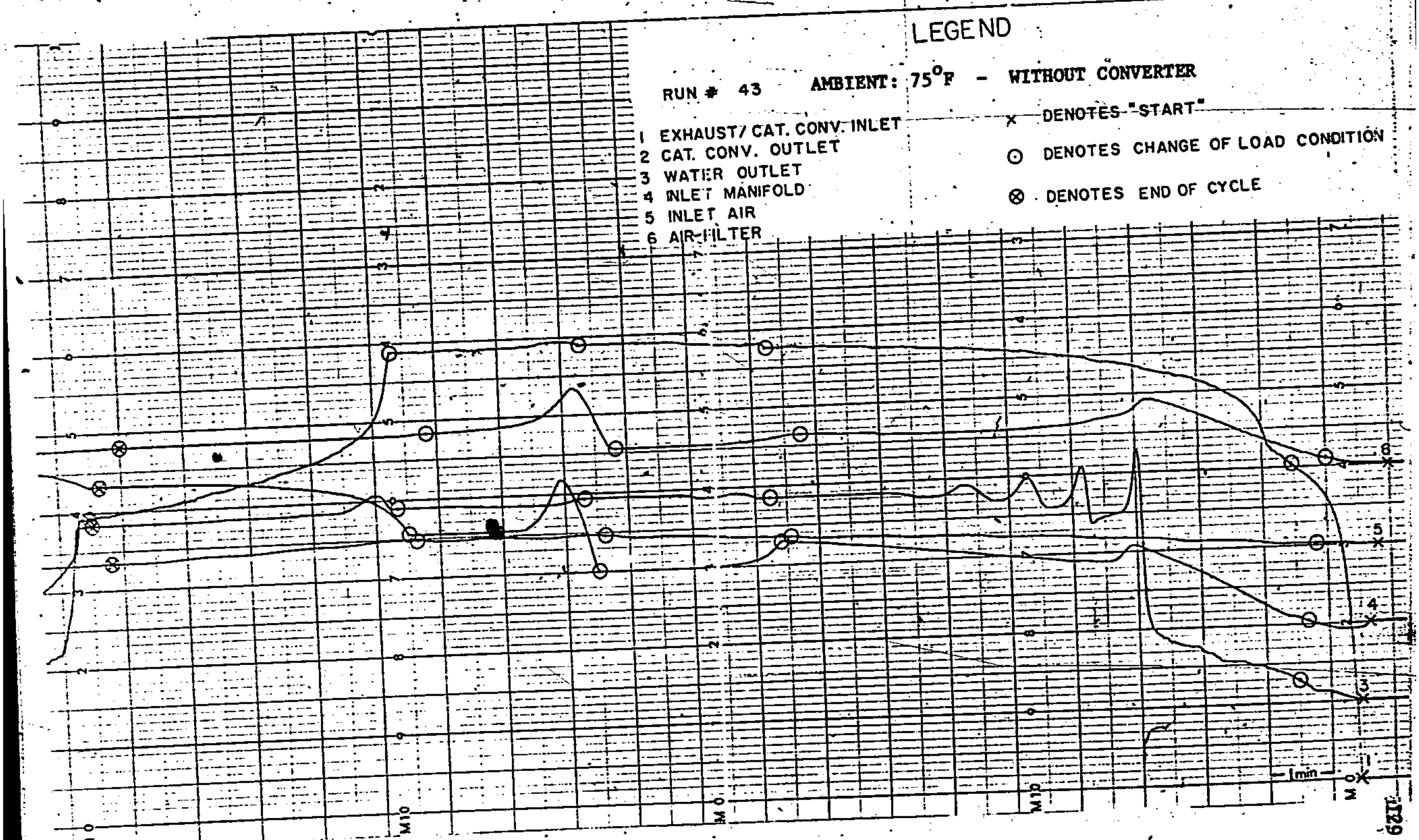

LEGEND
RUN # 43 AMBIENT: 75°F - WITHOUT CONVERTER
1 EXHAUST/ CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min
M0
M10

FIG. 5-28a.

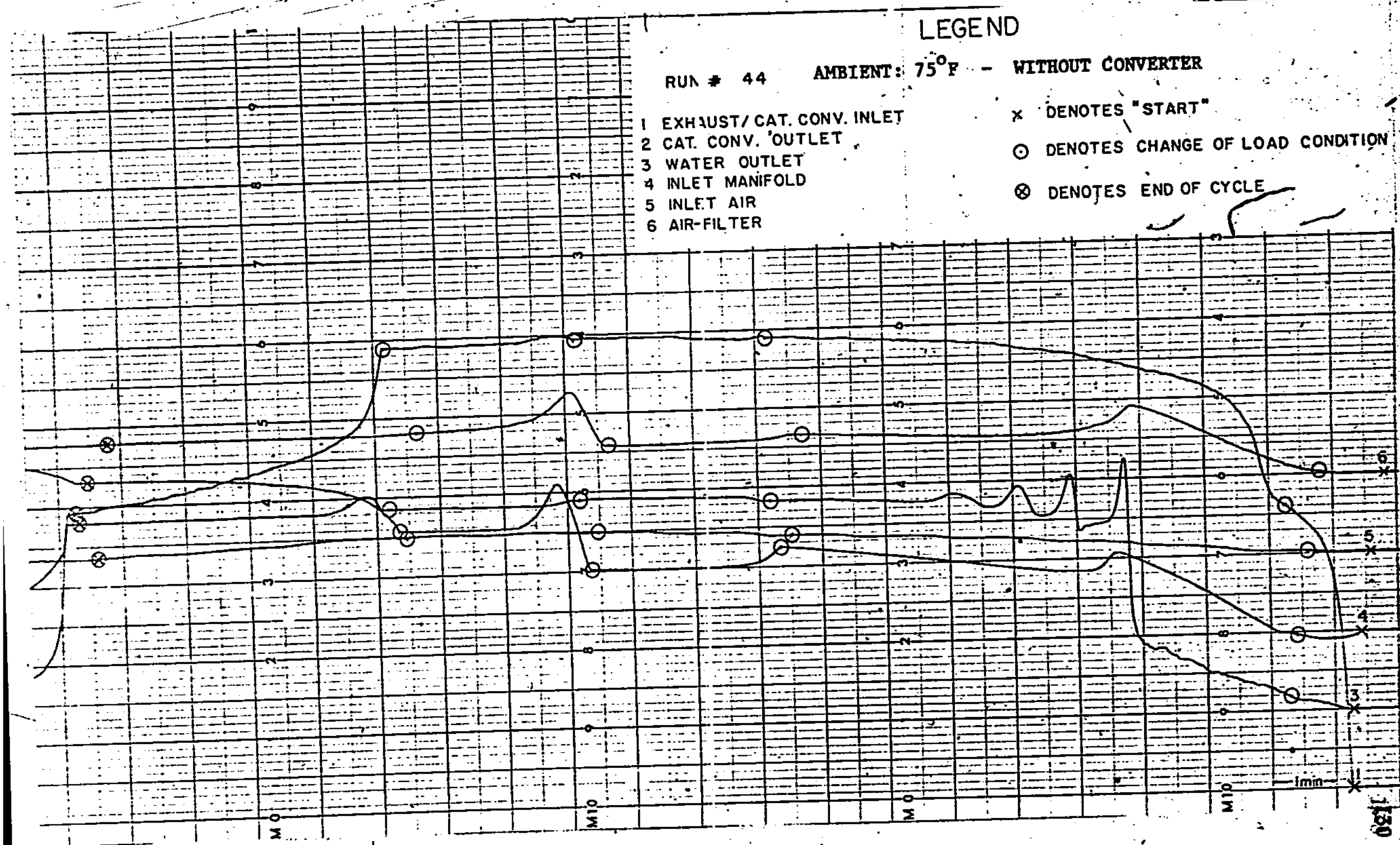

LEGEND
RUN # 44 AMBIENT: 75°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-29a.

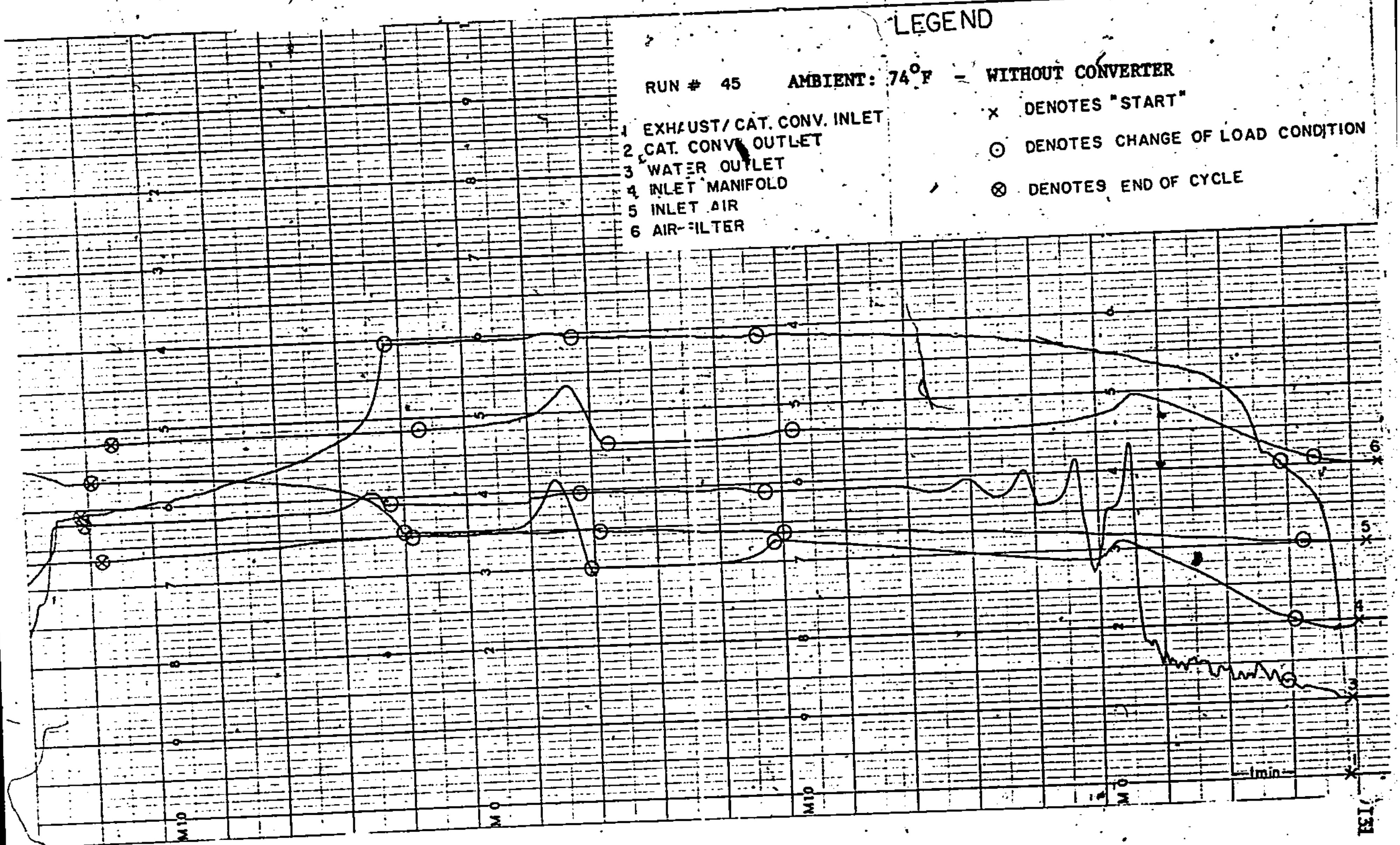

LEGEND
RUN # 45 AMBIENT: 74°F – WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-30a.

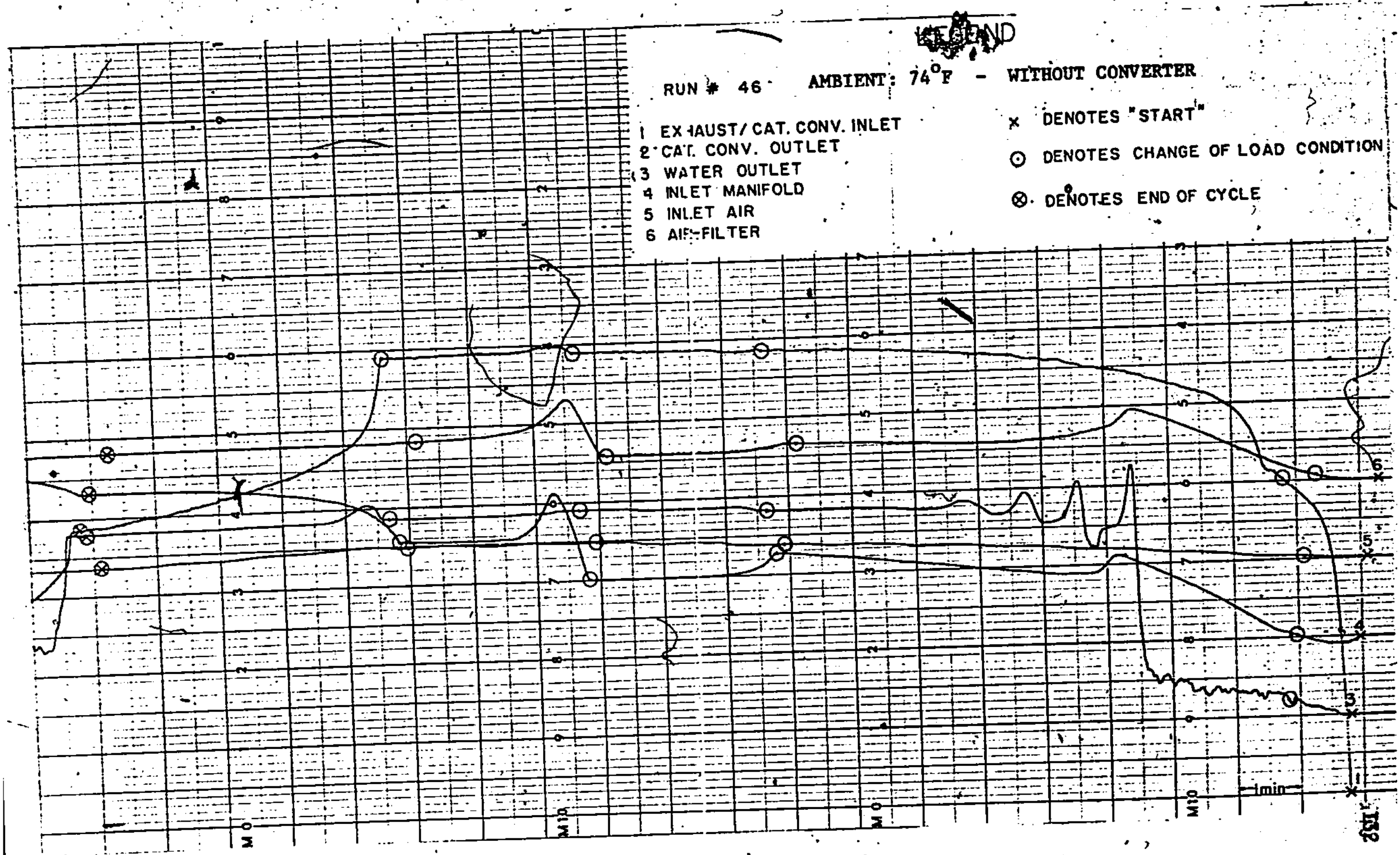
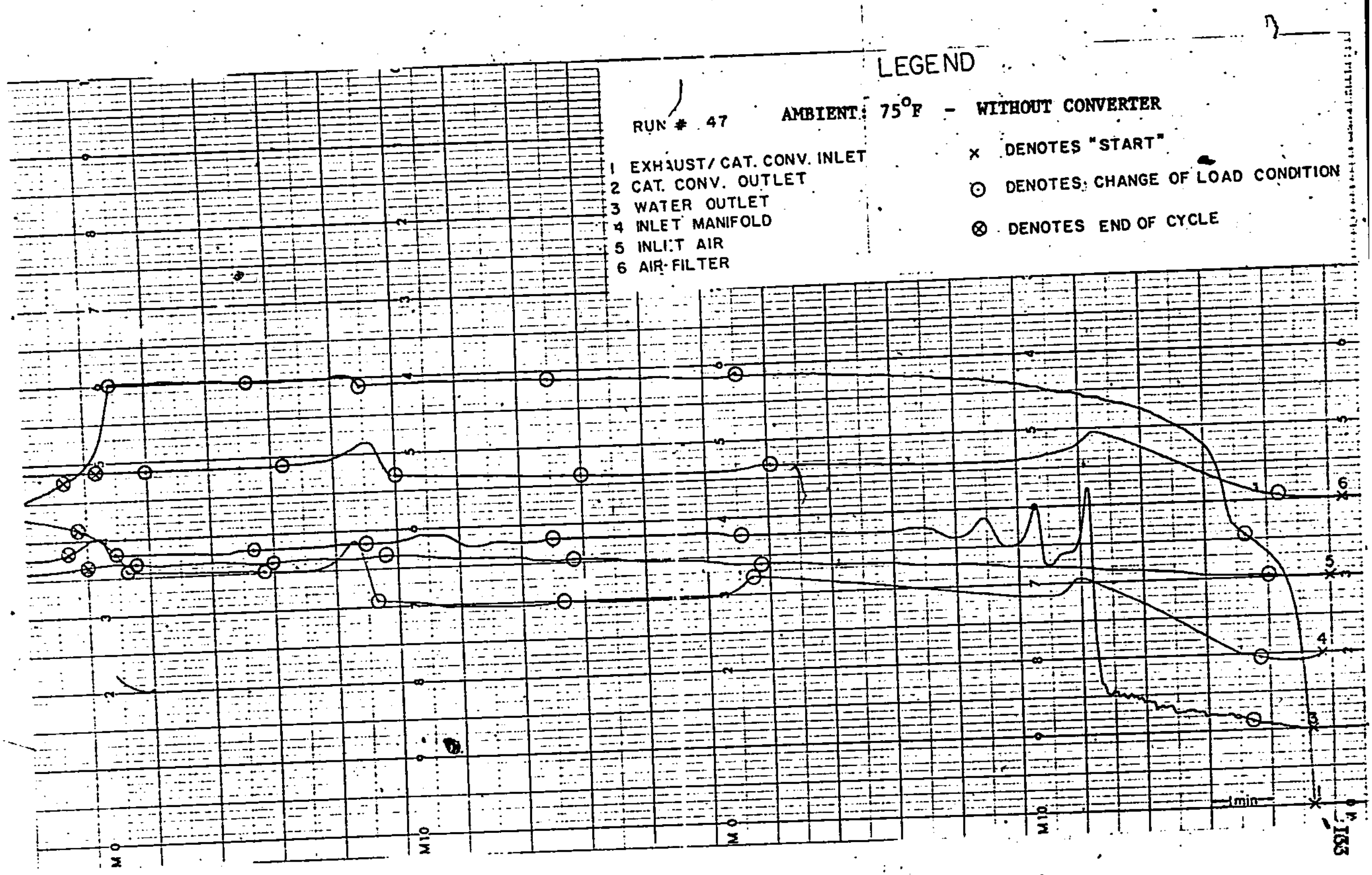
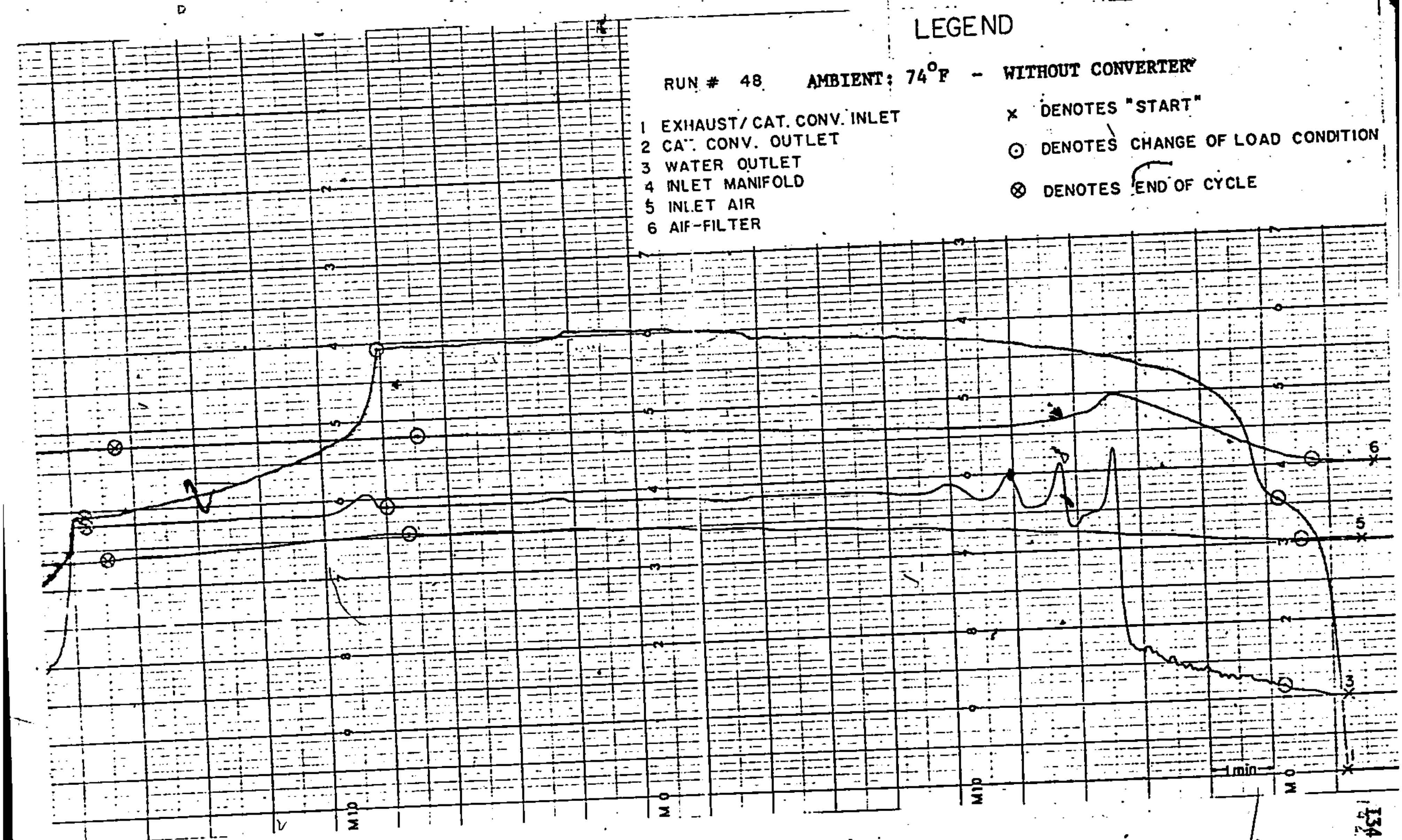

LEGEND
RUN # 46 AMBIENT: 74°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-31a.



LEGEND
RUN # 47
AMBIENT: 75°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIR FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min
M0
M10
M0
M10
133

FIG. 5-32a.



LEGEND
RUN # 48 AMBIENT: 74°F - WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 INLET MANIFOLD
5 INLET AIR
6 AIF-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min
M10
M0

FIG. 5-33a.

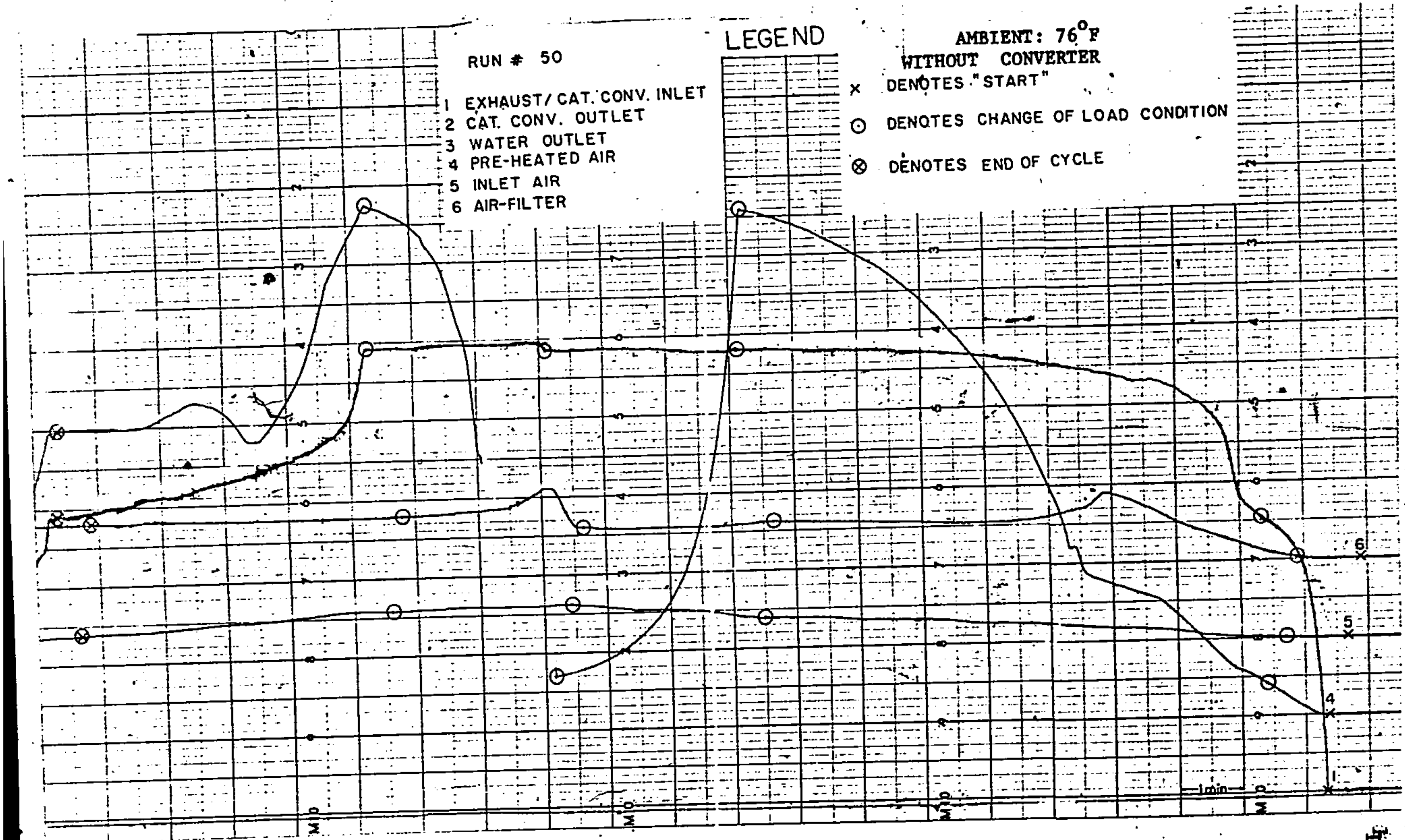

RUN # 50
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 PRE-HEATED AIR
5 INLET AIR
6 AIR-FILTER
LEGEND
AMBIENT: 76°F
WITHOUT CONVERTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-34a.

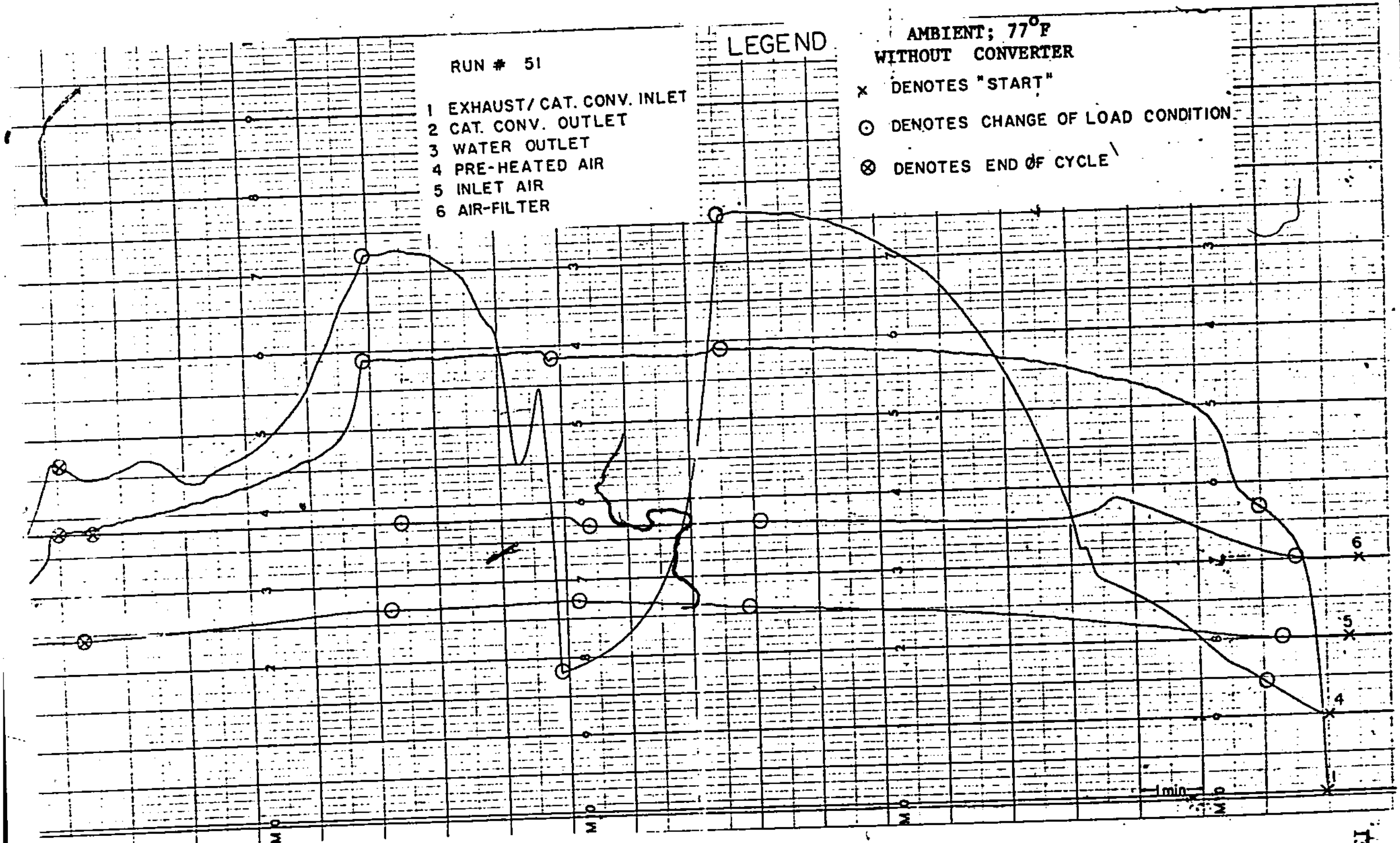

RUN # 51
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 PRE-HEATED AIR
5 INLET AIR
6 AIR-FILTER
LEGEND
AMBIENT; 77°F
WITHOUT CONVERTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-35a.

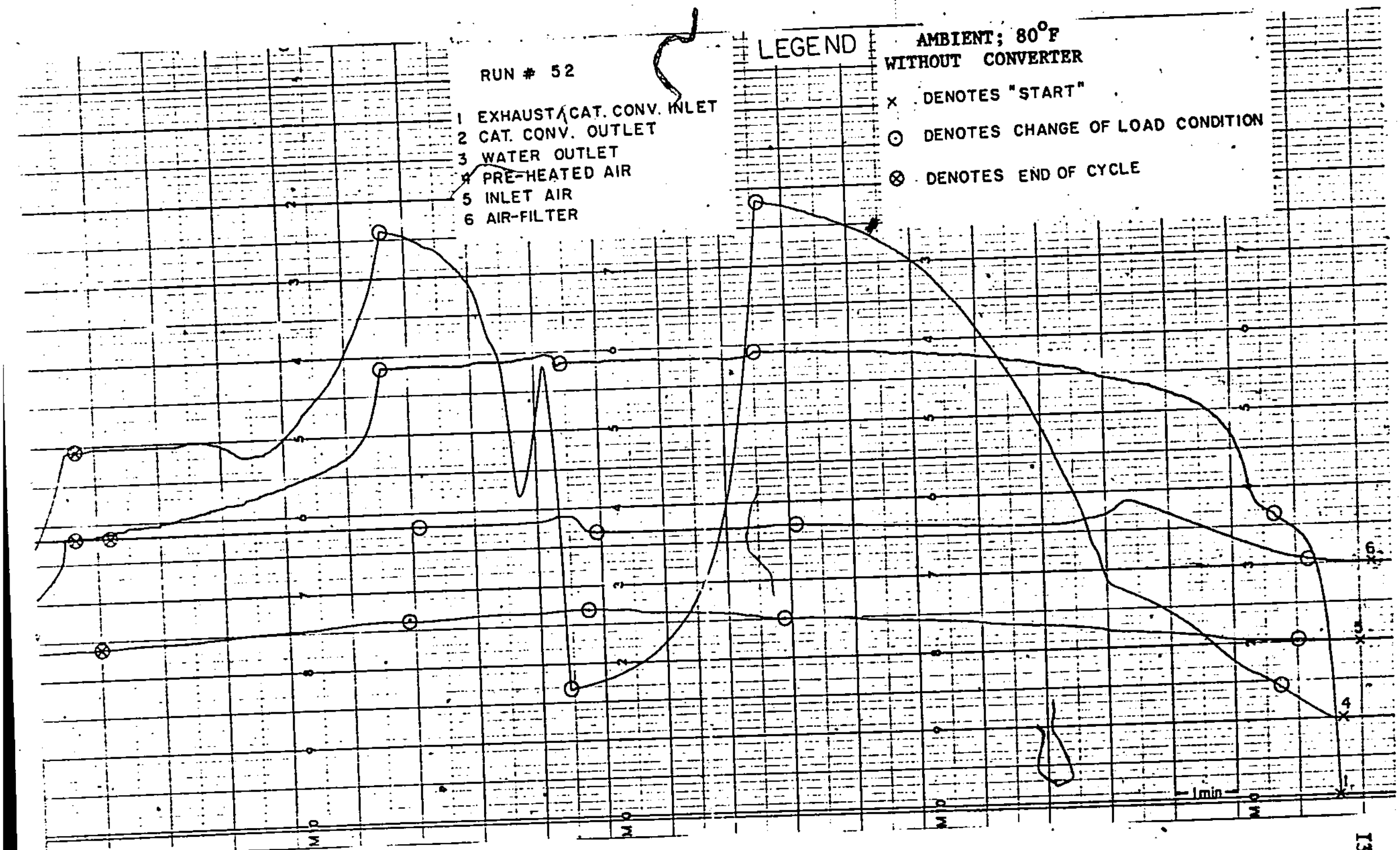
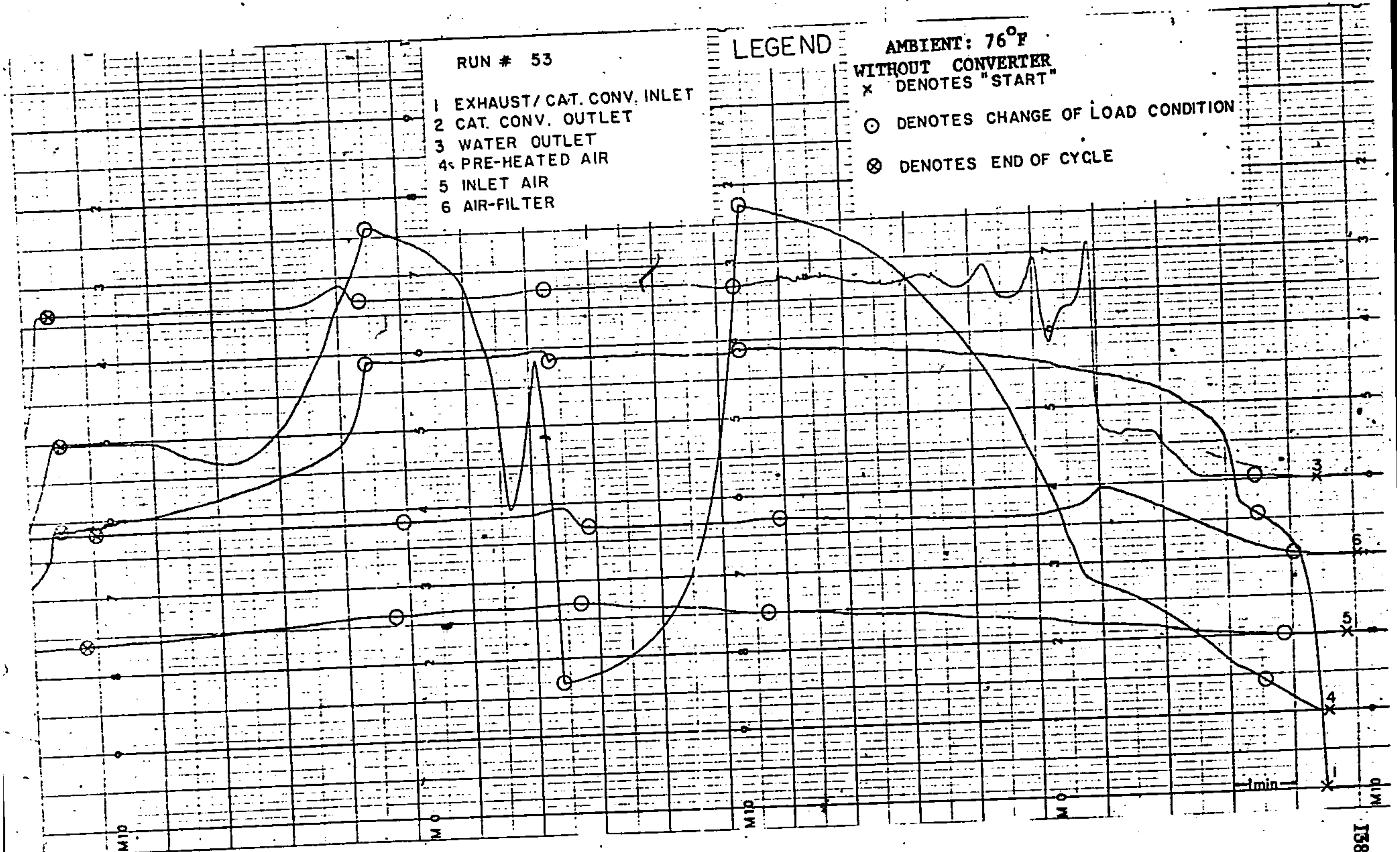

RUN # 52
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 PRE-HEATED AIR
5 INLET AIR
6 AIR-FILTER
LEGEND
AMBIENT; 80°F
WITHOUT CONVERTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-36a.



RUN # 53
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 PRE-HEATED AIR
5 INLET AIR
6 AIR-FILTER
LEGEND
AMBIENT: 76°F
WITHOUT CONVERTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min

FIG. 5-37a.

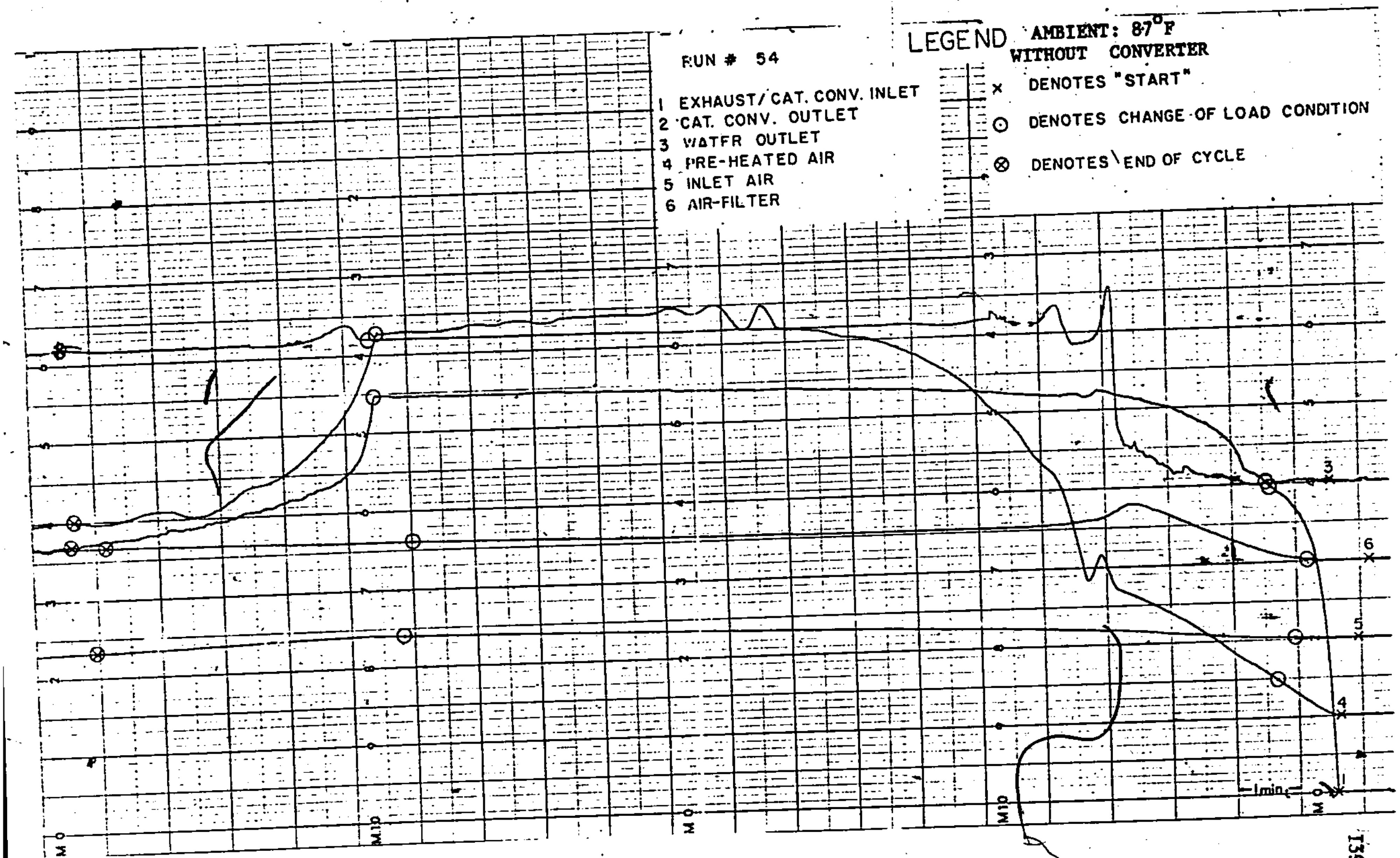
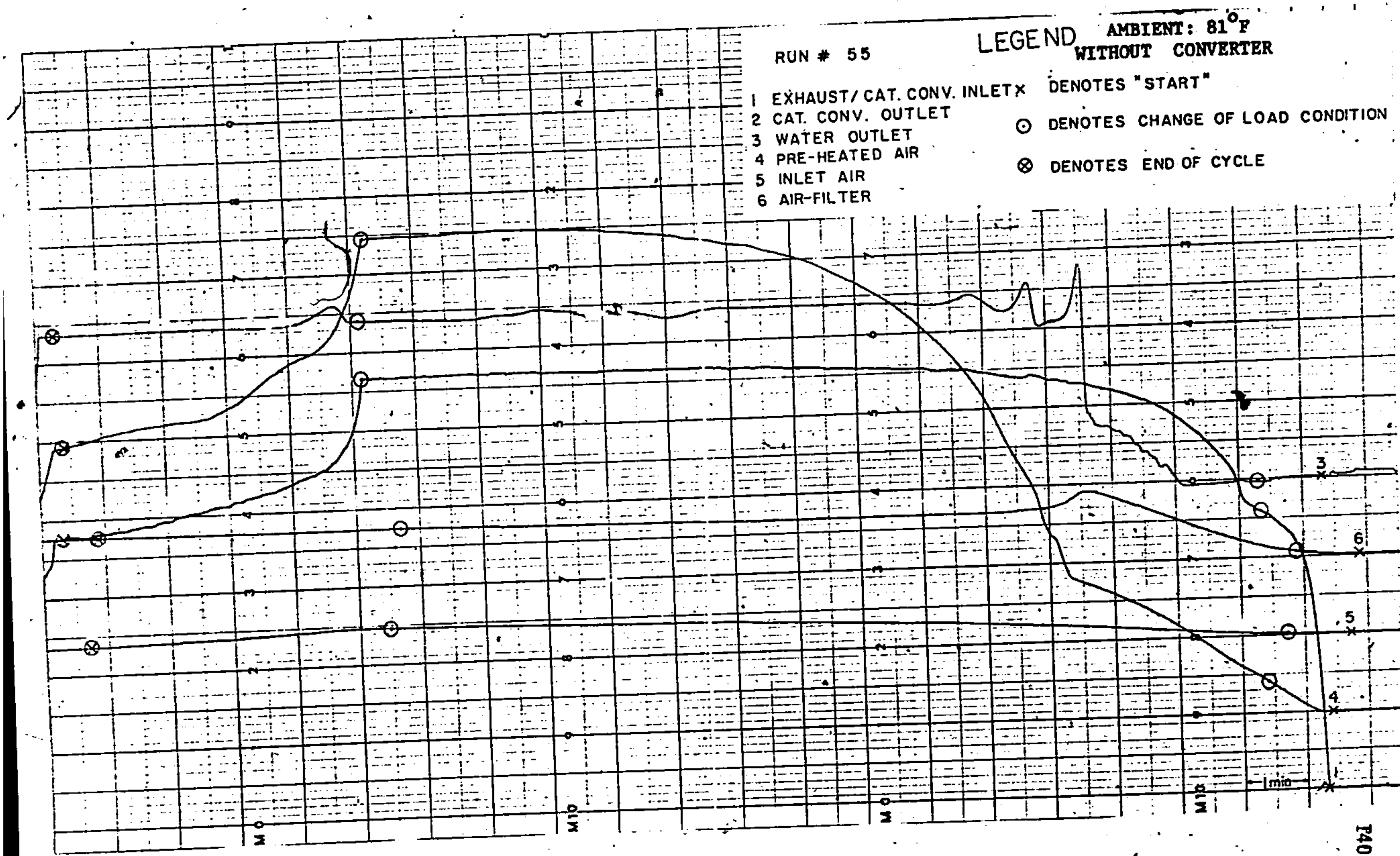
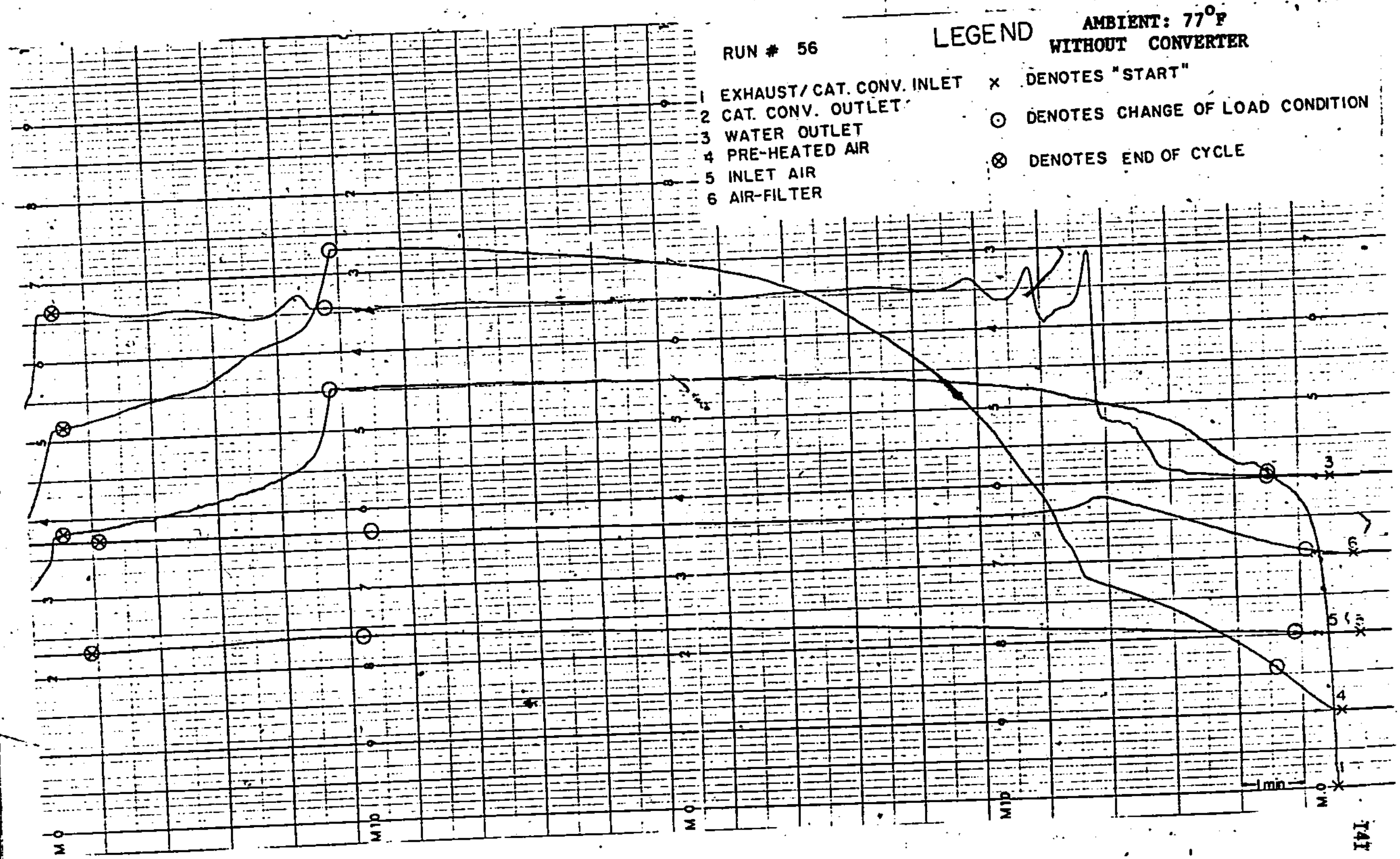

RUN # 54
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATFR OUTLET
4 PRE-HEATED AIR
5 INLET AIR
6 AIR-FILTER
LEGEND AMBIENT: 87°F
WITHOUT CONVERTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1min
M0
M10
3
6
5
4

FIG. 5-38a.



RUN # 55
LEGEND
AMBIENT: 81°F
WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 PRE-HEATED AIR
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min
T40

FIG. 5-39a.



RUN # 56
LEGEND
AMBIENT: 77°F
WITHOUT CONVERTER
1 EXHAUST/CAT. CONV. INLET
2 CAT. CONV. OUTLET
3 WATER OUTLET
4 PRE-HEATED AIR
5 INLET AIR
6 AIR-FILTER
× DENOTES "START"
⊙ DENOTES CHANGE OF LOAD CONDITION
⊗ DENOTES END OF CYCLE
1 min
M0
M10

FIG. 5-40a.

T41

J. EMISSION LEVELS RECORDED ON STRIP-CHART RECORDER

FIGURES 5-1b THROUGH 5-4b.

LEGEND

RUN # 18 AMBIENT: 23°F - WITHOUT CONVERTER

1 CARBON MONOXIDE

2 HYDROCARBONS

× DENOTES "START"

⊙ DENOTES CHANGE OF LOAD CONDITION

⊗ DENOTES "SHUT DOWN"

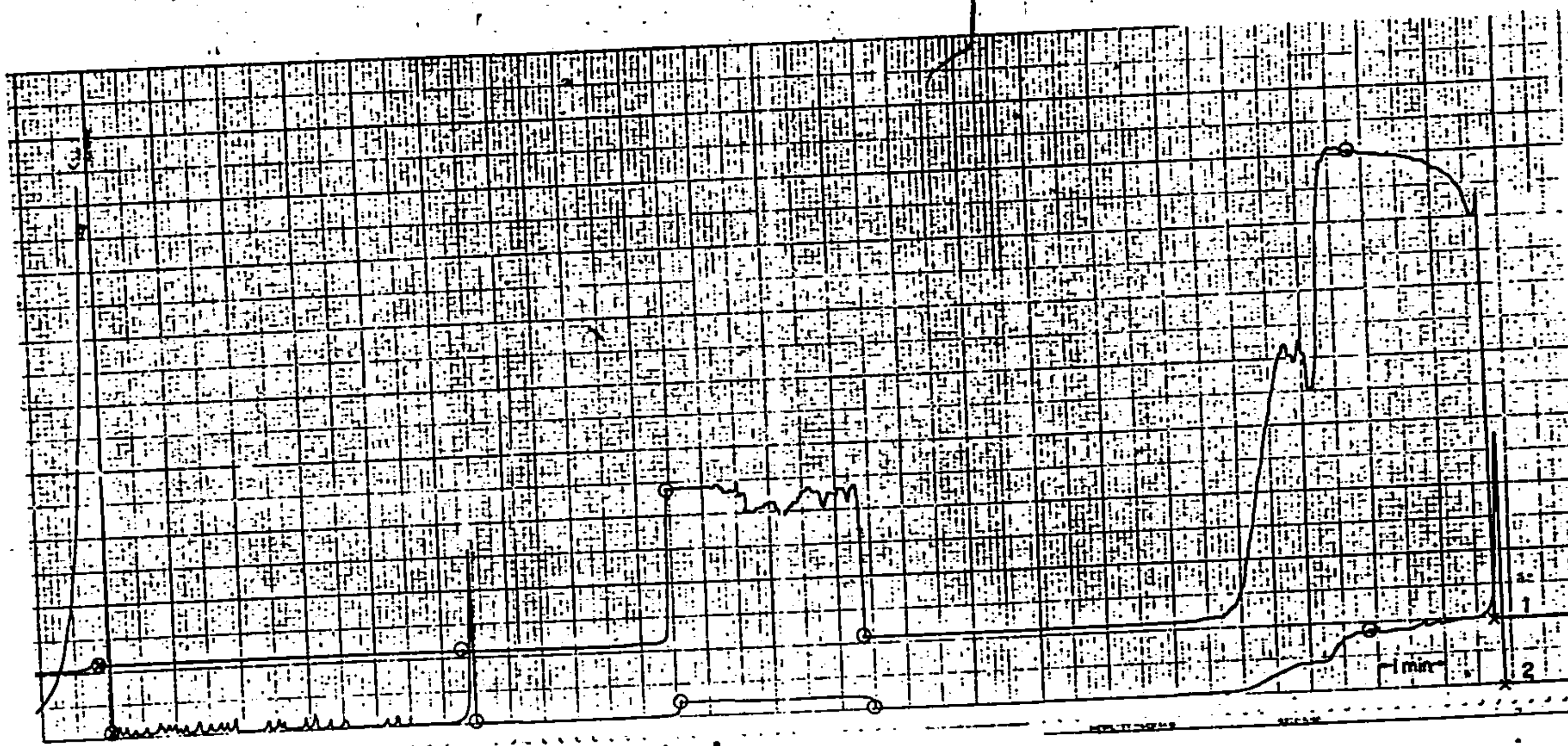


FIG. 5-1b. EMISSION LEVELS RECORDED ON STRIP-CHART RECORDER

LEGEND

RUN # 27

AMBIENT: 31°F - WITH CONVERTER

1 CARBON MONOXIDE

2 HYDROCARBONS

× DENOTES "START"

⊙ DENOTES CHANGE OF LOAD CONDITION

⊗ DENOTES "SHUT DOWN"

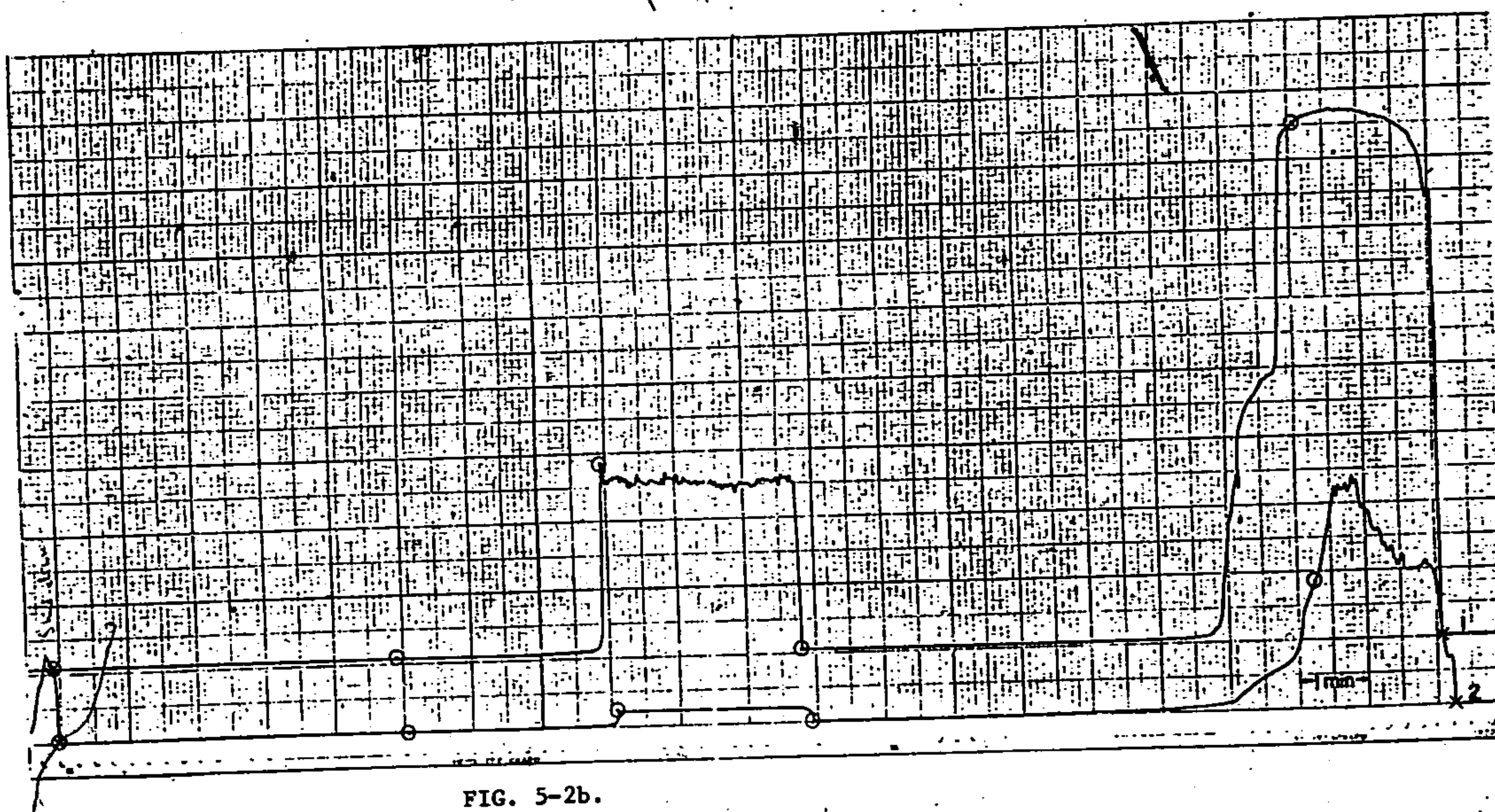


FIG. 5-2b.

LEGEND

RUN # 40 AMBIENT: 74°F - WITH CONVERTER

× DENOTES "START"

1 CARBON MONOXIDE - ⊙ DENOTES CHANGE OF LOAD CONDITION

2 HYDROCABBONS ⊗ DENOTES "SHUT DOWN"

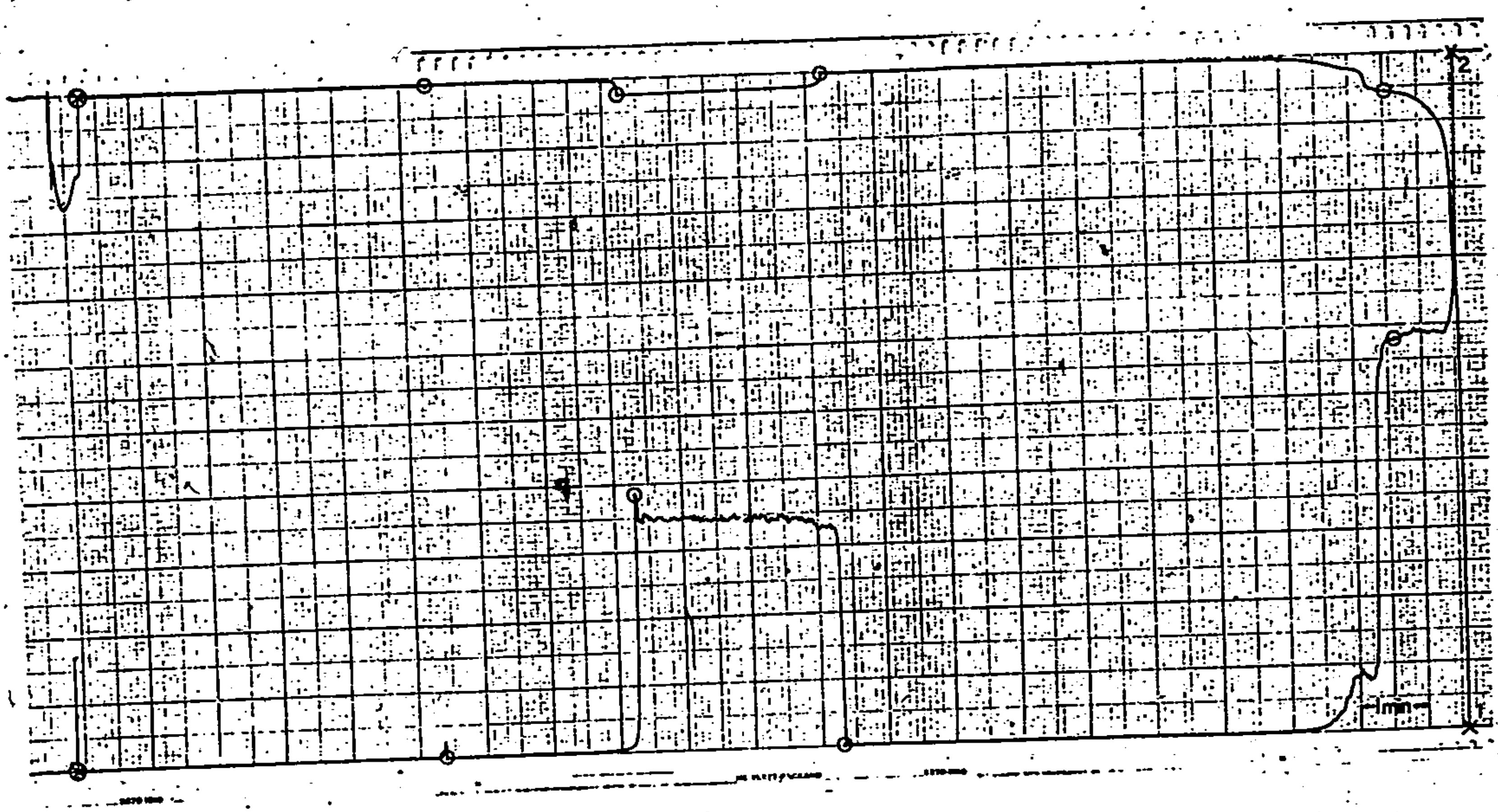


FIG. 5-3b.

LEGEND

RUN # 46 AMBIENT: 74°F - WITHOUT CONVERTER

× DENOTES "START"

1 CARBON MONOXIDE

⊙ DENOTES CHANGE OF LOAD CONDITION

2 HYDROCARBONS

⊗ DENOTES "SHUT DOWN"

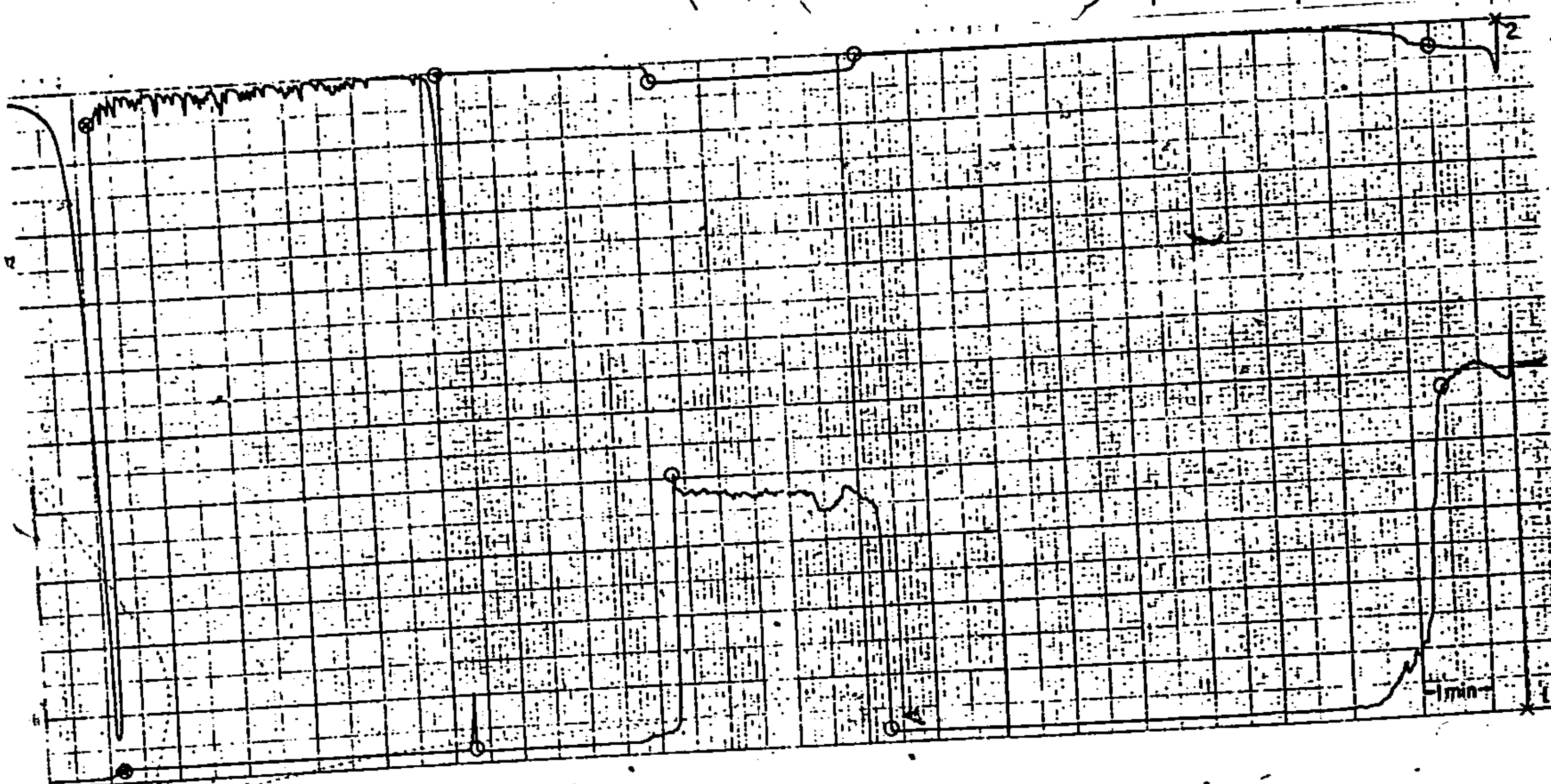
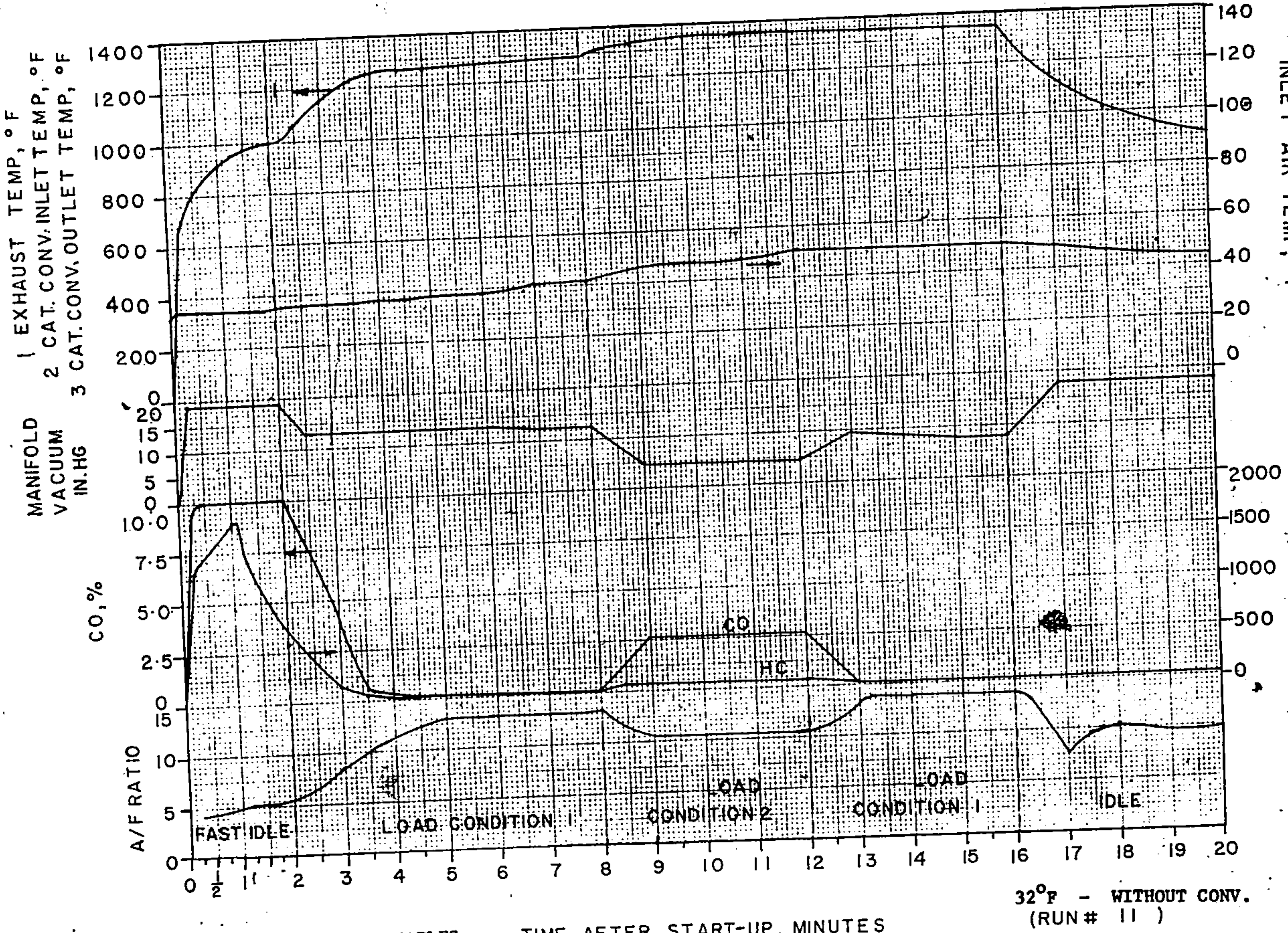


FIG. 5-4b.

K. ENGINE VARIABLES VS. TIME

FIGURES 5-1c THROUGH 5-32c.

K2



32°F - WITHOUT CONV.
(RUN # 11)

FIG. 5-1c. ENGINE VARIABLES VS. TIME.

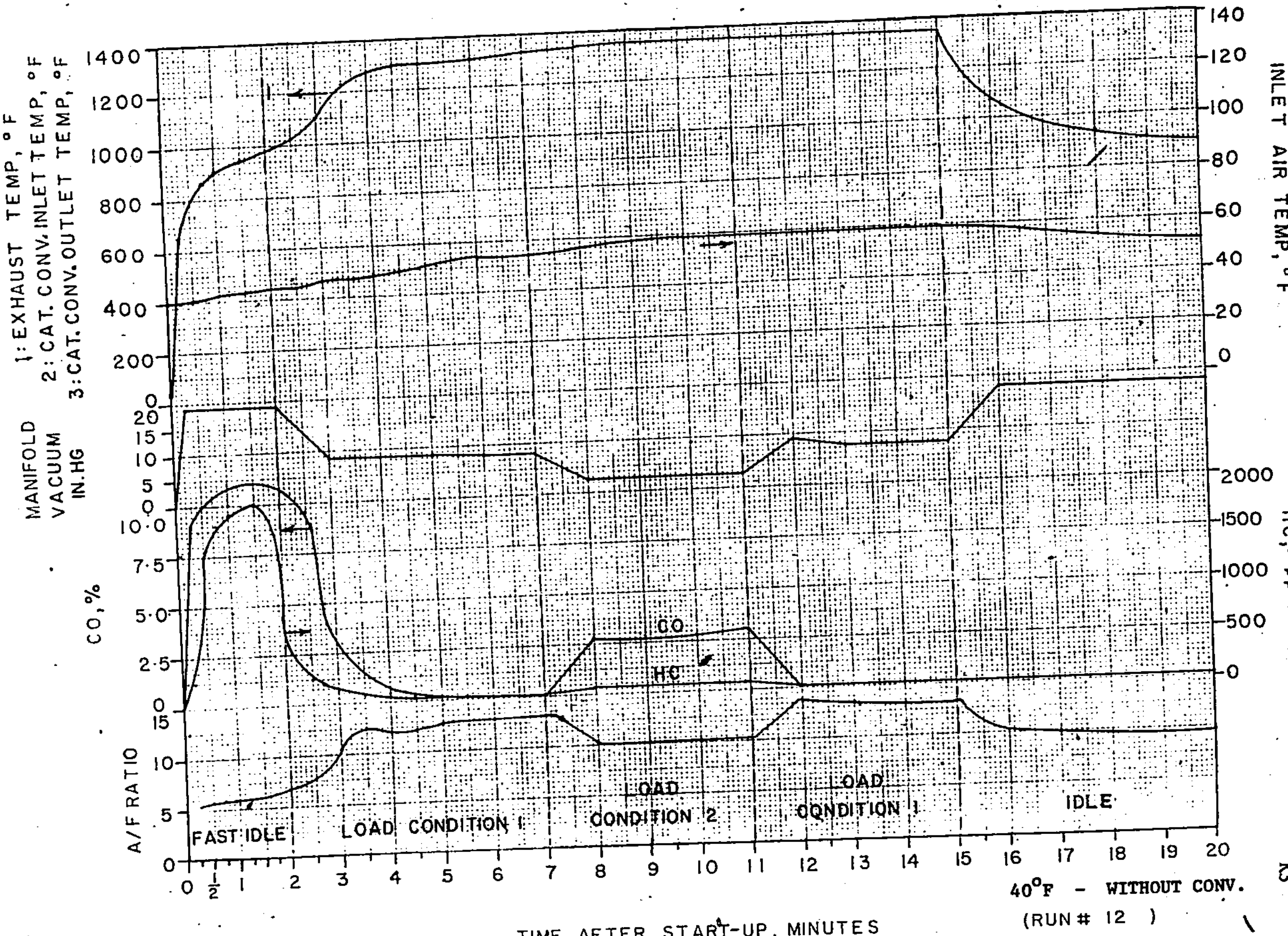

1: EXHAUST TEMP, °F
2: CAT. CONV. INLET TEMP, °F
3: CAT. CONV. OUTLET TEMP, °F
MANIFOLD VACUUM IN.HG
CO, %
A/F RATIO
INLET AIR TEMP, °F
HC, ppm
CO
HC
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
TIME AFTER START-UP, MINUTES
40°F - WITHOUT CONV.
(RUN # 12)

FIG. 5-2c.

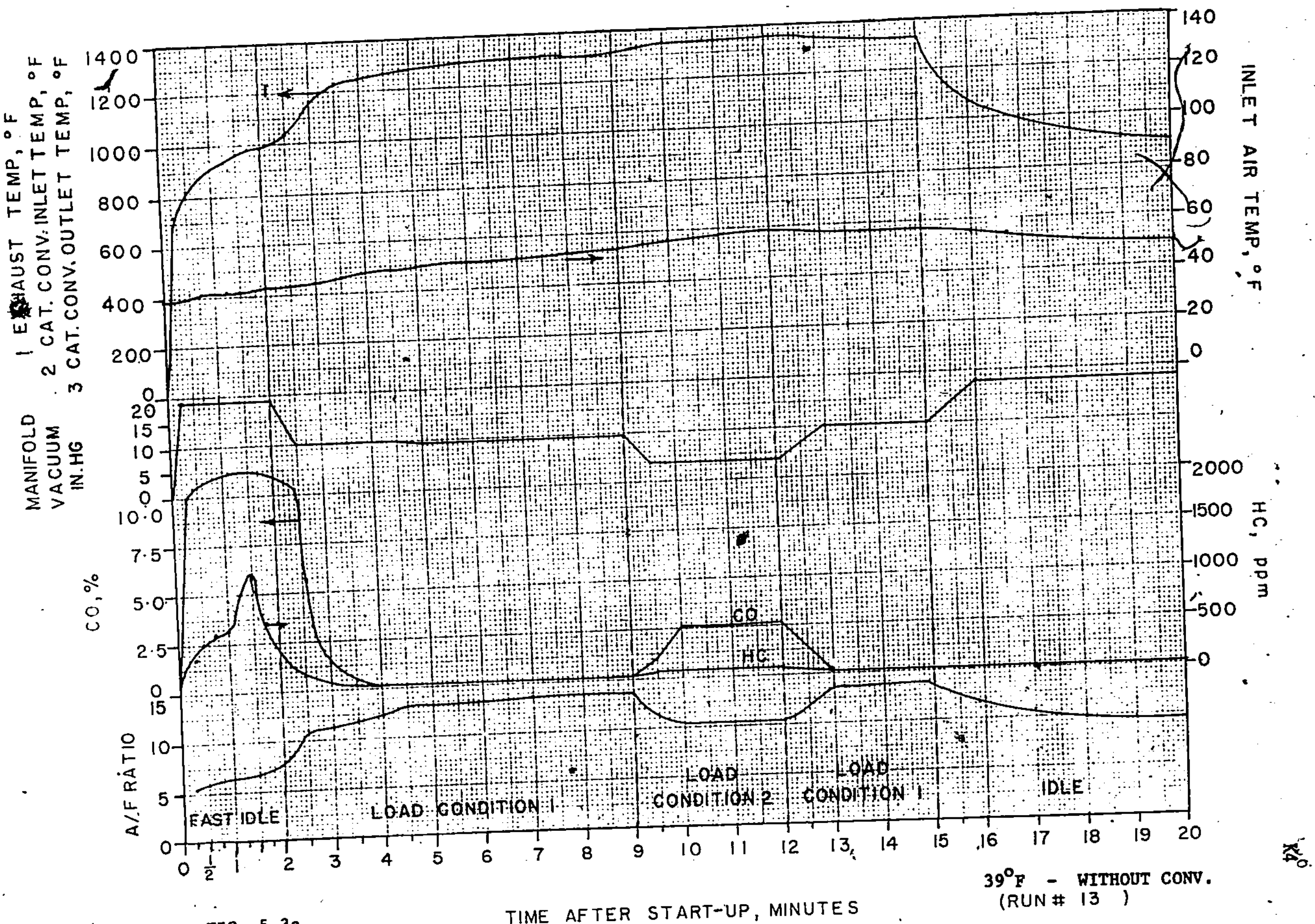
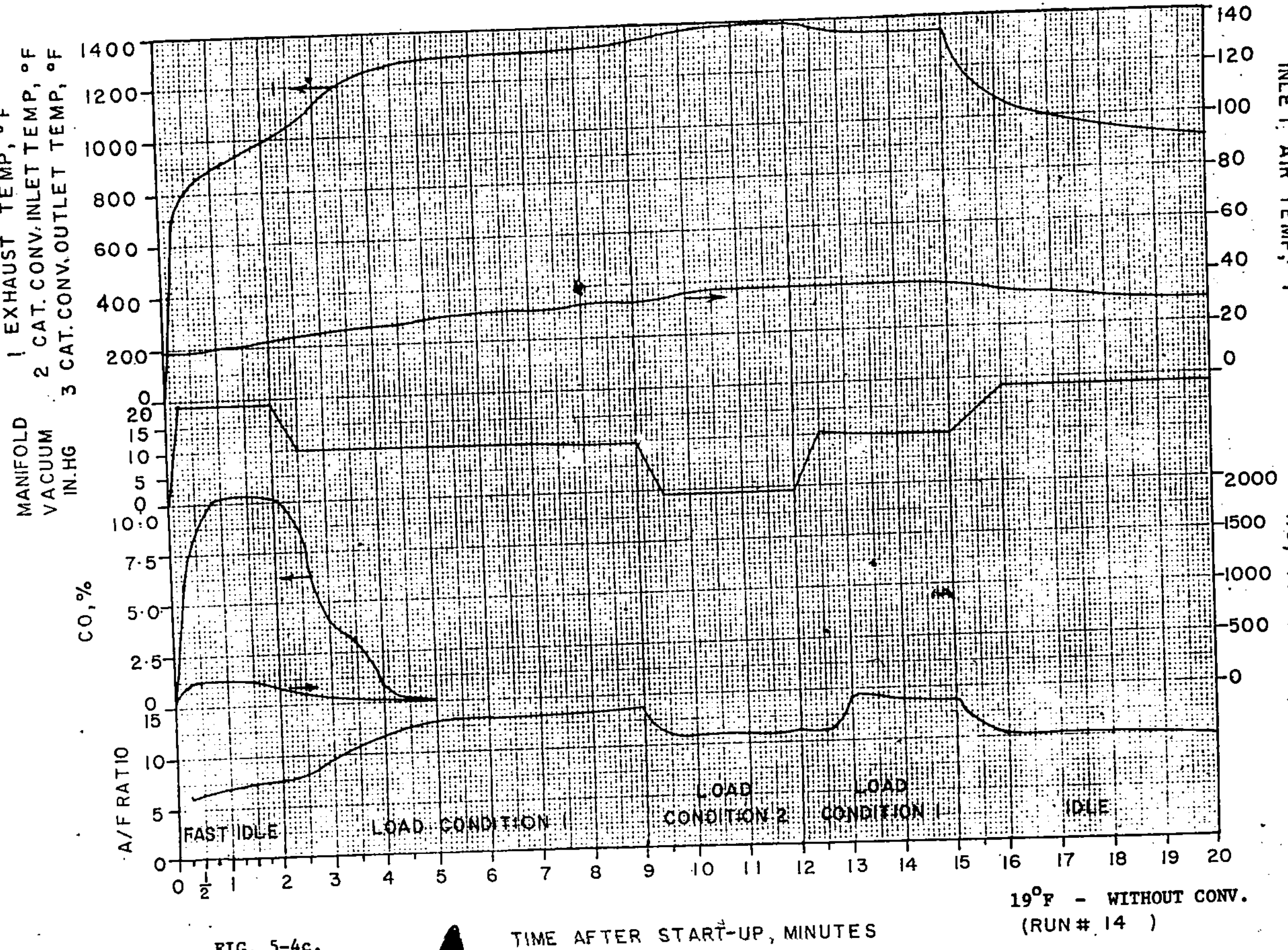

1 EXHAUST TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
1400
1200
1000
800
600
400
200
0
MANIFOLD VACUUM IN.HG
20
15
10
5
0
CO, %
10.0
7.5
5.0
2.5
0
A/F RATIO
15
10
5
0
INLET AIR TEMP, °F
140
120
100
80
60
40
20
0
HC, ppm
2000
1500
1000
500
0
CO
HC
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
0 1/2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TIME AFTER START-UP, MINUTES
39°F - WITHOUT CONV.
(RUN # 13)
K40

FIG. 5-3c.



19°F - WITHOUT CONV.
(RUN # 14)

K5

FIG. 5-4c.

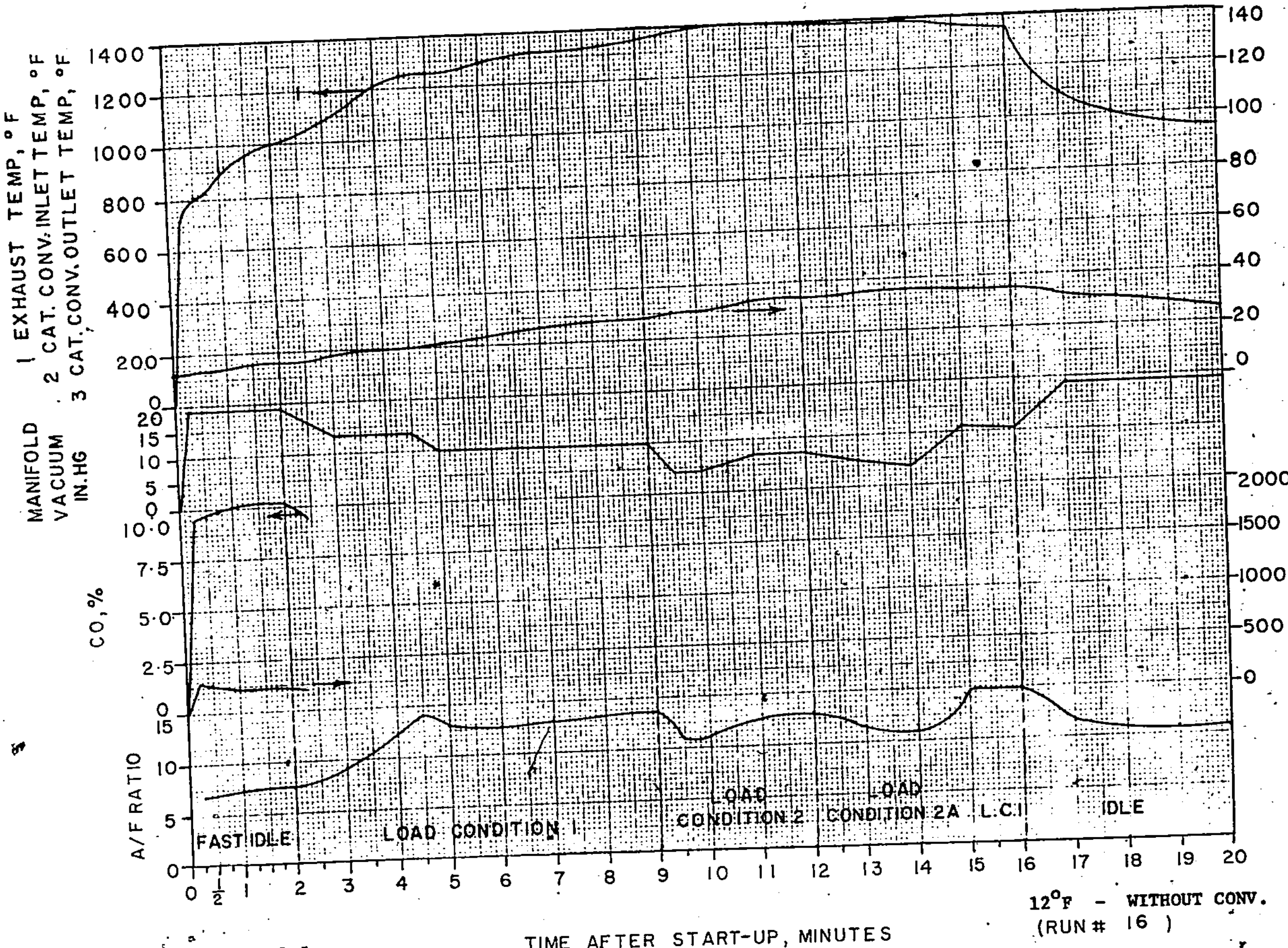


FIG. 5-5c.

12°F - WITHOUT CONV.
(RUN # 16)

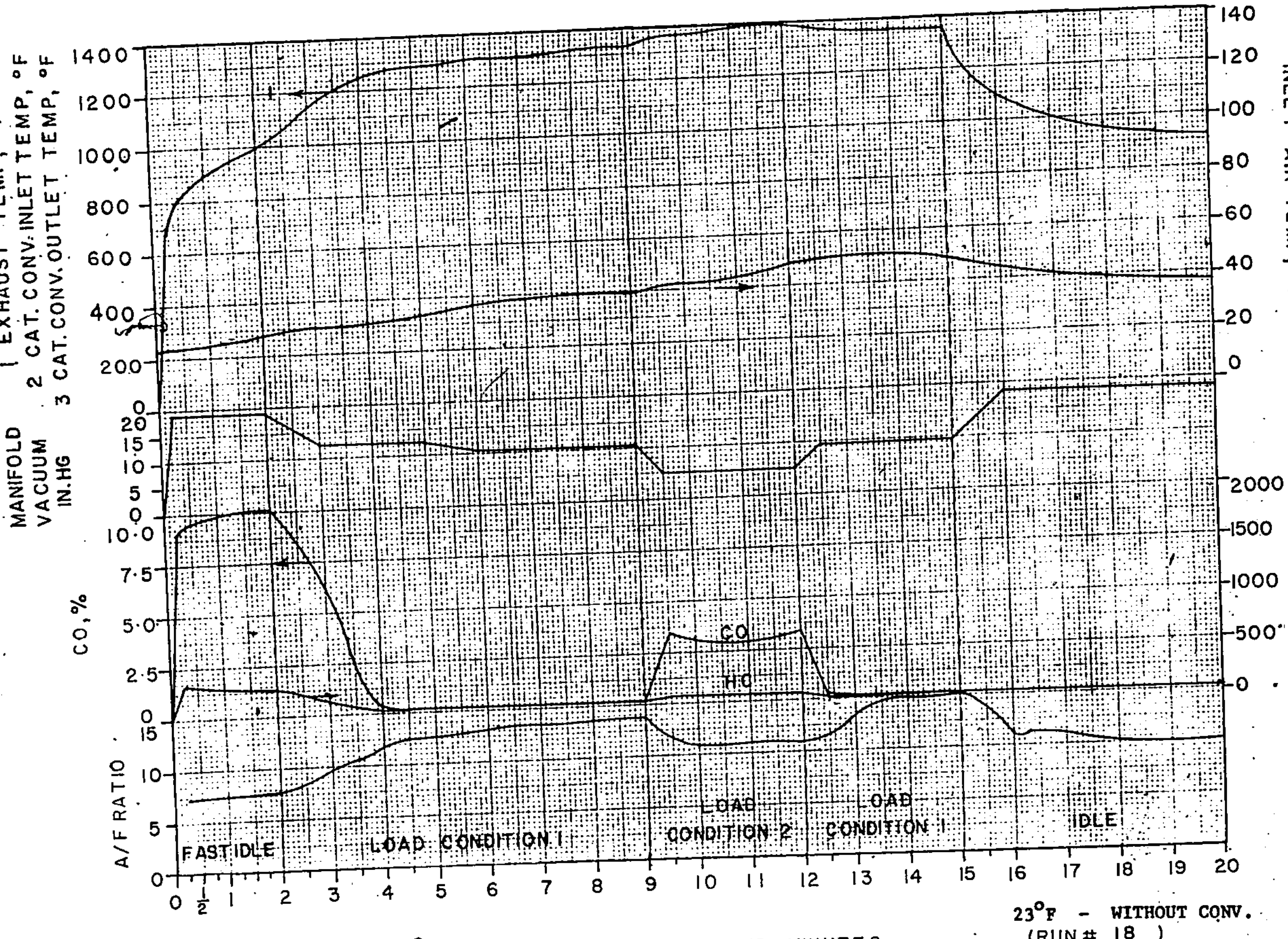

1 EXHAUST TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
1400
1200
1000
800
600
400
200
INLET AIR TEMP, °F
140
120
100
80
60
40
20
0
MANIFOLD VACUUM IN.HG
20
15
10
5
0
CO, %
10.0
7.5
5.0
2.5
0
HC, ppm
2000
1500
1000
500
0
CO
HC
A/F RATIO
15
10
5
0
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
0 1/2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TIME AFTER START-UP, MINUTES
23°F - WITHOUT CONV.
(RUN # 18)

FIG. 5-6c.

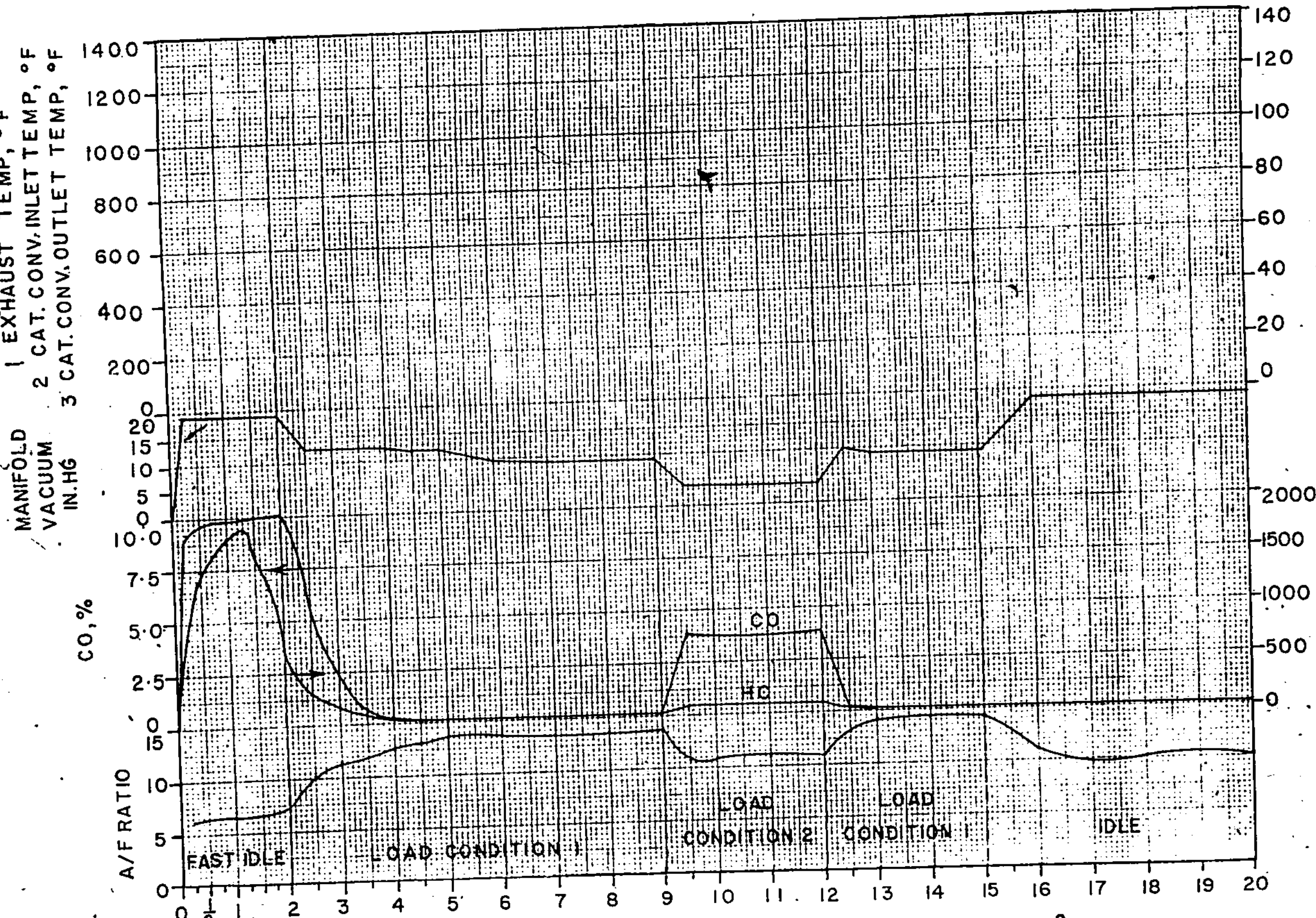


FIG. 5-7c.

34°F - WITHOUT CONV. (RUN # 19)

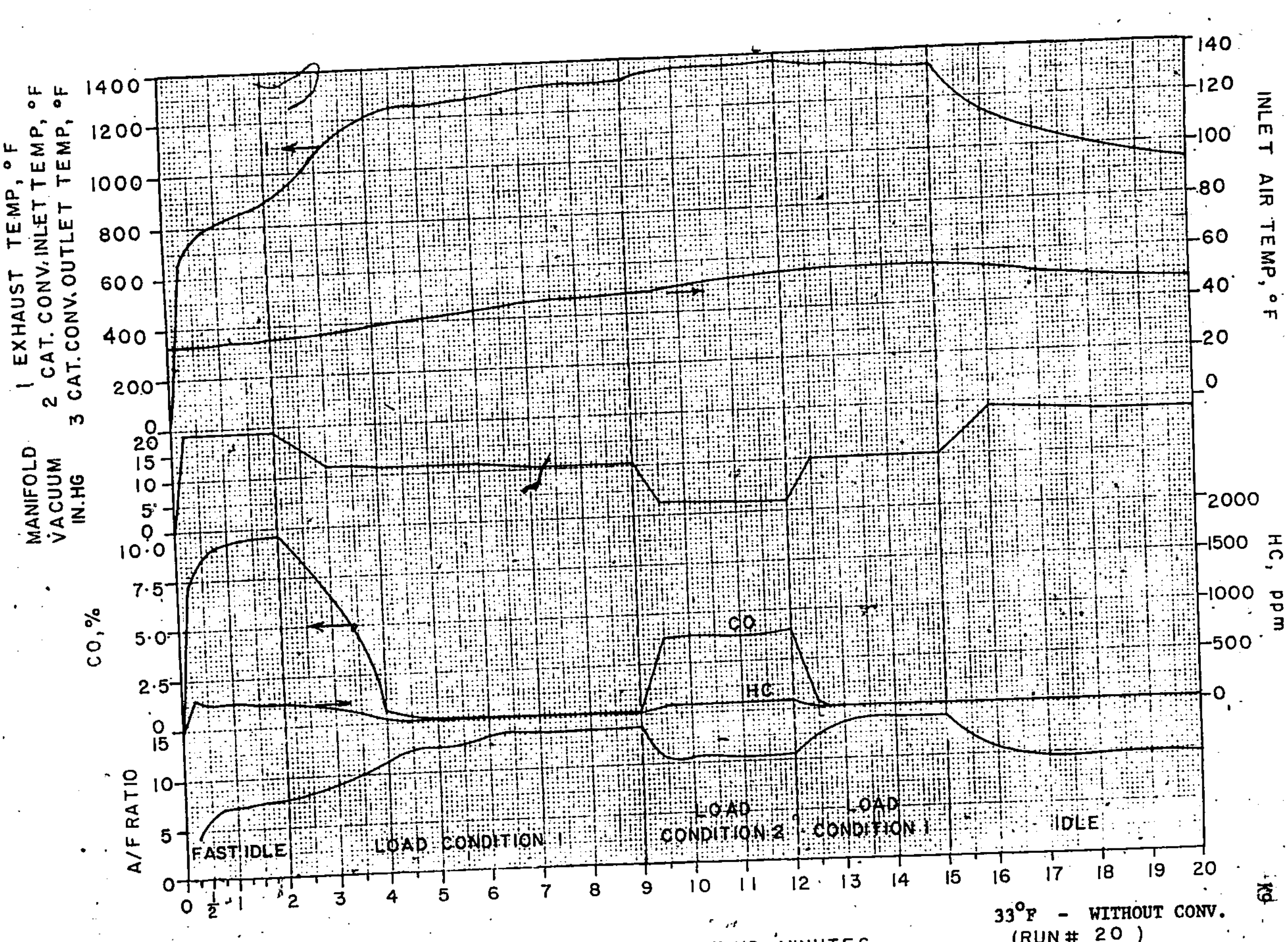
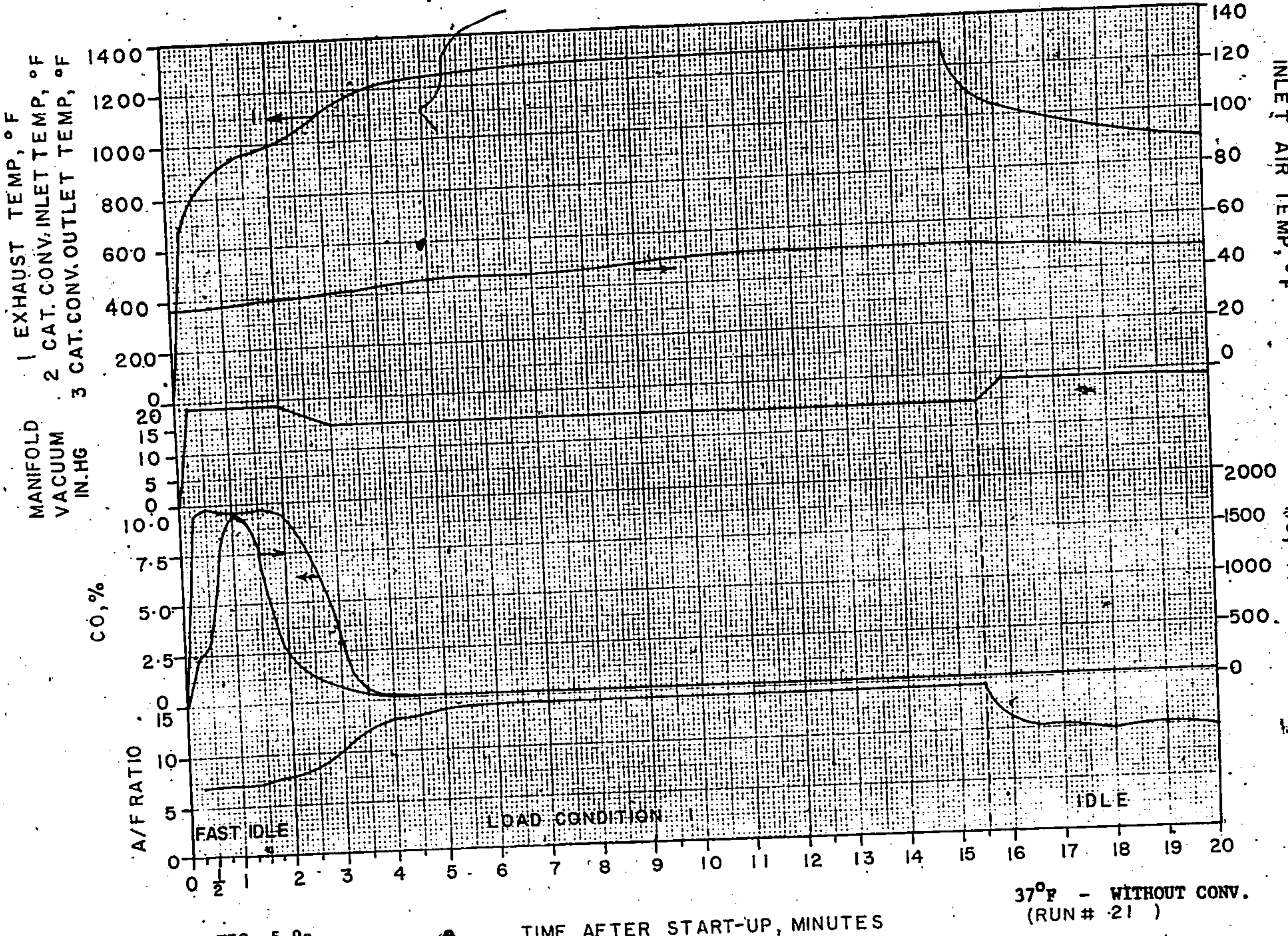

1 EXHAUST TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
INLET AIR TEMP, °F
MANIFOLD VACUUM IN.HG
CO, %
HC, ppm
A/F RATIO
CO
HC
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
TIME AFTER START-UP, MINUTES
33°F - WITHOUT CONV.
(RUN # 20)

FIG. 5-8c.



37°F - WITHOUT CONV.
(RUN # 21)

FIG. 5-9c.

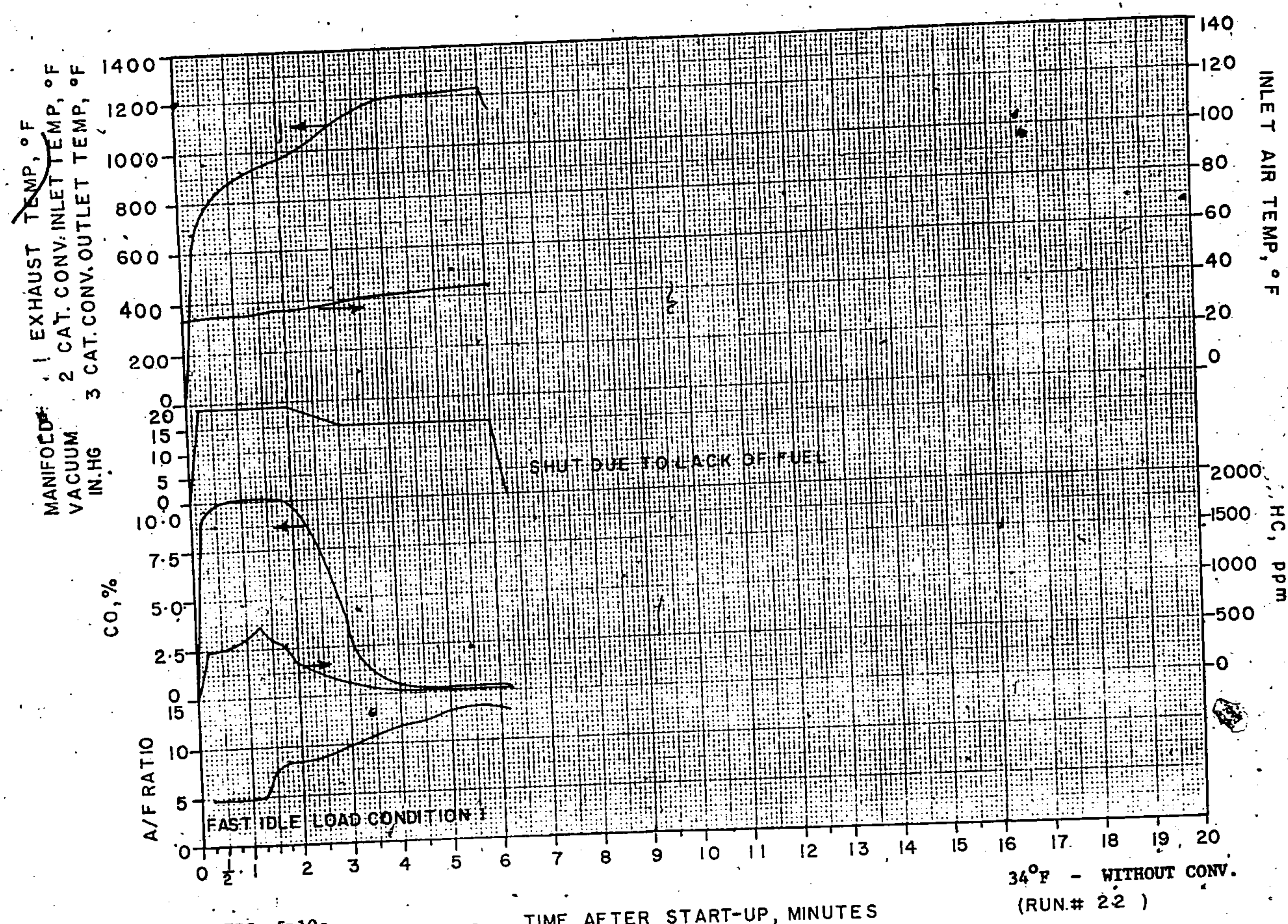

1 EXHAUST TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
1400
1200
1000
800
600
400
200
0
MANIFOLD VACUUM IN.HG
20
15
10
5
0
CO, %
10.0
7.5
5.0
2.5
0
A/F RATIO
15
10
5
0
INLET AIR TEMP, °F
140
120
100
80
60
40
20
0
HC, ppm
2000
1500
1000
500
0
SHUT DUE TO LACK OF FUEL
FAST IDLE LOAD CONDITION
0 ½ 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TIME AFTER START-UP, MINUTES
34°F - WITHOUT CONV.
(RUN.# 22)

FIG. 5-10c.

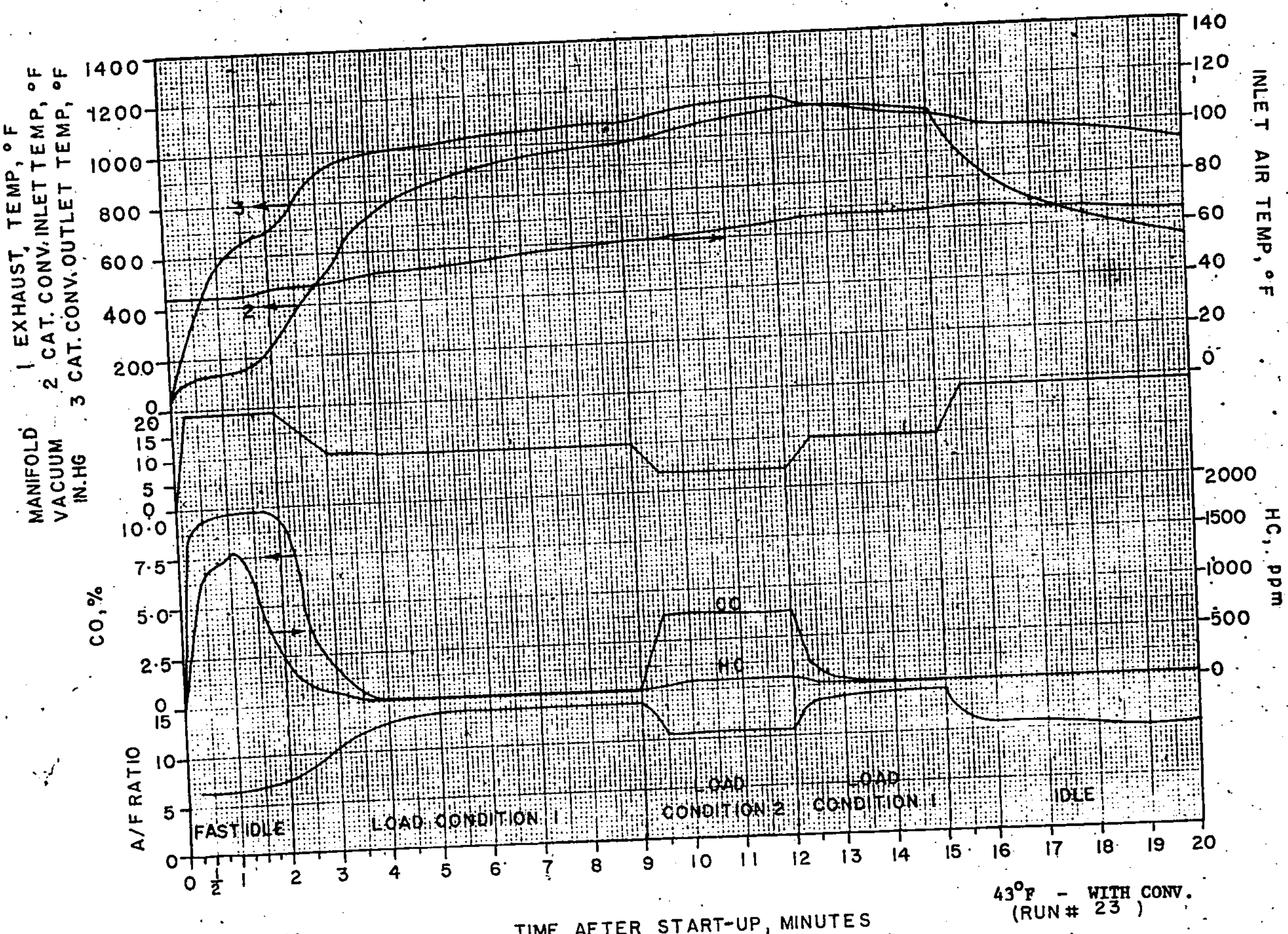

1 EXHAUST, TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
MANIFOLD VACUUM IN.HG
CO, %
A/F RATIO
INLET AIR TEMP, °F
HC, ppm
CO
HC
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
43°F - WITH CONV.
(RUN # 23)
TIME AFTER START-UP, MINUTES

FIG. 5-11c.

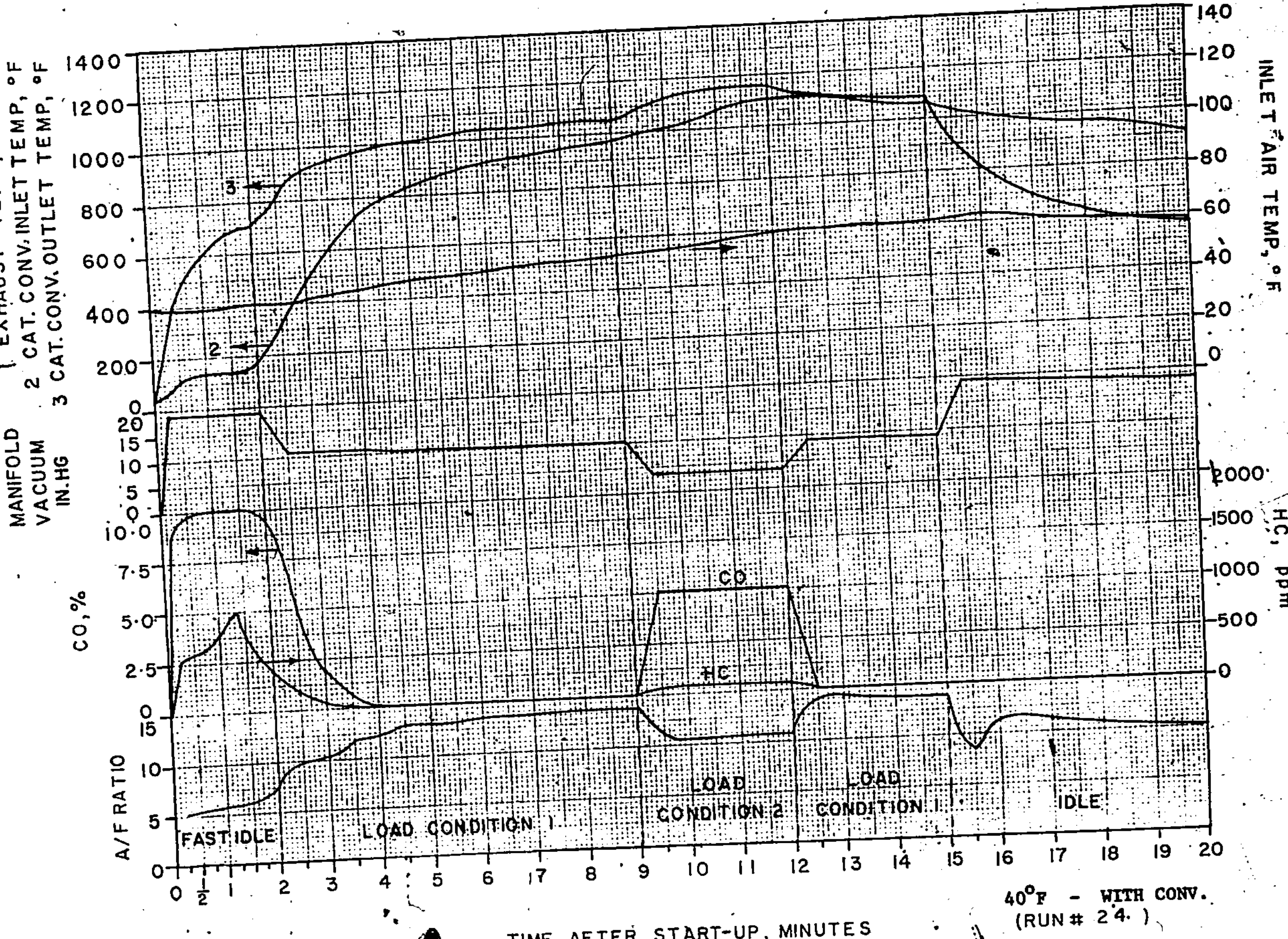

1 EXHAUST TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
MANIFOLD VACUUM IN.HG
CO, %
A/F RATIO
INLET AIR TEMP, °F
HC, ppm
CO
HC
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
TIME AFTER START-UP, MINUTES
40°F - WITH CONV.
(RUN # 24)

FIG. 5-12c.

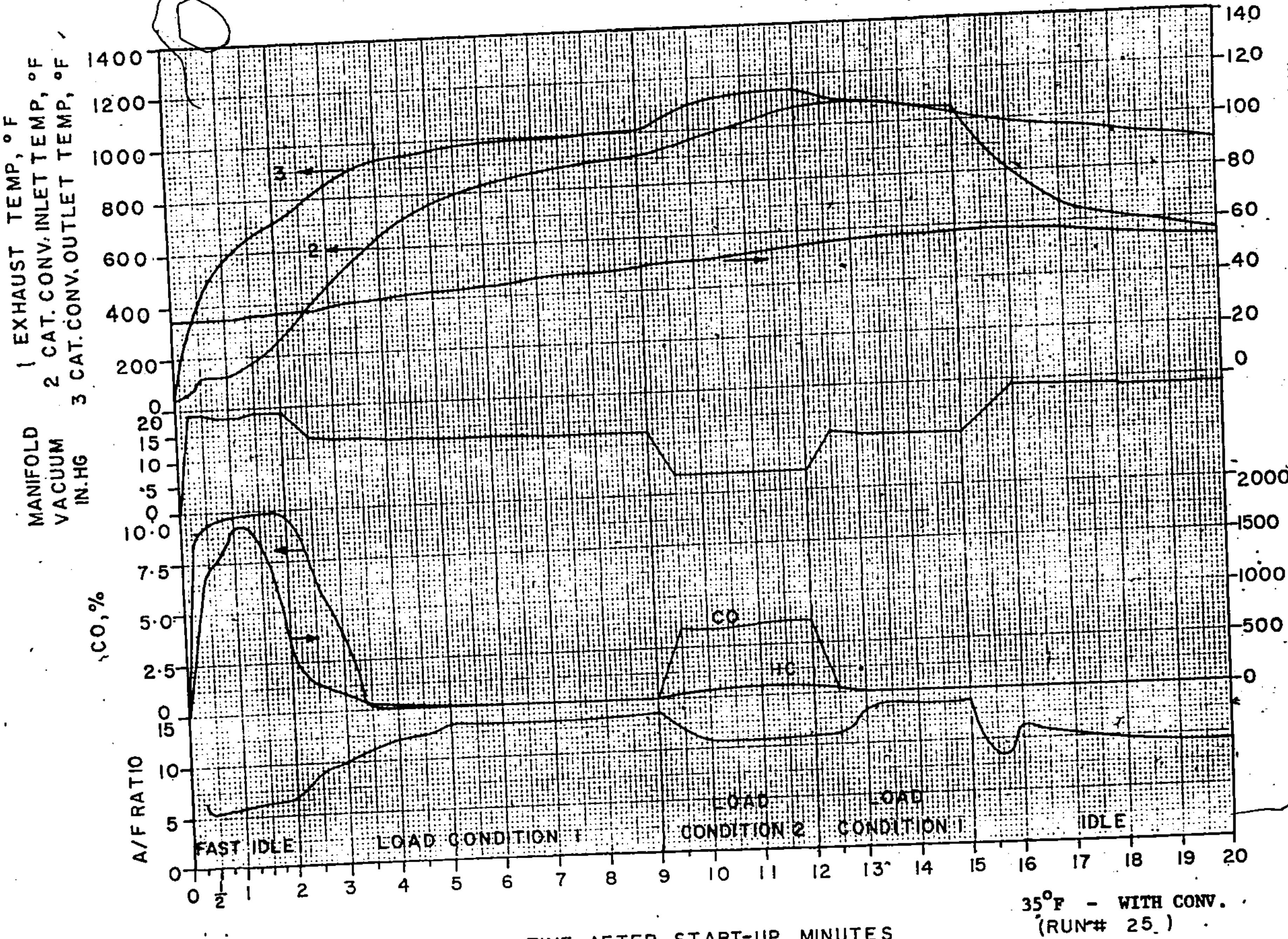


FIG. 5-13c.

35°F - WITH CONV.
(RUN# 25)

X14

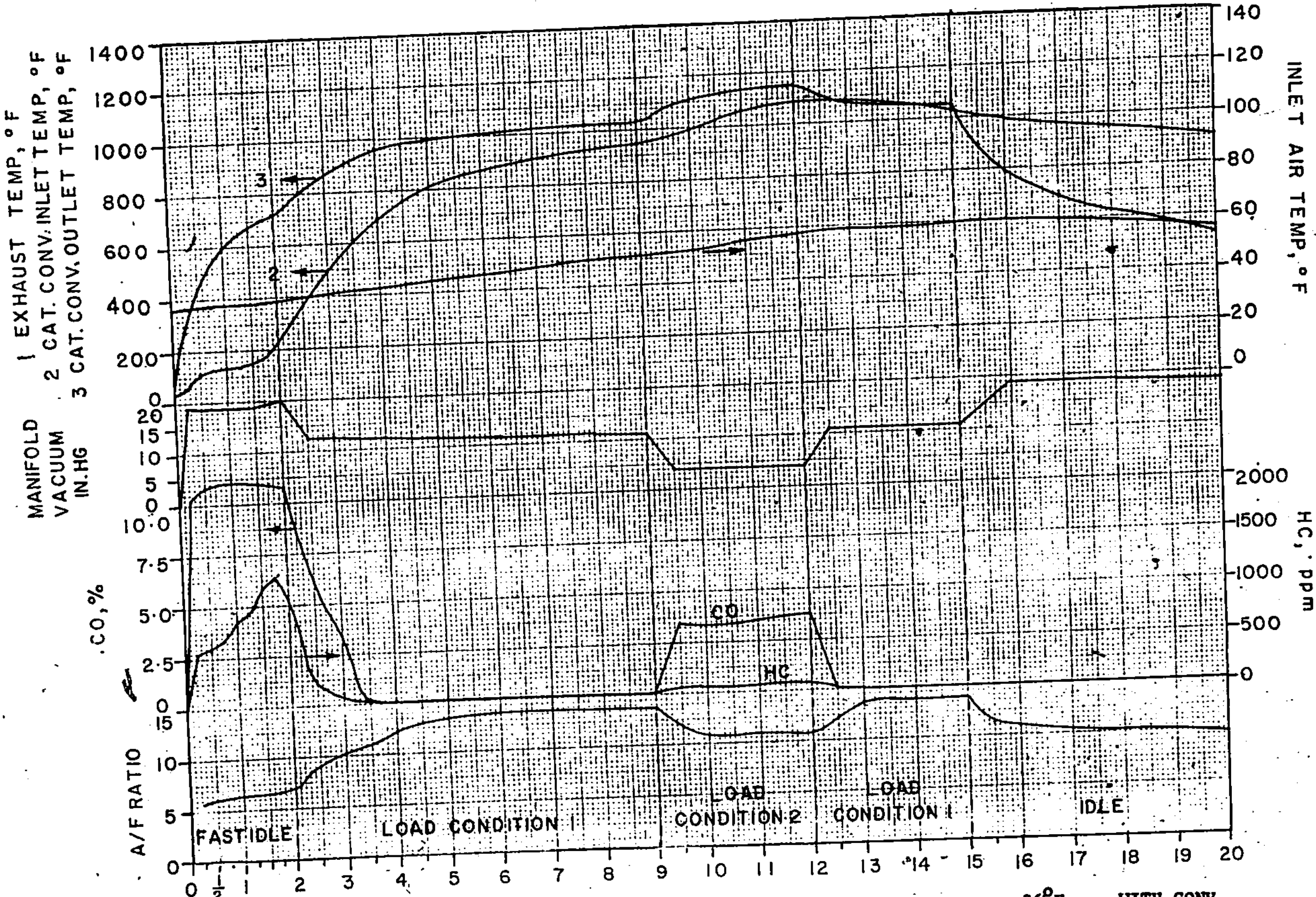
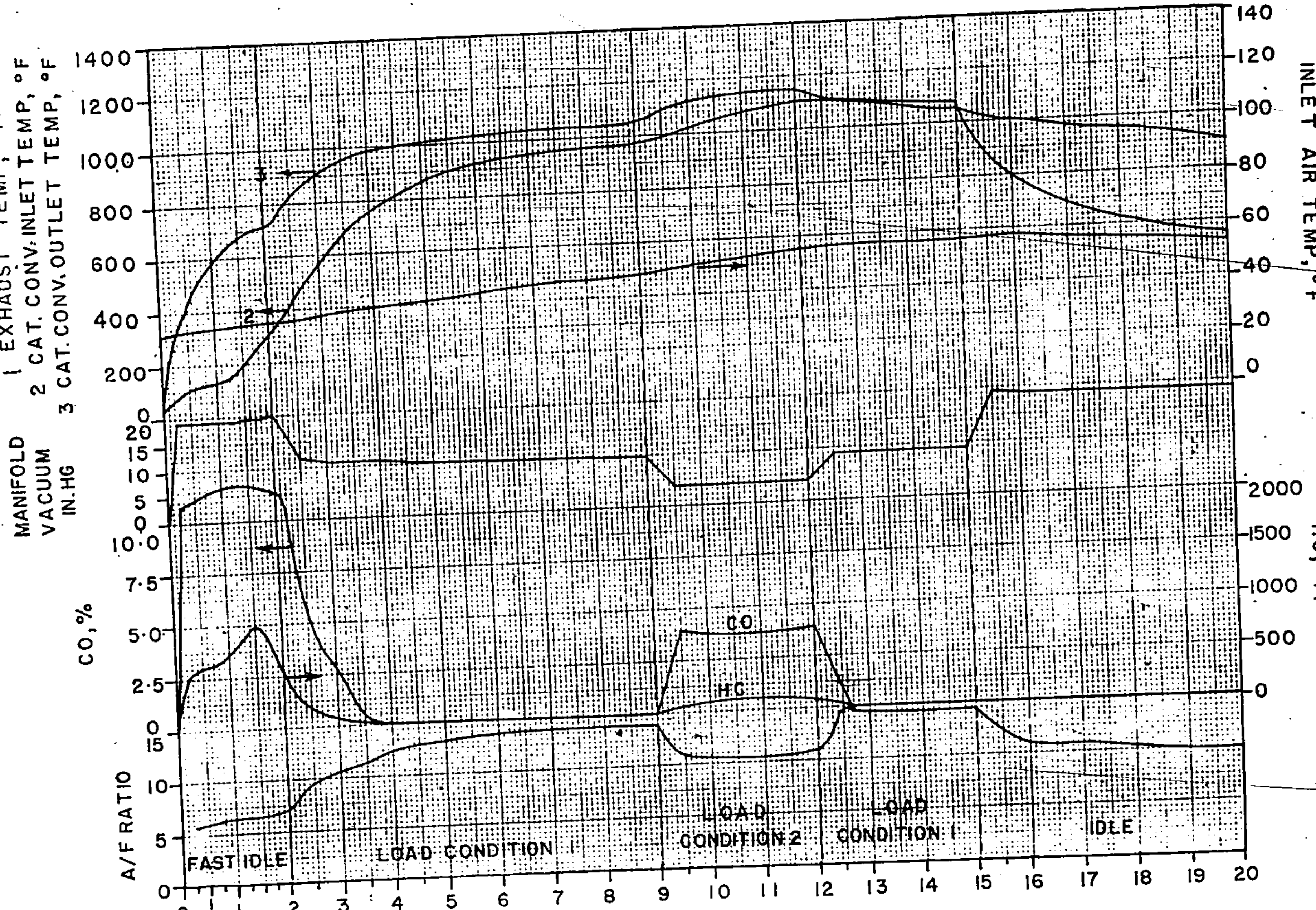


FIG. 5-14c.

36°F - WITH CONV.
(RUN # 26)



31°F - WITH CONV.
(RUN # 27)

FIG. 5-15c.

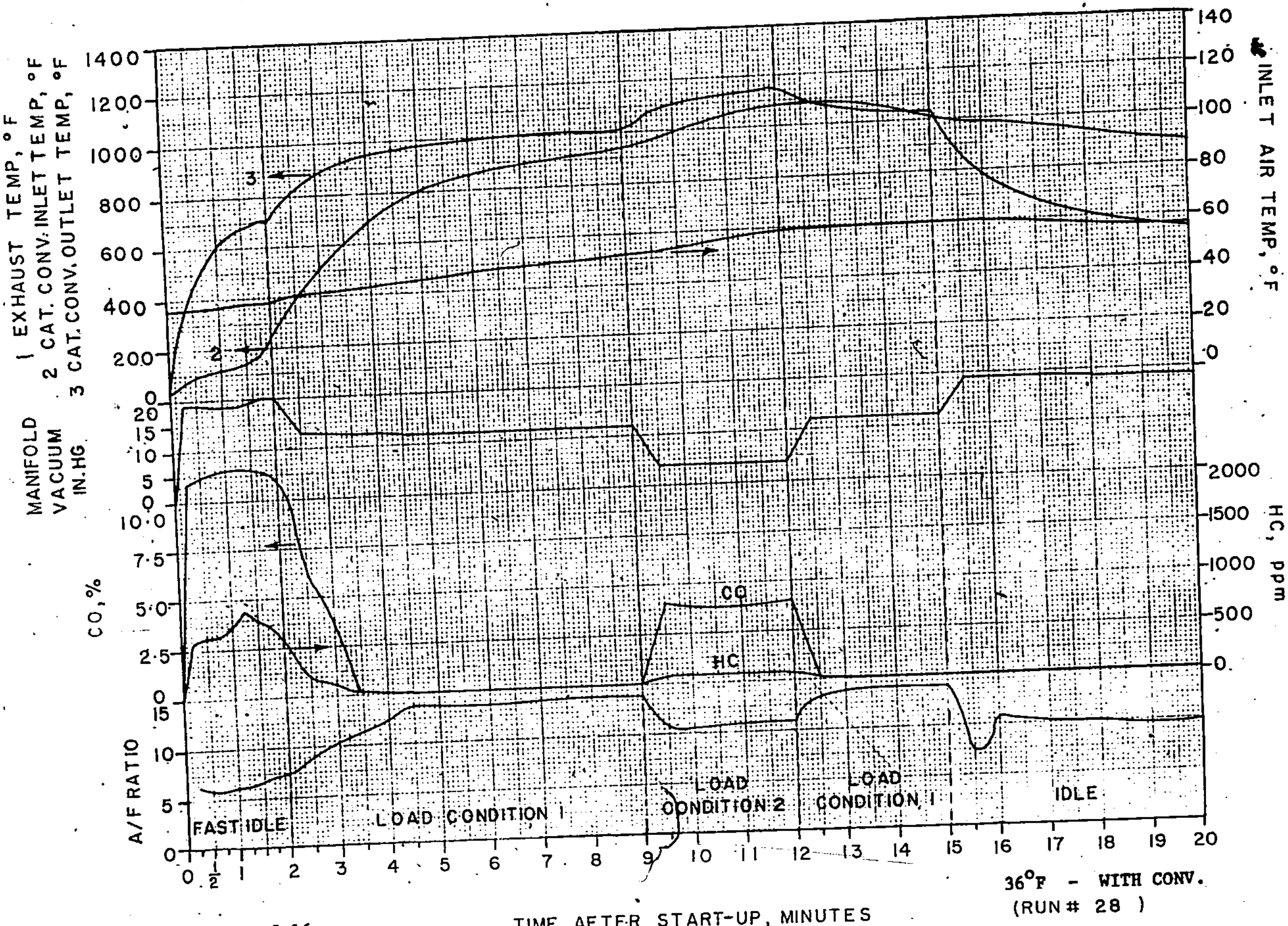

1 EXHAUST TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
MANIFOLD VACUUM IN. HG
CO, %
A/F RATIO
INLET AIR TEMP, °F
HC, ppm
CO
HC
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
TIME AFTER START-UP, MINUTES
36°F - WITH CONV.
(RUN # 28)

FIG. 5-16c.

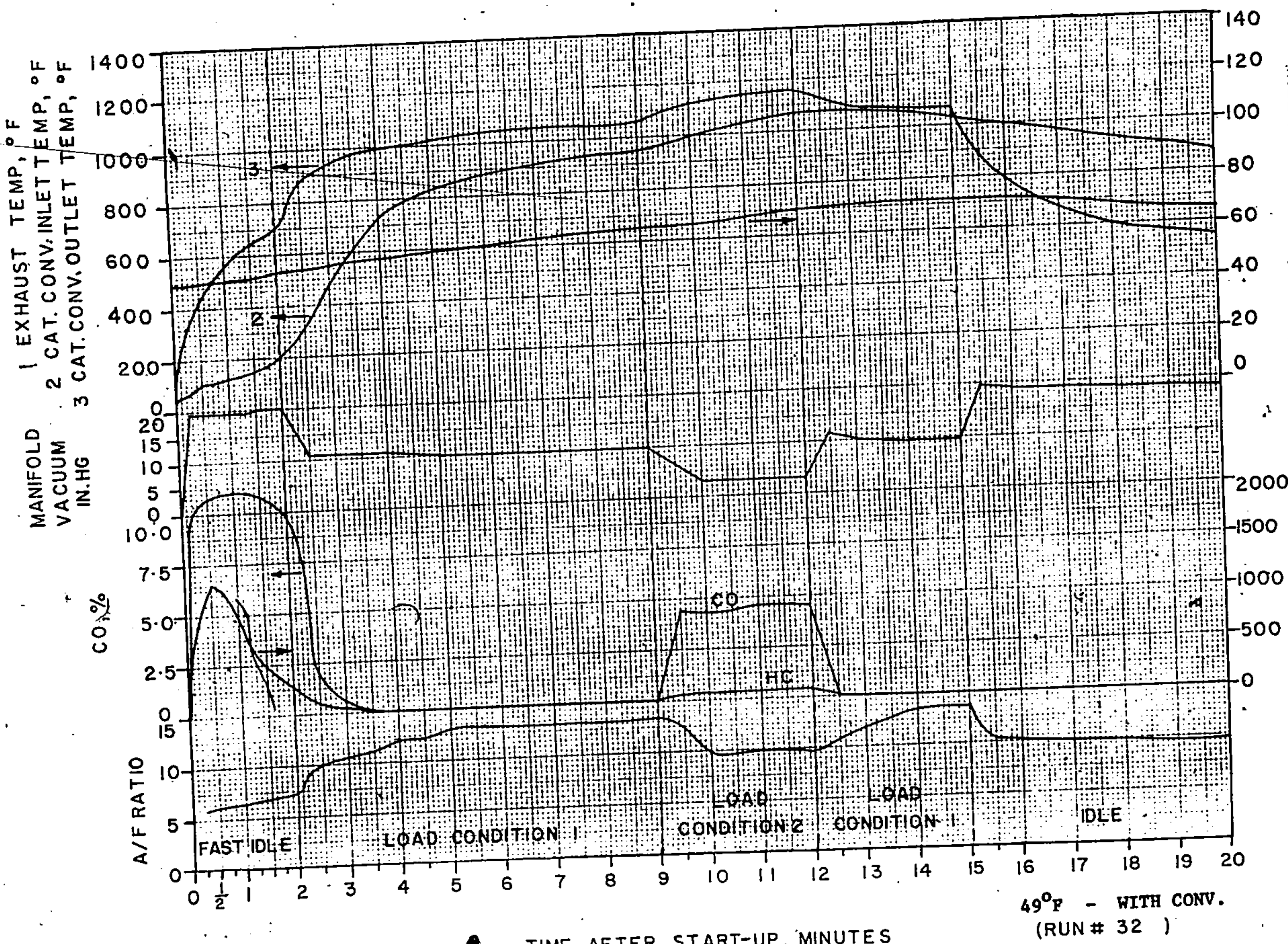
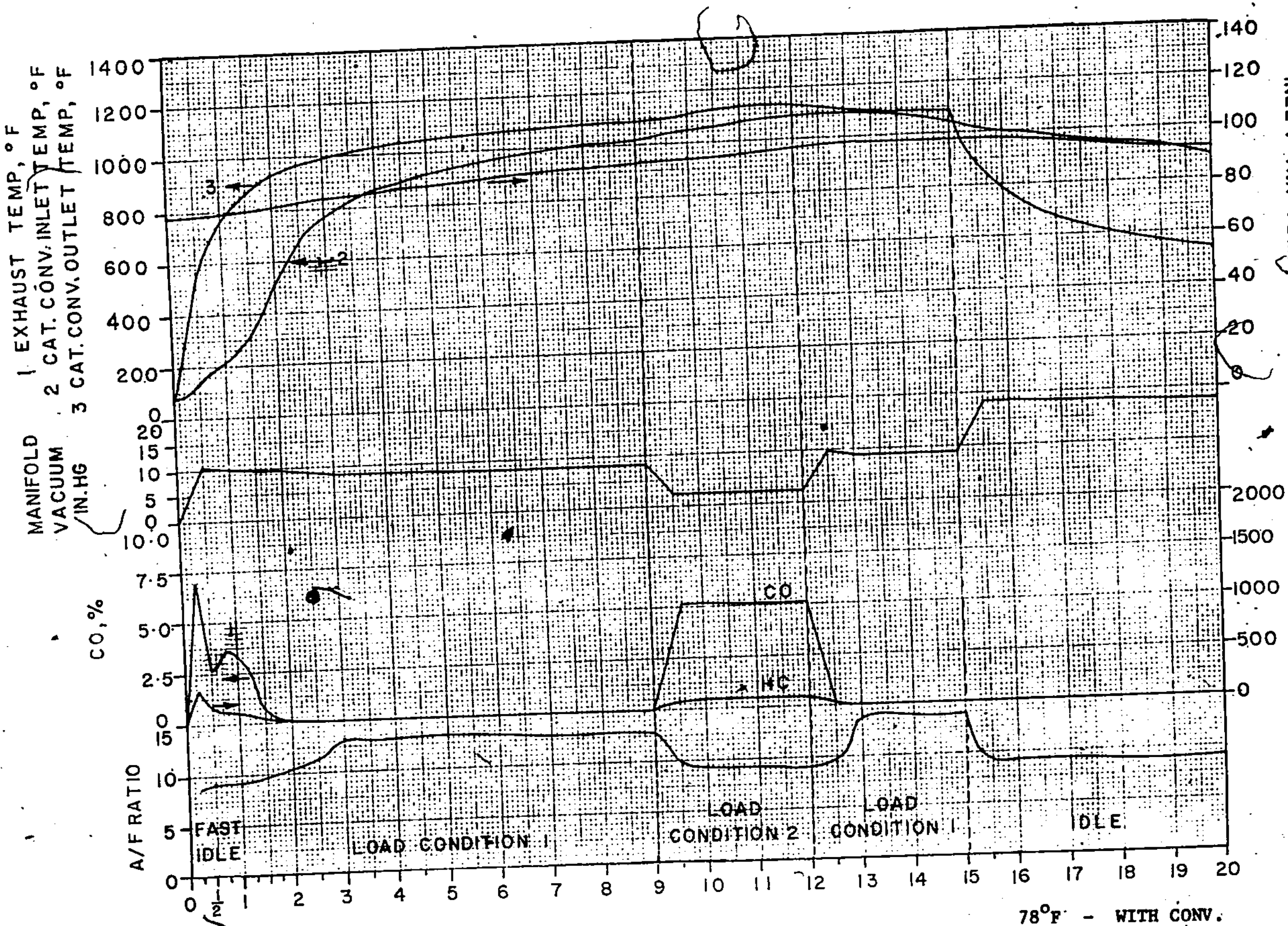

1 EXHAUST TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
1400
1200
1000
800
600
400
200
0
MANIFOLD VACUUM IN.HG
20
15
10
5
0
CO, %
10·0
7·5
5·0
2·5
0
A/F RATIO
15
10
5
0
INLET AIR TEMP, °F
140
120
100
80
60
40
20
0
HC, ppm
2000
1500
1000
500
0
CO
HC
FAST IDLE
LOAD CONDITION I
LOAD CONDITION 2
LOAD CONDITION I
IDLE
0 1/2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TIME AFTER START-UP, MINUTES
49°F - WITH CONV.
(RUN # 32)

FIG. 5-17c.



78°F - WITH CONV.
(RUN # 34)

FIG. 5-18c.

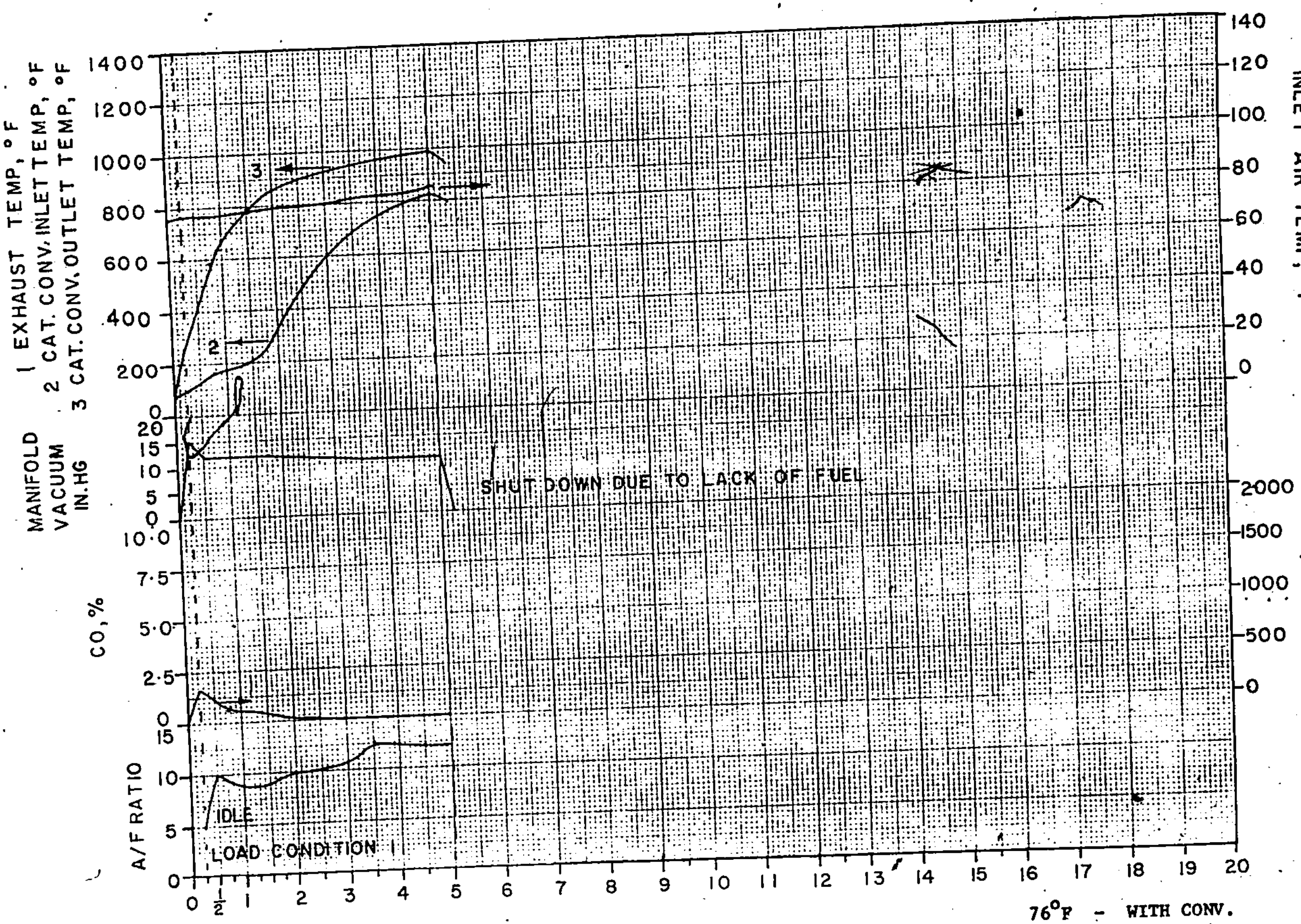
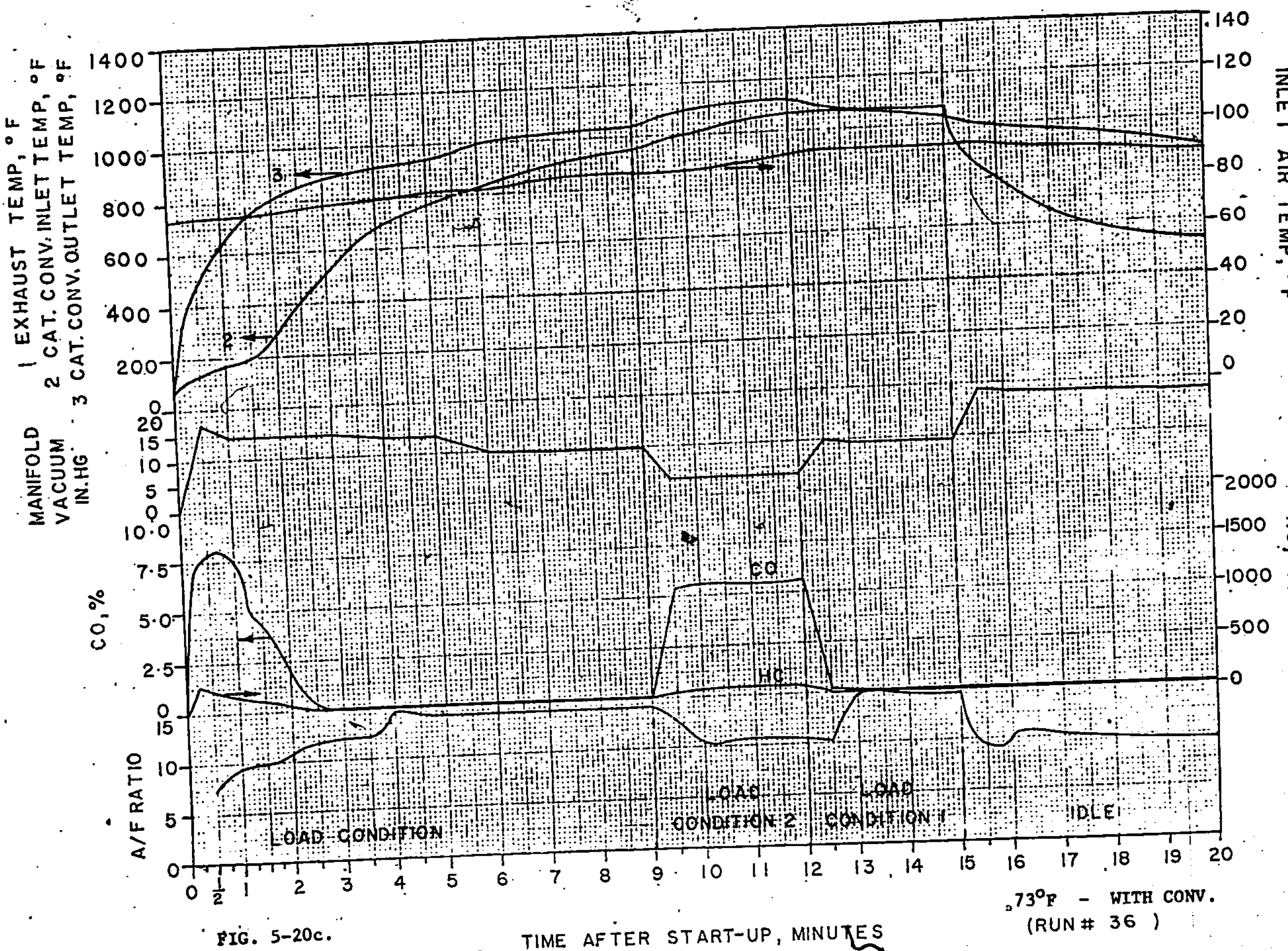


FIG. 5-19c.

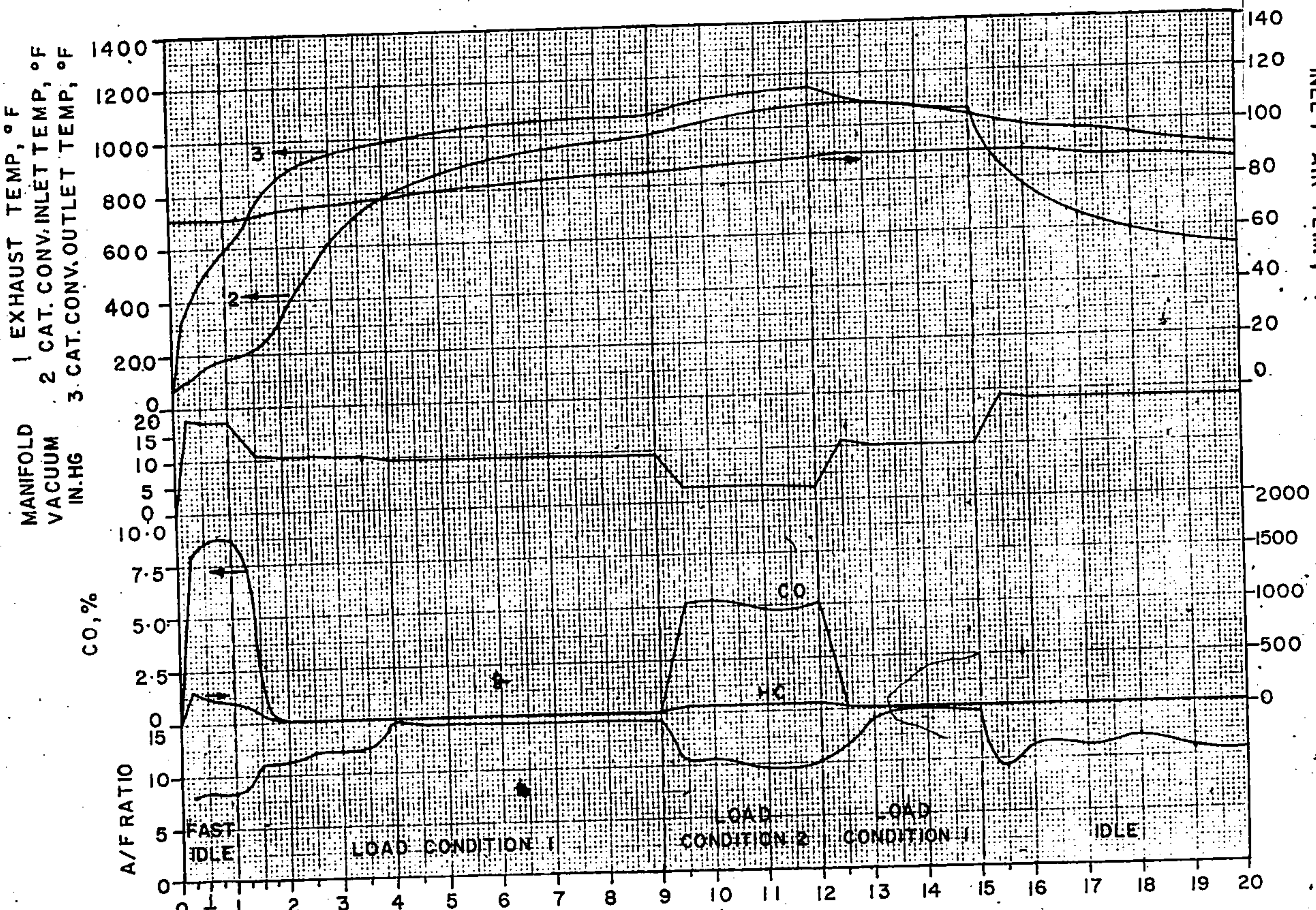
76°F - WITH CONV. (RUN # 35)

K20



73°F - WITH CONV. (RUN # 36)

FIG. 5-20c.



71°F - WITH CONV.
(RUN # 37)

FIG. 5-21c. TIME AFTER START-UP, MINUTES

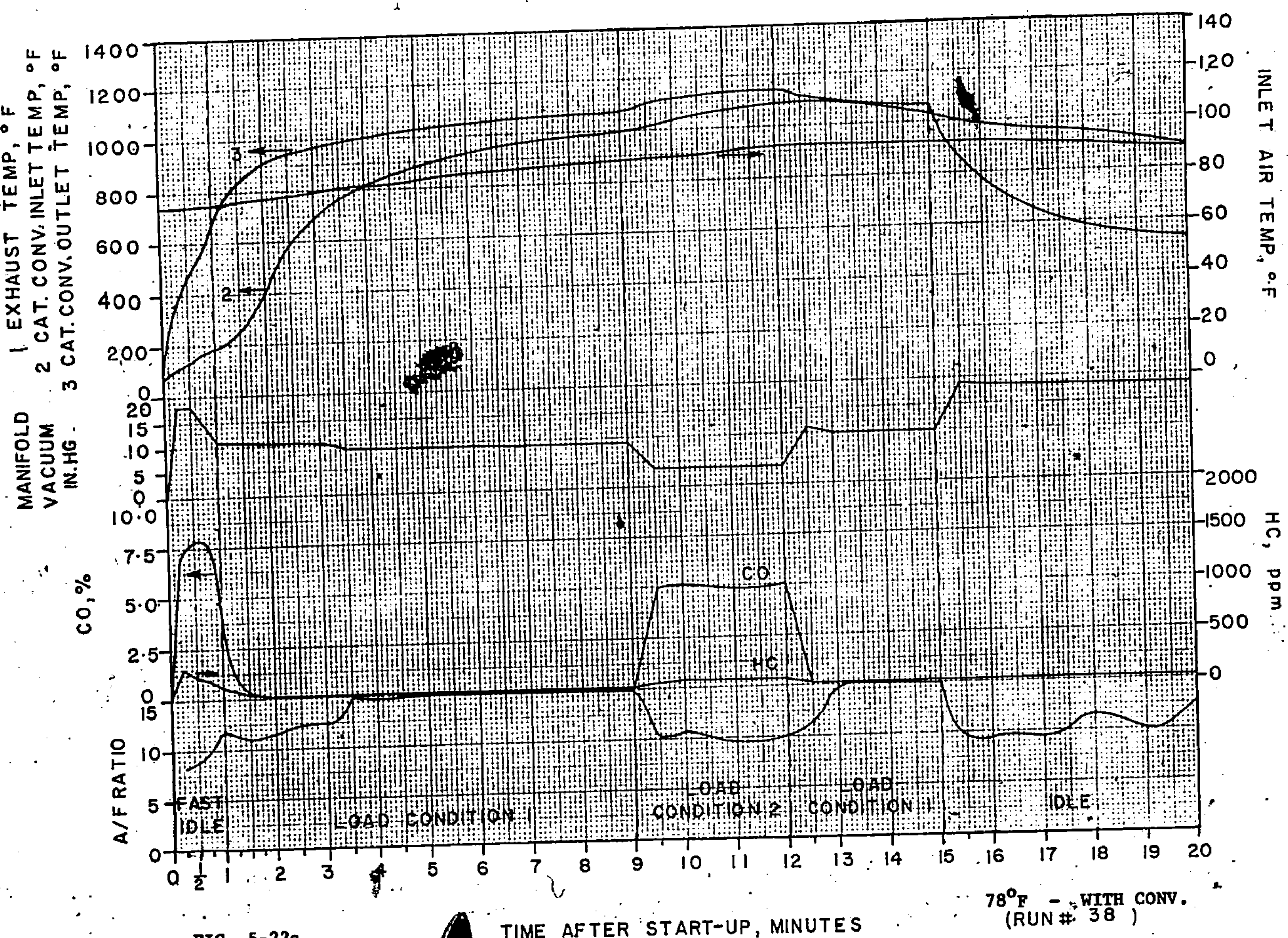
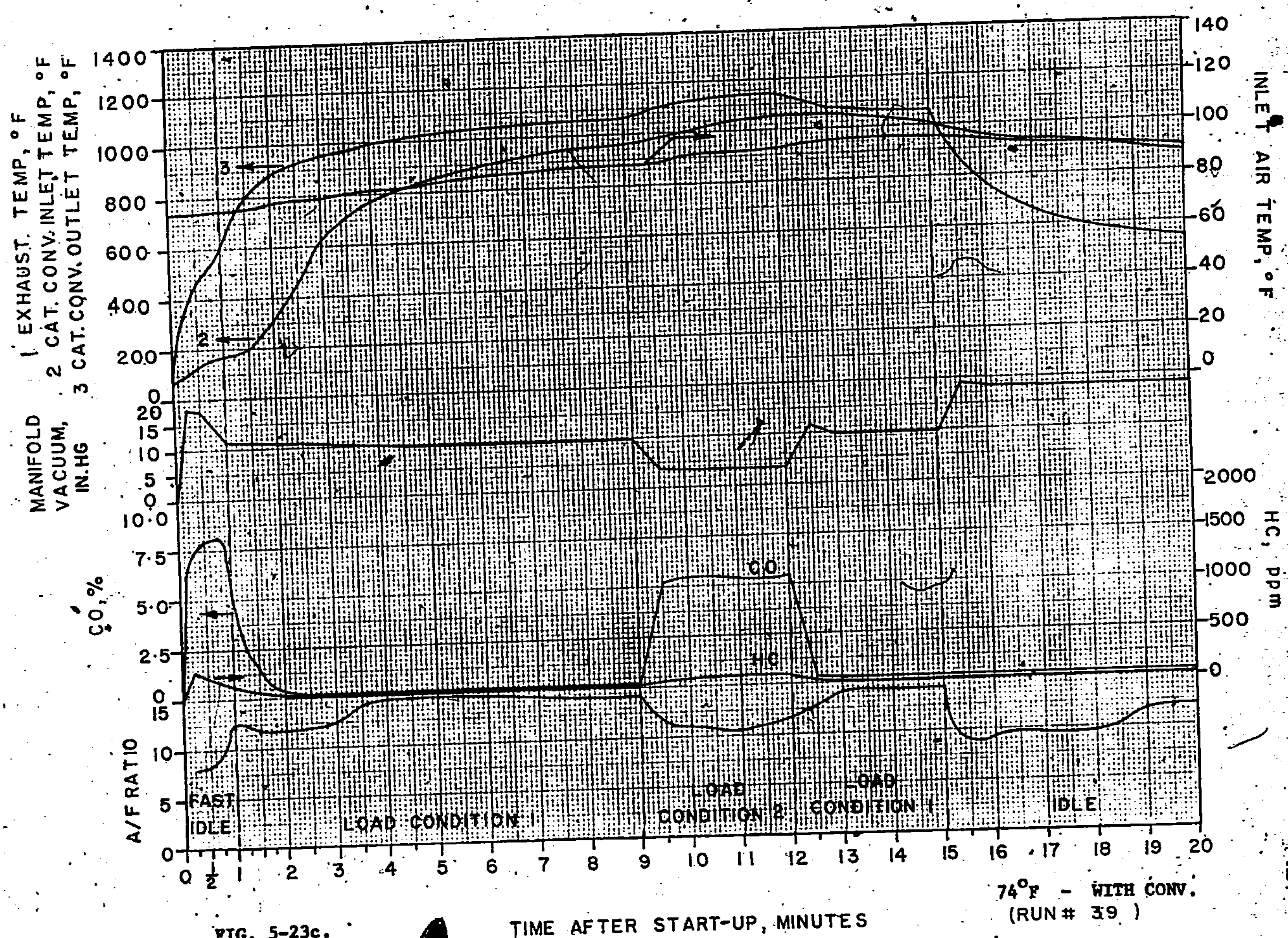

1 EXHAUST TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
MANIFOLD VACUUM IN.HG
CO, %
A/F RATIO
INLET AIR TEMP, °F
HC, ppm
CO
HC
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
TIME AFTER START-UP, MINUTES
78°F - WITH CONV.
(RUN # 38)

FIG. 5-22c.



1 EXHAUST. TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
MANIFOLD VACUUM, IN. HG
CO, %
A/F RATIO
INLET AIR TEMP, °F
HC, ppm
CO
HC
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
TIME AFTER START-UP, MINUTES
74°F - WITH CONV.
(RUN # 39)

FIG. 5-23c.

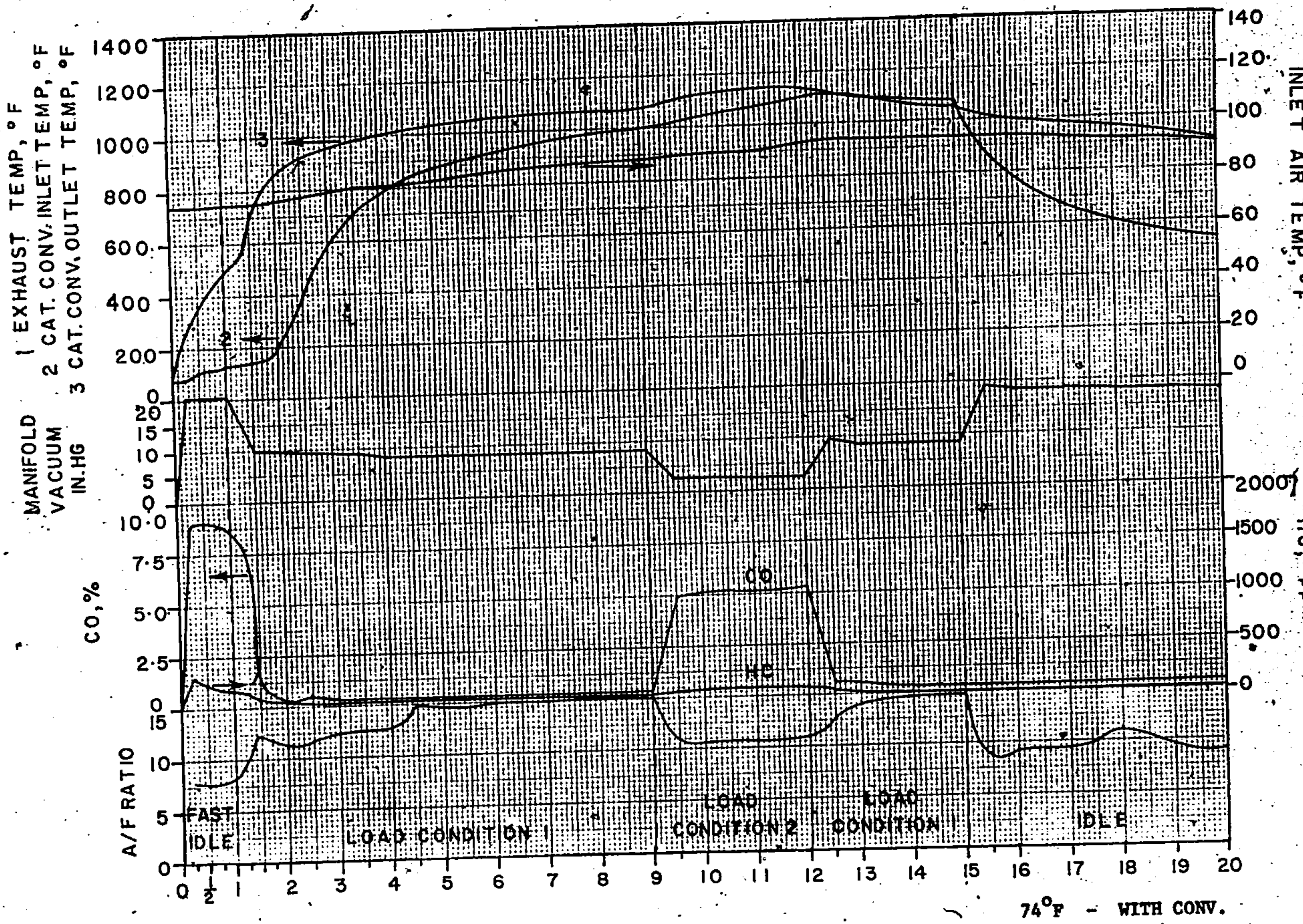
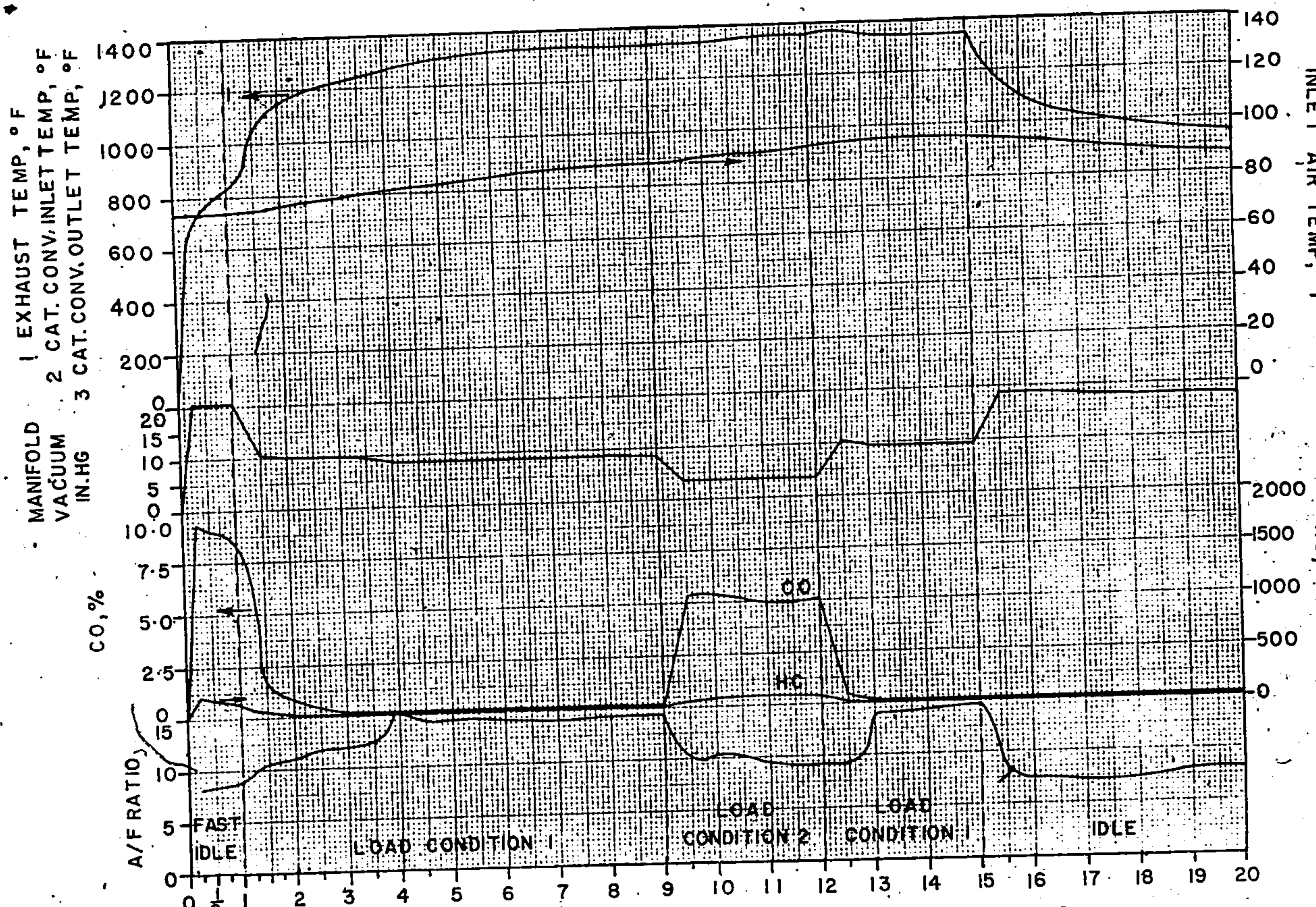

1 EXHAUST TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
1400
1200
1000
800
600
400
200
0
INLET AIR TEMP, °F
140
120
100
80
60
40
20
0
MANIFOLD VACUUM IN.HG
20
15
10
5
0
HC, ppm
2000
1500
1000
500
0
CO, %
10.0
7.5
5.0
2.5
0
A/F RATIO
15
10
5
0
CO
HC
3
2
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
0 ½ 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TIME AFTER START-UP, MINUTES
74°F - WITH CONV.
(RUN # 40)

FIG. 5-24c.



73°F - WITHOUT CONV.
(RUN # 41)

FIG. 5-25c.

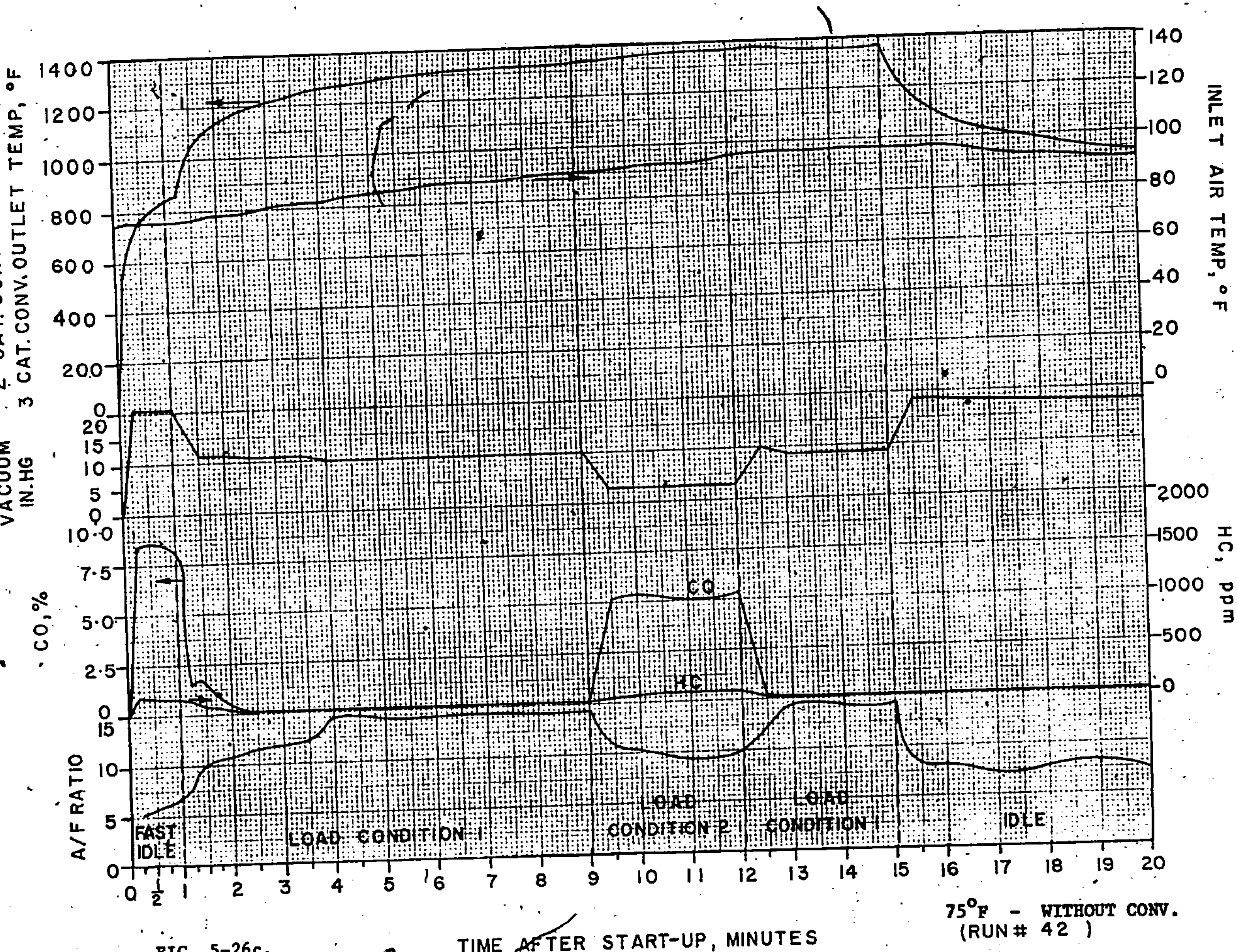
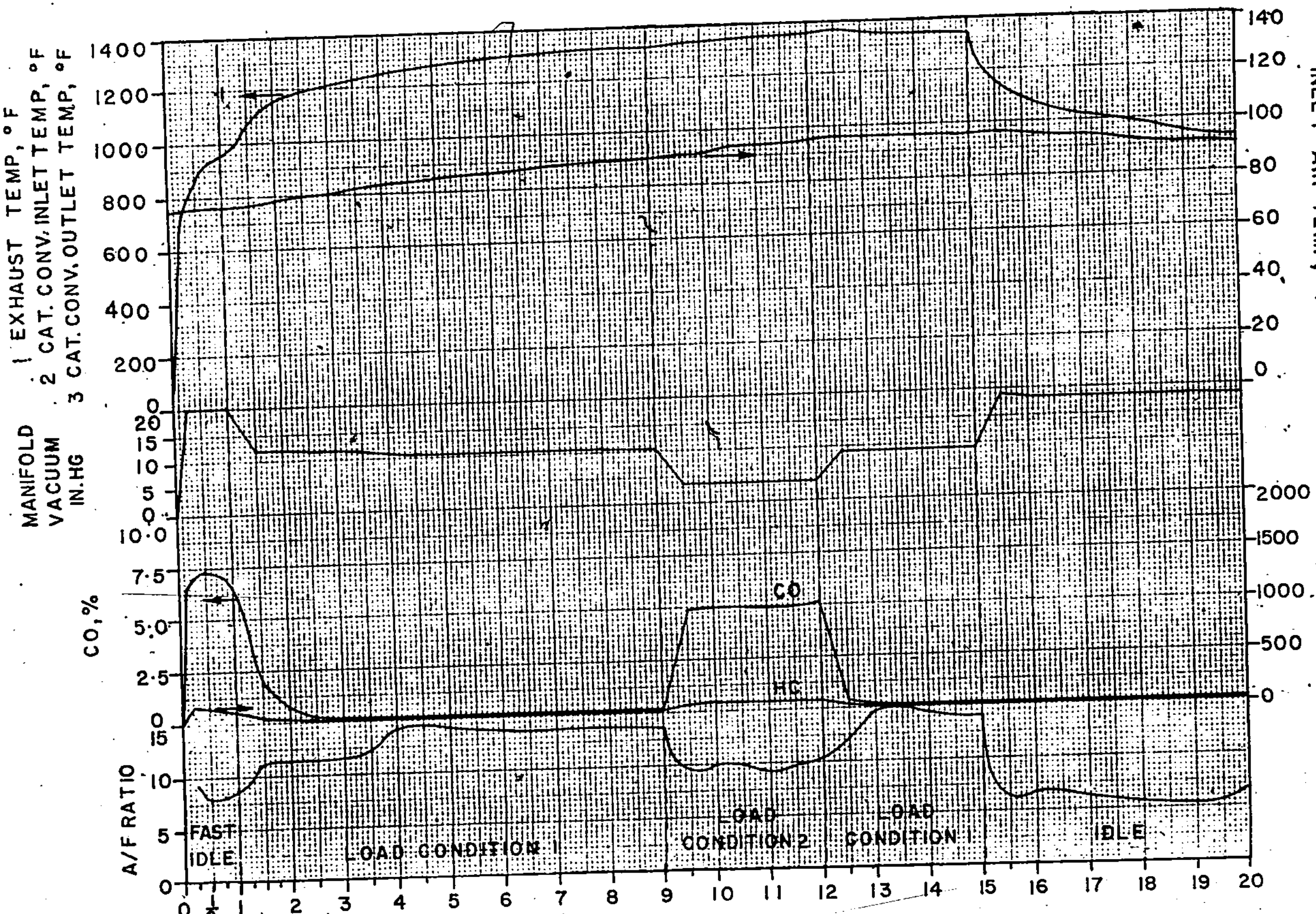


FIG. 5-26c.

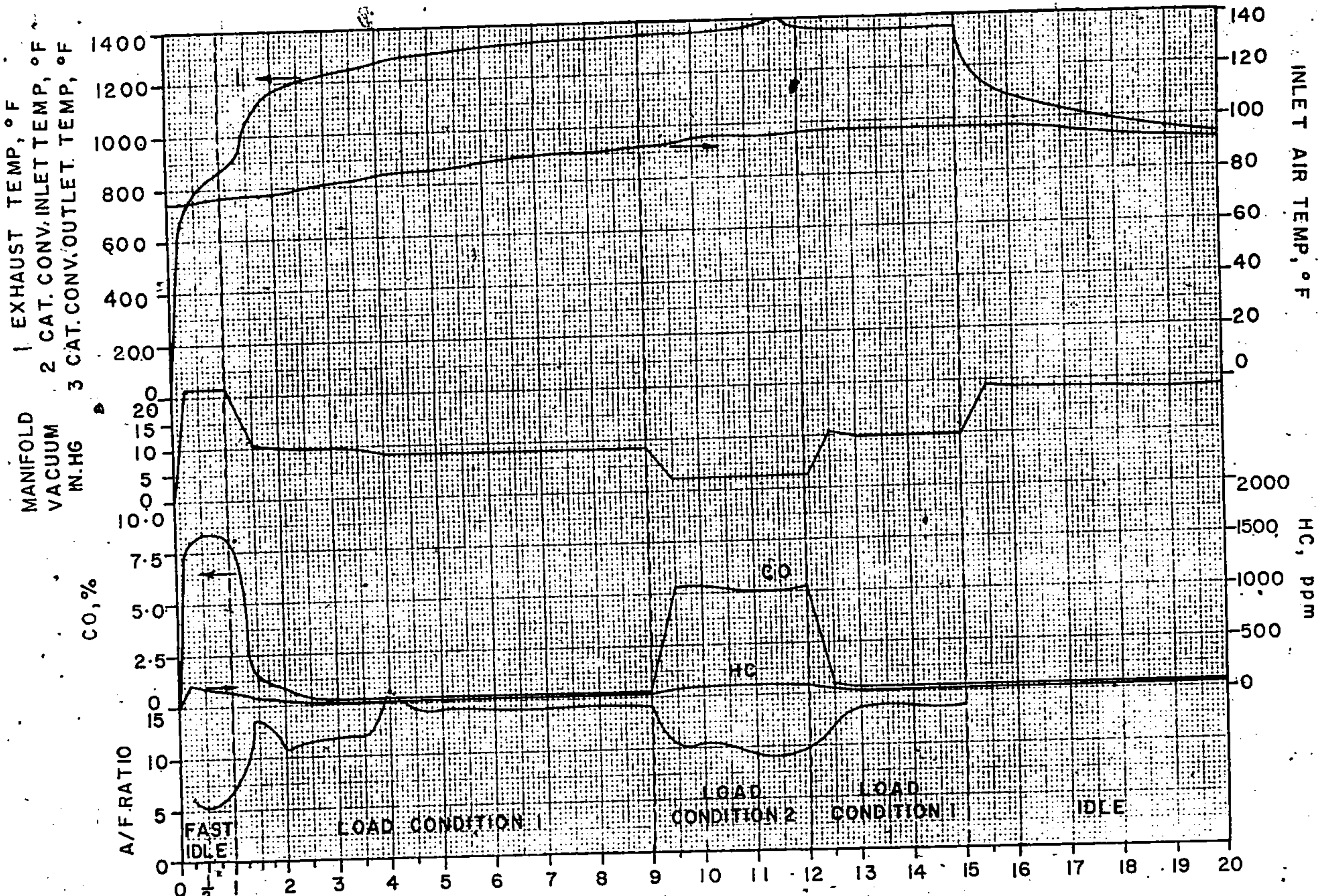
75°F - WITHOUT CONV.
(RUN # 42)



TIME AFTER START-UP, MINUTES

75°F - WITHOUT CONV.
(RUN # 43)

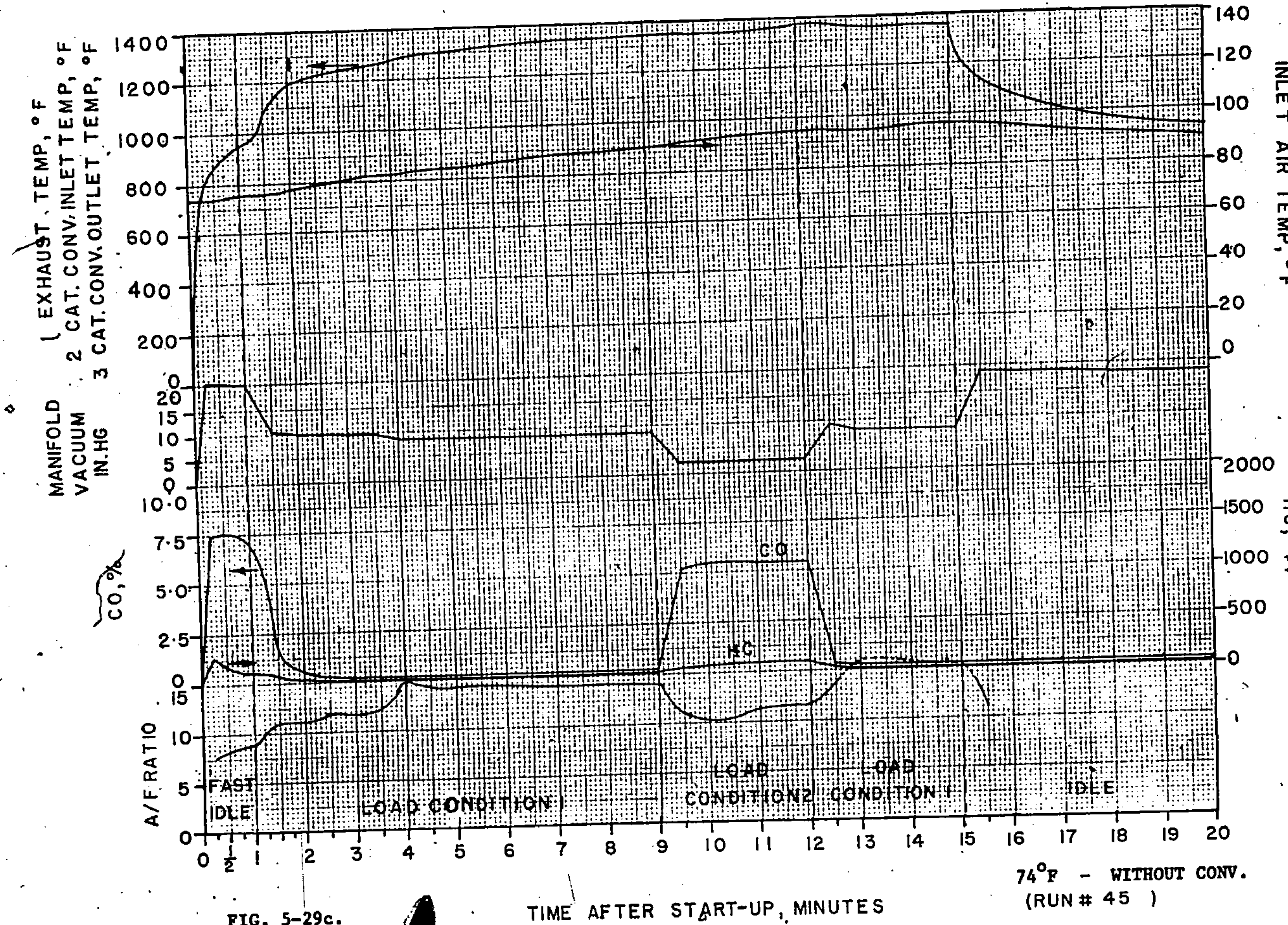
FIG. 5-27c.



TIME AFTER START-UP, MINUTES

FIG. 5-28c.

75°F - WITHOUT CONV. (RUN # 44)



74°F - WITHOUT CONV.
(RUN # 45)

FIG. 5-29c.

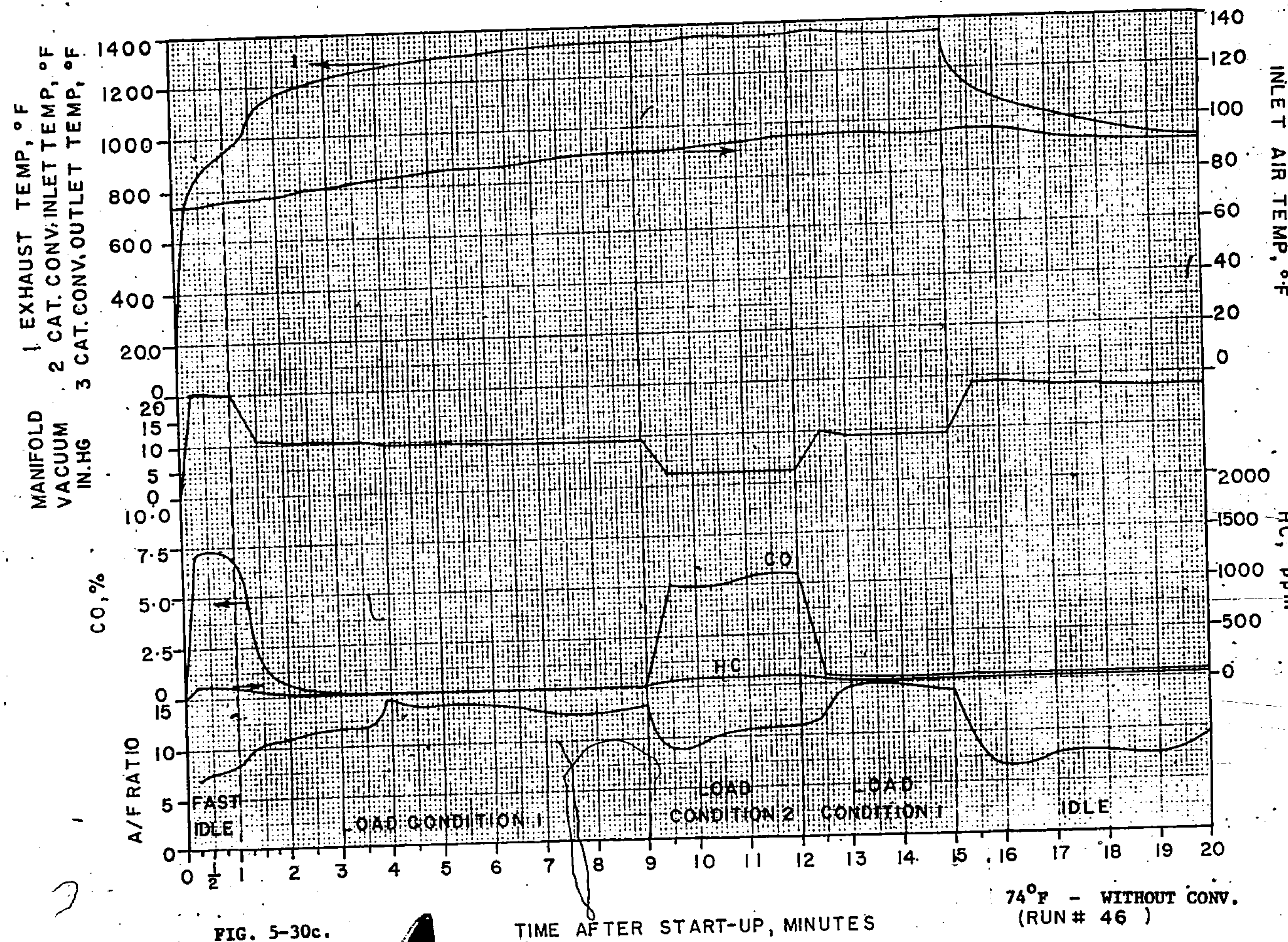
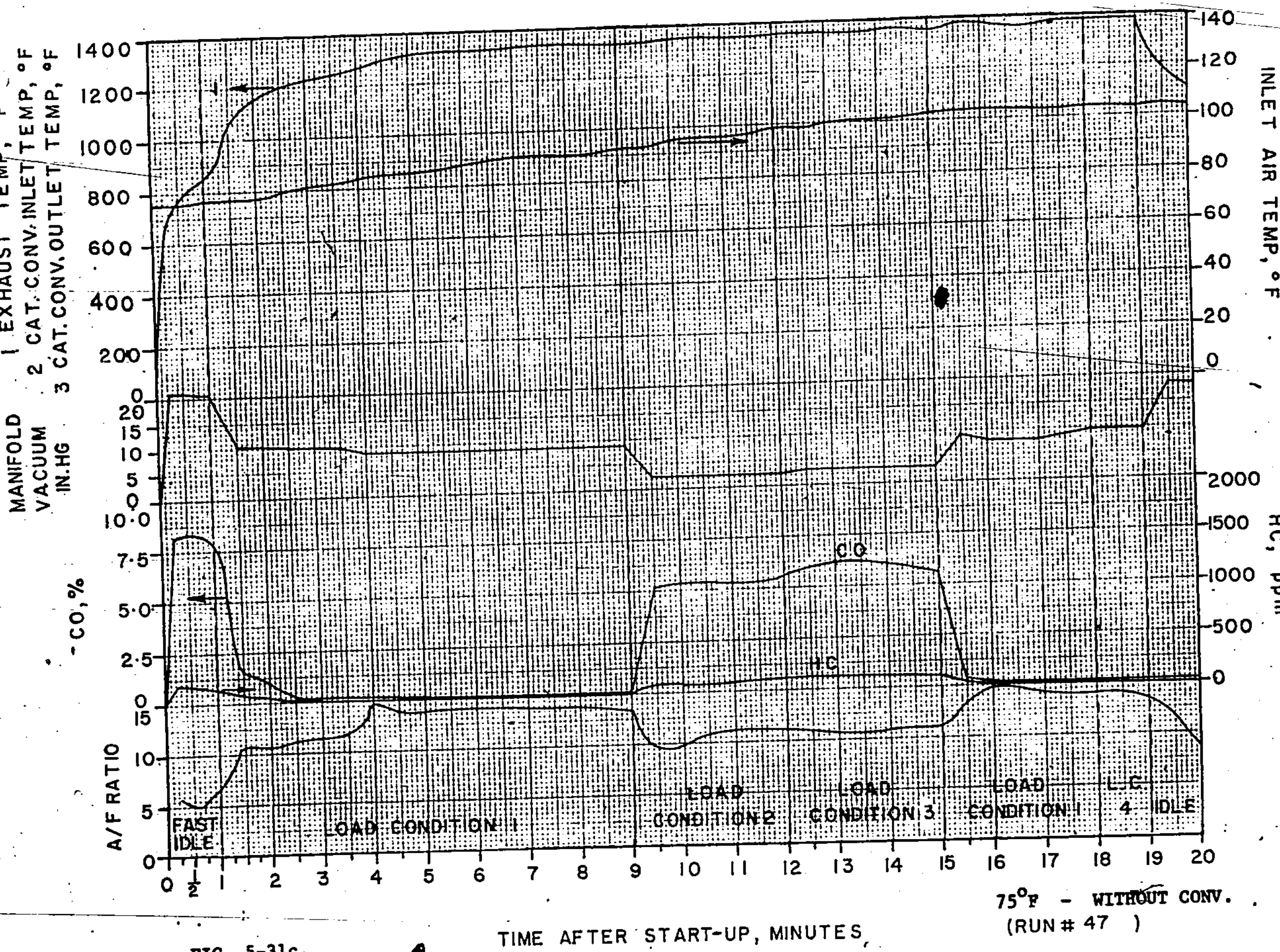


FIG. 5-30c.

74°F - WITHOUT CONV.
(RUN # 46)



75°F - WITHOUT CONV.
(RUN # 47)

FIG. 5-31c.

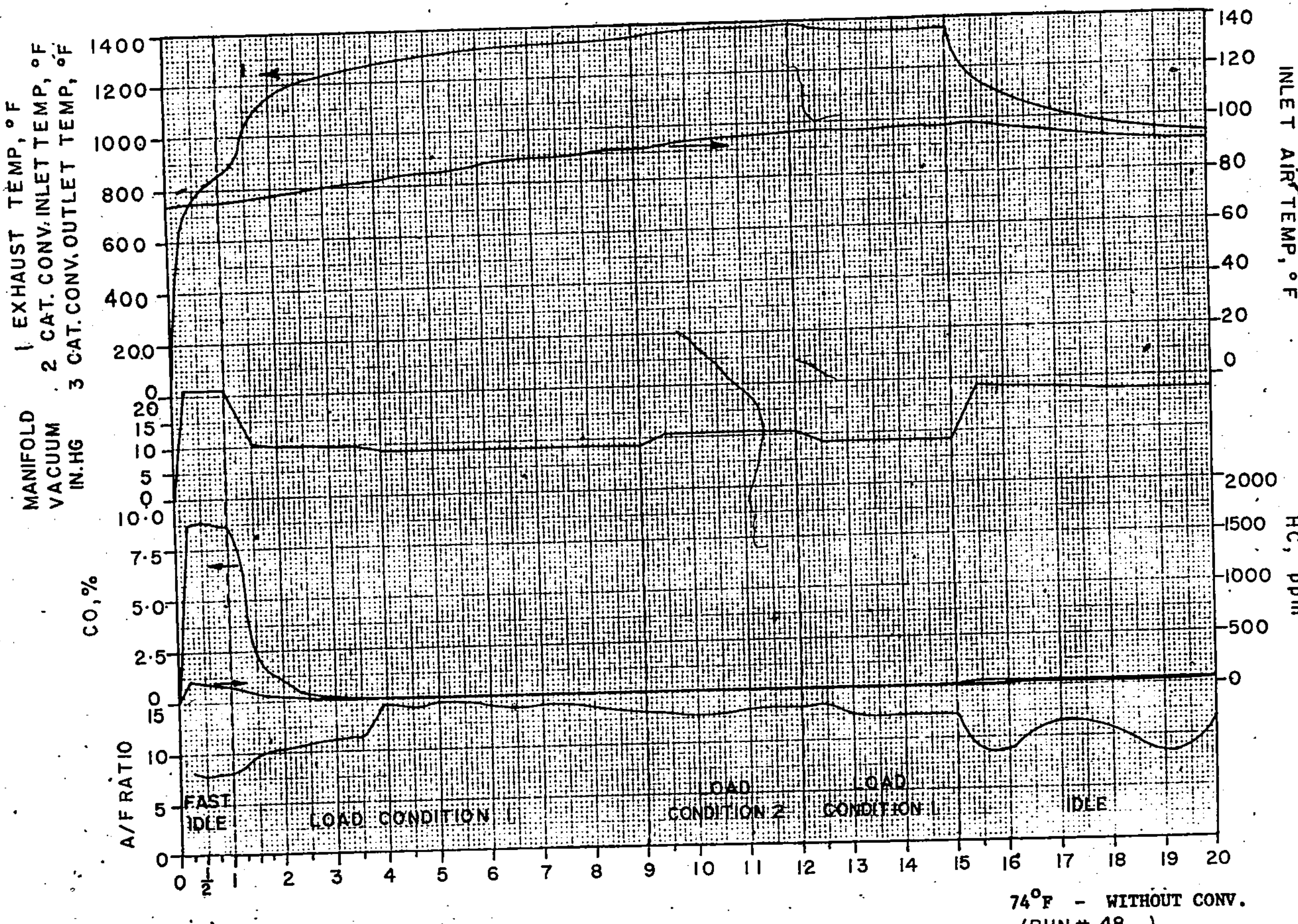

1 EXHAUST TEMP, °F
2 CAT. CONV. INLET TEMP, °F
3 CAT. CONV. OUTLET TEMP, °F
1400
1200
1000
800
600
400
200
0
MANIFOLD VACUUM IN.HG
20
15
10
5
0
CO, %
10.0
7.5
5.0
2.5
0
A/F RATIO
15
10
5
0
INLET AIR TEMP, °F
140
120
100
80
60
40
20
0
HC, ppm
2000
1500
1000
500
0
FAST IDLE
LOAD CONDITION 1
LOAD CONDITION 2
LOAD CONDITION 1
IDLE
0
$\frac{1}{2}$
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
TIME AFTER START-UP, MINUTES
74°F - WITHOUT CONV.
(RUN # 48)

FIG. 5-32c.

L. EFFECT OF INLET TEMPERATURE ON CATALYST PERFORMANCE

FIGURES 6-5 THROUGH 6-17.

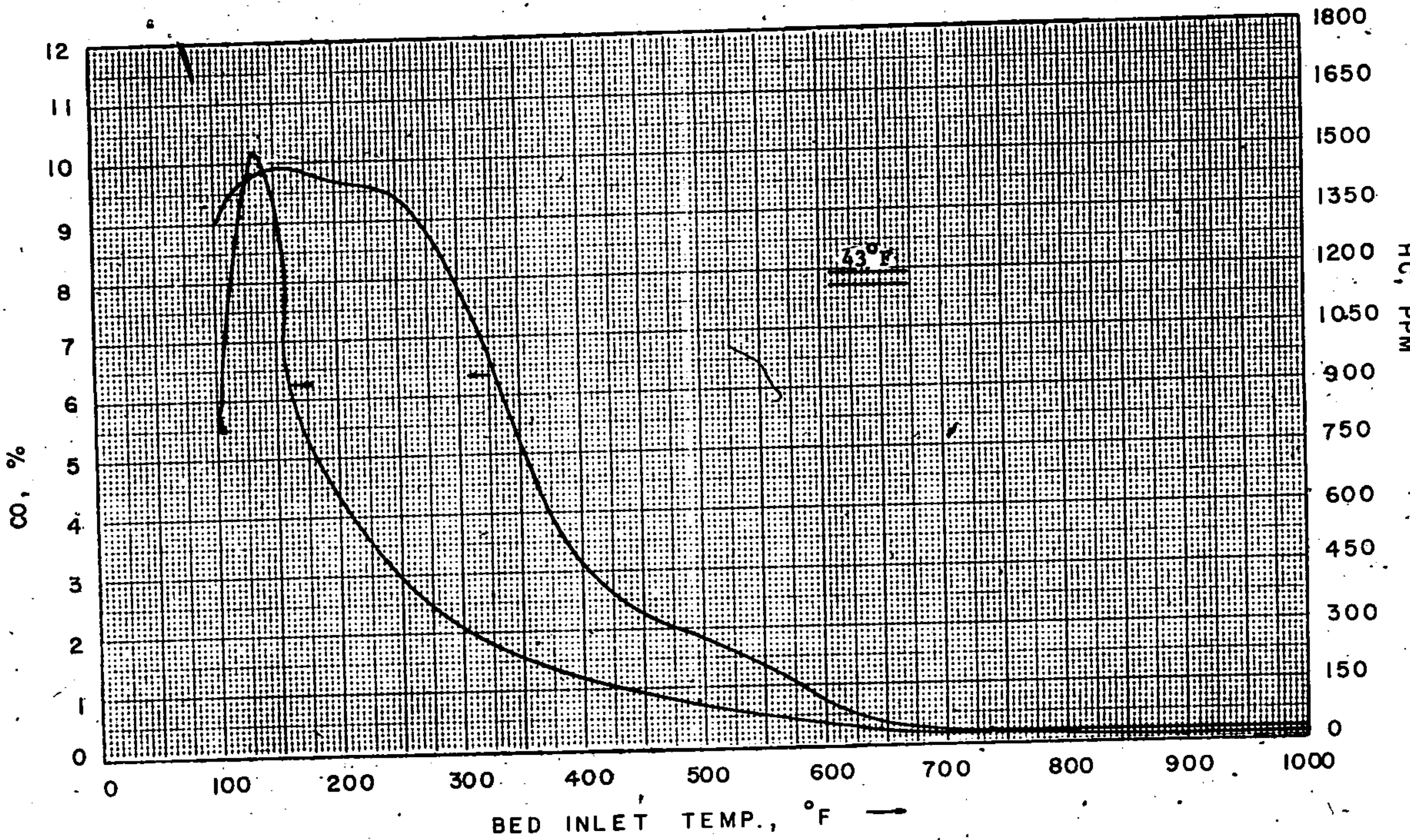
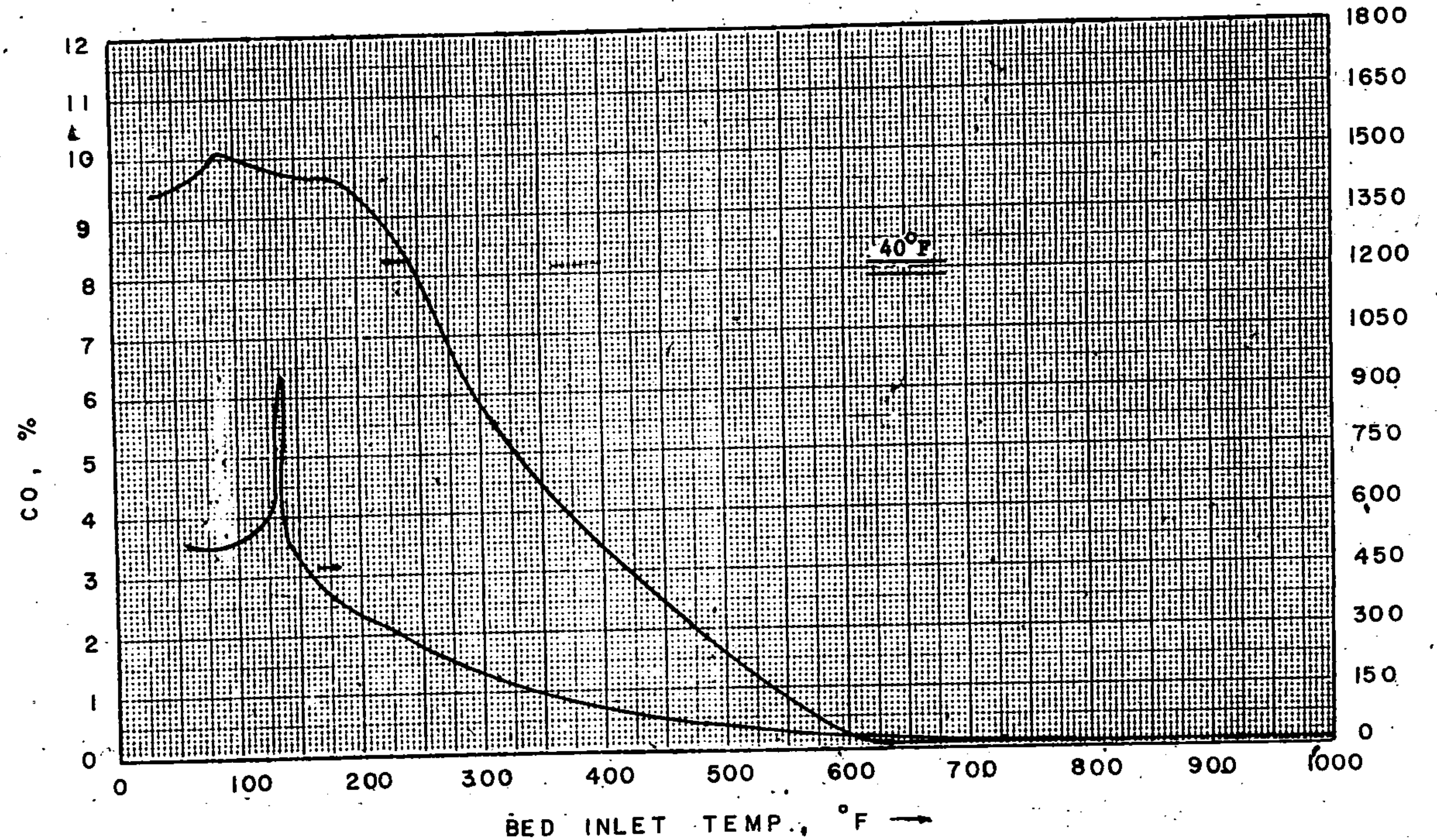


FIG. 6-5. EFFECT OF BED INLET TEMPERATURE ON CATALYST PERFORMANCE. (RUN # 23)



CO, %
12
11
10
9
8
7
6
5
4
3
2
1
0
HC, PPM
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
0
0
100
200
300
400
500
600
700
800
900
1000
40°F
BED INLET TEMP., °F

FIG. 6-6.

(RUN # 24)

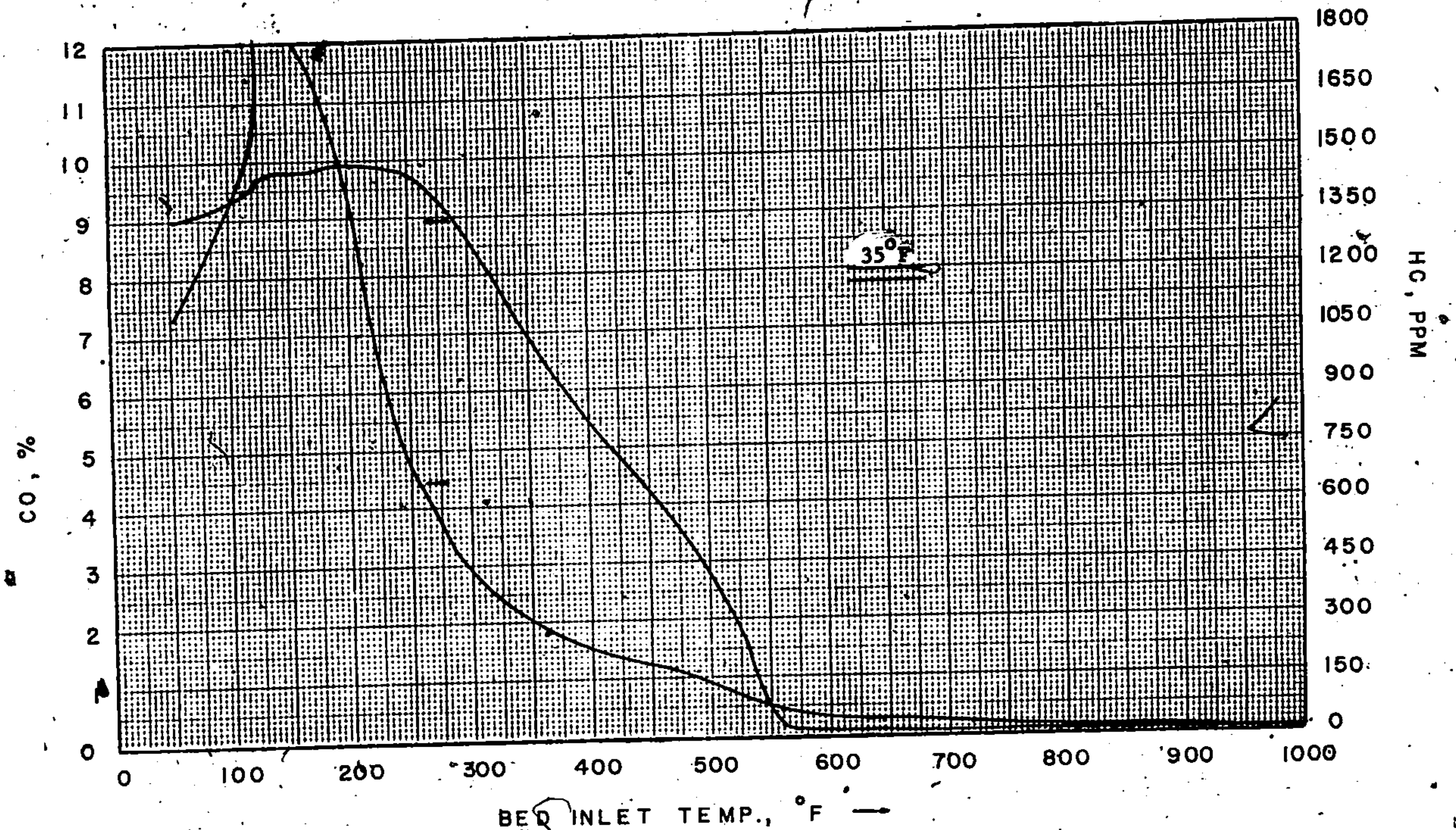
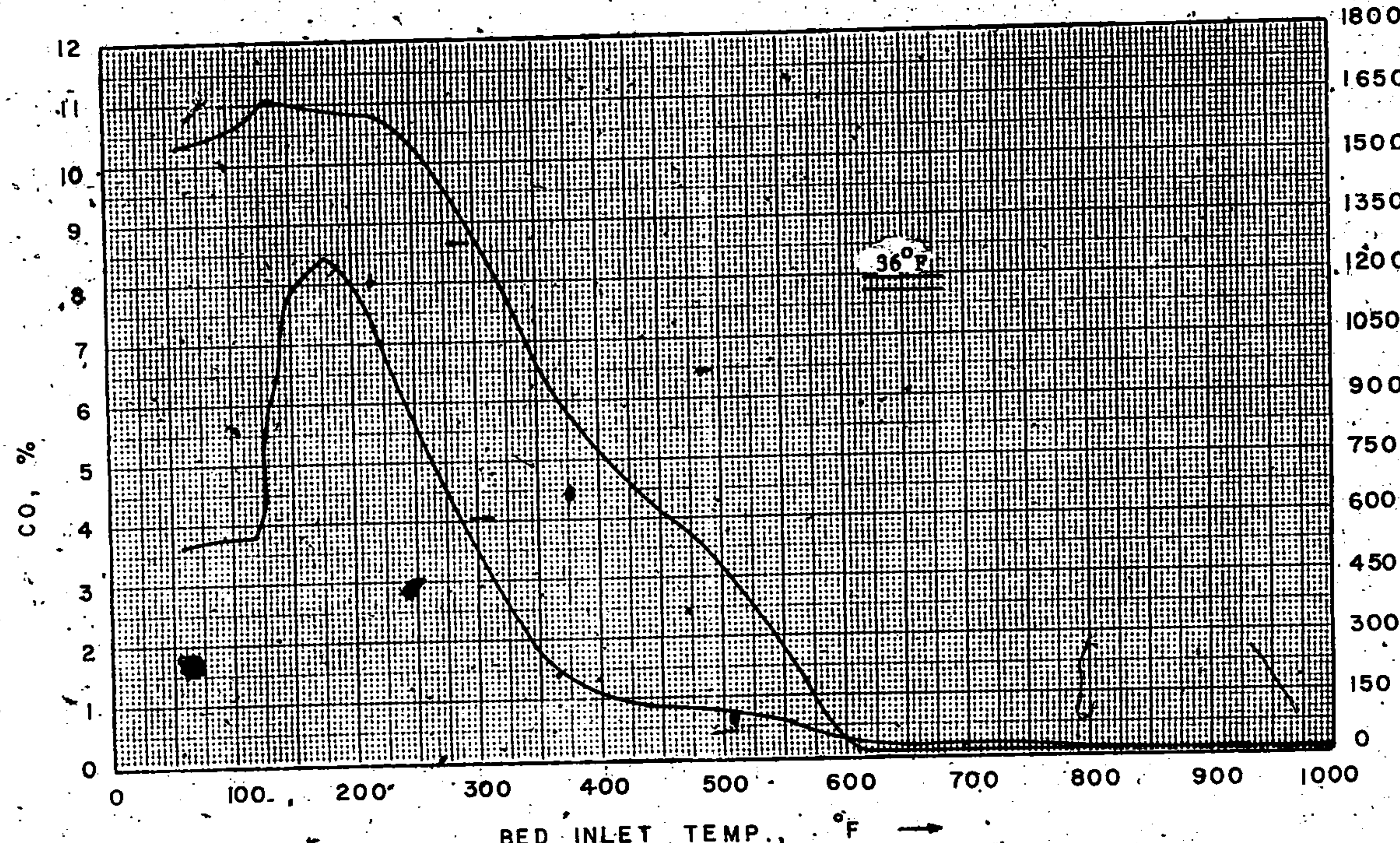

12
11
10
9
8
7
6
5
4
3
2
0
CO, %
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
0
HC, PPM
35°F
0
100
200
300
400
500
600
700
800
900
1000
BED INLET TEMP., °F

FIG. 6-7.

(RUN # 25)



CO, %
12
11
10
9
8
7
6
5
4
3
2
1
0
HC, PPM
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
0
0
100
200
300
400
500
600
700
800
900
1000
36°F
BED INLET TEMP., °F

(RUN # 26)

FIG. 6-8.

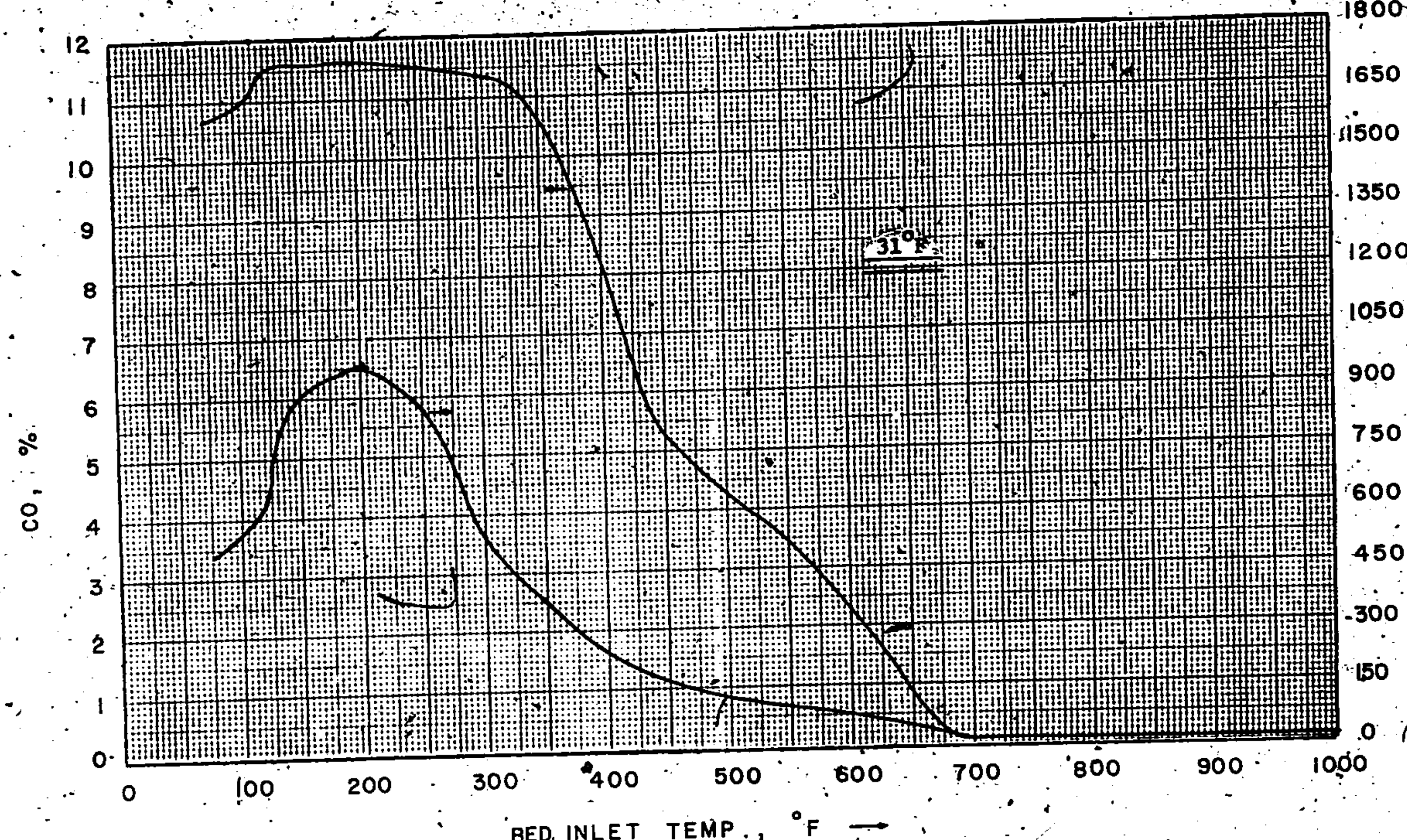
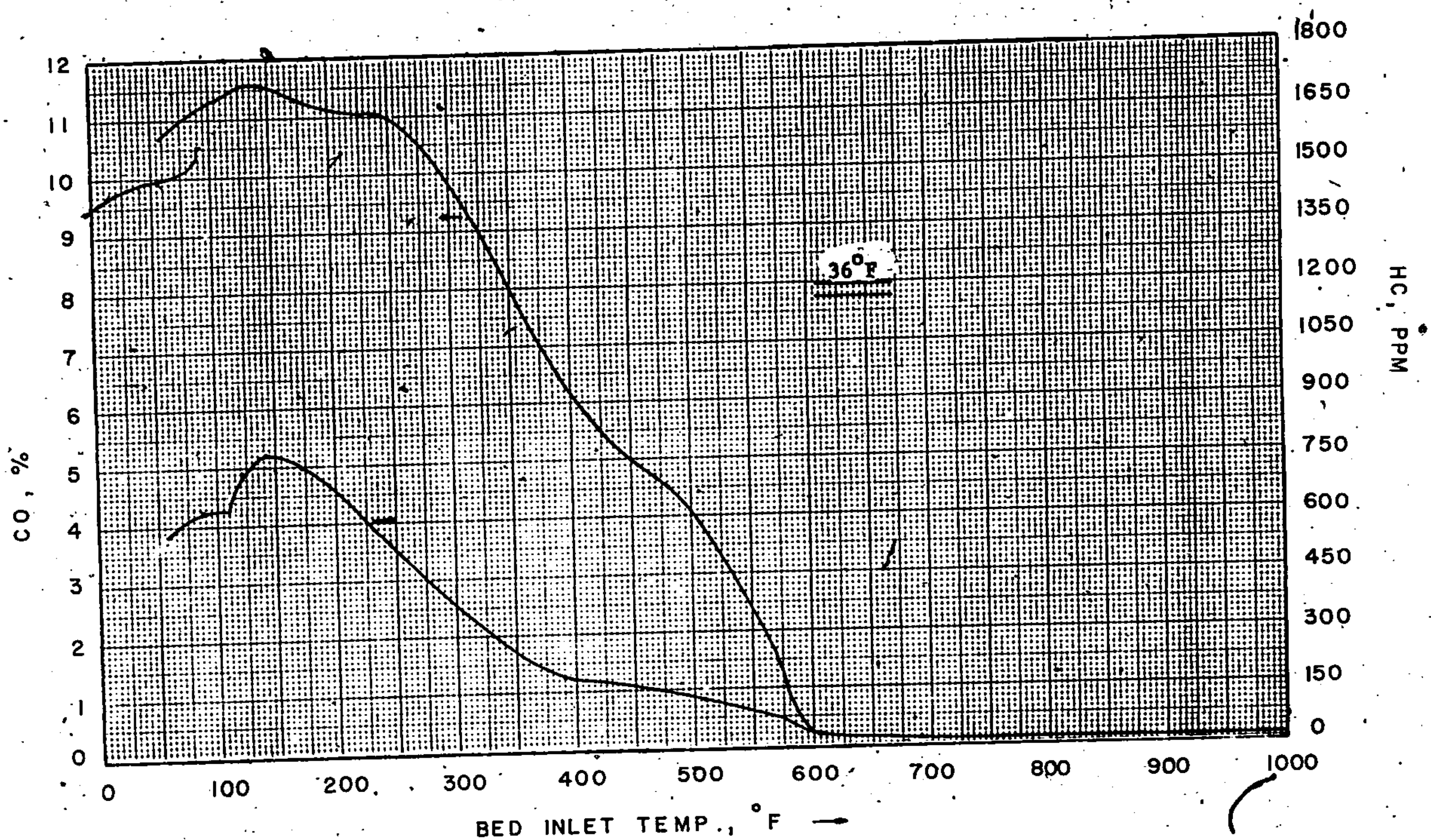

CO, %
12
11
10
9
8
7
6
5
4
3
2
1
0
HC, PPM
1800
1650
1500
1350
1200
1050
900
750
600
450
300
150
0
31 °F
0
100
200
300
400
500
600
700
800
900
1000
BED INLET TEMP., °F

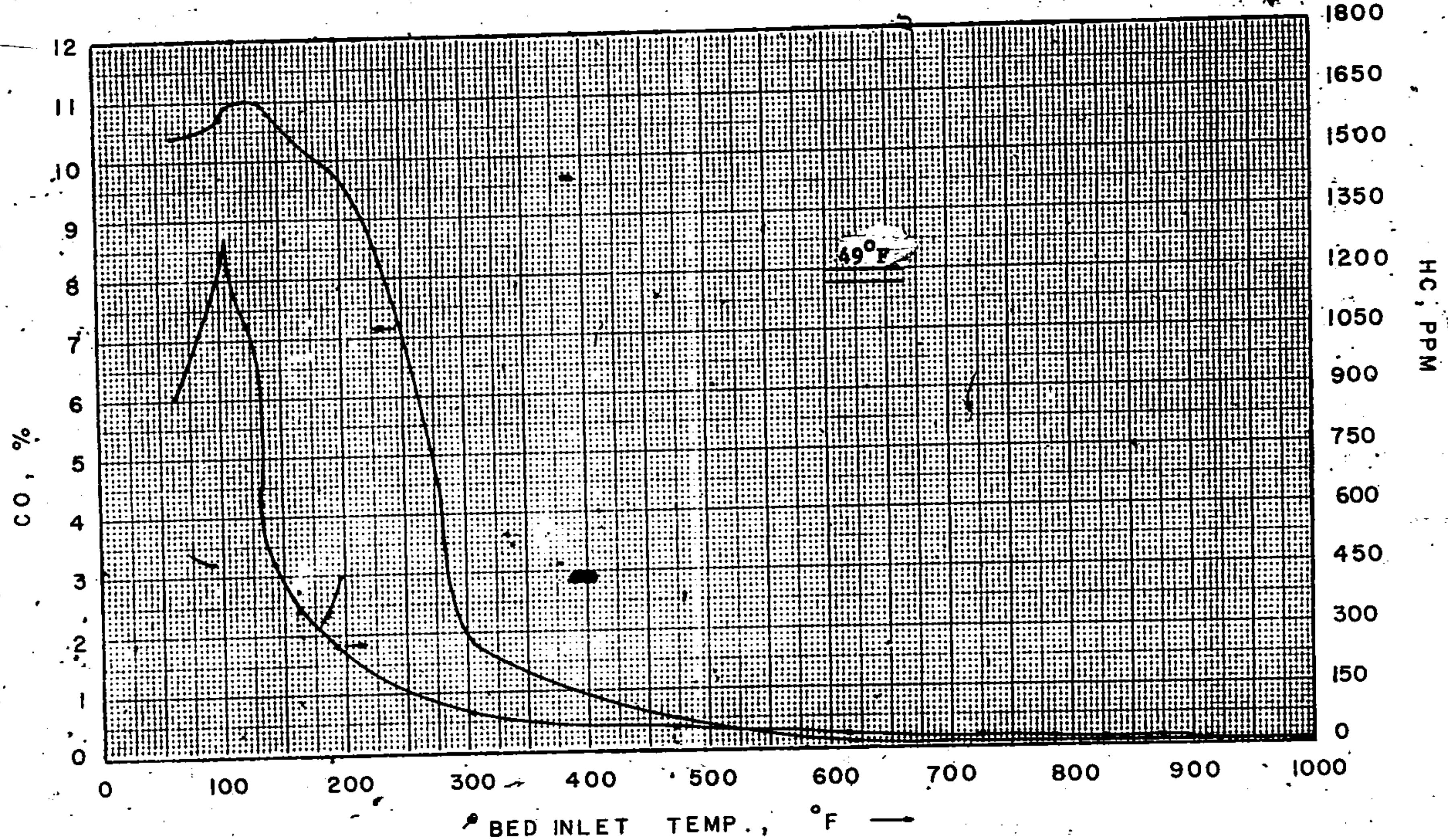
FIG. 6-9.

(RUN # 27)



(RUN # 28)

FIG. 6-10.



(RUN # 32)

FIG. 6-11.

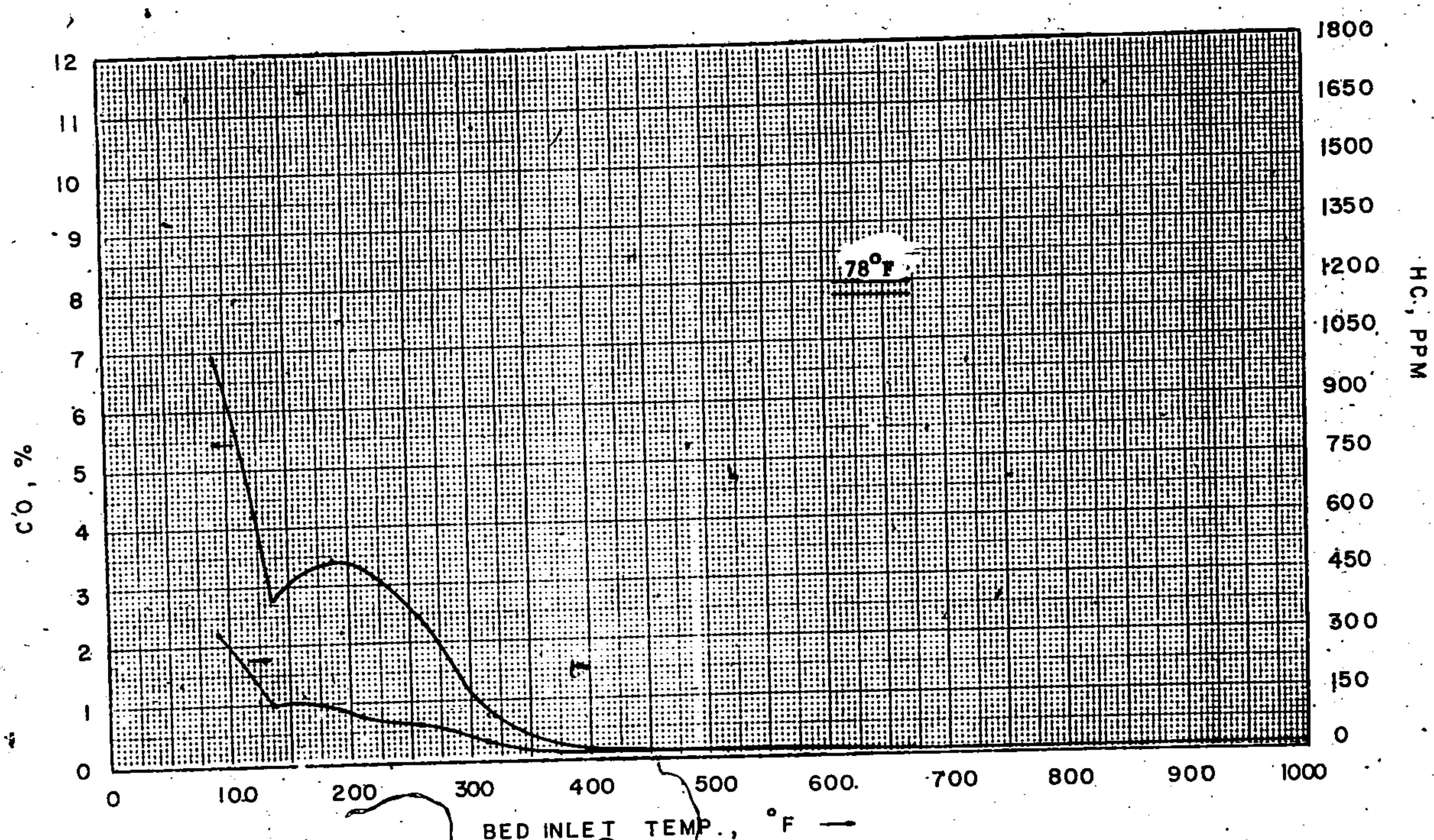


FIG. 6-12.

(RUN # 34)

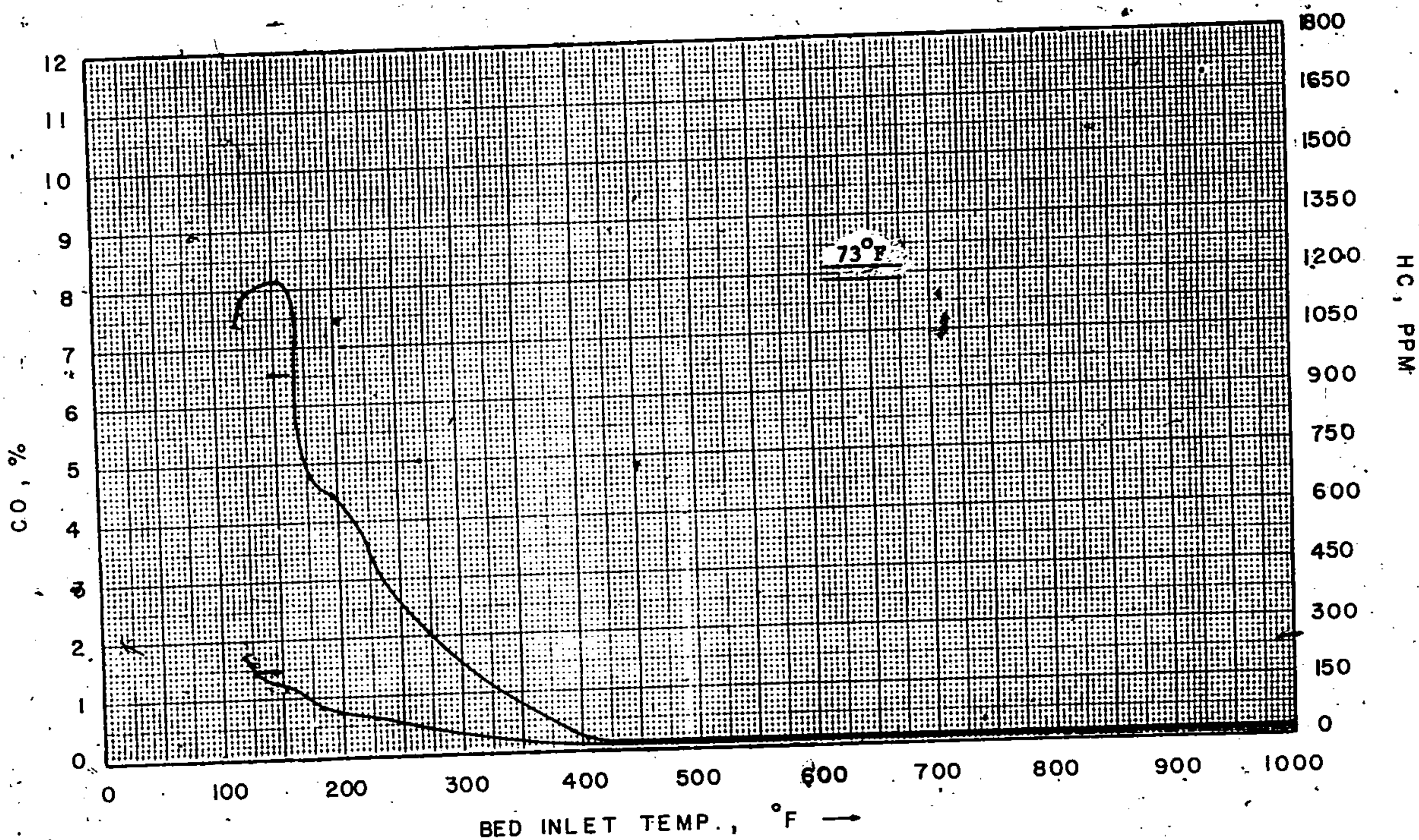


FIG. 6-13.

(RUN # 36)

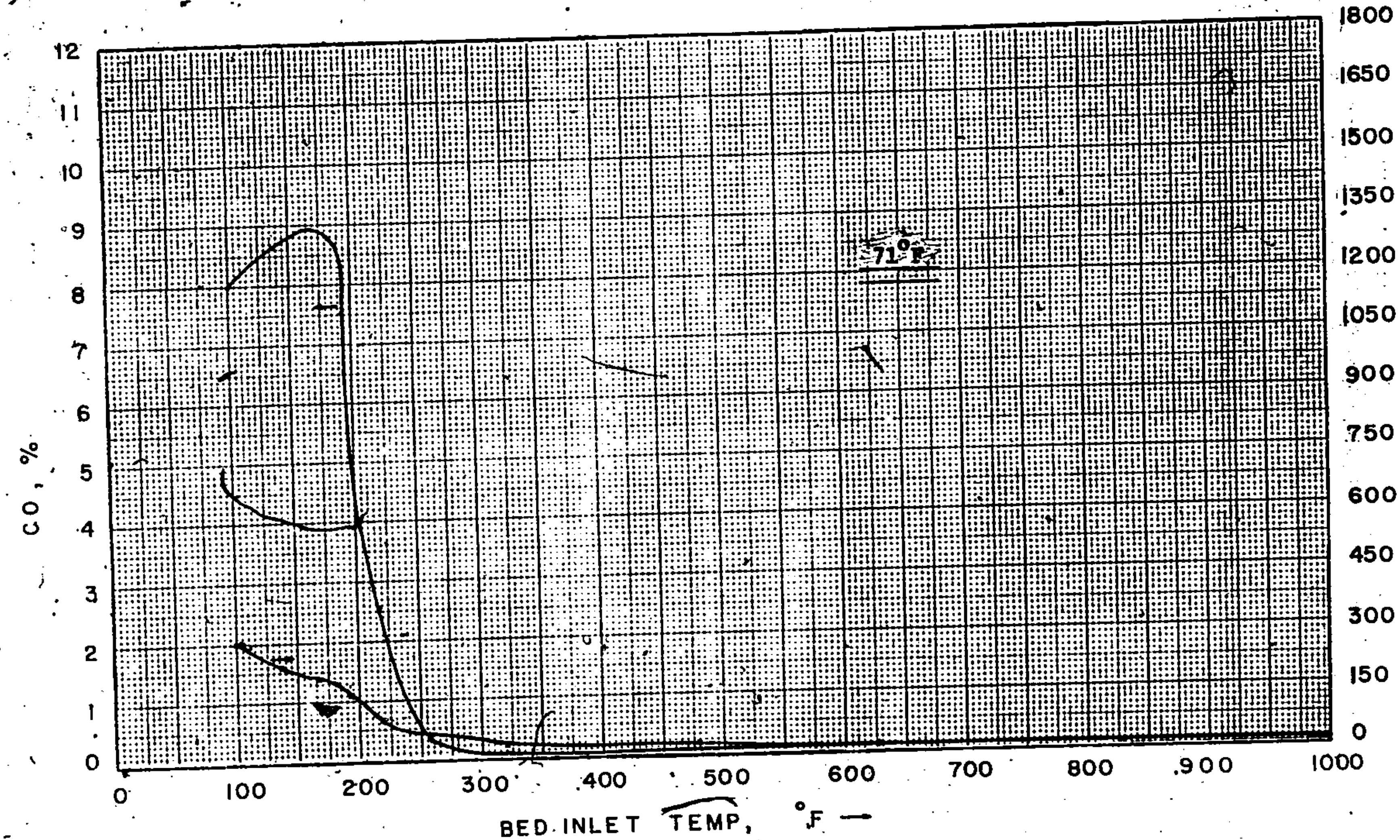


FIG. 6-14.

(RUN # 37)

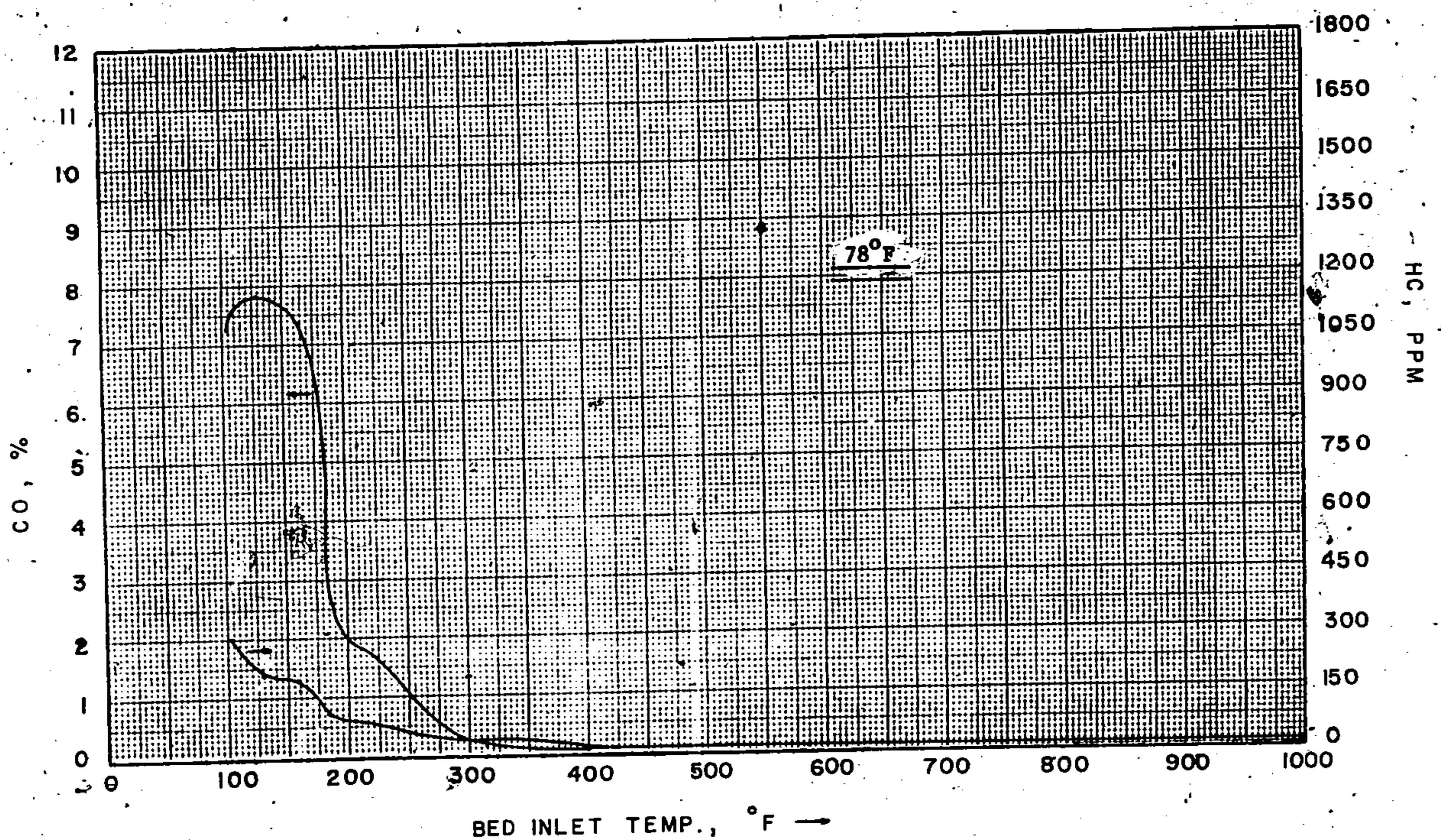


FIG. 6-15.

(RUN # 38)

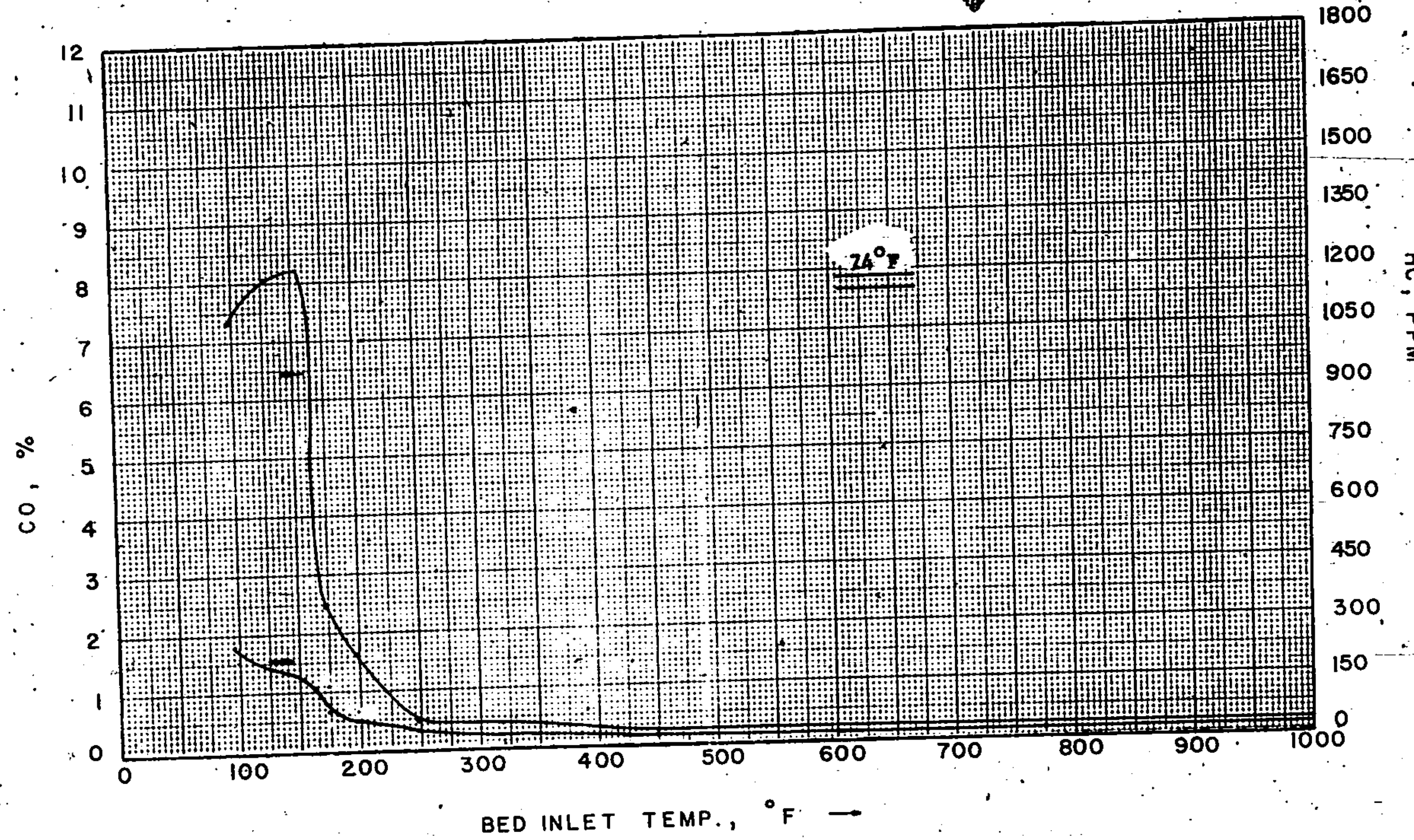


FIG. 6-16.

(RUN # 39)

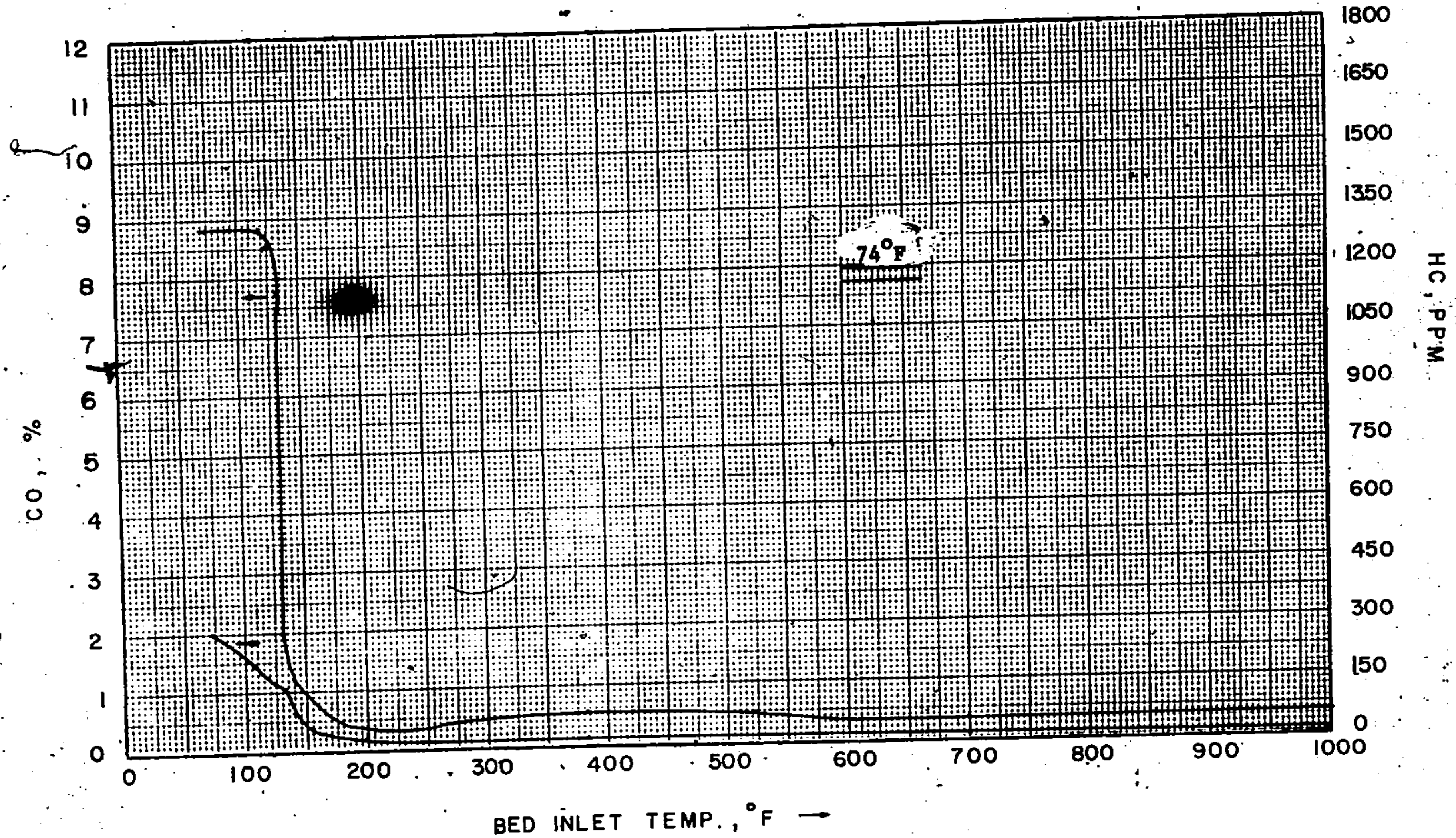


FIG. 6-17.

(RUN # 40)