United States
Environmental Protection
Agency

Motor Vehicle Emission Laboratory
2565 Plymouth Rd.
Ann Arbor, Michigan 48105

EPA 460/3-78-009
September 1978

Air

EPA

# 91 Ron-Increased Compression Ratio Engine Demonstration

# 91 RON-INCREASED COMPRESSION RATIO ENGINE DEMONSTRATION

by

Patrick E. Godici
and
Bernhard J. Kraus
Products Research Division
Exxon Research and Engineering Company

EPA Contract No. 68-03-2162

Project Officer

Robert Wagner
Emission Control Technology Division
United States Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, Michigan 48105

This report is the Final Report and is submitted in fulfillment of Contract No. 68-03-2162 under the sponsorship of the U. S. Environmental Protection Agency.

## DISCLAIMER

TABLE OF CONTENTS

ABSTRACT

A 1975 California model automobile with an 8:1 C.R. 350 CID engine was modified by increasing the compression ratio to 9:1 which resulted in improved fuel economy. The higher $NO_x$ emissions were reduced to the base level by substituting a back pressure-controlled EGR unit for the original valve and increasing the EGR flow. Four approaches were tried in an engine dynamometer installation to lower the octane requirement of the 9:1 C.R. engine. These were (1) increase turbulence by increasing the squish area, (2) use dual spark plug ignition to minimize flame travel time, (3) use aluminum heads to obtain better heat transfer, and (4) use knock sensor-actuated spark retard to temporarily de-tune the engine when knock occurs. Of these, the latter approach showed the most promise and was installed in the vehicle to control the level of detonation in the modified 9:1 C.R. vehicle.

The knock sensor (accelerometer) is attached to one of the cylinder heads of the engine. When knock occurs, the vibration is picked up by the sensor, the signal is filtered to remove some of the engine background noise, and the knock pulse is detected. When the amplitude of the detected knock signal exceeds a threshold value, the spark timing is retarded. When no knocking is detected over a waiting period, the timing is advanced back to its normal schedule. Using this system, the vehicle's octane requirement can be lowered several numbers with some performance debit, i.e., slower acceleration times.

# SECTION 1

## INTRODUCTION

The objective of this work was to develop an increased compression ratio engine which could be operated on 91 RON unleaded fuel. At the higher compression ratio, the vehicle would achieve better fuel economy but also would produce higher $NO_x$ emissions. Recalibration of emissions levels to the lower C.R. base case can be done using conventional means (e.g. increased EGR flow, etc.). However, the reduction of vehicle octane requirement to allow operation at the higher compression ratio necessitated a considerable effort to find a suitable approach. This subject, then, was the focus of attention during the research.

### 1.1 FACTORS AFFECTING OCTANE REQUIREMENTS

When an engine is operated on fuel of insufficient octane, detonation, or knock, occurs. Taylor and Taylor(1) present the following description of detonation:

> "It is now generally accepted that detonation is due to the autoignition of the end gas, which is the part of the charge which has not yet been consumed in the normal flame-front reaction. When detonation occurs, it is because piston motion, plus compression of the end gas by expansion of the burned part of the charge, raises its temperature and pressure to the point where the end gas autoignites. If the reaction of autoignition is sufficiently rapid, and a sufficient amount of end gas is involved, detonation can be observed."

The usual way of detecting detonation is by the audible "ping" it produces, though it is possible to record the pressure rise it creates, record the arrival of the flame front at a given point in the cylinder, or use a variety of other instrumental approaches.

Knock is a discrete event, which is dependent on events occurring in the individual cylinder. Two nominally identical engines may not knock under similar operating conditions, nor is it likely that all cylinders in a given engine will start to knock at the same threshold value. Any approach to the question of what conditions cause knock to occur must be statistical in nature.

Knock is objectionable for several important reasons. First, the noise of knock itself is objectionable. Second, knock may lead to localized overheating which in turn leads to preignition, that is, ignition before the spark plug is supposed to fire. Preignition causes loss of power and fuel economy, poor driveability, and may damage the engine. Finally, even without preignition, severe and prolonged knock can damage piston heads, exhaust valves, and piston rings.

There are two basic approaches to avoiding knock. First, is to design the engine in such a way as to keep the end gas temperature below the severe autoignition temperature or keep combustion time short enough to avoid detonation. This involves such steps as limiting compression ratio, adjusting spark timing, and designing combustion chambers to avoid large collections of end gas. Second, is to provide fuel which is less subject to autoignition. This can be done by controlling the hydrocarbon species in the fuel - isoparaffins and aromatics are less subject to autoignition than normal paraffins or olefins - or by use of additives such as tetraalkyl lead, which inhibit autoignition. Typically, the autoignition tendencies of fuels are characterized by octane number, determined either by the Research or Motor methods. Fuels are rated in comparison to mixtures of normal heptane, a straight chain paraffin with high autoignition tendencies, which is assigned zero octane number, and isooctane, a branched paraffin with low autoignition tendency, which is assigned an octane number of 100. Octane numbers of greater than 100 are compared against isooctane and given amounts of tetraethyl lead.

A second fuel related factor influencing tendency to knock is deposit forming tendency. All fuels form carbonaceous deposits in the combustion chamber. Fuels and lubes with lead or other metallic additives also form inorganic deposits. Deposits change the heat transfer characterisitcs of the combustion chamber. They tend to insulate the chamber and, therefore, increase the tendency for autoignition. Combustion chamber deposits build slowly to an equilibrium level during which time octane requirement increases. The amount of octane requirement increase observed depends on the characteristics of the fuel, the mileage accumulation schedule, and the characteristics of the engine used. This subject will be discussed in greater detail below.

As mentioned above, knock is a discrete phenomenon and can only be treated statistically. In the following sections, the effects of individual engine parameters on tendency to knock will be discussed. The differences between clean and equilibrated engines, and a statistical survey of octane requirements will also be illustrated.

COMPRESSION RATIO - Compression ratio is one of the primary determinents of octane requirement. Figure 1-1 shows the research octane number required to satisfy 90% of the vehicle population on full boiling range unleaded fuels as a function of compression ratio. These data were estimated by Corner and Cunningham[(2)] from data obtained in the CRC Octane Number Requirement Survey. These historical data indicate that 91 RON fuel will satisfy 90% of the vehicles at ~7.5:1 compression ratio. Since average compression ratio for the 1975 model year is assumed to be ~8.2:1, a significant portion of the vehicles on the road will not be satisfied unless some of the "mechanical octane" changes assumed possible in this proposal are used.

FIGURE 1-1

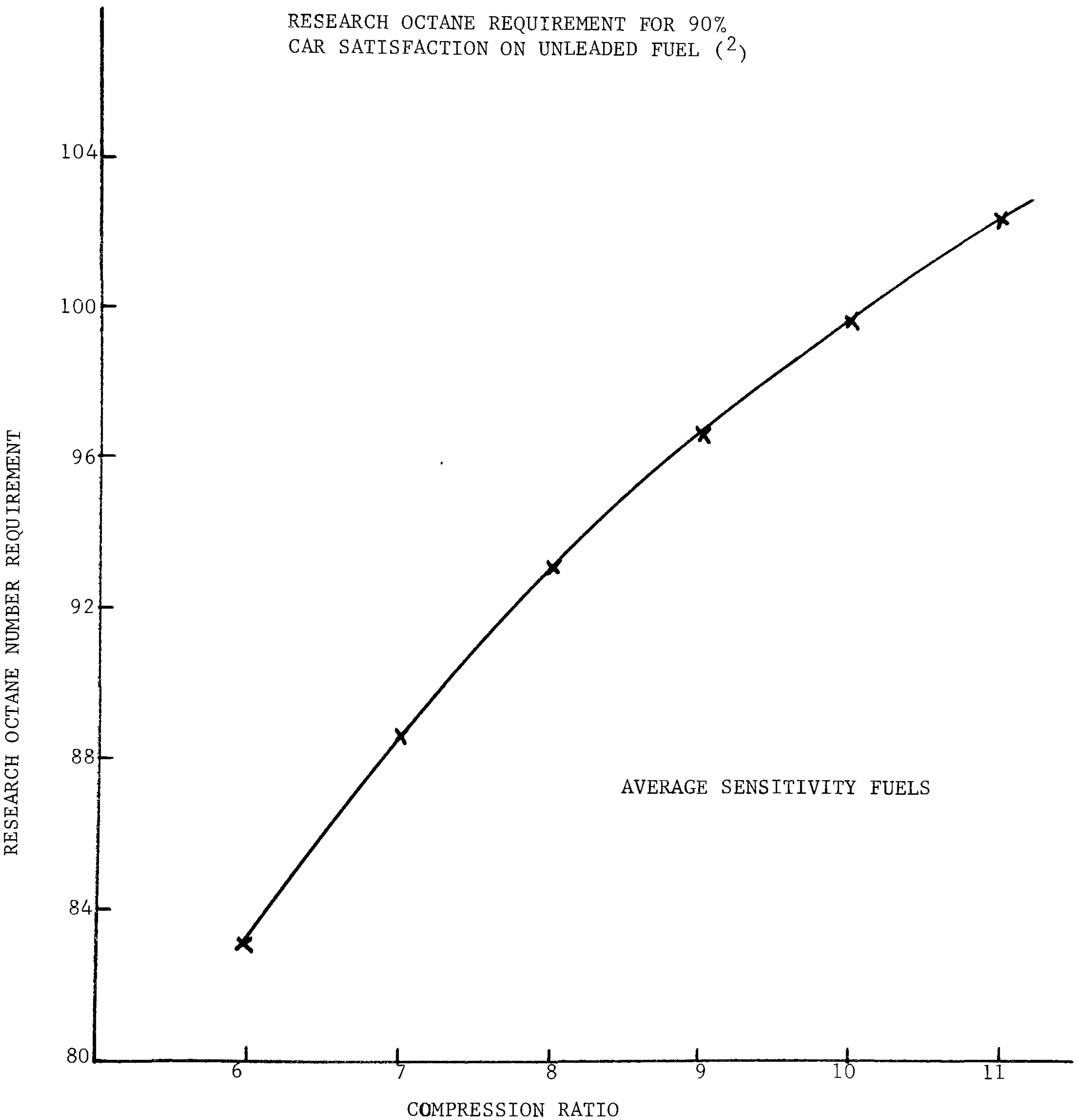
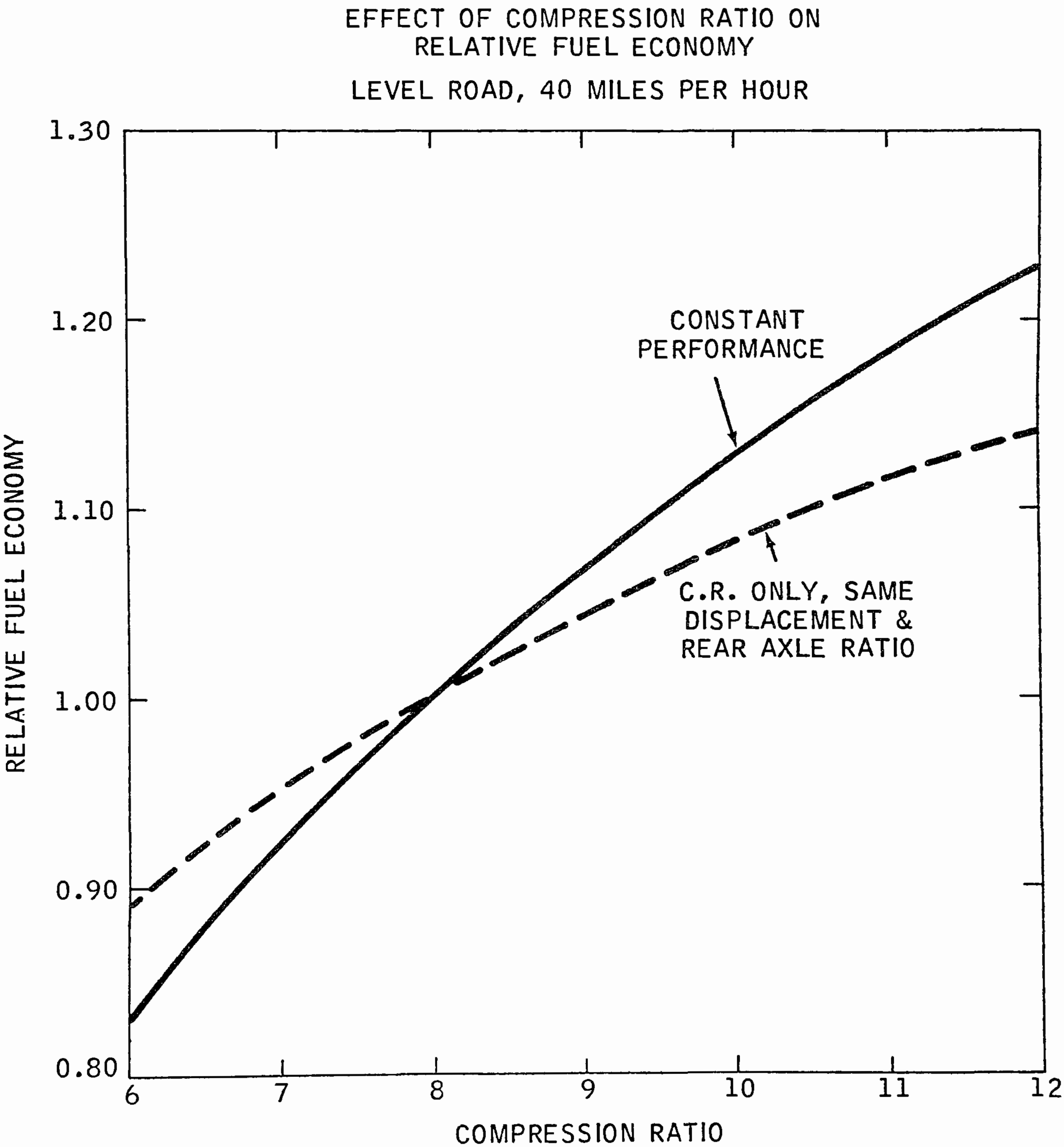

RESEARCH OCTANE REQUIREMENT FOR 90%
CAR SATISFACTION ON UNLEADED FUEL (2)
RESEARCH OCTANE NUMBER REQUIREMENT
104
100
96
92
88
84
80
AVERAGE SENSITIVITY FUELS
6
7
8
9
10
11
COMPRESSION RATIO

Figure 1-2


EFFECT OF COMPRESSION RATIO ON
RELATIVE FUEL ECONOMY
LEVEL ROAD, 40 MILES PER HOUR
RELATIVE FUEL ECONOMY
1.30
1.20
1.10
1.00
0.90
0.80
COMPRESSION RATIO
6
7
8
9
10
11
12
CONSTANT
PERFORMANCE
C.R. ONLY, SAME
DISPLACEMENT &
REAR AXLE RATIO

Compression ratio also has a significant effect on fuel economy. Corner and Cunningham also present a survey of the literature in this area. Figure 1-2 shows the effect of compression ratio on fuel economy for two cases, one in which performance is held constant by changing engine size and/or rear axle ratio, the second in which compression ratio is changed without making other changes in the engine. These data are for level road, 40 mph cruise conditions and represent tests by a number of different investigators using a wide variety of engines.

In actual customer use, only part of the steady state fuel economy benefit will be realized. Corner and Cunningham estimated that 80% of the steady state benefit would be available and that the automotive industry would make the changes necessary to maintain constant performance. The resulting fuel economy benefit as a function of compression ratio is shown in Figure 1-3.

Compression ratio generally has a major effect on $NO_x$ emissions with smaller effects on CO and HC emissions. As compression ratio is raised, peak cylinder temperature rises and $NO_x$ formation rate increases. In one typical experiment conducted by Exxon Research, raising compression ratio from 9:1 to 11:1 at an air-fuel ratio of 14.4 lbs. air/lb. fuel, raised $NO_x$ emissions 68%. An increase in compression ratio would have to be accompanied by steps to lower $NO_x$ emissions back to acceptable levels.

The data in Figure 1-1 show that octane requirement increase is a non-linear function of compression ratio, but that over the range of compression ratios from 7 to 10, octane requirement increases about 3.5-4 numbers/compression ratio. The data in Figure 1-3 show about a 5% increase in fuel economy/compression ratios. Therefore, compression ratio changes result in 1.3% improvement in fuel economy/octane number requirement increase.

SPARK TIMING - In order to maximize the work obtained from an Otto cycle engine, the pressure-volume integral for the expansion stroke must be maximized. This is achieved if peak pressure is reached slightly after the piston reaches its top dead center (TDC) position. The fuel-air mixture must be ignited before TDC to obtain this condition, that is, spark should occur in advance of TDC. Spark timing is usually stated in terms of crank angle degrees before or after TDC. The more degrees before TDC the spark occurs the more spark advance. Delaying spark, even if spark still occurs before TDC, is referred to as spark retard.

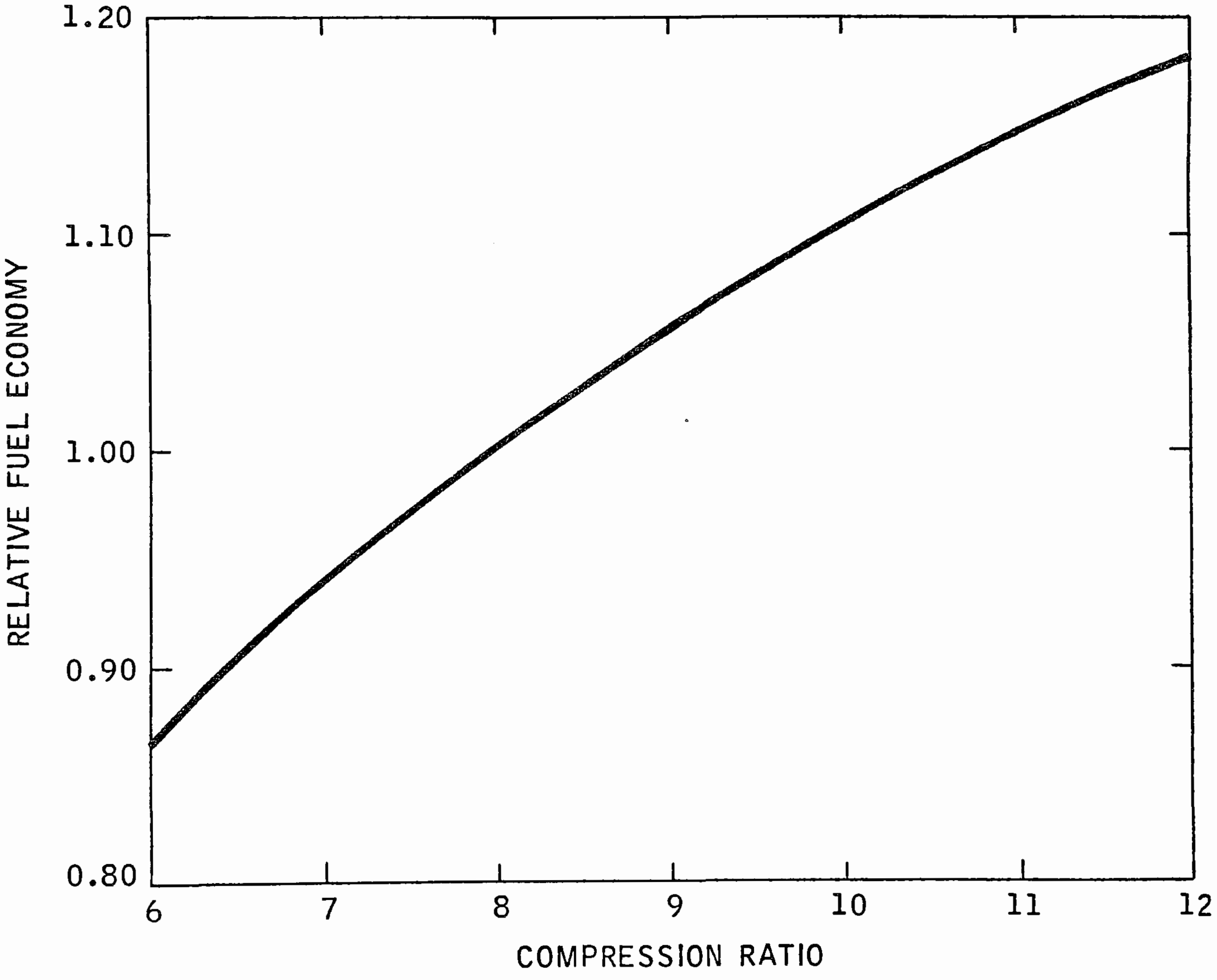
The optimum amount of spark advance varies widely with operating conditions. To provide the proper amount of advance under a wide range of conditions, three types of control are used. The first of these is a basic timing adjustment. This is the amount of advance needed to obtain proper performance at low engine speeds. In most engines, basic timing is set between TDC and 12 degrees before TDC. This adjustment is made with vacuum advance (described below) disconnected.

The second control is vacuum advance. At lower power outputs, the engine operates at high intake manifold vacuum levels, and therefore, at low peak cylinder pressure. Lower pressure in the cylinder means

Figure 1-3

EFFECT OF COMPRESSION RATIO
ON CUSTOMER RELATIVE
FUEL ECONOMY

80% OF LEVEL ROAD, 40 MILES PER HOUR



reduced flame speed. To obtain peak pressure at the correct time in the cycle, spark must be advanced. Most engines use an intake manifold vacuum actuated control to advance spark automatically.

The third control is centrifugal advance. As engine speed increases, the time available for the air-fuel charge to burn decreases. To allow time for the flame to develop properly, it is necessary to advance spark as a function of engine speed. This control is known as centrifugal advance.

Spark timing has a significant effect on emissions, fuel economy, and octane requirement. Since optimum timing results in the maximum temperature and pressure in the cylinder, it will also result in peak $NO_x$ formation. Retarding spark timing is one of the popular methods of reducing $NO_x$ emissions. Retarding spark timing will also generally reduce HC emissions. With retarded timing, less of the fuel's chemical energy is converted to mechanical energy. More is rejected as sensible heat in the exhaust. Higher exhaust temperatures promote post engine oxidation of hydrocarbons, and therefore, lower HC emissions. The effect of spark retard on CO emissions is relatively small and mixed. In some cases spark retard causes small reductions in emissions; in others, small increases.

Spark retard increases fuel consumption. Since with spark retard, less of the fuel's chemical energy is converted to work, more fuel must be consumed to do a given amount of work. Teasel, Calcamuggio, and Miller(3) showed a fuel economy debit of 1% per degree of spark retard.

Spark retard also reduces octane requirement. Since peak cylinder temperature and pressure are reduced, the tendency to knock is reduced. In 1970, the CRC Octane Number Requirement Survey included a study of the effect of 5 degrees spark retard on octane requirements. The average reduction in requirement for the roughly 100 cars tested was 0.7 octane number per degree of spark retard(4). Putting the octane requirement data and the fuel economy data together yields a fuel economy penalty of 1.4%/octane number requirement decrease if spark retard is used to reduce octane requirement. It should be realized, however, that spark retard will also cause a performance debit. If the amount of spark retard used is small, 5° or less, the power debit at the peak of the power curve is fairly small. For example, Caris, _et al_.(5) showed a 5 RON reduction in requirement for a 1% loss in peak power with 5° spark retard. At less than peak power, spark retard will cause greater reductions in power. Spark timing curves are typically retarded at the low speed, high load conditions which create maximum potential for detonation. This allows use of higher compression ratio and better efficiency at other operating conditions.

EXHAUST GAS RECYCLE (EGR) - EGR is a means of controlling $NO_x$ which involves taking part of the exhaust stream and recycling it to the intake manifold. This adds diluent to the combustion mixture and therefore, lowers combustion temperature which results in lower $NO_x$ formation rates. EGR generally has smaller effects on HC and CO emissions.

Since EGR functions by lowering peak flame temperature, it should be expected to lower octane requirement. EGR does in fact lower octane requirement. Musser, et al.[6] showed a decrease in octane requirement of 0.5 octane number/% EGR used. EGR is not used at full throttle in production vehicles because it reduces fuel economy at full throttle. However, at the more usual part throttle operation, a greater throttle opening, hence increased intake manifold pressure, is required to maintain constant power when EGR is used. Higher intake manifold pressure means less pumping loss, hence improved engine efficiency. This can compensate, at least in part, for the fuel economy lost by lower peak flame temperatures induced by EGR. EGR also lowers flame speed. To combust the charge at the appropriate time then, it is necessary to advance spark timing. The optimum air-fuel ratio for fuel economy moves to richer values with EGR for the same reason. Rich mixtures burn with faster flame speeds. Gumbleton, et al.,[7] showed that by adjusting spark timing and air-fuel ratio, it is possible to operate with as much as 15% EGR with no loss in fuel economy or part throttle performance compared to an optimized non-EGR case.

At full throttle, the reduction in pumping loss obtainable by opening the throttle wider is no longer available. Significant losses in performance occur because of the lower peak flame temperature. Glass et al.[8] give the following data on this subject:

Table 1-1 Effect of EGR at Wide Open Throttle (WOT) on 0-60 mph Acceleration Time

| | % EGR | 0-60 WOT Accel. Time | % Over Base |
|---|---|---|---|
| 318 CID Plymouth | 0 | 11.76 | --- |
| | 7 | 13.68 | 16.3 |
| | 9.5 | 14.22 | 20.9 |
| | 12.5 | 15.0 | 27.6 |
| 307 CID Chevrolet | 0 | 16.6 | --- |
| | 13.3 | 19.4 | 16.8 |
| | 20.2 | 26.3 | 58.4 |

The effect of EGR on WOT performance is great enough to make a fuel economy comparison between the non-EGR and EGR cases meaningless.

OTHER DILUENTS - Other diluents will have the same effect on peak flame temperature that EGR has. Therefore, they will also decrease knock but at the cost of reduced power. The diluent most often discussed in this context is water. Proponents of this approach point out that water injection was used in World War II piston engine aircraft to allow peak power to be developed at low altitude. The argument made is that water injection at WOT in an automobile engine would allow a reduction in octane requirement with no reduction in peak power or fuel economy. This argument overlooks the basic differences between a World War II aircraft engine and an automobile engine.

The aircraft engine was designed to provide a given power level at high altitude where ambient pressure is low. To provide reasonable charge density the engine was supercharged. If the supercharger were allowed to act at low altitude with no other compensation, very high peak cylinder temperatures would develop. The engine would either knock or develop excessive thermal loads. Engines and fuels which could tolerate these peak cylinder pressures could be developed, but these would have been overdesigned for high altitude. The more reasonable approach was to allow the engine to operate near design limit at high altitude and reduce peak "potential" power at low altitude. Water injection did this.

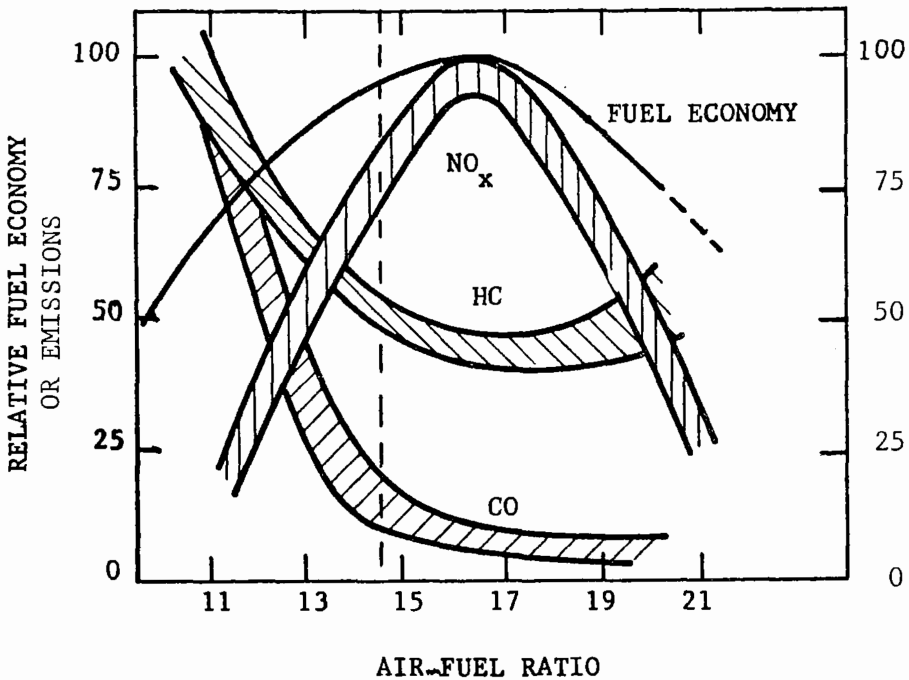
The automobile engine does not operate over this wide range of ambient conditions and therefore, does not need to be designed for reduced "potential" power. The cost of water injection is such that it could not compete with the means of suppressing knock already in the engine compartment.

AIR-FUEL RATIO - Air-fuel ratio affects octane requirement because it too affects peak cylinder temperature. Operating either with excess fuel (richer than stoichiometric) or excess air (leaner than stoichiometric) dilutes the burning charge and lowers peak cylinder temperature. Lower peak cylinder temperature results in lower octane requirement. As a rule of thumb, each air-fuel ratio leaner than stoichiometric lowers octane requirement 4 octane numbers.(5) The effects of air-fuel ratio on emissions and fuel economy are shown in Figure 1-4. Fuel economy is a non-linear function of air-fuel ratio. Therefore, it is difficult to calculate a fuel economy debit/octane number requirement decrease for changes in air-fuel ratio as had been done for changes in compression ratio, spark timing, and EGR rate. Such a computation would probably be of academic interest only, however. Most emission control systems depend on relatively tight control of air-fuel ratio and changing air-fuel ratio to change octane requirement would cause great difficulty.

COMBUSTION CHAMBER PROPERTIES - Since knock takes place in the end gas region, anything which changes either the degree of turbulence, in the chamber, the time for which the end gas exists, or the heat transfer characteristics of the region will affect the tendency to knock. Increasing turbulence should propagate the flame across the combustion chamber at a faster rate, leaving less time for autoignition to occur. Similar effects can be obtained by changing the shape of the combustion chamber or the location of the spark plug. Finally increasing

Figure 1-4

FUEL ECONOMY AND AIR-FUEL RATIO



heat transfer from the end gas zone cools the end gas and reduces the tendency to knock. Conversely, insulating the end gas zone with combustion chamber deposits will reduce heat transfer and increase the tendency to knock. Each of these subjects is discussed below.

Turbulence - The effects of increased turbulence on octane requirement have been studied by many investigators, but no method for accurately measuring changes in turbulence in the combustion chamber has been developed. One common approach to increasing turbulence is to shroud the intake valve. It involves masking a portion of the intake valve and thus forcing all of the intake charge to flow through a restricted portion of the normal intake opening. This causes the incoming charge to swirl as it enters the cylinder. A drawing of a shrouded intake valve is shown in Figure 1-5(a). Caris, et al.(5) present data of the effects of 90° and 180° shrouds in a single cylinder engine. At high engine RPM, the srouds caused a significant reduction in power since they acted as throttles. Power reductions occurred at engine speeds above 2000 RPM with the 180° shroud and above 2500 RPM with the 90° shroud. However, at lower speeds definite octane reductions were observed. At 1000 RPM, 9:1 compression ratio, the unshrouded engine required 98 RON. The 90° shroud reduced this to 95 RON; the 180° shroud to 93 RON. While these results are interesting, their practical application is severely limited by the throttling effect of shrouds.

Another, more practical approach to creating combustion chamber turbulence is to design the piston so that part of it matches the head at top dead center with only enough clearence to prevent interference. This has the effect of physically displacing the charge from one side of the chamber to another as the piston approaches top dead center. The thin zone thus created is generally referred to as a squish zone.

There are two general approaches to creating a squish zone. The first is to use a flat piston head and a wedge shaped cavity in the cylinder head. The second is to use a flat cylinder head and a bowl shaped cavity in the piston head. Both configurations are shown in Figure 2-5(b). Caris, et al.(5) show single cylinder engine octane requirement data comparing a flat cylinder head-flat piston head configuration with a flat cylinder head-bowl shaped cavity in the piston head configuration. At 1000 RPM, 9:1 compression ratio, the piston head with the cavity had a 19 RON lower requirement. No such direct comparison was made for wedge shaped combustion chambers.

Besides increasing turbulence, a squish zone increases heat transfer from the end gas and decreases its volume. Thickness of the squish zone is important in this respect. Caris, et al.(5) present octane requirement data for a single cylinder engine in which a depression in the piston head provided essentially all of the combustion chamber volume. Reducing the clearance between the cylinder head and the portion of the piston head not containing the depression from 0.100 inch to 0.040 inch reduced octane requirement by 10 numbers.

FIGURE 1-5

METHODS OF CREATING TURBULENCE IN
COMBUSTION CHAMBERS

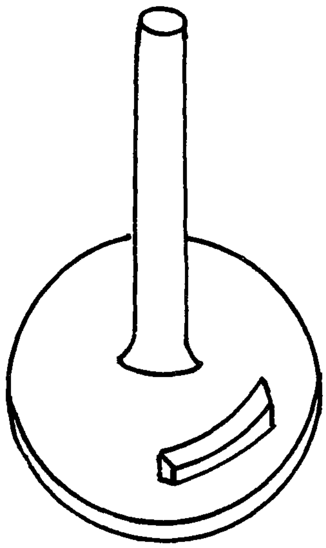
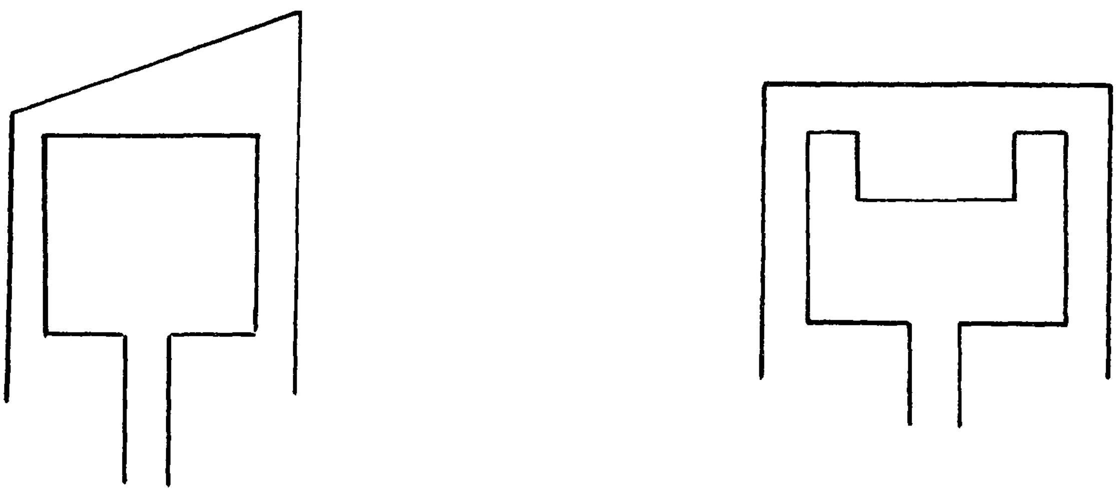


FIGURE 1-5 (a) SHROUDED INTAKE VALVE



WEDGE SHAPED
COMBUSTION CHAMBER

DEPRESSION IN
PISTON HEAD

FIGURE 1-5 (b) SQUISH ZONES

It should be remembered that Caris, et al. studied these problems in single cylinder engines with clean combustion chambers. Their results should be considered qualitative rather than quantitative, since, at best, only part of the benefit they observed would be found in a multi-cylinder engine operating with deposited combustion chambers. Despite this qualificiation, the benefits of squish zones were widely recognized, and by the mid-1960's they were a feature on most engines.

However, with the advent of emission control standards, squish zones had to be reevaluated in terms of their effect on emissions. The specific problem was the effect that squish zones have on hydrocarbon emissions. Most emitted hydrocarbon is the product of incomplete combustion, but part is fuel which survives the combustion chamber unburnt in a thin layer near the combustion chamber walls known as the quench zone. Quench zones exist because mechanical considerations dictate that the walls of the combustion chamber must be kept fairly cool. These cool walls quench the approaching flame a finite distance from themselves, thus creating the quench zone. All other factors being equal, the amount of hydrocarbon emitted from the quench zone is directly proportional to the surface-to-volume ratio of the combustion chamber. Combustion chambers with squish zones have higher surface-to-volume ratios than those without squish zones.

As a result, in the late 1960's when many auto manufacturers redesigned the combustion chamber of their engines to reduce surface-to volume ratio, they partially eliminated the squish zone and thus tended to increase octane requirement. Because these changes were made at the same time as major changes in air-fuel ratio and spark timing, it is impossible to quantify the magnitude of the effect of changes in combustion chamber design on octane requirement by comparison from one model year to the next.

Combustion Time Considerations - Knock is the result of chemical reactions occurring in the end gas region. These reactions are rate controlled and if insufficient time is allowed for the reaction to proceed, the flame will pass through the end gas region before knock occurs. The most critical factor in determining the time available for end gas reactions to occur is engine RPM. Knock may occur at the beginning of a wide open throttle acceleration, while engine speed is low, and disappear as engine speed increases. One method of minimizing the time required for the flame to travel through the combustion chamber is to place the spark plug in the center of the combustion chamber rather than at one end. This is done in most engines.

A further reduction in combustion time can be obtained by using multipoint ignition. This approach is attractive because it does not debit either power or fuel economy as do spark retard, use of EGR at full throttle, and the other techniques discussed above. In fact, directionally, multipoint ignition tends to increase efficiency and power by more closely approximating constant volume combustion.

Lichty[10] reports on the beneficial effect of using two spark plugs at opposite ends of the combustion chamber in valve-in-head engines. Taylor and Taylor[1] report on the effect of spark plug location on knocking tendency using as many as 17 spark plugs in a single cylinder engine. They show a substantial reduction in the octane requirement of the engine when all 17 plugs fired simultaneously. Of course, the authors themselves say that the practical approach would make use of two spark sources.

Varde and Lucas[11] reported that dual spark plug ignition shortens the combustion duration and thereby reaches higher maximum cylinder pressures at a higher rate of pressure rise. This would be expected to produce more power and greater $NO_x$ emissions which was found to be the case. Studies at General Motors[12] agree with these findings. In addition, by diluting the intake charge with $N_2$, large reductions in the $NO_x$ emissions were obtained primarily due to thermal effect.

The firing of the two sparks at different locations effectively acts as if the spark were advanced, as far as the pressure rise curve is concerned. Accordingly, the firing of the two plugs can be retarded to a point such that the peak pressure with two plugs is the same as obtained with one plug fired at the normal time. Again the benefits of reduced combustion time is obtained while retaining a more or less normal pressure rise. Without an undue increase in complexity, the two approaches could be combined, i.e., a delay between primary and secondary ignition with an overall retard of the primary ignition.

Combustion Chamber Deposits - Octane Requirement Differences Between Clean and Equilibrated Engines - It has been well established by numerous experiments that the octane requirement of engines increases from its value at zero miles to an equilibrium value. The magnitude of this octane requirement increase, or O.R.I., is dependent on the driving mode used during equilibration. The time required to reach equilibrium depends both on driving mode and fuel type.

O.R.I. is associated with the build-up of combustion chamber deposits. It is easy to picture these deposits filling part of the combustion chamber, raising the effective compression ratio, and thus raising octane requirement. This mechanism probably accounts for part of O.R.I., but the insulating effect of combustion chamber deposits seems to be more important. Insulating the combustion chamber raises end gas temperature and the tendency to knock. Combustion chamber deposits are composed of very high molecular weight carbonaceous materials, oxides of the metals present in lubes, and when leaded fuels are used, lead salts. All of these materials are good insulators.

Equilibrium occurs when the rate of combustion chamber deposit lay down is equalled by the rate of deposit scavenging due to thermal and mechanical shocking. Total O.R.I. to equilibrium depends on the driving mode used. O.R.I. will be high, up to ∿10 octane numbers, if a cycle with mild and/or infrequent accelerations is used, since this type of driving minimizes mechanical scavenging of deposits. Driving cycles with frequent and/or hard accelerations lead to lower O.R.I.'s because of better deposit scavenging.

In this context, the octane rating procedure with its repeated wide open throttle accelerations (See Section 2.2.1) is a good means of scavenging deposits. The act of octane rating an engine will reduce its octane requirement several numbers. Duplicate rating should always be made after some intervening mileage accumulation.

The time required to reach equilibrium depends on the fuel used. With leaded fuels at least 5,000 miles is normally considered sufficient time to reach equilibrium. However, with unleaded fuel, longer mileage accumulations are necessary. In our view, the reason for this is not understood at this time. In a 12 car program conducted by Exxon Research in 1971, we found that ∿7,500 miles was sufficient to reach equilibrium with unleaded fuel in simulated urban driving. A representative of General Motors(13) stated publically that equilibrium was reached within 12,000 miles of consumer driving on unleaded fuel. O.R.I. for this study was ∿7 numbers. Both values may be correct since the approach to equilibrium is a function of driving mode as well as fuel type.

OTHER ENGINE PARAMETERS - At least two other engine parameters have small but measurable effects on octane requirement. These are the temperature of the inlet air-fuel charge and the temperature of the coolant. Raising either temperature affects the heat balance in the cylinder and raises the end gas temperature, thus raising the tendency to knock.

AMBIENT CONDITIONS - Atmospheric temperature, pressure, and humidity all have an effect on end gas temperature. Raising either atmospheric temperature or pressure will raise end gas temperature and therefore tendency to knock. Moisture in the inlet air is a diluent which lowers end gas temperature. The effect of atmospheric pressure has been measured by the CRC in terms of the effect of altitude change on octane requirement of late model cars.[13] The average octane number requirement decrease for thirty-nine 1971 and 1972 model year cars was ∿2/in. of Hg pressure decrease.

RESEARCH OCTANE NUMBER VS. MOTOR OCTANE NUMBER - Thus far we have discussed octane requirement as if it were a single value and where data have been presented, they have been in terms of Research Octane Number Requirement. As stated earlier, there are two generally accepted methods of measuring octane number - the Research Method (ASTM Procedure D2699) and the Motor Method (ASTM D2700). Both methods use single cylinder, variable compression ratio engines and rate normal heptane as zero octane and isooctane as 100 octane. The Research Method is conducted at 600 RPM with an inlet air temperature of 125°F. Conditions for the Motor Method are somewhat more severe - 900 RPM and 300°F inlet air temperature.

Most fuels show a lower rating by the Motor Method than by the Research Method. The difference between the octane number determined by the two methods is referred to as "sensitivity." Sensitivity is a function of the chemical composition of the fuel. Paraffins and isoparaffins have relatively low sensitivity; aromatics and especially olefins, higher sensitivity.

Neither Research Octane nor Motor Octane Number exactly predict the octane requirement of vehicles in use. The CRC handles this problem by defining "road octane." The road octane number of a fuel is the octane number of a primary reference fuel, i.e,. a blend of isooctane and normal heptane, which has the same knocking characteristics as the fuel in question.

As a general trend, modern vehicles have become more dependent on Motor Octane Number. The importance of Motor Octane Number was recognized by the FTC, the auto industry and the petroleum industry in the decision to post octane number as an average of Research and Motor Octane Numbers, rather than posting just Research Octane Number as had typically been used in advertising. Reasons for the rising importance of Motor Octane Number are discussed below.

EFFECT OF TRANSMISSION CHARACTERISTICS ON MOTOR OCTANE NUMBER DEPENDENCE - A number of literature references [14-16] have discussed the knocking behavior of engines used with automatic transmissions. There is unanimous agreement in the literature that as engine speed increases, Motor Octane Number becomes a better predictor of fuel requirement than Research Octane Number. The use of automatic transmissions with torque convertors prevents engine loadings at speeds below the stall speed. Since the operating regime of engines with these transmissions is limited to a higher speed range, it should be expected that they respond to Motor rather than Research Octane Number. One method of relating the relative importance of Research and Motor octane is with a road octane number equation. Let:

$$\text{Road O.N.} = a\,(\text{RON}) + b\,(\text{MON}) + c, \qquad (2\text{-}1)$$

where: RON = Research Octane Number, and
MON = Motor Octane Number,

Then the relative importance of RON and MON is given by the ratio a/b. Fell and Hostetler(16) give this ratio as 15.7 for vehicles equipped with manual transmissions, but only 5.6 for vehicles equipped with automatic transmissions.

OCTANE REQUIREMENTS FOR ACTUAL VEHICLES - It should be obvious from the foregoing that estimating the equilibrated octane requirement of an engine from its design parameters is an impossible task. The large number of independent variables leads to a significant spread in the octane requirements of nominally similar vehicles. Figure 1-6 shows octane requirement data for 35 1973 V-8 vehicles of the same make and model obtained in the CRC's 1973 Octane Number Requirement Survey(17) using an 11 sensitivity fuel series. Minimum Octane Requirement was less than 84.5 RON, maximum greater than 100 RON. These type data are usually plotted as percent of cars satisfied by a given octane fuel. CRC plots such data for 12 models, each plot being based on 13-24 cars. The spread between the 10 and 90% satisfaction points for a given model for RON with full boiling range fuels averages about 10 numbers. For MON average spread is about 7 numbers. Spreads for the entire 1973 population (see Figures 1-7 and 1-8) are even larger.

The wide spread in the octane requirements of nominally similar vehicles presents serious problems in doing research on octane requirements. The only completely valid approach, the statistical approach in which measurements are made on a sufficient number of vehicles to characterize the population, is extremely costly and time consuming. Most research has been done in single engines with well characterized deposits where comparisons of the effects of different fuel and engine variables can be made. This is the approach used in determining octane number in single cylinder engines. The disadvantage to this approach is that results obtained in one engine may not be directly applicable to other engines. For example, a road octane equation must be developed to apply the octane number results obtained in single cylinder engines to multicylinder engines. The problem is particularly severe when a small number of engines is used. Neither the statistical approach nor the approach of well characterizing a particular engine can be used. Normal engine to engine variation can make interpretation of results extremely difficult.

FIGURE 1-6

DISTRIBUTION OF RESEARCH OCTANE NUMBER REQUIREMENTS
ON ~11 SENSITIVITY FUELS
35 - NOMINALLY SIMILAR VEHICLES

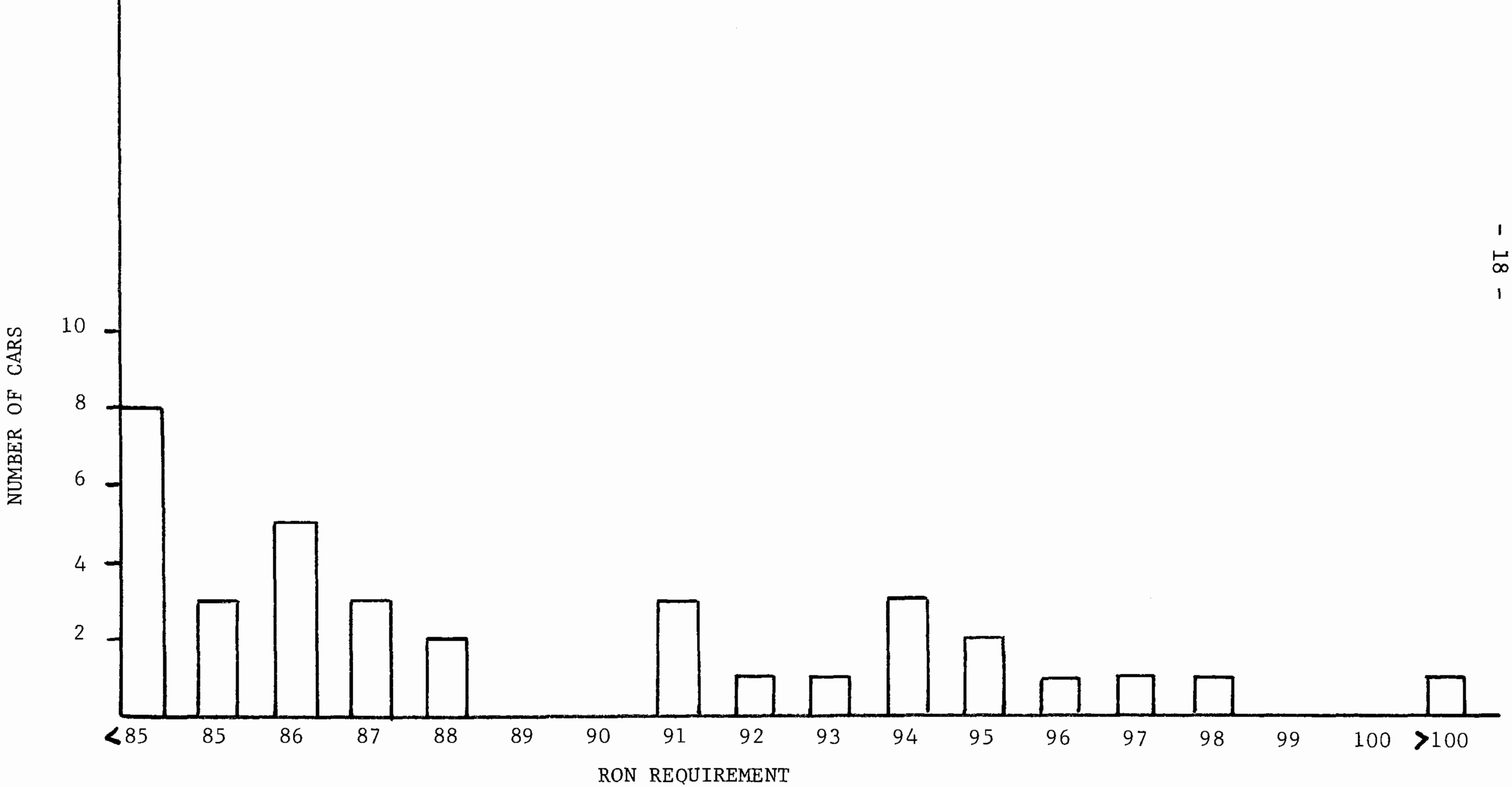


FIGURE 1-7

DISTRIBUTION OF
MAXIMUM RESEARCH O.N. REQUIREMENTS

ALL 1973 U.S. CARS INCLUDING IMPORTED MODELS (491 CARS)

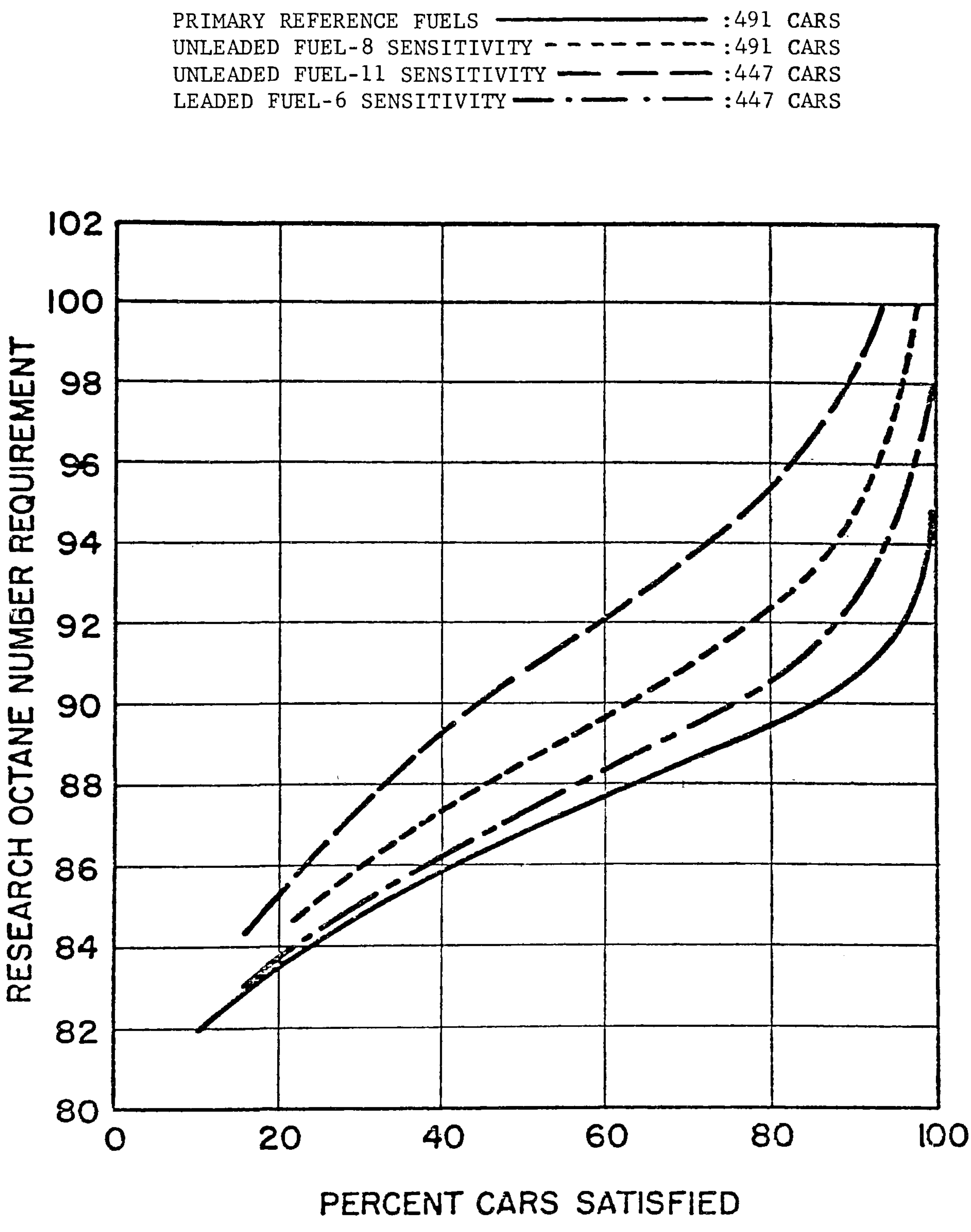
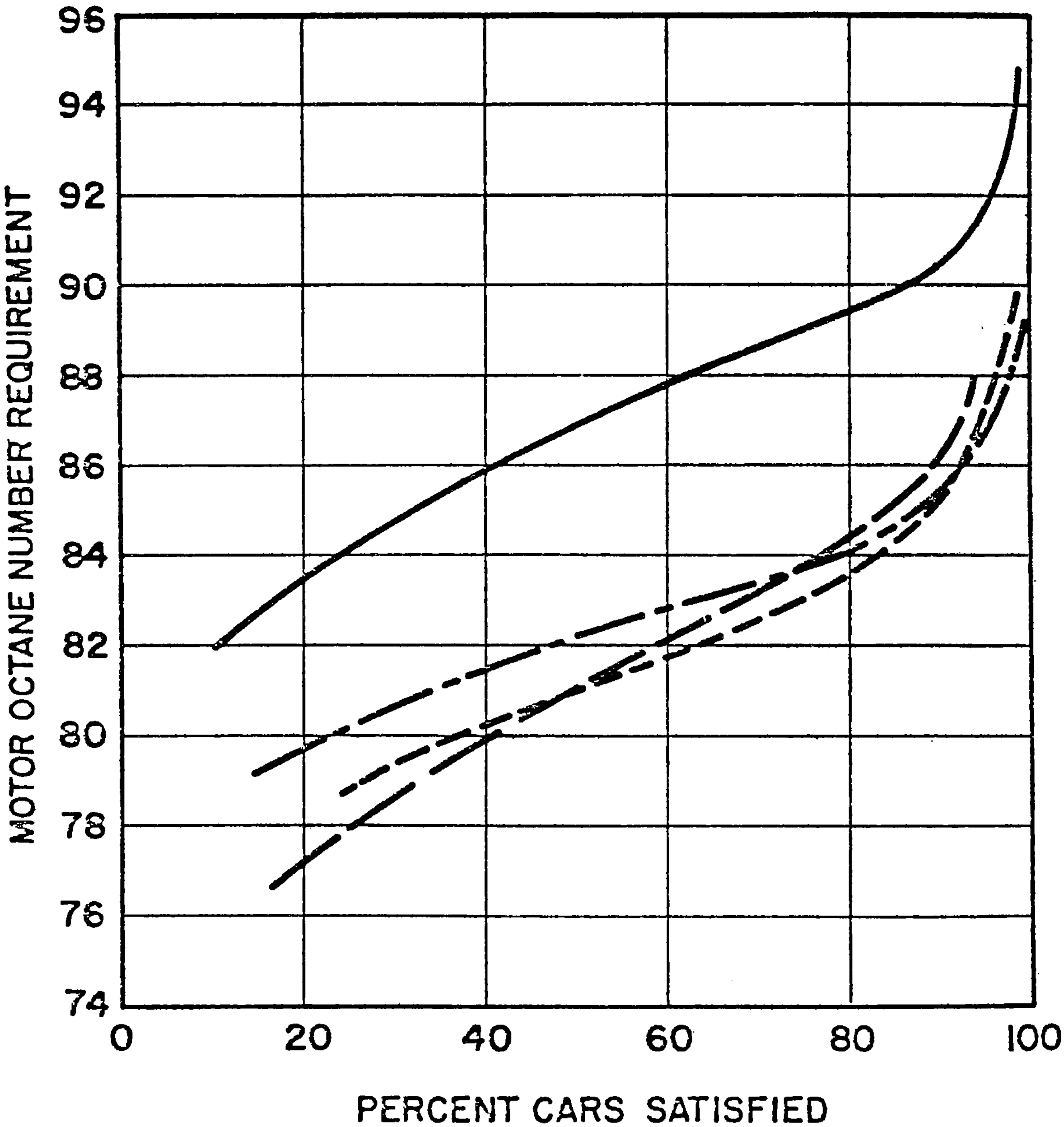


FIGURE 1-8

DISTRIBUTION OF
MAXIMUM MOTOR O.N. REQUIREMENTS

ALL 1973 U.S. CARS INCLUDING IMPORTED MODELS (491 CARS)

PRIMARY REFERENCE FUELS ————————— :491 CARS
UNLEADED FUEL-8 SENSITIVITY - - - - - - - - - - :491 CARS
UNLEADED FUEL-11 SENSITIVITY —— —— ——— :447 CARS
LEADED FUEL-6 SENSITIVITY —— · —— · —— · —— :447 CARS



## 1.2 EXXON RESEARCH AND ENGINEERING APPROACH

The approach taken at ER&E was as follows. A standard 8:1 C.R. 350 CID Chevrolet Nova (California) was tested for tailpipe and evaporative emissions, fuel economy, octane requirement, performance, and driveability. These tests were made with a clean engine and again following 12,000 miles of deposit accumulation to stabilize octane requirement.

The vehicle was then modified to obtain a 9:1 C.R. using 1969 high compression heads coupled with the standard 1975 engine block. Emissions were recalibrated to the 8:1 C.R. level primarily by adjusting EGR flow to lower the higher $NO_x$ emissions obtained at the 9:1 C.R. level. The big effort was in finding a suitable technique for reducing the vehicle's increased octane requirement. Several approaches were examined. These were:

Increased Turbulence - A greater amount of turbulence was generated using the 1969 heads, which have 30% greater squish area, together with head spacers to keep the compression ratio the same as the base case.

Shorter Combustion Duration - As discussed in this section, dual spark plug ignition increases engine power output and $NO_x$ emissions by combining this approach with charge dilution or spark retard, comparisons were made at a dual ignition power output equivalent to that of the single ignition case.

Aluminum Heads - Because of their better heat transfer properties, aluminum heads were compared to cast iron heads for effects on octane requirement.

Controlled Spark Retard - Spark retard, applied only when detonation occurs, can be effective at reducing knock while not having a deleterious effect on vehicle emissions, fuel economy, and performance.

A key element in the development of such a system is the ability to sense knock or detonation. Knock sensing has been studied by several investigators using pressure transducers and vibration sensors.(18-23) In fact, it is routinely used in the Research and Motor Octane methods of measuring fuel octane quality. In such single cylinder engine tests, the combustion chamber pressure behavior with time exhibits characteristics unique to detonation which can conveniently be measured. On a vehicle with a multicylinder engine, it would be very costly to use sensors in each cylinder. A more desirable device is one which can be mounted externally to the engine and can sense detonation irrespective of the cylinder in which it occurs. Keller, et al.,(21) used a vibration sensor mounted on the engine intake manifold to develop an automated technique for the octane rating of fuels. Using this technique, they found the predominant knock frequency to occur between 4 and 6 kHz for most cars examined. In the present work, the optimal location of an accelerometer used to measure detonation-induced vibration of the engine was determined. The signal from the accelerometer was then used to trigger the spark control circuit to retard the timing when detonation occurs.

This latter approach of applying a temporary spark retard when detonation occurred, as detected by a knock sensor, and removing the retard quickly, showed the best results in the engine dynamometer evaluation. This approach was used to complete the modification of the 9:1 C.R. vehicle. The 9:1 C.R. vehicle was then tested in the same manner as was outlined for the 8:1 C.R. base vehicle.

# SECTION 2

# CONCLUSIONS

A 1975 350 CID (California) V-8 Chevrolet Nova with 8:1 C.R. was tested to determine emissions, fuel economy, octane requirement, performance and driveability before and after 12,000 miles were accumulated. The engine was then cleaned of deposits and modified to achieve a 9:1 C.R. by using 1969 high compression heads. At the higher compression ratio, the vehicle achieved 6% better fuel economy. The higher $NO_x$ emissions at the 9:1 C.R. were reduced to the base level by substituting a back-pressure-modulated EGR unit for the original valve and increasing the EGR flow. Several techniques, outlined below, were examined to try to reduce the octane requirement of the 9:1 C.R. vehicle.

## Increased Turbulence

Increased turbulence was generated by increasing the squish area by 34% over the base case 8:1 C.R. engine. This was accomplished by using 1969 350 CID cylinder heads coupled with the 1975 engine block and inserting head spacers to obtain an 8:1 C.R. The results showed that the increased squish area did not appreciably reduce octane requirement. If anything, the octane requirement was higher for the increased squish area engine. No effect of this squish area change on fuel economy or emissions was noted.

## Dual Spark Plug Ignition

A second spark plug was inserted in the squish area of each cylinder directly opposite the primary spark plug. By firing two plugs, combustion duration is shortened. With dual ignition, power output, $NO_x$ emissions, and octane requirement increased. When spark retard was used to lower the power output of the dual ignition case to that of the single ignition base case, octane requirement was lowered but was still higher than the single ignition case. $NO_x$ emissions were lower than the base case. When EGR was used to lower the power output, similar results were obtained. However, EGR was not quite as effective as spark retard in regard to lowering the octane requirement.

## Aluminum Heads

An attempt to compare aluminum with cast iron cylinder heads was made to see if aluminum gave any octane requirement reduction due to its better heat transfer characteristics. An exact comparison could not be made because the aluminum cylinder heads were quite different in design to the cast iron heads although both gave 9:1 C.R. when coupled with the 1975 block. These aluminum heads gave a 4 octane number lower requirement when compared to the cast iron heads.

Knock-Sensor Activated Spark Retard

A system was developed which temporarily retards the spark timing when knock is detected by an accelerometer and associated electronics. The knock sensor is attached to the cylinder head of the engine. When knock occurs, the vibration is picked up by the sensor, the signal is filtered to remove some of the engine background noise, and the knock pulse is detected. When the amplitude of the detected knock signal exceeds a threshold, the spark timing is retarded. When no knocking is detected over a waiting period, the timing is advanced back to its normal schedule. Using this system, the engine's octane requirement can be lowered several numbers with little loss in accleration performance or deterioration of emissions or fuel economy. This approach seemed to have the most promise and was subsequently installed on the vehicle.

When the system was installed on the vehicle, the following was shown:

(1) By mounting the sensors (piezoelectric quartz accelerometers) in various engine locations, the optimal location and the frequency of knock were determined for this engine type.

(2) The knock sensor-actuated spark retard system was capable of detecting detonation and reducing its intensity.

(3) Utilization of long delay periods before advancing the spark timing after a retard results in excellent reduction of detonation but very long acceleration times. Shorter delay times combined with lower trigger thresholds give good knock reduction and reasonable acceleration performance.

(4) Emissions and fuel economy testing using fuel that produces trace knock on WOT accelerations does not cause spark retard on the FTP and HFET cycles, thus not affecting fuel economy or emissions on those cycles.

Two alternate engines were also tested to see if the frequency of knock changed. The results showed that for a 2.3 liter 4-cylinder and a 2.8 liter V-6 engine, the frequency of knock was different than the 350 CID V-8 engine. However, for each engine a frequency region could be identified where knock could be distinguished from engine noise. Using the data and with appropriate filtering and electronics, a similar system could be built which would detect knock and actuate spark retard.

# SECTION 3

## RECOMMENDATIONS

Several approaches were used during the course of this work to try to reduce vehicle octane requirement. Recommendations for future work in areas are given below.

### Increased Turbulence

In our work, a 35% increase in squish area showed little effect on octane requirement, emissions, or fuel economy. Any future study should focus on even more drastic changes in the shape of the combustion chamber. Additionally, several different designs need to be evaluated in order to reach a meaningful conclusion.

### Dual Spark Plug Ignition

When dual ignition was employed, octane requirement increased over the base single ignition case, at least for the particular engine and spark plug locations which were chosen. Future work in this area might be expanded to examine several different designs with various secondary plug locations. It is possible that an octane requirement benefit can be realized if the right combustion chamber geometry and plug locations are chosen. When the torque was equalized for the single and dual ignition case by retarding the spark timing or by adding diluent (EGR), a $NO_x$ benefit was observed for the dual ignition case. This is an interesting effect which might be exploitable to reduce vehicle $NO_x$ emissions. Nissan has published work on their fast burn engine which uses dual spark plug ignition and heavy EGR which shows marked reduction in $NO_x$ emissions.(25)

### Aluminum Head Work and Better Heat Transfer

An attempt was made to compare aluminum and cast iron cylinder heads to see if aluminum's better heat transfer characteristics could be translated into a lower octane requirement. Due to differences in head design, a good comparison could not be obtained, making the results inconclusive. To make a meaningful comparison, identical cylinder heads need to be made and compared using the same block, intake manifold and carburetor. Due to valve train misalignment in the aluminum head engine, the test had to be terminated before a deposit-equilibrated engine could be octane rated. Comparison of octane requirement at equilibrium conditions is a necessity, because it may have a strong influence on any octane requirement differences noted between the two head materials.

In a slightly different vein, better heat transfer in the squish area of individual cylinders could have a beneficial effect on octane requirement. In addition, studies have shown that an individual cylinder may have a significantly higher octane requirement if it is not cooled properly. If this is the case, i.e., one cylinder has a high requirement, and the others have a lower requirement, the higher octane gasoline is being wasted for all but one cylinder. A study could be directed at determining the requirements of individual cylinders in an engine and making modifications as necessary to insure that no single cylinder has insufficient cooling. This approach would only be useful if the problem is of sufficient magnitude that an appreciable octane benefit can be realized. The solution to the problem should also be generally applicable.

Knock Sensor-Actuated Spark Retard

This study clearly demonstrated the benefits obtainable from a knock sensor-controlled spark retard system and also touched on some of the performance tradeoffs involved. No further work in this area is justified at this time except where evaluation of manufacturer's knock sensor systems is desirable. If a system evaluation is made, an ability to obtain a cumulative knock intensity rating may be very useful. As shown in our work, it is very difficult to octane rate a vehicle with an operational spark retard system because several intensities of knock are heard during accelerations. A good way to do the rating is on the basis of cumulative knock during the entire acceleration. This is difficult to do audibly but it may be possible to do electronically by using the existing knock sensor signal. An instrument similar to that discussed above would be very useful in octane rating vehicles with knock sensor-spark retard systems.

During the course of this work, several problems arose with the application of knock sensor-spark retard technology. These are discussed below to provide guidance for future work in this area.

Performance Debits - There are significant acceleration performance debits associated with using spark retard to eliminate most of the knock for several octane numbers below the engine's normal requirement. While a 2 to 4 octane number benefit was shown, 10-30% slower acceleration times were obtained. When long spark advance delay times were employed however, limited testing indicates that if slightly higher levels of detonation are allowed, much lower performance debits are possible (on the order of 0-10% depending on how much detonation is permitted). This can be accomplished by raising the threshold so that the system is less sensitive to detonation, by decreasing the waiting period before advancing the spark schedule or by some combination of the two. Another technique to improve overall performance would be to sense the end of an acceleration, with an additional engine input, after which normal spark advance would be used. For example, use of a manifold vacuum or throttle position indicator would provide a signal whereby the end of an acceleration is well characterized, i.e., high manifold vacuum or closed throttle. This signal could be used to override the spark control system to immediately cut out any applied spark retard under conditions similar to these, thereby reducing excessively long periods of applied retard even though a long spark advance delay is used.

Spurious Retard - Occasionally, spurious retards were noted during the course of this work. Some of these were well defined extraneous electrical interference which could be corrected, such as moving any unnecessary AC-operated electronics out of the car, using DC-power for the controller itself, and removing tachometer leads from car. Others were ignored because they were not considered to be serious uncorrectable problems in a commercial unit, e.g., spark retards when cranking starter motor to start the engine. A more serious problem, which manifested itself just prior to replacing the cylinder heads with recessed valves, was that real engine noises other than knock could trigger the spark retard system occasionally. These retards were traced by listening to tape recordings slowed down to 1/16 of normal speed. In these recordings, knock is very apparent as a ringing drum-like sound and valve noises can be distinguished from it. A peculiar valve noise, which had some ringing character to it, occasionally produced a retard. These spurious retards could be eliminated by raising the threshold at the expense of lower sensitivity to knock. These 1969 heads were not induction hardened. When severe valve recession had occurred, the heads were replaced. No retards of this type have since been noted.

Surface Ignition - The accumulation of ashy oil-based deposits (40-50% ash) in the combustion chamber caused a significant surface ignition problem during one phase of the study. In fact, when the heads were removed, a large ashy particle was removed from the cylinder which had been knocking. In this case, spark retard actually made the surface ignition much worse, presumably due to the increased generation of heat in the engine. This would probably not be a general problem since surface ignition is rare with unleaded fuel. In this case, the severe driving schedule, i.e., more WOT accelerations, may have produced the high ash deposit problem due to high oil consumption.

Engine Overheating - Although tests were not made, the potential exists for engine overheating with long periods of running with retarded timing. This could occur either by a malfunction of the spark control system or by the use of a fuel of much lower octane quality than the engine's requirement. For this reason (and also for putting a limit on acceleration performance losses), only 10° maximum retard is allowed. This potential problem could probably be eliminated by using a coolant temperature sensor to override the spark retard system if high coolant temperatures occur.

# SECTION 4

# TESTING OF 8:1 C.R. BASE VEHICLE

## 4.1 TEST VEHICLE SELECTION

The feasibility demonstration of techniques to increase mechanical octane was, by the terms of the contract, to be carried out on a vehicle. The choice of vehicle was guided by the following factors. First, the car had to be compatible with modifications necessary to achieve increased mechanical octane. This meant that modification of the combustion chamber to increase 'squish' had to be achieved by off-the-shelf parts. The configuration of the cylinder head or heads had to allow insertion of a spark plug into the squish area of each cylinder for the evaluation of the dual spark plug technique to increase mechanical octane. Finally, the ignition system of the vehicle also had to be compatible with the proposed knock sensor actuated spark retard system.

The second factor taken into consideration in the choice of a test vehicle was related to the future trend in passenger cars. It was assumed that vehicle weights would decrease with successive model years in an effort to meet more stringent fuel economy standards. The 1975 Chevrolet Nova was chosen as typical of the large end of future passenger car lines. The engine of choice for the Nova was the 350 CID V-8, with an 8:1 compression ratio with no deposits. While it was felt that this power plant would be somewhat large in terms of future expectations, it had the advantage of having the flexibility for combustion chamber modifications with production parts more so than other candidate engines. With the approval of the Project Office, a 1975 production Chevrolet Nova with the 350 V-8 engine was purchased in California. This vehicle, equipped with an air injection pump and oxidation catalyst, was designed to meet the California Standard of 9.0 g/mile carbon monoxide, 0.9 g/mile hydrocarbons, and 2.0 g/mile nitrogen oxides. A complete vehicle description is given in Table 4-1.

## 4.2 BASELINE TESTING

Base tests of the vehicle consisted of octane rating, emissions testing and evaluation of driveability at the start and at various intervals during mileage accumulation. It was realized that during the course of accumulation and testing of the vehicle some catalyst deactivation could take place. Therefore, to compare the emissions characteristics of the modified vehicle to the base, fresh catalyst was to be used during testing of the demonstration vehicle. To eliminate any emission effects attributable to differences in catalyst used at various stages of the program, it was decided to obtain sufficient quantitites of a single batch of catalyst pellets from the original supplier, AC Spark Plug Division of General Motors, to be used in all phases of testing including the base vehicle tests.

TABLE 4-1

VEHICLE DESCRIPTION

1975 Chevrolet Nova (California)

| | | |
|---|---|---|
| Inertia Weight | - | 4000 lb |
| Rear Axle Ratio | - | 3.08/1 |
| Transmission | - | 3 Speed Automatic |
| Engine: | | |
| Ignition Timing | - | 6°BTC Basic Timing |
| 350 CID Displacement | | |
| 4.00" Bore | | |
| 3.48" Stroke | | |
| 8.0:1 Compression Ratio | | |
| Rochester M4MC 4 Barrel Carburetor | | |

Emissions Control System:

- Ported EGR System
- Thermostatic Air Cleaner
- Catalytic Converter
- Converter Air Injection
- Early Fuel Evaporation System

MILEAGE ACCUMULATION - Mileage accumulation was performed entirely on a dynamometer with an automatic driver responding to a magnetic tape input signal which dictated the driving cycle. This cycle consisted of city, suburban, and highway driving. The total cycle time was approximately five hours and forty minutes, covering a distance of 183 miles for an average speed of 32 miles per hour. This average speed is similar to that of the AMA durability cycle. Accumulation was on an around-the-clock basis with only one scheduled shutdown in a 24 hour period for normal maintenance checks.

The fuel used during mileage accumulation was blended from standard refinery streams to give a research octane number of 91 to 92 clear, with a sensitivity of about 9. Certain specifications on aromatic and olefin content set by the Project Officer also had to be met. The fuel sulfur content was adjusted to approximately 300 ppm by the addition of a mixture of three sulfur compounds consisting of 87% thiophene, 11% diethyl sulfide, and 2% ditertiary butyl disulfide. A commercial additive package was added to the fuel. Properties of the mileage accumulation fuel used during base vehicle testing are given in Table 4-2.

TABLE 4-2

MILEAGE ACCUMULATION FUEL PROPERTIES

| | |
|---|---|
| Research Octane Number | - 91.7 |
| Motor Octane Number | - 82.9 |
| API Gravity @ 60°F | - 57.2 |
| Lead Content | - <0.01 g Pb/gal. |
| FIA: Aromatics | - 29.1% |
| Olefins | - 7.1% |
| Saturates | - 63.8% |
| Sulfur | - 295 ppm |
| RVP | - 9.13 psi |
| I.B.P. | - 94°F |
| 10% | - 133°F |
| 50% | - 223°F |
| 90% | - 334°F |
| F.B.P. | - 427°F |

BASE VEHICLE EMISSIONS AND FUEL CONSUMPTION - Emissions and fuel consumption were measured on the 1975 Federal Urban Cycle (CVS-CH) and the highway fuel economy cycle (HFET) using high octane indolene clear. Measurements were made in triplicate at the start and end of accumulation and in duplicate at various intervals. Test results for emissions are given in Table 4-3. The vehicle had undergone several

TABLE 4-3

BASE VEHICLE EMISSIONS

| Mileage | CO-g/mile CVS-CH | CO-g/mile HFET | HC-g/mile CVS-CH | HC-g/mile HFET | $NO_x$-g/mile CVS-CH | $NO_x$-g/mile HFET |
|---|---|---|---|---|---|---|
| 564 | 2.97 | 0.41 | 0.47 | 0.35 | 2.64 | 3.75 |
| 585 | 3.73 | 0.14 | 0.54 | 0.22 | 2.39 | 3.71 |
| 606 | 4.42 | 0.27 | 0.70 | 0.13 | 2.30 | 3.53 |
| 6,860 | 3.47 | 0.50 | 0.41 | 0.28 | 1.77 | 3.34 |
| 6,882 | 4.09 | 0.53 | 0.39 | 0.24 | 1.84 | 3.34 |
| 8,903 | 4.34 | 0.27 | 0.49 | 0.14 | 1.80 | 3.81 |
| 8,925 | 4.96 | 0.37 | 0.43 | 0.20 | 1.61 | 3.36 |
| 11,025 | 6.16 | 0.70 | 0.48 | 0.23 | 2.33 | 4.58 |
| 11,046 | 4.96 | 0.31 | 0.49 | 0.14 | 2.02 | 3.71 |
| 13,148 | 4.32 | 0.62 | 0.49 | 0.21 | 2.23 | 5.73 |
| 13,170 | 4.33 | 0.68 | 0.44 | 0.17 | 2.18 | 4.74 |
| 13,191 | 5.50 | 0.71 | 0.51 | 0.23 | 2.34 | 4.93 |

hundred miles of driving, as the table shows, by the time mileage accumulation was initiated. This was due to the fact that the vehicle was first octane rated so as to obtain a clean engine requirement. After this initial octane rating, the catalyst bed was refilled with fresh catalyst and emissions testing was begun. From the repeat tests of Table 4-3, the variances of the test procedure can be calculated. The average emissions at start and end of mileage accumulation with the corresponding variances are shown in Table 4-4.

TABLE 4-4

EMISSION TRENDS WITH MILEAGE

| | CO | | HC | | $NO_x$ | |
|---|---|---|---|---|---|---|
| | CVS-CH | HFET | CVS-CH | HFET | CVS-CH | HFET |
| Average-g/mile: | | | | | | |
| Start | 3.71 | 0.27 | 0.57 | 0.23 | 2.44 | 3.66 |
| 13,000 miles | 4.72 | 0.67 | 0.48 | 0.20 | 2.25 | 5.13 |
| Variance | 0.4396 | 0.01745 | 0.00464 | 0.00471 | 0.01614 | 0.1513 |

Certainly on the emissions cycle there is no clear trend of emissions with mileage. The indicated increase in CO is, in a statistical sense, significant at about 90% confidence. The increase observed in both CO and $NO_x$ on the fuel economy cycle is highly significant. The vehicle readily met the standards of 9 g/mile CO and 0.9 g/mile HC but had nitrogen oxide emissions approximately 10% above the 2 g/mile standard at the end of mileage accumulation.

Early in the course of mileage accumulation, evaporative emissions were also measured from the base vehicle by the SHED test. Results are shown in Table 4-5 for three repeat tests. Total emissions were found to be relatively high, coming primarily from the hot soak portion of the test from leaks around the carburetor. In this vehicle the carburetor was not vented to the charcoal canister so that expanding vapors during the hot soak could escape only through any openings on the carburetor and air cleaner housing. Fuel vapors generated in the fuel tank such as is the case during diurnal cycling were reasonably well controlled by the tank vent to the charcoal canister.

TABLE 4-5

EVAPORATIVE EMISSIONS - GRAMS

| Test | Diurnal Cycle | Hot Soak | Total |
|---|---|---|---|
| 1 | 1.59 | 7.96 | 9.55 |
| 2 | 2.49 | 10.97 | 13.46 |
| 3 | 2.32 | 9.84 | 12.16 |

Estimates of fuel economy for the base vehicle were obtained from the carbon balance of the exhaust constituents and by weight of fuel consumed during the two test cycles. Fuel economy values for both test procedures were calculated from the total fuel consumed during each test and the miles driven. Data for the CVS-CH cycle shown in Table 4-6 are, therefore, not weighted like the emissions. Such weighted fuel economy data are, however, given for each test in Appendix B.

TABLE 4-6

FUEL ECONOMY OF BASE VEHICLE-MPG

| | FROM EMISSIONS | | | FROM WEIGHT | | |
|---|---|---|---|---|---|---|
| Miles | CVS-CH | HFET | COMBINED | CVS-CH | HFET | COMBINED |
| 564 | 12.12 | 17.24 | 14.00 | 12.72 | 17.56 | 14.52 |
| 585 | 11.58 | 16.36 | 13.33 | 12.01 | 16.35 | 13.64 |
| 606 | 11.81 | 16.40 | 13.51 | 12.36 | 17.23 | 14.16 |
| 6,860 | 12.00 | 16.27 | 13.61 | 12.30 | 15.27 | 13.48 |
| 6,882 | 12.19 | 16.39 | 13.78 | 12.13 | 15.56 | 13.47 |
| 8,903 | 11.11 | 15.48 | 12.73 | 11.14 | 14.91 | 12.57 |
| 8,925 | 11.62 | 15.87 | 13.21 | 11.91 | 15.16 | 13.18 |
| 11,025 | 12.55 | 18.63 | 14.71 | 12.11 | 15.95 | 13.58 |
| 11,046 | 12.72 | 19.71 | 15.14 | 12.15 | 16.35 | 13.74 |
| 13,148 | 11.94 | 15.95 | 13.46 | 12.24 | 15.75 | 13.60 |
| 13,170 | 11.95 | 16.74 | 13.72 | 12.58 | 16.11 | 13.96 |
| 13,191 | 11.93 | 16.39 | 13.59 | 12.45 | 16.03 | 13.84 |
| Averages: | 11.96 | 16.79 | 13.73 | 12.18 | 16.02 | 13.64 |
| Variances: | 0.04423 | 0.2100 | 0.07091 | 0.08895 | 0.1439 | 0.09394 |

Inspection of the data in Table 4-6 shows there to be relatively little difference in the fuel economies measured from emissions and by weighing, nor is the variability significantly different from the two measurement techniques. The only discrepancies of note are on the fuel economy cycle at 11,000 miles. The fuel economies obtained from emissions at that point of testing were unusually high. By weight the results remained consistent throughout. No effect of mileage accumulation on fuel economy was found for the base car.

BASE VEHICLE OCTANE REQUIREMENT - Octane requirements were measured at the same intervals as exhaust emissions and are shown in Table 4-7. At both the beginning and end of mileage accumulation, ratings were made on the road and on the mileage accumulation dynamometer (MAD) with three fuel series: primary reference fuels, a full boiling range series of constant 8 sensitivity, and another full boiling range series of 11 sensitivity. The CRC rating procedure was used. Octane requirement at intermediate mileage points were determined only on the MAD with the eight sensitivity fuel series. As the ratings with the eight sensitivity series show, 'equilibrium' had been established by about

TABLE 4-7

OCTANE REQUIREMENT OF 1975 NOVA

| Test Site | Mileage | PRF[2] | Research Octane Requirement CSU-8[3] | CSU-11[4] | RMFD 276-74 |
|---|---|---|---|---|---|
| Road | 121 | 79 | 79 | <86 | <84 (78.8 MON) |
| MAD[1] | 278 | 84 | 84 | <86 | 84 (78.8 MON) |
| Road | 425 | 81 | 82 | <86 | <84 (78.8 MON) |
| MAD | 6,903 | | 90 | | |
| MAD | 8,960 | | 88 | | |
| MAD | 11,068 | | 90 | | |
| Road | 13,239 | 86 | 91 | 93 | |
| MAD | 13,411 | 86 | 91 | 92 (2.5 in. Hg. vac.)<br>93 (8 in. Hg. vac.) | |
| Clean Engine { MAD | 13,520 | 80 | 82 | <86 | <84 (78.8 MON) |
| Clean Engine { Road | 13,650 | 78 | 79 | <86 | <84 (78.8 MON) |

(1) Mileage Accumulation Dynamometer
(2) Primary Reference Fuels
(3) Constant Sensitivity of ∿8
(4) Constant Sensitivity of ∿11

7,000 miles. The octane requirement increase, as measured on the road was 7 for primary reference fuels and 12 for the 8 sensitivity fuel series. Whereas initially the engine was sensitive only to the research octane number of the fuel, as shown by the ratings at 278 miles, the final road rating indicates that the motor octane number had become the more important fuel property. In terms of full boiling range fuels, the deposit stabilized vehicle is satified by 91 RON-82.7 MON and also by 93 RON-81.6 MON. Accordingly, a change of two research octane numbers is compensated by a change of 1.1 motor number. The vehicle, therefore, 'appreciates' 35%of the RON and 65% of the MON of the fuel.

The octane requirement increase (ORI) experienced by the base vehicle was large compared to historical experience. To determine if this ORI was due entirely to deposit buildup, the combustion chambers of the engine were physically cleaned to remove deposits from the cylinder heads and piston tops. Clean engine ratings on both the MAD and on the road showed the octane requirement to be the same again as at the start of mileage accumulation. The measured ORI of 12 numbers was, therefore, entirely attributable to combustion chamber deposit buildup.

DRIVEABILITY AND PERFORMANCE - After completion of mileage accumulation, the vehicle was tested for acceleration performance on the test track normally used for road octane rating. Two types of tests were run: 0-60 MPH full throttle accelerations and elapsed time for the quarter mile from a standing chart. Results are given in Table 4-8.

TABLE 4-8

ACCELERATION PERFORMANCE OF BASE VEHICLE

| A) 0-60 MPH | Direction | Time-sec. |
|---|---|---|
| | South | 11.20 |
| | " | 11.40 |
| | " | 11.70 |
| | " | 11.45 |
| | Ave. South | 11.44 |
| | North | 10.65 |
| | " | 11.05 |
| | Ave. North | 10.85 |
| | Ave. excluding wind | 11.14 |

| B) Quarter Mile | | Time-sec. |
|---|---|---|
| | | 18.1 |
| | | 17.5 |
| | | 17.6 |
| | Average | 17.7 |

Driveability tests were carried out on a chassis dynamometer with four fuels blended to varying volatility characteristics as given in Table 4-9. The four fuels were blended to give low front end volatility with low and high midfill. Front end volatility affects ease of starting. Midfill volatility determines the driveability before the engine has reached operating temperature. The four fuels, therefore, were blended to determine how critical the vehicle is to these fuel variables. All rating tests were run at 70°F. Both the 'cold start-driveaway' and the "warm vehicle" evaluation of the CRC procedure were run on each of the four fuels. With the exception of occasional hesitation during part throttle acceleration and a stall during a wide open throttle acceleration with fuel D-3, driveability was generally rated as satisfactory on all fuels. Detailed results of these tests are to be found in Appendix D.

TABLE 4-9

PROPERTIES OF DRIVEABILITY FUELS

| | D-1 | D-2 | D-3 | D-4 |
|---|---|---|---|---|
| Reid Vapor Pressure, psi | 7.03 | 6.87 | 11.92 | 11.18 |
| % (D+L)* @ 158°F | 9.9 | 10.0 | 25.8 | 32.5 |
| " @ 212°F | 47.7 | 65.7 | 46.5 | 64.5 |
| " @ 302°F | 87.9 | 92.9 | 85.5 | 93.5 |
| RON | 93.5 | 94.2 | 98.2 | 95.0 |
| MON | 86.4 | 85.3 | 86.9 | 85.9 |

* (D+L) is the sum of the portion of fuel distilled and the loss.

# SECTION 5

## LABORATORY EVALUATION OF MEANS TO ACHIEVE ADDITIONAL MECHANICAL OCTANE

Four independent techniques for reducing engine octane requirement were examined in this work. These were: 1) increased turbulence through the use of higher squish area heads, 2) shortened combustion duration through the use of two spark plugs per cylinder, 3) better heat transfer characteristics of the head material obtained through the use of aluminum heads, and 4) controlled spark retard actuated by a knock sensor. These four approaches were evaluated in an engine dynamometer installation with a 350 CID engine. They are discussed in detail below. The most promising approach proved to be the knock sensor-actuated spark retard which imposed a temporary retard in response to knock. This technique was then used to control the octane requirement of the vehicle modified to obtain a 9:1 C.R.

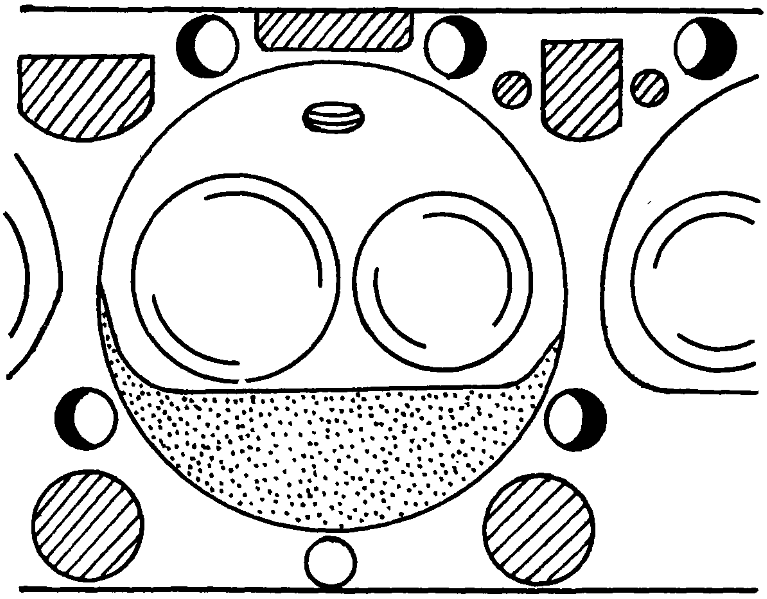
### 5.1 ENGINE EVALUATION OF INCREASED SQUISH COMBUSTION CHAMBERS

By the provisions of the contract, the techniques for increasing mechanical octane were to be evaluated on an engine dynamometer using the engine of the demonstration vehicle. After completing base vehicle testing, the engine was removed from the Chevrolet Nova and transferred to an engine cell. The first of the three techniques to be evaluated was the use of increased squish areas in the combustion chamber. As has been previously pointed out, one of the chief reasons for selecting the NOVA with the 350 CID V-8 engine as the test vehicle was the possibility of evaluating the effect of squish with off-the-shelf hardware. Cylinder heads and pistons of high compression ratio versions of this engine from earlier years were readily interchangeable with the basic block of the 1975 engine. The heads from the 1969 engine, which in combination with flat-topped pistons, gave a nominal compression ratio of 11.25:1 had larger squish areas than the 1975 heads. This made it relatively easy to test this concept without modifying either pistons or heads of the 1975 engine. Figure 5-1 is a schematic drawing, to scale, of sections of the 1975 and 1969 cylinder heads showing the squish areas as shaded zones. The squish areas in the 1969 heads are approximately 34% larger than in the 1975 heads. Over half of this increase comes from the extra squish area behind the spark plug.

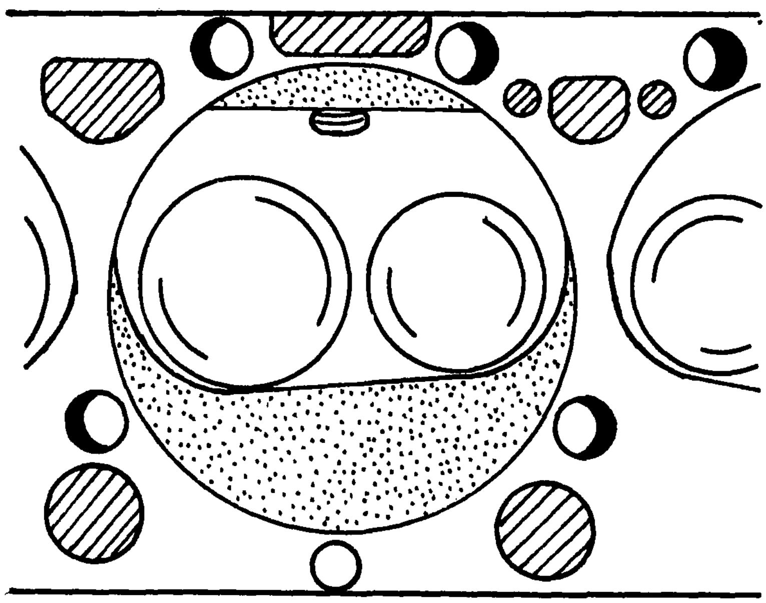
The compression ratio of the base engine, nominally 8.5:1 with deposits, was determined from the piston displacement and from measurements of the combustion chamber volume at the top dead center position of the piston. With a clean combustion chamber the compression ratio was found to be 8.0:1. Similar measurements using the 1969 heads

FIGURE 5-1 Top View of 350 CID Cylinder Heads

1975 HEAD



1969 HEAD



in conjunction with the 1975 block gave a compression ratio of 9.0:1. It was possible to make a comparison of the octane requirement of the two combustion chamber configurations at the same compression ratio, 8.0:1, by using the 1969 heads together with a head spacer of 0.045 inches thickness and two standard gaskets. The squish thickness, i.e., the thickness of the gap between piston top and that part of the head surface which is shaded in Figure 5-1, was of course greater with the 1969 heads. Results of the octane requirement comparison are shown in Table 5-1 with results from the base vehicle tests for comparison.

Table 5-1

Octane Requirement with Squish Area Variation

| | PRF* | CSU-8** | Test Conditions |
|---|---|---|---|
| 1975 Heads, C.R. - 8:1: | 79 | 79 | Road, 120 Miles |
| | 86 | 91 | Road, 13,200 Miles |
| | 78 | 79 | Road, 13,500 Miles, Clean |
| | 80 | 78 | Eng. Cell, Manual Operation |
| | 78.5 | 79 | Eng. Cell, Automatic Operation |
| 1969 Heads, C.R. - 8:1: | 81 | 81 | Eng. Cell, Automatic Operation |
| 1969 Heads, C.R. - 9:1: | 90 | 91 | Eng. Cell, Automatic Operation |

* Primary reference fuels
** Full boiling range fuels with sensitivity of 8.

Octane rating in the engine cell was carried out in high gear during full throttle accelerations from 30 to 70 MPH. Road rating of the base vehicle had shown that it was full throttle limited. Loading of the engine during the accelerations was initially performed by manual control to give acceleration times during rating of about 15 to 20 seconds to go from 30 to 70 MPH in high gear. In later testing the engine was automatically loaded by a closed loop load control system which adjusted the load as a function of velocity and acceleration rates. Comparison of clean engine requirement obtained on the road with the base vehicle and ratings of the base engine in the engine cell (Table 5-1) show that the engine rating procedure simulated road performance very well.

Engine cell data of Table 5-1 at a compression ratio of 8:1 show that the 1969 heads with the higher squish area gave a two number higher octane requirement with primary and full boiling range fuels. This increase, while undoubtedly real, was not further investigated. Higher end gas temperatures in one or more cylinders of the high squish heads, perhaps due to poorer cooling system circulation, is only one of several explanations consistent with the unexpected observation of increased octane requirement with the higher squish area heads.

Despite the absence of any beneficial effect of increasing squish area, the engine was retested with the 1969 heads at a 9:1 compression ratio. At this compression ratio, obtained without the use of the head spacer, the squish thickness was identical to that of the base engine with the 1975 heads. The one number increase in compression ratio resulted in an increase of nine octane numbers in clean engine primary reference fuel requirement, a surprisingly large effect.

The effect of the various cylinder head configurations on fuel consumption was measured on the Federal Urban Emission Cycle. Operation on this or any arbitrary cycle was made possible by an "automatic cycle follower" control system. With this system, the engine throttle is automatically driven from a magnetic tape of speed as a function of time to give the desired "vehicle speed" as a function of time through a closed loop controller which compares actual speed to the desired speed. The load is also adjusted by a closed loop controller as a function of velocity and rate of acceleration. Fuel consumption data are given in Table 5-2. The results show that the standard engine consumed 8 to 9% more fuel in the engine cell than in the vehicle on the chassis dynamometer. The comparison of the standard heads and 1969 heads at an 8:1 compression ratio gave no statistically significant difference. The effect of increasing the compression ratio from 8:1 to 9:1 reduced the fuel consumption significantly. In the cold start test cycle the reduction amounted to 6.5% combined for the three bags. For the same test cycle but with hot starts the reduction in fuel consumption averaged 5.8%. An effect of this magnitude is not unexpected for the indicated change in compression ratio.

Emission effects are compared in Table 5-3. In the absence of a constant volume sampling system, it was not readily feasible to obtain mass emissions for cyclic operation. In order to obtain an indication of the effect of combustion chamber configuration on emissions, the continuous traces of CO, HC, and $NO_x$ emissions were time averaged on the urban emission cycle. The catalyst-out emissions for carbon monoxide and hydrocarbons of Table 5-3 are strongly influenced by the startup 'quality' of the engine and are therefore subject to considerable variation. The increase of hydrocarbon emissions commonly claimed when the compression ratio is increased is by no means obvious from these results, at least not after the catalyst. However, even a cursory glance at the continuous trace of nitrogen oxide emissions showed that the $NO_x$ emissions are significantly higher in the 9:1 compression ratio tests. The data of Table 5-3 suggest the effect to be an approximately 50% increase in $NO_x$ when going from 8:1 to 9:1 compression ratio.

As a result of the discouraging data on the effect of increased squish area on octane requirement, that approach was abandoned. While still more drastic changes in combustion chamber shape than those tried in this study might reduce octane requirement, the construction of the necessary hardware was beyond the scope of this contract.

Table 5-2

Fuel Consumption with Squish Area Variation

| | Fuel Used - Pounds | | | |
|---|---|---|---|---|
| | Cold Start | | Hot Start | |
| | Bags 1&2 | Bag 3 | Bags 1&2 | Bag 3 |
| Chassis Dynamometer: | | | | |
| Standard Vehicle | 4.12 | 1.69 | | |
| Engine Dynamometer: | | | | |
| Standard (C.R.=8:1): | 4.36 | 1.85 | 4.14 | 1.96 |
| | 4.40 | 1.83 | 4.07 | 1.90 |
| | 4.58 | 1.87 | 4.00 | 1.86 |
| Average | 4.45 | 1.85 | 4.07 | 1.91 |
| 1969 Heads (C.R.=8:1): | 4.45 | 1.83 | 4.13 | 1.87 |
| | | | 4.11 | 1.87 |
| | | | 4.10 | 1.84 |
| Average | 4.45 | 1.83 | 4.11 | 1.86 |
| 1969 Heads (C.R.=9:1): | 4.14 | 1.73 | 3.89 | 1.76 |
| | | | 3.84 | 1.75 |
| | | | 3.89 | 1.75 |
| Average | 4.14 | 1.73 | 3.87 | 1.75 |

Table 5-3

Hot Start Emissions with Squish Area Variation

| | Time Averaged Concentrations | | | | | |
|---|---|---|---|---|---|---|
| | CO-% | | HC-ppm $C_6$ | | $NO_x$-ppm | |
| | Bags 1&2 | Bag 3 | Bags 1&2 | Bag 3 | Bags 1&2 | Bag 3 |
| Standard (C.R.=8:1); | 0.22 | 0.22 | 29.6 | 38.0 | 249 | 396 |
| 1969 Heads (C.R.=8:1): | 0.18 | 0.09 | 26.9 | 19.2 | 266 | 388 |
| 1969 Heads (C.R.=9:1): | 0.13 | 0.07 | 33.1 | 12.4 | 415 | 596 |

## 5.2 DUAL SPARK PLUG IGNITION

One technique used to try to lower the engine's octane requirement was minimization of the time required for the flame to travel through the combustion chamber. This can be accomplished by utilizing two spark plugs in each cylinder. By igniting the air-fuel charge both by the normal spark plug and by one located in the end-gas region, hopefully the end-gas volume would be minimized before autoignition can take place.

This approach was attempted by modifying a set of both 1975 and 1969 350 CID heads to accept an additional spark plug in the squish area of each cylinder. A photograph of a modified 1969 head is given in Figure 5-2 showing the location of the primary (normal) and secondary spark plugs. In all of these tests, the secondary spark plugs were always located in the end-gas region directly opposite the primary spark plug. In addition to the head modification, a special dual distributor had to be built to permit independent firing of both plugs. This distributor is shown in Figure 5-3.

When the engine was first fired up, there was a serious problem of cooling fluid leaking past the seals of the secondary plugs into the combustion chamber. This problem could not completely be eliminated in the case of the 1975 heads, but satisfactory results were obtained with the 1969 heads modified with the dual spark plug system. A schematic showing the alignment of the secondary plug through the water jacket into the cylinder is given in Figure 5-4. A high temperature sealant was used at the threads and the seats of each of the secondary plugs to isolate the cooling system from the combustion chamber. These secondary plugs, obtained from Champion, operated satisfactorily when assembled in this manner.

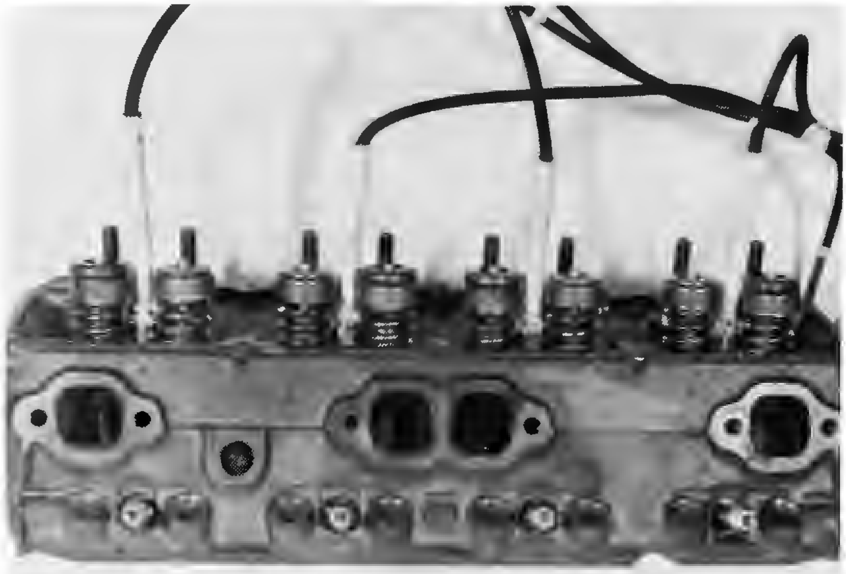
EFFECT OF DUAL IGNITION ON TORQUE AND SPEED - The effect of dual ignition on torque at the automatic transmission output shaft was measured at a speed equivalent to 40 mph with the transmission in high gear.

Table 5-4 - Effect of Dual Plugs on Torque

| Firing Mode | Engine rpm | Transmission Output Shaft: Torque - Ft. Lbs. | Transmission Output Shaft: rpm |
|---|---|---|---|
| Standard Plugs | 1685 | 65 | 1585 |
| Standard and Secondary Plugs | 1885 | 73 | 1590 |

FIGURE 5-2

DUAL SPARK PLUG IGNITION ENGINE



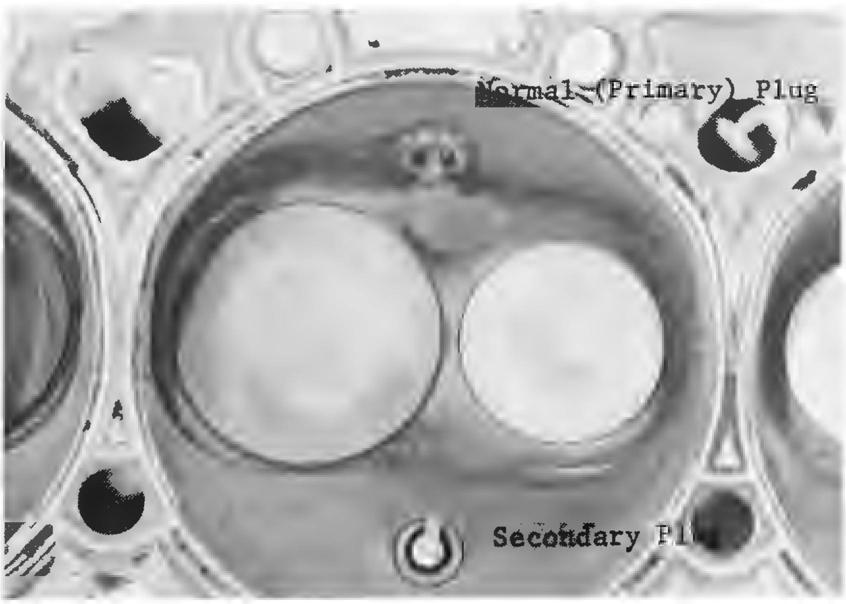
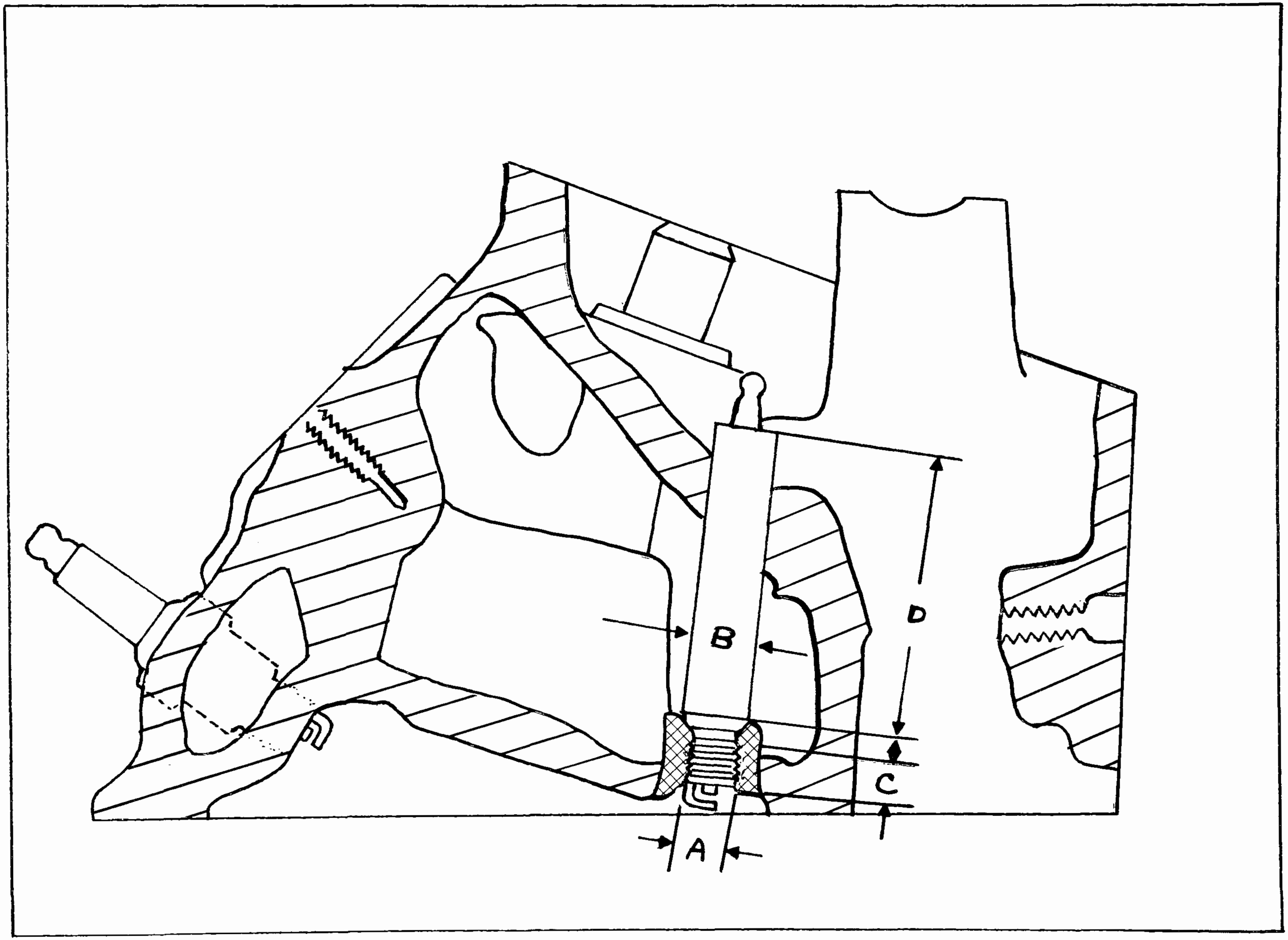


FIGURE 5-3

DUAL SPARK PLUG DISTRIBUTOR

DUAL SPARK PLUG CONFIGURATION



In the comparison made in Table 5-4 the only change made was in the number of spark plugs firing per cylinder. The throttle position remained unchanged and the spark timing was set at 6°BTDC basic on both primary and secondary plugs. The output shaft speed of the transmission was being held constant by the dynamometer. With both plugs firing simultaneously, torque or power output increased by over 12% at the output shaft of the automatic transmission.

At a somewhat higher output shaft speed the power output was compared for firing with the primary plugs only, the secondary plugs only, and both simultaneously.

Table 5-5 - Torque with Different Firing Modes

| Firing Mode | Engine rpm | Transmission Output Shaft Torque - Ft. Lbs. | Transmission Output Shaft rpm |
|---|---|---|---|
| Primary | 1890 | 45 | 1831 |
| Primary and Secondary | 2000 | 50 | 1830 |
| Secondary | 1940 | 36 | 1818 |
| Primary and Secondary | 2050 | 51 | 1832 |

Table 5-5 shows the preferred firing arrangement in terms of power output. Again with dual ignition output shaft power is 12% greater than firing with the standard plugs only. It is clear from the table that firing with the primary plugs by themselves is more effective than firing only with the secondaries. Igniting the charge in the squish area gave about 20% less power than igniting the mixture at the standard location opposite the squish zone.

The effect of dual spark plug ignition on torque was measured at several different speed-load combinations with isooctane to avoid knocking and a standard transmission to minimize transmission power losses. These comparisons were made at 10" manifold vacuum at 1500, 2000, 2500, and 3000 rpm. Additionally, tests were run at 2000 rpm and 3, 6, 9, and 12" vacuum to look at the effect of varying engine load. The percentage torque increase as a result of firing two plugs per cylinder instead of one is tabulated in Table 5-6.

Table 5-6 - Increase in Torque of Dual Ignition Case Compared to Single Ignition Case

| rpm | Man. Vacuum | Avg. Torque (ft-lb) Single | Dual | Avg. % Increase |
|---|---|---|---|---|
| 1500 | 10" | 138 | 148.5 | 7.6 |
| 2000 | 10" | 147 | 151 | 2.8 |
| 2500 | 10" | 146 | 151 | 3.4 |
| 3000 | 10" | 137.5 | 142.5 | 3.7 |
| 2000 | 3" | 246 | 260 | 1.6 |
| 2000 | 6" | 190 | 195 | 2.6 |
| 2000 | 9" | 160 | 166.5 | 4.1 |
| 2000 | 12" | 122.5 | 125 | 2.0 |

This increase ranged between 1.6 and 7.6% depending on speed and load. The highest torque increase was observed at lower engine speed (1500 rpm) while the lowest percentage increase was seen at wide open throttle.

OCTANE REQUIREMENT - Octane ratings were performed in the engine cell to determine the effect of dual spark plug ignition on engine octane requirement. These ratings were obtained during simulated 40 to 70 mph WOT accelerations on the modified 9:1 C.R. 350 CID engine. To factor out effects of deposits and ambient conditions, the rating with the standard spark plugs only was repeated several times. The data in Table 5-7 show that, if the primary plugs fire at standard timing and the secondary plugs are brought into operation, the increase in octane requirement changes in a nearly linear fashion with the firing delay between the primary and secondary plugs. For example, with the primary plugs only, the octane requirement was 86 RON at 6°BTC basic timing. When both primary and secondary plugs fire at 6°BTC basic timing the octane requirement increases to 95 RON. As a time delay is put between the firing points of the two plugs, the octane requirement drops until with a 16°CA delay in the firing of the secondary plugs the requirement is the same as if ignition is initiated only by the primary plugs.

It is clear from these results that when two flame fronts are established at opposite ends of the combustion chamber, the end gas which is now probably located near the valves, is more susceptible to autoignition despite the shorter burning time. Interestingly, the octane

Table 5-7 - Effect of Dual Ignition on Octane Requirement

| Basic Timing | | Octane Requirement | |
|---|---|---|---|
| Primary Plugs | Secondary Plugs | RON | MON |
| 6°BTC | Off | 86 | 77.0 |
| 6°BTC | 6°BTC | 95 | 84.1 |
| 6°BTC | 12°BTC | 97 | 86.2 |
| 6°BTC | 1°BTC | 93 | 83.0 |
| 6°BTC | Off | 87 | 78.3 |
| 1°BTC | 1°BTC | 89.8 | 80.8 |
| 1°BTC | - | 82 | 73.2 |
| 6°BTC | 10°ATC | 87 | 78.3 |
| 6°BTC | Off | 87 | 78.3 |
| 6°BTC | 24°ATC | 87 | 78.3 |
| Off | 6°BTC | 91 | 81.6 |
| 6°BTC | Off | 87.9 | 78.9 |
| 6°BTC | 4°ATC | 91 | 81.6 |
| 6°BTC | 20°BTC | ∿102 | ∿90.8 |

requirement with ignition in the squish area only is about three numbers higher than with ignition in the standard location. This is further evidence that when the end gas is in the squish area, it is cooler than when it is in the open part of the combustion chamber and therefore less likely to detonate. If it is true that the efficacy of the squish area is due more to its capability for cooling the end gas rather than generating turbulence, it would explain why in our tests on the effect of increasing squish area no octane benefit was observed. The increased squish between the standard and the high compression heads was not likely to increase heat loss from the end gas. The result also suggests that octane benefits might be achieved by increasing the heat transfer rate from the squish zone possibly by increasing the flow of cooling fluid in that area.

These results indicate that when the only change that is made is that of switching on the secondary plugs, the engine speed, power output, and octane requirement increase.

## COMPARISON OF SINGLE AND DUAL IGNITION AT EQUAL POWER

Spark Retard - In order to properly evaluate single and dual plug ignition, it is necessary to compare these cases at the same engine power output. Since a greater amount of torque is generated by dual ignition, the engine operating conditions must be changed to lower the power output when both plugs are on. One way of achieving this is by retarding the spark timing on both distributors. The amount of torque increase and of spark retard necessary to compensate for this varies somewhat with engine speed and load as shown in Table 5-8.

Table 5-8 - Amount of Spark Retard Necessary to Equalize Torque

| Engine rpm | Manifold Vacuum | % Torque Increase with Dual Plugs | Spark Retard to Equalize Torque |
|---|---|---|---|
| 1500 | 10" | 7.6 | 7° |
| 2000 | 10" | 2.8 | 7° |
| 2500 | 10" | 3.4 | 10° |
| 3000 | 10" | 3.7 | 9° |
| 2000 | 3" | 1.6 | 1.5° |
| 2000 | 6" | 2.6 | 4.5° |
| 2000 | 9" | 4.1 | 5° |
| 2000 | 12" | 2.0 | 8° |

This makes it impossible to compare single and dual ignition at equal power on acceleration because the torque cannot be equalized at all speeds. Even if the amount of spark retard necessary to equalize power in the dual ignition case was independent of engine speed, the fact that the two distributors did not have the same centrifugal advance curve make accelerations difficult to interpret. The distributors, when new, both gave the same centrifugal advance curves equivalent to the present primary curve (see Figure 5-5). The secondary distributor centrifugal curve became advanced over the primaries at engine speeds above 1800 rpm. This is probably due to a change in spring tension or wear. Thus, the evaluation of dual ignition at equal power to the single ignition case was done at steady state to make the results interpretable.

In this phase of the work, the increased torque due to dual ignition was compensated for by retarding both distributors to produce a torque equal to the case of single ignition. When the secondary plugs are first turned on, a much higher $NO_x$ output (along with higher power) is produced. However, when the spark timing is retarded to the point where the torque is equal to the single ignition case, usually a lower $NO_x$ emissions level is observed as shown in Table 5-9.

Table 5-9 - Amount of Spark Retard of Dual Distributors Necessary to Make Torque Equal to Single Ignition Case, Associated % $NO_x$ Decrease from Single Ignition Case, and Δ Octane Requirement

| | Relative to Single Ignition Case | | |
|---|---|---|---|
| rpm-Vacuum | ° Retard | % $NO_x$ Decrease | Δ OR |
| 1500-10" | 7* | 15* | +2 |
| 2000-10" | 7** | 15** | +4 |
| 2500-10" | 11* | 40* | +1 |
| 3000-10" | 9* | 18* | -1 |
| 2000-3" | 1.5 | 0 | >+1 |
| 2000-6" | 4.5 | -18.5 | +3 |
| 2000-9" | 5 | 2.7 | +2 |
| 2000-12" | 8 | 7.0 | +4 |

*Average of two tests.
**Three determinations.

The percentage $NO_x$ decrease at part throttle (10" vacuum) ranged between 15 and 40%. At 2000 rpm and low manifold vacuums, the effect was essentially nonexistent. In one case (2000 rpm and 6" vacuum) a $NO_x$ increase was seen. The effect of dual ignition on hydrocarbon and CO emissions was small.

In almost all instances, the octane requirement was higher for dual plug ignition than for single ignition. The increase ranged between 1 and 4 numbers. In one case (3000 rpm - 10" vacuum), the octane requirement went down one number, however.

A couple of acceleration runs were made for octane requirement and acceleration times using full-boiling range (CX) reference fuels as shown in Table 5-10.

FIGURE 5-5

SPARK ADVANCE CURVES FOR DUAL DISTRIBUTORS

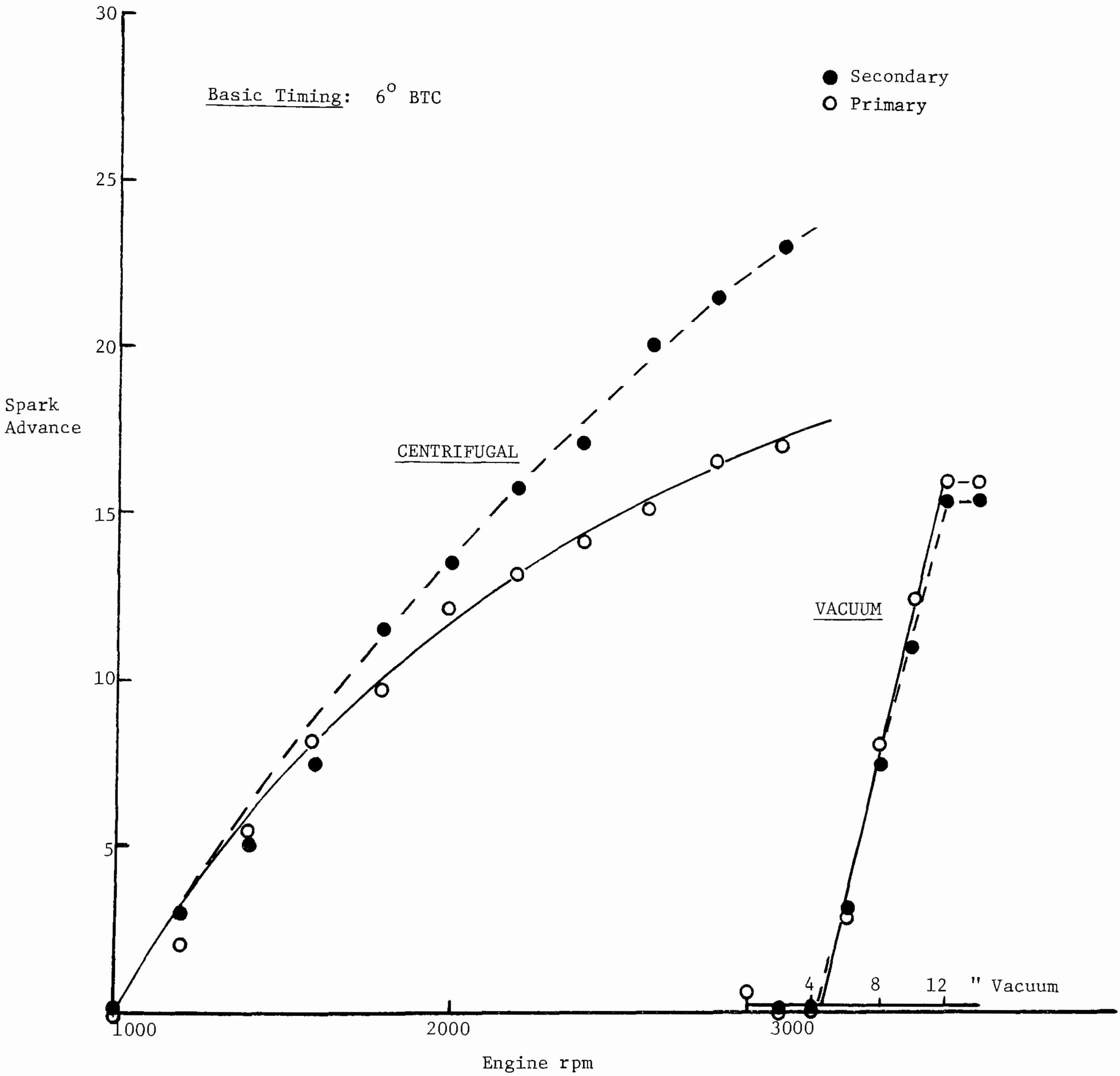


Table 5-10 - Full Throttle Acceleration Octane Ratings (CX Fuels)

| Description | Octane Requirement | 40-70 mph Acceleration Time (sec.) |
|---|---|---|
| Primaries Only - 6°BTC | 89 | 14.7 |
| Primaries - 6°BTC<br>Secondaries - 6°BTC | 99 | 14.5 |
| Equal Power Set Up at 1500 rpm - 10"<br>Basic Timing:<br>Primaries - 1.5°ATC<br>Secondaries - 1.5°ATC | 94 | 15.5 |
| Equal Power Set Up at 2500 rpm - 10"<br>Basic Timing:<br>Primaries - 6°ATC<br>Secondaries - 12°ATC | 84 | 19.1 |

These runs are the equivalent of 40 to 70 mph full throttle, road load, accelerations. In the first set, the single ignition case can be compared to the dual ignition one with both distributors set at standard basic timing. Here, the power is higher with both plugs on giving rise to a 10 unit higher octane requirement. In the next case, the dual ignition case was set up such that power equal to the single ignition case was obtained at 1500 rpm - 10" manifold vacuum. The power is about equal early in the acceleration but because of the advanced secondary distributor curve, more power is produced at high speed. The result is a 5 unit higher octane requirement for the dual ignition case. In the final comparison, the dual distributors were set up for equal power at 2500 rpm - 10" vacuum. The timing is so retarded, however, at low speed that a 30% longer acceleration time and 5 unit lower octane requirement result.

Using spark retard to lower the torque in the dual ignition case to the same level obtained for single spark plug ignition has shown the following:

(1) Spark retard reduced the high dual ignition engine's octane requirement. However, the reduction was not large enough to lower the octane requirement to the base single ignition level and thus the requirement was elevated from 0 to 4 numbers above the base case.

(2) $NO_x$ emissions were reduced on the average of 22% at part throttle with no effect observed at 3 and 6" manifold vacuums.

(3) CO and HC emissions were only slightly affected.

These results suggest that the dual ignition engine has a higher octane requirement which cannot easily be overcome by conventional means. This may be due, in part, to the location of the secondary spark plug. That is, by generating two flame fronts, the end gas may be raised to higher temperatures and pressures than normal, resulting in higher octane requirement. It is possible that with the optimal secondary plug location, different results would be obtained. However, this was beyond the scope of this work.

Throttle Reduction - Steady state fuel consumption was measured with single and dual ignition at constant throttle, with no differences, as would be expected. In other tests, the throttle was adjusted to reduce the torque in the dual ignition case to the base single ignition level. In this comparison at equal torque, the dual ignition runs used 1.6 to 3.9% less fuel depending on speed and load as shown in Table 5-11.

Table 5-11 - Reduction of Fuel Consumption by Reducing Throttle to Achieve Equal Torque

| Engine rpm | Manifold Vacuum | % Reduction in Fuel Consumption |
|---|---|---|
| 1500 | 10" | 3.9 |
| 2000 | 3" | 3.9 |
| 2500 | 10" | 1.6 |

EGR Flow - A similar attempt was made to compare single and dual ignition at equivalent power by increasing EGR flow in the dual ignition case. The comparison between dual and single ignition was made at constant throttle position. To accomplish this, the engine could not be shut down in between changes in EGR flow, since the throttle might not return to exactly the same position. Thus, the standard GM ported EGR valve was used to run a series of base case EGR flows given in Table 5-12.

Table 5-12 - Measurement of % EGR Flow for Standard GM Recycle Valve on 350 Chevrolet Engine in Engine Cell

| Engine rpm | Manifold Vacuum | % EGR |
|---|---|---|
| 1500 | 10" | 7.2 |
| 2000 | 10" | 6.0 |
| 2500 | 10" | 5.3 |
| 2000 | 6" | 4.7 |
| 2000 | 3" | <0.5 |

The valve was then replaced permanently with the GM proportional recycle valve and the new "base case" flow set to correspond to that of the stock valve. The second set of plugs was then turned on to measure the increase in torque from dual ignition. EGR was then added at constant throttle position, allowing the manifold vacuum to decrease, to lower the torque to approximately the base case level. The comparison between single ignition with standard EGR rates and dual ignition with increased EGR was made at several different engine speeds and vacuums shown in Table 5-13. The detailed individual test results are given in Appendix E. In all cases, the octane requirement increases substantially (from 3 to 8 units).

The emissions results showed that $NO_x$ emissions decreased by typically 20% while the hydrocarbon emissions levels increased by 25% or more. The fact that $NO_x$ emissions are reduced by EGR but the octane requirement remains high suggests that the high octane requirement generated in the dual ignition case is not effectively compensated for by increasing the EGR flow. This was also noted in the case of spark retard. However, EGR flow increase seems to be less effective than spark retard in lowering the engine's octane requirement. Fuel consumption was observed to decrease from 0.6% to 5.3% depending on speed or load.

In some of the tests shown in Table 5-13, an additional case was run where the EGR flow was increased even further and the throttle adjusted to keep equal torque. In the case run at 2000 rpm and 6.0" manifold vacuum, the octane requirement was just lowered to the base level using this further EGR increase. However, CO increased dramatically and fuel consumption also increased. This, of course, was due to the fact that we had to go deeper into the throttle to get equal torque with the additional EGR. At 2000 rpm and 3" manifold vacuum, where the octane requirement is the highest, this additional EGR increase coupled with more throttle may have increased the octane requirement due to the larger throttle opening.

In conclusion, the dual ignition work has shown a strong tendency toward higher octane requirements. With few exceptions, this tendency cannot be overcome by retarding spark timing or doubling the EGR flow. However, these procedures do give much lower $NO_x$ emissions when compared at equivalent torque. It is possible that a dual ignition system which had the spark plugs positioned differently might show an octane requirement benefit. However, the spark plug design which we have studied very clearly has a tendencey toward higher octane requirement.

Table 5-13 - Effect of Increased EGR Flow at Constant Throttle Position on Octane Requirement, Emissions and Fuel Consumption of Dual Ignition Engine

| Engine rpm | Manifold Vacuum (in. Hg) | Total % EGR | Δ Manifold Vacuum* (in. Hg) | Δ RON Requirement | % Change | | | % Change in Fuel Consumption |
|---|---|---|---|---|---|---|---|---|
| | | | | | CO | HC | $NO_x$ | |
| 1500 | 10 | 13.5 | -0.7 | +3 | 0 | +26 | -27 | -0.6 |
| 2000† | 10 | 12.5 | -1.0 | +7 | 0 | +14 | -25 | -3.3 |
| 2500 | 10 | 10.2 | -0.7 | +7 | 0 | +38 | -4 | -4.5 |
| 2000† | 6 | 8.1 | -0.5 | +5 | +13 | +40 | -20 | -1.7 |
| 2000 | 3 | 6.1 | -0.3 | +8 | - | +2 | Instrument Malfunction | -5.3 |
| EGR Further Increased and Throttle Adjusted to Equalize Torque | | | | | | | | |
| 2000 | 10 | 16.1 | -2.2 | +4 | 0 | +3 | -53 | -2.0 |
| 2000 | 6 | 12.6 | -1.5 | 0 | +109 | +24 | -45 | +2.5 |
| 2000 | 3 | 8.1 | -1.4 | >9 | - | +7.7 | Instrument Malfunction | -6.2 |

*Change in manifold vacuum when EGR flow is increased.
†Average of two cases.

## 5.3 ALUMINUM HEADS

A comparison was made between aluminum and cast iron cylinder heads to determine if the better heat transfer properties of aluminum could be translated into an octane requirement benefit. The intention was to obtain a direct comparison of cast iron versus aluminum heads on a 350 C.I.D. Chevrolet engine.

The aluminum heads were obtained through EPA from Speedmasters, a Chicago speed shop. These heads were of identical volume to the 1969 cast iron heads. A 9:1 C.R. was achieved for both the aluminum and cast iron heads by coupling them with the standard 1975 350 CID engine block (see Figure 5-6). Photographs of these heads are shown in Figure 5-7 for comparison.

Octane requirements were measured on three rating fuel series during simulated 40 to 70 mph WOT accelerations in high gear. The requirement was measured initially with a clean engine and again after 150 hours of deposit accumulation on unleaded fuel at 50 mph road load. The data are summarized in Table 5-14. For the three fuel series, the requirement increased by only one unit after 150 hour deposit equilibration for the cast iron head. This increase is quite low and may be due to the steady speed used in testing. The cast iron head data formed the base case with which the aluminum head data was compared.

Table 5-14 Comparison of Octane Requirement of Cast Iron Versus Aluminum Heads

| Fuel Series | Cast Iron 0 Hrs | Cast Iron 150 Hrs | Aluminum 0 Hrs. |
|---|---|---|---|
| CX | 93 | 94 | 88 |
| C | 91 | 92 | 87 |
| P | 90 | 91 | 87 |

In the assembly of the aluminum head engine, it was noted that several major differences existed between the aluminum and cast iron heads. The intake ports were considerably larger and there was an increased intake breathing area in the aluminum heads. Because of the larger ports, the head could not be sealed properly to the intake manifold. After an extensive effort to locate a different manifold, it was decided to "Heliarc" enough aluminum into the head ports so that the manifold could be sealed. When the engine was assembled, an additional problem was encountered. In the Standard 350 engine, the valve to valve center measurement is 1 7/8" compared to 2" in the aluminum heads. Thus, one of the rocker arms of each cylinder was slightly cocked. A push rod guide plate supplied with these heads was used.

The engine was octane rated at 0 hrs. with the results shown in Table 5-14. After 3 hours of running, the test was discontinued because of a bent push rod due to the valve train assembly misalignment mentioned previously. The comparison of initial ratings show that the aluminum head engine gave a 3 to 5 number lower octane requirement than the cast iron engine. Due to the differences in the construction of the heads, it is not possible to attribute this lower requirement exclusively to the aluminum. Although the compression ratios were identical, the aluminum head used different valves and had a different intake port design. The effects of these variables on octane requirement were not determined. In addition, a comparison at deposit equilibrium could not be obtained. It is possible that any benefit obtained by the use of aluminum might be negated by the extremely good insulating properties of combustion chamber deposits after equilibration. Therefore, the results are really inconclusive.

FIGURE 5-6

350 CID ENGINE ASSEMBLED WITH ALUMINUM HEADS

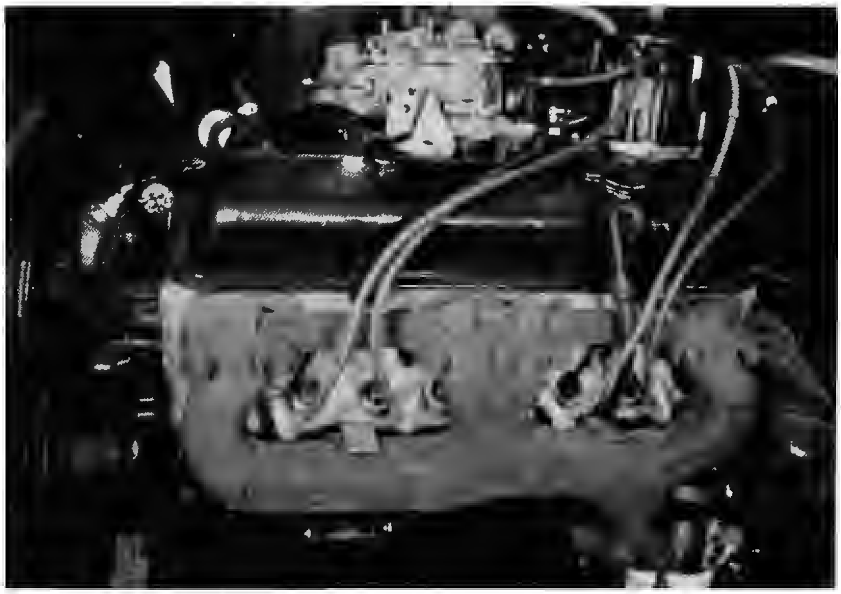
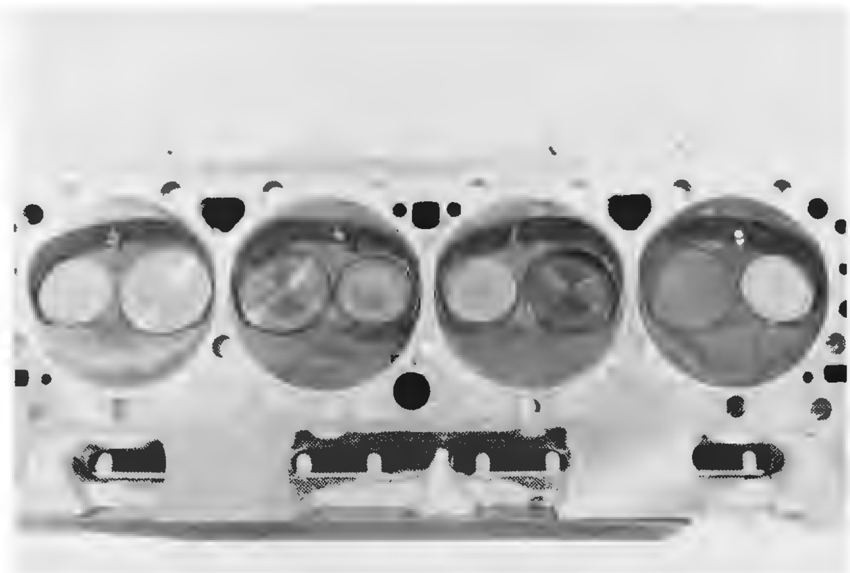
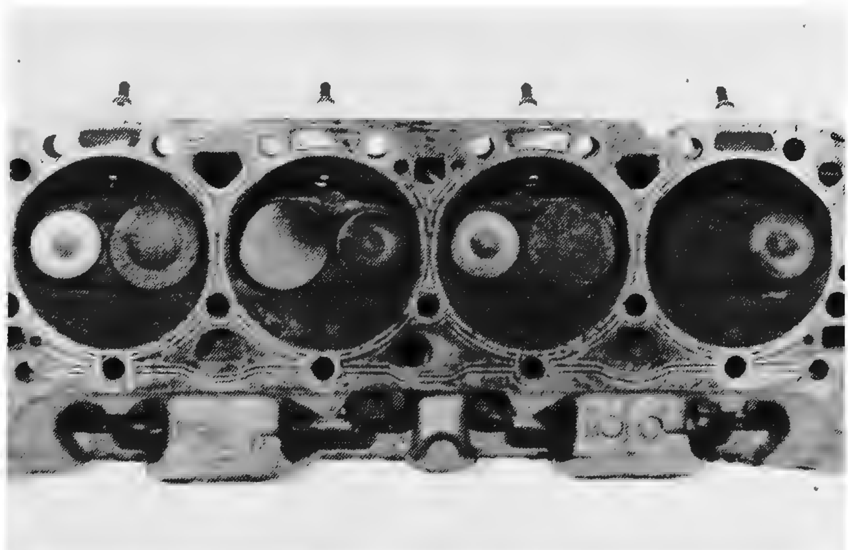


FIGURE 5-7

ALUMINUM AND CAST IRON HEADS



Aluminum
Heads



1969 Cast
Iron Heads

## 5.4 KNOCK SENSOR-ACTUATED SPARK RETARD

The final approach used to try and lower the engine's octane requirement was the use of controlled spark retard. The concept was to use spark retard only when detonation occurred and then only for the duration that was necessary to prevent additional detonation. In this manner, the engine would only be retarded for a small fraction of the typical driving regime and thus fuel economy and exhaust emissions would not appreciably be affected. This approach proved to be the best and was incorporated into the vehicle modifications to lower the 9:1 C.R. vehicle's octane requirement.

FREQUENCY ANALYSIS - In order to ascertain the feasibility of using a knock sensor-actuated spark retard system, accelerometers were mounted on a standard 350 CID engine with an 8:1 C.R. in an engine cell. Quartz piezoelectric transducers (accelerometers) were used to pick up vibrations of the engine and convert them to an electronic signal. The accelerometer, shown in Figure 5-8 with the attached mounting pedestal, is epoxied onto the metal surface as shown in Figure 5-9. Accelerometers were mounted in various locations on the cylinder heads and on the intake manifold as shown in Figure 5-10. Five of the accelerometers were mounted perpendicular to the axis of the crankshaft while the one located at the rear of the engine was affixed with its axis parallel to that of the crankshaft. Tape recordings of the accelerometer output were made under steady state and accelerating conditions with and without detonation. Three types of tests were run. Fuel change tests were run at steady state with the fuel changed from no knock to a low octane fuel to obtain different knock intensities. The steady state tests were run on the same fuel in each run. Acceleration tests were run from 1700 to 3000 rpm (40 to 70 mph) at wide open throttle with fuels of different octane quality. The accelerometer signals from these tests were analyzed to determine the frequency of knock in the 350 CID engine. Comparison of the signals from the accelerometers showed that the accelerometer with its axis parallel to the crankshaft and located at the rear face of the engine detected detonation most consistently. Representative traces of the frequency spectrum obtained from the accelerometer signal are given in Figure 5-11A for a fuel without detonation and in Figure 5-11B for a fuel with very light knock intensity. A complete set of these frequency analyses is given in Appendix A. These plots represent the signal amplitude expressed as g-force vs. frequency obtained during a wide open throttle 40-70 mph acceleration in top gear. In comparing the two plots in Figure 5-11, it can be seen that when detonation occurs, the intensity of the signal at approximately 5.2 kHz and at 9.0 kHz is increased. The 5.2 kHz peak was used to design the filter for the spark control system. The 9.0 kHz peak was not tried but might also be usable. The engine from the vehicle was tested with the results being virtually identical. For this engine, the accelerometers were located on the heads as shown in Figure 5-12. This vehicle engine was then modified by the use of 1969 350 CID heads to raise the compression ratio to 9:1. Analyses again indicated that the accelerometers located at the rear of the engine with their axes parallel to the crankshaft gave the best results and that the frequency of detonation was about the same. This latter engine was reinstalled in the vehicle. The fact that the two engines tested gave identical results suggests that within an engine type, the knock frequency is about the same.

FIGURE 5-8 Kistler Piezoelectric Accelerometer With Mounting Pedestal

FIGURE 5-9 - Accelerometer Attached to Right Rear Cylinder Head of 350 CID Engine with Axis Parallel to Engine Crankshaft

FIGURE 5-10 Location of Accelerometers On Spare 350 CID Engine As Tested For Knock Frequency Analysis

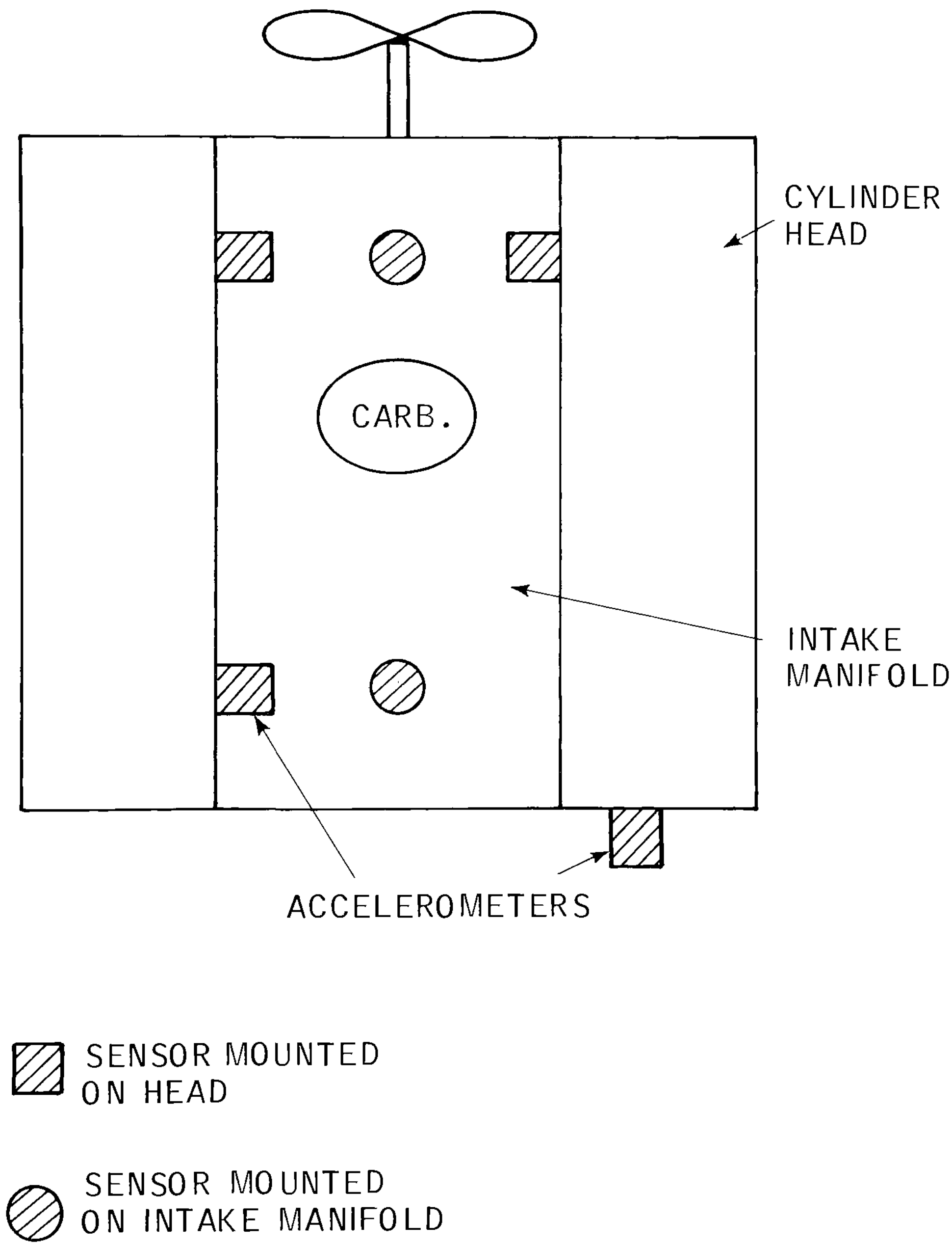


FIGURE 5-11 Frequency Analysis Of Accelerometer Signal
A) In The Absence of Detonation and
B) With Very Light Knock

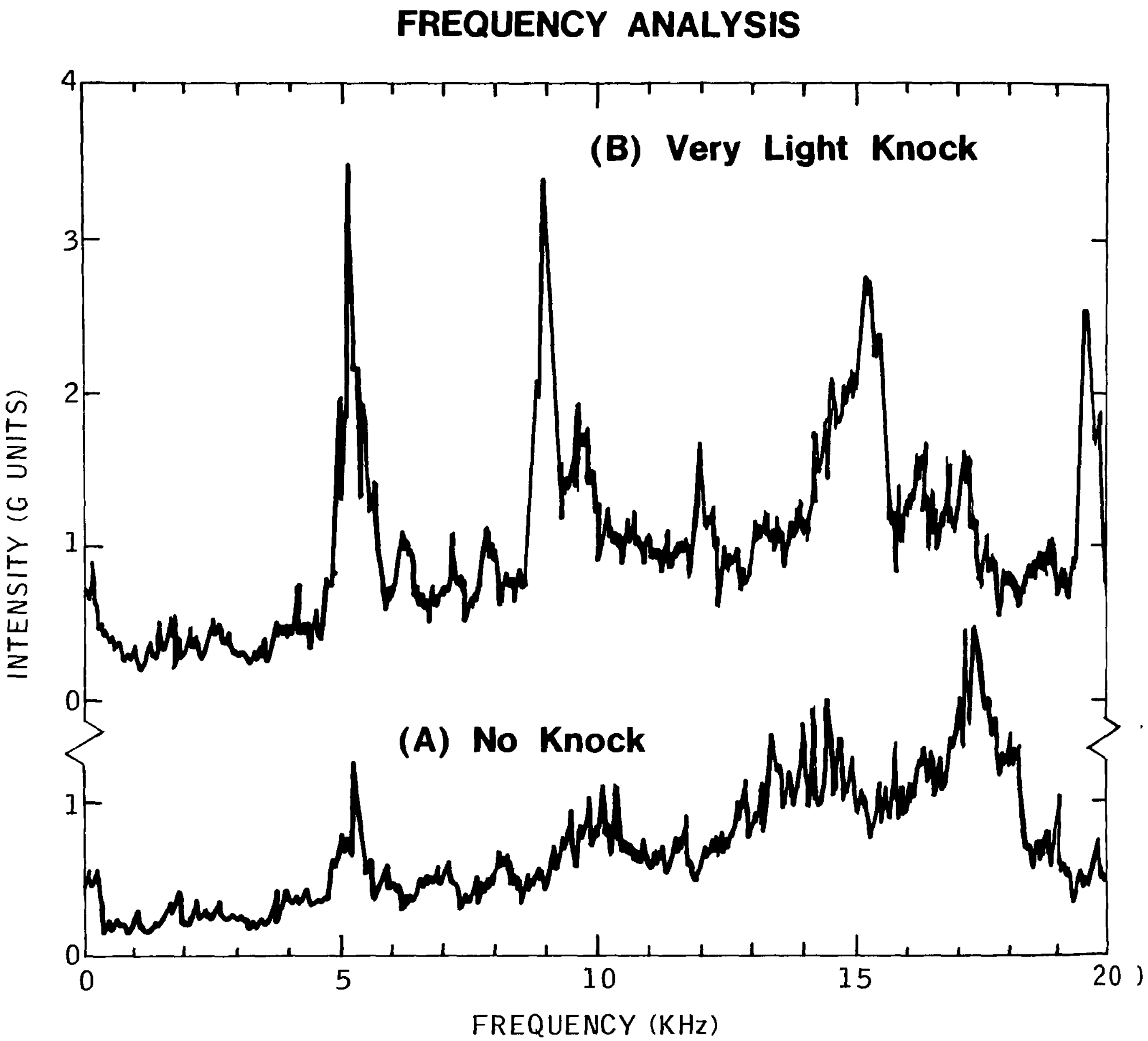
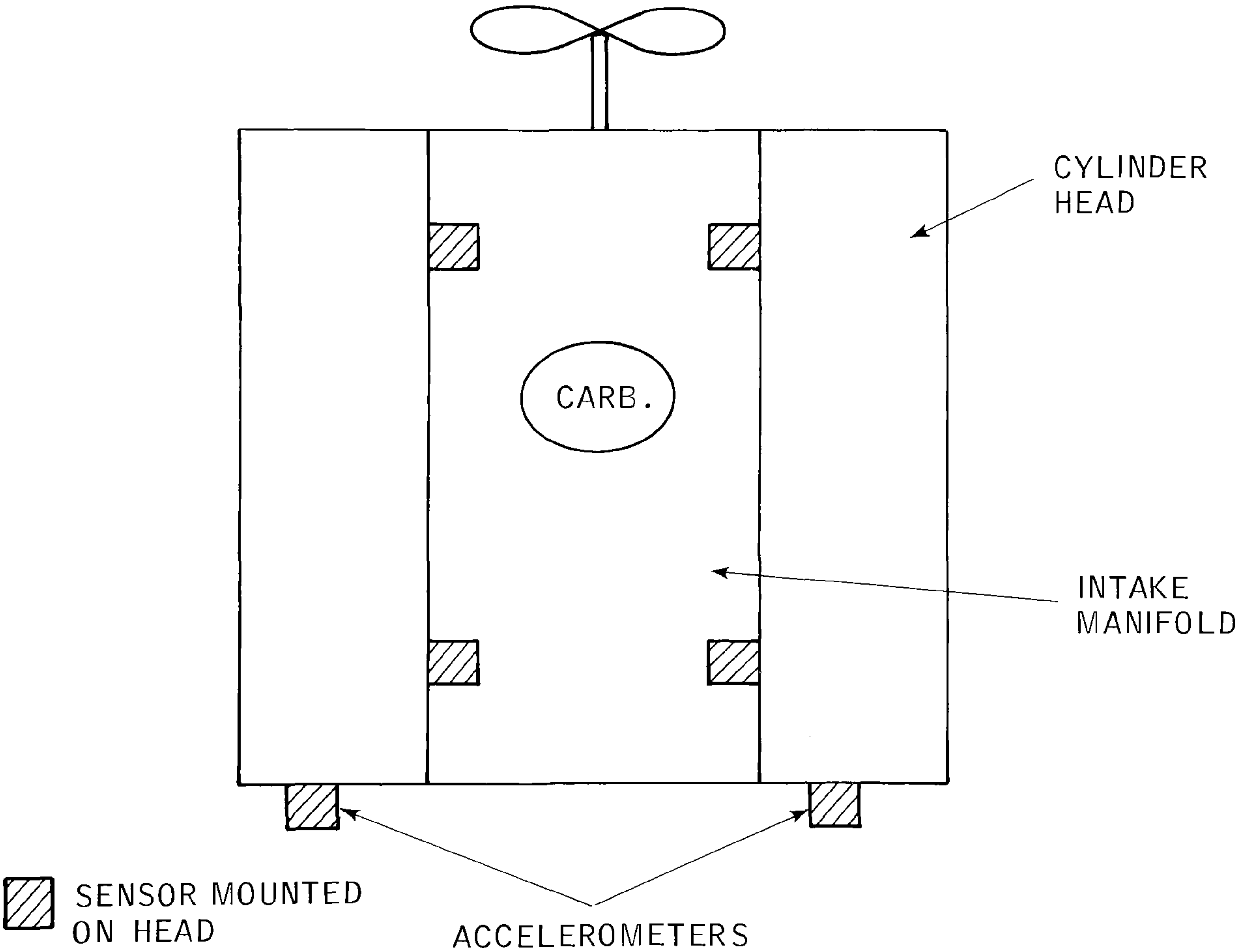


FIGURE 5-12

# LOCATION OF ACCELEROMETERS

ENGINE IN VEHICLE



CHARACTERISTICS OF ACCELEROMETER SIGNAL - A recording of engine noise as detected by the accelerometer is shown in Figure 5-13. Here, contiguous segments of signal amplitude are shown vs. time for approximately three crankshaft revolutions. The data were obtained during a 40-70 mph WOT acceleration of the engine in third gear. The engine speed is approximately 2200 rpm, and the approximate engine crank angle degrees are given for orientation. Two knock pulses are marked in the figure. They occur approximately 720° apart, indicating that they are from the same cylinder. One knock pulse lasts for 2.5 msec and the other 4.6 msec, which is fairly typical of others examined. The other signals seen are valve noises which are of a much shorter duration than detonation.

ELECTRONICS ASSOCIATED WITH KNOCK DETECTOR AND SPARK CONTROL SYSTEM - There are two characteristic features of the accelerometer signal from the 350 CID engine which can be used to identify detonation. Firstly, spectrum analyses of the accelerometer signal show that most detonation is characterized by vibration in the range of 5-5.5 kHz. Secondly, oscilloscope recordings indicate that most knock pulses last for a period of about three milliseconds or longer. The electronics module has been optimized to recognize both the narrow frequency range and longer duration of the knock signature and thus differentiates between detonation and other engine noises. A special automatic gain control circuit holds the engine background noise constant.

A block diagram of the knock sensor-spark retard system used to control the level and quantity of detonation is shown in Figure 5-14. The accelerometer signal (see Fig. 5-15) is amplified, passed through a 5.35 kHz filter with a 580 Hz bandwidth, is rectified, integrated, and compared with a preset threshold level, (see Fig. 5-16) resulting in a detected knock pulse. This threshold level is set so that the system will respond to a specified level of audible knock. When a knock signal is detected, the digital controller produces a DC control voltage. This DC voltage is the input to the spark delay control. The degrees of spark retard from the production spark curve are proportional to this DC voltage level generated by the digital controller. This controller also receives the distributor signal, which acts as the reference clock for the system, and delays it when knock is sensed (i.e., spark retard is implemented electronically). The spark retard is accomplished in a stepwise manner in response to each knock pulse sensed. The retard is maintained for a programmed number of engine revolutions, after the last detected knock (delay 1). The spark timing is then advanced in steps back to the standard spark schedule with a specified number of revolutions (delay 2) between steps. Should a knock signal be detected at any point in the sequence, the spark timing is immediately retarded.

The detailed control schematic is shown in Figure 5-17. The circuit to the right representing the filter circuit and the digital control leading to the 0-11 volt control voltage was designed at Exxon. The circuit operating off this control voltage is a Delco design.

FIGURE 5-13 Accelerometer Signal Vs. Engine Crank Angle Degrees Showing Duration of Engine Noises

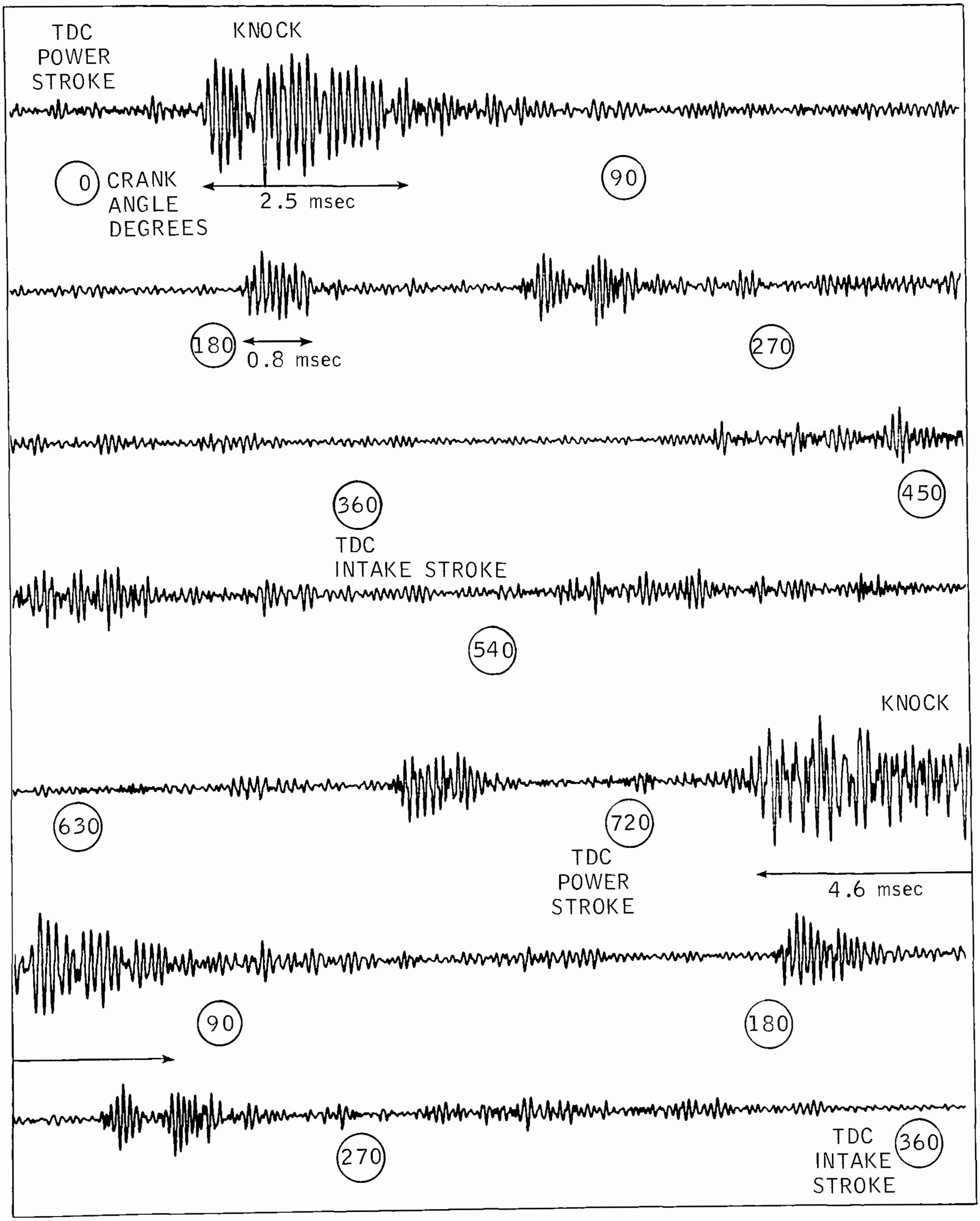


FIGURE 5-14

## BLOCK DIAGRAM OF KNOCK SENSOR ELECTRONICS

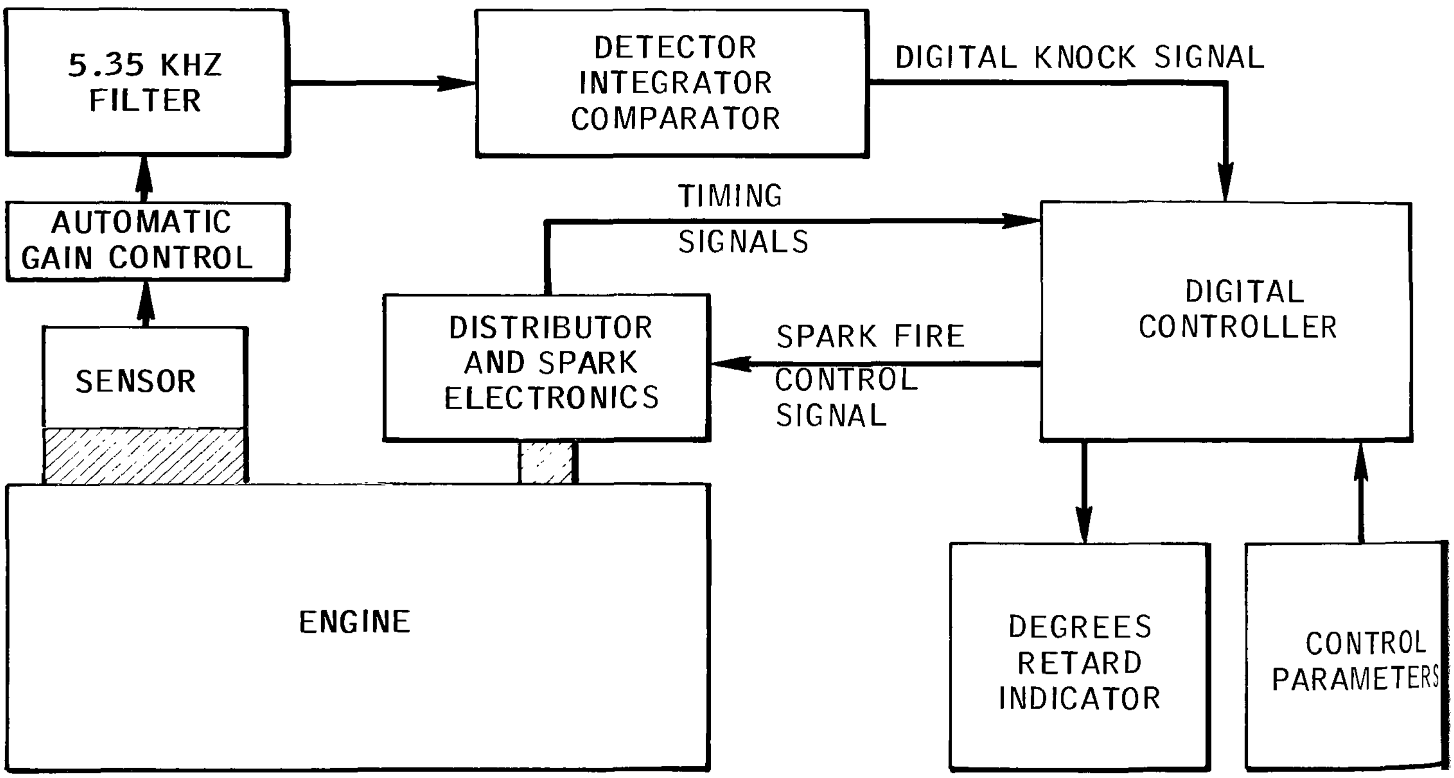


FIGURE 5-15

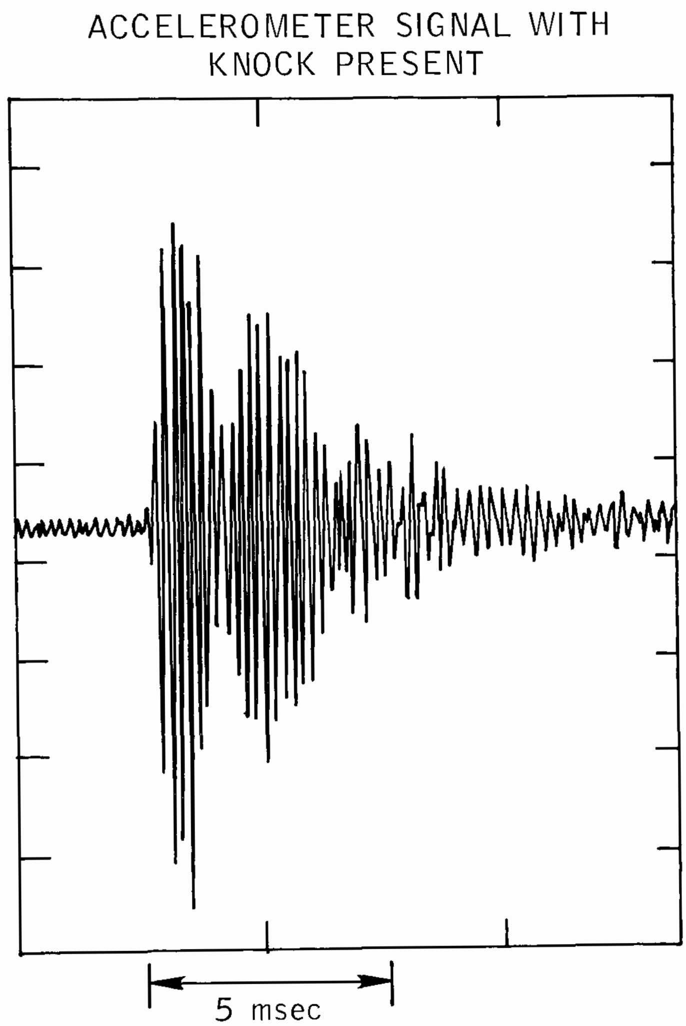


FIGURE 5-16

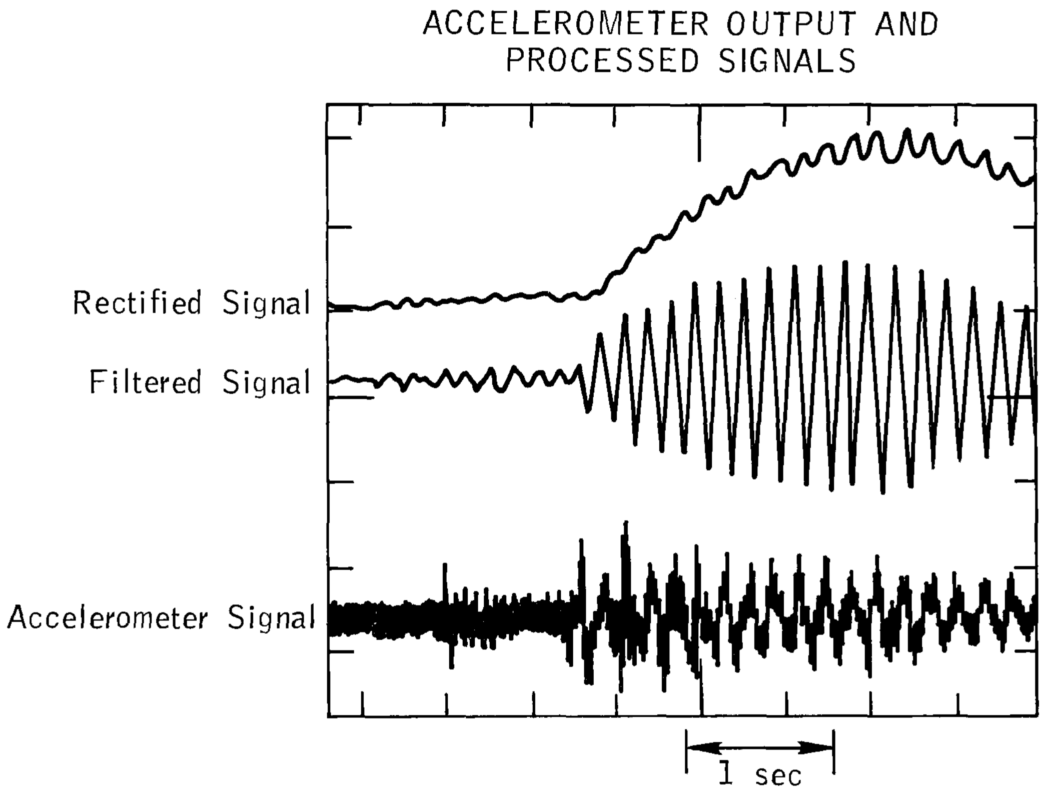
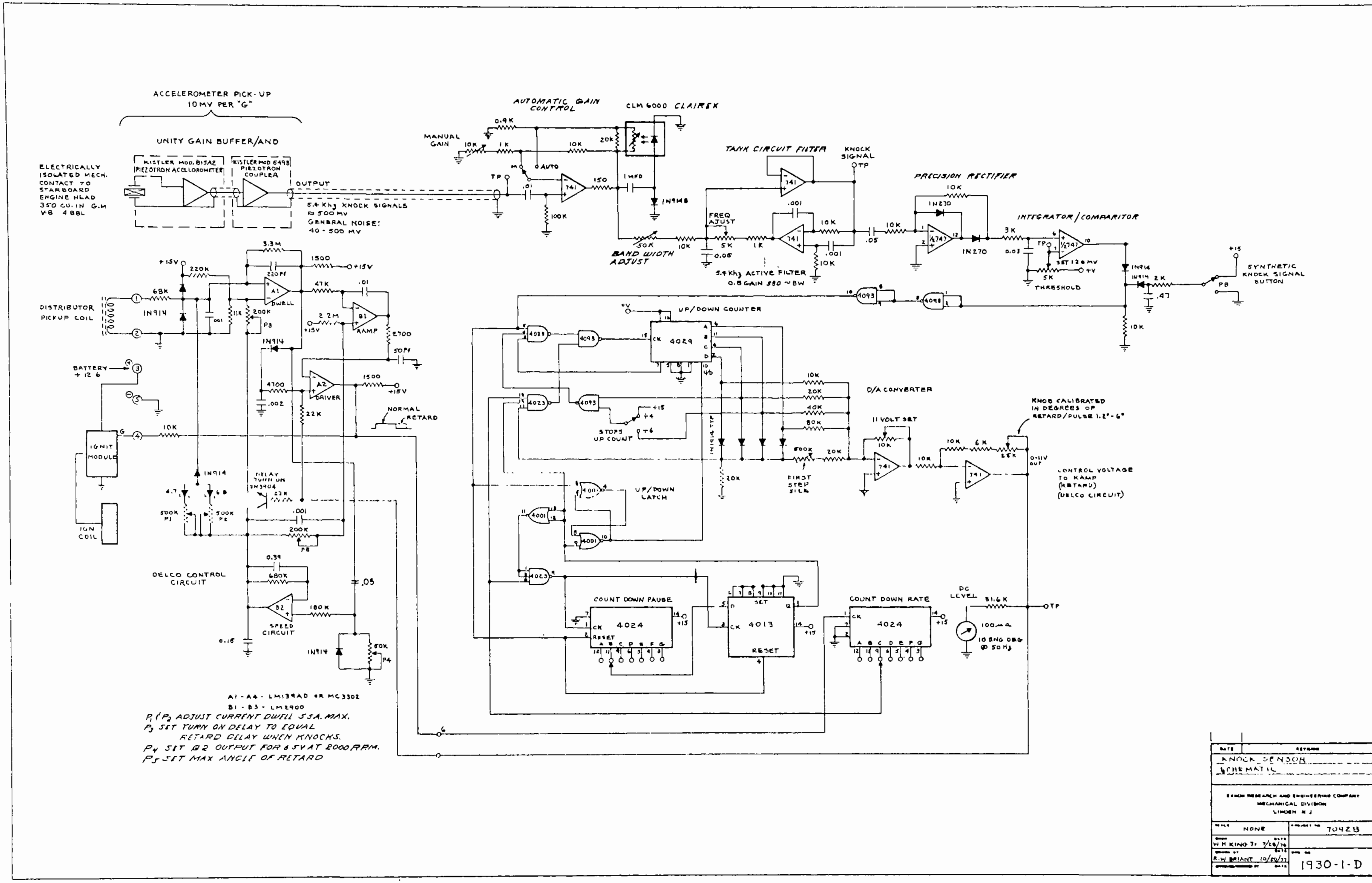

ACCELEROMETER OUTPUT AND
PROCESSED SIGNALS
Rectified Signal
Filtered Signal
Accelerometer Signal
1 sec

FIGURE 5-17 Detailed Circuit Diagram of Knock Sensor - Spark Retard System Electronics



EVALUATION OF KNOCK SENSOR-ACTUATED SPARK CONTROL SYSTEM ON ENGINE - The knock sensor-actuated spark control system was first tested on an engine dynamometer stand on both the standard 8:1 C.R. 350 CID engine and on the modified 9:1 C.R. engine. Both engines were tested without significant deposit accumulation. For these tests, manual gain control was used with the sensitivity set such that the system would not retard with a no-knock fuel but would respond to $T^-$ knock. The filter was fixed at 5.2 kHz with a 400 Hz bandwidth. Octane requirement determinations for $T^-$ knock, made during simulated 40-70 mph WOT accelerations, are summarized in Table 5-15. The data indicate that controlled spark retard gives a 3-7 number octane benefit depending on how long the spark retard is held (i.e., the length of the delay time before spark advance begins). Of course, as the total amount of spark retard was increased or the time was lengthened before allowing the spark to advance, power output decreased and acceleration times increased. These data provided the basis for the subsequent attempts to utilize this technology on the vehicle.

OPTIMIZATION OF SPARK CONTROL SYSTEM - The knock sensor-actuated spark control system and the 9:1 C.R. 350 CID V-8 engine on which the system had been tested on the dynamometer stand were moved to the 1975 California vehicle. Prior to vehicle testing, system optimization was accomplished by examining the response of the control system to tape recordings of the vehicle accelerometer and distributor signals. The same sections of tape could be played back and changes made to optimize the performance of the spark control system. In this manner, several variables were examined in the process of arriving at the final settings used in the vehicle tests.

Manual vs. Automatic Gain Control - All of the work done in the engine cell was with manual gain control, with the gain being constant. During an acceleration, the accelerometer signal level increases as the engine speed increases due to the natural increase in noise level with increasing engine rpm. If the gain were set such that the controller would retard in response to knock at low engine speeds, it might also retard in the absence of knock at high engine speeds. On the other hand, if the gain is set so that retard will not occur at high speed with no knock present, the system would be less sensitive in responding to knock at lower engine speeds. For this reason, it is desirable to incorporate automatic gain control (AGC) into the system. AGC attempts to hold the output signal from the amplifier relatively constant by changing the gain automatically as the accelerometer output signal varies with engine speed. It was found, in practice, that the system with AGC responded to knock equally well at all engine speeds. Therefore, with the exception of a small amount of diagnostic work, all of the vehicle testing was done using automatic gain control.

**Table 5-15** Effect of Knock Sensor-Actuated Spark Control in Engine Cell

| | Research Octane Requirement | | | |
|---|---|---|---|---|
| | No Control | | Controlled Spark | |
| | Primary Reference Fuels | High Sensitivity (CX) Full Boiling Reference Fuels* | Primary Reference Fuels | High Sensitivity (CX) Full Boiling Reference Fuels* |
| Standard 8:1 C.R. | 81 | | 76 | |
| Modified 9:1 C.R. | 87 | 85.5 | 84 | 79 |
| Modified 9:1 C.R. (Long Delay Time) | 86 | | 79 | |

Delay-1 - 1024 engine revolutions
Delay-2 - 32 engine revolutions

* See Appendix 2.

Filter Settings - One of the most critical parts of the entire system is the filtering of the input signal. Originally, the filter was set according to the frequency analysis data obtained under knocking conditions in the engine cell. This data indicated that for the 350 CID engine the predominant knock signal was centered about 5.1-5.2 kHz and was approximately 400 to 500 Hz wide. The filter was designed to approximately match the knock signal envelope. Using tape recordings of actual vehicle accelerometer signals, the system was tested for response to knock for a range of filter center frequencies from 4.9 to 5.7 kHz. In Figure 5-18, the relative intensity of the detected knock signal is plotted against filter center frequency setting for three different detonation intensities. It was apparent from these tests that 5.35 kHz was the optimal filter center frequency. Several filter bandwidths ranging from 200 to 1400 Hz were also examined. A bandwidth of 580 Hz was chosen for the vehicle studies.

Threshold Setting - The threshold value at which a detected knock pulse is allowed to trigger the spark control system is very important in determining the overall performance of the system. The threshold can be set such that inaudible "knock" will produce spark retard. Although in this case, most of the detonation will be eliminated, even with low octane fuels, it will result in some unnecessary retard and excessively long acceleration times. The threshold was chosen such that some small amount of knock ($T^-$ level) would be tolerated by the system, i.e., the system sometimes responds to $T^-$ level knock and sometimes does not. Since occasional low intensity detonation is not harmful to the engine or generally perceived by the driver, such a threshold setting (i.e., lower sensitivity to detect knock) seems appropriate.

Degrees of Retard per Knock Event - In all experimentation with the spark control system on the vehicle, 10° was the maximum retard allowed. This retard is achieved in either four or six incremental steps. Most of the work was done with six steps to a total of 10° maximum retard. A refinement was made to allow the first step to be larger (usually 2.5°) than the remaining five steps.

Spark Advance Delay Times - There are two delay controls for allowing the spark timing to advance back to its normal schedule. These two controls determine the number of engine revolutions before the spark advances the first step and the number of engine revolutions between subsequent steps. The effect of these delay times on detonation is illustrated in Figures 5-19 through 5-22 where the knock signal and amount of spark retard are displayed: for Figure 5-19 - an uncontrolled case, Figure 5-20 - a short delay where the initial stepdown occurs after 16 engine revolutions followed by 2 engine revolutions between each additional step, Figure 5-21 - a medium delay whereby the initial step of spark advance occurs after 128 revolutions with each additional step every 16 revolutions, and Figure 5-22 - a long delay where the initial delay is 1,024 revolutions followed by 32 revolutions between each additional step. It can be seen that while considerable detonation is eliminated for the short delay time case, it is necessary to go to longer delay times to prevent detonation from occurring in the middle of an acceleration due to the premature advance of the spark timing. In the vehicle studies, most of the work was done with the long delays, i.e., delay 1 was 1,024 engine revolutions and delay 2 was 32 engine revolutions. Some tests were also run with delays of 128 and 32 engine revolutions respectively.

FIGURE 5-18 INTENSITY OF KNOCK SIGNAL VS. FILTER CENTER FREQUENCY FOR THREE KNOCK PULSES OF DIFFERENT INTENSITY

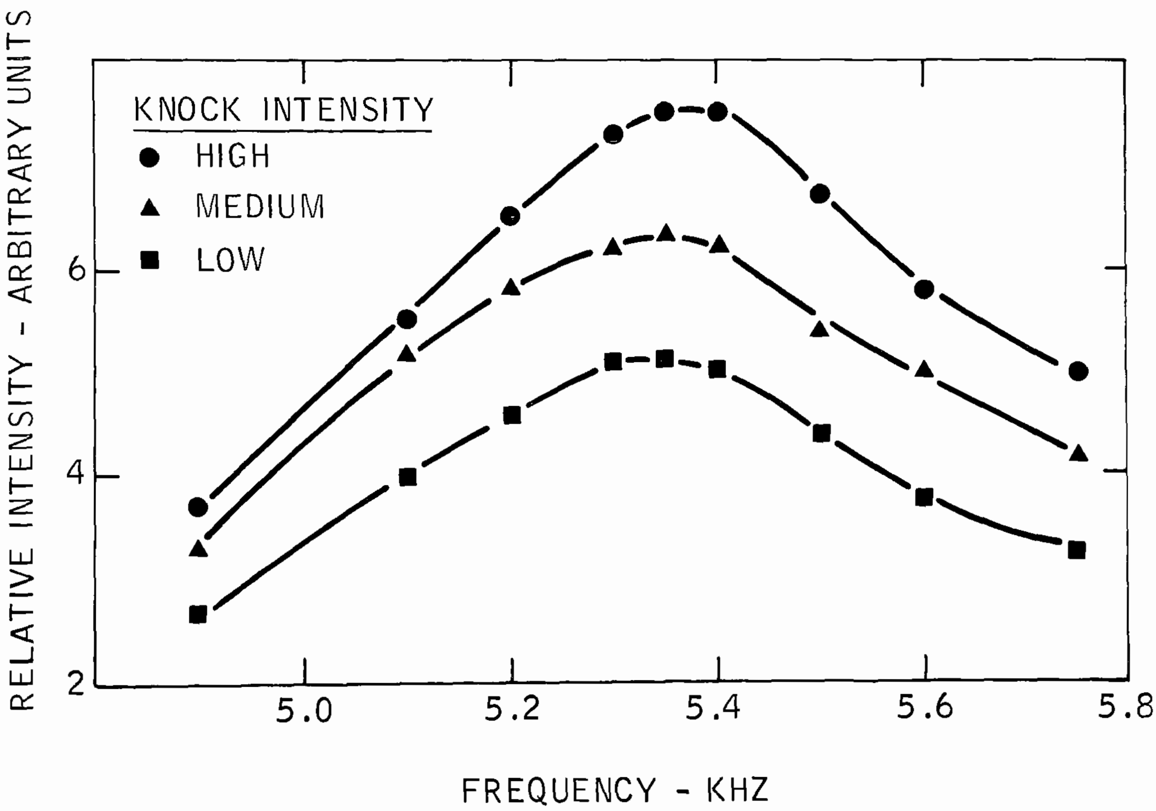


FIGURE 5-19

KNOCK SIGNAL VS. TIME DURING 40-60 MPH ACCELERATION USING KNOCKING FUEL WITH NO SPARK CONTROL

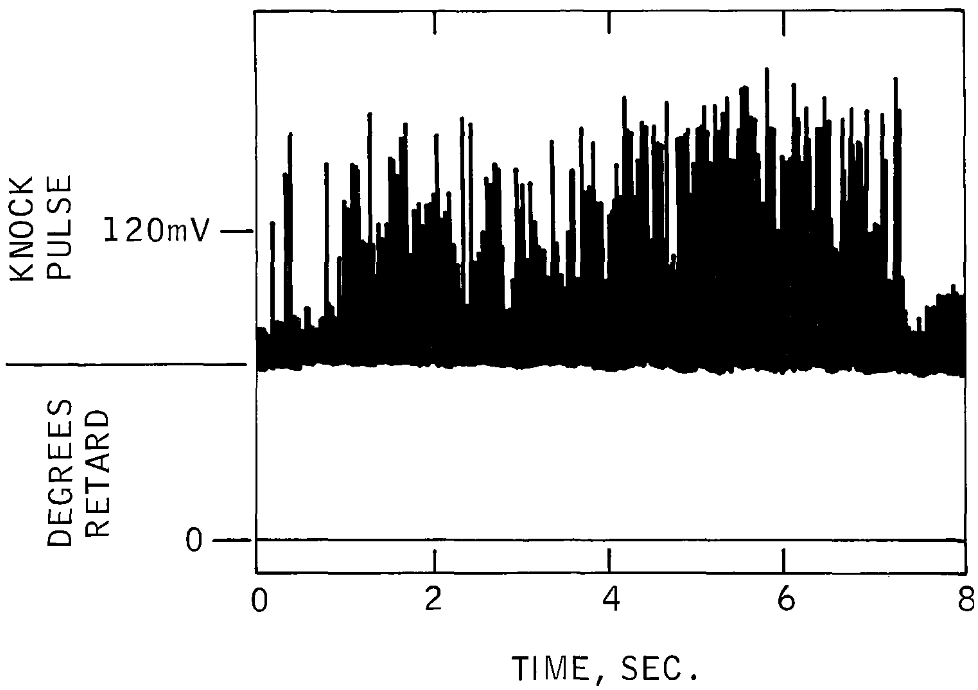


FIGURE 5-20

TOP — KNOCK SIGNAL VS. TIME DURING 40-60 MPH ACCELERATION USING KNOCKING FUEL WITH CONTROLLED SPARK TIMING

BOTTOM — SPARK RETARD WITH SHORT SPARK ADVANCE DELAY TIMES

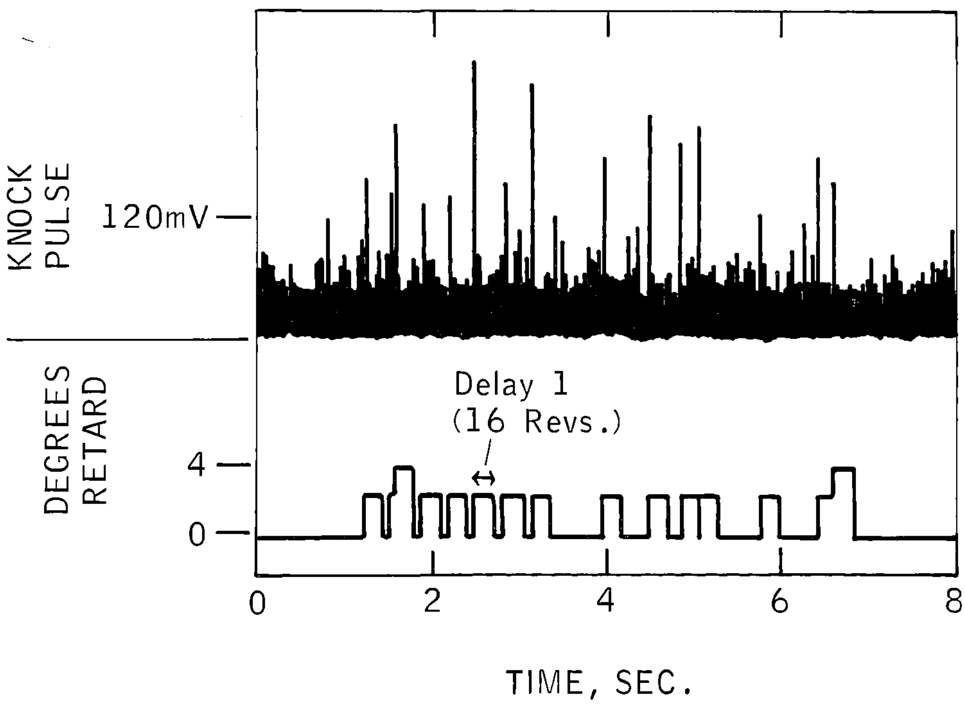


FIGURE 5-21

TOP KNOCK SIGNAL VS. TIME DURING 40-60 MPH ACCELERATION USING KNOCKING FUEL WITH CONTROLLED SPARK TIMING

BOTTOM - SPARK RETARD WITH MEDIUM SPARK ADVANCE DELAY TIMES

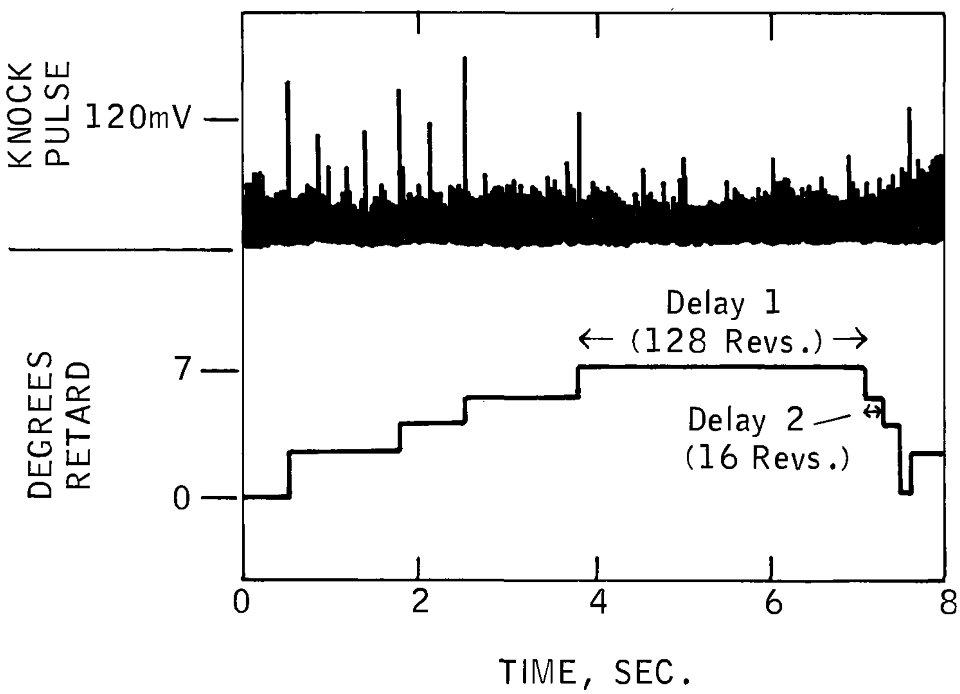
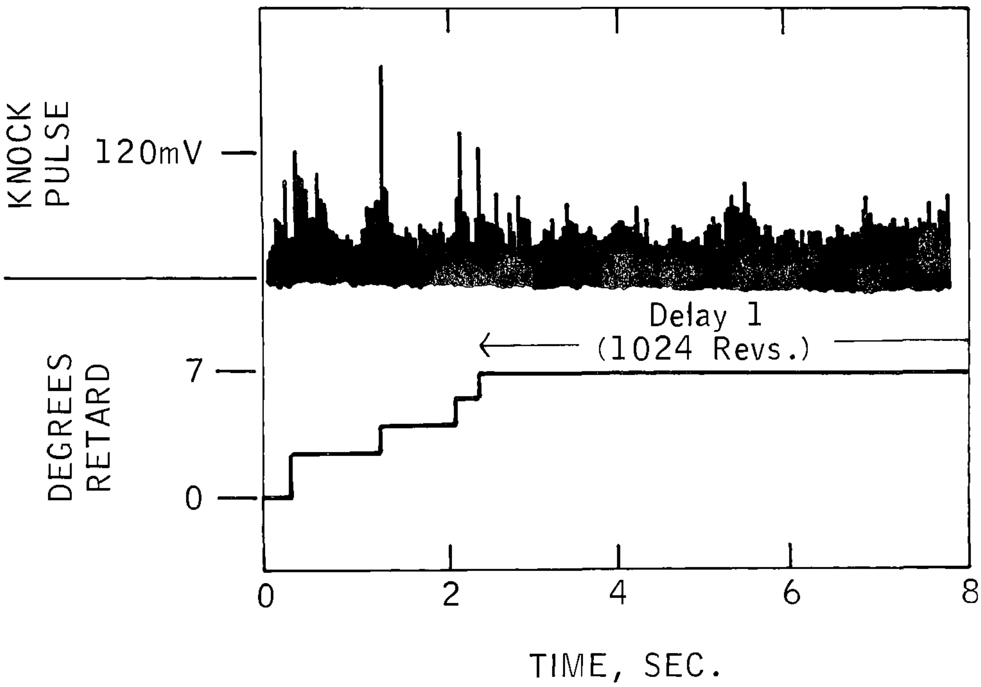


FIGURE 5-22

TOP - KNOCK SIGNAL VS. TIME DURING 40-60 MPH ACCELERATION USING KNOCKING FUEL WITH CONTROLLED SPARK TIMING

BOTTOM SPARK RETARD WITH LONG SPARK ADVANCE DELAY TIMES



KNOCK SENSOR ACTUATED SPARK RETARD SYSTEM OPERATION - The knock sensor (piezoelectric crystal transducer) located on the passenger side cylinder head is wired into the piezotron coupler. This coupler contains three 8.4 volt batteries as shown in Figure 5-23 which should be checked periodically to insure that each has not dropped below 7.0 volts. The on/off switch on the coupler is used to cut off the signal and thus can be used to run the car with and without the knock sensor controlling the spark timing.

The entire system is shown in Figure 5-24. The output from the accelerometer coupler is fed to the controller. The controller is powered by a DC power supply and needs a minimum of 15 volts to operate. Generally the batteries are replaced when the voltage drops to around 17 volts.

The controller itself contains all the electronic hardware of the system and was built to allow sufficient flexibility during the research to obtain the optimum working system. Beginning from the upper left hand corner of Figure 5-25 and proceeding from left to right, these are the functions:

(1) Auto/Manual - allows either automatic or manual gain control.

(2) 1st Step - adjusts the size of the retard for 1st step only, normally set at 2.5° crank angle.

(3) Thresh - adjust threshold level for knock perception.

(4) Deg/k - used to adjust total maximum retard - normally 10° crank angle.

(5) Syn knk - punched to apply to a synthetic retard.

(6) MV/G - used to adjust gain when manual gain control is used.

(7) Frequency - center frequency of filter, normally set at 5350 Hz.

(8) Bandwidth of filter, normally set at 540 Hz.

(9) Control knob - off means no power to box standby and bypass are used for diagnostics and allow box electronics to function with no retard effected on engine. Control is the normal setting used to have spark control when piezotron coupler is on. If coupler if off, no spark control is obtained since accelerometer signal is disconnected. Set thresh turns meter into 0-200 mv meter for adjusting threshold. All the uncontrolled spark cases in our work were run with the knob in the control position with the coupler turned off.

(10) Decay and Delay - used to adjust the delay before spark advance is begun after last spark retard implemented.

$\frac{\text{Decay x Delay}}{8}$ = Delay -1 before initial advance in engine revolutions
Where F is an empirically-determined correction factor for the delay knob setting. F, which ranges between 1 and 2, can be read off the curve shown in Figure 5-26.

$\frac{\text{Decay}}{4}$ = Delay -2 before subsequent advances in engine revolutions

For our work, the optimal settings were a Delay of 4 and Decay of 128.

(11) Selector Switch - for using either 4 or 6 steps of spark retard.

(12) Meter - to read degrees of retard implemented.

(13) Output Taps - for diagnostic purposes.

(14) Cancel Retard - button which cancels immediately any applied retard.

(15) Sensor Input - lead from accelerometer.

(16) Ignition - input and output leads to and from distributor.

FIGURE 5-23

PIEZOTRON COUPLER

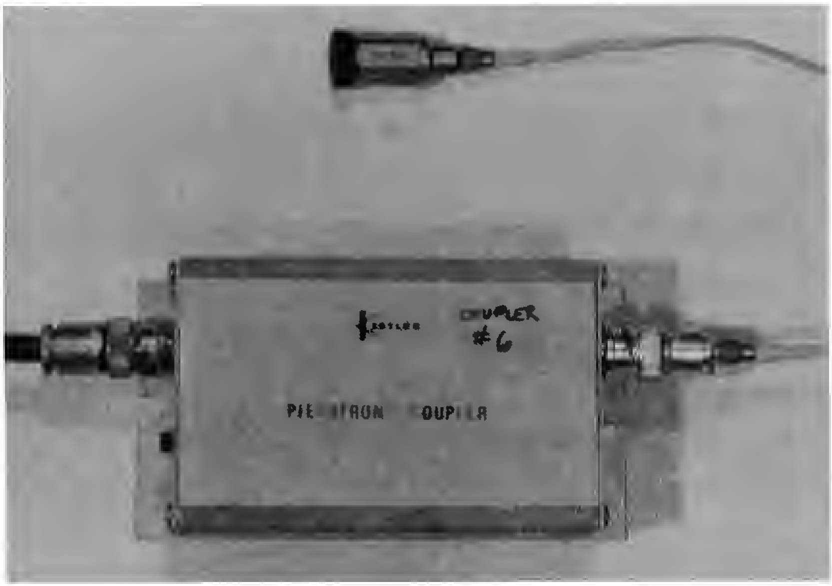



FIGURE 5-24

ENTIRE SYSTEM

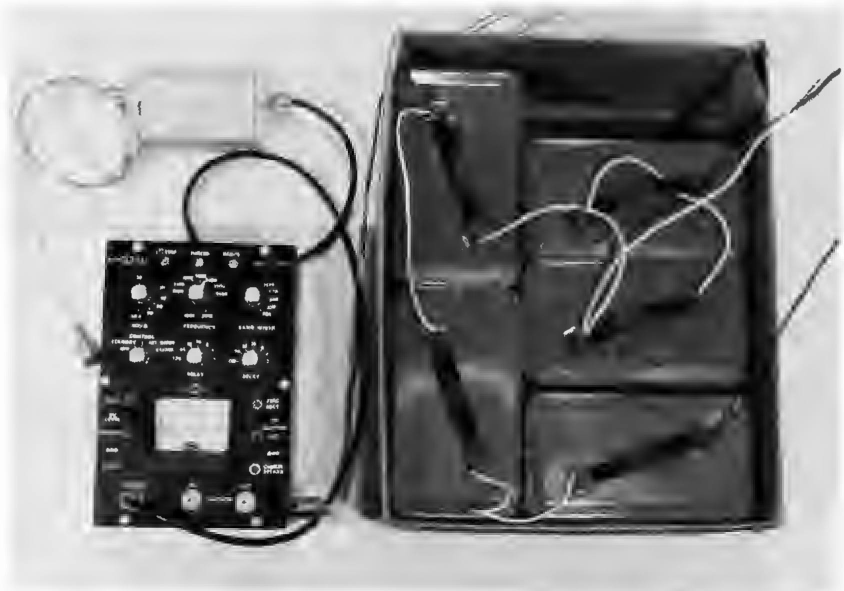


FIGURE 5-25

CONTROLLER

CORRECTION FACTOR (F) FOR DELAY SETTING

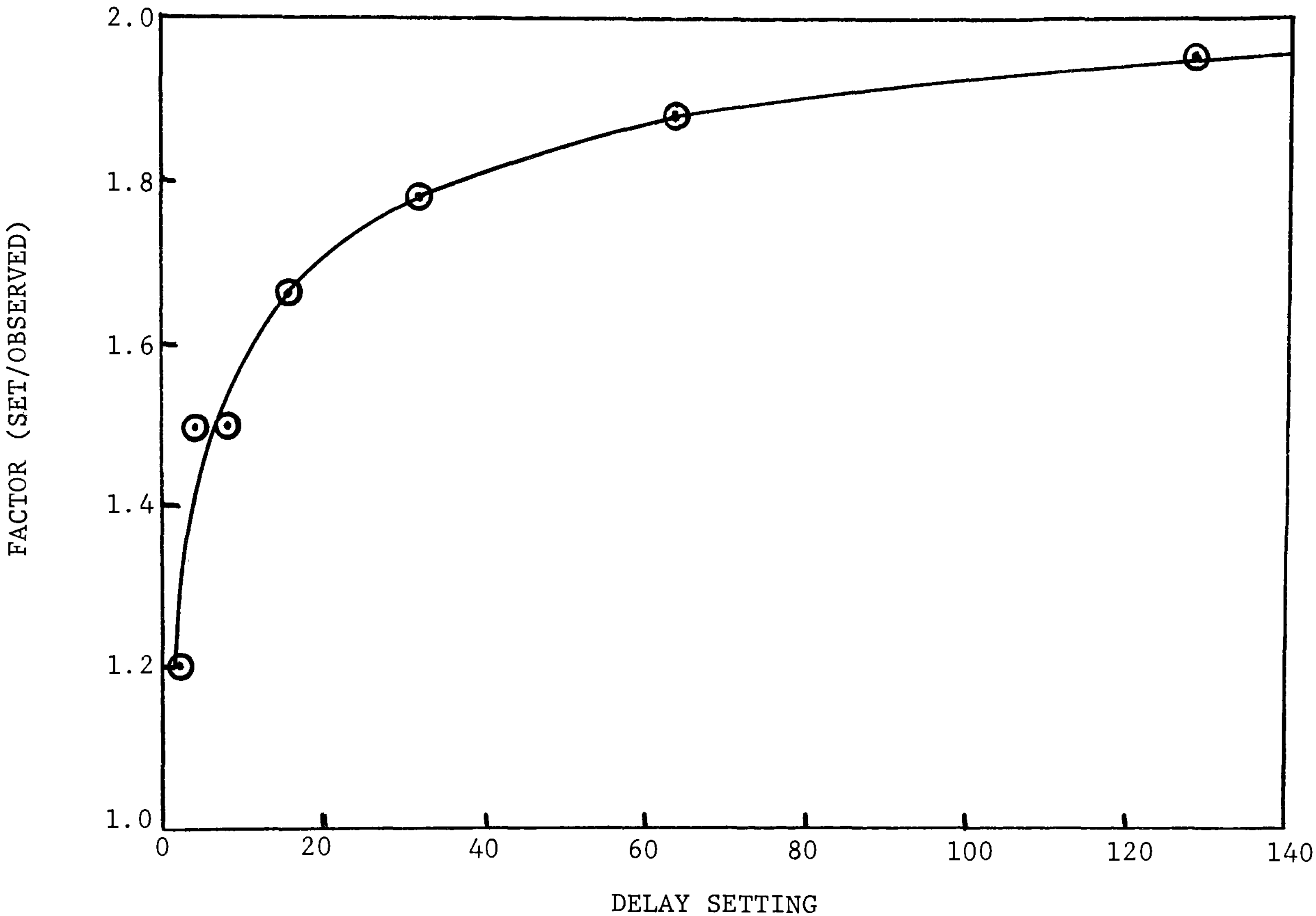



FIGURE 5-26

# SECTION 6

## MODIFICATIONS TO VEHICLE

The base vehicle (1975 California Chevrolet Nova - 350 V-8 engine) was to be modified to 9:1 C.R. At this higher compression ratio, it was necessary to recalibrate the engine to the 1975 California emissions standards. With these modifications made, the fuel economy benefit was measured at 9:1 C.R. and compared to 8:1 C.R. The vehicle was then equipped with the knock sensor-spark retard system which had been demonstrated to be an effective means of reducing octane requirement in engine dynamometer testing.

### 6.1 EFFECTS OF INCREASED COMPRESSION RATIO

The base vehicle had a production 350 CID V-8 (California) engine with an 8:1 compression ratio. A 9:1 compression ratio can be achieved by replacing the standard heads with those from the 1969 10.25:1 C.R. engine. Compression ratios were determined by measurement of the combustion chamber volumes at top and bottom dead center by liquid displacement. These measurements were made for the 1975 blocks containing standard and notched pistons. Notched pistons were used so that the dual ignition heads would have enough clearance when coupled with the standard 350 CID block (see Figure 6-1). The effect of the piston cavity on compression ratio was less than 0.1 C.R. unit as shown in Table 6-1.

Table 6-1 Combustion Chamber Volumes of 350 CID Engine

| | 1975 Heads, cc. | | 1969 Heads, cc. | |
|---|---|---|---|---|
| Volumes | Standard | With Piston Cavities | Standard | With Piston Cavities |
| TDC | 102.5 | 103.3 | 88.4 | 89.2 |
| BDC | 817.1 | 817.9 | 803.0 | 803.8 |
| C.R. | 7.97 | 7.92 | 9.08 | 9.01 |

The 1969 heads have about 35% greater squish area (the areas of heads in Fig. 6-2 which come in closest proximity to piston at TDC). A comparison between the base 8:1 C.R. engine and a modified engine with the 1969 heads at an 8:1 C.R. (obtained through the use of head spacers), showed no effect of the increased squish area on octane requirement, emissions, and fuel economy as shown in the section on the effects of increased turbulence on octane requirement. Thus, any effects on emissions, fuel economy, or octane requirement produced by using the 1969 heads are due only to the change in compression ratio. These effects are described below.

EMISSIONS - Emissions results are shown in Table 6-2. For each

Table 6-2 Comparison of FTP Emissions for 8:1 and 9:1 Configurations

| Case | C.R. | EGR | Emissions - g/mile CO | HC | $NO_x$ |
|---|---|---|---|---|---|
| 1 | 8:1 | Standard | 6.0 | 0.5 | 1.7 |
| 2 | 9:1 | Standard | 8.1 | 0.6 | 2.2 |
| 3 | 9:1 | Proportional(1) | 3.9 | 0.5 | 1.7 |
| 4 | 9:1(2) | Proportional(1) | 4.8 | 0.8 | 1.9 |
| 5 | 9:1(3) | Proportional(1) | 4.9 | 0.7 | 2.0 |

(1) EGR flow proportional to engine speed. Orifice size increased from 1/4" to 21/64" diameter to increase flow. Choke a little leaner.

(2) Rings changed, new 1969 heads installed.

(3) After 12,000 miles.

case, the tabulated data are the average of at least three emissions tests using Indolene (a high octane unleaded) fuel. The details of the emissions tests, including individual bag results for the FTP cycle are given in Appendix B. $NO_x$ emissions increased with an increase in compression ratio (see Table 6-2, cases #1 and 2). Since emissions were to be controlled at the base case level, it was necessary to increase the exhaust recycle flow. The standard EGR valve was replaced with an exhaust back pressure-modulated valve which gave somewhat higher recycle flow with increased engine speed. The fraction of recycle was increased over all operating regimes by enlarging the area of the control orifice until $NO_x$ emissions were lowered to the base 8:1 C.R. level as shown in case 3 of Table 6-2. Photographs of the proportional EGR valve showing the removable orifices are given in Figure 6-3. The recycle flow as percentage of intake was calculated to be 7% at 30 mph and 12% at 50 mph. This calculation was based on $CO_2$ measurements in the exhaust crossover and intake manifold corrected for $H_2O$ content. Somewhat leaner choke settings was also employed. The comparison of cases 1 and 3 shows that the 9:1 C.R. emissions can be maintained at the 8:1 C.R. level by modification of the exhaust recycle system.

FIGURE 6-1

350 CID ENGINE BLOCK WITH NOTCHED PISTONS

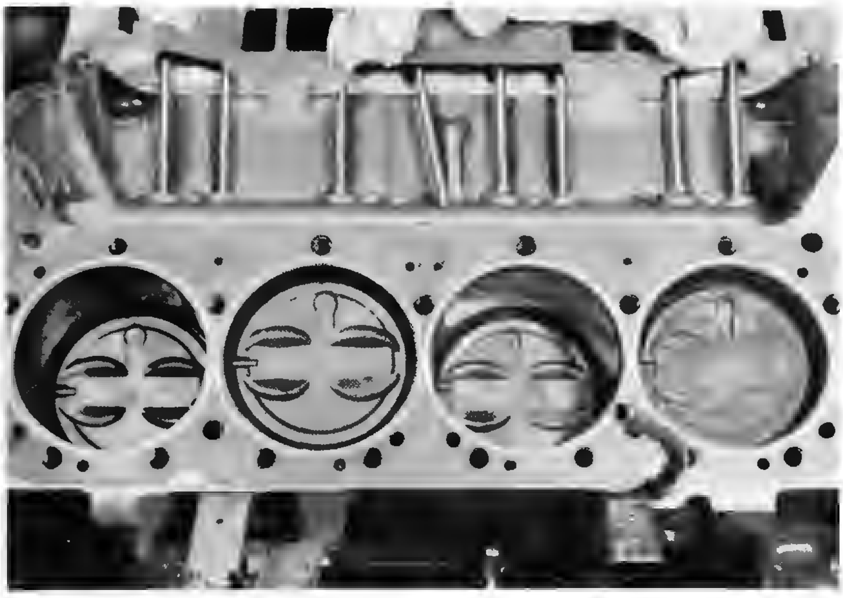


FIGURE 6-2

PHOTOGRAPHS OF 1975 AND 1969 350 CID HEADS

1975 Head

1969 Head

FIGURE 6-3

GM PROPORTIONAL EGR VALVE

Orifices

After these initial comparisons were completed, work began to evaluate the knock sensor system on the vehicle. During this period when the knock sensor-actuated spark retard system was being optimized for use on the vehicle, several problems were encountered. First, the accumulation of heavy oil-based deposits in the combustion chamber necessitated that new piston rings be installed. The accumulation of these ashy deposits presented some surface ignition problems which were accentuated by spark retard. The cylinder heads were cleaned of deposits and new pistons and rings were installed at 16,500 miles. After a 350 mile break-in, the emissions testing showed that the $NO_x$ and hydrocarbon emissions were increased considerably (see Table 6-3). The octane requirement also was much higher. The compression ratio was measured at 8.8-9.0/1 and no problems could be found with the engine. It was apparent, however, that the engine had been significantly altered and therefore the old pistons were put in with a new set of rings. After a 1,200 mile break-in to assure proper ring seating, the $NO_x$ emissions were found to be lower. It was necessary to rebuild the carburetor and adjust the choke setting to achieve the same CO and HC emissions as shown in Table 6-3. At this point, the vehicle's emissions had been recalibrated. Slightly lower fuel economy was measured on the FTP cycle but somewhat higher values on the HFET cycle. The knock sensor-spark retard system was re-installed and work on optimization was resumed. When this was completed, the heads were removed to scrape combustion chamber deposits so that clean engine initial requirement data could be obtained. At this time, severe valve recession was noted. The valve seats were more than twice as wide as in the new engine. This was presumably due to the fact that the 1969 heads were not induction hardened and therefore were more vulnerable to wear with unleaded fuel. New 1969 heads and valves were installed at 21,600 miles, which again resulted in an engine different in operation than the previous ones. The $NO_x$ emissions were recalibrated by changing the size of the EGR orifice and the carburetor was rebuilt and adjusted. The end result is shown in Table 6-3. Although the emissions levels were successfully recalibrated, the fuel economy was lower than that obtained previously, especially on the FTP cycle. At the start of durability testing, emissions were as shown in Table 6-2, case 4 and after 12,000 miles with the spark control system operative little change had taken place (Table 6-2, case 5).

FUEL ECONOMY - The purpose of increasing the compression ratio was to obtain better fuel eocnomy. The fuel economy results are given in Table 6-4. The complete emissions data are given in Appendix B. Here the tabulated data represent averages of at least three tests in which the fuel economy was measured by three methods - carbon balance from emissions, fuel weight, and fuel metering. For each case, the average city (FTP), highway (HFET), and combined city/highway fuel economies are given along with the percentage improvement over the 8:1 C.R. case for the combined city/highway values. Case 2 shows that a one unit compression ratio change resulted in a significant benefit, both on the

FTP and HFET cycles. A 5.6% combined fuel economy benefit was measured for this vehicle, which is in the range of historically measured fuel economy benefits for a one C.R. unit change (7,8). This is the best estimate of the increase in fuel economy resulting from the unit C.R. change which can be made from our data since the runs were made back-to-back with only the heads being changed. Case 3 shows the effect of the addition of the proportional recycle system with increased EGR flows and somewhat leaner choke setting. Almost all the additional fuel economy benefit is seen in the FTP cycle.

As mentioned previously, two engine problems developed which necessitated the replacement of piston rings and the installation of new cylinder heads. The fuel economy data including these changes are given in Table 6-4, case 4. These changes, particularly the head replacement, resulted in significantly lower fuel economy. The final case (#5) gives the fuel economy data after 12,000 miles on the vehicle with new heads and rings.

OCTANE REQUIREMENT - An increase in vehicle octane requirement generally accompanies an increase in compression ratio. Based on historical data, a one unit increase in compression ratio should result in a 3-4 number octane requirement increase (7).

The octane ratings were done using three series of rating fuels, identical to those used in the CRC procedures. These are of two types: primary reference fuels and full boiling range fuels. The latter are classified by sensitivity: a high sensitivity (CX) series, which averages 10 and is 7 for the lowest octane fuels and increases to 12 for the highest octane fuels, and a lower sensitivity (C) series, ranging from 6 to 10 with an 8 average. A complete summary of these full-boiling rating fuels and octane rating procedures is given in Appendix C.

The clean engine research octane requirements, obtained during 40-70 mph wide open throttle (WOT) accelerations in high gear, are given in Table 6-5 for the 8:1 C.R. and the two 9:1 cases. The initial 8:1 to 9:1 (case #2) comparison showed a 4-6 number requirement increase. The octane requirement for the engine with new heads and rings (case 3) is two numbers higher than the 8:1 C.R. case. This engine subsequently was equipped with the knock sensor-actuated spark retard system used to control the vehicle's octane requirement during the accumulation of 16,000 miles.

Table 6-3 Comparison of Emission, Fuel Economy and Octane Requirement

| Mileage | Condition | During Troubleshooting Period: Emissions (FTP) g/mile CO | HC | $NO_x$ | Fuel Economy -g/mile CVS-CH | HFET | Octane Requirement (PRF) |
|---|---|---|---|---|---|---|---|
| 14,000 | 8:1 C.R.-Base Vehicle Standard EGR Valve | 6.0 | 0.5 | 1.7 | 11.4 | 16.3 | 80 |
| 15,000 | 9:1 C.R.-Proportional EGR | 3.9 | 0.5 | 1.7 | 12.6 | 17.6 | 86 |
| 16,500 | 9:1 C.R.-New Pistons + Rings -Proportional EGR | 6.3 | 0.9 | 2.6 | 11.9 | 18.2 | 90 |
| 18,500 | 9:1 C.R.-Old Piston + New Rings -Proportional EGR | 4.0 | 0.6 | 2.0 | 12.0 | 18.1 | 88 |
| 22,600 | 9:1 C.R.-New 1969 Heads -Proportional EGR | 4.8 | 0.8 | 1.9 | 11.5 | 17.3 | 84 |

**Table 6-4** Comparison of Fuel Economy for 8:1 and 9:1 C.R. Configurations

| Case | C.R. | EGR | Fuel Economy - mpg FTP | HFET | Combined | % Improvement Over 8:1 C.R. |
|---|---|---|---|---|---|---|
| 1 | 8:1 | Standard | 11.4 | 16.3 | 13.2 | --- |
| 2 | 9:1 | Standard | 12.0 | 17.5 | 13.9 | 5.6% |
| 3 | 9:1 | Proportional(2) | 12.6 | 17.6 | 14.5 | 9.6% |
| 4 | 9:1(3) | Proportional(2) | 11.5 | 17.3 | 13.5 | 2.4% |
| 5 | 9:1(4) | Proportional(2) | 11.8 | 17.2 | 13.7 | 3.9% |

(1) Calculated from $1/(0.55/mpg_{FTP} + 0.45/mpg_{HFET})$

(2) EGR flow proportional to engine speed. Orifice size increased from 1/4" to 21/64" diameter to increase flow. Choke one notch leaner.

(3) New rings installed, new 1969 heads installed.

(4) After 12,000 miles.

Table 6-5 Research Octane Requirement of Vehicle on Mileage Accumulation Dynamometer (MAD)

| Case | C.R. | EGR | Primary Reference Fuels | Full Boiling Range Reference Fuels | |
|---|---|---|---|---|---|
| | | | | High Sensitivity - CX[2] | Low Sensitivity - C[2] |
| 1 | 8:1 | Standard | 80 | 83 | 82 |
| 2 | 9:1 | Proportional[1] | 86 | 87 | 86 |
| 3 | 9:1[3] | Proportional[1] | 82 | 85 | 84 |

(1) EGR flow proportional to engine speed. Orifice size increased from 1/4" to 21/64" diameter to increase flow.

(2) See Appendix C.

(3) Rings and heads replaced.

## 6.2 EVALUATION OF SPARK CONTROL SYSTEM ON VEHICLE

Prior to the evaluation of the spark control system on the vehicle, the system was optimized. This procedure is discussed in detail in this laboratory evaluation section on knock sensor-actuated spark retard. The system as tested on the vehicle included automatic gain control, a filter of 5.35 kHz center frequency and 580 Hz bandwidth, and adjustable threshold and spark advance delay time settings. The spark retard was implemented in six distinct steps up to a maximum of 10° crank angle retard, with the initial retard being 2.5° and each additional one being 1.5°. The effects of the knock sensor-actuated spark retard system on vehicle octane requirement, acceleration performance, emissions, and fuel economy are discussed below.

OCTANE REQUIREMENT OF THE VEHICLE - The octane requirement of the vehicle was determined during 40-70 mph accelerations with wide open throttle (WOT) in high gear. The vehicle was checked to insure that its maximum octane requirement was at WOT and was not at part throttle or in second gear. Octane ratings were made using standard CRC reference octane fuels and were conducted both on the mileage accumulation dynamometer (MAD) and on the road at a test track. The rating designations are as follows: no knock (NK), trace minus (T$^-$), is the lowest perceptible knock detectable by a trained octane rater and is defined as the technical octane requirement of the vehicle, trace (T), trace plus (T$^+$) - typically lowest level noticed by average customer, very light (VL), very light plus (VL+), light minus (L$^-$), light (L), light medium (LM), and heavy knock. Generally, anything above very light plus knock is not rated because it is quite loud. The octane requirement data are summarized in Table 6-6. The requirements

Table 6-6 Research Octane Requirement of 9:1 C.R. Vehicle (Clean Engine)

| | Reference Fuel(1) | Normal Spark Timing | Knock Sensor Controlled Spark Timing(2) |
|---|---|---|---|
| Road | CX | 85 | 82 |
| | C | 83 | 80 |
| | Primary | 82 | 80 |
| MAD | CX | 85 | 82 |
| | C | 84 | 81 |
| | Primary | 82 | 81 |

(1) See Appendix C.

(2) Delay 1 is 1,024 engine revolutions, Delay 2 is 32 engine revolutions.

given with the normal spark timing schedule are the requirements of the vehicle for trace minus ($T^-$) level knock. The octane rating quoted for the control system case is the lowest octane fuel which produces $T^-$ knock excluding the initial detonation. The initial detonation may become quite intense with lower octane fuels. However, after the control system responds to it, only $T^-$ to T knock usually is heard with fuels several octane numbers lower than the normal requirements. Using these criteria, a reduction in vehicle octane requirement of one to three numbers can be achieved depending on which fuel series was used. This reduction in octane requirement was approximately the same whether the vehicle was rated on the MAD or on the road.

The detailed test results both for the MAD and road octane ratings are given in Appendix C. The system threshold is set to detect $T^-$ to T level knock. Thus, after the initial burst of knock, the system allows only $T^-$ to T level knock to be heard audibly for several octane numbers below the normal requirement.

PERFORMANCE OF THE VEHICLE - The performance of the vehicle was evaluated by measuring acceleration times during octane rating at the test track for 40-70 mph, 0-60 mph, and 1/4 mile accelerations. These tests were conducted both with and without the spark control system to determine the effect of the applied spark retard on the vehicle's performance.

In Figure 6-4, 40-70 mph WOT acceleration times are plotted against octane number for the C series (lower sensitivity) rating fuels. It can be seen that there is a performance debit associated with the use of the controlled spark retard system when long spark advance delay times are used. For a fuel that is five numbers below the normal no knock requirement fuel, 16% slower acceleration times were observed.

The performance of the vehicle during 0-60 mph and quarter mile WOT accelerations was measured using CX-84 fuel which gave trace plus intensity knock on these accelerations. With this fuel, only very small performance debits were observed (see Table 6-7).

Table 6-7 Acceleration Performance of Vehicle Using Knocking - High Sensitivity CX - 84 RON Fuel

| | 0-60 mph | 1/4 Mile |
|---|---|---|
| Uncontrolled Spark | 10.4 sec | 17.7 sec |
| Controlled Spark | 10.6 sec | 18.3 sec |

VEHICLE MILEAGE ACCUMULATION - In order to assess the durability of the knock sensor-actuated spark retard system, 16,000 miles was accumulated on a mileage accumulation dynamometer (MAD). The cycle for the first 12,000 miles consisted of combined city-suburban driving with an average speed of 32 mph. For the last 4,000 miles, the AMA durability cycle was used. Properties of the mileage accumulation fuel, which was blended to be a minimum octane specification unleaded fuel, are given in Table 6-8. Octane requirement, emissions, and fuel economy were measured

Table 6-8 Properties of Mileage Accumulation Fuel

| | |
|---|---|
| Research Octane Number | 91.8 |
| Motor Octane Number | 82.5 |
| Lead - g/gal. | <0.01 |
| Sulfur, ppm | 237 |
| API Gravity @ 60°F | 60.8 |
| FIA: Aromatics | 22.5% |
| Olefins | 14.5% |
| Saturates | 63.0% |
| RVP | 7.3 psi |
| IBP | 100°F |
| 10% | 138°F |
| 50 | 215°F |
| 90 | 331°F |
| F.B.P. | 415°F |

at 0, 6,000, 8,000, 10,000, 12,000 and 16,000 miles. During this period of mileage accumulation, any spark retard occurring over the driving cycle was recorded continuously on a strip chart recorder. Initially, some problems were encountered with spurious retard from electrical interference when the controller was powered by an AC power supply. Operation with a 15 volt DC power supply essentially eliminated these spurious retards. After these problems were corrected, only 29 spurious retards were recorded over the 16,000 miles, due in part to non-vehicle electrical intereference and possibly some engine noises.

Octane Requirement and Performance - A plot of vehicle MAD octane requirement vs. accumulated mileage is given in Figure 6-5 for the 8-average sensitivity (C) fuel series including both the uncontrolled and the controlled spark cases. The octane requirement increased approximately 3 numbers over the 12,000 miles. It should be noted that the controlled spark timing case gave approximately a 3 number lower octane requirement than the no control case at all mileage intervals. This benefit is considerably less than that observed in the engine dynamometer evaluation. This may be due to the fact that knock is more difficult to hear in the engine dynamometer installation. Acceleration performance debits similar to those mentioned previously were measured with the spark timing controlled.

FIGURE 6-4

ACCELERATION PERFORMANCE (40-70 MPH) VS. RESEARCH OCTANE NUMBER FOR CLEAN ENGINE USING 8 SENSITIVITY (C SERIES) FUELS; FOR CONTROLLED SPARK CASE, DELAY 1 AND DELAY 2 ARE 1,024 AND 32 ENGINE REVOLUTIONS RESPECTIVELY

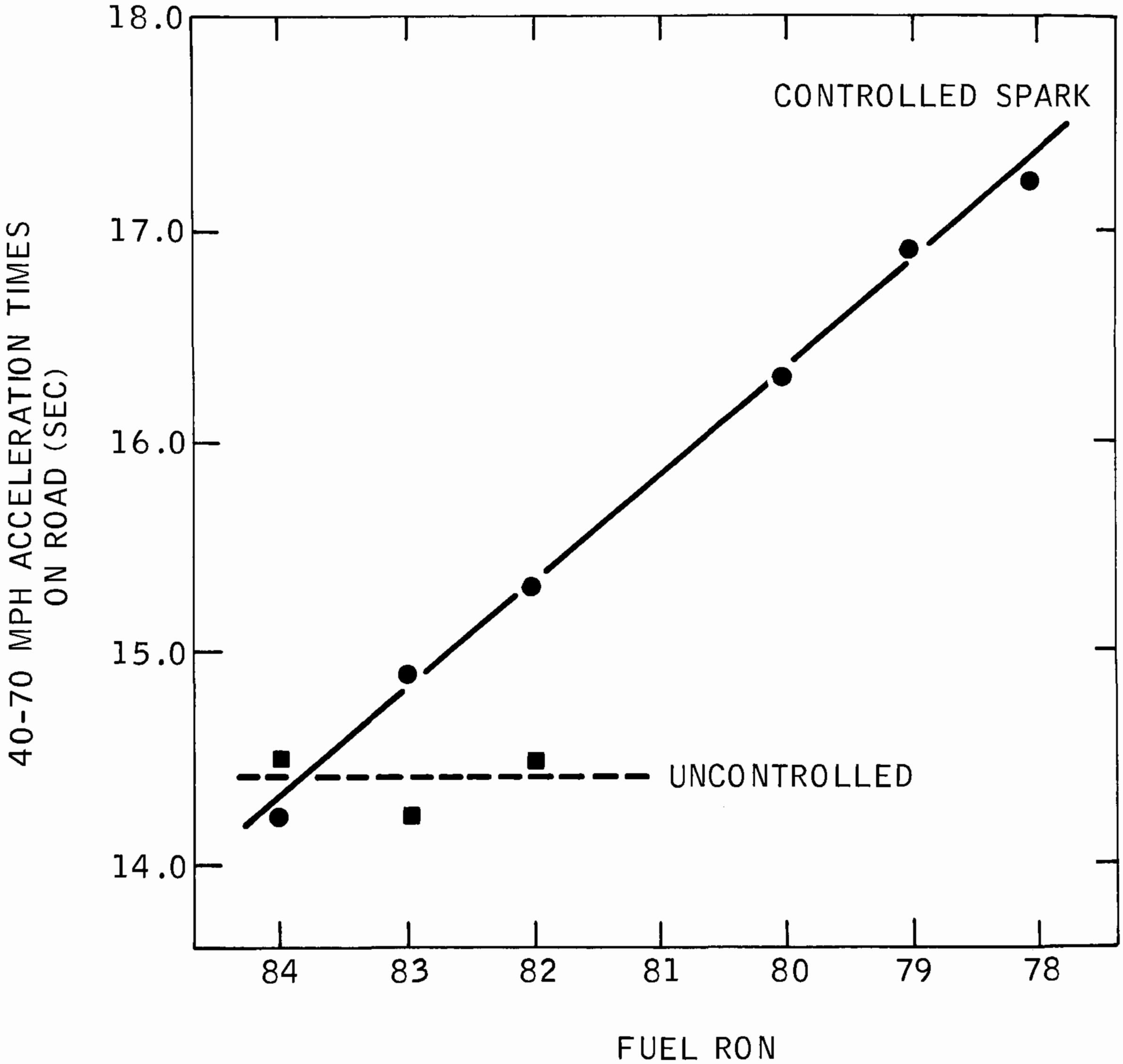
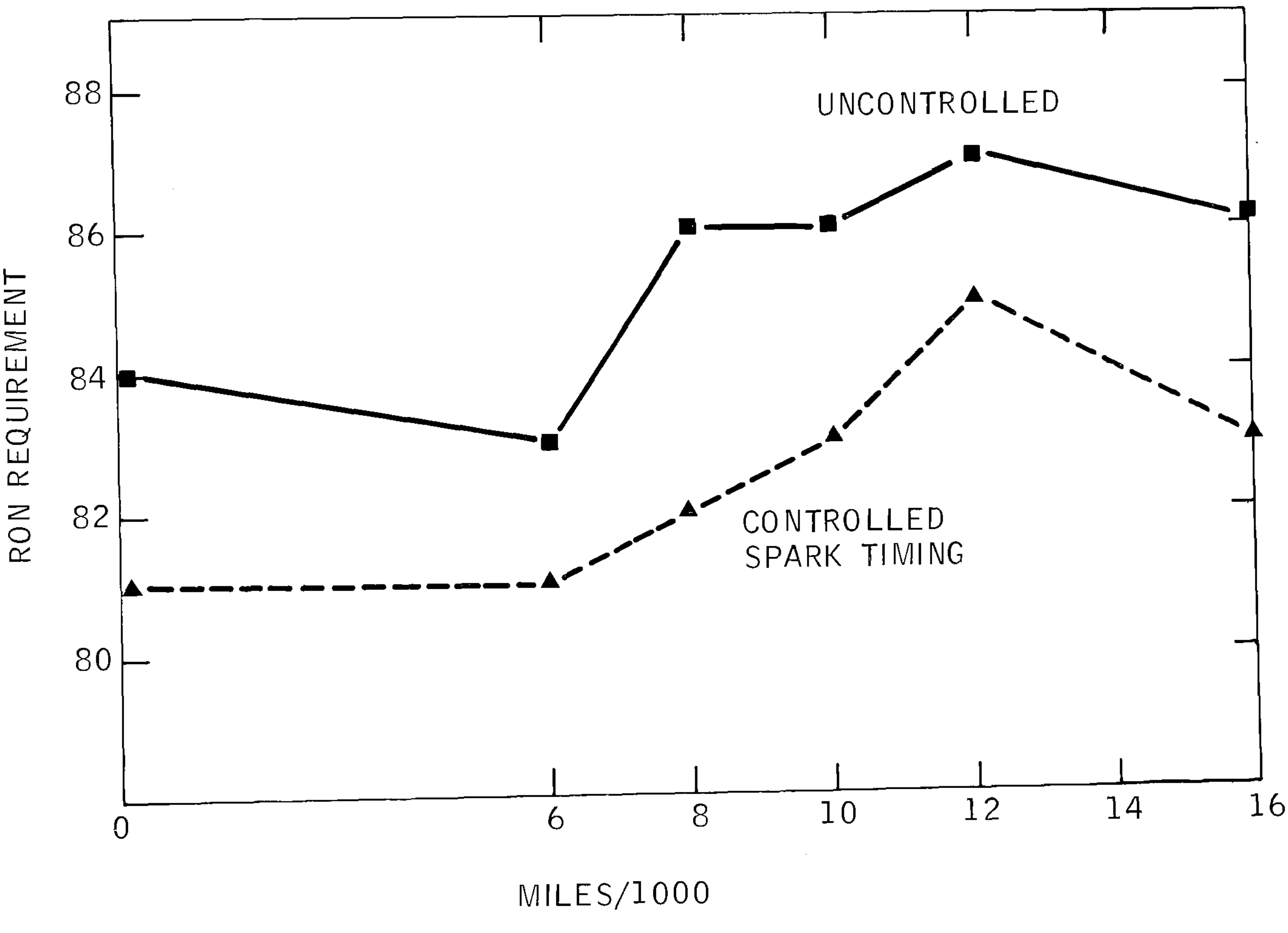


FIGURE 6-5

VEHICLE OCTANE REQUIREMENT WITH 8 SENSITIVITY (C) FUELS VS. ACCUMULATED MILEAGE FOR CONTROLLED AND UNCONTROLLED SPARK CASES; FOR CONTROLLED SPARK CASE, DELAY 1 AND 2 ARE 1,024 AND 32 ENGINE REVOLUTIONS RESPECTIVELY FOR THE FIRST 12,000 MILES AND ARE 128 AND 32 ENGINE REVOLUTIONS FOR THE LAST 4,000 MILES



The vehicle was also octane rated at the test track after the 12,000 mile accumulation. These octane requirement data are given in Table 6-9 for all three series of reference fuels. The 12,000 mile MAD data are also included for comparison. Approximately, a two number reduction in octane requirement was obtained with the controller operational, using long spark advance delay times.

At this time, it was noted that the accelerometer, located on the driver side head (rear) had lost some sensitivity. A new sensor was located on the passenger side head (rear). When the testing was repeated on the MAD with the new accelerometer, using the long countdown delays (1,024 and 32 engine revolutions respectively for initial and subsequent delays in spark advance), a three number benefit was observed (see Table 6-9). However, it was found that the threshold could be lowered for greater sensitivity to knock and shorter delays used (128 and 32 engine revolutions) which resulted in a two number octane reduction and considerably better acceleration performance of the vehicle.

During the last 4,000 miles on the AMA durability cycle, the shorter delay times and lower threshold were used since this seemed to give the best overall results (i.e., reduction of knock intensity and acceleration performance of vehicle). The octane requirement data at 16,000 miles is given in Table 6-10. Again a one to three octane number benefit can be attributed to the controlled spark case when the initial knocks are ignored. However, in this case of short delay times and low threshold, the knock intensity heard after the initial clatter can be controlled to the T to $T^+$ level even as low as 78 RON with acceptable acceleration performance.

The vehicle was octane rated on the MAD with three commercial unleaded fuels. All had greater octane quality than 92 RON. Since the vehicle requirement was so low, no knock was obtained for all three commercial fuels and, therefore, no spark retard was observed.

In Figure 6-6, the vehicle acceleration time on the MAD during 40-70 mph WOT accelerations is plotted against the research octane number of the fuel. Curves are shown for three cases: 1) uncontrolled spark timing, 2) controlled spark timing - 120 mV threshold-long countdown delays, and 3) controlled spark timing - 100 mV threshold-shorter countdown delay. No decrease in acceleration performance is seen with decreases in fuel octane for the uncontrolled case. For the controlled case with long countdown spark advance delays, a significant performance debit is seen, which is consistent with the road data shown in Figure 6-4. At 78 RON, 30% slower 40-70 mph acceleration times are observed. With this fuel, a trace plus to very light initial burst of knock causes a 5.5° retard followed by trace knock to a full 10° retard, eliminating the detonation but producing very long acceleration times. Another case of controlled spark timing with shorter countdown delays was run with a lower threshold (100 mV). With these settings, the same 78 RON fuel gives trace plus initial knock retarding to 7° and then intermittent trace knock as the spark timing continuously advances and retards in response to the accelerometer signal. With the 78 RON fuel, 7 numbers below the vehicle's no knock requirement, the level of knock can be

Table 6-9 Research Octane Requirement of 9:1 C.R. Vehicle After 12,000 Miles

| Place | Location of Sensor* | Reference Fuel | Uncontrolled Spark | Controlled Spark | Threshold (mV) | Spark Advance Delay (Engine Revolutions) | |
|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 2 |
| MAD | Driver Side | Primary | 84 | 82 | 120 | 1024 | 32 |
| | | C | 87 | 85 | | | |
| | | CX | 86 | 84 | | | |
| Road | Driver Side | Primary | 81 | 79 | 120 | 1024 | 32 |
| | | C | 81 | 80 | | | |
| | | CX | 84 | 82 | | | |
| MAD | Passenger Side | C | 83 | 80 | 120 | 1024 | 32 |
| MAD | Passenger Side | C | 83 | 81 | 100 | 128 | 32 |

* Sensor located on rear of head with axis parallel to crankshaft.

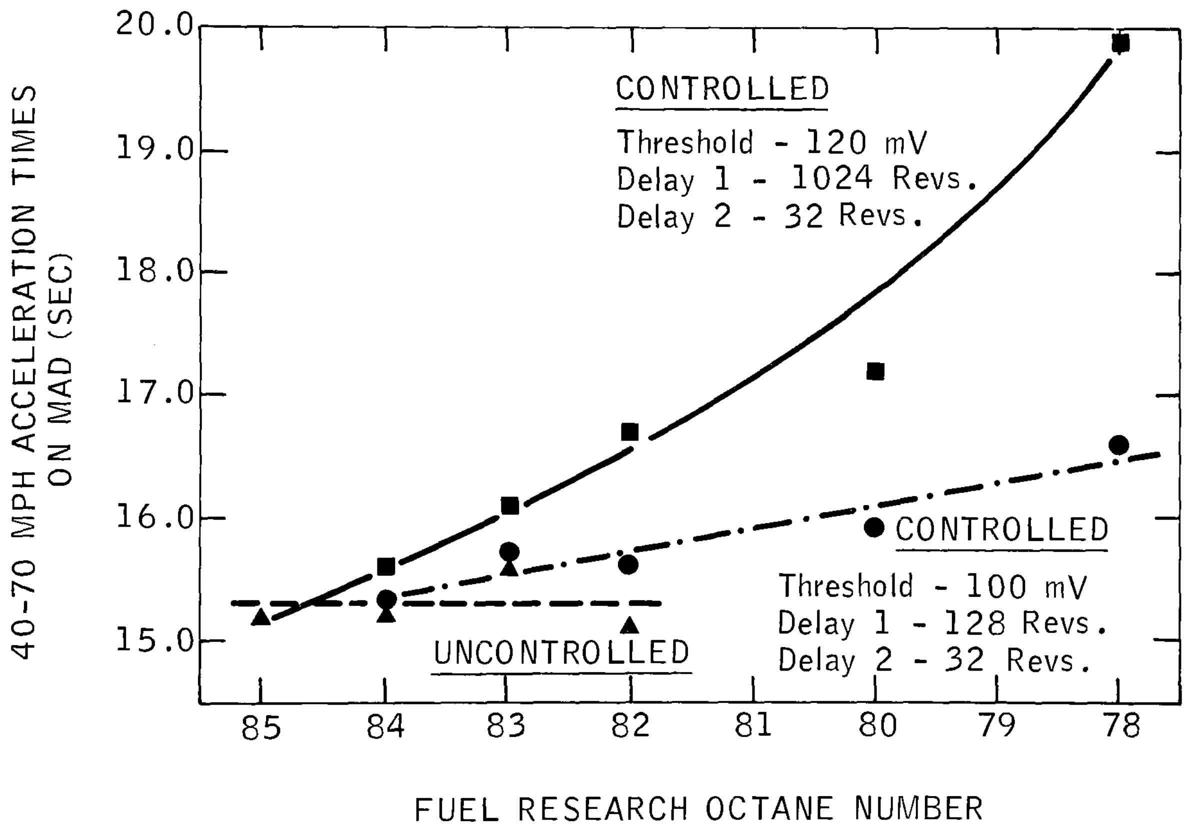
Table 6-10 Research Octane Requirement of 9:1 C.R. Vehicle After 4,000 AMA Durability Cycle*

| | Reference Fuel | Uncontrolled Spark | Controlled Spark |
|---|---|---|---|
| MAD | C | 86 | 83 |
| | P | 82 | 81 |
| Road | C | 83 | 82 |
| | P | 83 | 82 |
| | CX | 85 | ∿82 |

* Spark Advance Delays of 128 and 32 engine revolutions, threshold - 100 mV.

FIGURE 6-6

ACCELERATION PERFORMANCE (40-70 MPH) VS. RESEARCH OCTANE NUMBER AFTER 12,000 MILES USING 8 SENSITIVITY (C) FUELS FOR UNCONTROLLED CASE, AND CONTROLLED CASES WITH SHORT AND LONG SPARK ADVANCE DELAYS



held to trace with only a 9-10% performance debit. Road tests also showed approximately a 10% performance debit with controlled spark and very low octane fuels (see Appendix C).

The 1/4 mile and 0-60 mph acceleration times, on the road after the 12,000 mile accumulation using the longer delay times and after 16,000 miles using the shorter delay times and lower threshold setting, are given in Table 6-11. These data indicate that the vehicle is not significantly affected by spark retard on these types of accelerations, as was seen previously before mileage accumulation, although the overall acceleration performance even with no spark control deteriorated (compare with Table 6-7).

Emissions and Fuel Economy - Emissions and fuel economy were measured in duplicate at 6,000, 8,000, and 10,000 miles and in triplicate at 0 and 12,000 and 16,000 miles. The averages of these data are plotted in Figure 6-7 for emissions and Figure 6-8 for fuel economy. Due to the piston and head changes and mileage accumulated during break-in and testing, the catalyst was used for approximately 7,000 miles at the start of the "zero" mile testing.

The zero mile testing was done with uncontrolled spark timing. All subsequent testing was with the controller with spark advance delays set for 1,024 and 32 engine revolutions for the first and subsequent steps respectively. During this phase a total of 9 FTP-HFET sets were run with only 2 total retards occurring. Both of these occurred during the 57 mph cruise portion of HFET cycle. Since Indolene fuel (~98 RON) was used for these tests, it can be assumed that no knock was present. Thus, these 2 retards are from some other source, i.e., extraneous electrical or other engine noises.

At 8,000 miles, the idle CO was leaned somewhat and the carburetor was cleaned. This may account for the reduced CO emissions levels shown in Figure 6-7. At 12,000 miles, new plugs were installed due to oil fouling. Oil consumption over the 16,000 miles averaged 0.9 quarts/1,000 miles. Except for the deviations in CO at 6,000 miles and HC at 10,000 miles (subsequently corrected by the new spark plugs), the vehicle emissions remained below the California standards of 9.0 g CO/mile, 0.9 g HC/mile, and 2.0 g $NO_x$/mile through the 16,000 miles accumulated.

Referring to Figure 6-8, the fuel economy improved on both cycles after the carburetor cleaning and idle CO leaning prior to 8,000 mile testing. When the spark plugs were replaced prior to the 12,000 mile testing, the fuel economy improved, especially on the FTP. These final 16,000 mile fuel economies show a 4% combined fuel economy benefit over the base 8:1 C.R. unmodified vehicle with no deposits accumulated.

<u>Comparison of Mileage Accumulation Results with Those From 8:1 C.R. Vehicle</u> - A comparison of the final MAD octane requirement, emissions levels and fuel economies is given in Table 6-12 for the 8:1 and 9:1 C.R. vehicles. The 8:1 C.R. vehicle had a 12 number octane requirement increase (ORI) during mileage accumulation resulting in a 91 RON requirement. In contrast, the 9:1 C.R. modified vehicle finished at 86 RON with only a 2 number ORI. The requirement with the knock sensor operational was 83 RON. This is quite a low requirement especially

Table 6-11 Acceleration Times on Road with Controlled Spark

| Accumulated Miles | Fuel | Quarter Mile | | | 0-60 mph | | | Delay (Engine Revs.) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Retard | Rating | Time | Retard | Rating | Time | 1 | 2 |
| 12,000 | CX 84 (Knocking) | 5.5° | T+ | 18.6 | 5.5° | T+ | 12.0 | 1024 | 32 |
| | CX 100 (No Knock) | 0° | NK | 18.6 | 0° | NK | 11.8 | | |
| 16,000 | CX 84 (Knocking) | 7° | T+ | 18.3 | 7° | T+-VL | 11.8 | 128 | 32 |
| | CX 100 (No Knock) | 0° | NK | 18.4 | 0° | NK | 11.5 | | |

FIGURE 6-7

FTP EMISSIONS VS. ACCUMULATED MILEAGE

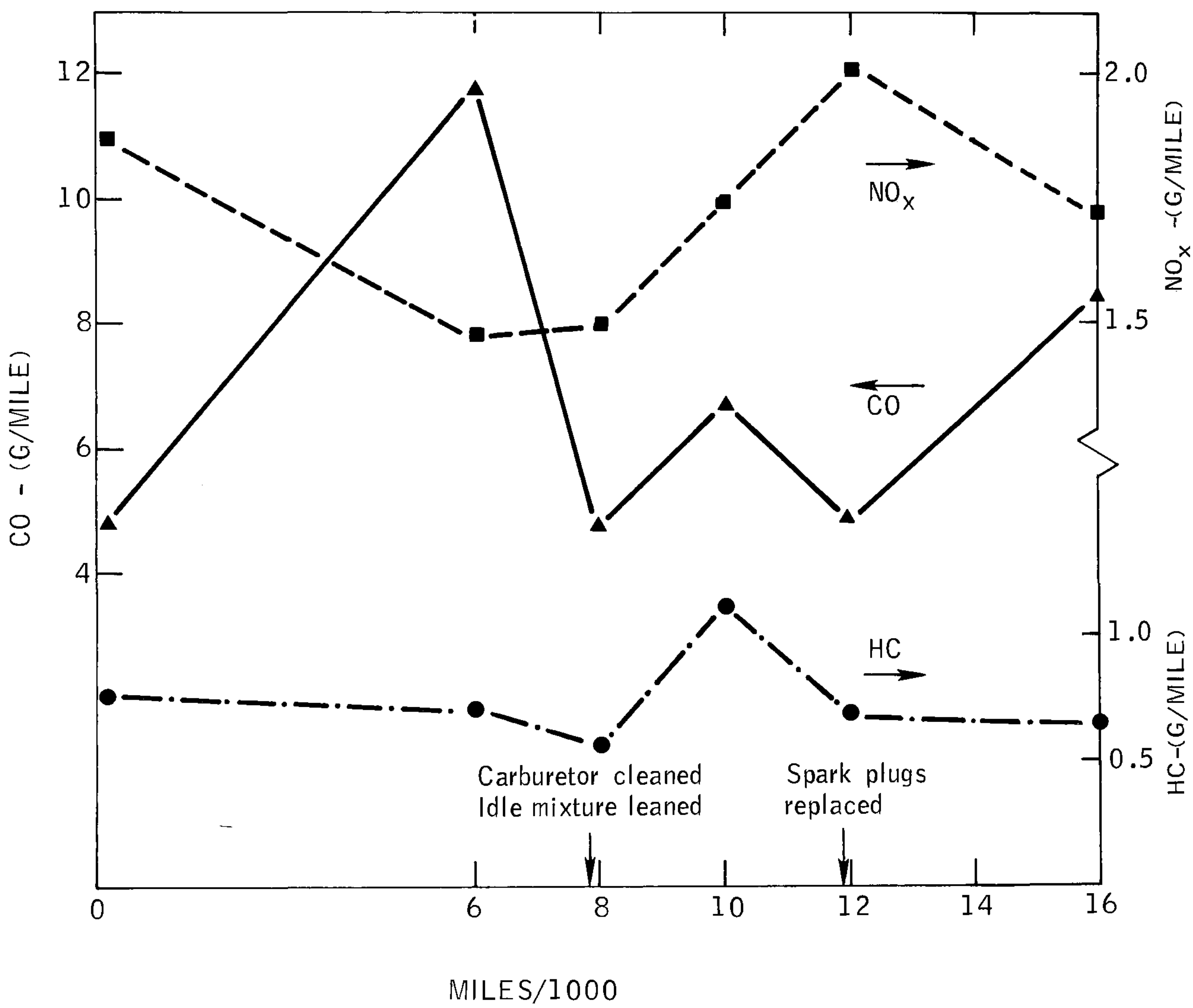
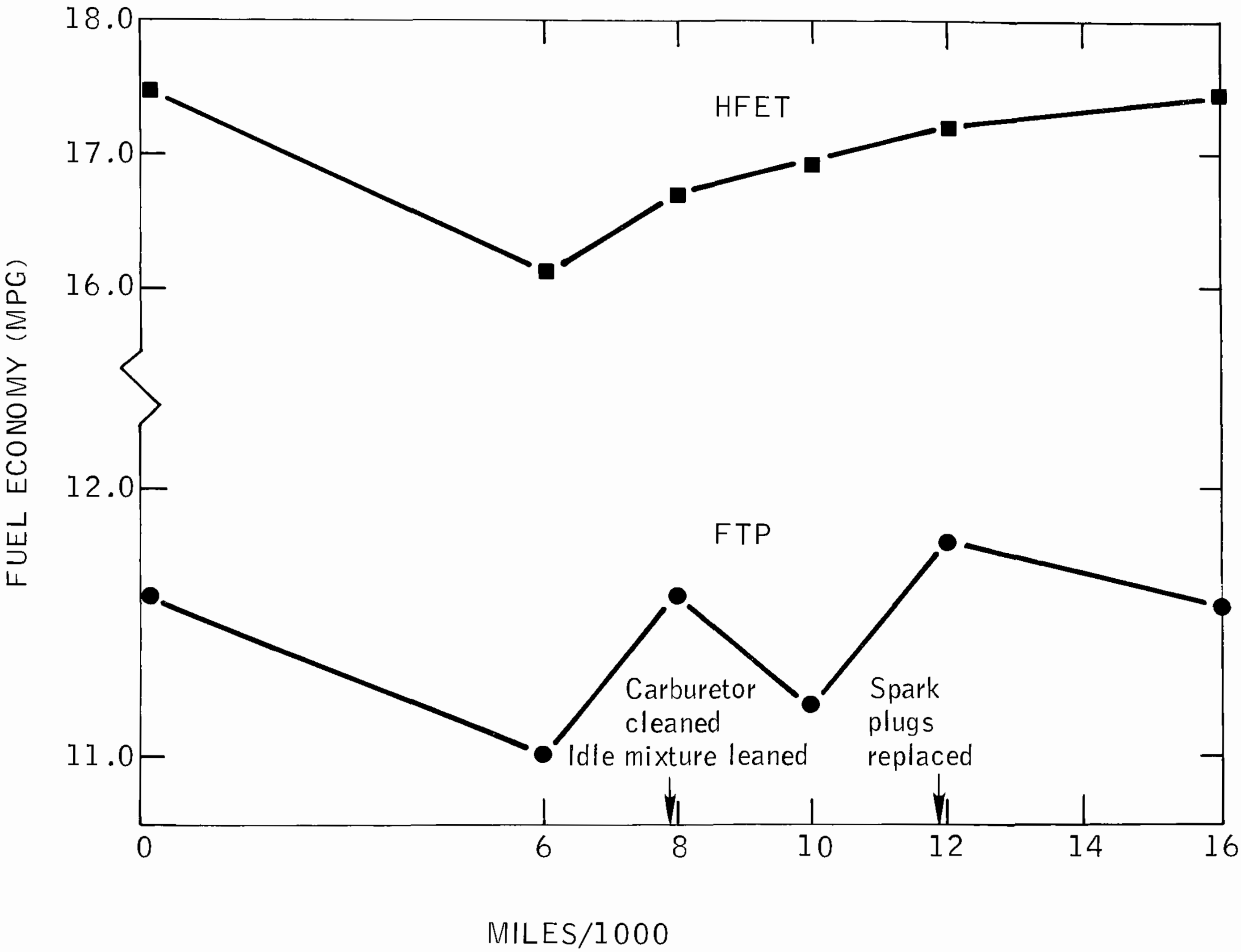


FIGURE 6-8

FTP AND HFET FUEL ECONOMY VS. ACCUMULATED MILEAGE



for a 9:1 C.R. vehicle. The primary factor is the low ORI. ORI can vary considerably from engine to engine even within one engine type, so this result is not surprising. Fuel composition also affects ORI. However, the fuels used for these two sets of mileage accumulations were blended as identically as possible and should not be a factor. The low requirement appears to be characteristic of this particular vehicle.

The emissions data show that the base 8:1 C.R. vehicle failed the 2.0 g/mile $NO_x$ standard after mileage accumulation while the modified 9:1 C.R. vehicle passed. The 9:1 C.R. fuel economy values are lower on the FTP cycle and higher on the HFET cycle than the 8:1 C.R. data. When weighed to get the city/highway composite fuel economy, the two cases are virtually identical.

It needs to be pointed out, however, that the two engines compared here are quite different due to the drastic changes that occurred during the course of the program. The 9:1 C.R. case represents an engine which has different pistons and rings than the 8:1 C.R. engine. Furthermore, the carburetor was rebuilt several times. Thus, although the values listed in Table 6-12 accurately represent the final vehicle conditions at 8:1 and 9:1 C.R., the comparison between the two leaves much to be desired.

EMISSION AND FUEL ECONOMY TESTING WITH LOW OCTANE FUEL - Tests were run to determine whether or not a fuel which knocked during WOT octane ratings and produced spark retard would also cause retard on the FTP and HFET driving cycles and thereby cause significant changes in emissions or fuel economy. A fuel was chosen which gave trace level knock during 40-70 mph WOT accelerations on the MAD. The emissions and fuel economy data are tabulated in Table 6-13 for three cases: 1) Indolene fuel-long delay times, 2) C-82 (see Appendix C) fuel-long delay times, and 3) C-82 fuel-shorter delay times. No retards were observed on any of these emissions tests due to the mild acceleration conditions. In another test, where the ignition timing was advanced by 6° (12° BTC basic timing) and a 86 RON fuel was used (4 octane numbers below the no knock requirement), no retards were observed. This indicates that fuels two and four numbers below the vehicle's no knock requirement can be operated satisfactorily most of the time with occasional performance debits on severe accelerations.

OPTIMIZATION OF SYSTEM BY ADVANCING SPARK TIMING - Additional fuel economy benefit might be extracted by advancing the timing closer to MBT timing. Since an MBT distributor could not be obtained for the vehicle, the spark timing was advanced by 6° to 12° BTC basic timing to ascertain if additional fuel economy benefit was attainable without upsetting the emissions and octane requirement. The results of this testing are compared to the data obtained after the 4,000 AMA cycle in Table 6-14. The octane requirement increased by 3-4 numbers, and the $NO_x$ emissions increased by 30%. The additional fuel economy benefit measured was 8% on the FTP cycle and 2% on the HFET cycle. However, the vehicle failed the $NO_x$ standard.

Table 6-12 Comparison of Deposit - Accumulated 8:1 and 9:1 C.R. Engines

| Vehicle | Octane Req. | ORI | Emissions | | | Fuel Economy | |
|---|---|---|---|---|---|---|---|
| | | | CO | HC | $NO_x$ | CVS-CH | HFET |
| 8:1 @ 13,000 miles | 91 | 12 | 4.7 | 0.5 | 2.3 | 12.2 | 16.2 |
| 9:1 @ 16,000 miles | 86(83)* | 2 | 8.4 | 0.7 | 1.7 | 11.6 | 17.4 |

---

* Knock Sensor - Spark Retard System operational.

Table 6-13 Emissions and Fuel Economy Measurements of 9:1 C.R. Vehicles Using Low Octane Fuel (C-82)(1) After 12,000 Miles

| Fuel | Delay (Engine Revolutions) 1 | Delay (Engine Revolutions) 2 | Threshold (mV) | FTP Emissions (g/mile) CO | FTP Emissions (g/mile) HC | FTP Emissions (g/mile) $NO_x$ | Fuel Economy (mpg) FTP | Fuel Economy (mpg) FET | Fuel Economy (mpg) Combined(2) |
|---|---|---|---|---|---|---|---|---|---|
| Indolene | 1024 | 32 | 120 | 4.9 | 0.7 | 2.0 | 11.8 | 17.2 | 13.7 |
| C-82 RON | 1024 | 32 | 120 | 5.3 | 0.5 | 1.9 | 11.3 | 16.8 | 13.2 |
| C-82 RON | 128 | 32 | 100 | 5.2 | 0.6 | 1.8 | 11.7 | 17.3 | 13.7 |

---

(1) Gives trace knock on WOT 40-70 mph accelerations.

(2) Calculated from $1/(0.55/mpg_{FTP} + 0.45/mpg_{HFET})$

Table 6-14 Comparison of Octane Requirement, Emissions and Fuel Economy for 12° BTC vs. 6° BTC Spark Timing

| Basic Timing | Octane Requirement (C) | | Emissions (g/mile) | | | Fuel Economy (mpg) | |
|---|---|---|---|---|---|---|---|
| | Uncontrolled | Controlled Spark | CO | HC | $NO_x$ | CVS-CH | HFET |
| 12° BTC | 89 | 87 | 8.2 | 0.8 | 2.5 | 12.5 | 17.8 |
| 6° BTC | 86 | 83 | 8.4 | 0.7 | 1.7 | 11.6 | 17.4 |

PROBLEMS ENCOUNTERED WITH SYSTEM - During the course of this work, several problems arose with the application of knock sensor-spark retard technology. These are discussed below to provide guidance for future work in this area.

Performance Debits - There are significant acceleration performance debits associated with using spark retard to eliminate most of the knock for several octane numbers below the engine's normal requirement. When long spark advance delay times were employed to realize a large reduction in total detonation heard, 10-30% slower acceleration times were obtained. However, limited testing indicates that if slightly higher levels of detonation are allowed, much lower performance debits are possible (on the order of 0-10% depending on how much detonation is permitted). This can be accomplished by raising the threshold so that the system is less sensitive to detonation, by decreasing the waiting period before advancing the spark schedule or by some combination of the two. Another technique to improve overall performance would be to sense the end of an acceleration, with an additional engine input, after which normal spark advance would be used. For example, use of a manifold vacuum or throttle position indicator would provide a signal whereby the end of an acceleration is well characterized, i.e., high manifold vacuum or closed throttle. This signal could be used to override the spark control system to immediately cut out any applied spark retard under conditions similar to these, thereby reducing excessively long periods of applied retard even though a long spark advance delay is used.

Spurious Retard - Occasionally, spurious retards were noted during the course of this work. Some of these were well defined extraneous electrical interference which could be corrected, such as moving any unnecessary AC-operated electronics out of the car, using DC-power for the controller itself, and removing tachometer leads from car. Others were ignored because they were not considered to be serious uncorrectable problems in a commercial unit, e.g., spark retards when cranking starter motor to start the engine. A more serious problem, which manifested itself just prior to replacing the cylinder heads with recessed valves, was that real engine noises other than knock could trigger the spark retard system occasionally. These retards were traced by listening to tape recordings slowed down to 1/16 of normal speed. In these recordings, knock is very apparent as a ringing drum-like sound and valve noises can be distinguished from it. A peculiar valve noise, which had some ringing character to it, occasionally produced a retard. These spurious retards could be eliminated by raising the threshold at the expense of lower sensitivity to knock. Since the heads were replaced, however, no retards of this type have been noted.

Surface Ignition - The accumulation of ashy oil-based deposits (40-50% ash) in the combustion chamber caused a significant surface ignition problem during one phase of the study. In fact, when the heads were removed, a large ashy particle was removed from the cylinder which had been knocking. In this case, spark retard actually made the surface ignition much worse, presumably due to the increased generation of heat in the engine. This would probably not be a general problem since surface ignition is rare with unleaded fuel. In this case, the severe driving schedule, i.e., more WOT accelerations, may have produced the high ash deposit problem due to high oil consumption.

Engine Overheating - Although tests were not made, the potential exists for engine overheating with long periods of running with retarded timing. This could occur either by a malfunction of the spark control system or by the use of a fuel of much lower octane quality than the engine's requirement. For this reason (and also for putting a limit on acceleration performance losses), only 10° maximum retard is allowed. This potential problem could probably be eliminated by using a coolant temperature sensor to override the spark retard system if high coolant temperatures occur.

## 6.3 DRIVEABILITY AND EVAPORATIVE EMISSION TESTING

EVAPORATIVE EMISSIONS - After the vehicle was modified to change the compression ratio to 9:1 and the tailpipe emissions were recalibrated to the base case level, evaporative emissions were measured in the SHED test. The data compiled in Table 6-15 are the averages of 3 tests and can be compared to that measured on the base vehicle. The diurnal emissions are approximately the same as that measured in the base case. However, the hot soak data are about 6 grams lower. The vehicle probably had a leak source which was corrected during the modifications to the vehicle to give the lower numbers.

Table 6-15 Evaporative Emissions of 1975 Chevrolet Nova (9:1 C.R.)

| Grams | | |
|---|---|---|
| Diurnal Cycle | Hot Soak | Total |
| 1.4 | 3.0 | 4.4 |

DRIVEABILITY TESTING - Driveability testing was conducted on the 9:1 C.R. modified vehicle prior to the start of and at the completion of the 16,000 mile accumulation. These tests, which were done with the knock sensor-spark retard system operational, can be compared to those conducted prior to vehicle modification to see if any change in driveability had occurred. The test procedure and detailed data sheets are given in Appendix D. A summary of the results is given in Table 6-16 for the four specially blended driveability test fuels. The vehicle exhibited good driveability overall. Prior to mileage accumulation, the vehicle had some cold starting problems with Fuels D-2 and D-3. These cold starting problems were not as evident after the 16,000 mile accumulation during which time the carburetor was rebuilt.

Table 6-16 Summary of Driveability Test Results for 9:1 C.R. Modified Vehicle

| | Fuel | Cold Start | | Warm Vehicle | |
|---|---|---|---|---|---|
| | | Stalls | Retards | Stalls | Retards |
| Prior to 16,000 Mile Accumulation | D-1 | 0 | 0 | 0 | 0 |
| | D-2 | Hard Start | 0 | 0 | 0 |
| | D-3 | 6 | 0 | 0 | 0 |
| | D-4 | 0 | 1(10°) | 0 | 1(WOT) |
| After 16,000 Mile Accumulation | D-1 | 1 | 0 | 0 | 0 |
| | D-2 | 0 | 0 | 0 | 1(WOT) |
| | D-3 | 1 | 0 | 0 | 0 |
| | D-4 | 0 | 0 | 0 | 0 |

On only a single occasion a 10° retard was recorded during a period of poor cold driveability (i.e., stumbling and surging). It is assumed that the retards were in response to the poor vehicle driveability, since driveability problems have not been encountered due to the operation of the knock sensor in any of the vehicle octane ratings. On two occasions, a retard was noted on a wide open throttle acceleration after the vehicle was warmed up. This could be due to some engine combustion noise or knock. In general, though, little response was observed from the knock sensor actuated-spark retard system during these tests.

## SECTION 7

## KNOCK FREQUENCY ANALYSIS OF ALTERNATE ENGINES

A study was undertaken to examine knock frequency characteristics of other engines to determine whether the 5-5.5 kHz band was unique to the 350 CID engine. An attempt was made to obtain two engines which were very different than the 350 CID V-8 engine used in the program. The 2.3 liter 4-cylinder engine used in the Ford Pinto and the 2.8 liter V-6 engine used in the Ford Mustang-II were selected. A comparison of engine displacement, bore, and stroke is given in Table 7-1.

Table 7-1 Comparison Between 350 V-8 and 2.3 L and 2.8 L Engines

| Engine | Displacement $in^3$ | Displacement L | Bore | Stroke |
|---|---|---|---|---|
| Chevrolet V-8 | 350 | 5.7 | 4.0 | 3.5 |
| Ford L-4 | 140 | 2.3 | 3.8 | 3.1 |
| Ford V-6 | 171 | 2.8 | 3.66 | 2.7 |

It can be seen from the table that the engines are considerably different in design not just in total displacement. The standard straight 4 cylinder, V-6 and V-8 engines are represented by this group. In addition, the bore and strokes are different and thus individual cylinder dimensions are quite different. If significant changes in the frequency of knock were to be observed by changing the engine geometry, one would expect to see it with a comparison between these three engines.

These engines were obtained from Ford Motor Company through EPA. Each engine was individually mounted in the engine dynamometer test stand with the associated automatic transmission. Photographs of these engines are shown in Figure 7-1. The cycle follower was programmed according to road load information that was available for each engine. Six accelerations were then mounted on the engine and after an initial 2-3 hour break-in period testing began. The testing, as in the case of the 350 CID engine, included steady state, fuel changeover, and acceleration runs to examine the knock frequency under a variety of different engine operating modes.

FIGURE 7-1

PHOTOGRAPHS OF ENGINE DYNAMOMETER
INSTALLATIONS OF 2.3 L AND 2.8 L ENGINES

2.3 Liter
L-4 Engine
(Pinto)

2.8 Liter
V-6 Engine
(Mustang-II)

## 7.1 FORD 2.3 LITER L-4 PINTO ENGINE

A 1978 2.3 liter engine complete with accessories and automatic transmission was mounted in the engine dynamometer stand after removing the air conditioning unit and power steering pump. A load curve as shown in Table 7-2 was programmed into the cycle follower.

Table 7-2 Load Curve Used for 2.3 L and 2.8 L Engines on Dynamometer Stand

| Vehicle Speed (mph) | Road Horsepower |
|---|---|
| 20 | 0 |
| 30 | 7.8 |
| 40 | 9.8 |
| 50 | 13 |
| 60 | 18 |

The critical loading particular for acceleration testing is the inertia loading. The inertia was set to give acceleration times equivalent to those obtained on a 2.3 L Pinto test vehicle on the MAD. For a 30- to 60-mph acceleration in top gear, this was approximately 33 sec. The test vehicle was also measured to determine the engine rpm equivalent of road speed so that our testing in the engine cell could be correlated with vehicle speed. These data are shown in Table 7-3.

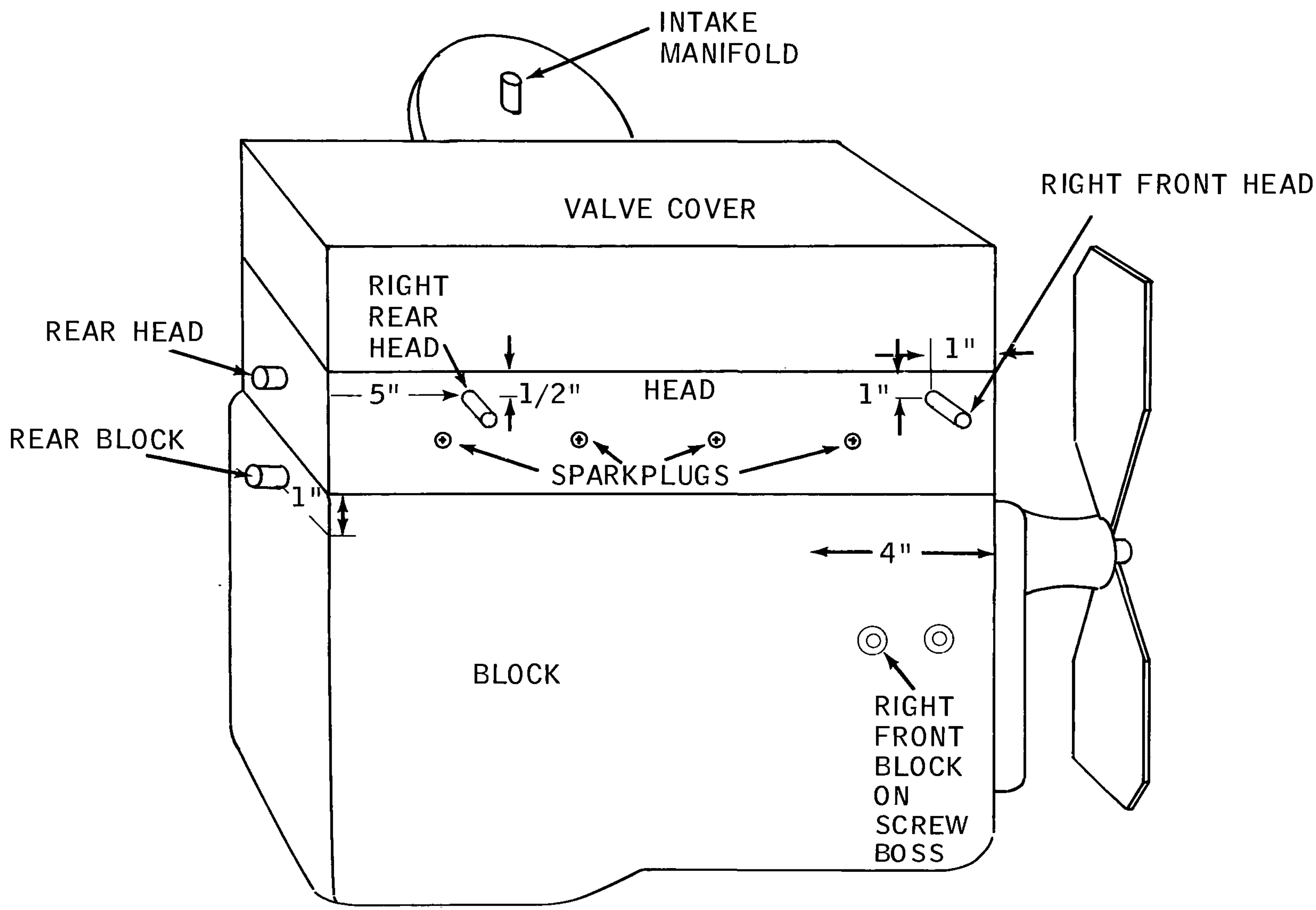
Table 7-3 Engine RPM Measured at Various Vehicle Speeds on Pinto

| | Engine, RPM | |
|---|---|---|
| MPH | Acceleration | Steady State |
| 30 | 1650 | 1650 |
| 35 | 2550 | |
| 40 | 2650 | 2100 |
| 45 | 2750 | |
| 50 | 2950 | 2650 |
| 55 | 3100 | |
| 60 | 3250 | 3200 |

A schematic showing the location of the six accelerometers tested on the 2.3 liter engine is given in Figure 7-2. Three accelerometers were located on the head, 2 on the block and 1 on the intake manifold. The output of these accelerometers was recorded on tape for specific operating conditions and representative segments of the recordings were frequency analyzed. For each of the test conditions shown below, recordings were made for a no-knock and a knocking fuel.

FIGURE 7-2

LOCATION OF ACCELEROMETERS ON
2.3 LITER 4 CYLINDER PINTO ENGINE (SIDE VIEW)



7-5

1. Acceleration Tests - engine was accelerated from 30 to 60 mph at WOT.

2. Steady State Tests were run at 30 and 40 mph (1600 and 2600 rpm).

3. Fuel Change Tests were run at 40 mph with the fuel changed from VL knock to NK back to VL knock.

A complete set of the frequency analyses from the tests is given in Appendix F. For brevity, only a summary of these results is given here. A set of frequency analyses is given in Figures 7-3 to 7-8.

Each figure is a frequency analysis of an individual accelerometer signal recorded at 2600 rpm (50 mph) steady state operation for a trace plus knocking fuel and a no-knock fuel. The set contains a frequency analysis of each accelerometer location under these conditions. The following conclusions can be drawn from the data.

1. Trace plus knock intensity produces 2 to 4 G peaks. Background no-knock gives 1 to 2 G peaks. Thus, the engine appears to have considerable background noise to begin with. This may be due to the specific engine design (i.e. the overhead cam engine is noisier than most).

2. The rear head accelerometers (both axial and transverse to the crankshaft) gave the largest knock signals and thus would appear to be the ones to use for knock detection.

3. The axial rear head signals contain peaks at 5.4, 9.4, 11.0, and 13.5 kHz whereas the transverse accelerometer only showed 5.4 and 10.0 kHz peaks. The same peaks occur to a lesser degree in the no-knock recordings. The ratios of peak intensities between the knocking and no-knock runs are given in Table 7-4 for the 50 mph steady state and 30-60 mph acceleration runs. These data suggest that in the right rear head (transverse) recordings, the 5.4 and 10.0 kHz peaks had greater signal/noise ratios than the corresponding 5.4 and 9.4 peaks in the rear head (axial) recordings. With no other basis to use, the accelerometer with the greater signal/noise ratio would be chosen as the optional location.

FIGURE 7-3

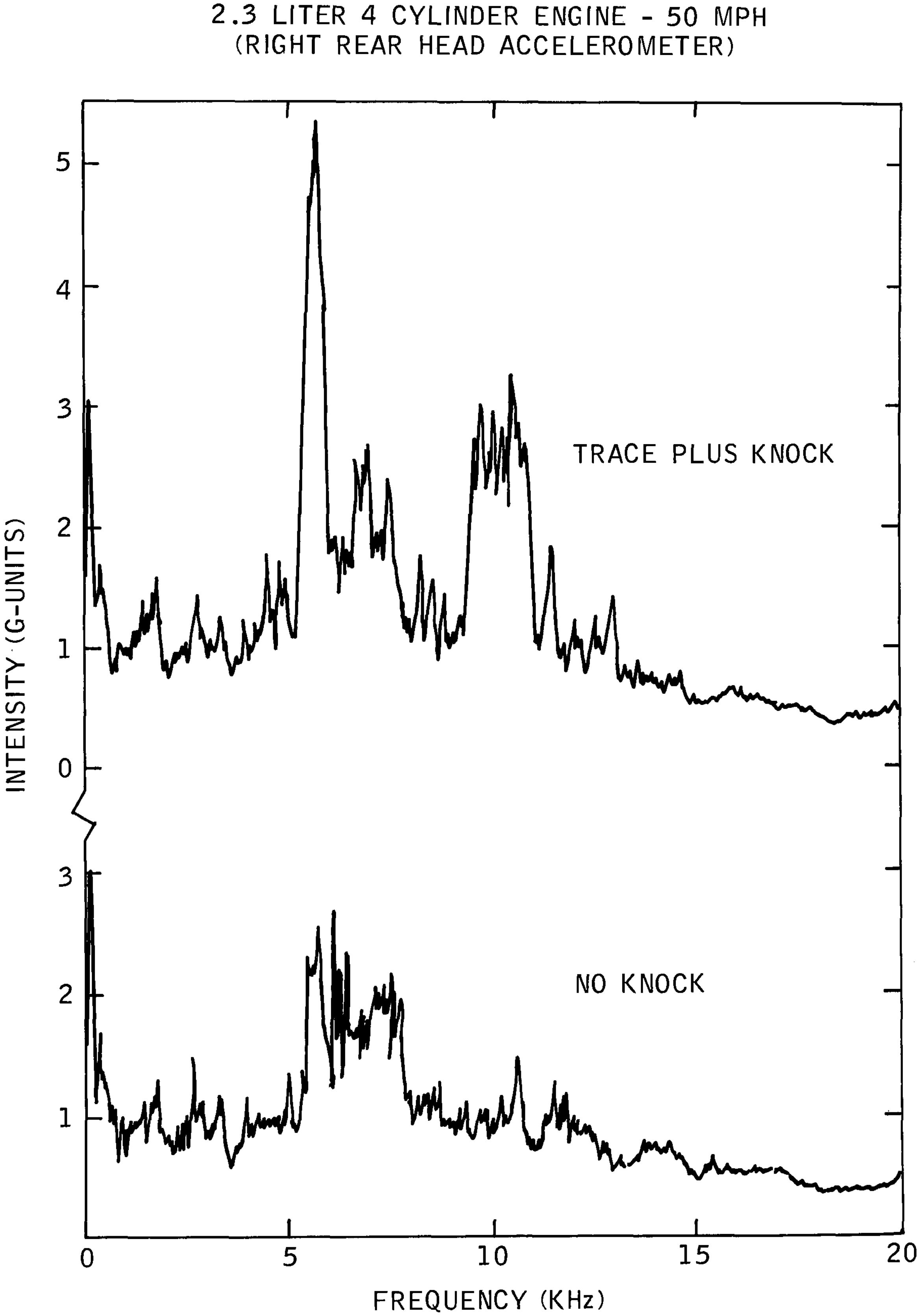

2.3 LITER 4 CYLINDER ENGINE - 50 MPH
(RIGHT REAR HEAD ACCELEROMETER)
TRACE PLUS KNOCK
NO KNOCK
INTENSITY (G-UNITS)
0
1
2
3
4
5
FREQUENCY (KHz)
10
15
20

FIGURE 7-4

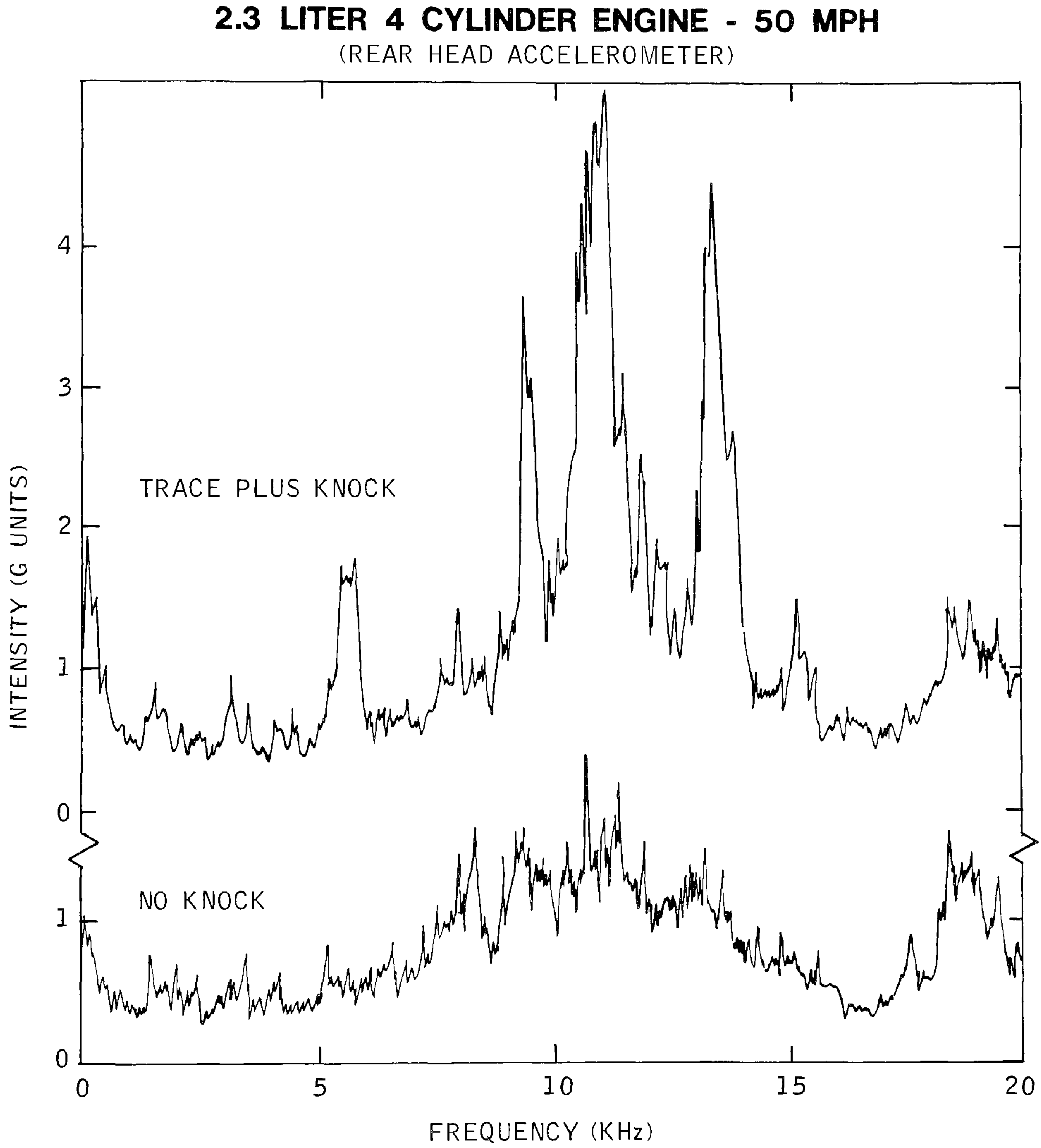

2.3 LITER 4 CYLINDER ENGINE - 50 MPH
(REAR HEAD ACCELEROMETER)
INTENSITY (G UNITS)
TRACE PLUS KNOCK
NO KNOCK
FREQUENCY (KHz)
0
1
2
3
4
0
1
0
5
10
15
20

FIGURE 7-5

2.3 LITER 4 CYLINDER ENGINE - 50 MPH
(REAR BLOCK ACCELEROMETER)

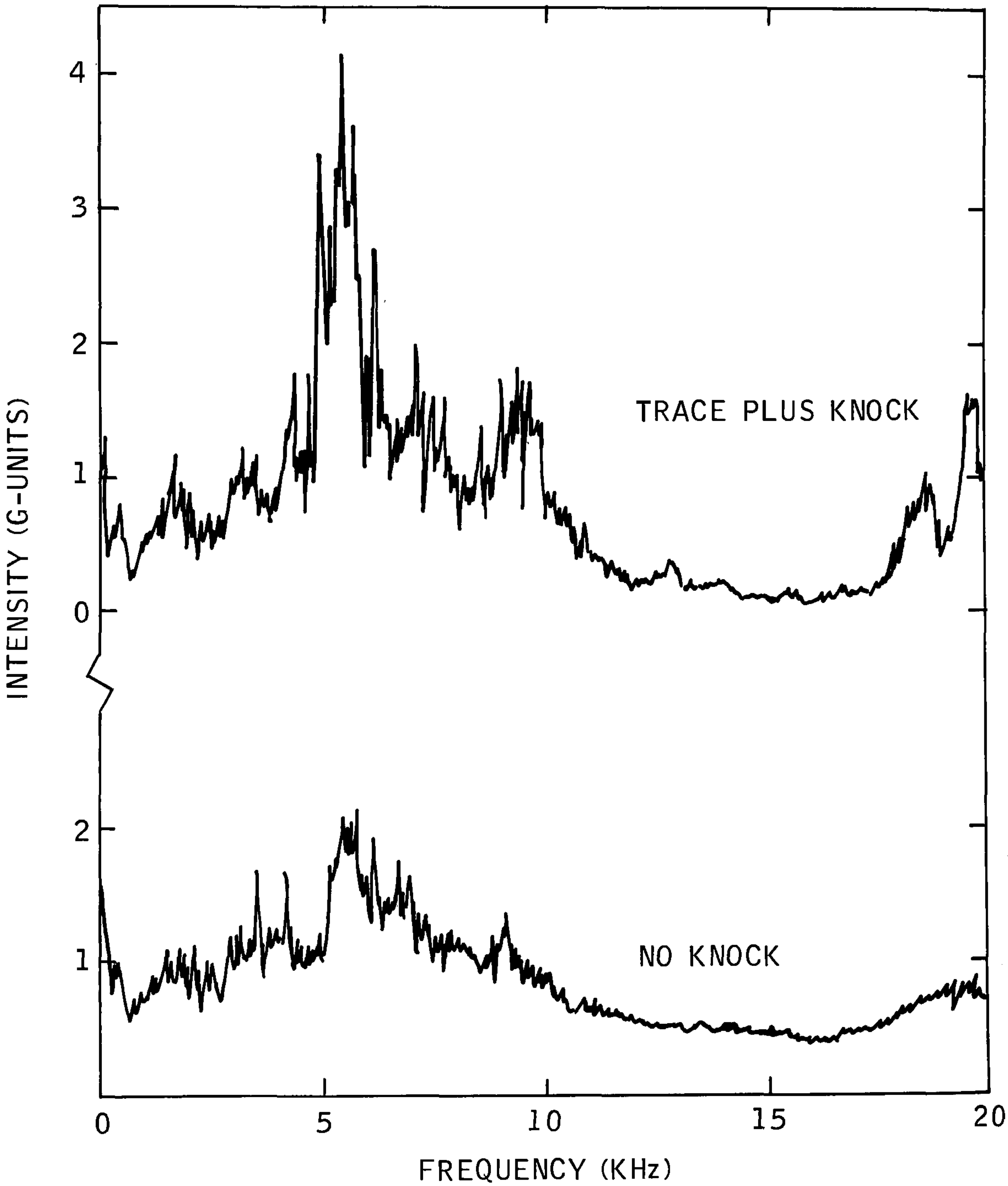


FIGURE 7-6

2.3 LITER 4 CYLINDER ENGINE 50 MPH
(INTAKE MANIFOLD ACCELEROMETER)

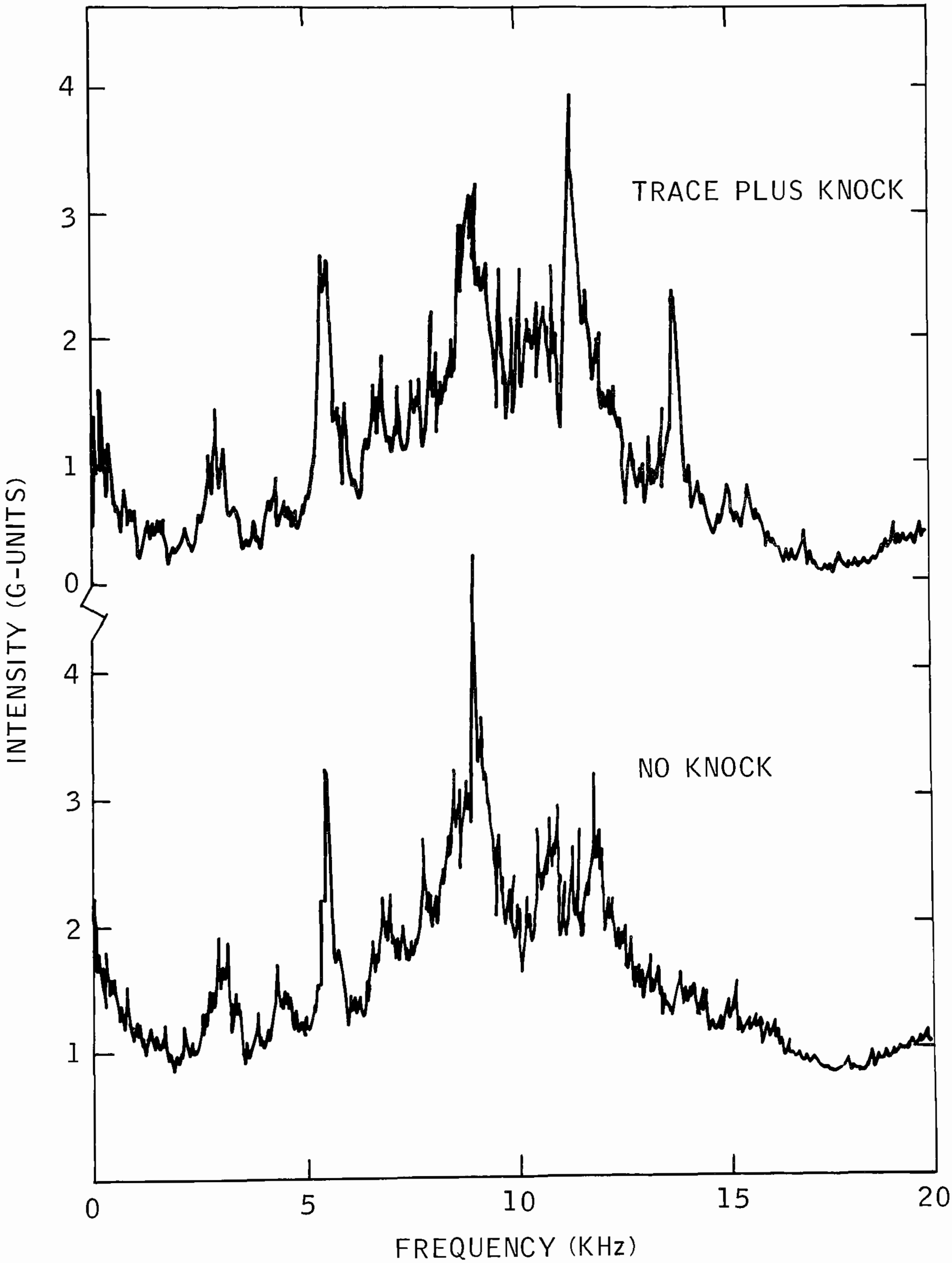


FIGURE 7-7

2.3 LITER 4 CYLINDER ENGINE - 50 MPH
(RIGHT FRONT HEAD ACCELEROMETER)

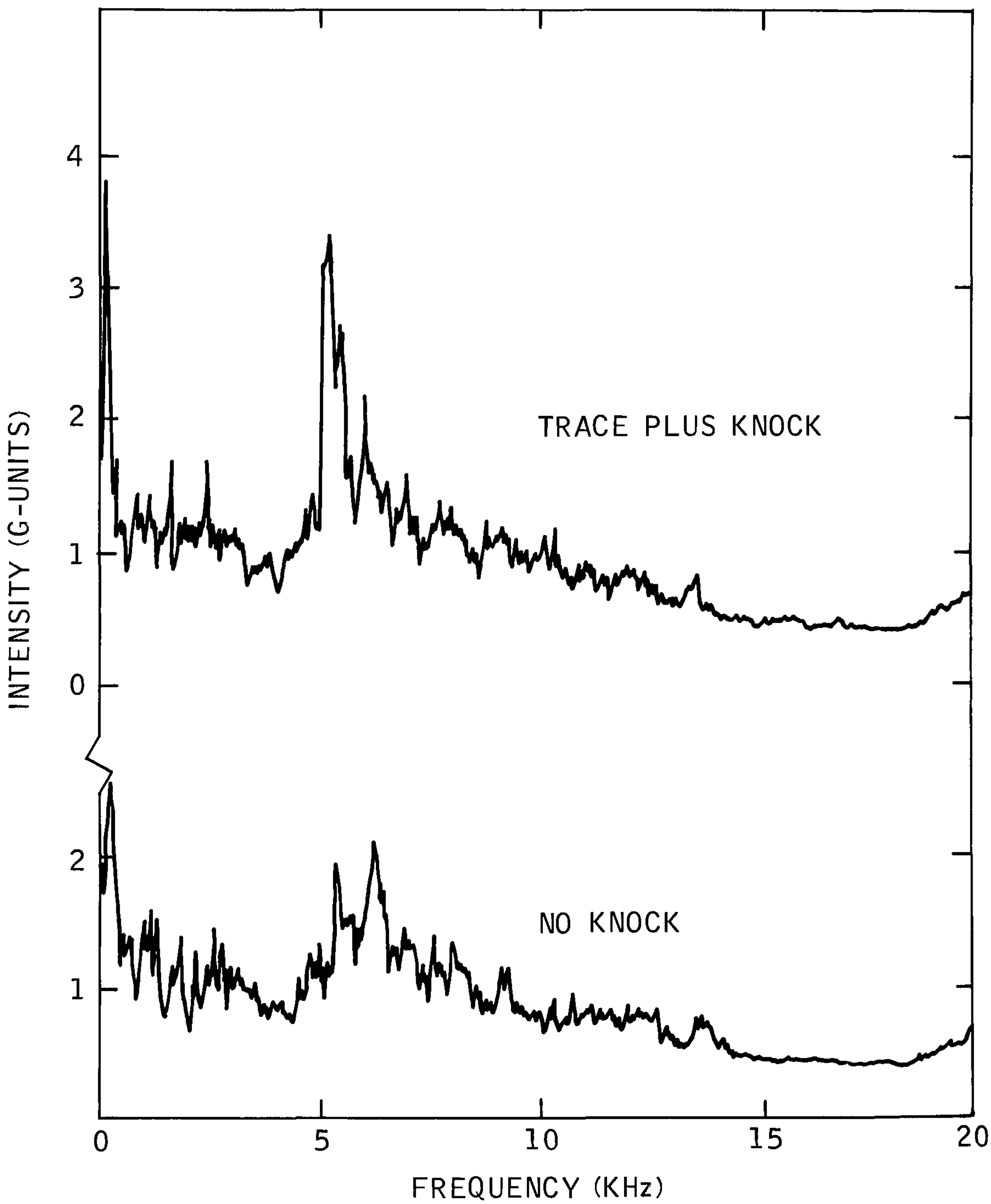


FIGURE 7-8

2.3 LITER 4 CYLINDER ENGINE - 50 MPH
(RIGHT FRONT BLOCK ACCELEROMETER)

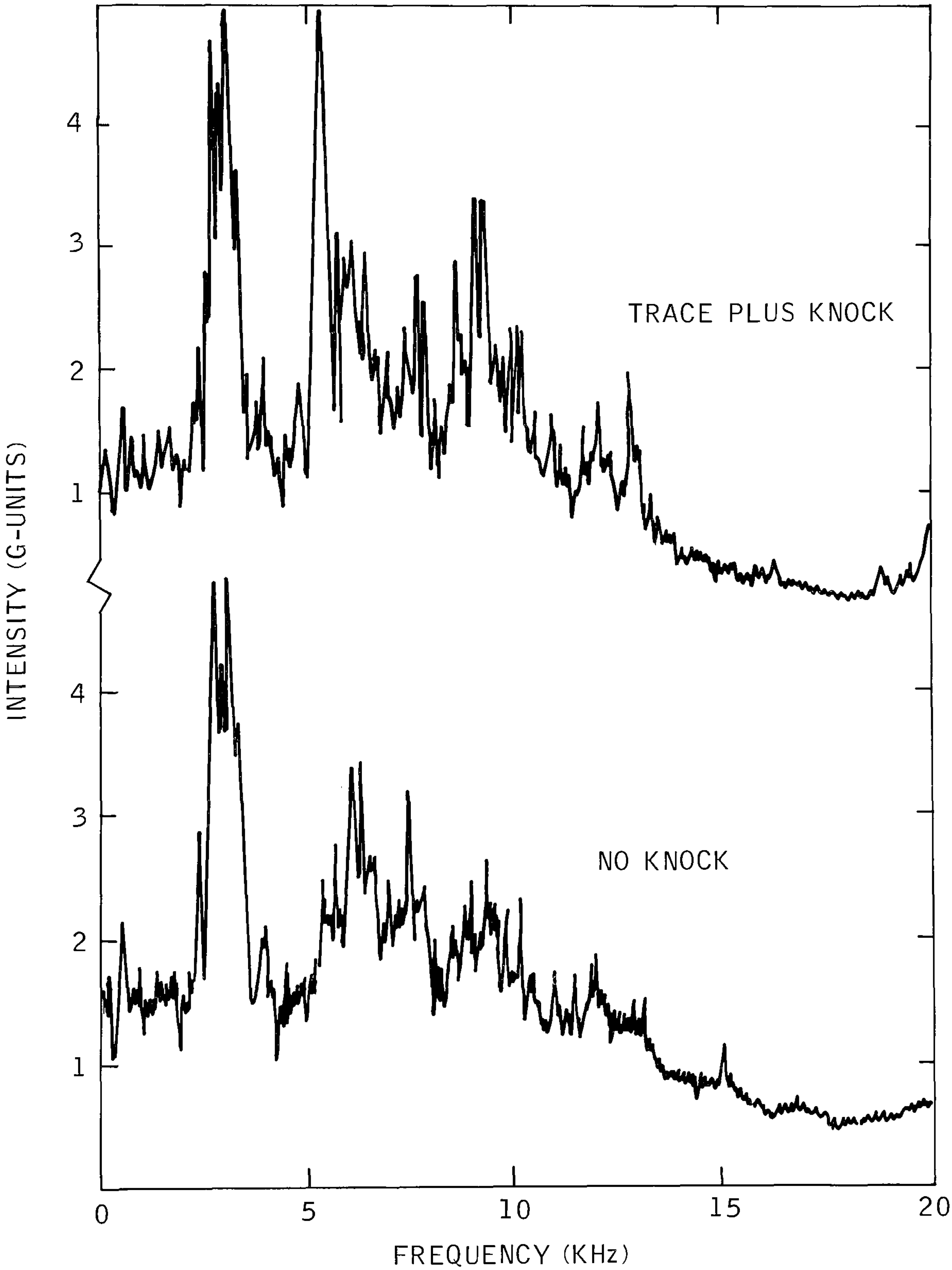


Table 7-4 Frequency and Intensity of the Accelerometer Signals for 2.3 Liter Engine

| | Position | Ratio of Knocking to No-Knock Signal Areas | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5.4 | 9.4 | 10.0 | 11.0 | 13.5 | kHz |
| Steady State 50 mph | Rear Head (axial) | 3.4 | 2.1 | -- | 2.5 | 4.0 | |
| | Right Rear Head (transverse) | 2.1 | -- | 3.9 | -- | -- | |
| 30-60 mph Accel. | Rear Head (axial) | 2.8 | 7.7 | -- | 4.6 | 5.0 | |
| | Right Rear Head (transverse) | 3.2 | -- | 10.3 | -- | -- | |

## 7.2 FORD 2.8 LITER V-6 MUSTANG-II ENGINE

A 2.8 liter V-6 engine was also mounted on an engine dynamometer stand and tested to determine its knock frequency. The cycle follower was programmed with the same road load curve as used in the case of the 2.3 liter engine. The inertia loading was increased slightly since the engine typically went into a Mustang-II which is somewhat heavier than the Pinto. Six accelerometers were mounted as shown in the schematic in Figure 7-9. Two accelerometers were mounted on the intake manifold, 2 on front head bolts transverse to the crankshaft, and the other 2 were mounted in axial positions on the rear of the heads.

As in the case of the 2.3 liter engine, acceleration tests (from 40 to 70 mph at WOT), and steady state tests at 1600 rpm (∿35 mph) and 2550 rpm (∿55 mph). These data are compiled in Appendix F with only a summary presented here.

Representative frequency analyses obtained during 40 to 70 mph accelerations are given in Figures 7-10 through 7-15 for all six accelerometer locations. It can be seen from looking at these frequency-intensity plots that the range of frequencies which can be attributed to knock is much wider than that seen either in the 350 CID V-8 or the 2.3 liter 4-cylinder engine. In fact, when trying to assign peaks corresponding to knock by comparing the no-knock and very light knock intensity plots, 20-30 peaks could be found. Since many of these peaks are closely spaced together, frequency intervals rather than individual peaks were used for the comparison of knocking and no-knock spectra. The ratio of areas between the knock and no-knock cases for the intervals 5 to 8, 8 to 11, and 12 to 15 kHz is given in Table 7-5.

FIGURE 7-9

LOCATION OF ACCELEROMETERS ON
FORD 2.8 LITER V6 ENGINE (TOP VIEW)

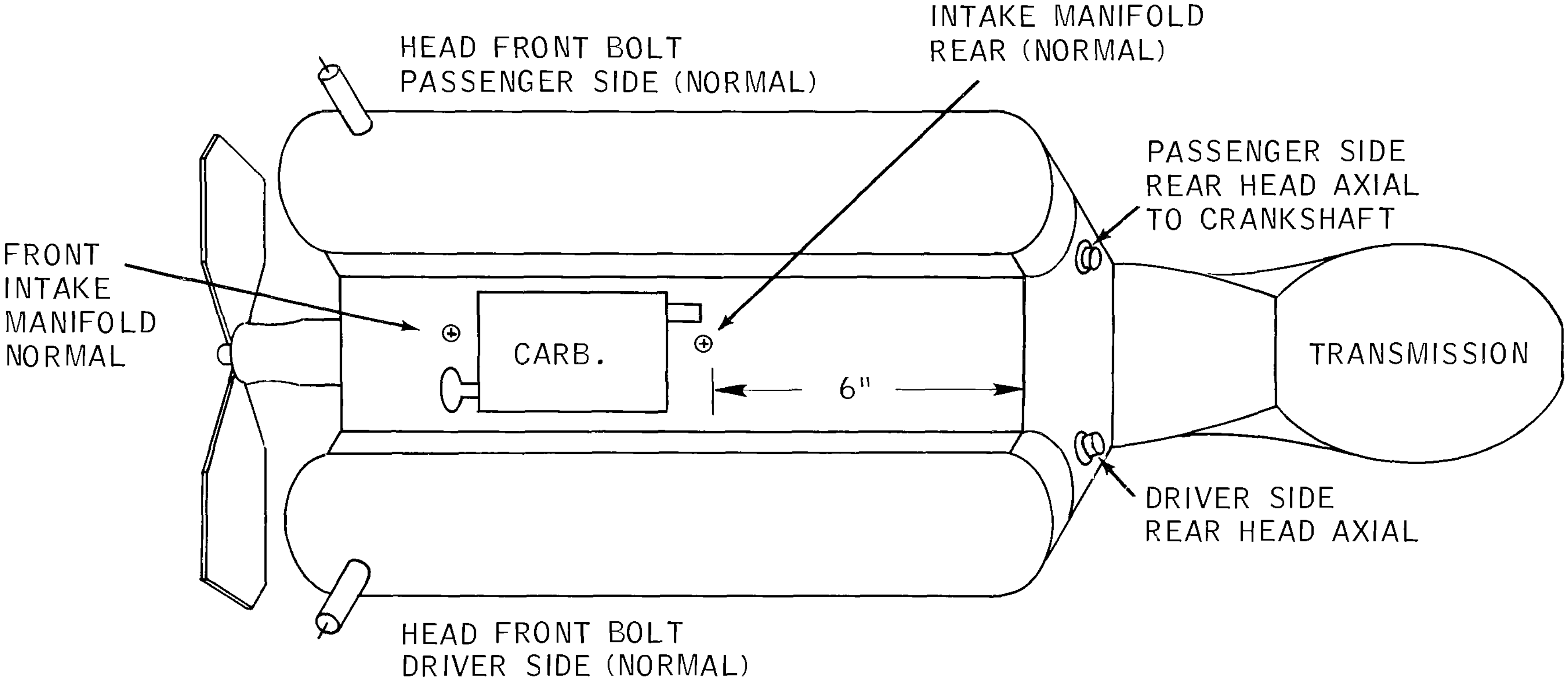


FIGURE 7-10

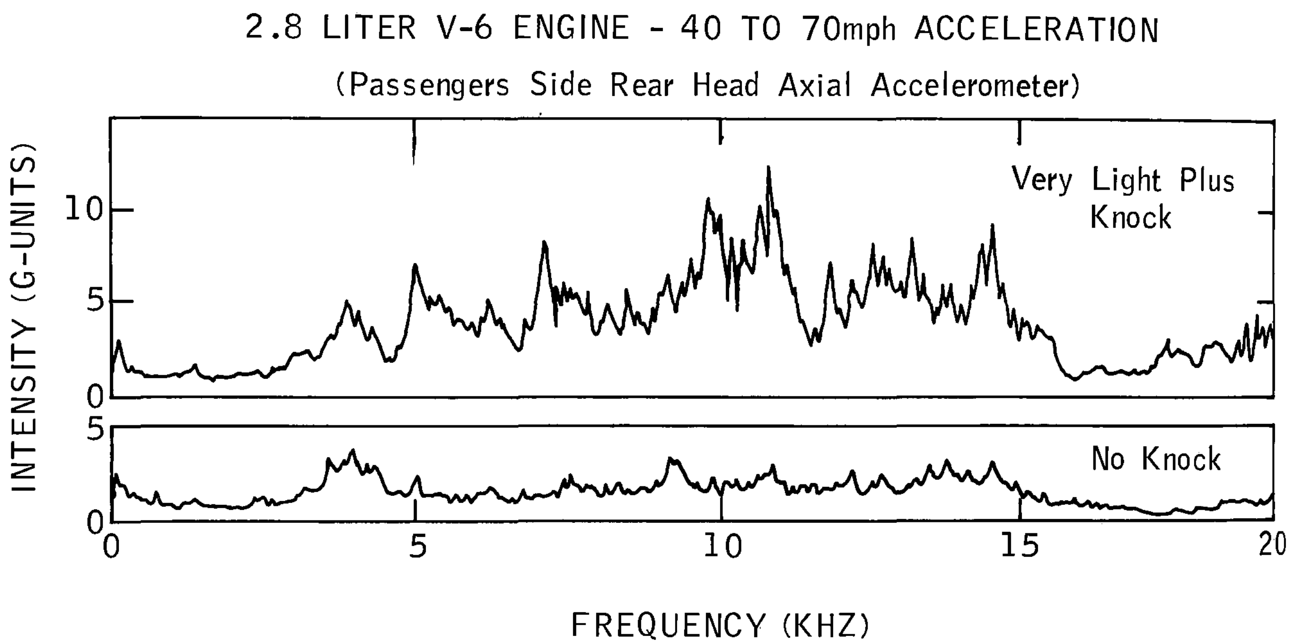

2.8 LITER V-6 ENGINE - 40 TO 70mph ACCELERATION
(Passengers Side Rear Head Axial Accelerometer)
INTENSITY (G-UNITS)
10
5
0
5
0
Very Light Plus Knock
No Knock
0
5
10
15
20
FREQUENCY (KHZ)

FIGURE 7-11

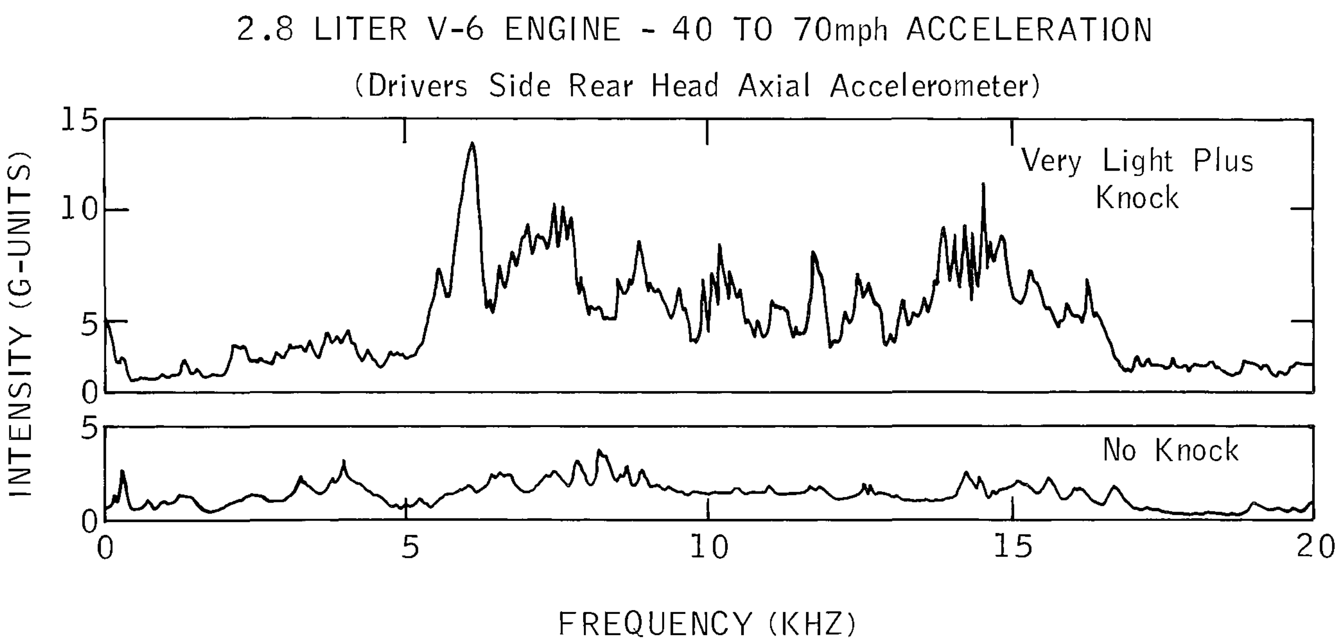

2.8 LITER V-6 ENGINE - 40 TO 70mph ACCELERATION
(Drivers Side Rear Head Axial Accelerometer)
INTENSITY (G-UNITS)
15
10
5
0
5
0
Very Light Plus Knock
No Knock
0
5
10
15
20
FREQUENCY (KHZ)

FIGURE 7-12

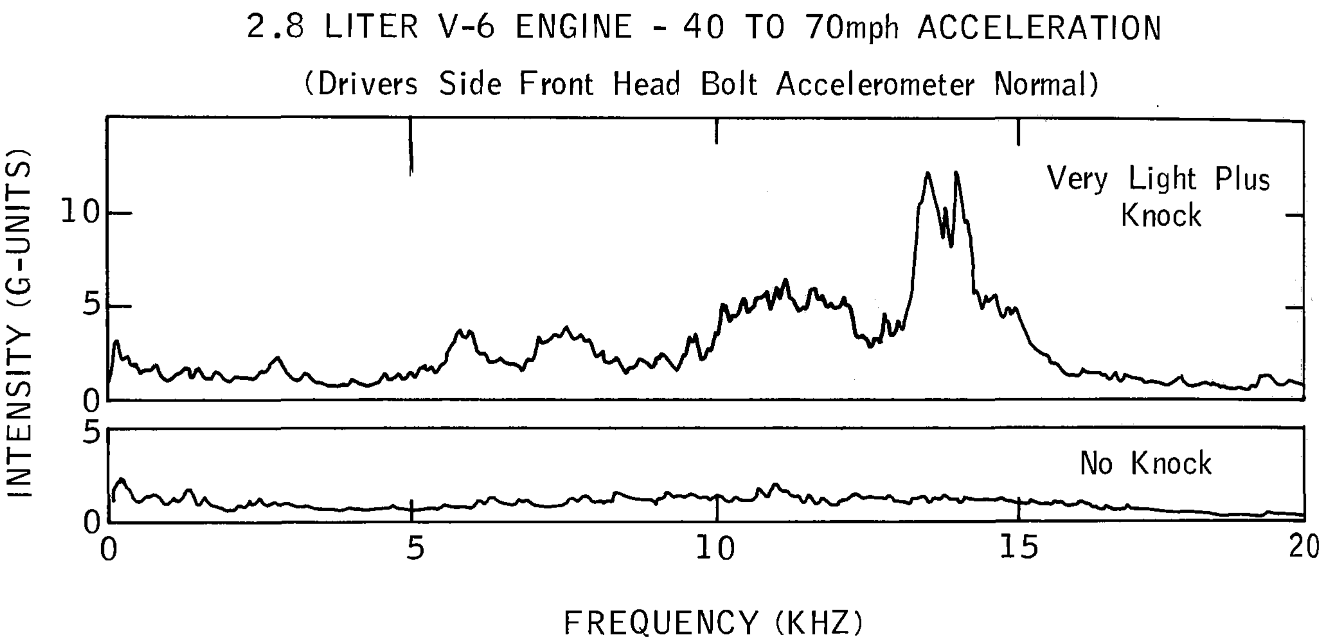

2.8 LITER V-6 ENGINE - 40 TO 70mph ACCELERATION
(Drivers Side Front Head Bolt Accelerometer Normal)
INTENSITY (G-UNITS)
10
5
0
5
0
Very Light Plus Knock
No Knock
0
5
10
15
20
FREQUENCY (KHZ)

FIGURE 7-13

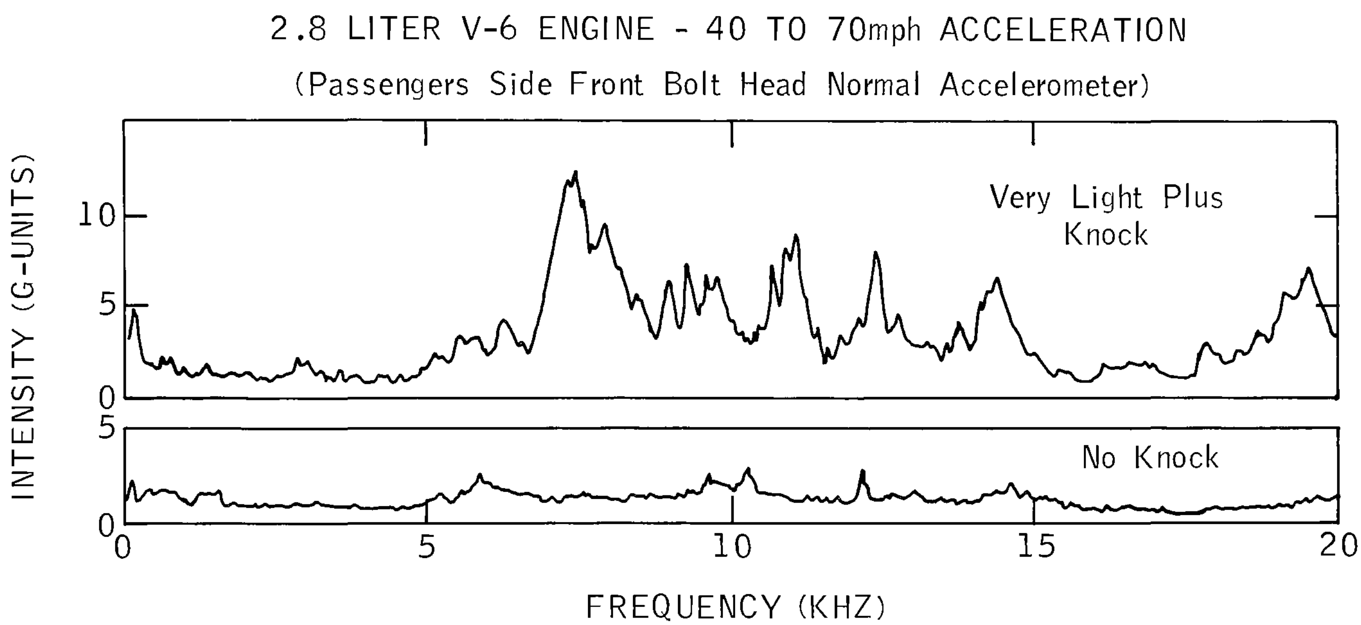

2.8 LITER V-6 ENGINE - 40 TO 70mph ACCELERATION
(Passengers Side Front Bolt Head Normal Accelerometer)
INTENSITY (G-UNITS)
10
5
0
5
0
Very Light Plus Knock
No Knock
0
5
10
15
20
FREQUENCY (KHZ)

FIGURE 7-14

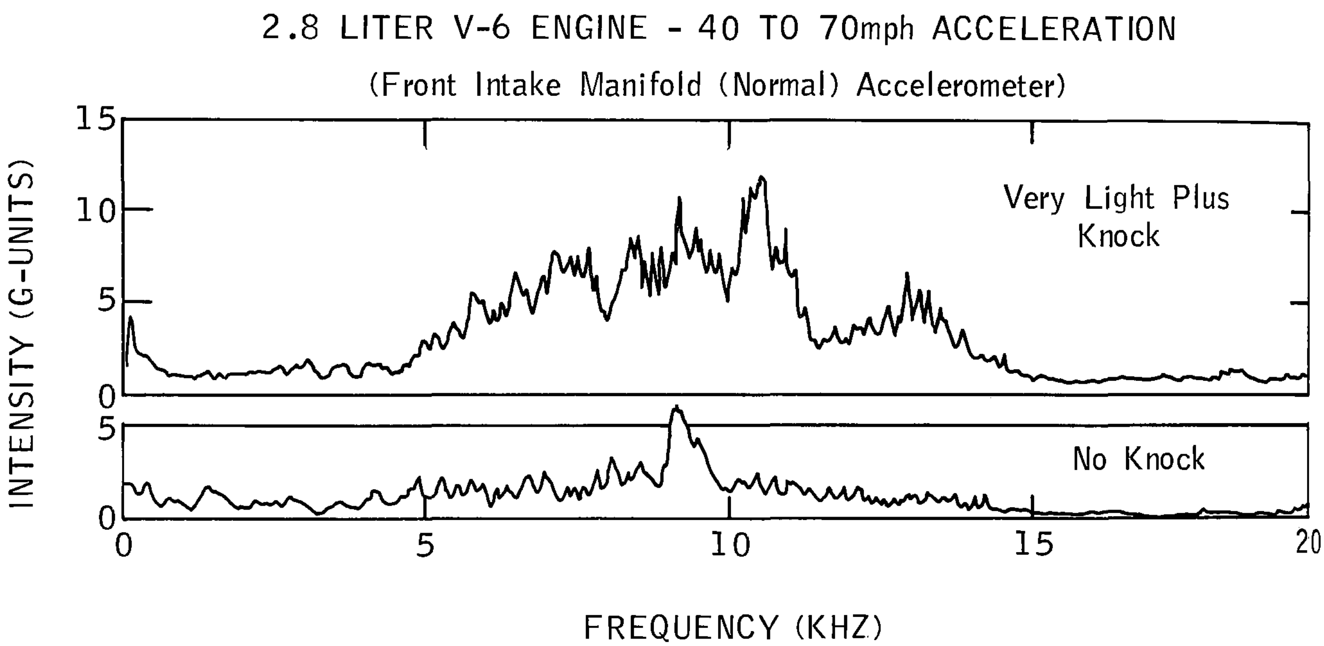

2.8 LITER V-6 ENGINE - 40 TO 70mph ACCELERATION
(Front Intake Manifold (Normal) Accelerometer)
INTENSITY (G-UNITS)
15
10
5
0
5
0
Very Light Plus Knock
No Knock
0
5
10
15
20
FREQUENCY (KHZ)

FIGURE 7-15

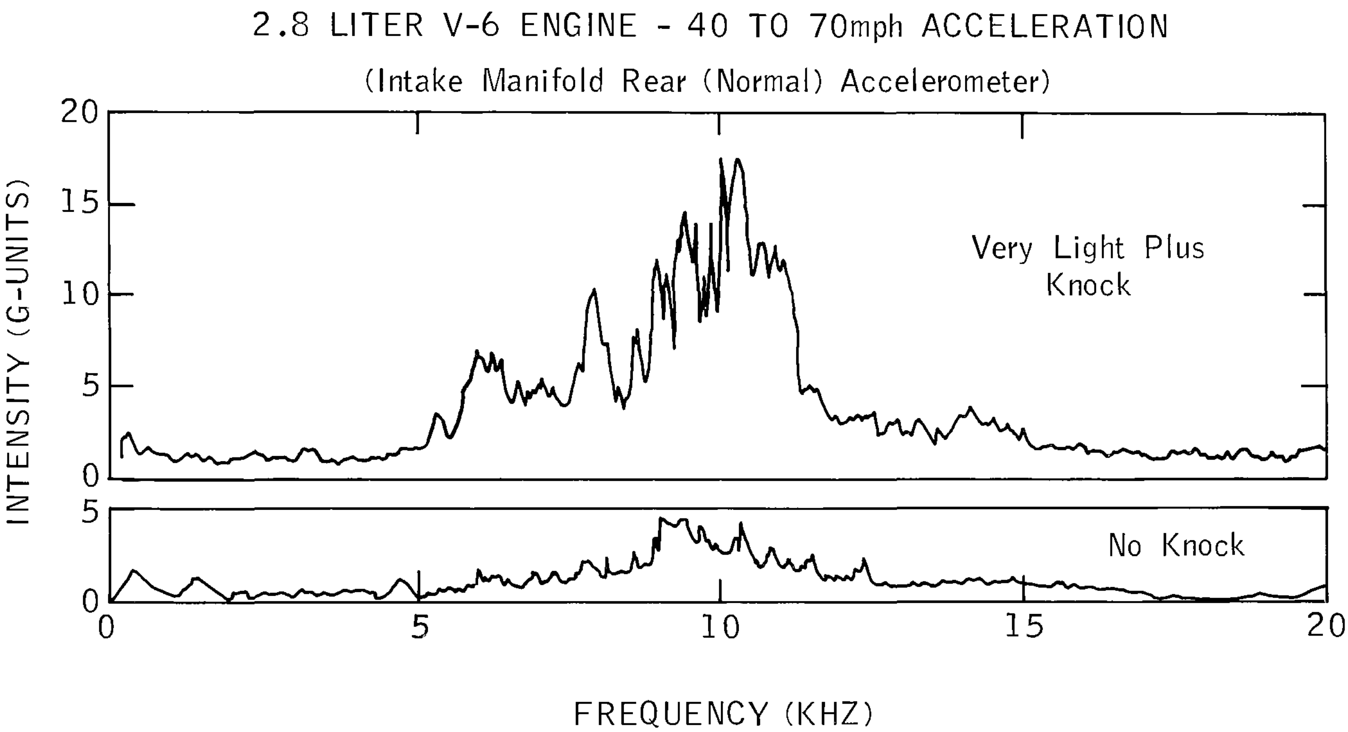

2.8 LITER V-6 ENGINE - 40 TO 70mph ACCELERATION
(Intake Manifold Rear (Normal) Accelerometer)
INTENSITY (G-UNITS)
20
15
10
5
0
5
0
Very Light Plus Knock
No Knock
0
5
10
15
20
FREQUENCY (KHZ)

Table 7-5 Summary of Frequency Analysis of Ford 2.8 Liter V-6 Engine

| Accelerometer | Signal/Noise (Area) Ratio 5 to 8 kHz | 8 to 11 kHz | 12 to 15 kHz |
|---|---|---|---|
| Rear Head - Passenger Side | 7.7 | 2.9 | 2.8 |
| Rear Head - Driver Side | 5.0 | 2.5 | 4.4 |
| Front Head Bolt - Driver Side | 3.1 | 2.4 | 7.9 |
| Front Head Bolt - Passenger Side | 3.1 | 1.6 | 2.6 |
| Intake Manifold - Front | 2.6 | 3.5 | 2.5 |
| Intake Manifold - Rear | 3.8 | 3.5 | 2.5 |

The following conclusions can be drawn from the data.

1. Wider frequency intervals rather than sharp peaks appear to be characteristic of this 2.8 liter V-6 engine. This would suggest that if a knock sensor actuated control system were to be developed, a wider filter bandwidth might be considered to take advantage of these relatively wide frequency windows.

2. The rear head (axial) accelerometer locations both on the driver and passenger side gave very good signal to noise ratios for the 5 to 8 kHz interval. This result agrees well with our findings on the 350 CID V-8 engine, where the rear head axial positions showed the best signal/noise ratios for a relatively well-defined 5.3 kHz peak.

3. A high signal/noise ratio peak located in the 12 to 15 kHz interval was found in the front head bolt-driver side frequency analysis.

The results of the 2.8 liter V-6 engine's frequency analyses suggest that the rear head axial location may be the best for optimizing signal/noise ratio for this engine. This was also found to be very clearly the case for the 350 CID V-8 engine. In the case of 2.3 liter 4-cylinder engine, where background engine noise is a problem, the choice between the axial and transverse locations on the cylinder head was not that obvious. However, again it was clear that accelerometers located on the cylinder heads gave better signal/noise ratio than those either mounted on the block or the intake manifold.

Nothing found on the frequency analysis results would cause concern regarding the building of a knock sensor-actuated spark control system for these engines. Frequency intervals with good signal/noise ratios can be found for both the 2.3 and 2.8 liter engines. After that, it is simply a matter of designing and building a filter to match the intervals chosen with some broadening added to allow for engine-to-engine variations. Thus this type of approach would appear to be feasible in all three engines examined.

## REFERENCES

1. Taylor, C. F. and Taylor, E. S., "The Internal Combustion Engine, 2nd Edition" (1961).

2. Corner E. S. and Cunningham, A. R., "Value of High Octane Number Unleaded Gasoline in the U.S." Presented to the A.C.S., Los Angeles (March, 1971).

3. Teasel, R. C., Calcamuggio, G. L., and Miller, R. D., Trans. SAE, 74:896-910 (1966).

4. "Octane Number Requirement Survey, 1970," CRC Report No. 466, (July, 1971).

5. Caris, D. F. et al., Trans. SAE, 64:76-100 (1956).

6. Musser, G. S., et al., "Effectiveness of Exhaust Gas Recirculation with Extended Use," SAE Paper 710013 (January, 1971).

7. Gumbleton, J. J. et al., "Optimizing Engine Parameters with Exhaust Gas Recirculation," SAE Paper 740140 (February, 1974).

8. Glass, W., et al., "Evaluation of Exhaust Gas Recirculation for Control of Nitrogen Oxides Emissions," SAE Paper 700146 (January, 1970).

9. Ricardo, H. R. and Hempson, J. G. G., "The High Speed Internal-Combustion Engine, 5th ed." (1968).

10. Lichty, L. C., "Internal Combustion Engines, 6th ed." (1951).

11. Varde, K. S. and Lucas, G. G., "Effects of Pressure Variation and Combustion Duration on the Emission of Hydrocarbons and Nitric Oxides," SAE Paper 760142.

12. Quader, A. A., "Effects of Spark Location and Combustion Duration on Nitric Oxide and Hydrocarbon Emissions," SAE Paper 730153.

13. "Effect of Altitude Change on Octane Number Requirements of Late Model Cars," CRC Report No. 454 (October, 1973).

14. Corner, E. S., "Octanes - from Laboratory to Road," SAE Paper No. 777, presented at SAE Summer Meeting, Atlantic City, New Jersey, (June, 1956).

15. Campbell, J. M., Caris, D. F., and Withrow, L. L., Trans. SAE, 3:341-352 (1949).

16. Fell, R. B. and Hostetler, H. F., "Laboratory Octane Ratings - What Do They Mean?", SAE Paper No. 263, presented at the National Fuels and Lubricant Meeting, Cleveland, Ohio (November, 1957).

17. "Octane Number Requirement Survey, 1973," CRC Report No. 467 (May, 1974).

18. Wostl, W. J. and Heintz, J. A., "Knock and Rumble Detector for Internal Combustion Engines." U.S. Patent 3,540,262, November 17, 1970.

19. Krause, W. H., "Knock Detection Instrument." U.S. Patent 3,201,972, August 24, 1965.

20. Barton, R. K., Lestz, S. S. and Duke, L. C., "Knock Intensity as a Function of Engine Rate of Pressure Change." Paper 700061 presented at SAE Meeting, Detroit, January 12-16, 1970.

21. Keller, B. D., Wright, L. T., Ginsburgh, I. and Rueckel, H. E., "Automated Fuel Road Octane Ratings." Paper 730550, SAE Meeting, 1973.

22. Arrigoni, V., Gaetani, B. and Ghezzi, P., "Method and Apparatus for Measuring Knocking in Internal Combustion Engines." U.S. Patent 3,942,359, March 9, 1976.

23. Harned, J. L., "Borderline Spark Knock Detector." U.S. Patent 4,012,942, March 22, 1977.

24. Gumbleton, J. J., Niepoth, G. W. and Currie, J. H., "Effect of Energy and Emissions Constraints on Compression Ratio," Paper 760826, presented at SAE Meeting, Dearborn, Michigan, October 18-22, 1976.

25. Kuroda, H., Nakajima, Y. et al., "The Fast Burn with Heavy EGR, A New Approach for Low $NO_x$ and Improved Fuel Economy," SAE Auto. Eng. Congr., Detroit 2/27/78, Paper No. 780006.

# APPENDIX A

## FREQUENCY ANALYSIS OF ACCELEROMETER SIGNALS FROM 350 CID CHEVROLET V-8 ENGINE

| | |
|---|---|
| A-1 through A-84 | Test #1 Spare Engine |
| A-85 through A-122 | Test #2 Engine from Vehicle |

TEST #1

SPARE 350 CID ENGINE

| Accelerometer No. | Location | |
|---|---|---|
| 1 | Left Front Cylinder Head | Transverse |
| 2 | Left Rear Cylinder Head | Transverse |
| 3 | Rear Intake Manifold | Transverse |
| 4 | Front Intake Manifold | Transverse |
| 5 | Right Front Cylinder Head | Transverse |
| 6 | Right Rear Cylinder Head | Axial |

## SUMMARY OF SPECTROGRAM RESULTS

| Plot No. | Accelerometer Number | Test | Plot Axis | Amp. Scale | Rated Knock Level | Max. Response | Comments |
|---|---|---|---|---|---|---|---|
| 1 | 1 to 6 | Steady State | Freq & Time | .5g/major div. | Trace Plus | | |
| 1 - 1 | 1 | Fuel Change | Freq & Time | .5g/major div. | Trace Plus | .4g max | poor response |
| 1 - 2 | 2 | Fuel Change | Freq & Time | .5g/major div. | Trace Plus | .6g max | poor response |
| 1 - 3 | 3 | Fuel Change | Freq & Time | .5g/major div. | Trace Plus | .75 max | med response |
| 1 - 4 | 4 | Fuel Change | Freq & Time | .5g/major div. | Trace Plus | .3g max | poor response |
| 1 - 5 | 5 | Fuel Change | Freq & Time | .5g/major div. | Trace Plus | | no response |
| 1 - 6 | 6 | Fuel Change | Freq & Time | .5g/major div. | Trace Plus | 1.8g max | good response |
| 2 - 1 | 1 | Steady State | Freq & Time | .5g/major div. | Trace | | no response |
| 2 - 2 | 2 | Steady State | Freq & Time | .5g/major div. | Trace | | no response |
| 2 - 3 | 3 | Steady State | Freq & Time | .5g/major div. | Trace | | no response |
| 2 - 4 | 4 | Steady State | Freq & Time | .5g/major div. | Trace | | no response |
| 2 - 5 | 5 | Steady State | Freq & Time | .5g/major div. | Trace | | no response |
| 2 - 6 | 6 | Steady State | Freq & Time | .5g/major div. | Trace | 1.0 max | med response |
| 3 - 1 | 1 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 3 - 2 | 2 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 3 - 3 | 3 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 3 - 4 | 4 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 3 - 5 | 5 | Steady State | Freq & Time | .5g/major div. | None | | no response |

| Plot No. | Accelerometer Number | Test | Plot Axis | Amp. Scale | Rated Knock Level | Max. Response | Comments |
|---|---|---|---|---|---|---|---|
| 3 - 6 | 6 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 4 - 1 | 1 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 4 - 2 | 2 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 4 - 3 | 3 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 4 - 4 | 4 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 4 - 5 | 5 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 4 - 6 | 6 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 5 - 1 | 1 | Steady State | Freq & Time | .5g/major div. | Very light plus | | no response |
| 5 - 2 | 2 | Steady State | Freq & Time | .5g/major div. | Very light plus | | no response |
| 5 - 3 | 3 | Steady State | Freq & Time | .5g/major div. | Very light plus | | no response |
| 5 - 4 | 4 | Steady State | Freq & Time | .5g/major div. | Very light plus | | no response |
| 5 - 5 | 5 | Steady State | Freq & Time | .5g/major div. | Very light plus | | no response |
| 5 - 6 | 6 | Steady State | Freq & Time | .5g/major div. | Very lt. plus | 2g max | good response |
| 6 - 4 | 4 | Fuel Change | Freq & Time | .5g/major div. | Very light | | no response |
| 6 - 5 | 5 | Fuel Change | Freq & Time | .5g/major div. | Very light | | no response |
| 6 - 6 | 6 | Fuel Change | Freq & Time | .5g/major div. | Very light | 1.2g max | med response |
| 7 - 1 | 1 | Acceleration | Freq & RPM | 1g/major div. | All levels | 1.6g max | med response |
| 7 - 2 | 2 | Acceleration | Freq & RPM | 1g/major div. | All levels | 2.5g max | med response |
| 7 - 3 | 3 | Acceleration | Freq & RPM | 1g/major div. | All levels | 2g max | med response |

| Plot No. | Accelerometer Number | Test | Plot Axis | Amp. Scale | Rated Knock Level | Max. Response | Comments |
|---|---|---|---|---|---|---|---|
| 7 - 4 | 4 | Acceleration | Freq & RPM | lg/major div. | All levels | | no response |
| 7 - 5 | 5 | Acceleration | Freq & RPM | lg/major div. | All levels | | no response |
| 7 - 6 | 6 | Acceleration | Freq & RPM | lg/major div. | All levels | 5g max | good response |
| 8 - 1 | 1 | Acceleration | Freq & RPM | lg/major div. | All levels | | no response |
| 8 - 2 | 2 | Acceleration | Freq & RPM | lg/major div. | All levels | 2.5g max | med response |
| 8 - 3 | 3 | Acceleration | Freq & RPM | lg/major div. | All levels | 2g max | med response |
| 8 - 4 | 4 | Acceleration | Freq & RPM | lg/major div. | All levels | 1.5g max | poor response |
| 8 - 5 | 5 | Acceleration | Freq & RPM | lg/major div. | All levels | .6g max | poor response |
| 8 - 6 | 6 | Acceleration | Freq & RPM | lg/major div. | All levels | 5g max | good response |
| 9 - 1 | 1 | Acceleration | Freq & RPM | lg/major div. | None | | no response |
| 9 - 2 | 2 | Acceleration | Freq & RPM | lg/major div. | None | | no response |
| 9 - 3 | 3 | Acceleration | Freq & RPM | lg/major div. | None | | no response |
| 9 - 4 | 4 | Acceleration | Freq & RPM | lg/major div. | None | | no response |
| 9 - 5 | 5 | Acceleration | Freq & RPM | lg/major div. | None | | no response |
| 9 - 6 | 6 | Acceleration | Freq & RPM | lg/major div. | None | | no response |
| 10- 1 | 1 | Acceleration | Freq & RPM | lg/major div. | Very light | .7g max | poor response |
| 10- 2 | 2 | Acceleration | Freq & RPM | lg/major div. | Very light | 2.5g max | med response |
| 10- 3 | 3 | Acceleration | Freq & RPM | lg/major div. | Very light | | no response |
| 10- 4 | 4 | Acceleration | Freq & RPM | lg/major div. | Very light | | no response |

| Plot No. | Accelerometer Number | Test | Plot Axis | Amp. Scale | Rated Knock Level | Max. Response | Comments |
|---|---|---|---|---|---|---|---|
| 10- 5 | 5 | Acceleration | Freq & RPM | 1g/major div. | Very light | | no response |
| 10- 6 | 6 | Acceleration | Freq & RPM | 1g/major div. | Very light | 3g max | gooc response |
| 11- 1 | 1 | Acceleration | Freq & RPM | 1g/major div. | None | | no response |
| 11- 2 | 2 | Acceleration | Freq & RPM | 1g/major div. | None | | no response |
| 11- 3 | 3 | Acceleration | Freq & RPM | 1g/major div. | None | | no response |
| 11- 4 | 4 | Acceleration | Freq & RPM | 1g/major div. | None | | no response |
| 11- 5 | 5 | Acceleration | Freq & RPM | 1g/major div. | None | | no response |
| 11- 6 | 6 | Acceleration | Freq & RPM | 1g/major div. | None | | no response |
| 12- 1 | 1 | Steady State | Freq & Time | .5g/major div. | Trace | | no response |
| 12- 2 | 2 | Steady State | Freq & Time | .5g/major div. | Trace | | no response |
| 12- 3 | 3 | Steady State | Freq & Time | .5g/major div. | Trace | | no response |
| 12- 4 | 4 | Steady State | Freq & Time | .5g/major div. | Trace | | no response |
| 12- 5 | 5 | Steady State | Freq & Time | .5g/major div. | Trace | | no response |
| 12- 6 | 6 | Steady State | Freq & Time | .5g/major div. | Trace | 1.2g max | med response |
| 13- 1 | 1 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 13- 2 | 2 | Steady State | Freq & Time | .5g/major div, | None | | no response |
| 13- 3 | 3 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 13- 4 | 4 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 13- 5 | 5 | Steady State | Freq & Time | .5g/major div. | None | | no response |
| 13- 6 | 6 | Steady State | Freq & Time | .5g/major div. | None | | no response |

| Plot No. | Accelerometer Number | Test | Plot Axis | Amp. Scale | Rated Knock Level | Max. Response | Comments |
|---|---|---|---|---|---|---|---|
| 14- 1 | 1 | Fuel Change | Freq & Time | .5g/major div. | Trace | | no response |
| 14- 6 | 6 | Fuel Change | Freq & Time | .5g/major div. | Trace | 1.5g max | good response |

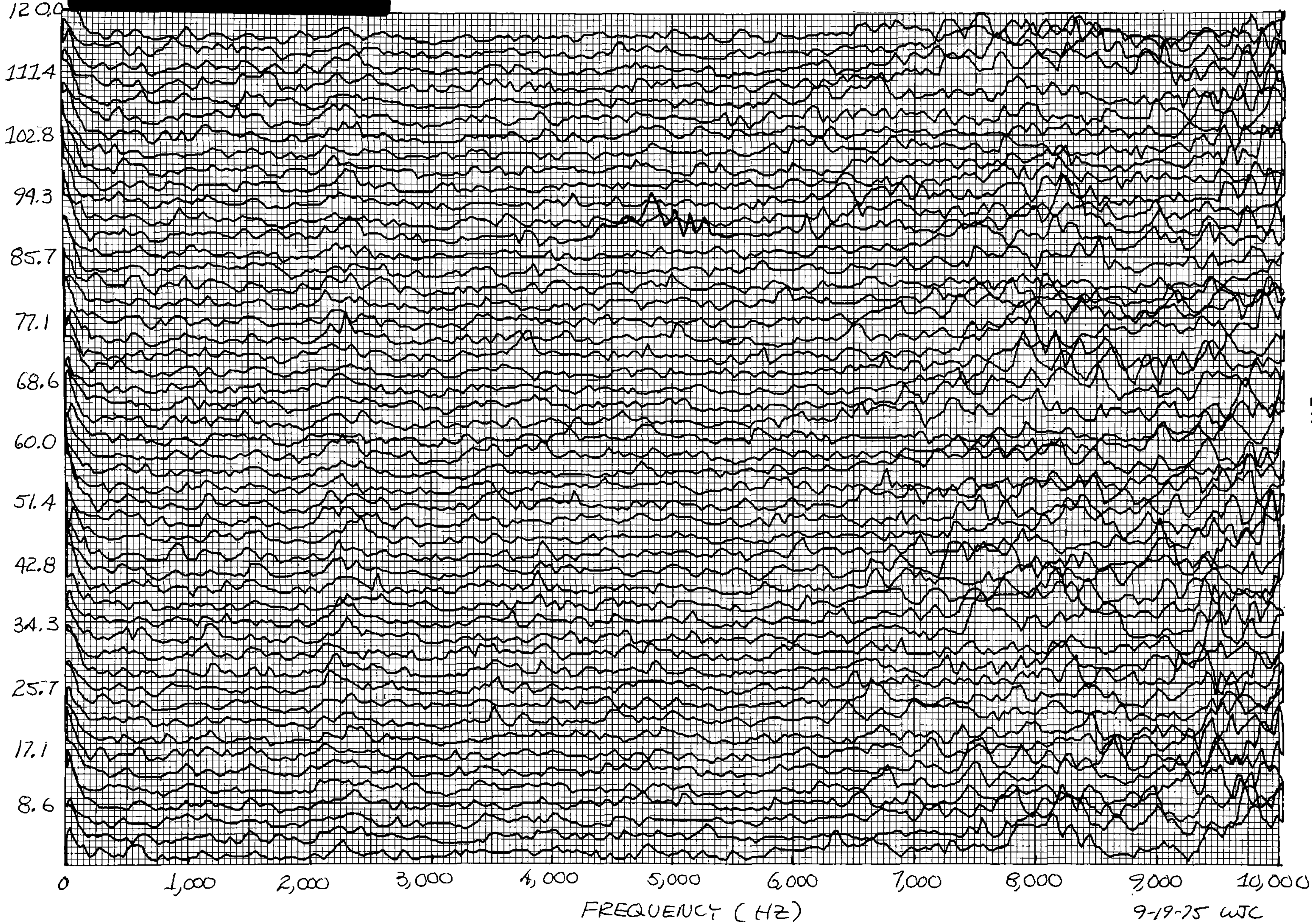
[redacted]

#1

**Typical Accelerometer Output**
**Steady State Test #1**
**1750 RPM 193 FT LBS TORQUE 25" HG**
**Trace Plus Level Knock**

TIME (SEC) [redacted] #1-1

Accelerometer #1 - L.F. Cylinder Head Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Plus Level Knock



Fuel Change - House To 78 Octane Fuel
Accelerometer #2 - L.R. Cylinder Head
Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Plus Level Knock

#1-2

#1-3

Accelerometer #3 - R. Intake Manifold
Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Plus Level Knock


9-19-75 WJC

[illegible] Research and Engi-
neering Co.
Knock Detection Test
Test Cell, ERC Building 4
September 16, 1975

#1-4

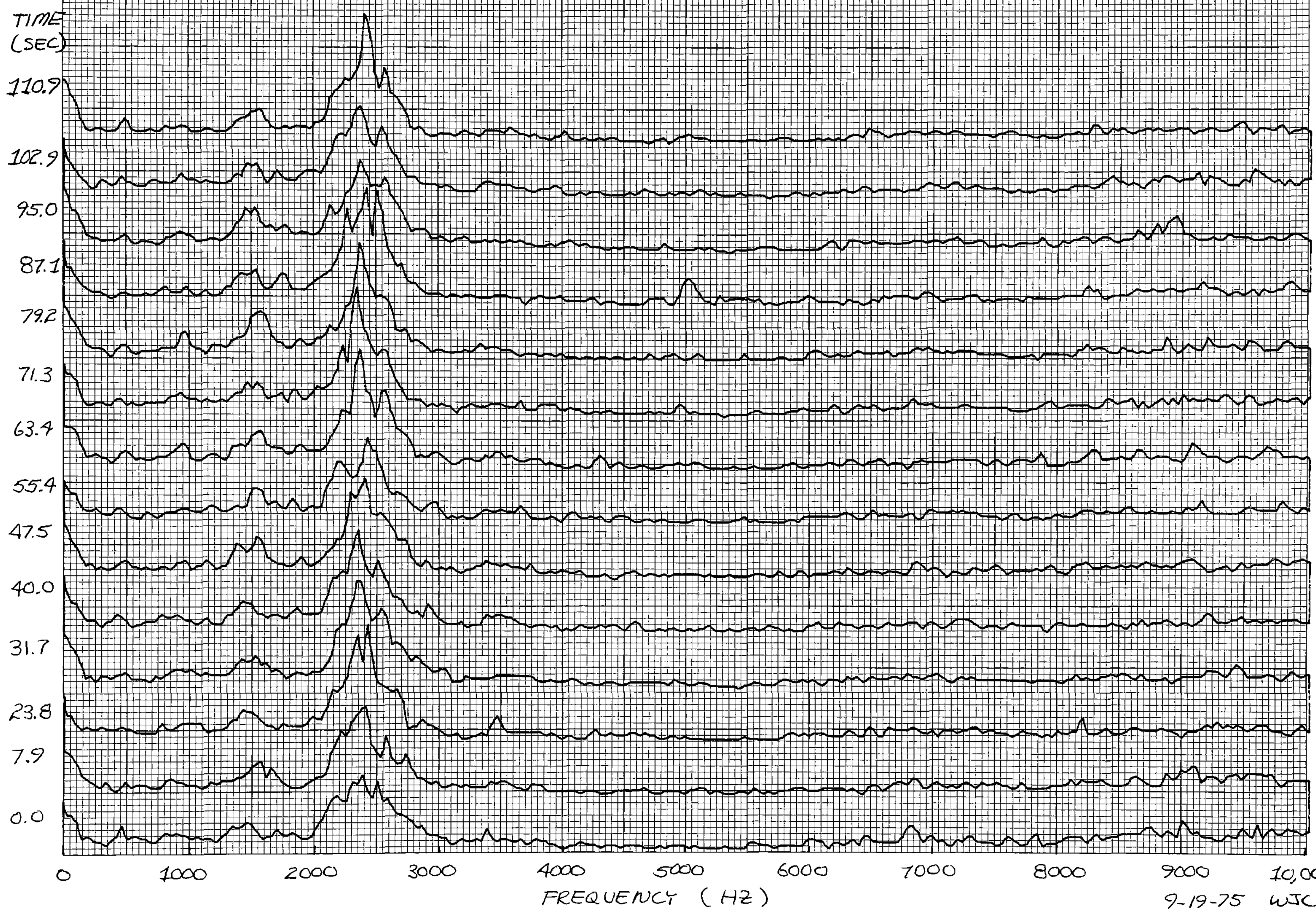
Fuel Change - House To 78 Octane Fuel
Accelerometer #4 - F. Intake Manifold
Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Plus Level Knock


9-19-75 WJC

eering Co.
Knock Detection Test
Test Cell, ERC Building 4
September 16, 1975

#1-5

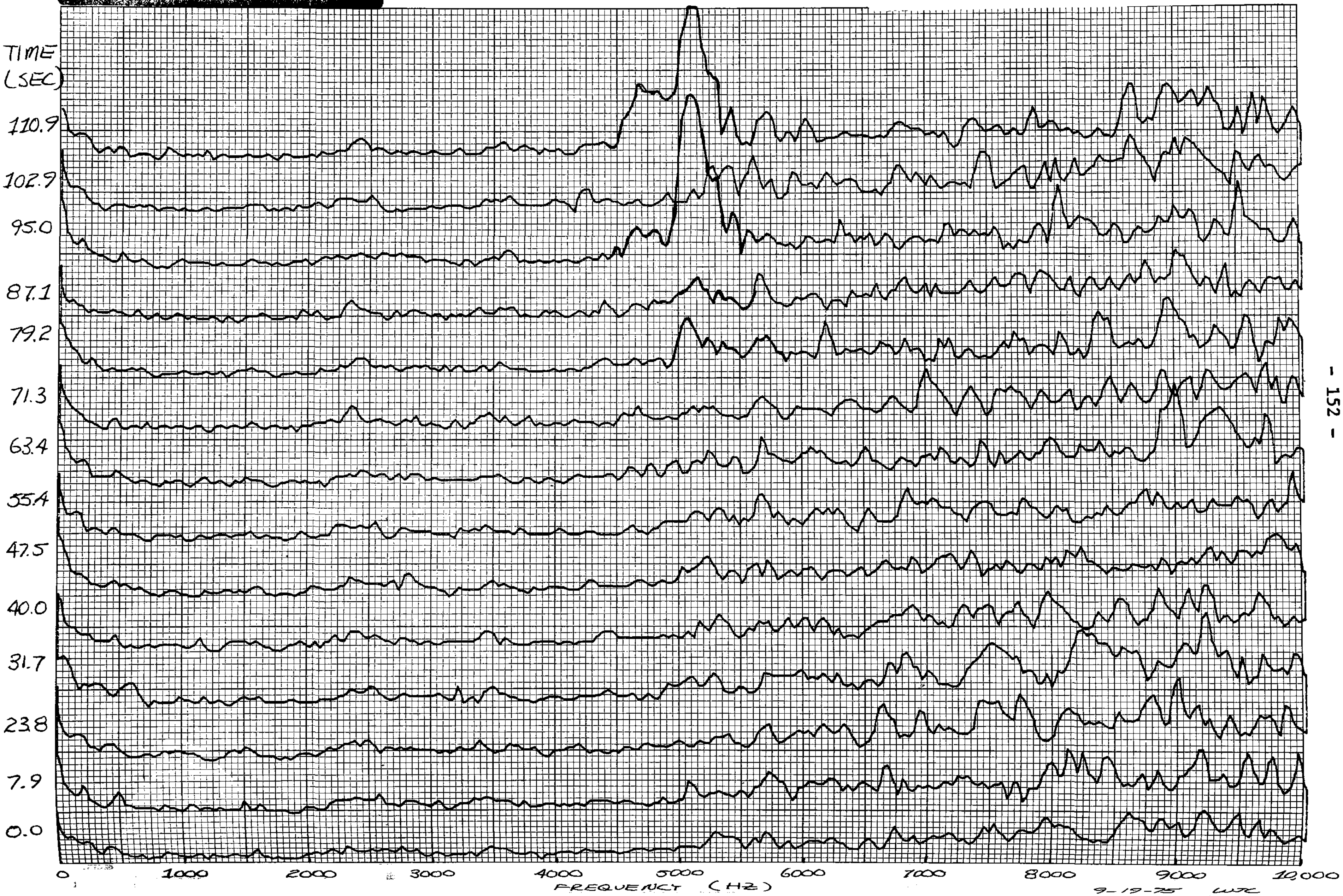
Accelerometer #5 - R.F. Cylinder Head
Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Plus Level Knock



Exxon Research And Engineering Co.
Knock Detection Test
Test Cell, ERC Building 4
September 16, 1975

#1-6

Fuel Change - House To 78 Octane Fuel
Accelerometer #6 - R.R. Cylinder Head Hor.
1750 RPM 193 FT LBS Torque 24" HG
Trace Plus Level Knock



[illegible] Co.
[illegible] Test
Test Cell, [illegible] Building [illegible]
September 16, 1975

#2-1

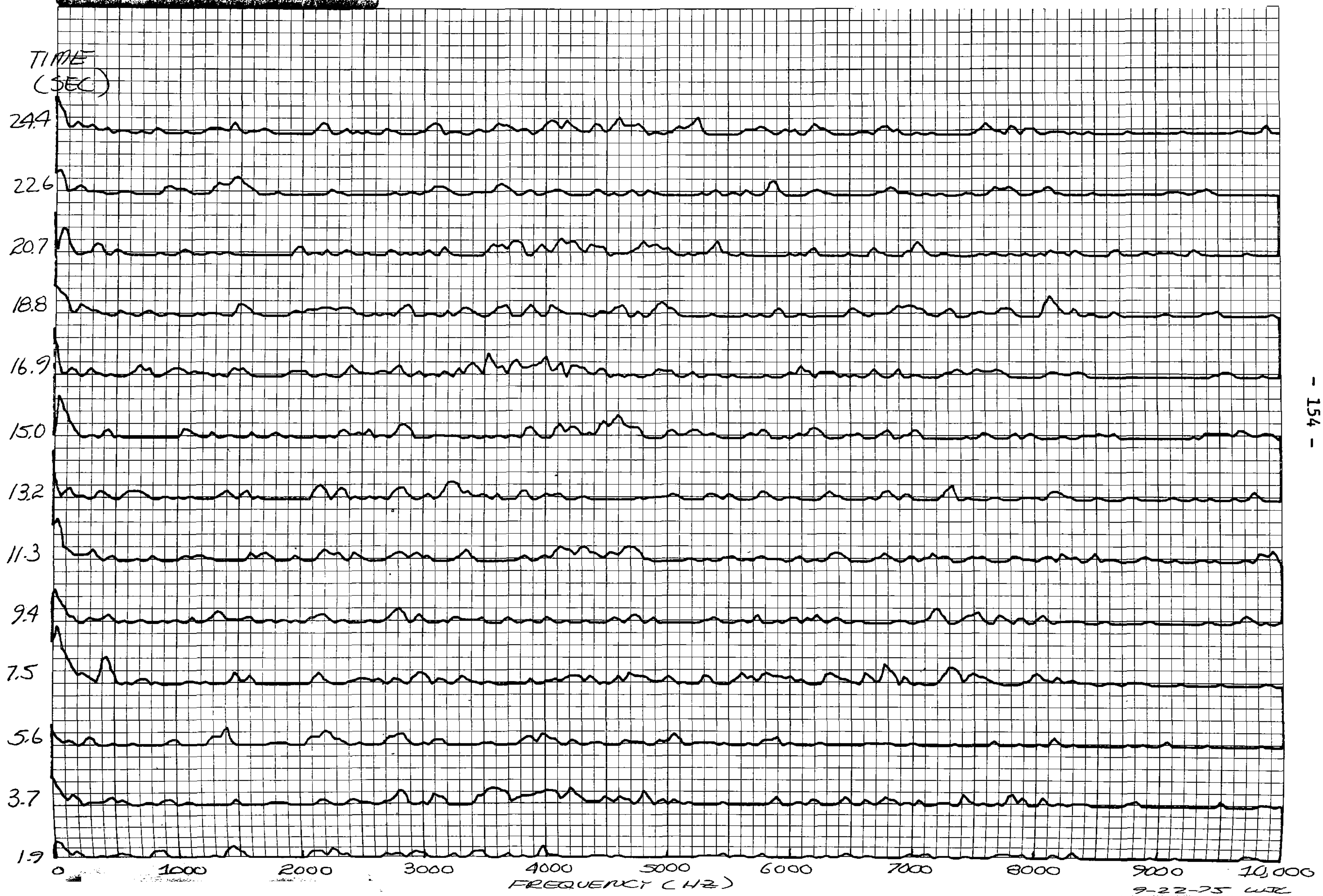
Accelerometer #1 - L.F. Cylinder Head
Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Level Knock


9-22-75 WJC

[illegible] Research And Engi-
neering Co.
Knock Detection Test
Test Cell, [illegible] Building A
September 16, 1975

#2-2

Steady State Test - 78 Octane Fuel
Accelerometer #2 - L.R. Cylinder Head
Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Level Knock



4Accelerometer #3 - R. Intake Manifold
Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Level Knock

#2-3


9-22-75 WJC

[illegible] Research And Engineering Co.
Knock Detection Test
Test Cell, ERC Building 4
September 16, 1975

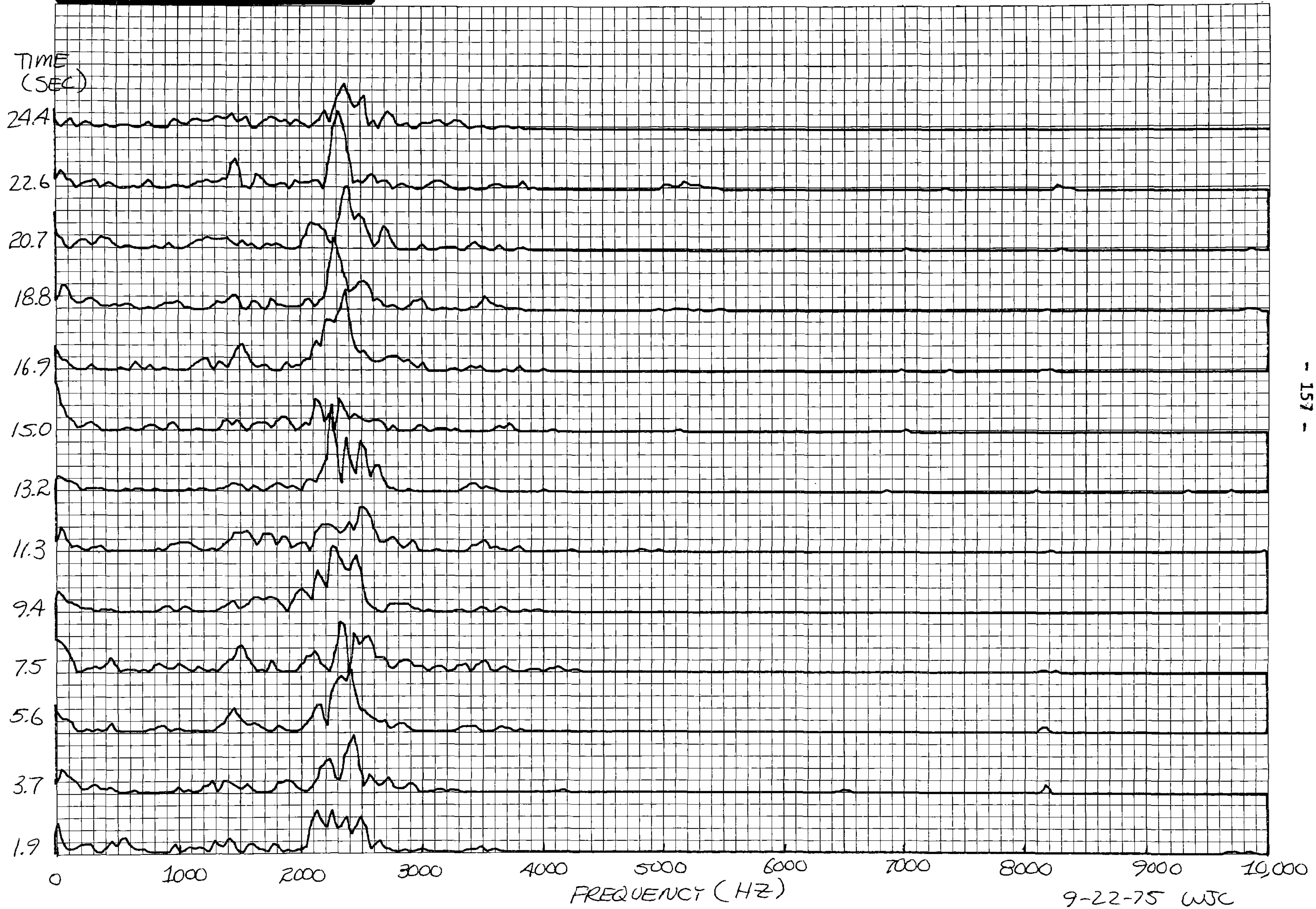
#2-4

Steady State Test - 78 Octane Fuel
Accelerometer #4 - F. Intake Manifold
Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Level Knock


9-22-75 WJC

Accelerometer #5 - R.F. Cylinder Head
Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Level Knock

#2-5



... Research and Engi-
neering Co.
Knock Detection Test
Test Cell, ERC Building ...
September 16, 197...

#2-6

Steady State Test - 78 Octane Fuel
Accelerometer #6 - R.R. Cylinder Head
Vert.
1750 RPM 193 FT LBS Torque 24" HG
Trace Level Knock

[redacted]

#3-1

Accelerometer #1 - L.F. Cylinder Head
Vert.
1750 RPM 170 FT LBS Torque 22" HG
No Knock - Slight Surface Ignition


9-22-75 WJC

Exxon Research And Engineering Co.
Knock Detection Test
Test Cell, ERC Building 4
September 16, 1975

#3-2

Steady State Test - 78 Octane Fuel
Accelerometer #2 - L.R. Cylinder Head Vert.
1750 RPM 170 FT LBS Torque 22" HG
No Knock - Slight Surface Ignition

[illegible] Test
Test Cell, [illegible] Building &
[illegible] 1975

#3-3

Accelerometer #3 - R. Intake Manifold
Vert.
1750 RPM 170 FT LBS Torque 22" HG
No Knock - Slight Surface Ignition


9-22-75 WJC

- 161 -

Exxon Research And Engineering Co.
Knock Detection Test
Test Cell, [illegible] Building 4
September 16, [illegible]

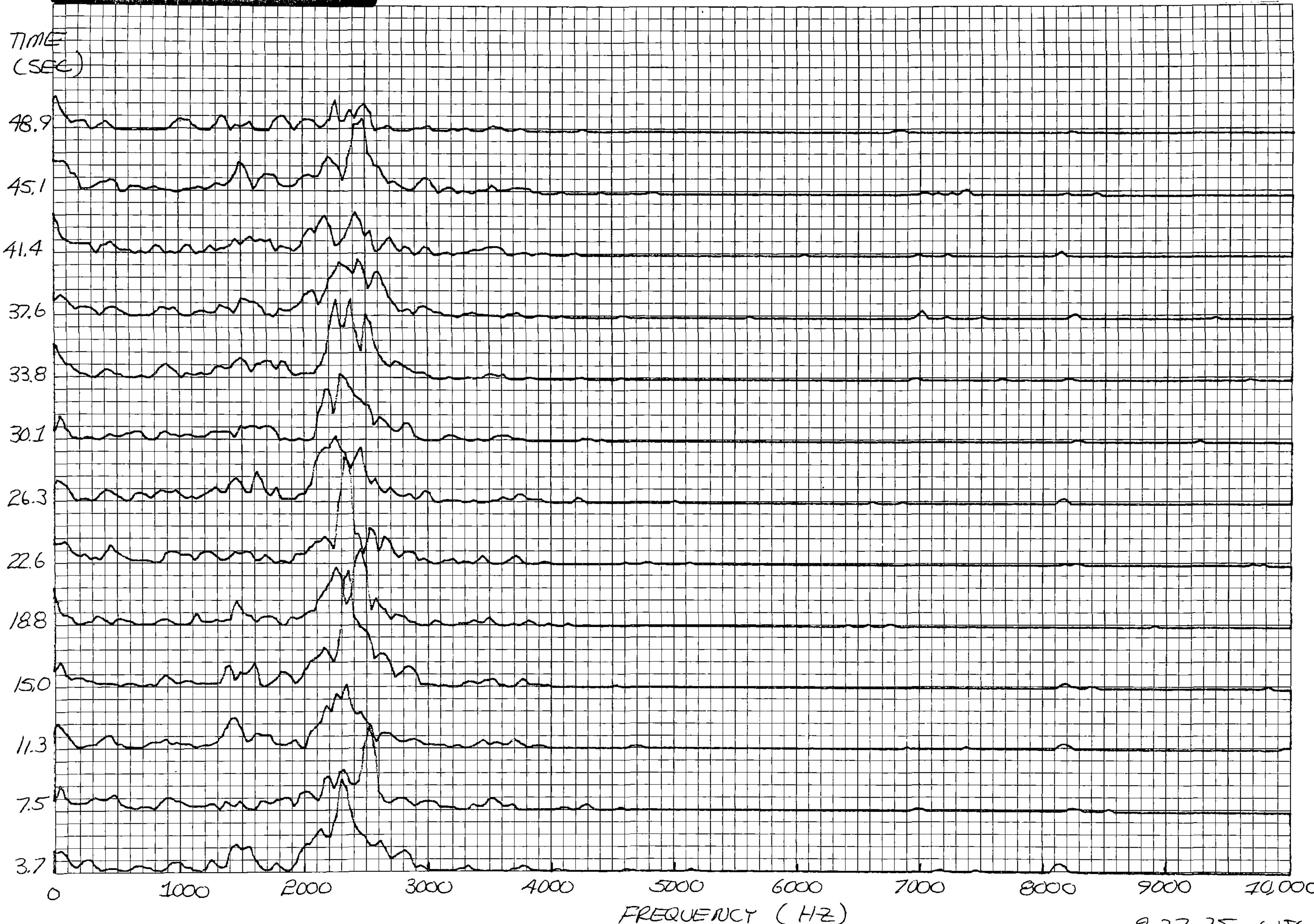
#3-4

Steady State Test - 78 Octane Fuel
Accelerometer #4 - F. Intake Manifold
Vert.
1750 RPM 170 FT LBS Torque 22" HG
No Knock - Slight Surface Ignition

Knock Detection Test
Cell, Building 4

#3-5

Accelerometer #5 - R.F. Cylinder Head
Vert.
1750 RPM 170 FT LBS Torque 22" HG
No Knock - Slight Surface Ignition




9-22-75 WJC

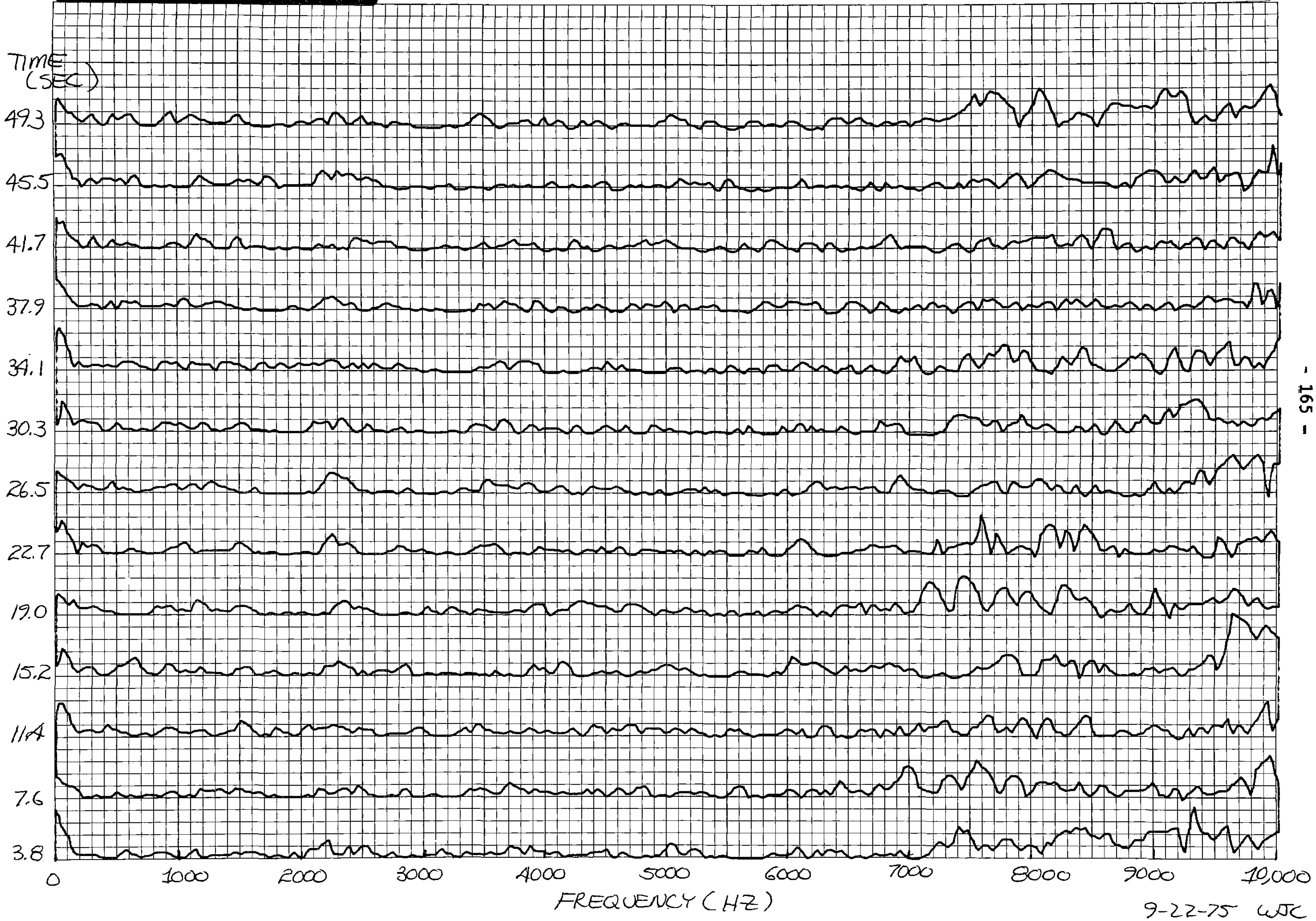
#3-6

Steady State Test - 78 Octane Fuel
Accelerometer #6 - R.R. Cylinder Head Hor.
1750 RPM 170 FT LBS Torque 22" HG
No Knock - Slight Surface Ignition

[redacted]

#4-1

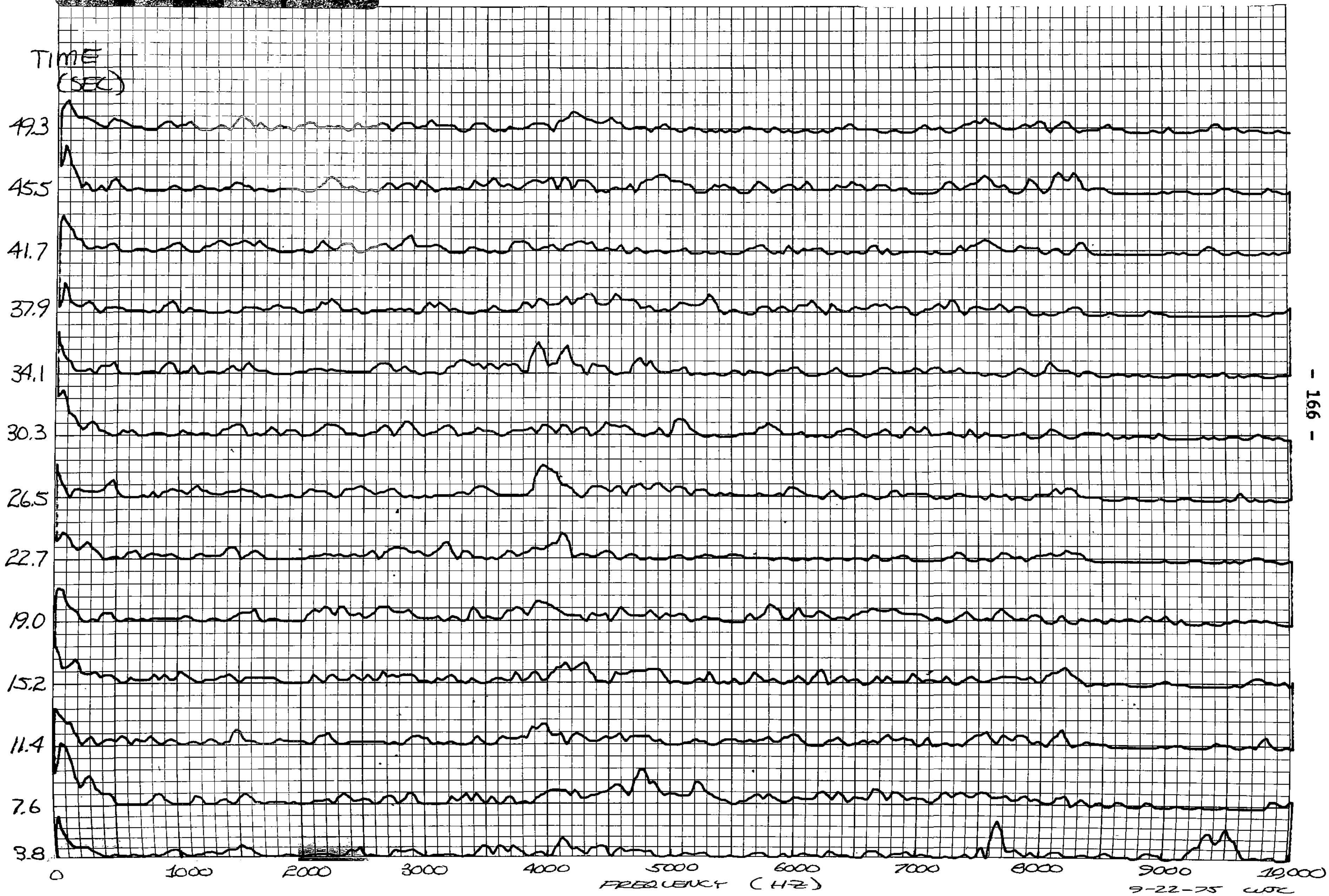
Accelerometer #1 - L.F. Cylinder Head
Vert.
1750 RPM 179 FT LBS 22.5" HG
No Knock - Surface Ignition Present




9-22-75 WJC

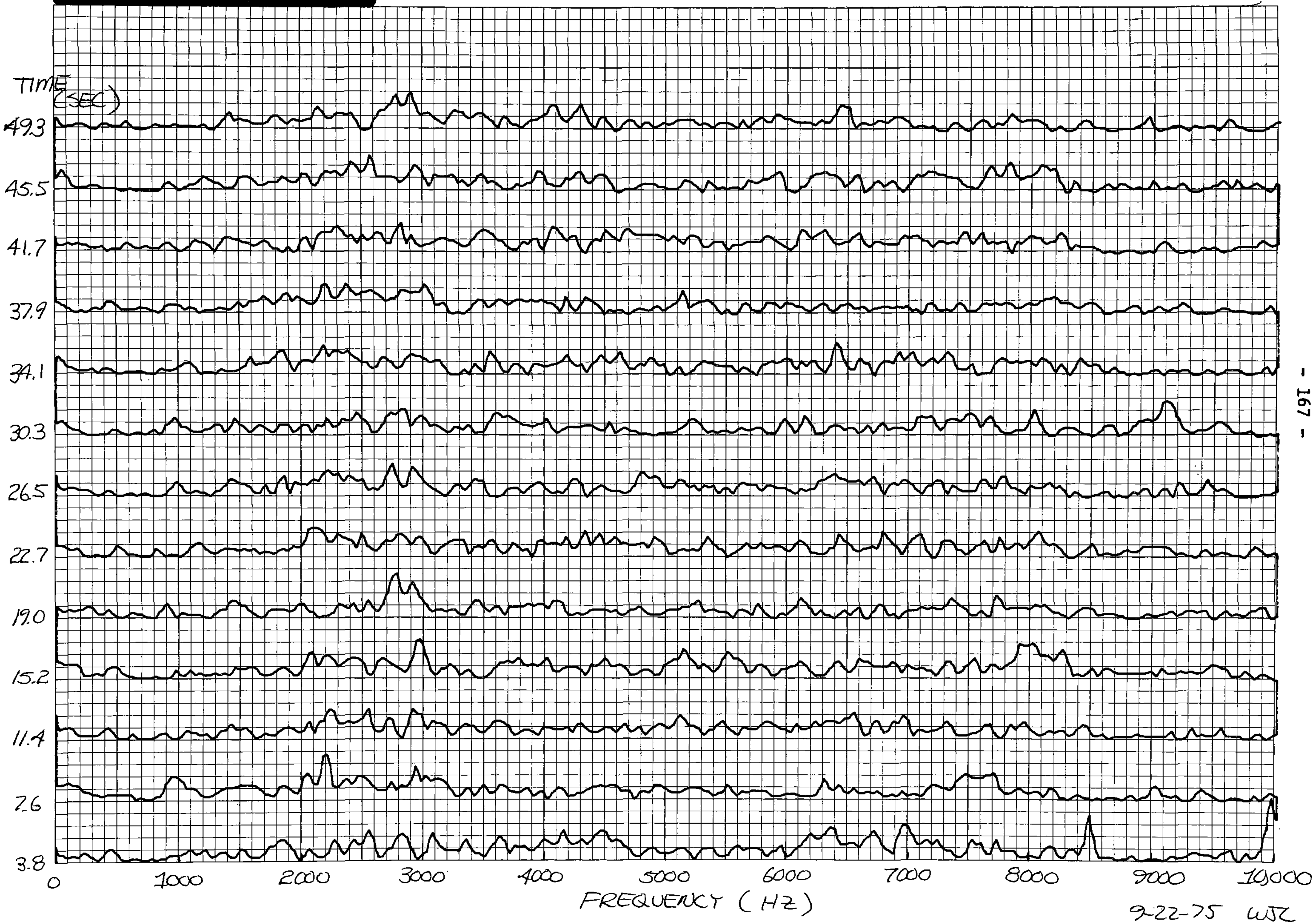
#A-2

Steady State Test - 78 Octane Fuel
Accelerometer #2 - L.R. Cylinder Head
Vert.
1750 RPM 179 FT LBS 22.5" HG
No Knock - Surface Ignition Present

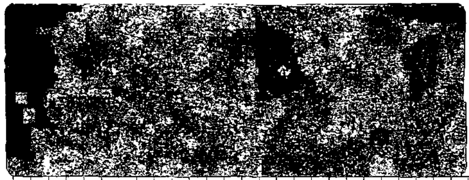


[redacted] #4-3

Accelerometer #3 - R. Intake Manifold
Vert.
1750 RPM 179 FT LBS 22.5" HG
No Knock - Surface Ignition Present




9-22-75 WJC



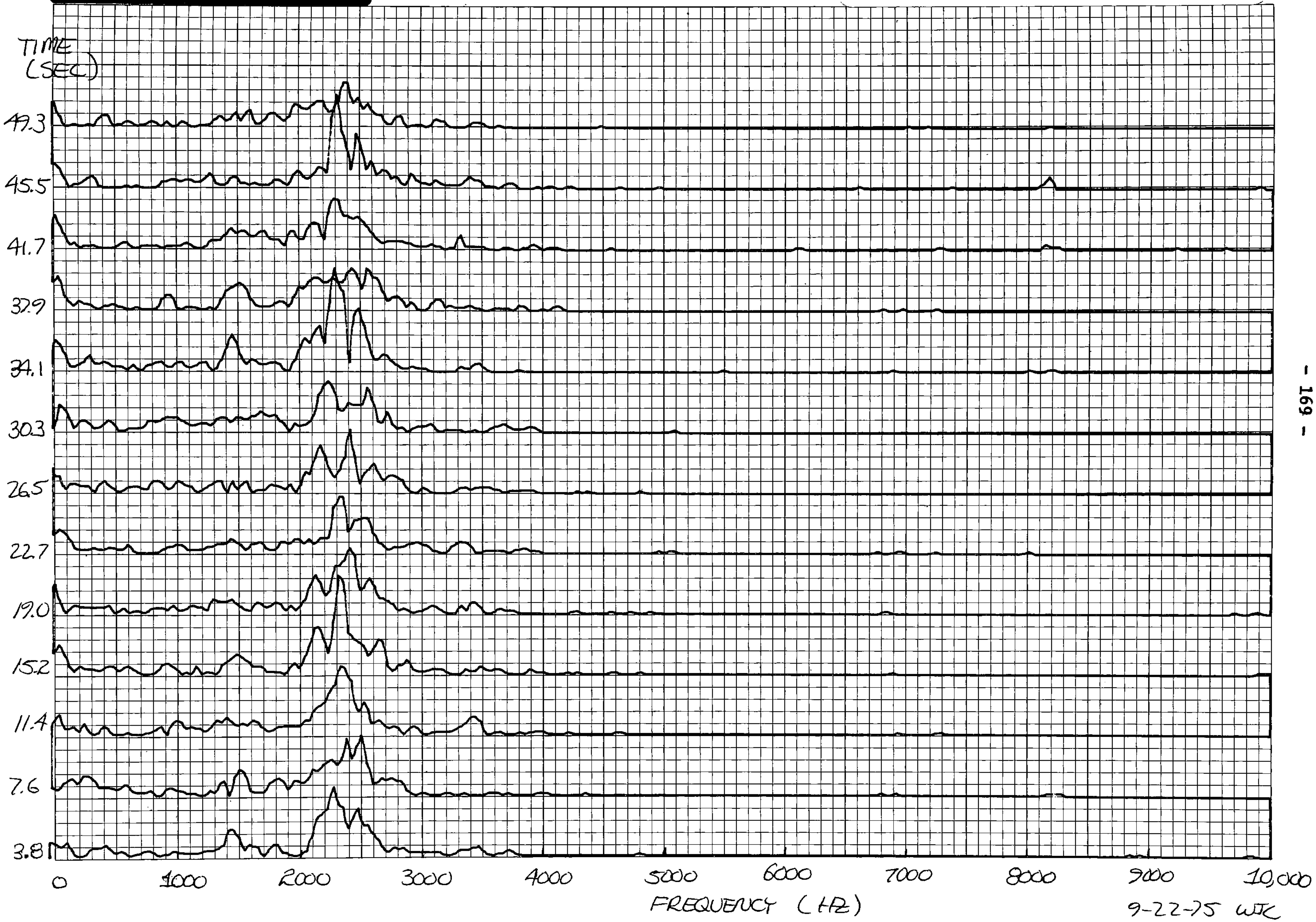
#A-4

Steady State Test - 78 Octane Fuel
Accelerometer #4 - F. Intake Manifold
Vert.
1750 RPM 179 FT LBS 22.5" HG
No Knock - Surface Ignition Present

[redacted]

#4-5

Accelerometer #5 - R.F. Cylinder Head
Vert.
1750 RPM 179 FT LBS 22.5" HG
No Knock - Surface Ignition Present




9-22-75 WJC

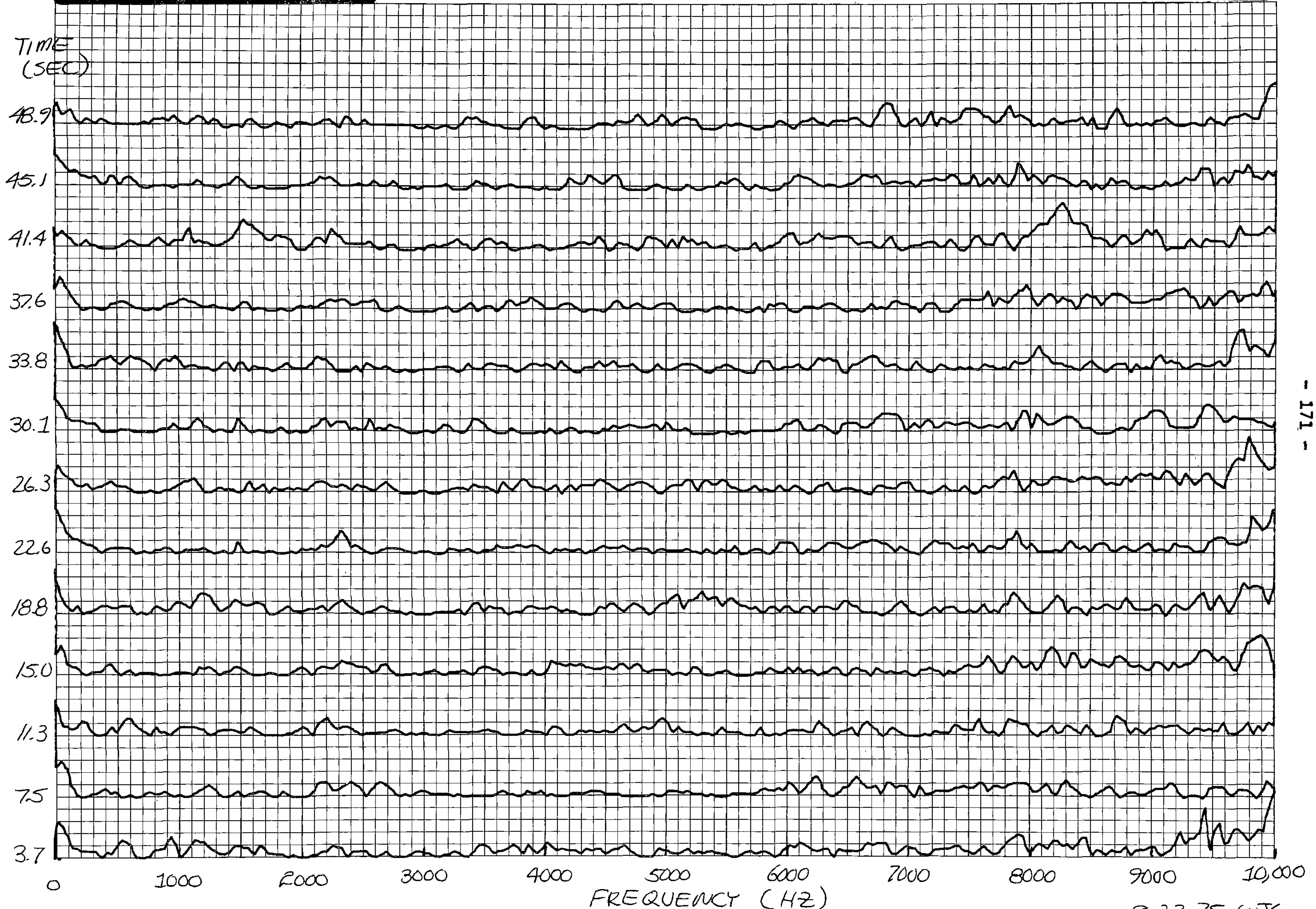
#4-6

Steady State Test - 78 Octane Fuel
Accelerometer #6 - R.R. Cylinder Head
Hor.
1750 RPM 179 FT LBS 22.5" HG
No Knock - Surface Ignition Present

[redacted]

#5-1

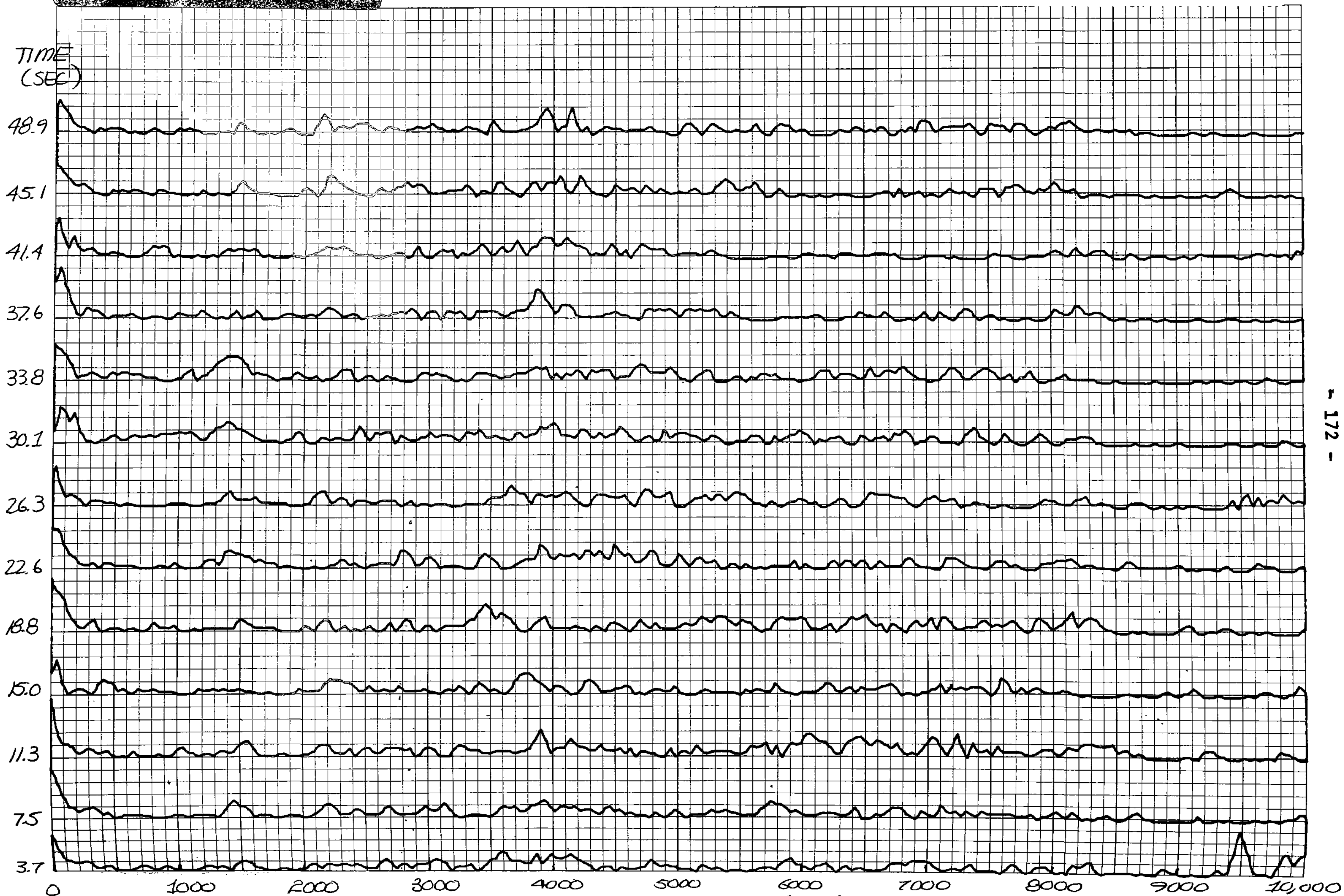
Accelerometer #1 - L.F. Cylinder Head
Vert.
1750 RPM 200+ FT LBS Torque 24.5" HG
Very Light ~~Plus Le~~vel Knock




9-22-75 WJC

#5-2

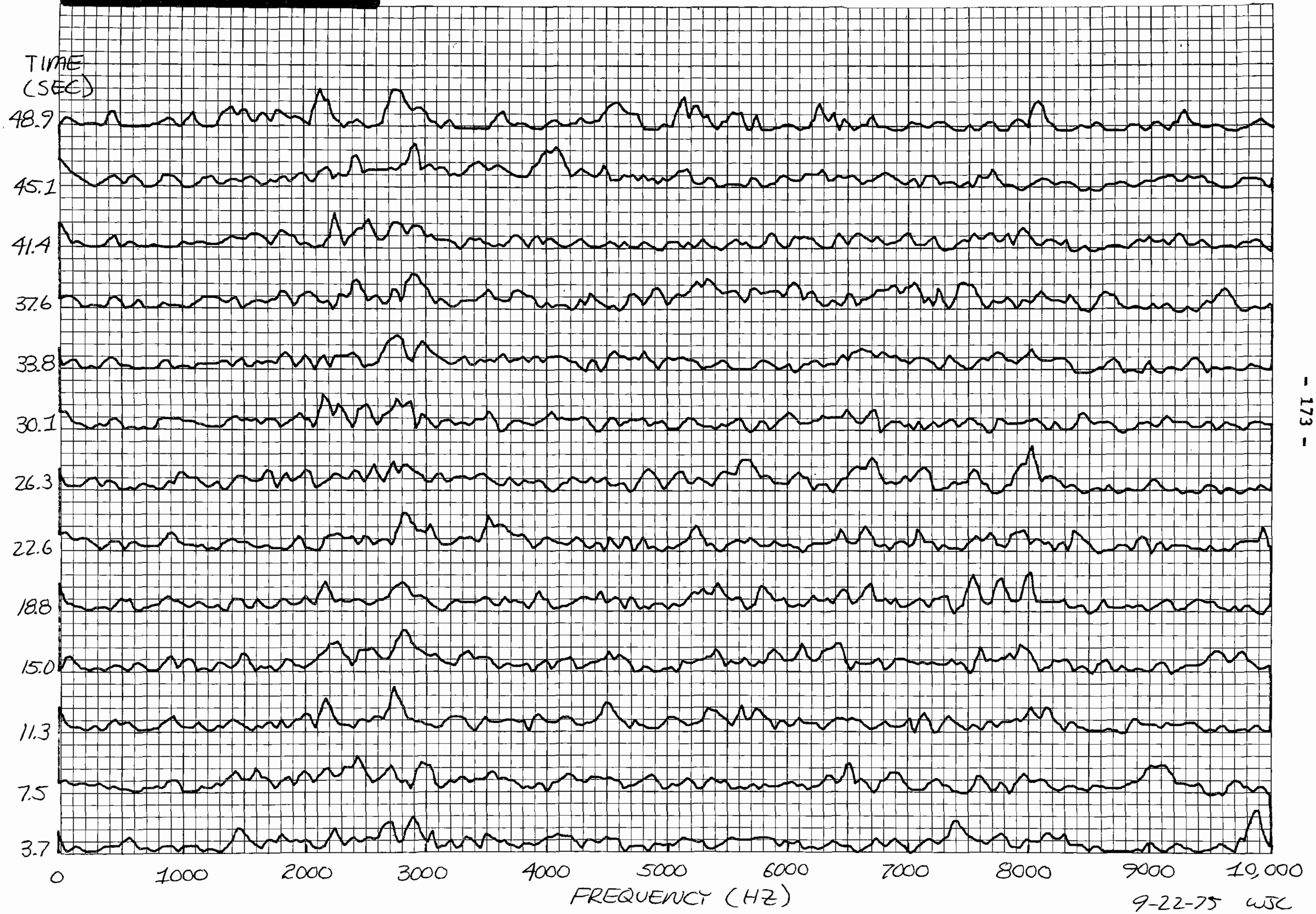
Steady State Test - 78 Octane Fuel
Accelerometer #2 - L.R. Cylinder Head
Vert.
1750 RPM 200+ FT LBS Torque 24.5" HG
Very Light Plus Level Knock




9-22-75 WJC

[redacted]

Accelerometer #3 - R. Intake Manifold
Vert.
1750 RPM 200+ FT LBS Torque 24.5" HG
Very Light Plus Level Knock




9-22-75 WJC

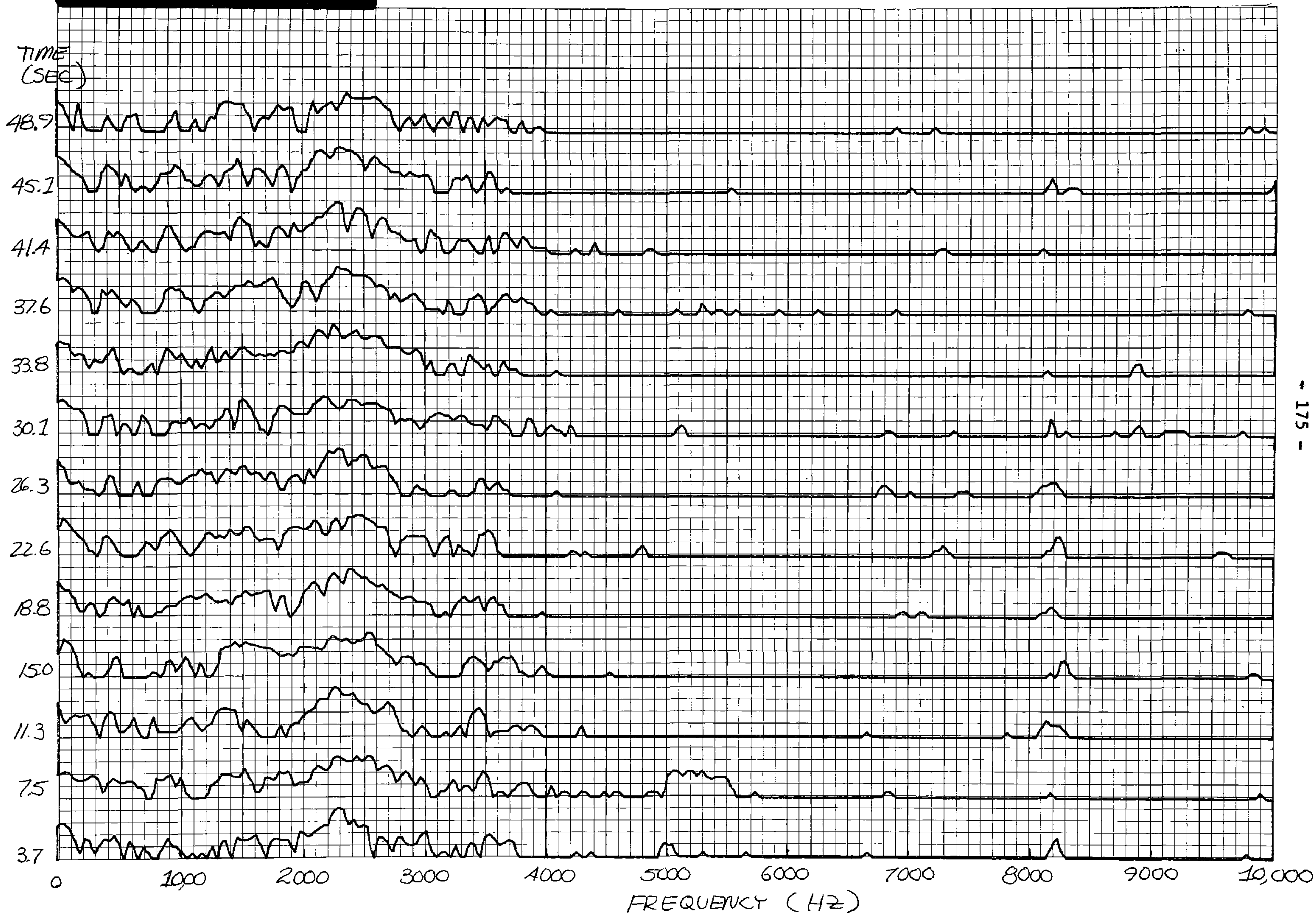
#5-4

Steady State Test - 78 Octane Fuel
Accelerometer #4 - F. Intake Manifold
Vert.
1750 RPM 200+ FT LBS Torque 24.5" HG
Very Light Plus Level Knock

[redacted]

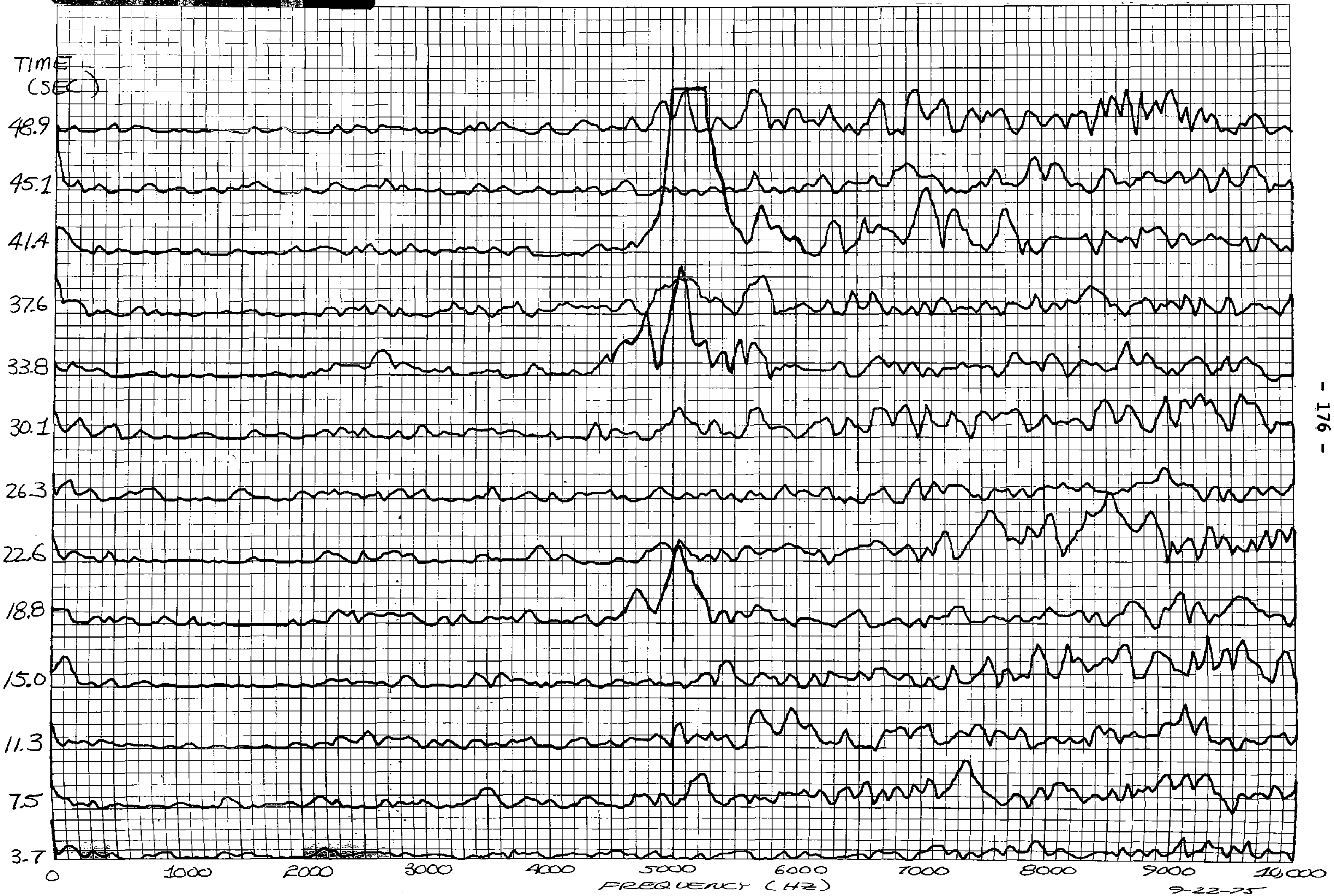
#5-5

Accelerometer #5 - R.F. Cylinder Head
Vert.
1750 RPM 200+ FT LBS Torque 24.5" HG
Very Light Plus Level Knock



#5-6

Steady State Test - 78 Octane Fuel
Accelerometer #6 - R.R. Cylinder Head
Hor.
1750 RPM 200+ FT LBS Torque 24.5" HG
Very Light Plus Level Knock

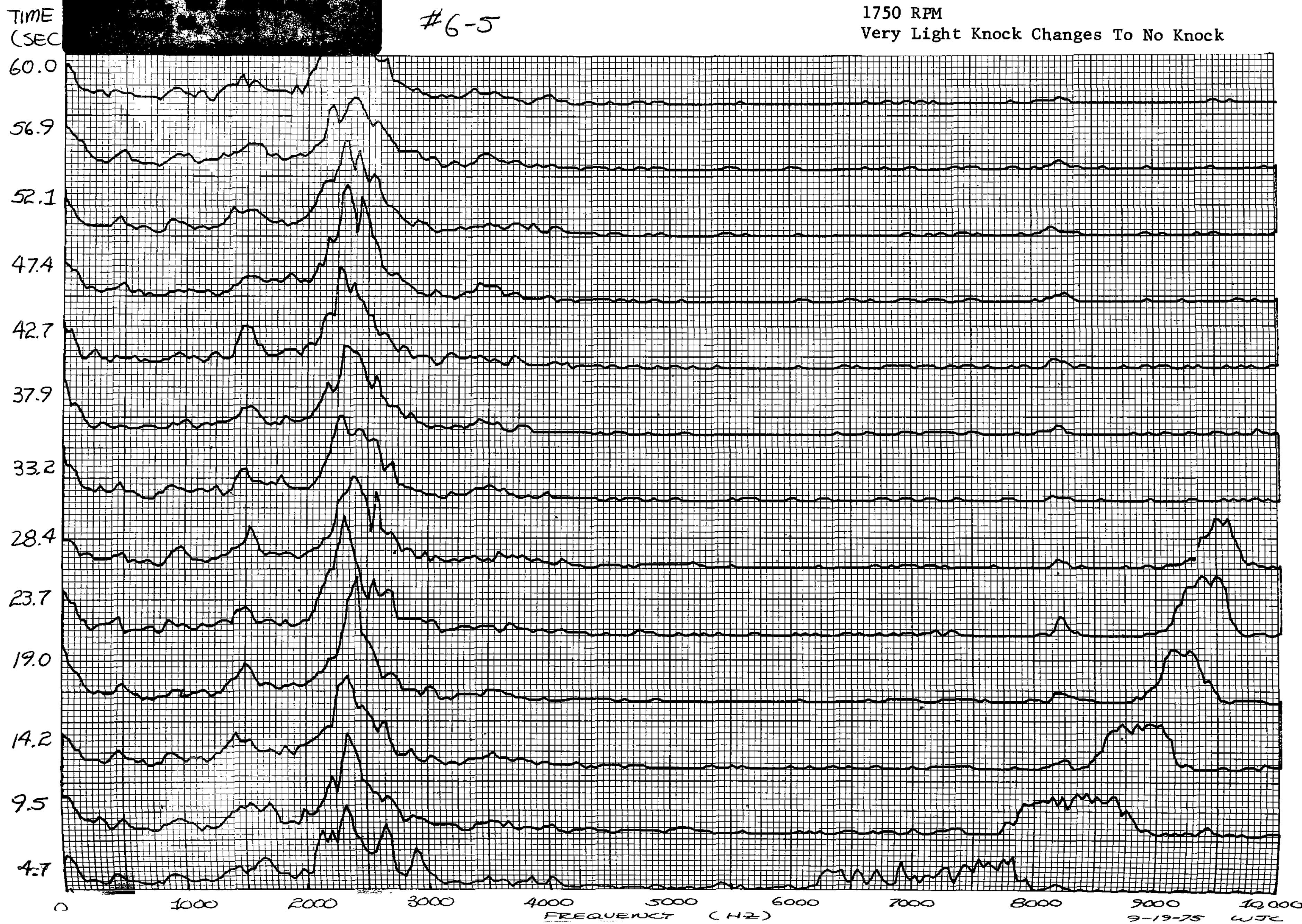


TIME [redacted] #6-4

Accelerometer #4 - F. Intake Manifold
Vert.
1750 RPM
Very Light Knock Changes To No Knock

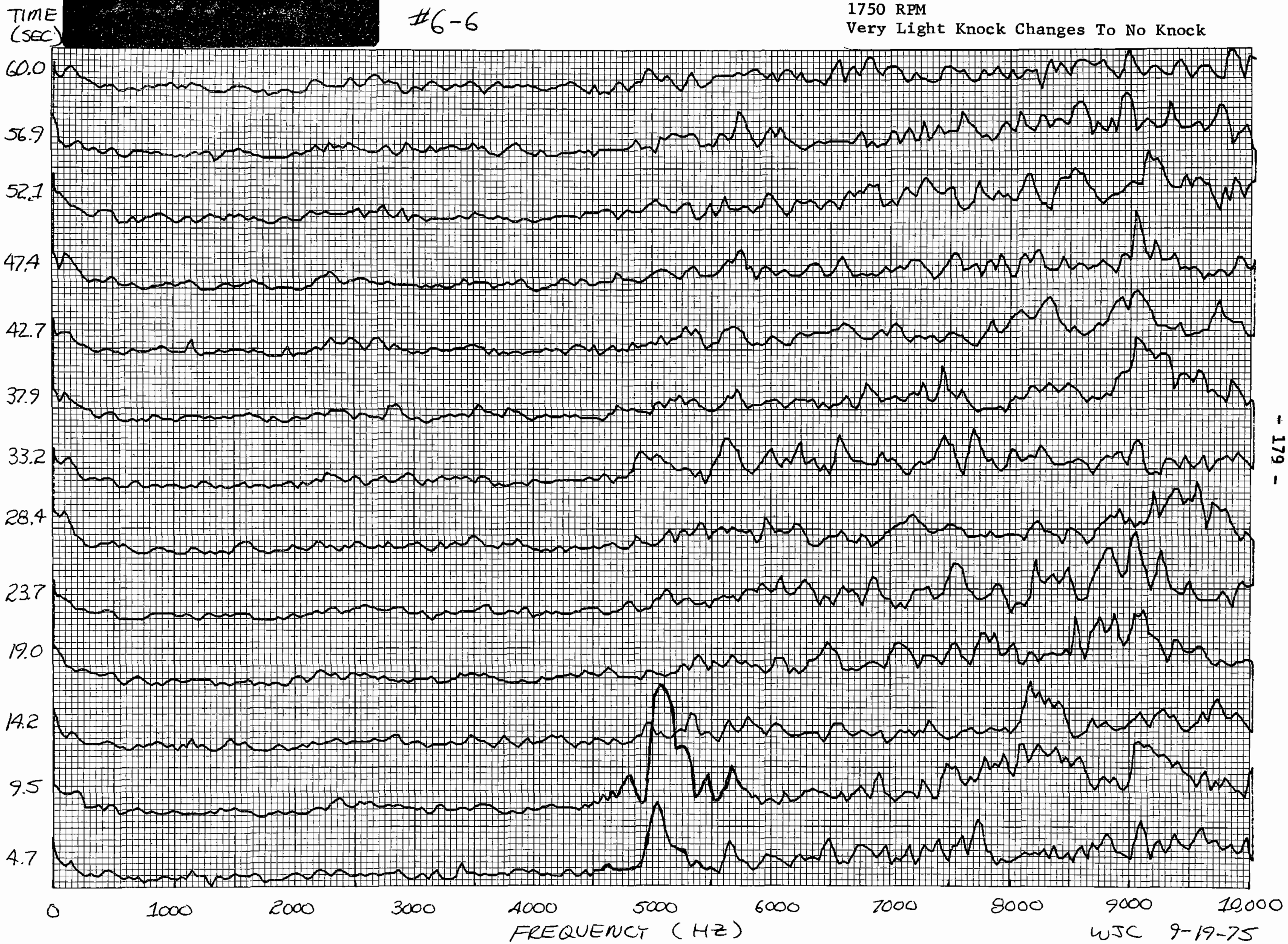

9-19-75 WJC

Fuel Change - 78 Octane To House Fuel
Accelerometer #5 - R.F. Cylinder Head
Vert.
1750 RPM
Very Light Knock Changes To No Knock



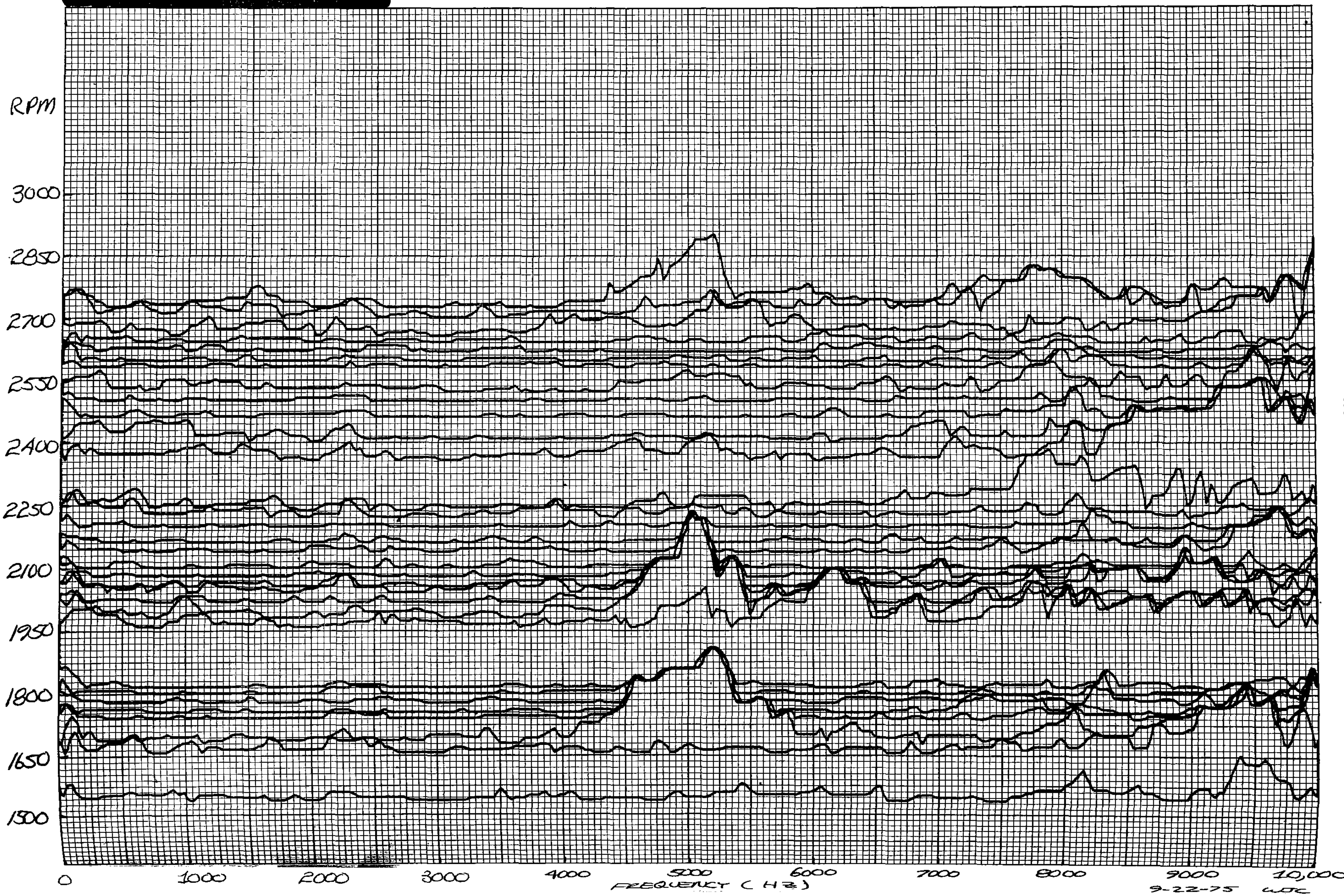

- 178 -

Accelerometer #6 - R.R. Cylinder Head
Hor.
1750 RPM
Very Light Knock Changes To No Knock



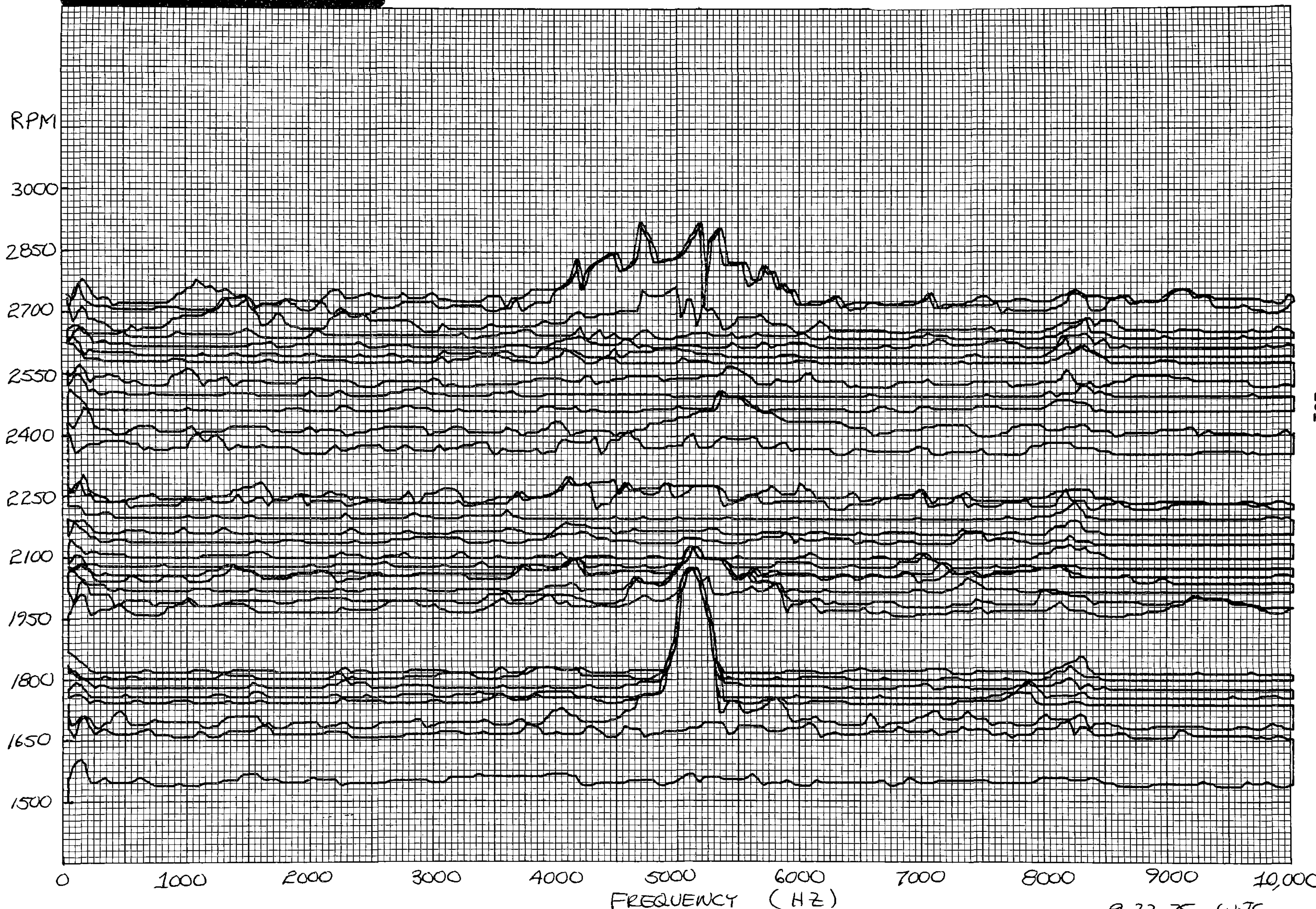
Acceleration Test - 78 Octane Fuel
Accelerometer #1 - L.F. Cylinder Head
Vert.
1700 70 2900 RPM
No Knock To Light Minus Knock

#1-1



[redacted] #7-2

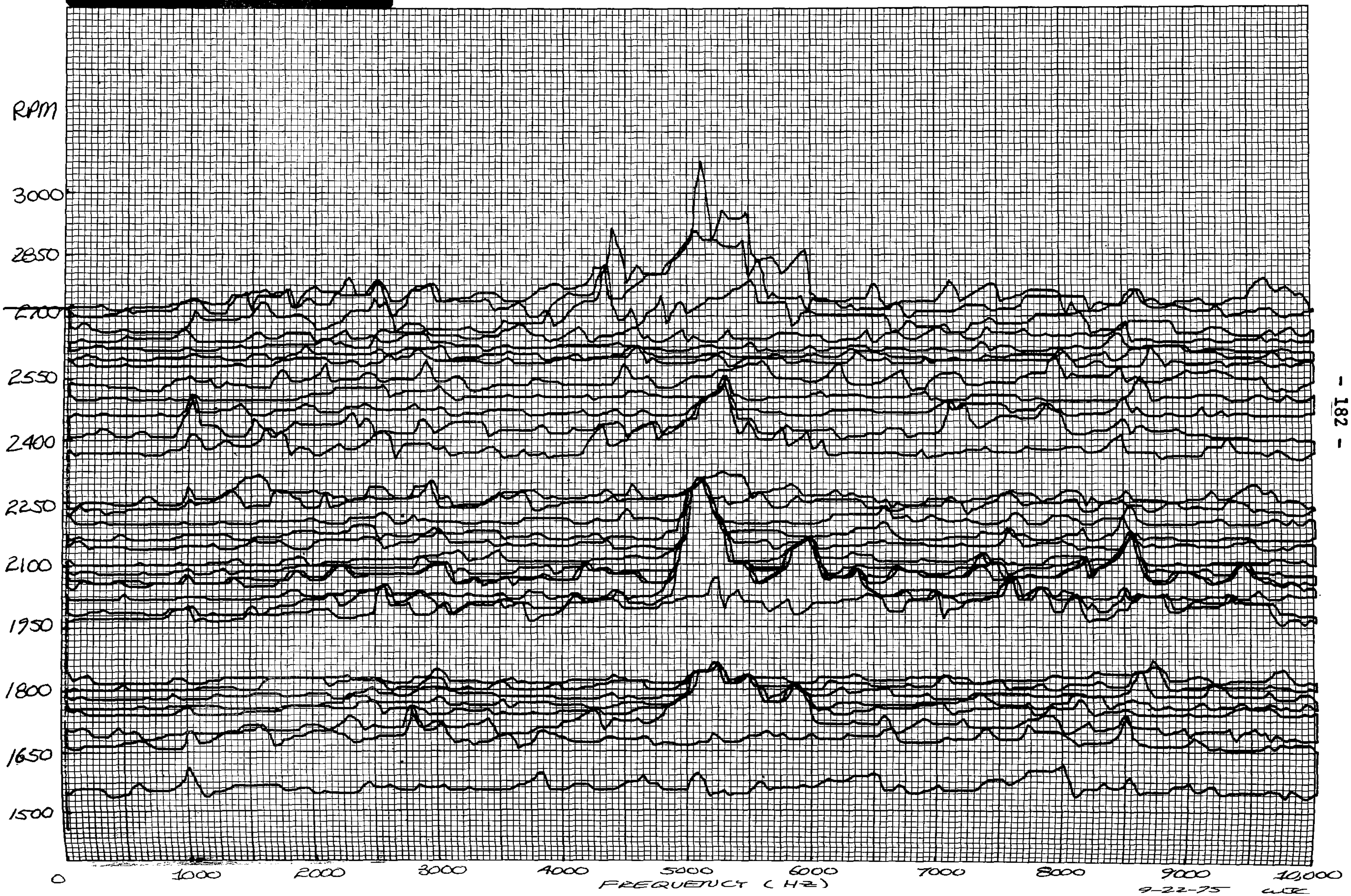
Vert.
1700 70 2900 RPM
No Knock To Light Mimus Knock




9-22-75 WJC

Acceleration Test - 78 Octane Fuel
Accelerometer #3 - R. Intake Manifold
Vert.
1700 70 2900 RPM
No Knock To Light Minus Knock

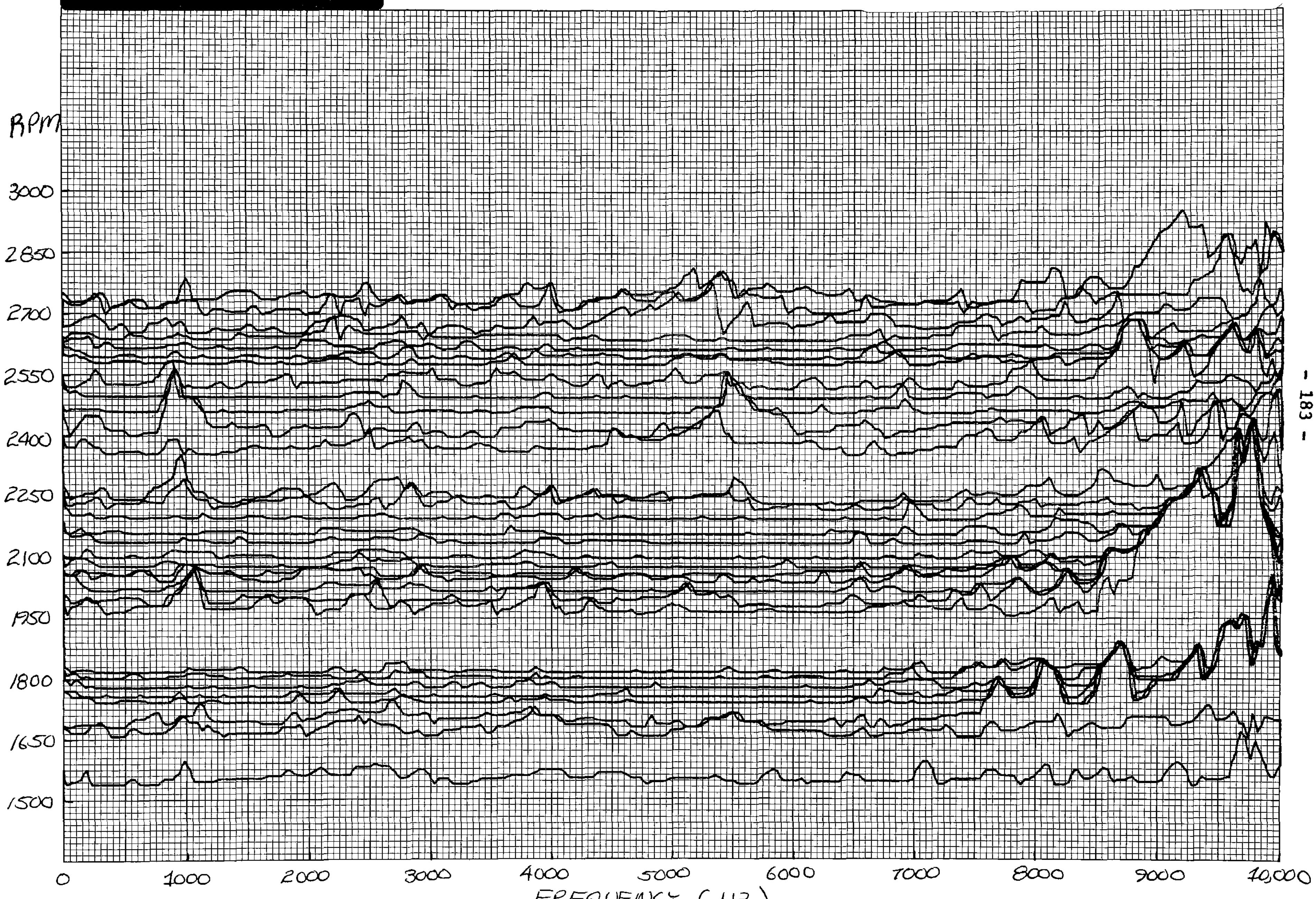
#7-3



[redacted]

#7-A

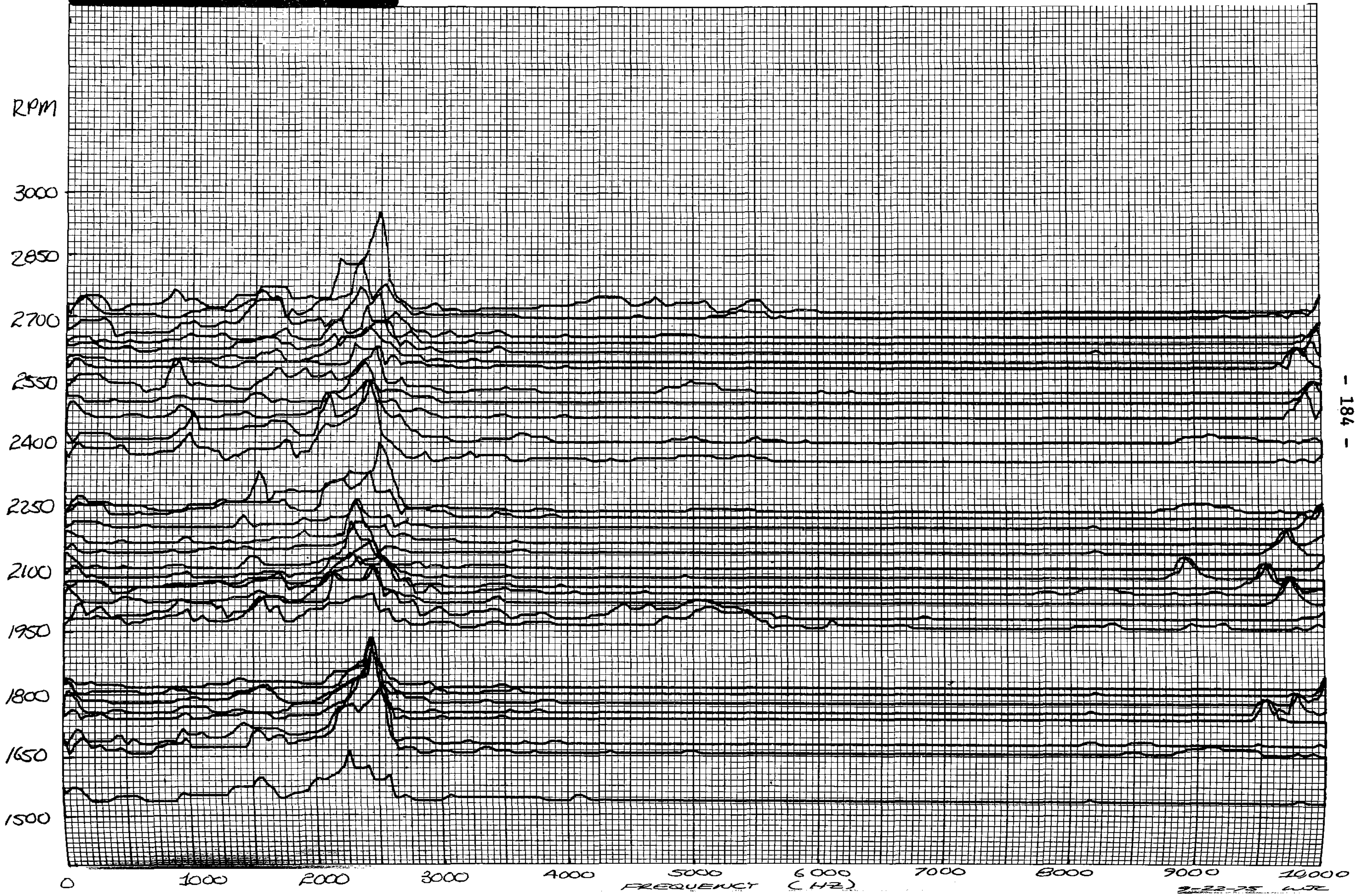
Accelerometer #4 - F. Intake Manifold
Vert.
1700 70 2900 RPM
No Knock To Light Minus Knock




9-22-75 WJC

\# 7-5

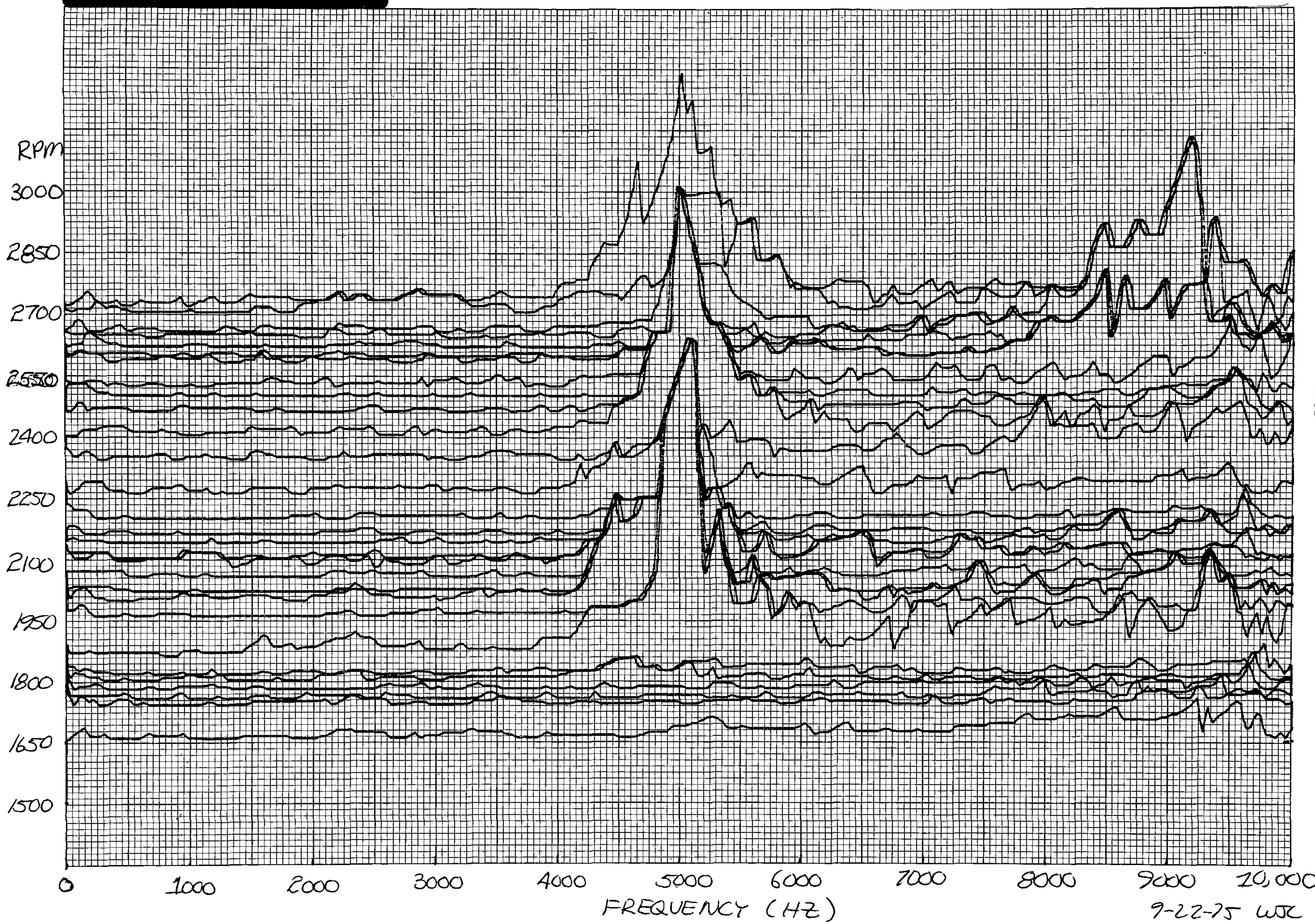
Acceleration Test - 78 Octane Fuel
Accelerometer #5 - R.F. Cylinder Head
Vert.
1700 70 2900 RPM
No Knock To Light Minus Knock



[redacted]

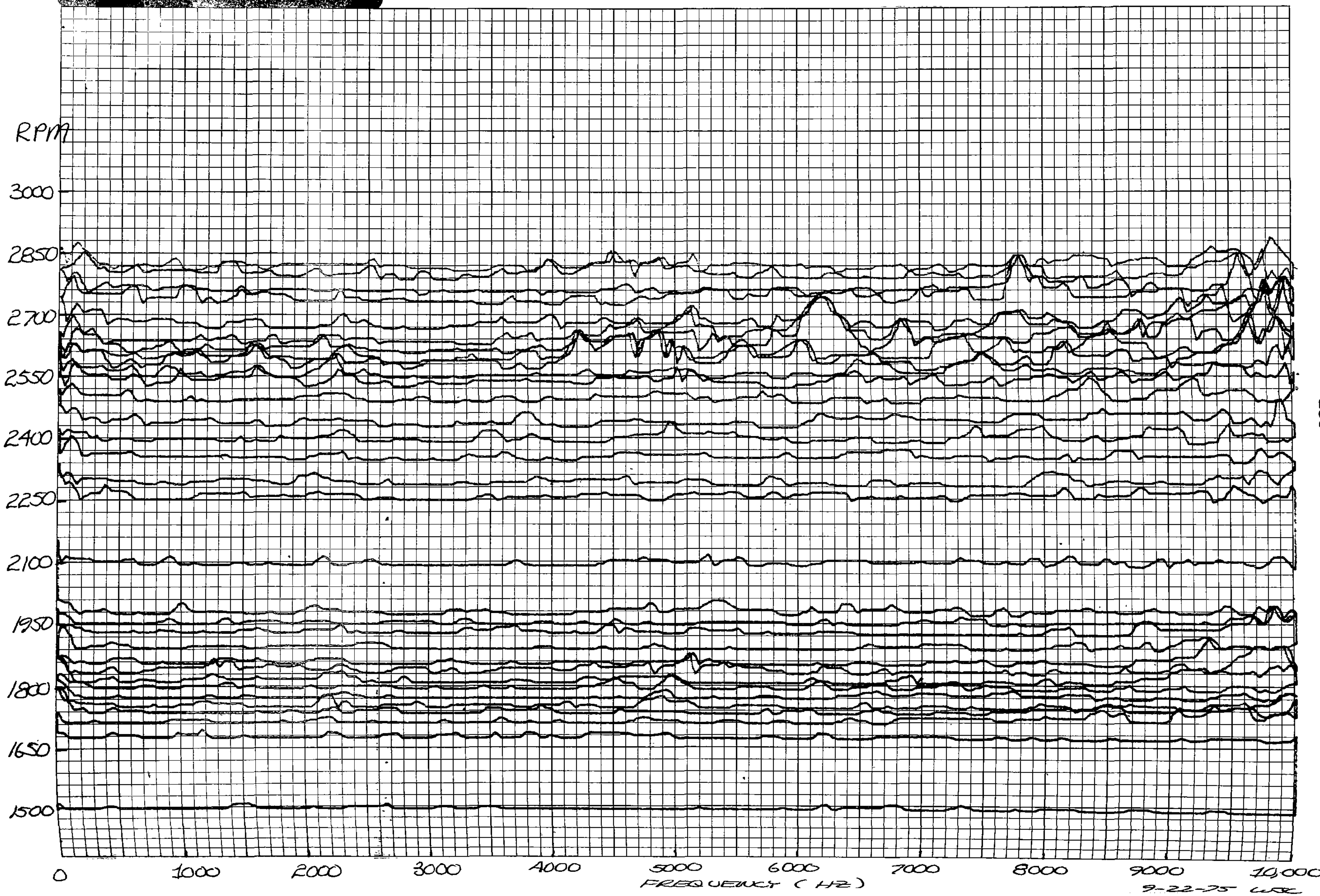
#7-6

Accelerometer #6 - R.R. Cylinder Head
Hor.
1700 70 2900 RPM
No Knock To Light Minus Knock



Acceleration Test - 78 Octane Fuel
Accelerometer #1 - L.F. Cylinder Head
Vert.
1700 to 2900 RPM

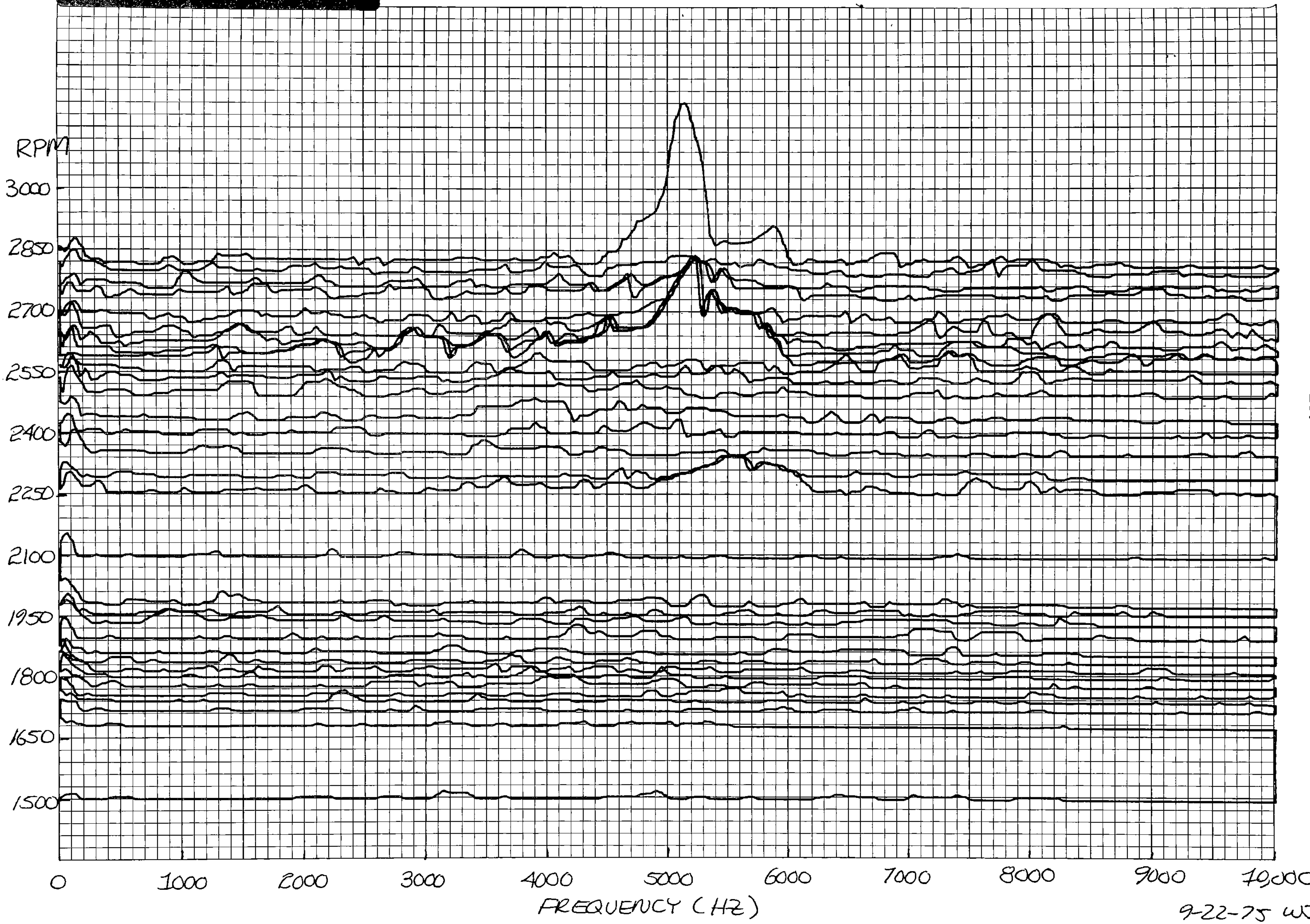
#8-1



[redacted]

#8-2

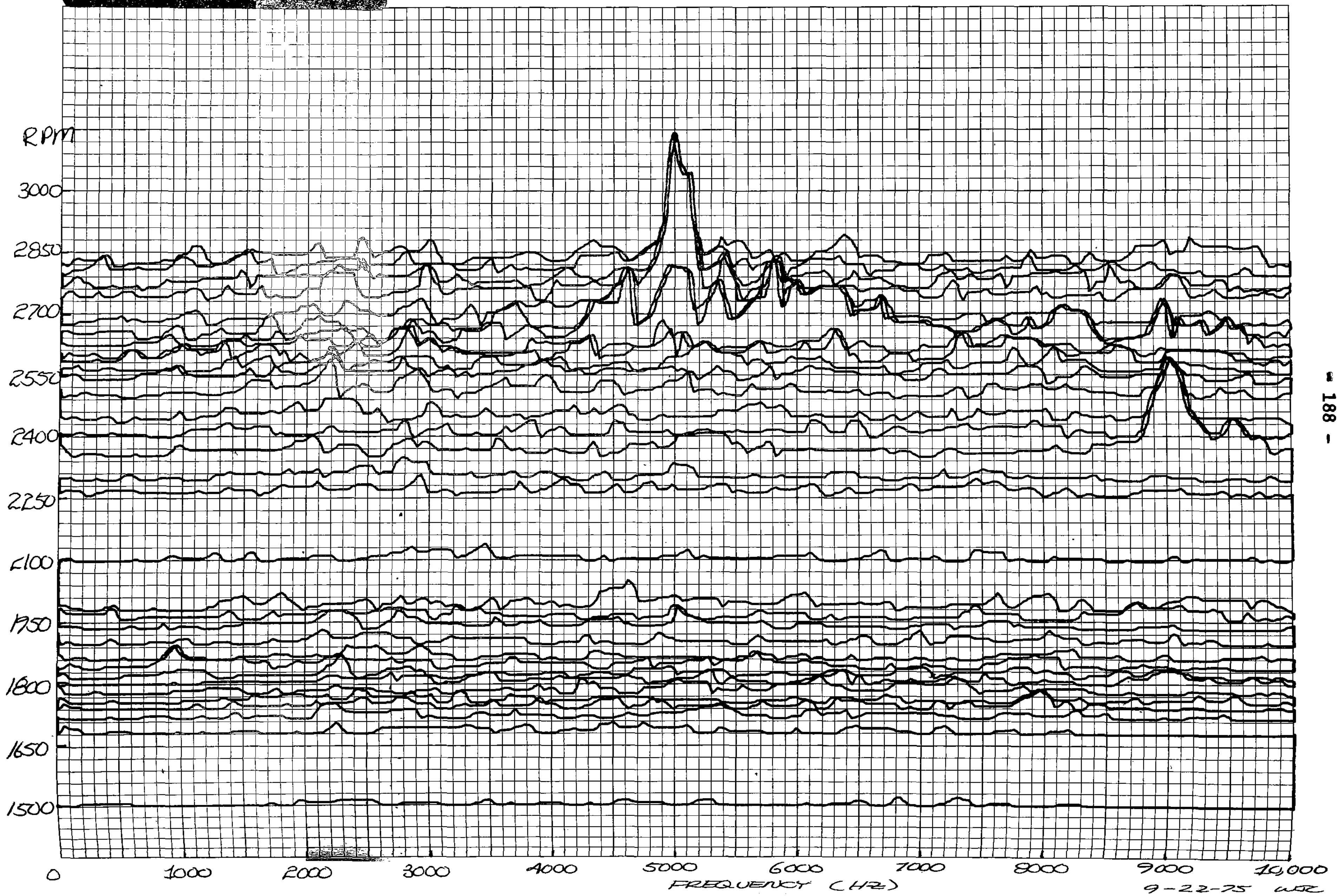
Accelerometer #2 - L.R. Cylinder Head
Vert.
1700 to 2900 RPM




9-22-75 WJC

#8-3

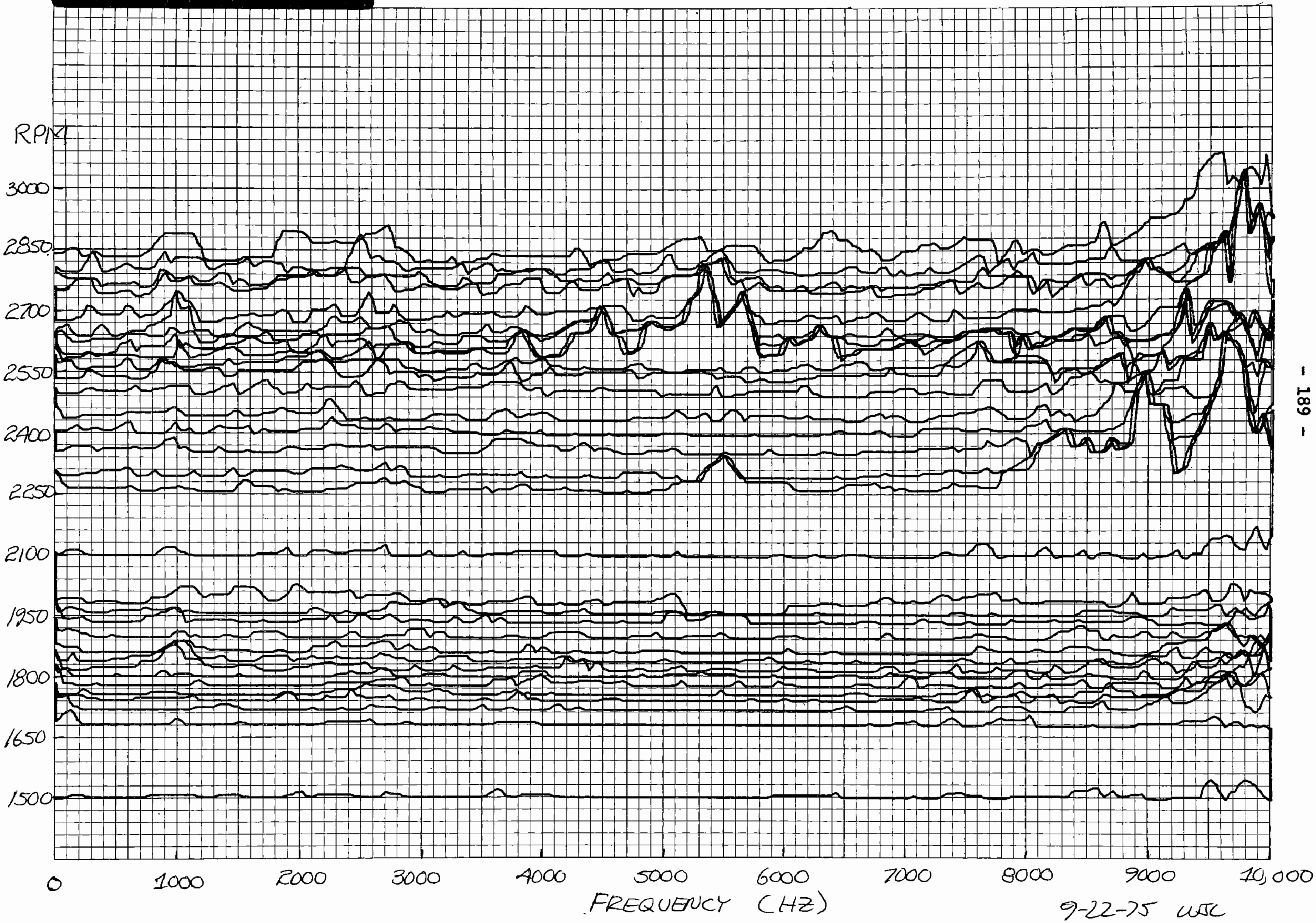
Acceleration Test - 78 Octane Fuel
Accelerometer #3 - R. Intake Manifold
Vert.
1700 to 2900 RPM



[redacted]

#8-4

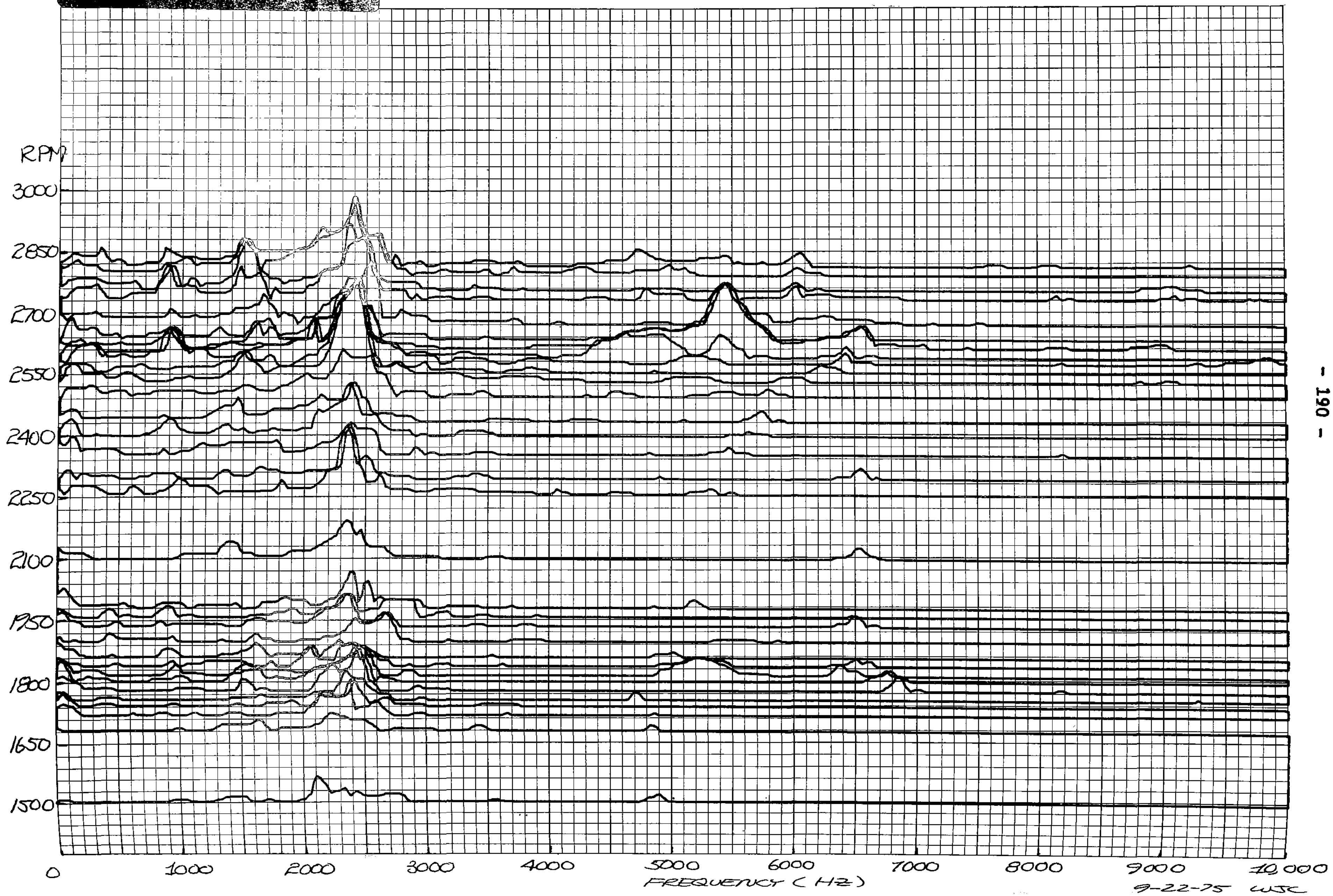
Accelerometer #4 - F. Intake Manifold
Vert.
1700 to 2900 RPM




9-22-75 WJC

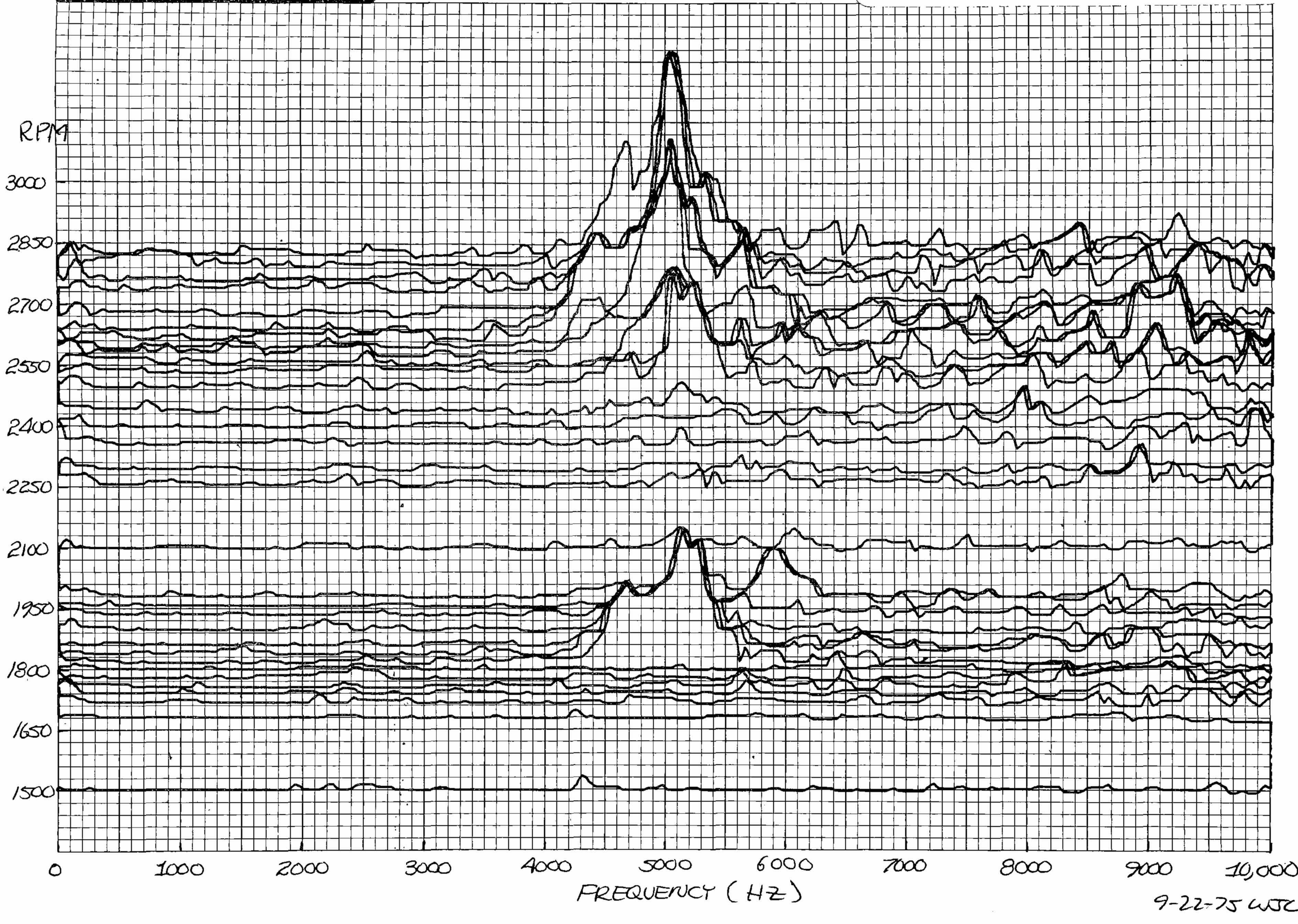
#8-5

Acceleration Test - 78 Octane Fuel
Accelerometer #5 - R.F. Cylinder Head
Vert.
1700 to 2900 RPM



[redacted] #8-6

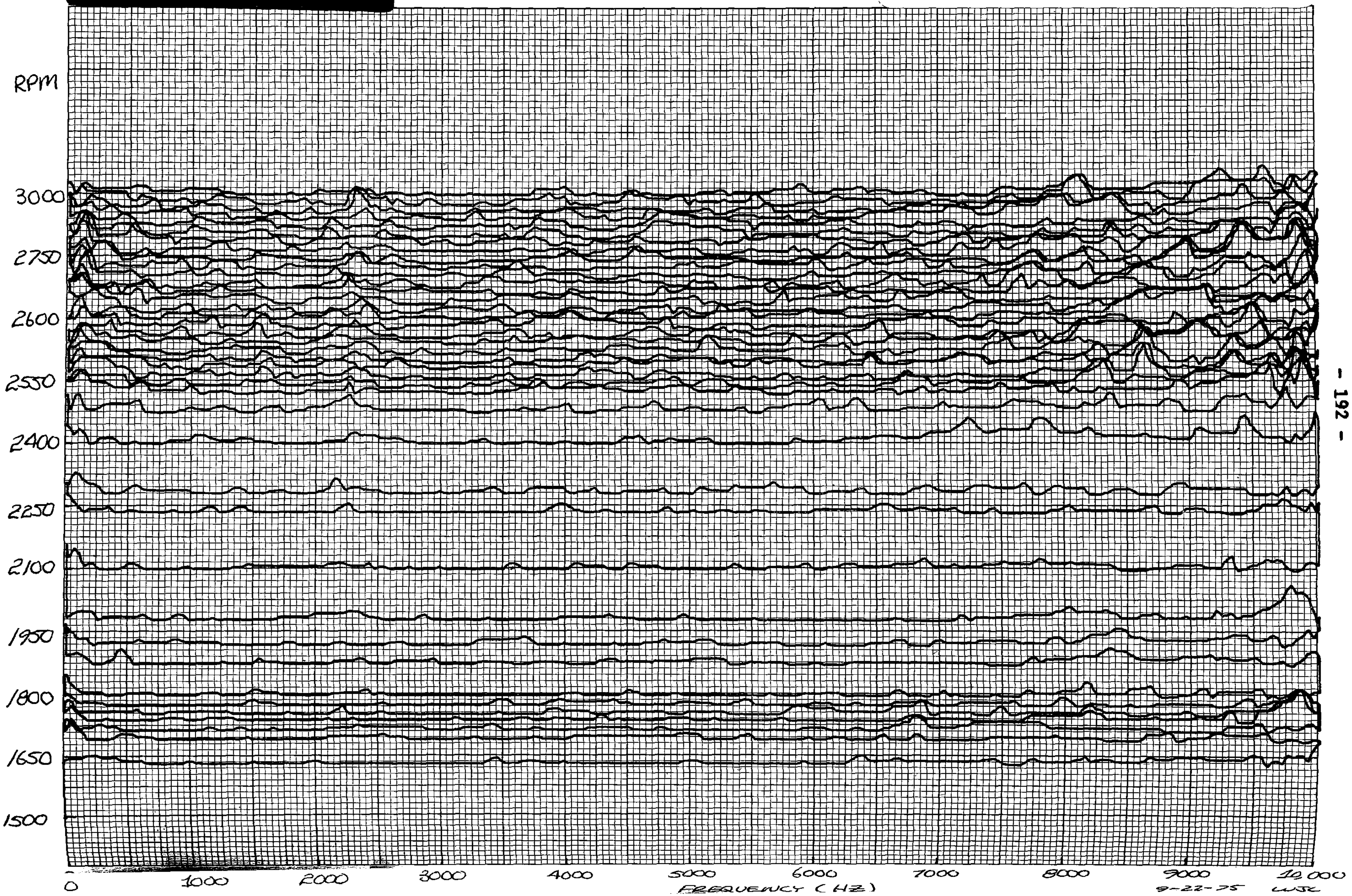
Accelerometer #6 - R.R. Cylinder Head
Hor.
1700 to 2900 RPM



[redacted]

#9-1

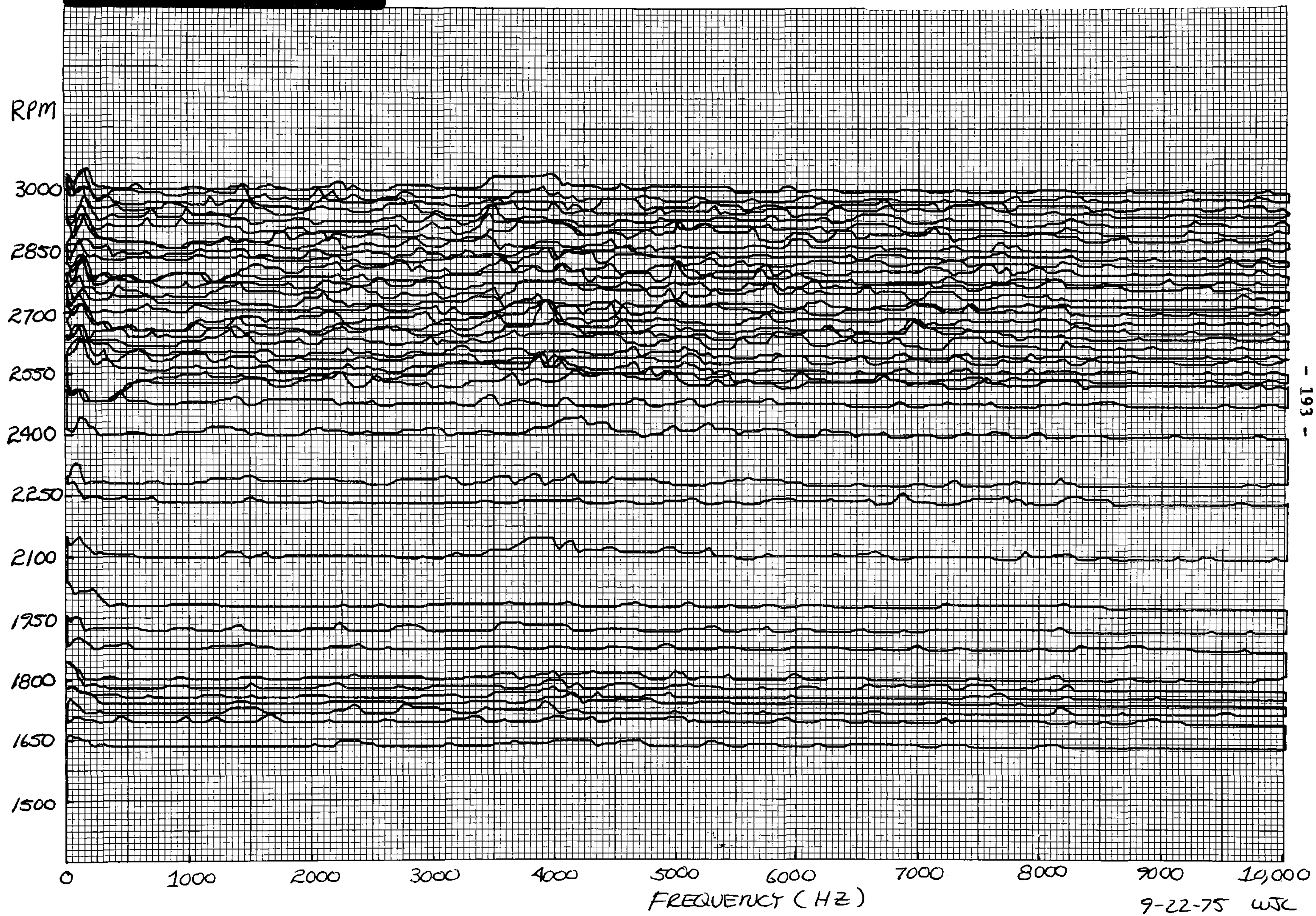
Acceleration Test - House Fuel
Accelerometer #1 - L.F. Cylinder Head
Vert.
1700 to 2800 RPM
No Knock Detected



[redacted]

#9-2

Accelerometer #2 - L.R. Cylinder Head
Vert.
1700 to 2800 RPM
No Knock Detected

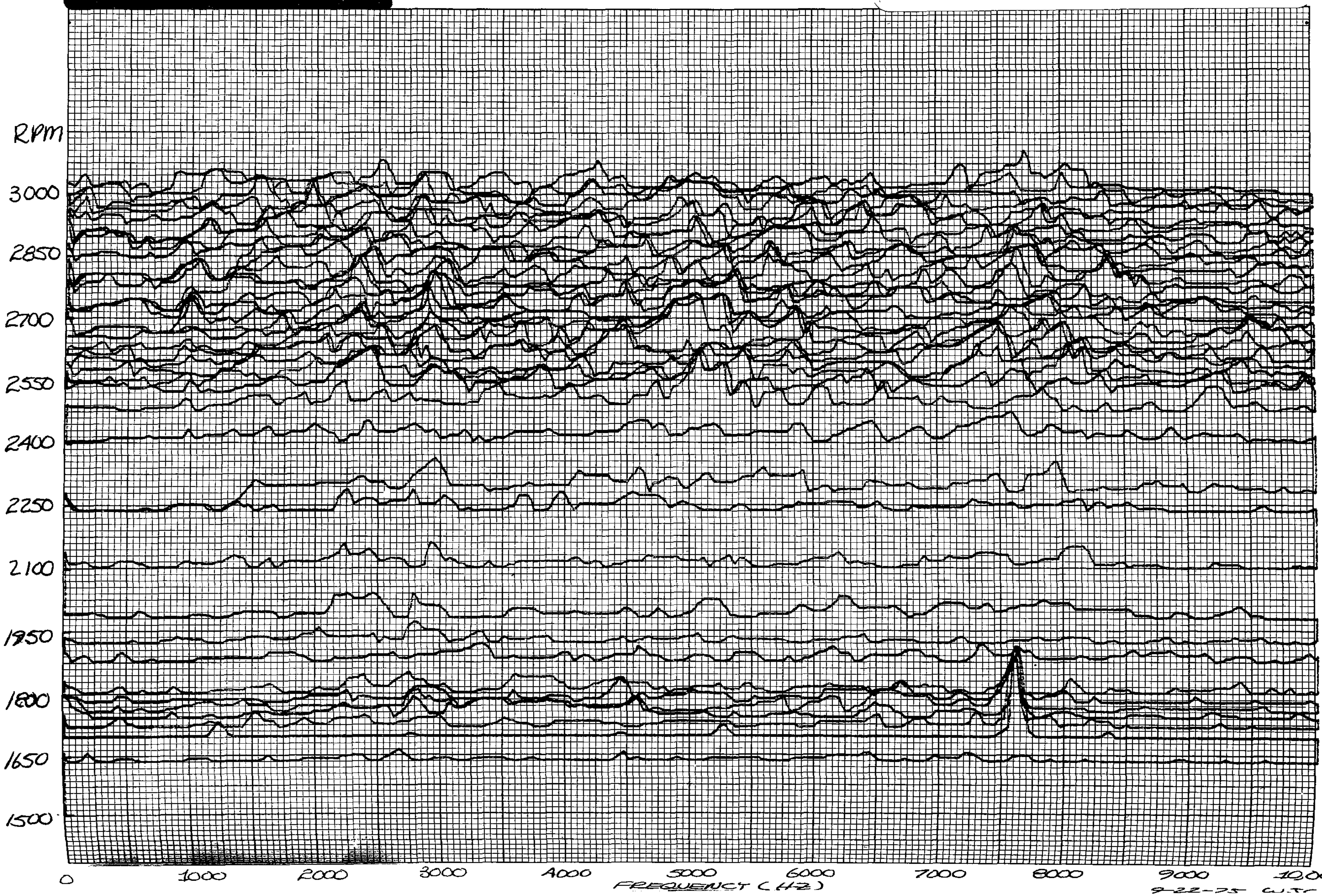



9-22-75 WJC

[redacted]

#9-3

Acceleration Test - House Fuel
Accelerometer #3 - R. Intake Manifold
Vert.
1700 to 2800 RPM
No Knock Detected

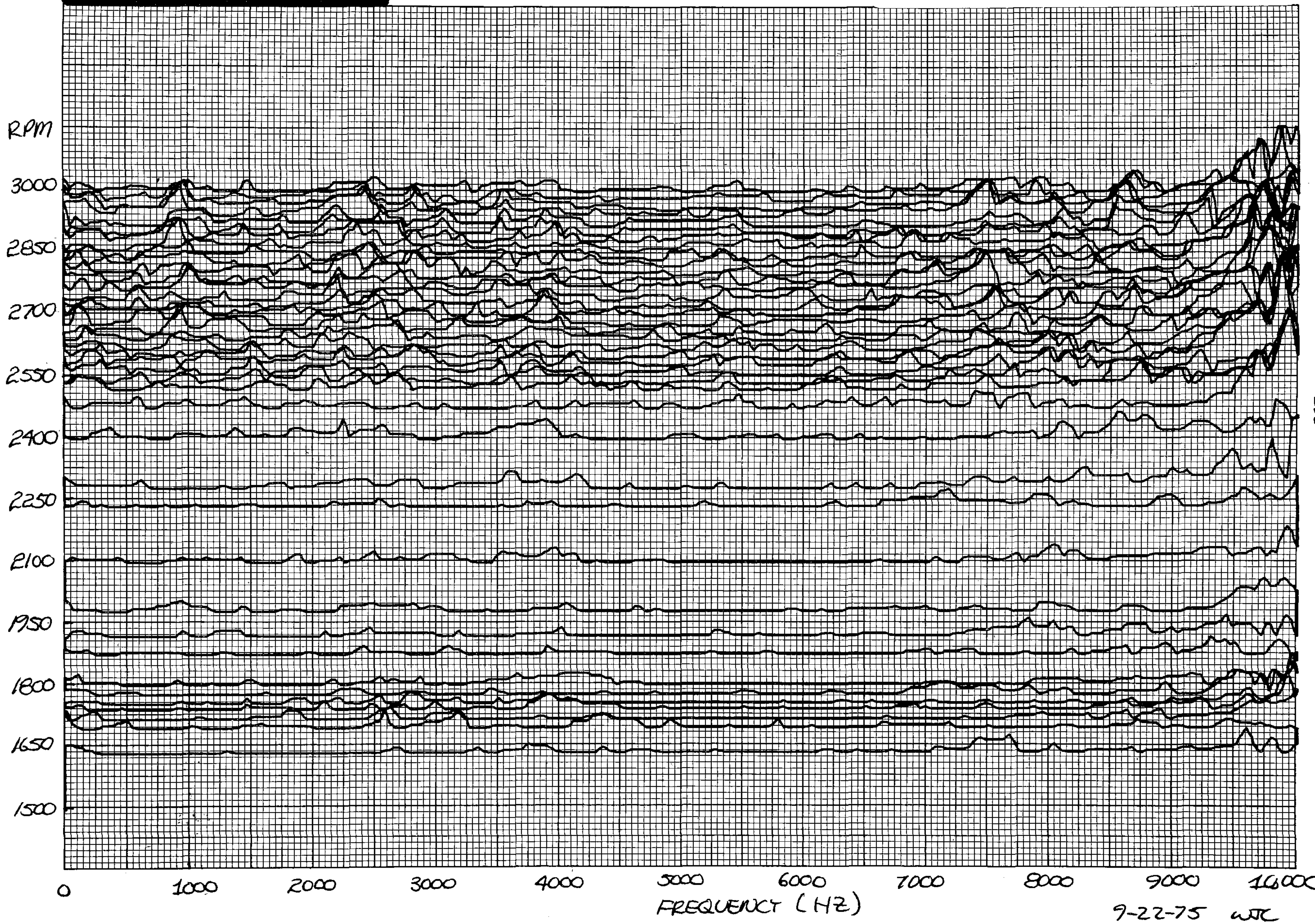



9-22-75 W.J.C.

[redacted]

#9-4

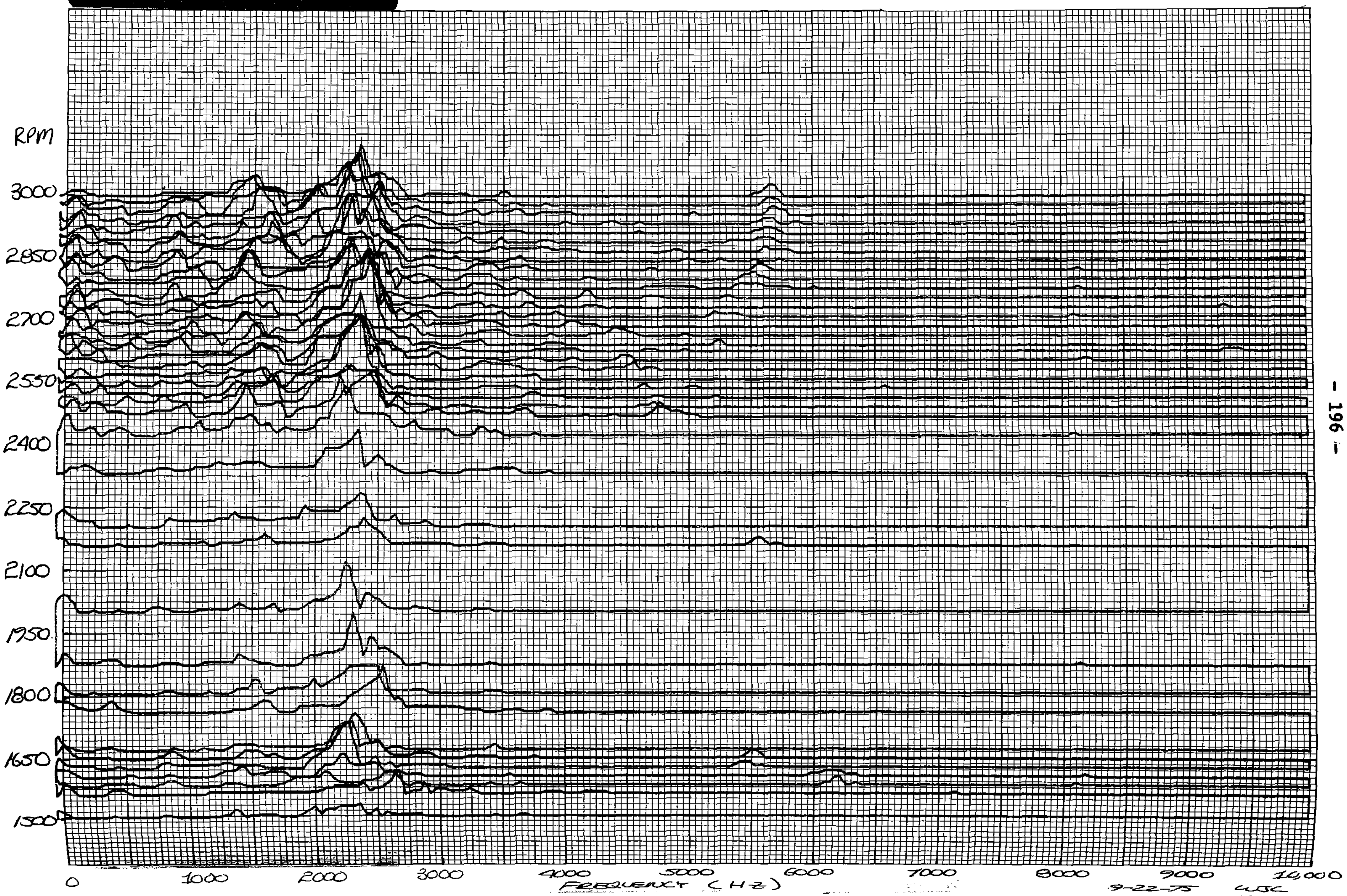
Accelerometer #4 - F. Intake Manifold
Vert.
1700 to 2800 RPM
No Knock Detected




9-22-75 wJC

[redacted] #9-5

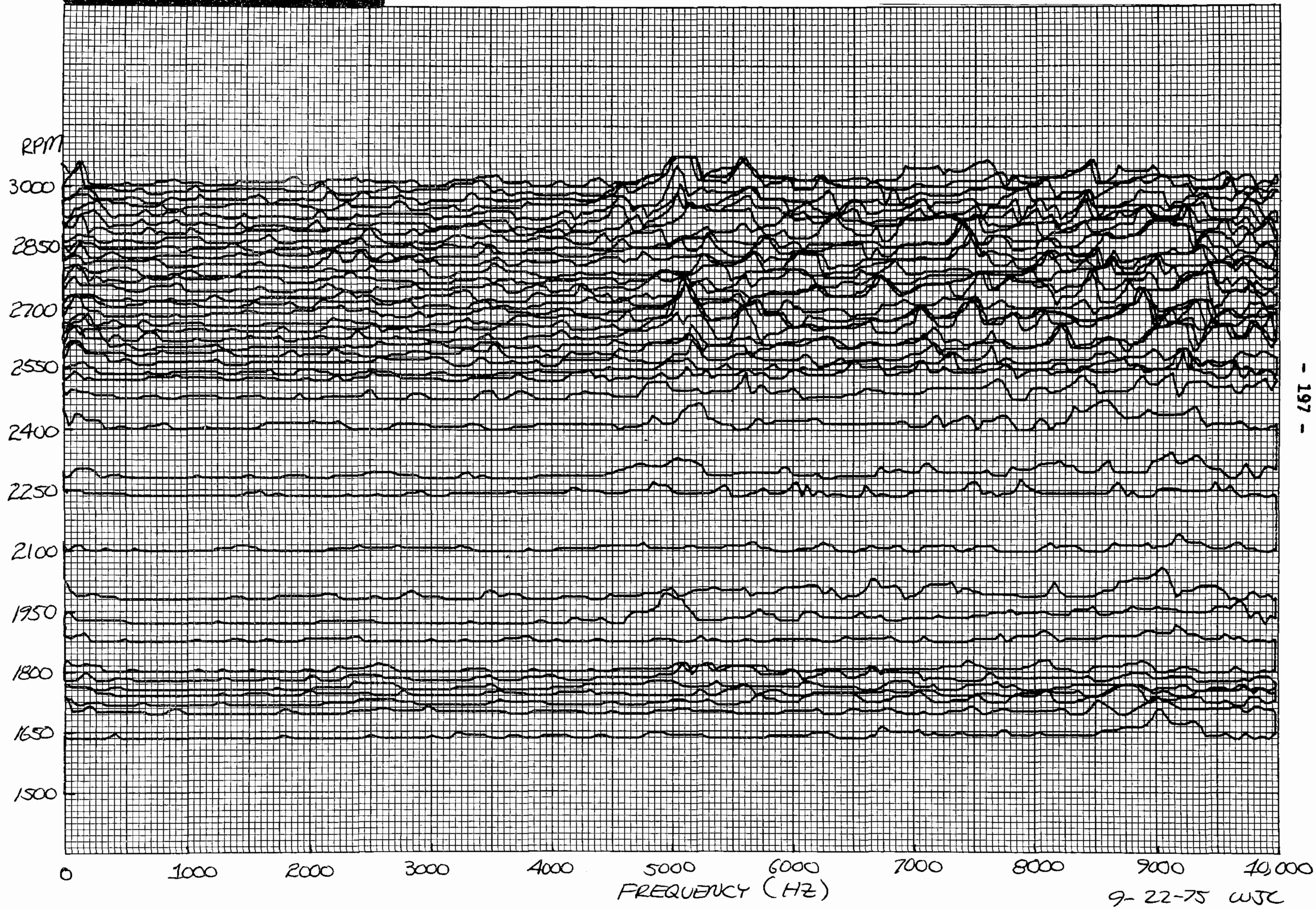
Acceleration Test - House Fuel
Accelerometer #5 - R.F. Cylinder Head
Vert.
1700 to 2800 RPM
No Knock Detected



[redacted]

#9-6

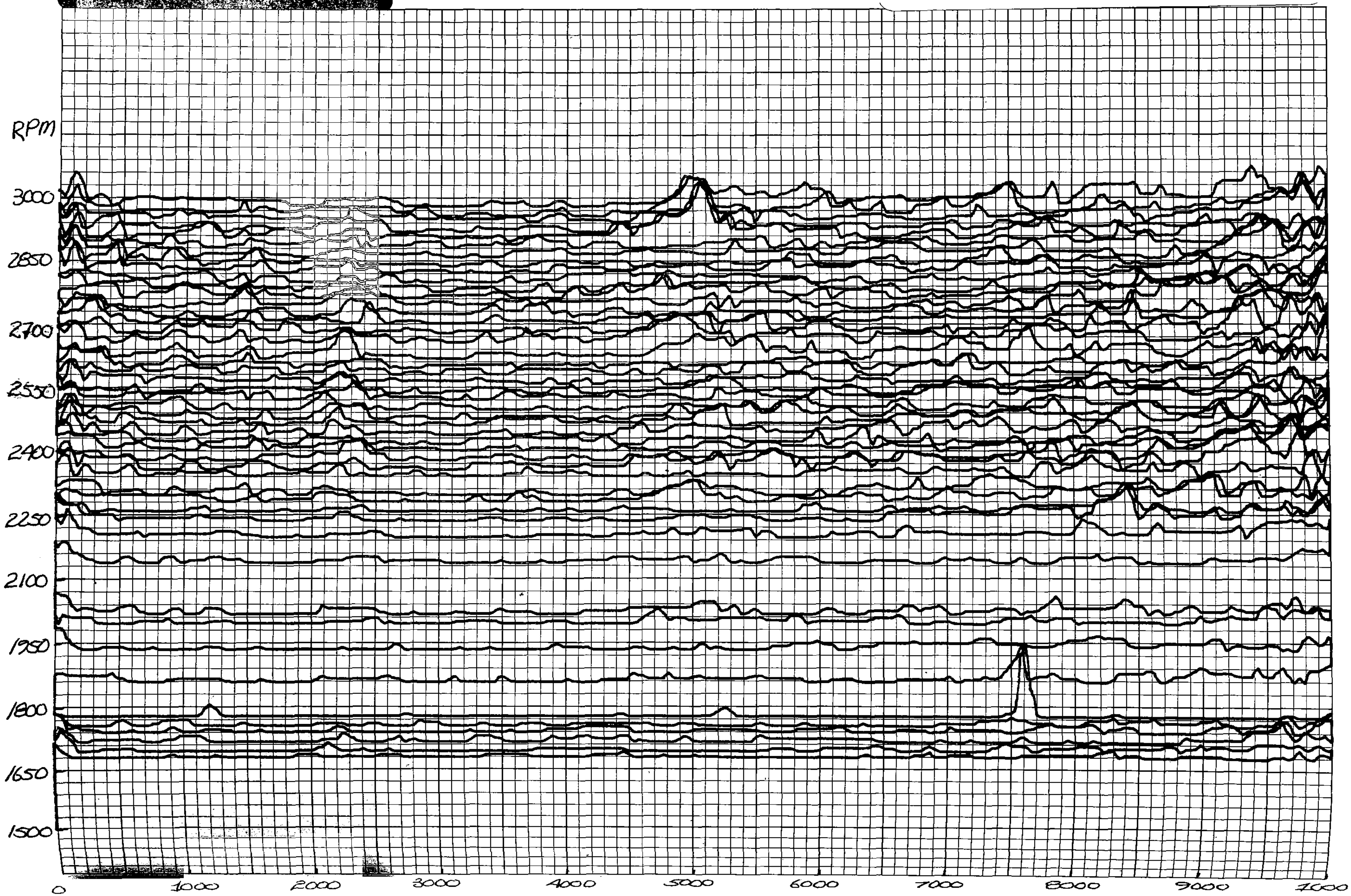
Accelerometer #6 - R.R. Cylinder Head
Hor.
1700 to 2800 RPM
No Knock Detected




9-22-75 WJC

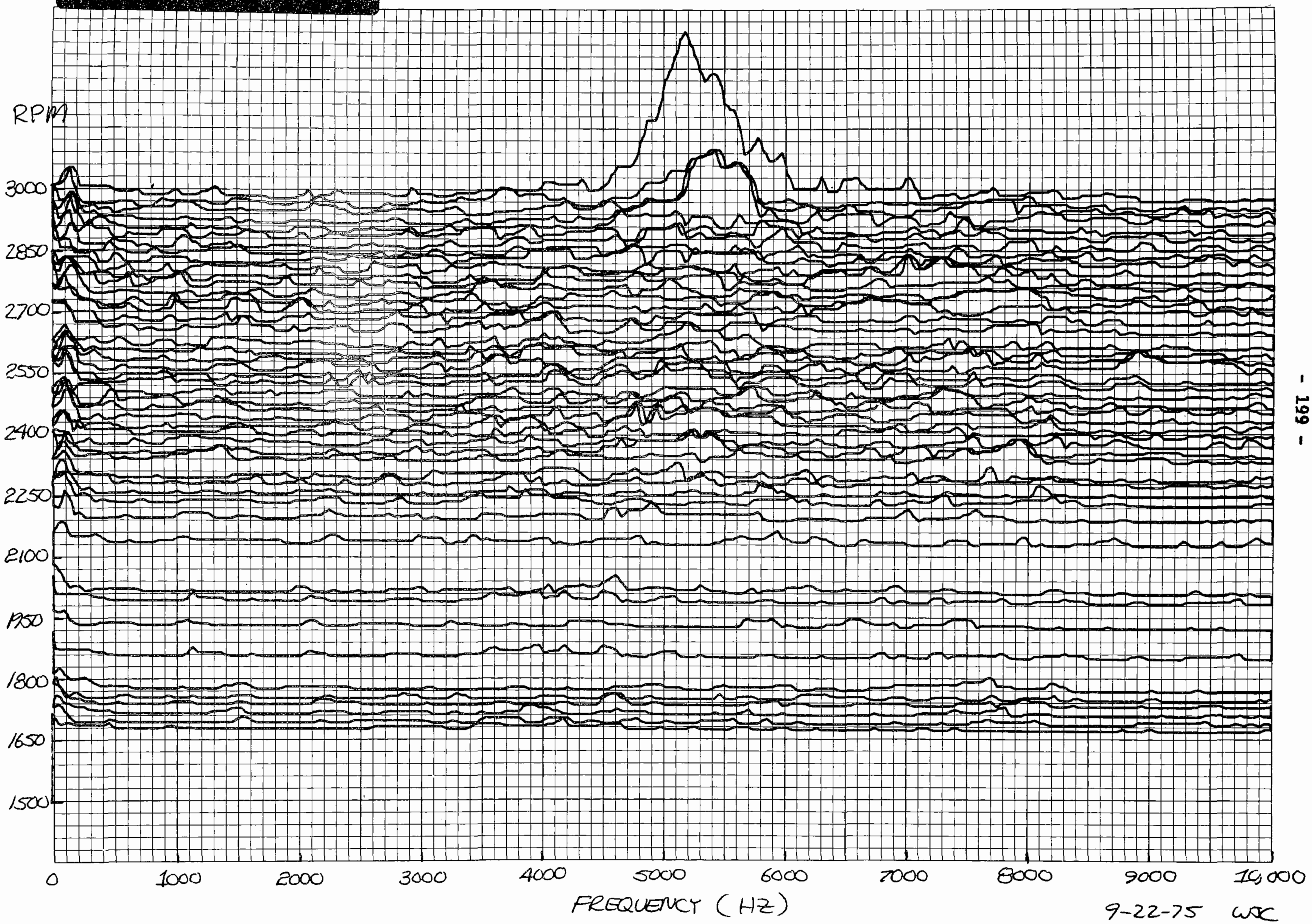
Acceleration Test - 82 Octane Fuel
Acceler[redacted]ter #1 - L.F. Cylinder Head
Vert.
1750 to 3000 RPM
No Knock [redacted] Very Light Knock

#10-1



[redacted] #10-2

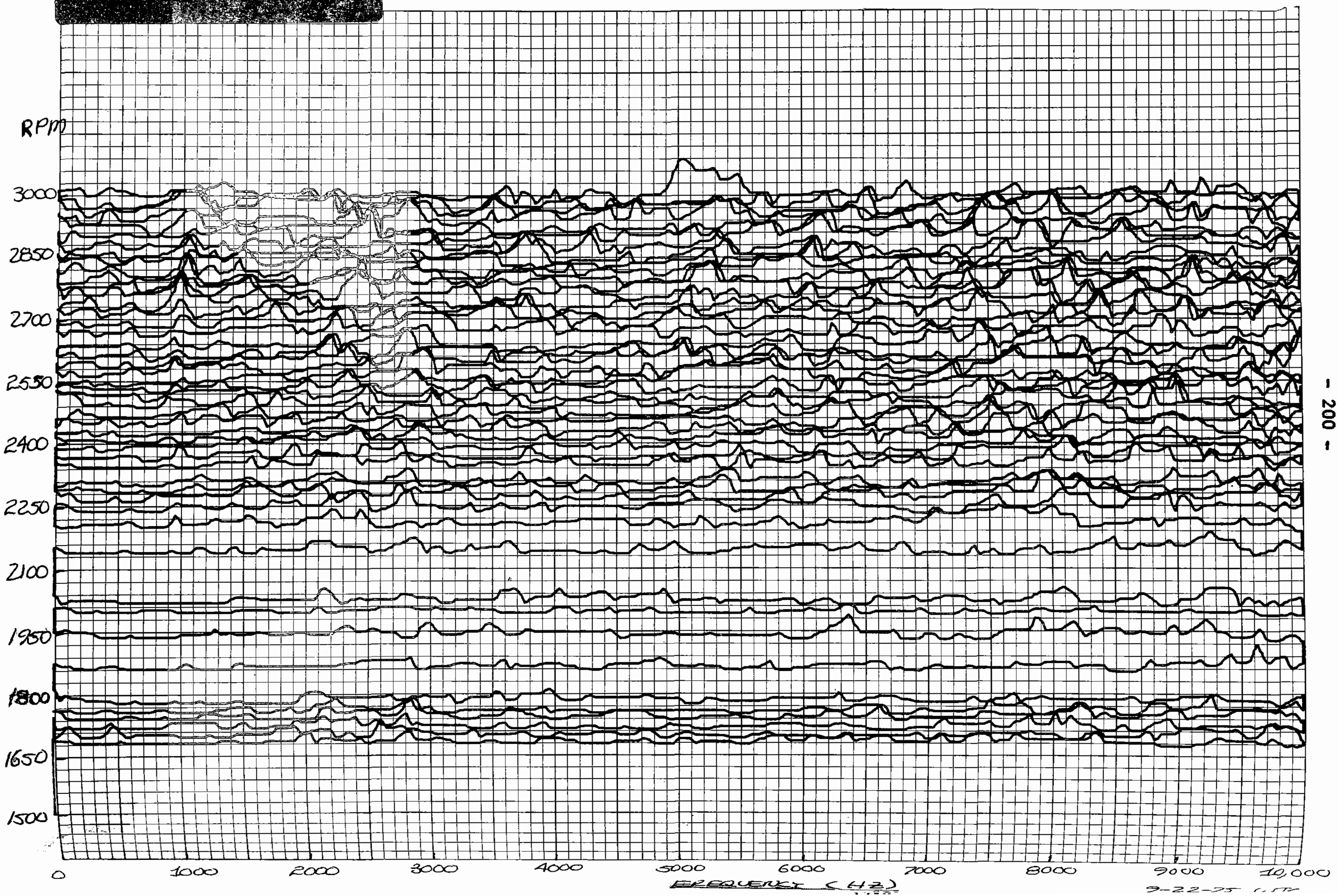
Vert.
1750 to 3000 RPM
No Knock To Very Light Knock




9-22-75 WJC

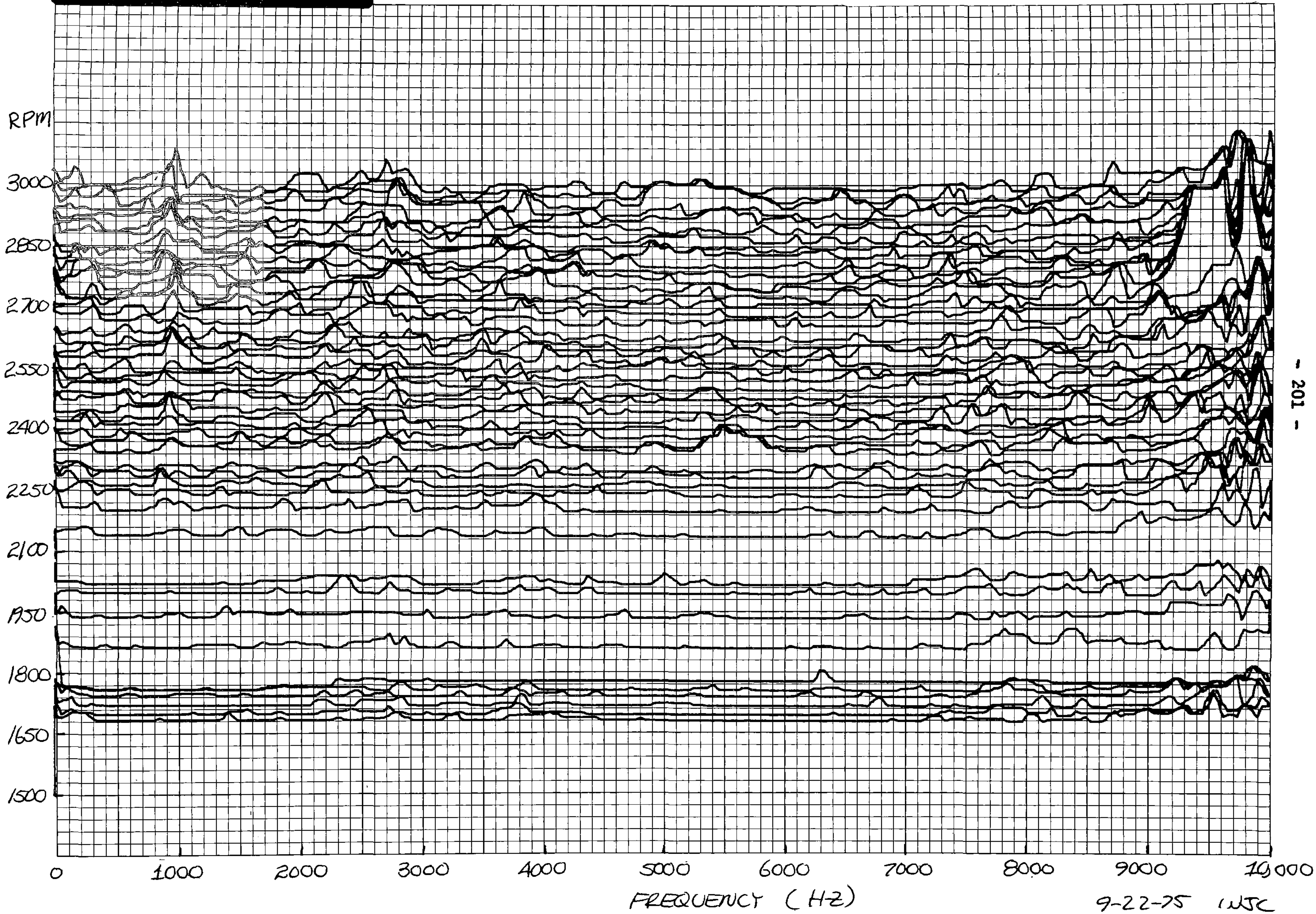
Acceleration Test - 82 Octane Fuel
Accelerometer #3 - R. Intake Manifold
Vert.
1750 to 3000 RPM
To Knock To Very Light Knock

#10-3



[redacted] #10-4

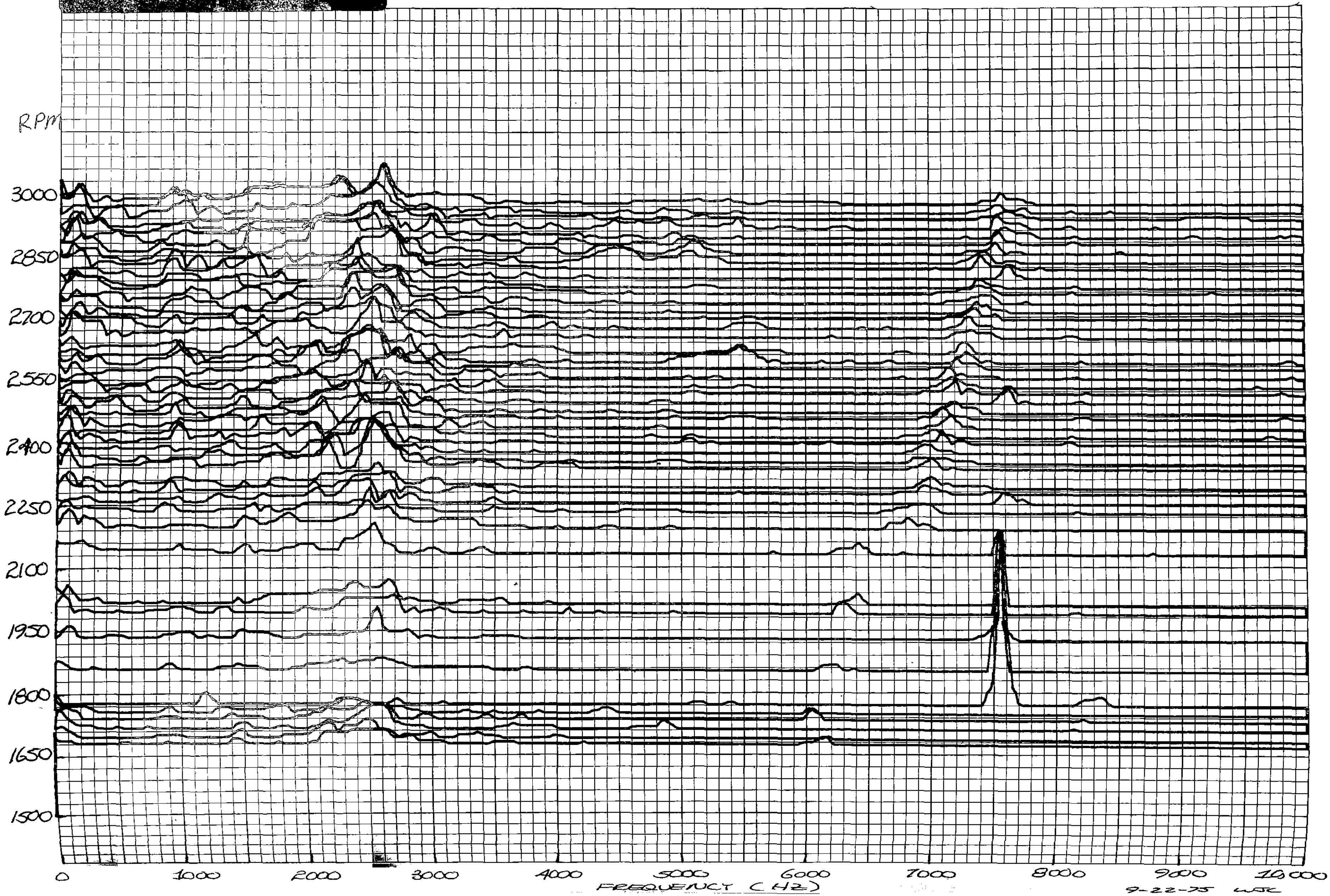
Vert.
1750 to 3000 RPM
To Knock To Very Light Knock




9-22-75 WJC

**Acceleration Test - 82 Octane Fuel**
**Accelerometer #5 - R.F. Cylinder Head Vert.**
**~~1750 to~~ 3000 RPM**
**To Knock To Very Light Knock**

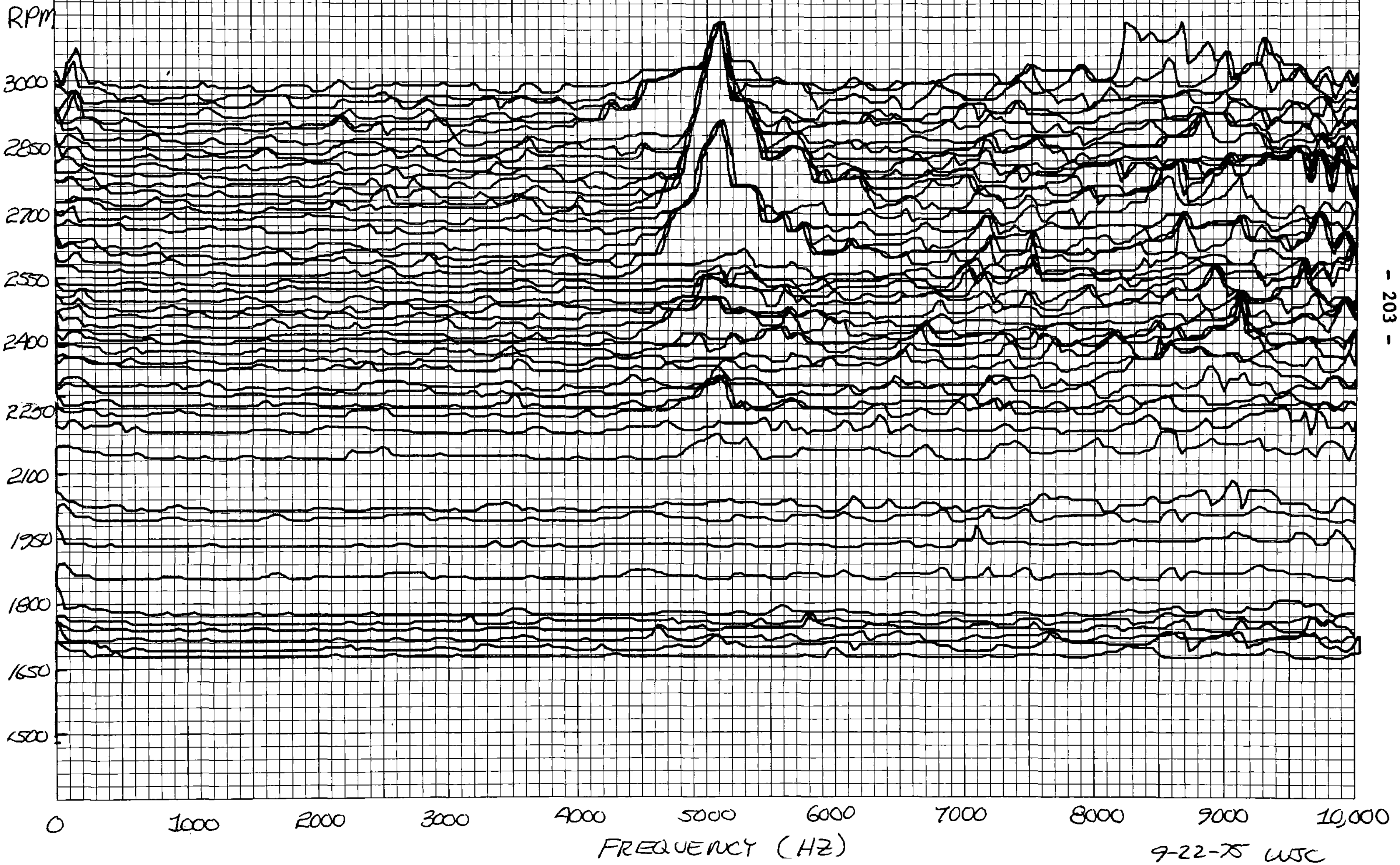
#10-5



[redacted]

#10-6

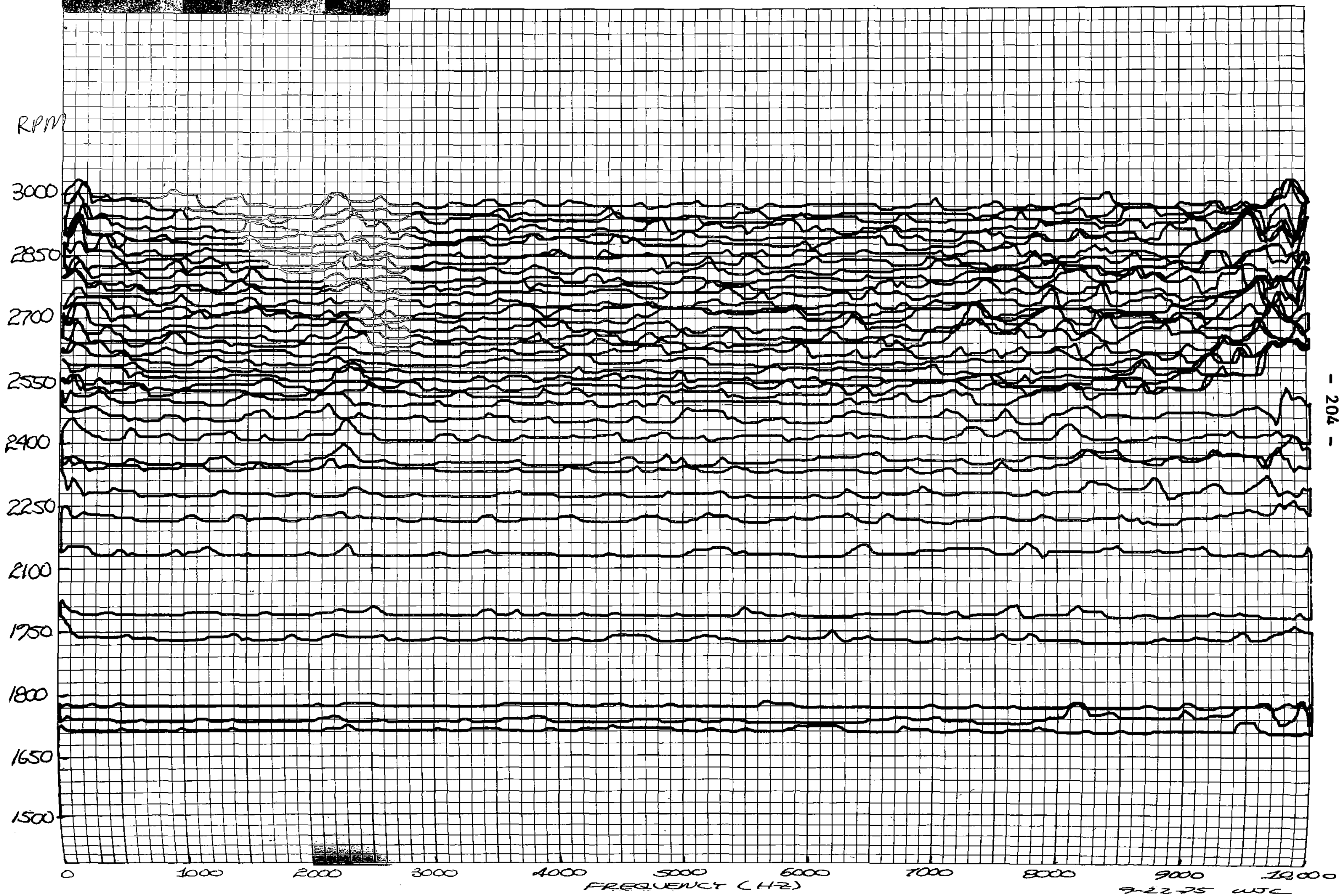
Accelerometer #6 - R.R. Cylinder Head
Hor.
1750 to 3000 RPM
To Knock To Very Light Knock




9-22-75 WJC

#11-1

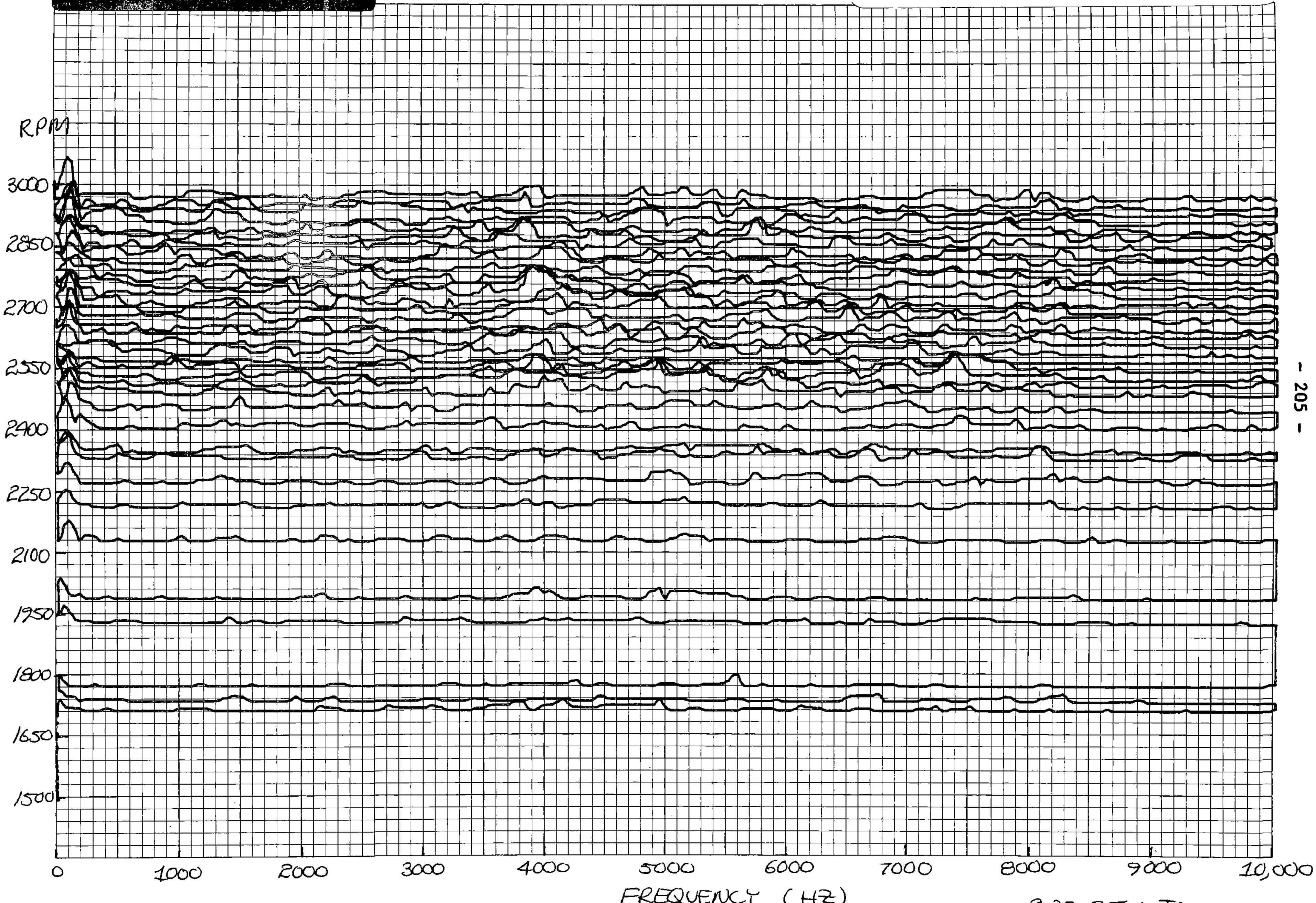
Acceleration Test - House Fuel
Accelerometer #1 - L.F. Cylinder Head
Vert.'
No Knock Detected



[redacted]

#11-2

Accelerometer #2 - L.R. Cylinder Head
Vert.
No Knock Detected

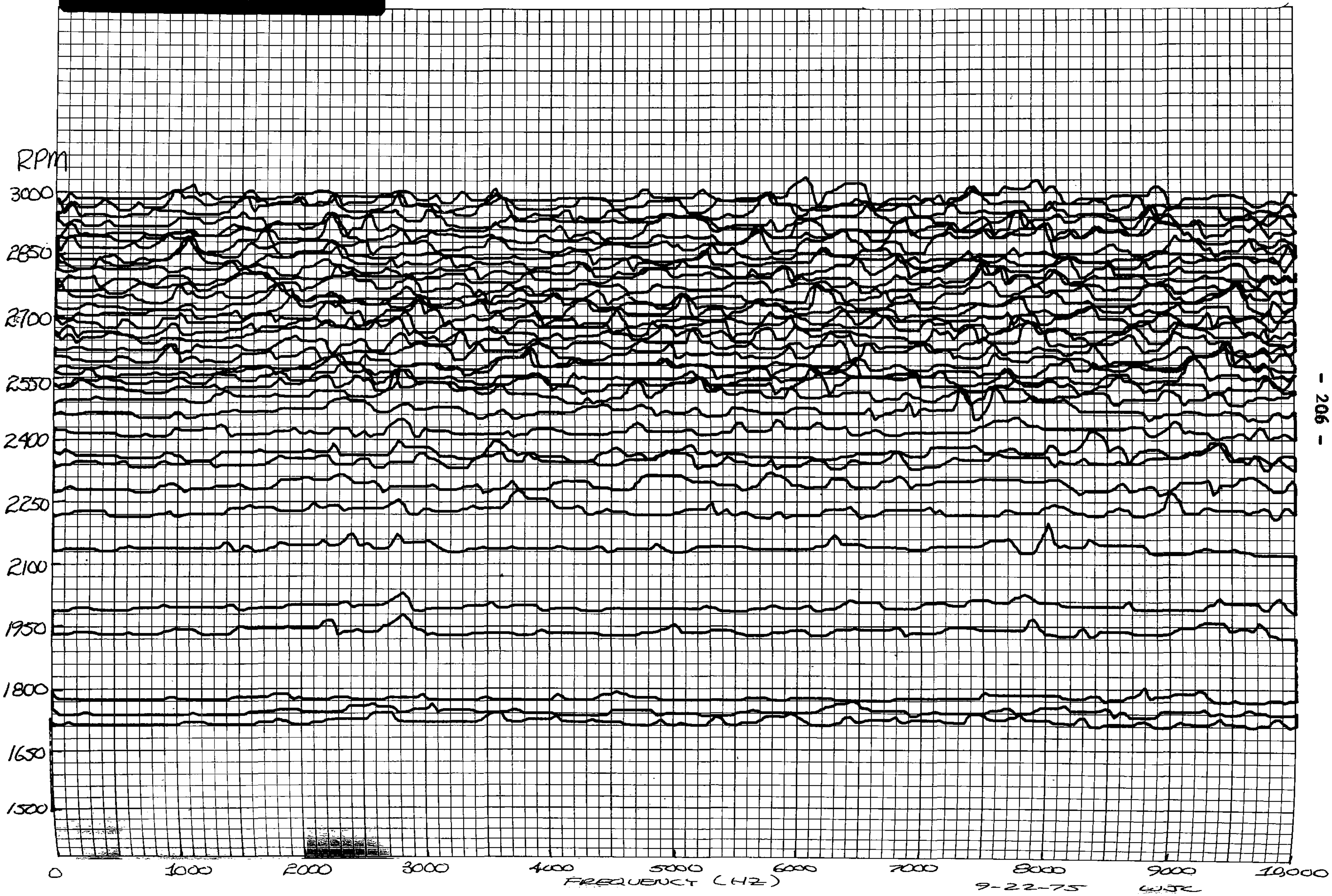



9-22-75 WJC

[redacted]

#11-3

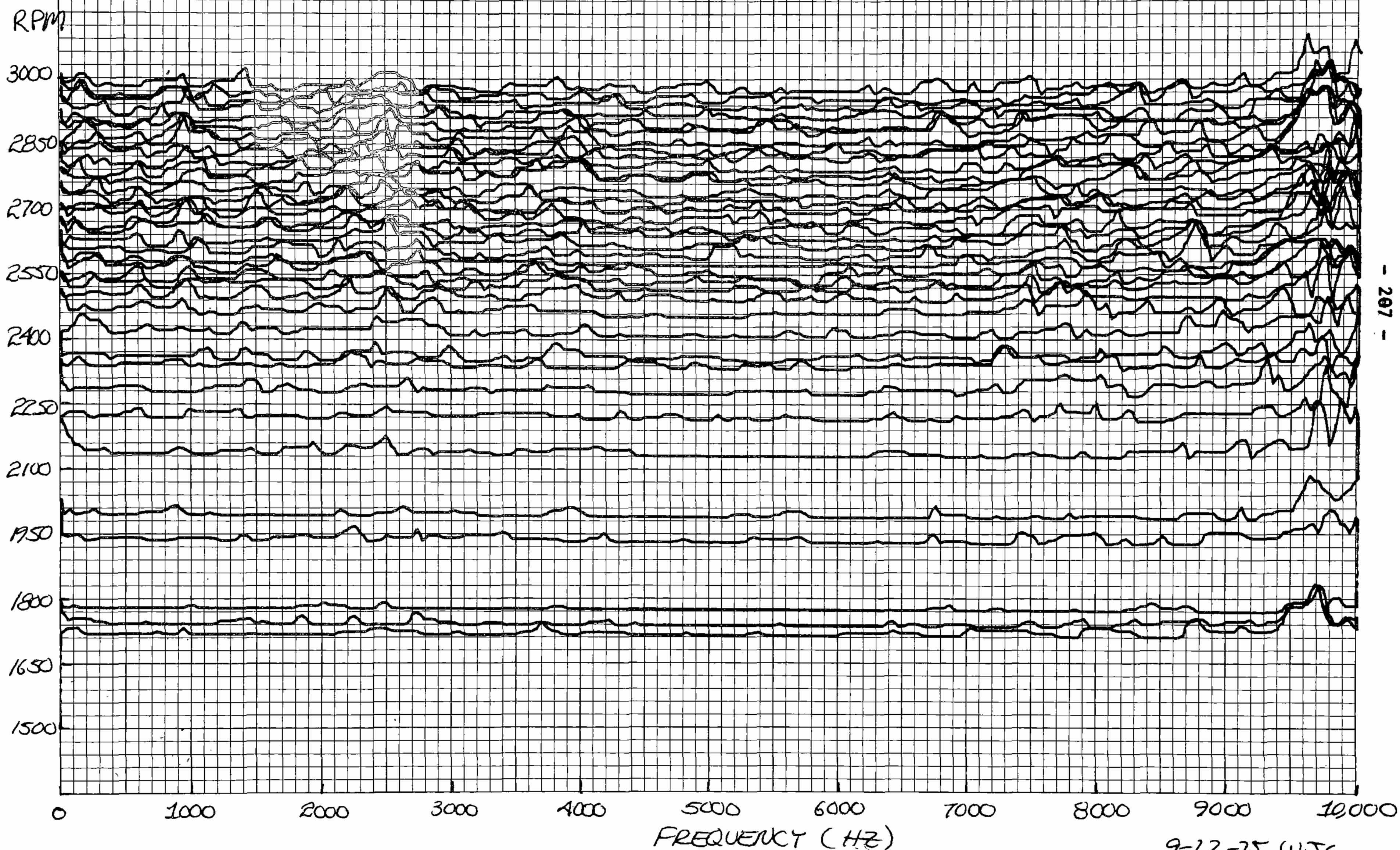
Acceleration Test - House Fuel
Accelerometer #3 - R. Intake Manifold
Vert.
No Knock Detected



[redacted]

#11-4

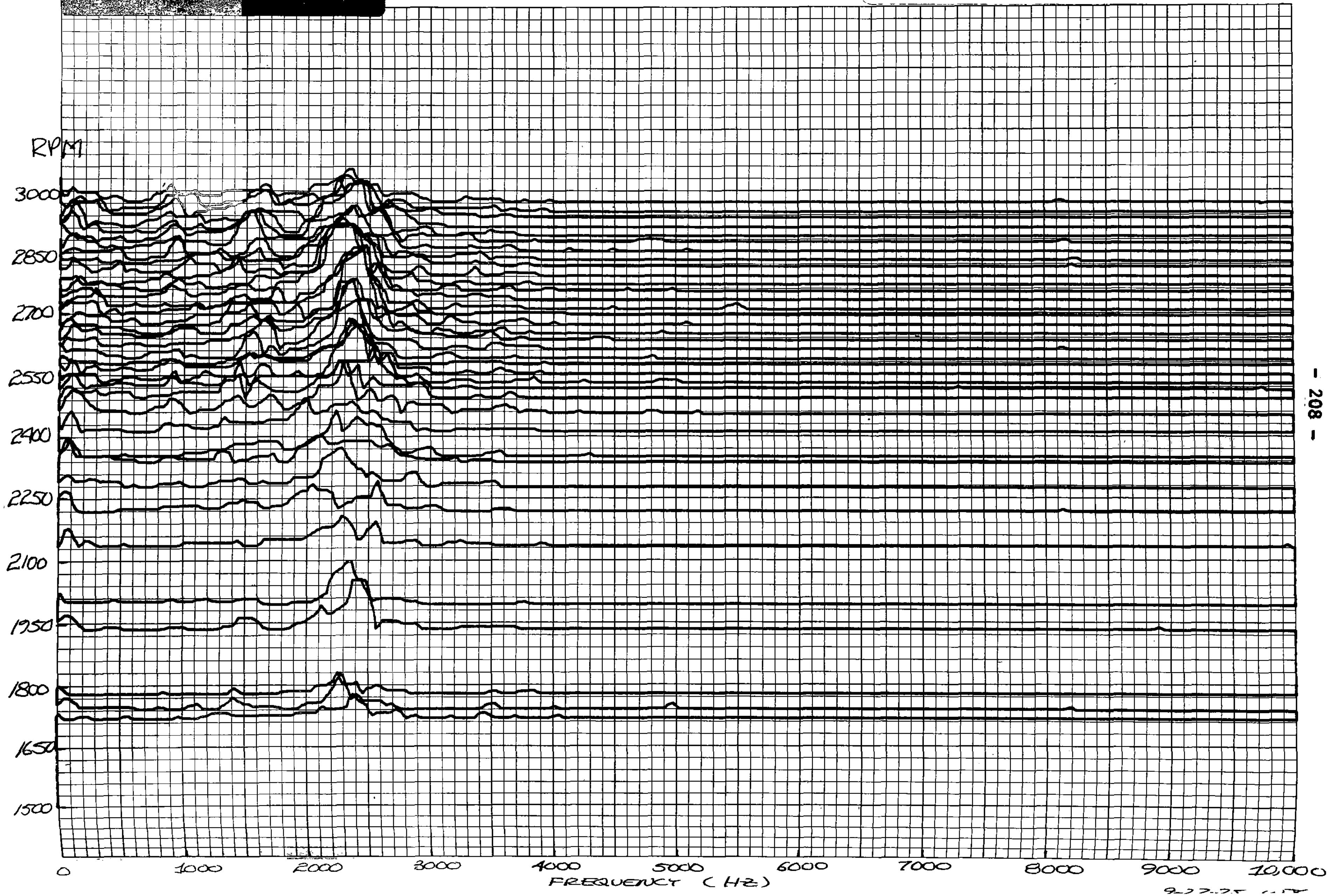
Accelerometer #4 - F. Intake Manifold
Vert.
No Knock Detected




9-22-75 WJC

Acceleration Test - House Fuel
Accelerometer #5 - R.F. Cylinder Head
Vert.
No Knock Detected

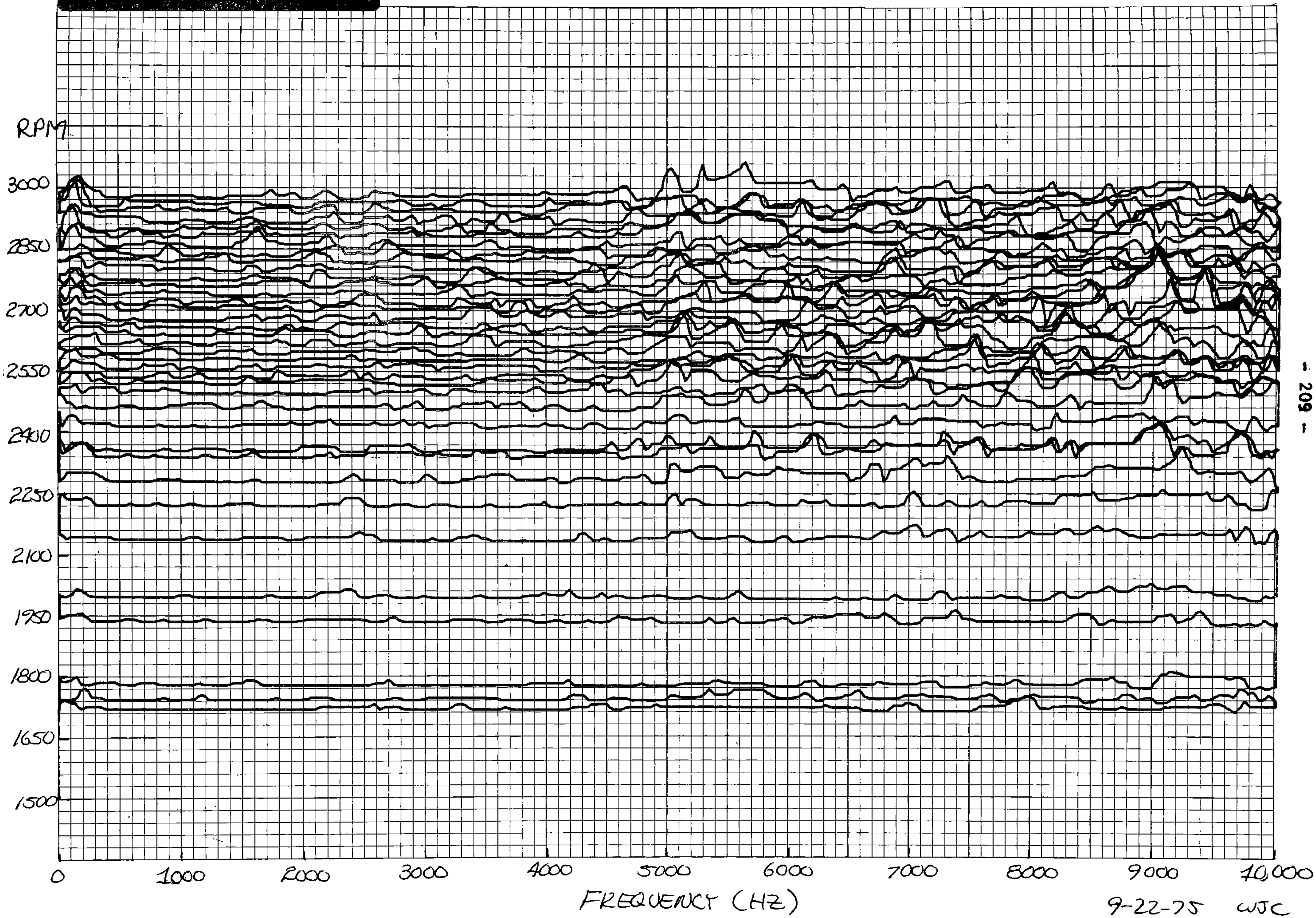
#11-5



[redacted]

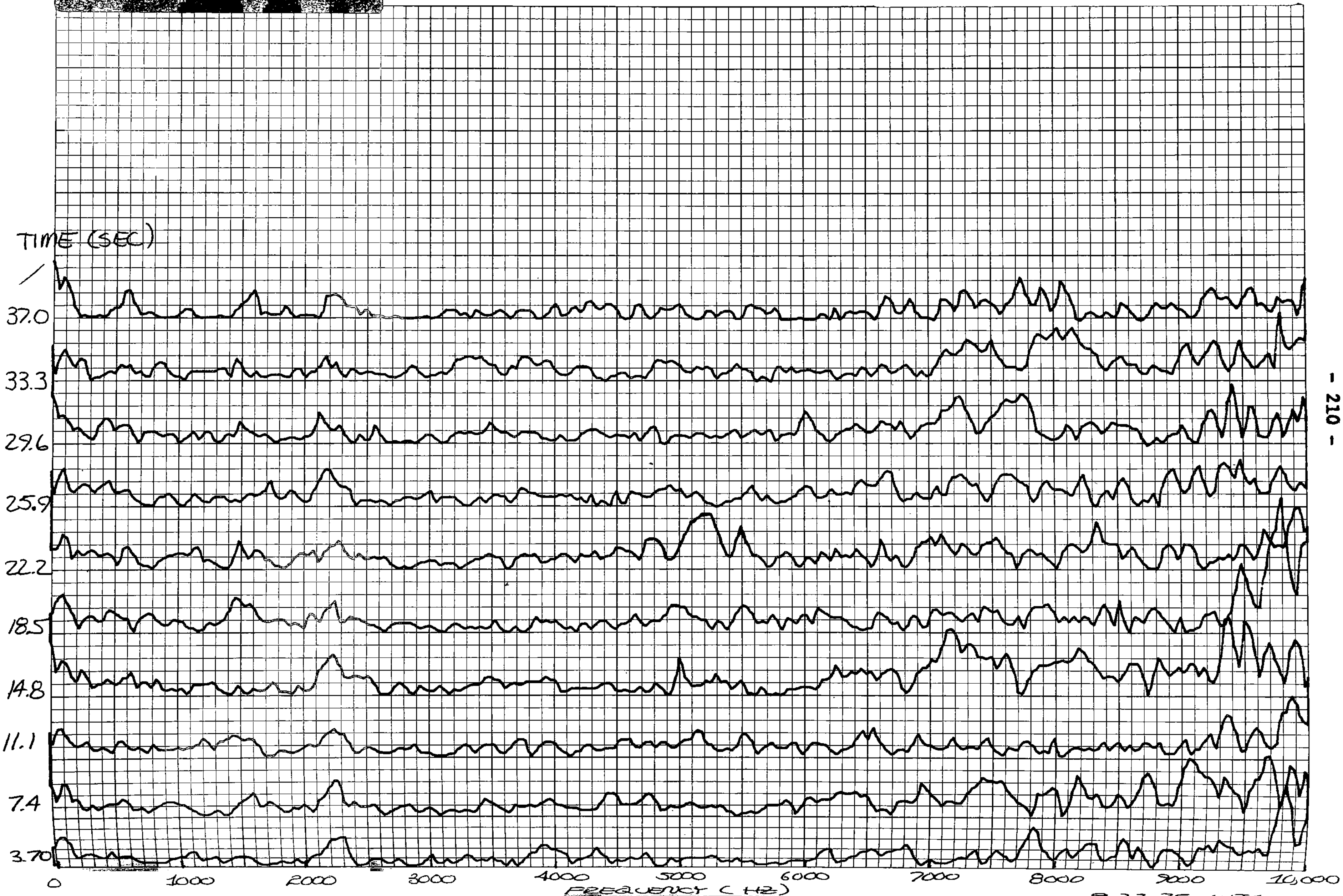
#11-6

Accelerometer #6 - R.R. Cylinder Head
Hor.
No Knock Detected



Steady State Test - 82 Octane Fuel
Accelerometer #1 - L.F. Cylinder Head
Vert.
2500 RPM 180 FT LBS Torque 25" HG
Trace Knock Level

#12-1



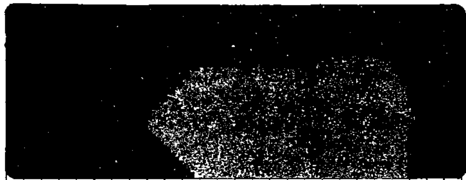

9-22-75

[redacted]

#12-2

Accelerometer #2 - L.R. Cylinder Head
Vert.
2500 RPM 180 FT LBS Torque 25" HG
Trace Knock Level


9-22-75 WJC



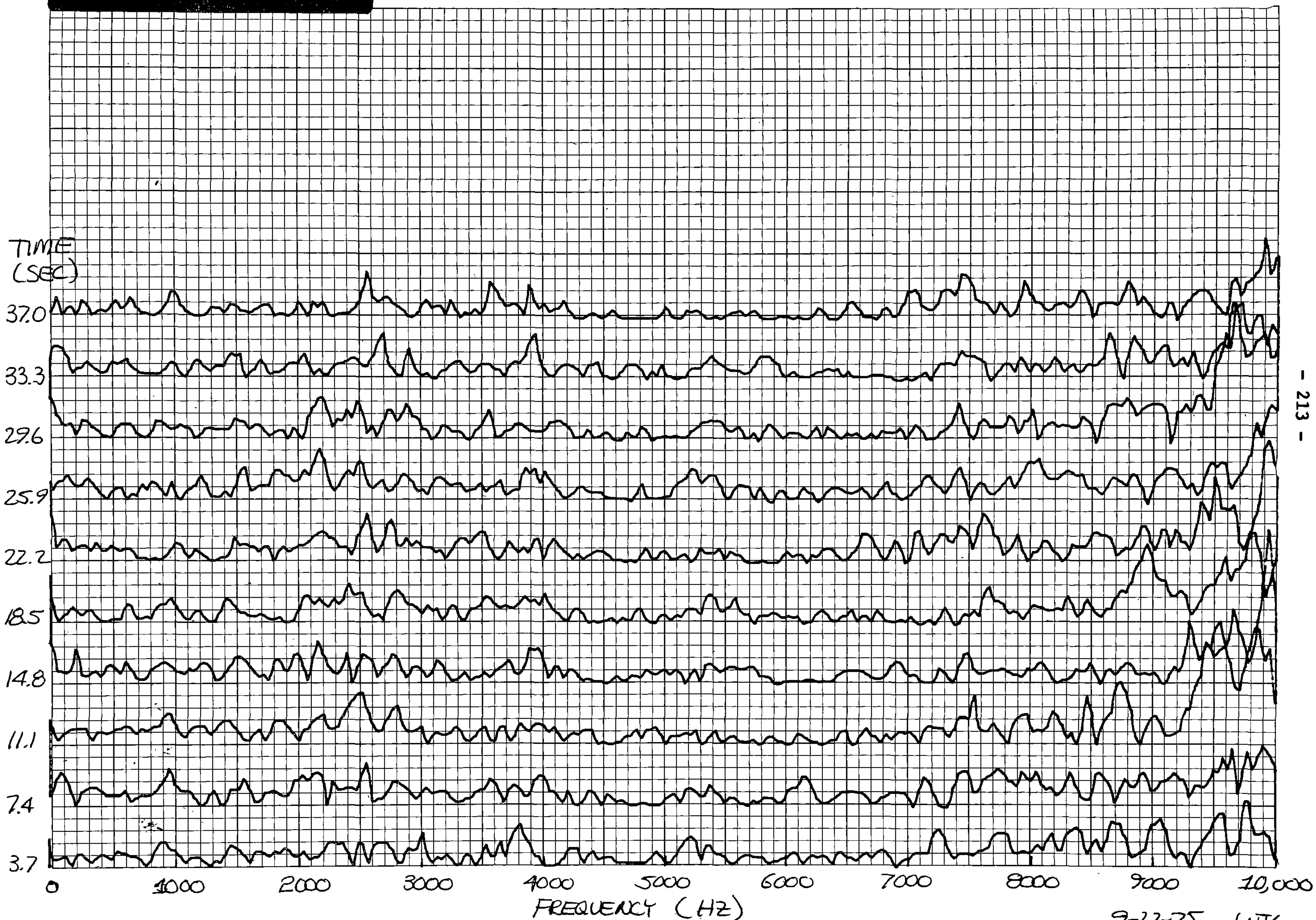
#12-3

Steady State Test - 82 Octane Fuel
Accelerometer #3 - R. Intake Manifold
Vert.
2500 RPM 180 FT LBS Torque 25" HG
Trace Knock Level

[redacted]

#12-4

Accelerometer #4 - F. Intake Manifold
Vert.
2500 RPM 180 FT LBS Torque 25" HG
Trace Knock Level

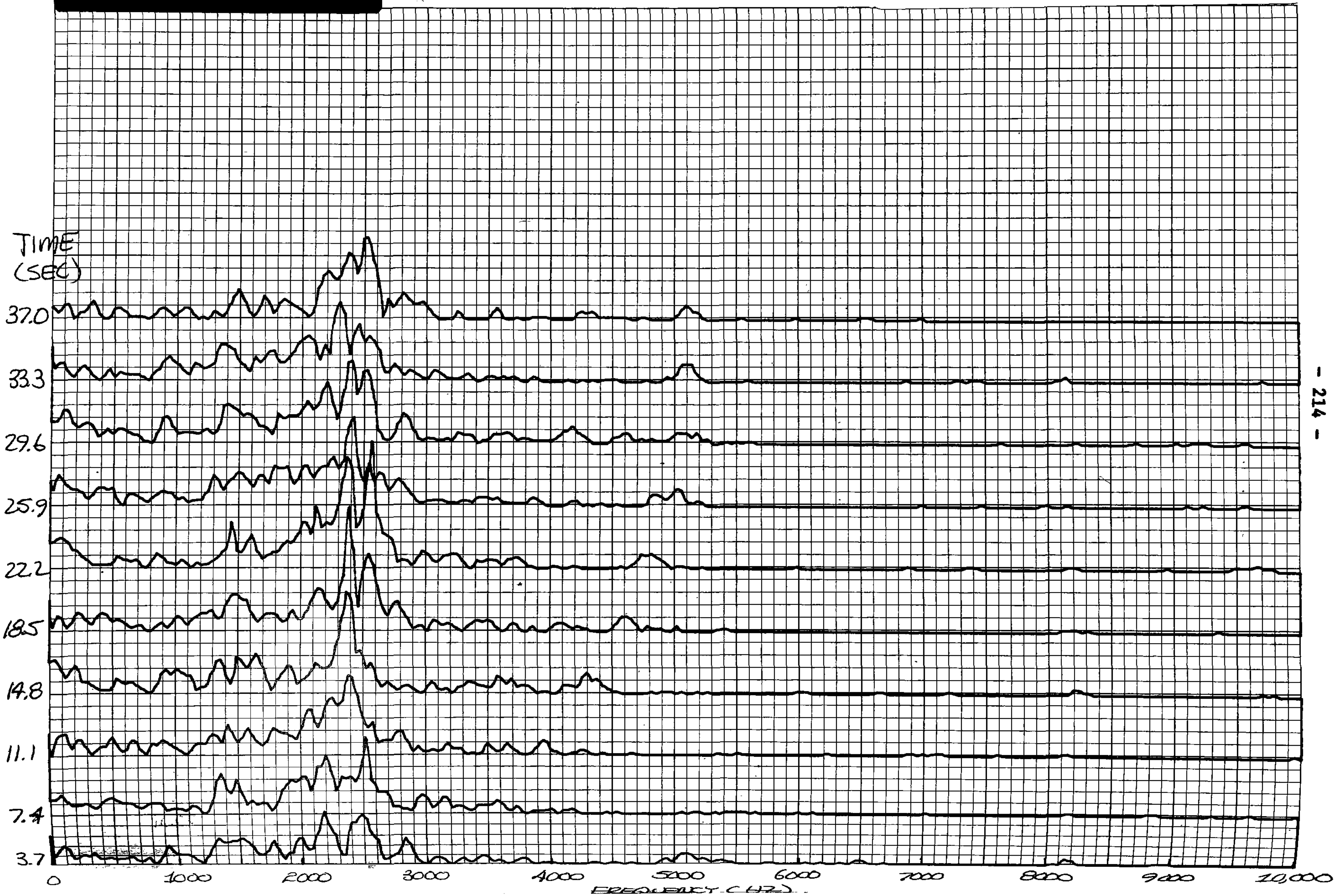



9-22-75 WJC

[redacted]

#12-5

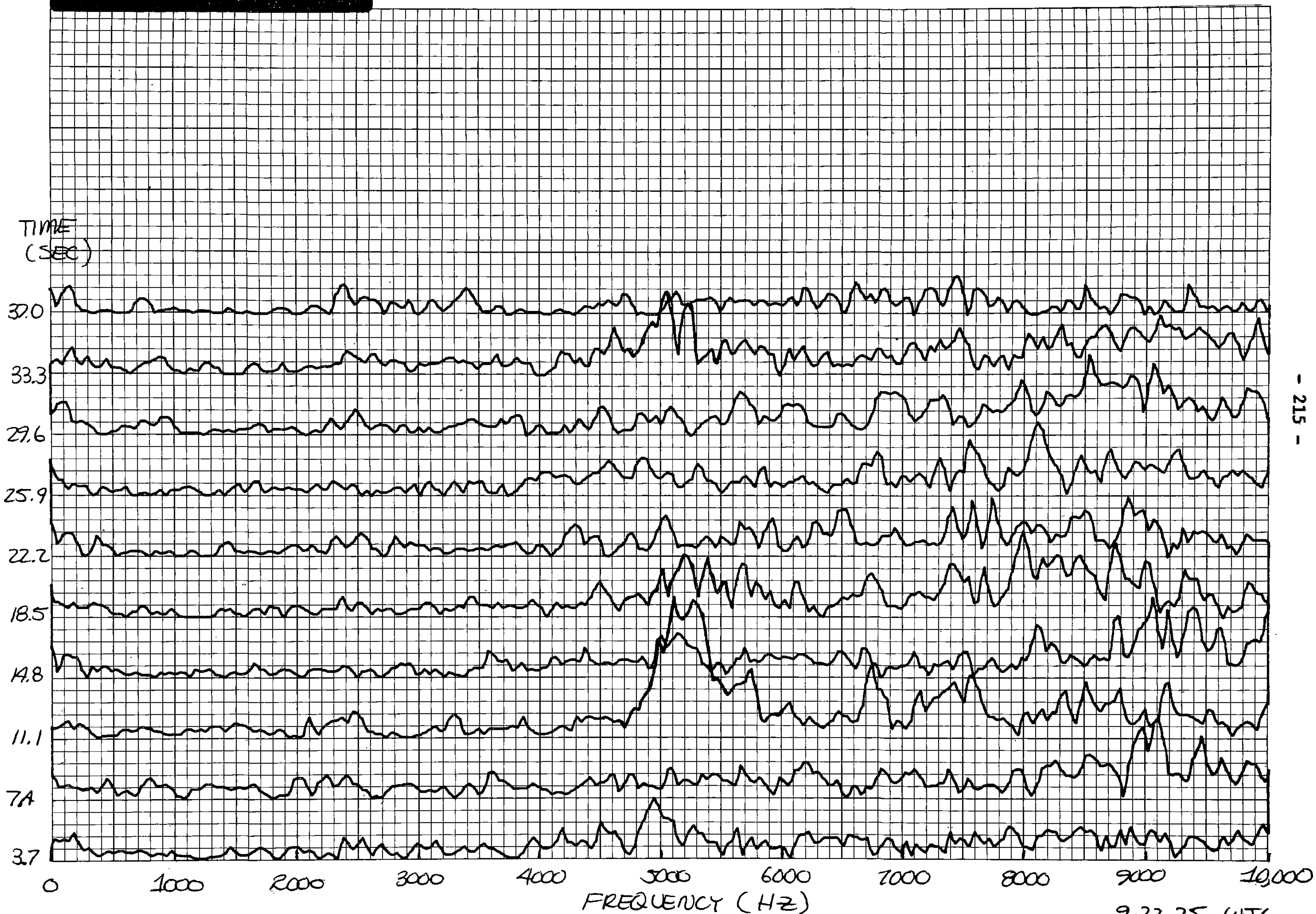
Steady State Test - 82 Octane Fuel
Accelerometer #5 - R.F. Cylinder Head Vert.
2500 RPM 180 FT LBS Torque 25" HG
Trace Knock Level



[redacted]

#12-6

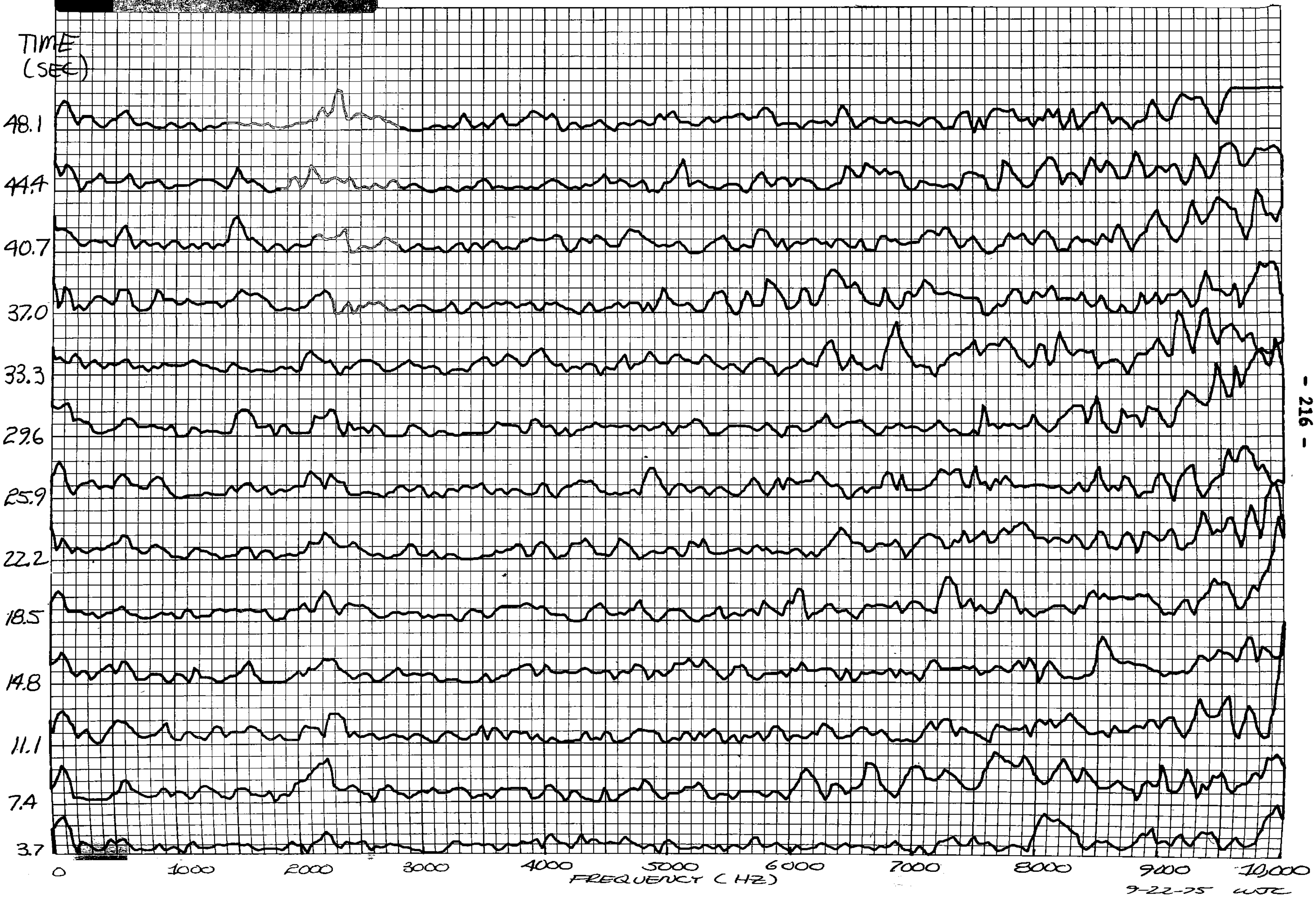
Accelerometer #6 - R.R. Cylinder Head Hor.
2500 RPM 180 FT LBS Torque 25" HG
Trace Knock Level




9-22-75 WJC

Steady State Test - House Fuel
Accelerometer #1 - L.F. Cylinder Head
Vert.
2500 RPM 176 FT LBS Torque 25" HG
No Knock Detected

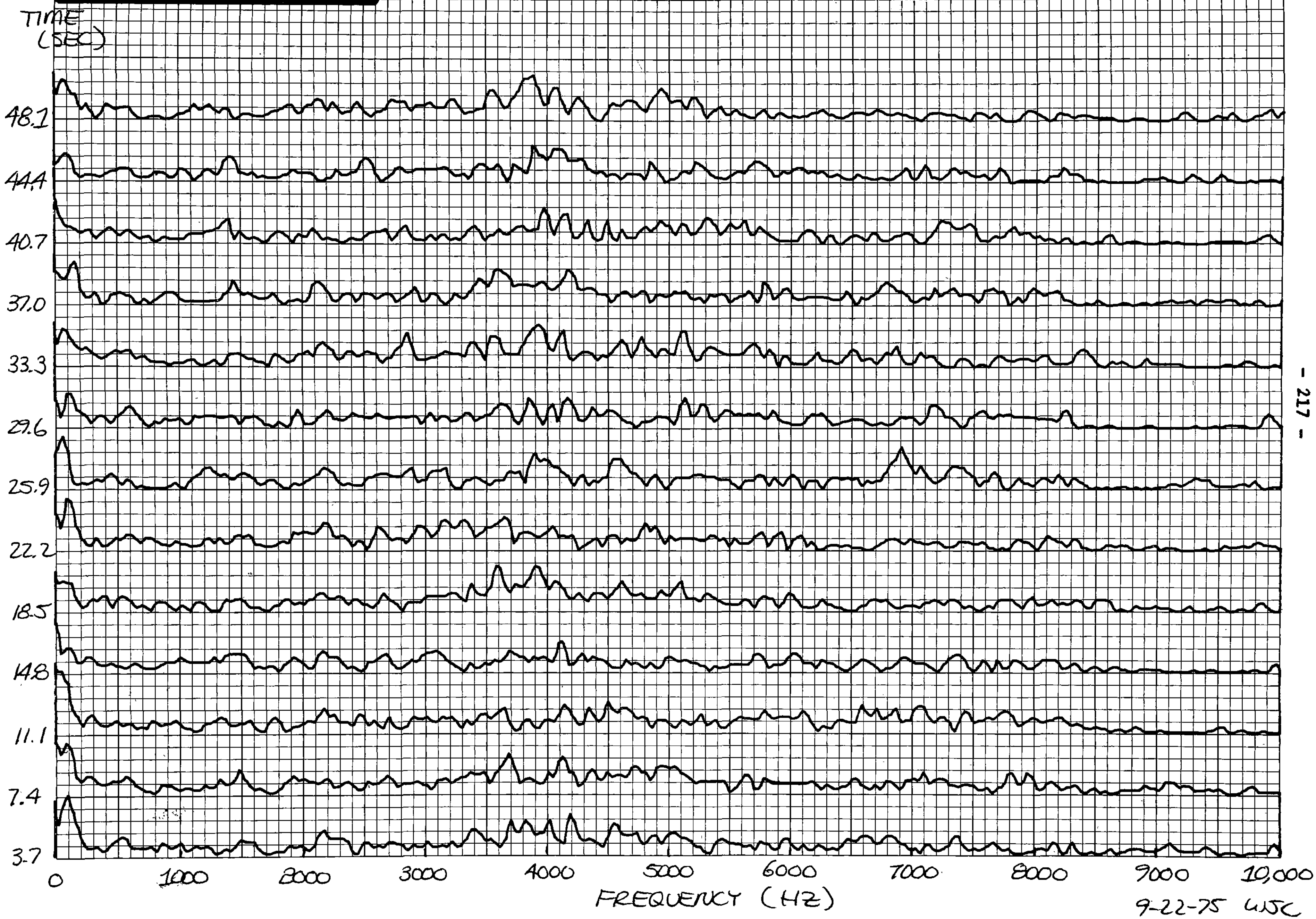
#13-1



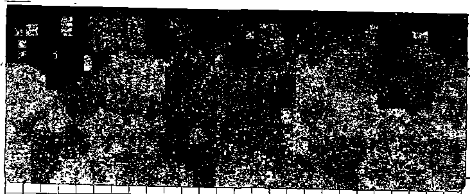
[redacted]

#13-2

Accelerometer #2 - L.R. Cylinder Head
Vert.
2500 RPM 176 FT LBS Torque 25" HG
No Knock Detected




9-22-75 WJC

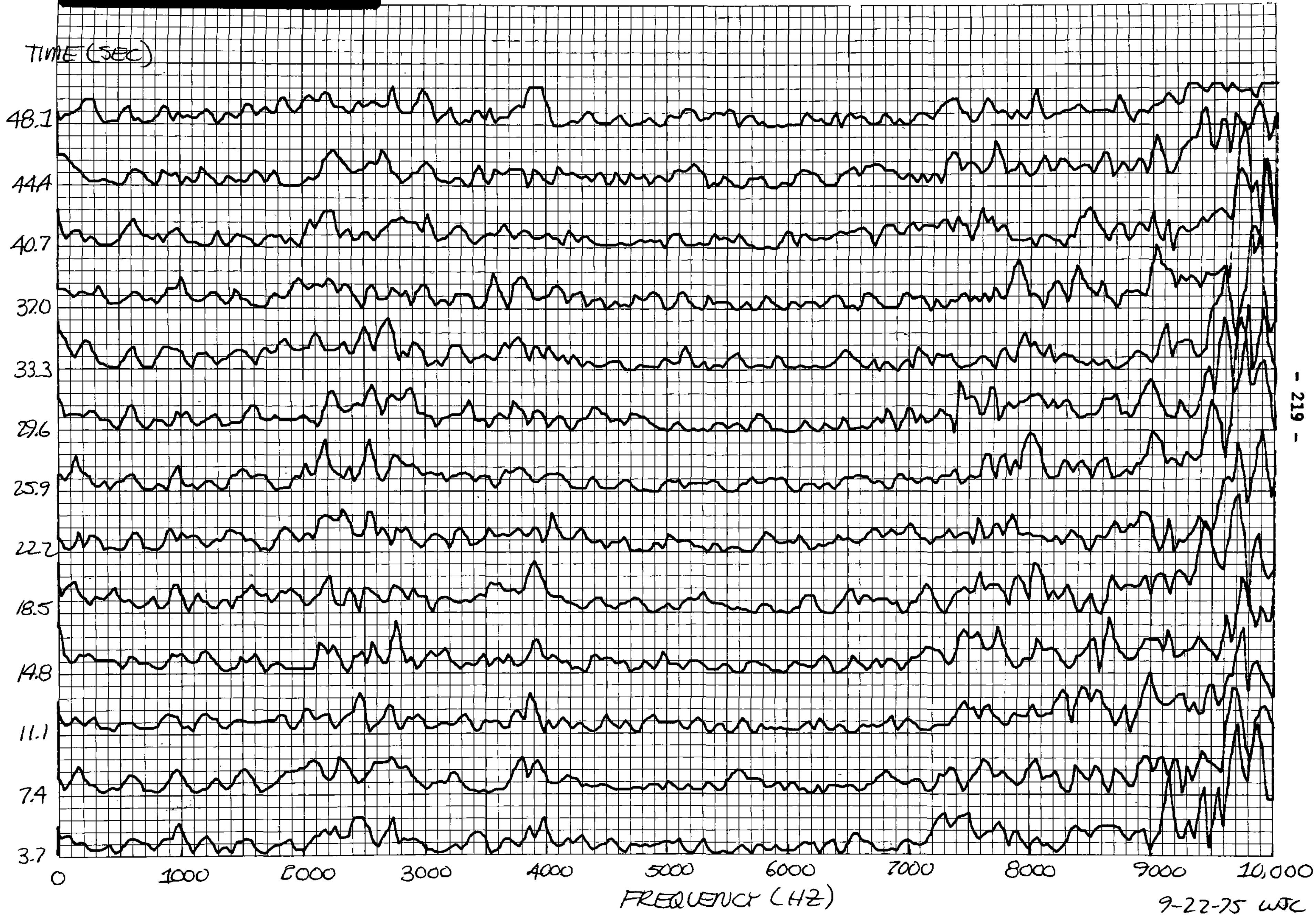


#13-3

Steady State Test - House Fuel
Accelerometer #3 - R. Intake Manifold Vert.
2500 RPM 176 FT LBS Torque 25" HG
No Knock Detected

[redacted] #13-A

Accelerometer #4 - F. Intake Manifold
Vert.
2500 RPM 176 FT LBS Torque 25" HG
No Knock Detected

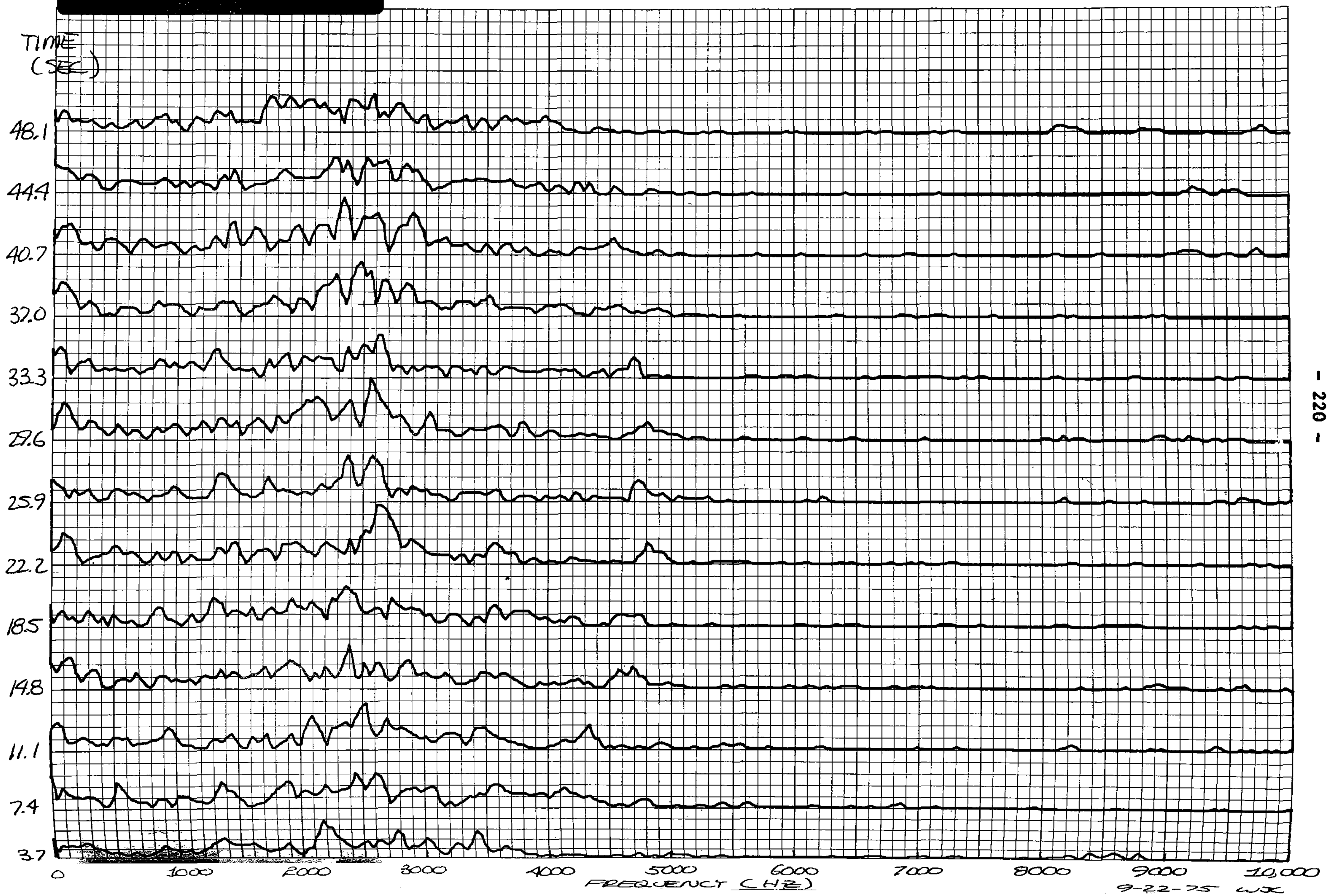



9-22-75 WJC

[redacted]

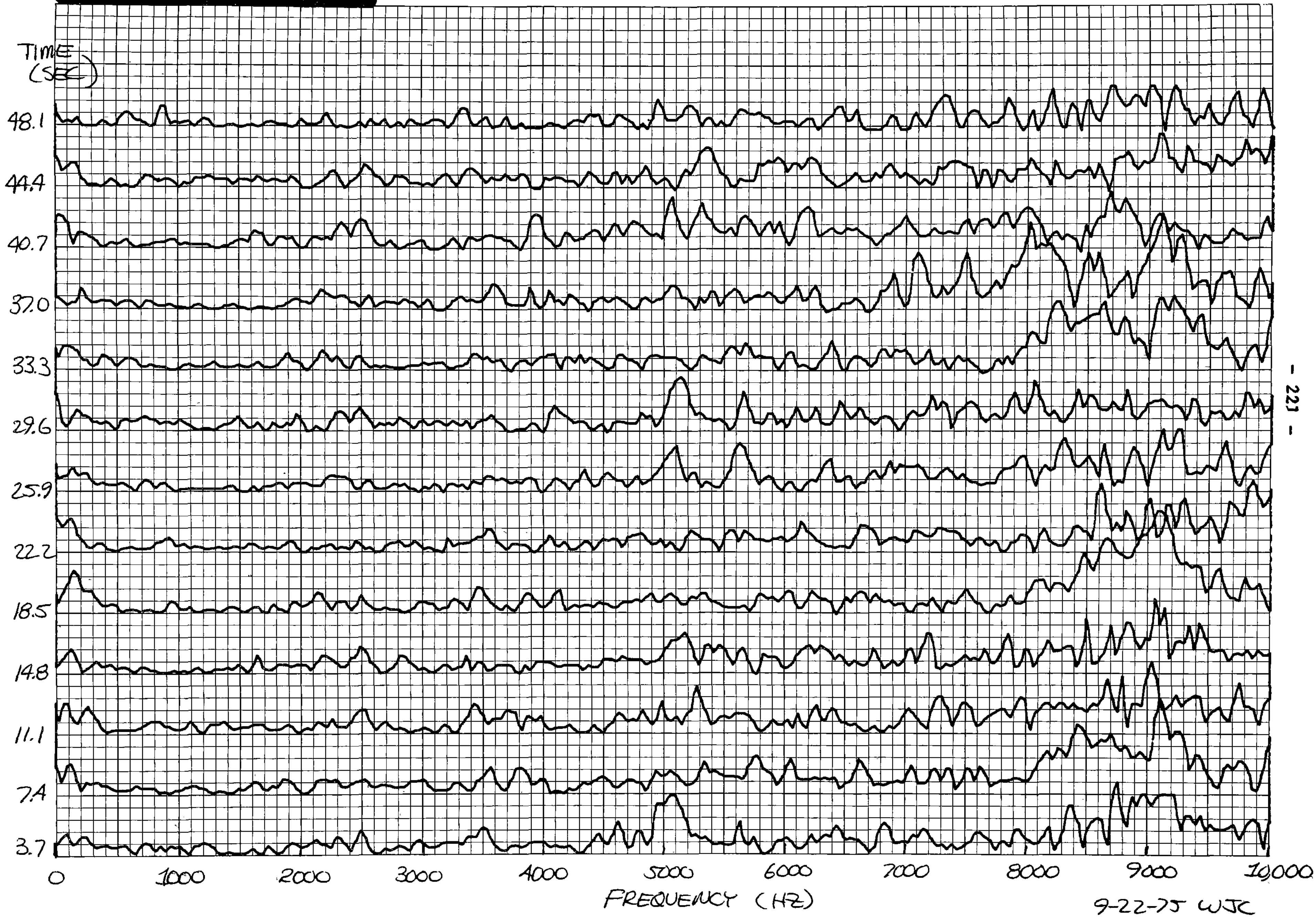
#13-5

Steady State Test - House Fuel
Accelerometer #5 - R.F. Cylinder Head
Vert.
2500 RPM 176 FT LBS Torque 25" HG
No Knock Detected



[redacted] #13-6

**Accelerometer #6 - R.R. Cylinder Head Hor.**
**2500 RPM 176 FT LBS Torque 25" HG**
**No Knock Detected**

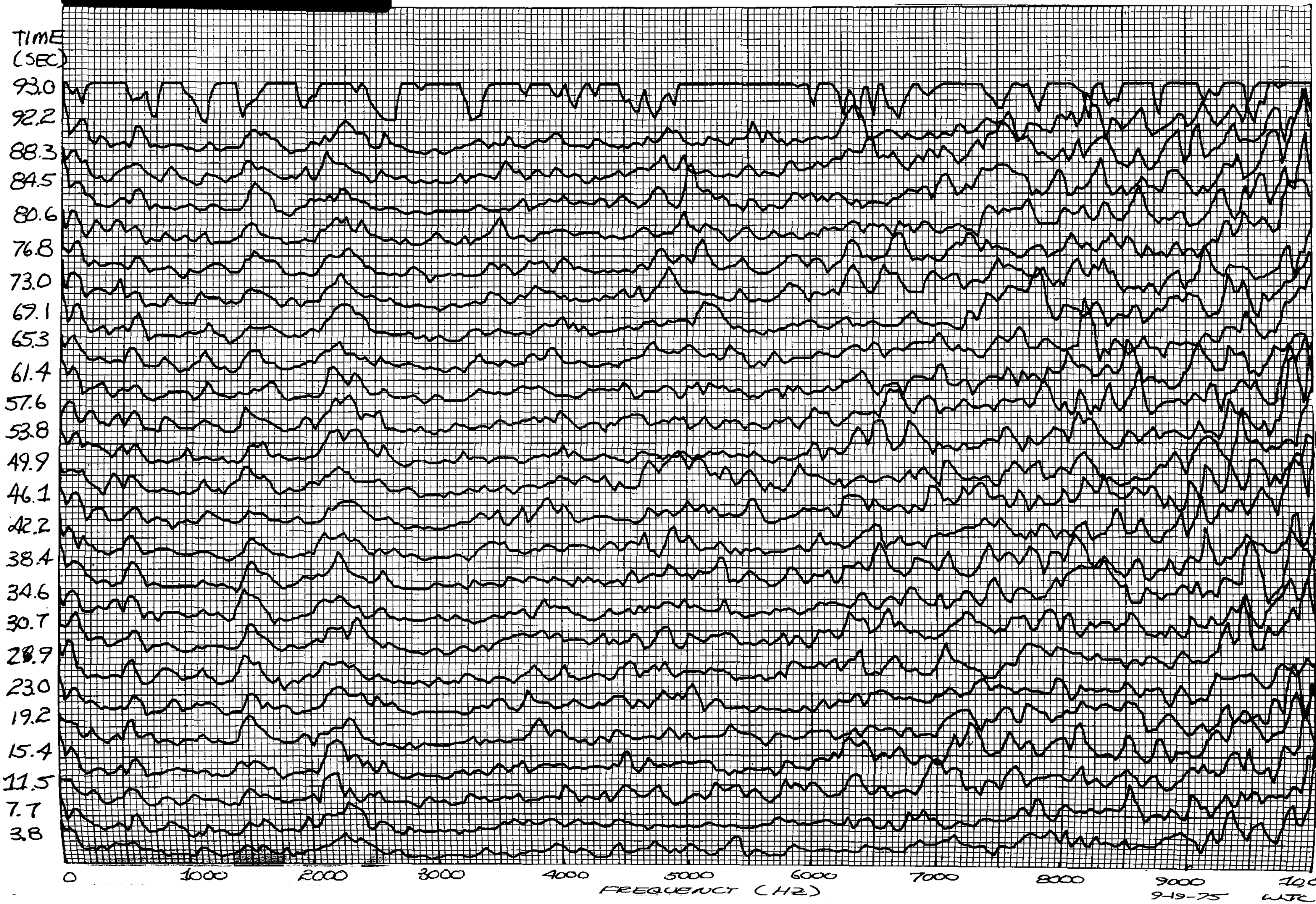



9-22-75 WJC

[redacted]

#14-1

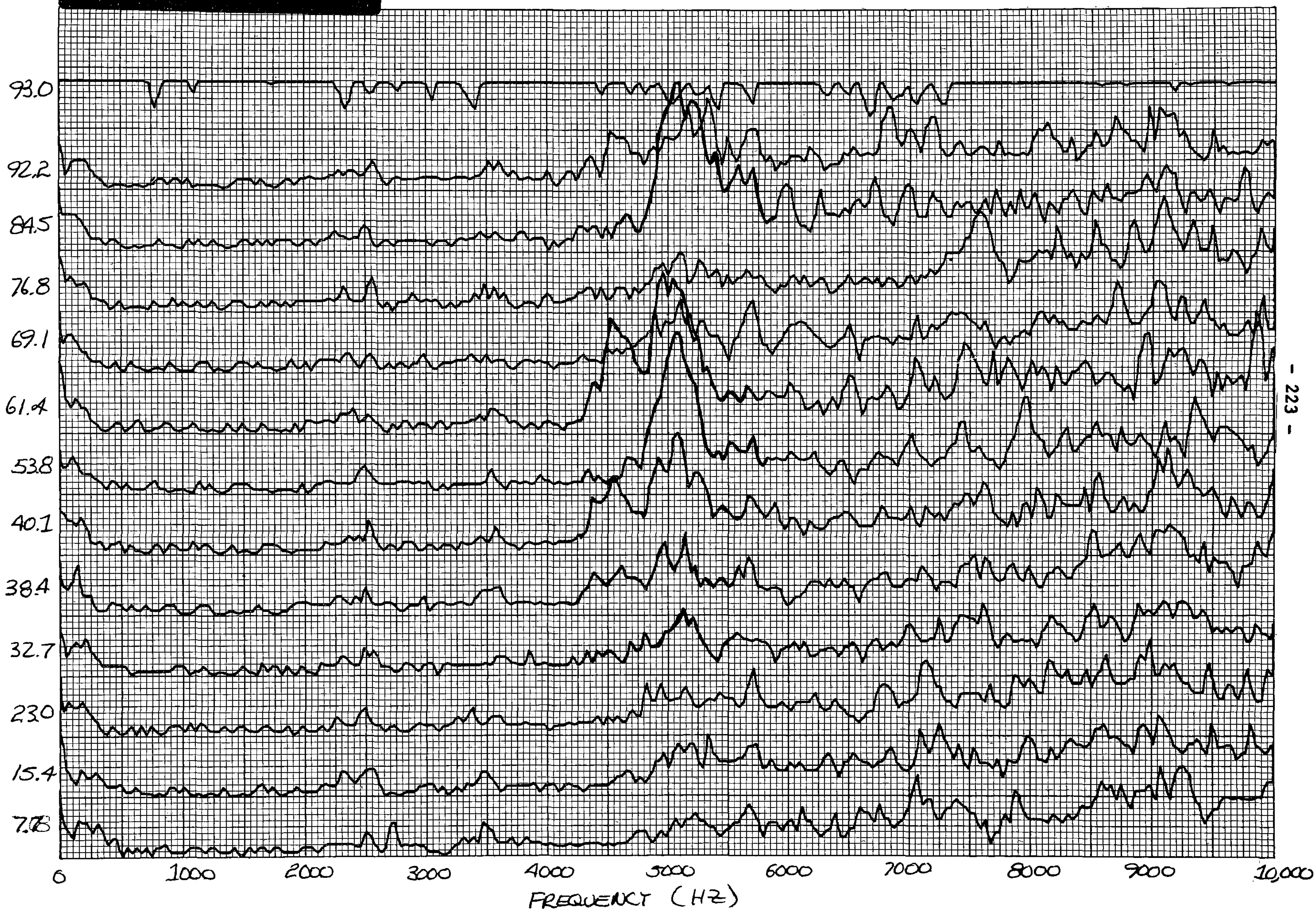
Fuel Change Test
Accelerometer #1 - L.F. Cylinder Head Vert.
2500 RPM 176 LBS Torque 25" HG
Knock Begins At Trace Level



[redacted]

#14-6

Accelerometer #6 R.R. Cylinder Head
Hor.
2500 RPM 176 LBS Torque 25" HG
Knock Begins At Trace Level



# TEST #2

## 350 CID Engine from Vehicle

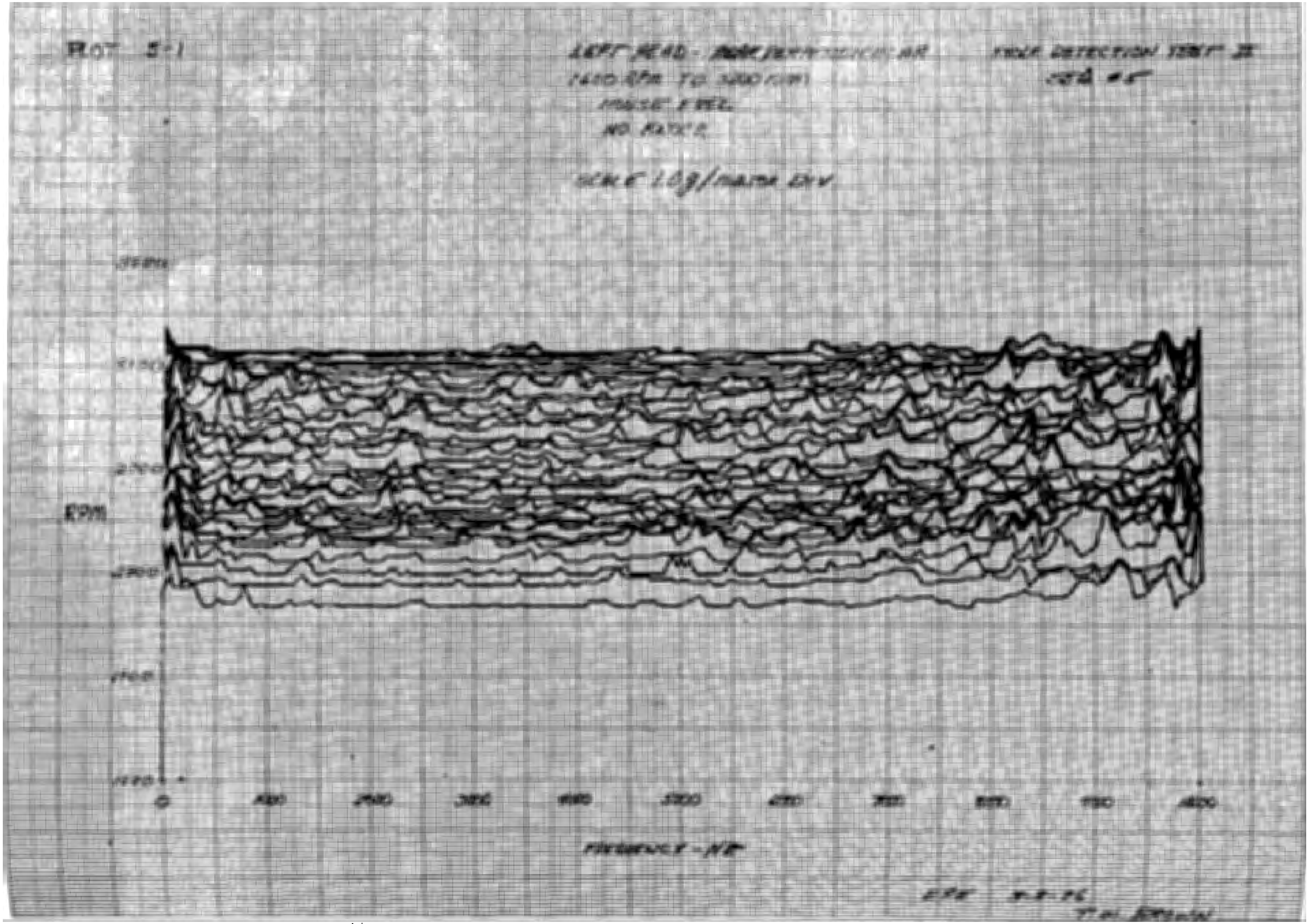
# TEST #2

## 350 CID ENGINE FROM VEHICLE

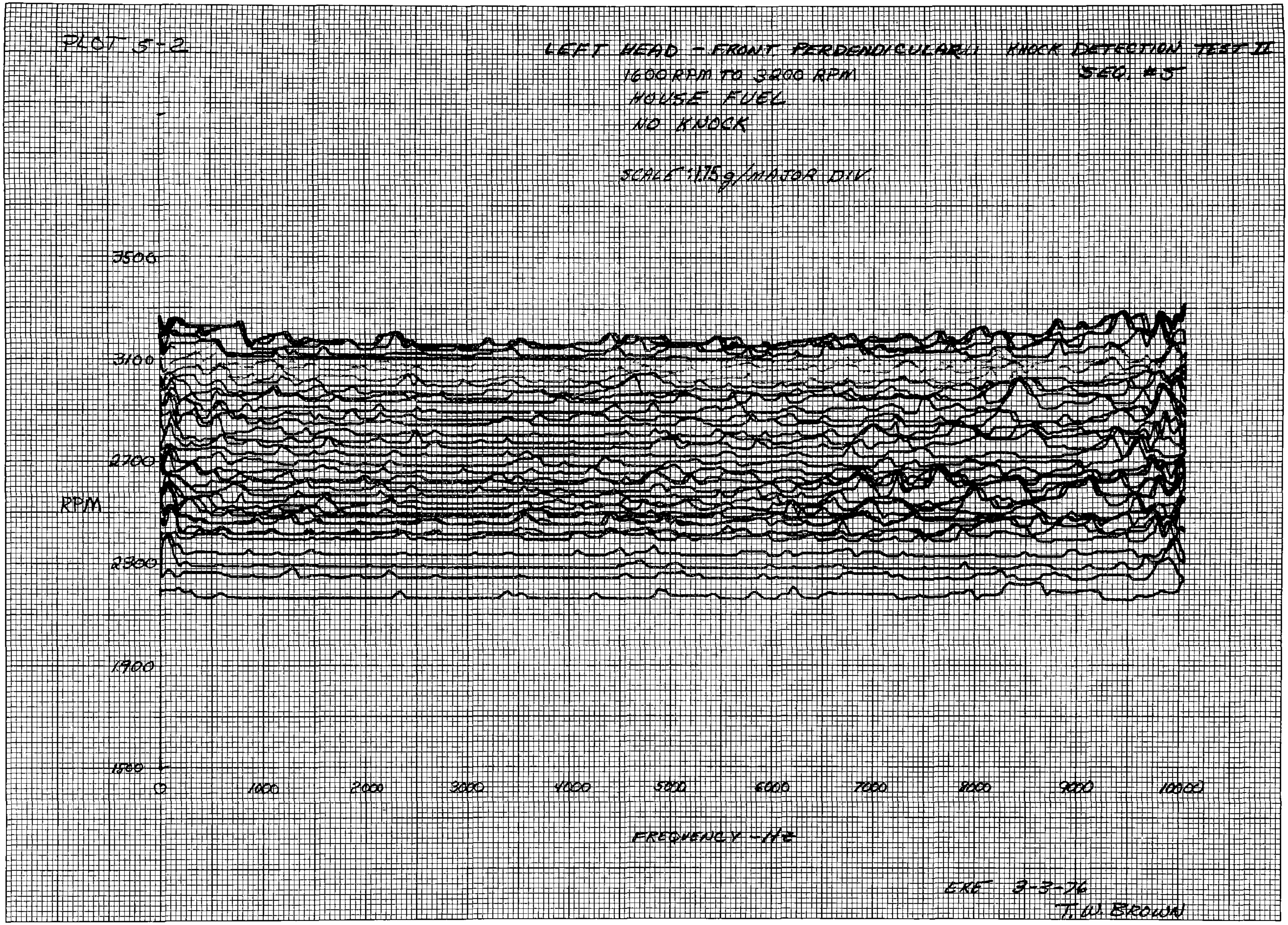
### SUMMARY OF SPECTROGRAM RESULTS

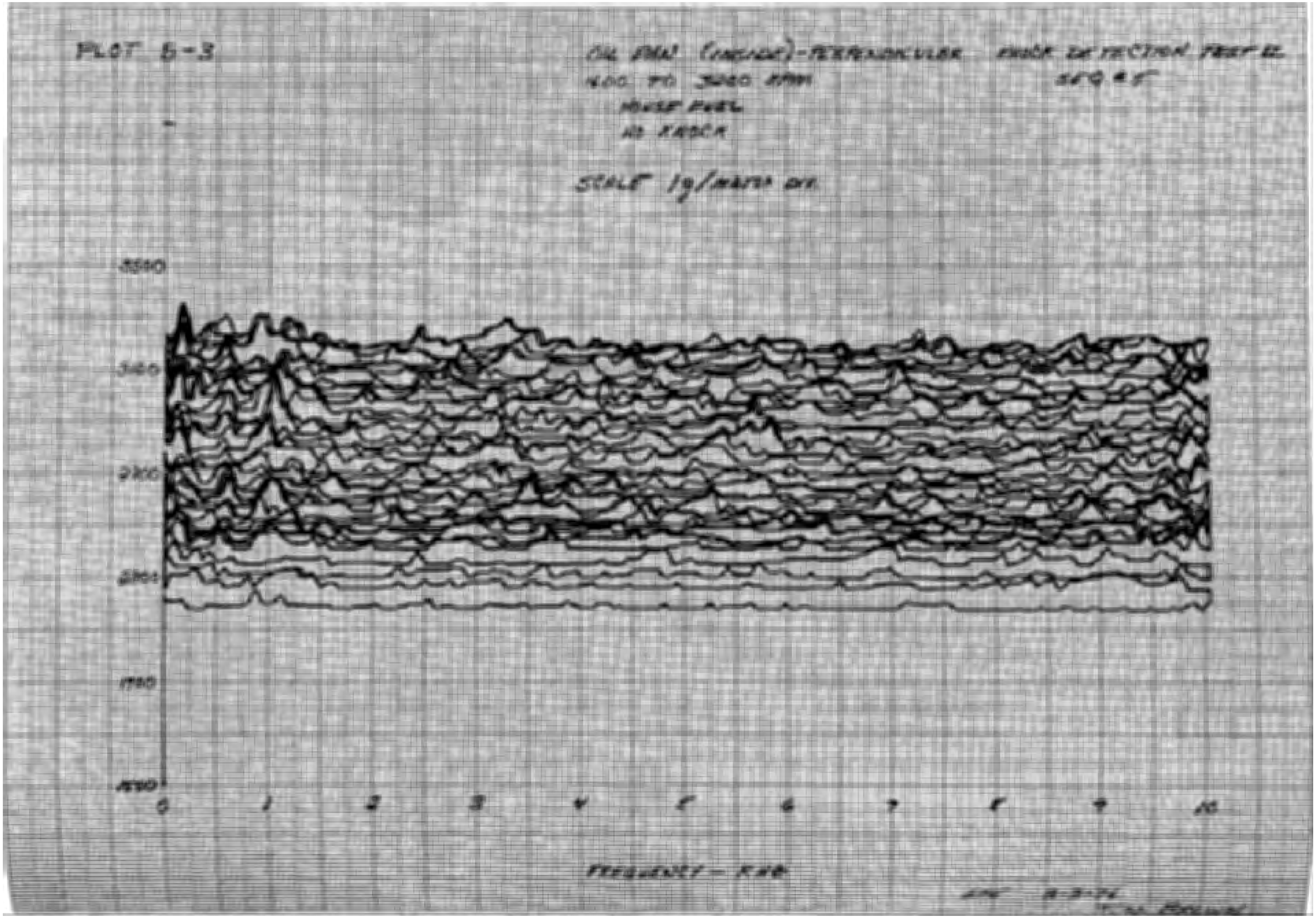
Electronic Knock Detection Test 1975 CID Engine W/20,000 Miles

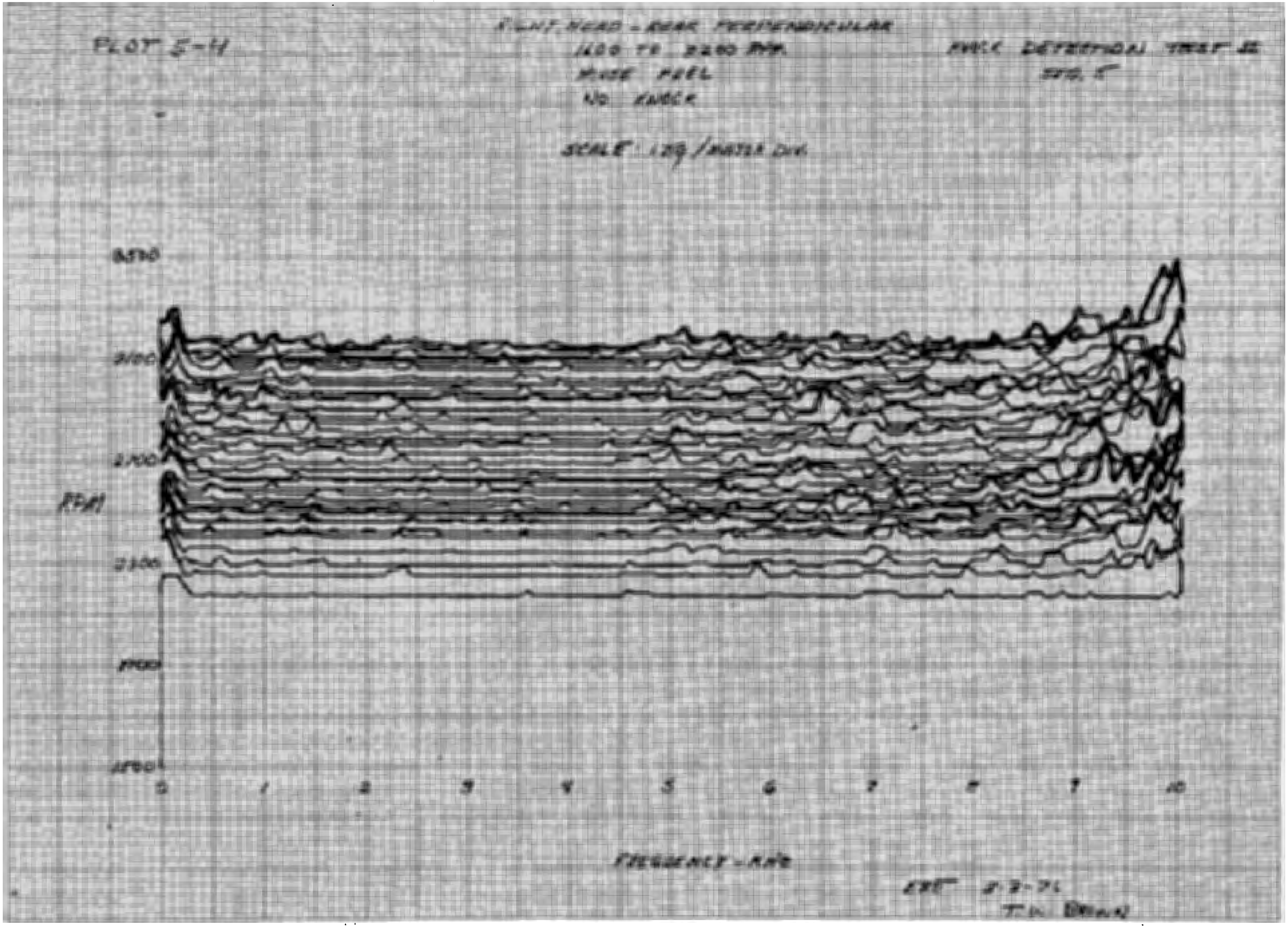
| Plot No. | Accelerometer | Position Relative To Crank | Test | Plot Axis | Rated Knock Level | Maximum Response | Comments |
|---|---|---|---|---|---|---|---|
| 5-1 | Left Head-Rear | Perpendicular | Acceleration | RPM vs. Freq. | None | | No Response |
| 5-2 | Left Head-Front | Perpendicular | Acceleration | RPM vs. Freq. | None | | No Response |
| 5-3 | Oil Pan | Perpendicular | Acceleration | RPM vs. Freq. | None | | No Response |
| 5-4 | Right Head-Rear | Perpendicular | Acceleration | RPM vs. Freq. | None | | No Response |
| 5-5 | Right Head-Front | Perpendicular | Acceleration | RPM vs. Freq. | None | | No Response |
| 5-6 | Right Head-Rear | Parallel | Acceleration | RPM vs. Freq. | None | | No Response |
| 8-1 | Left Head-Rear | Perpendicular | Acceleration | RPM vs. Freq. | Very Light | 0.9g | Medium Response |
| 8-2 | Left Head-Front | Perpendicular | Acceleration | RPM vs. Freq. | Very Light | 0.8g | Medium Response |
| 8-3 | Oil Pan | Perpendicular | Acceleration | RPM vs. Freq. | Very Light | 0.5g | Poor Response |
| 8-4 | Right Head-Rear | Perpendicular | Acceleration | RPM vs. Freq. | Very Light | 1.6g | Good Response |
| 8-5 | Right Head-Front | Perpendicular | Acceleration | RPM vs. Freq. | Very Light | >5.0g | Repeated Plot 8-6 |
| 8-6 | Right Head-Front | Perpendicular | Acceleration | RPM vs. Freq. | Very Light | 8.0g | Good Response |
| 8-7 | Right Head-Rear | Parallel | Acceleration | RPM vs. Freq. | Very Light | 3.1g | Good Response |
| 11-1 | Left Head-Rear | Perpendicular | Acceleration | RPM vs. Freq. | Trace Plus | 0.7g | Poor Response |
| 11-2 | Left Head-Front | Perpendicular | Acceleration | RPM vs. Freq. | Trace Plus | 0.7g | Poor Response |
| 11-3 | Oil Pan | Perpendicular | Acceleration | RPM vs. Freq. | Trace Plus | 1.0g | Medium Response |
| 11-4 | Right Head-Rear | Perpendicular | Acceleration | RPM vs. Freq. | Trace Plus | 1.0g | Medium Response |
| 11-5 | Right Head-Front | Perpendicular | Acceleration | RPM vs. Freq. | Trace Plus | 2.2g | Good Response |
| 11-6 | Right Head-Rear | Parallel | Acceleration | RPM vs. Freq. | Trace Plus | 4.0g | Good Response |
| 14-1 | Left Head-Rear | Perpendicular | Fuel Change | Time vs. Freq. | Trace Plus | | No Response |
| 14-2 | Left Head-Front | Perpendicular | Fuel Change | Time vs. Freq. | Trace Plus | | No Response |
| 14-3 | Oil Pan | Perpendicular | Fuel Change | Time vs. Freq. | Trace Plus | 0.5g | Poor Response |
| 14-4 | Right Head-Rear | Perpendicular | Fuel Change | Time vs. Freq. | Trace Plus | 1.0g | Medium Response |
| 14-5 | Right Head-Front | Perpendicular | Fuel Change | Time vs. Freq. | Trace Plus | 1.6g | Good Response |
| 14-6 | Right Head-Rear | Parallel | Fuel Change | Time vs. Freq. | Trace Plus | 0.6g | Medium Response |
| 19-1 | Left Head-Rear | Perpendicular | Acceleration | RPM vs. Freq. | Very Light Plus | 1.7g | Good Response |
| 19-2 | Left Head-Rear | Parallel | Acceleration | RPM vs. Freq. | Very Light Plus | 3.3g | Good Response |
| 19-3 | Oil Pan | Perpendicular | Acceleration | RPM vs. Freq. | Very Light Plus | | No Response |
| 19-4 | Right Head-Rear | Perpendicular | Acceleration | RPM vs. Freq. | Very Light Plus | 4.3g | Good Response |
| 19-5 | Right Head-Front | Perpendicular | Acceleration | RPM vs. Freq. | Very Light Plus | 4.2g | Good Response |
| 19-6 | Right Head-Rear | Parallel | Acceleration | RPM vs. Freq. | Very Light Plus | 3.6g | Good Response |
| 22-1 | Left Head-Rear | Perpendicular | Acceleration | RPM vs. Freq. | None | | No Response |
| 22-2 | Left Head-Rear | Parallel | Acceleration | RPM vs. Freq. | None | | Small Response Noted |
| 22-3 | Oil Pan | Perpendicular | Acceleration | RPM vs. Freq. | None | | No Response |
| 22-4 | Right Head-Rear | Perpendicular | Acceleration | RPM vs. Freq. | None | | No Response |
| 22-5 | Right Head-Front | Perpendicular | Acceleration | RPM vs. Freq. | None | | No Response |
| 22-6 | Right Head Rear | Parallel | Acceleration | RPM vs. Freq. | None | | Small Response Noted |

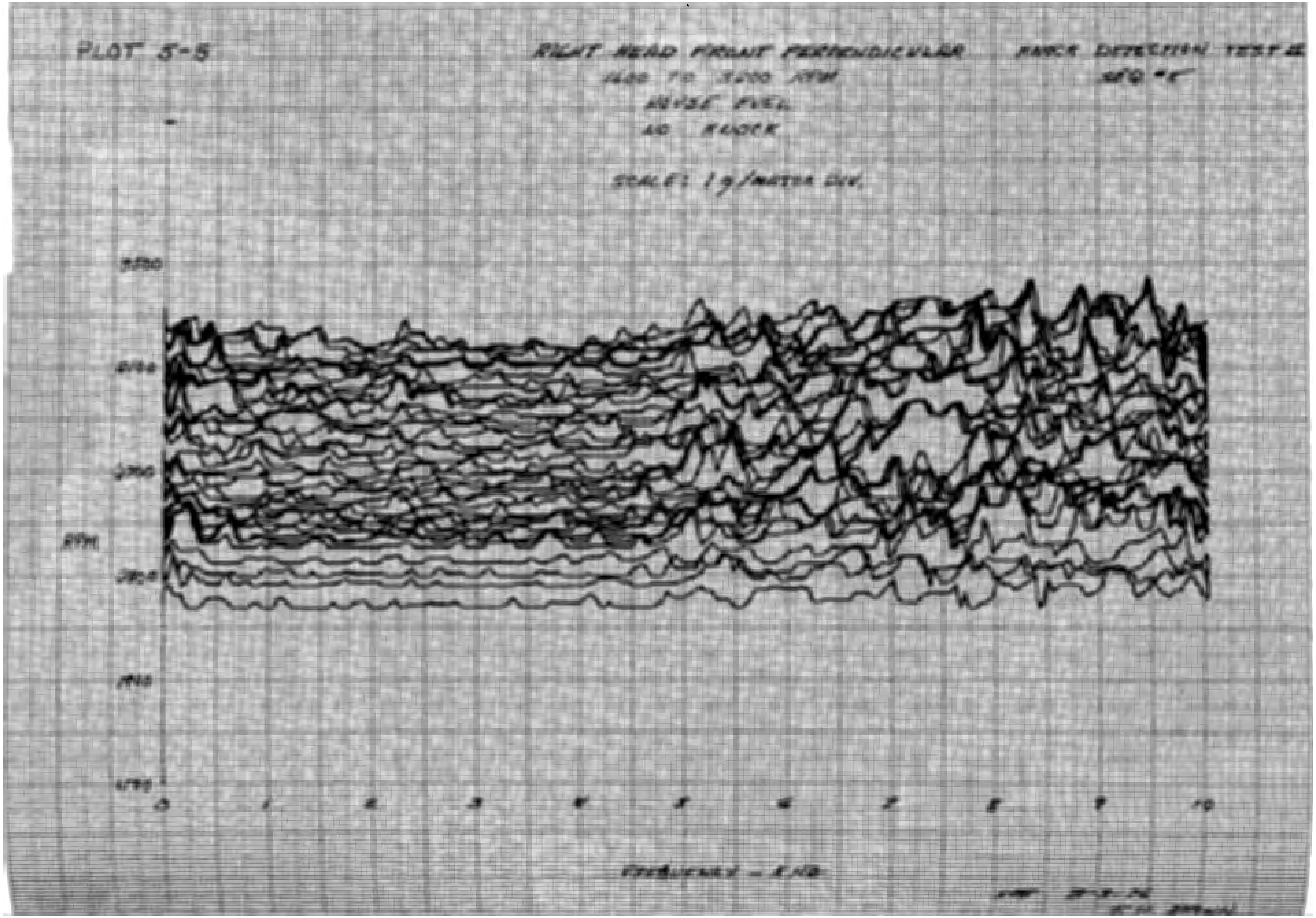


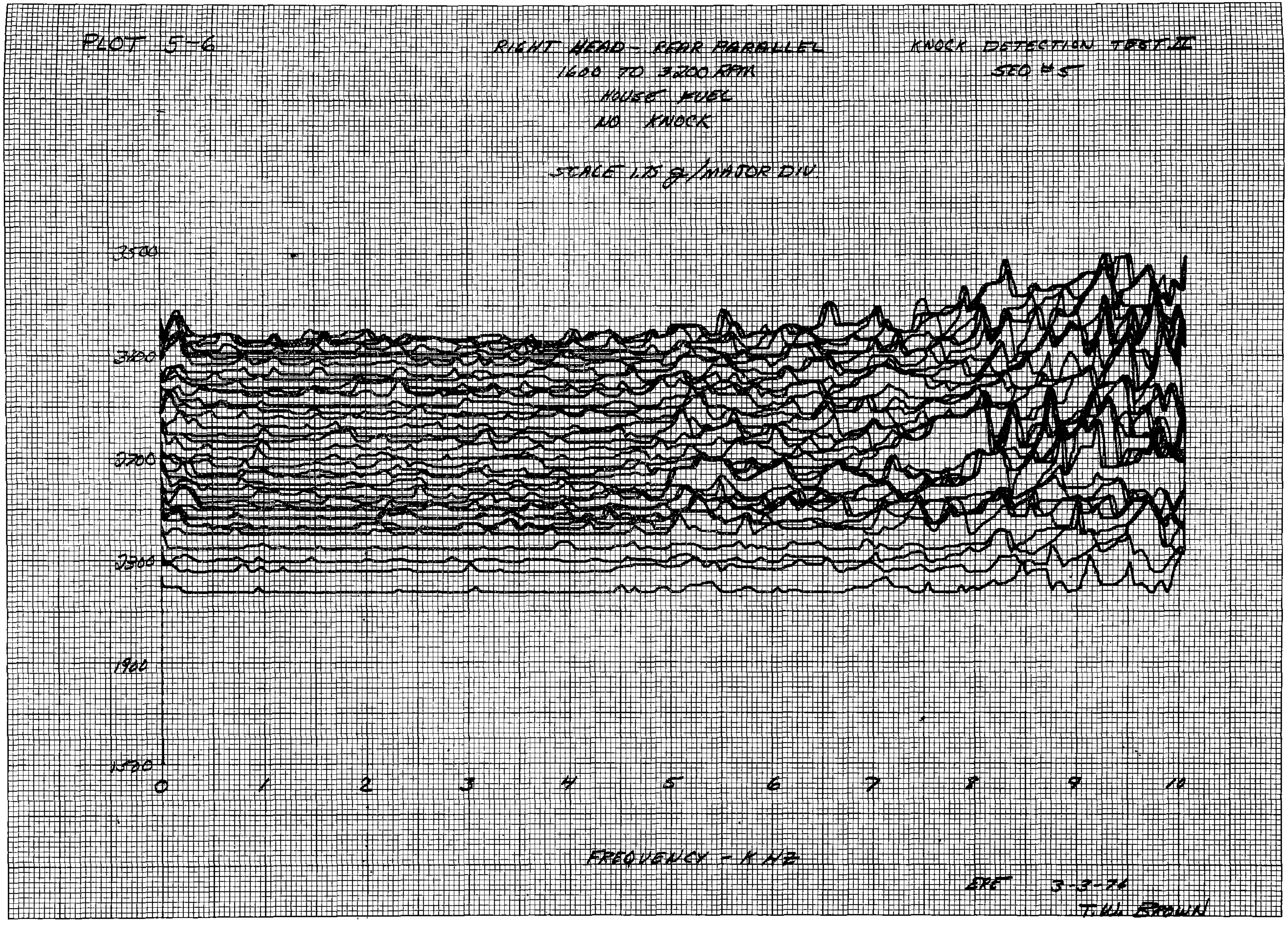
PLOT 5-1
RPM
0

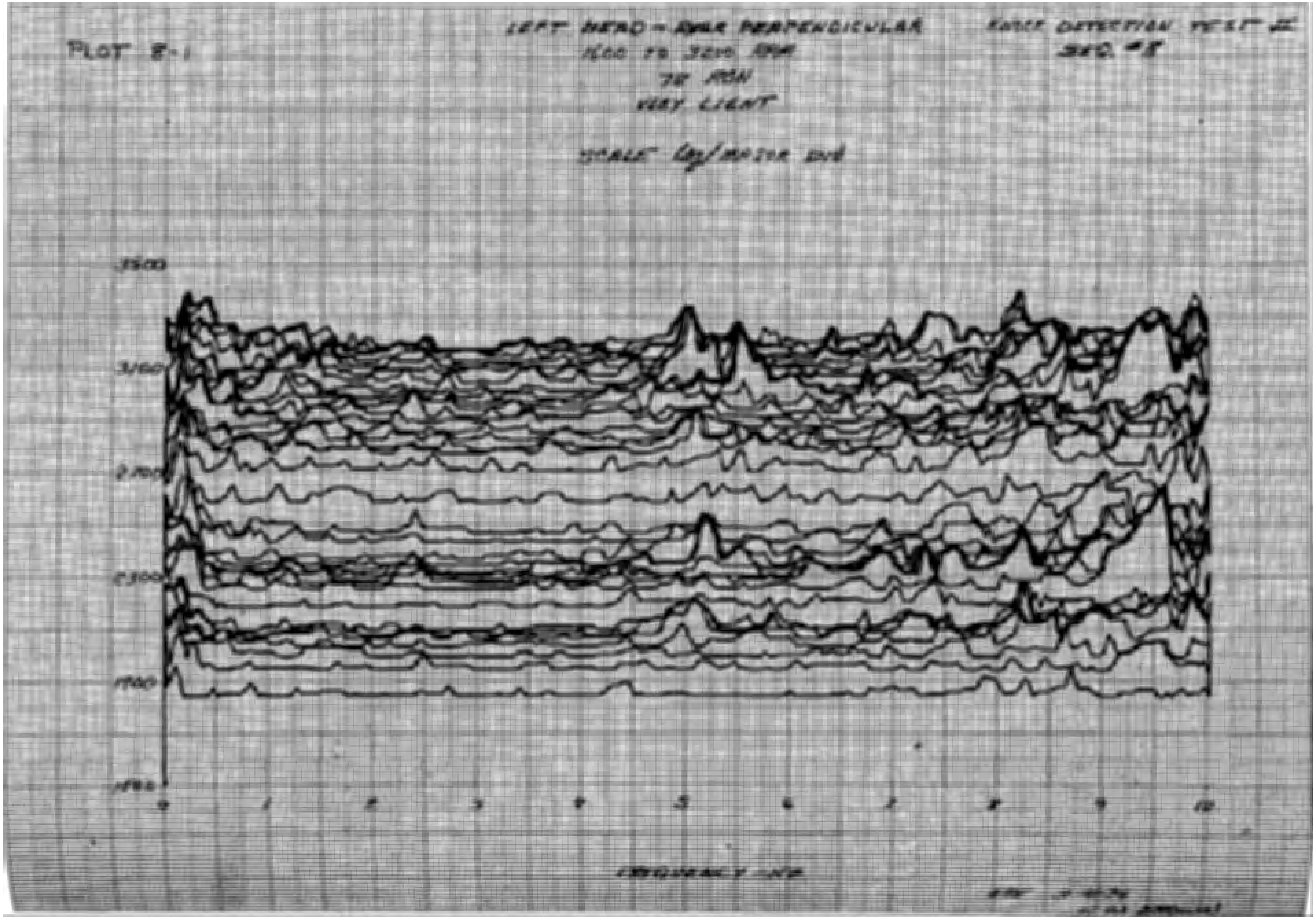

PLOT 5-2
LEFT HEAD - FRONT PERPENDICULAR KNOCK DETECTION TEST II
SEQ. #5
1600 RPM TO 3200 RPM
HOUSE FUEL
NO KNOCK
SCALE: 1.75 g/MAJOR DIV.
3500
3100
2700
RPM
2300
1900
1500
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
FREQUENCY - Hz
EKE 3-3-76
T.W. BROWN


PLOT 5-3
HOUSE FUEL
NO KNOCK
0
1
2
3
4
5
6
7
8
9
10

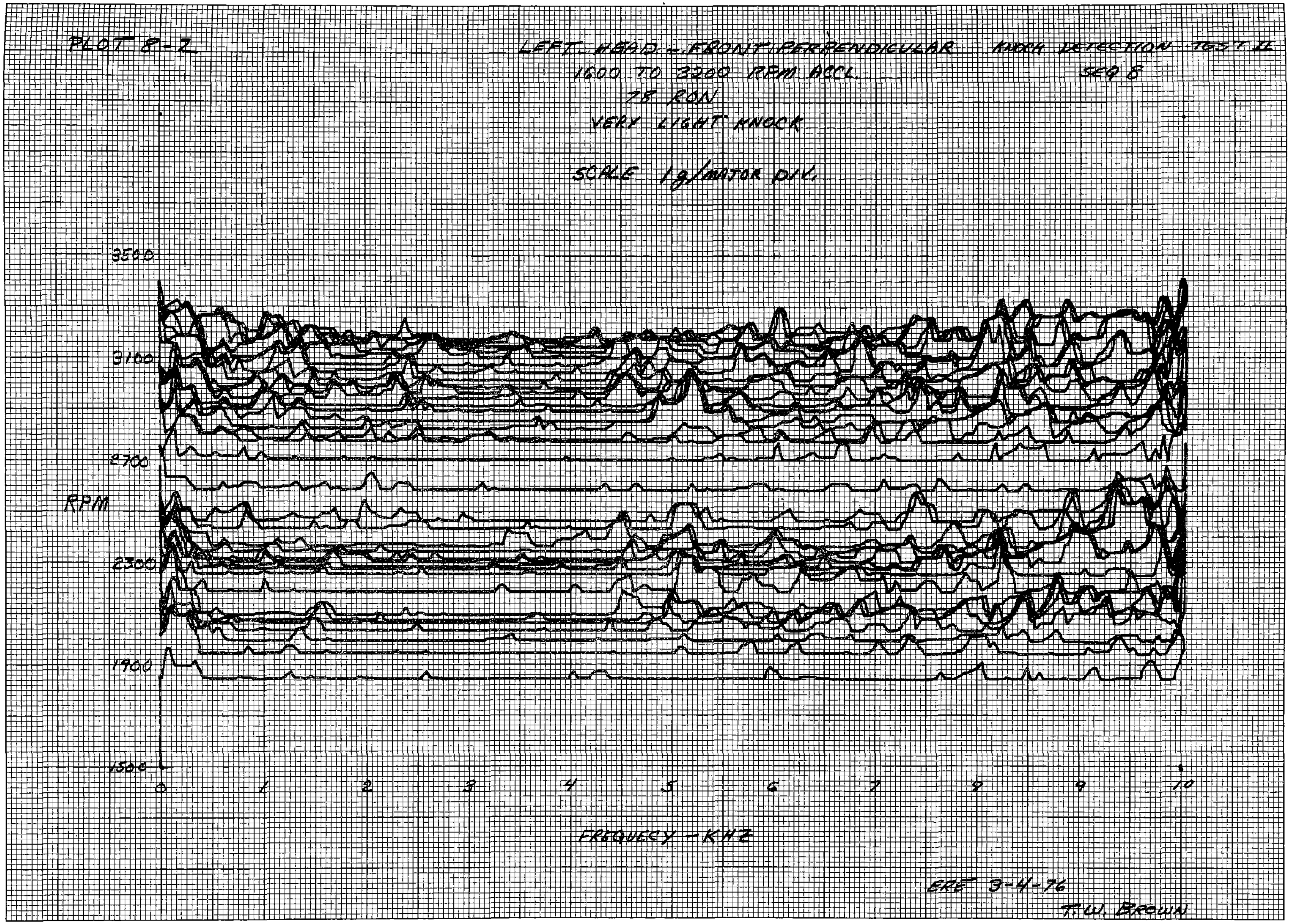

PLOT 5-11
RIGHT HEAD - REAR PERPENDICULAR
NO KNOCK
KNOCK DETECTION TEST
SCALE
RPM
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHz
T. W. BROWN

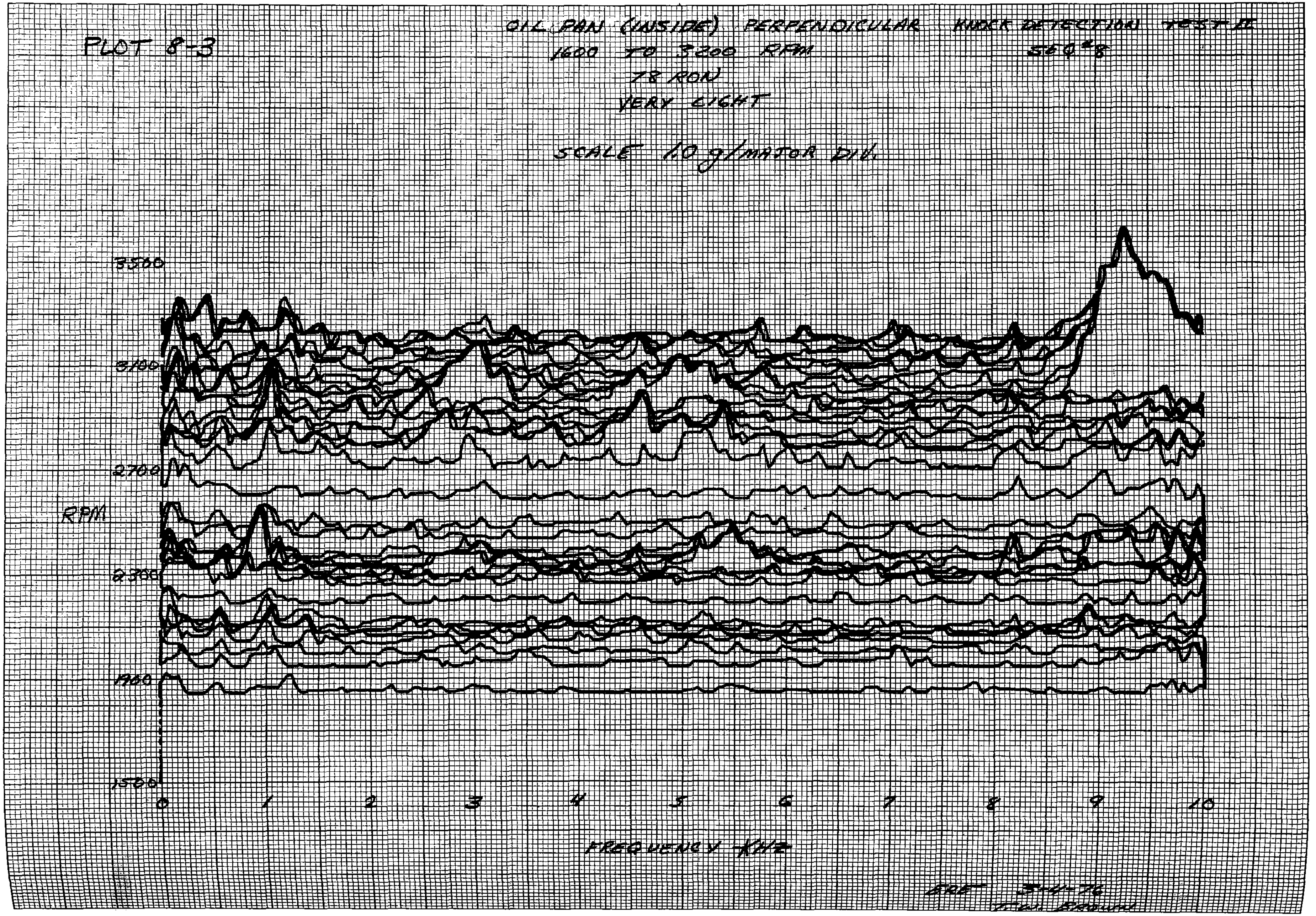

PLOT 5-5
NO KNOCK
SCALE: 1 g/MAJOR DIV.
RPM
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY – KHZ


PLOT 5-6
RIGHT HEAD - REAR PARALLEL
1600 TO 3200 RPM
HOUSE FUEL
NO KNOCK
KNOCK DETECTION TEST II
SEQ #5
SCALE 1.25 g/MAJOR DIV.
3500
3100
2700
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ
EXE 3-3-76
T.W. BROWN



LEFT HEAD - REAR PERPENDICULAR
VERY LIGHT
3500
3100
2700
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10

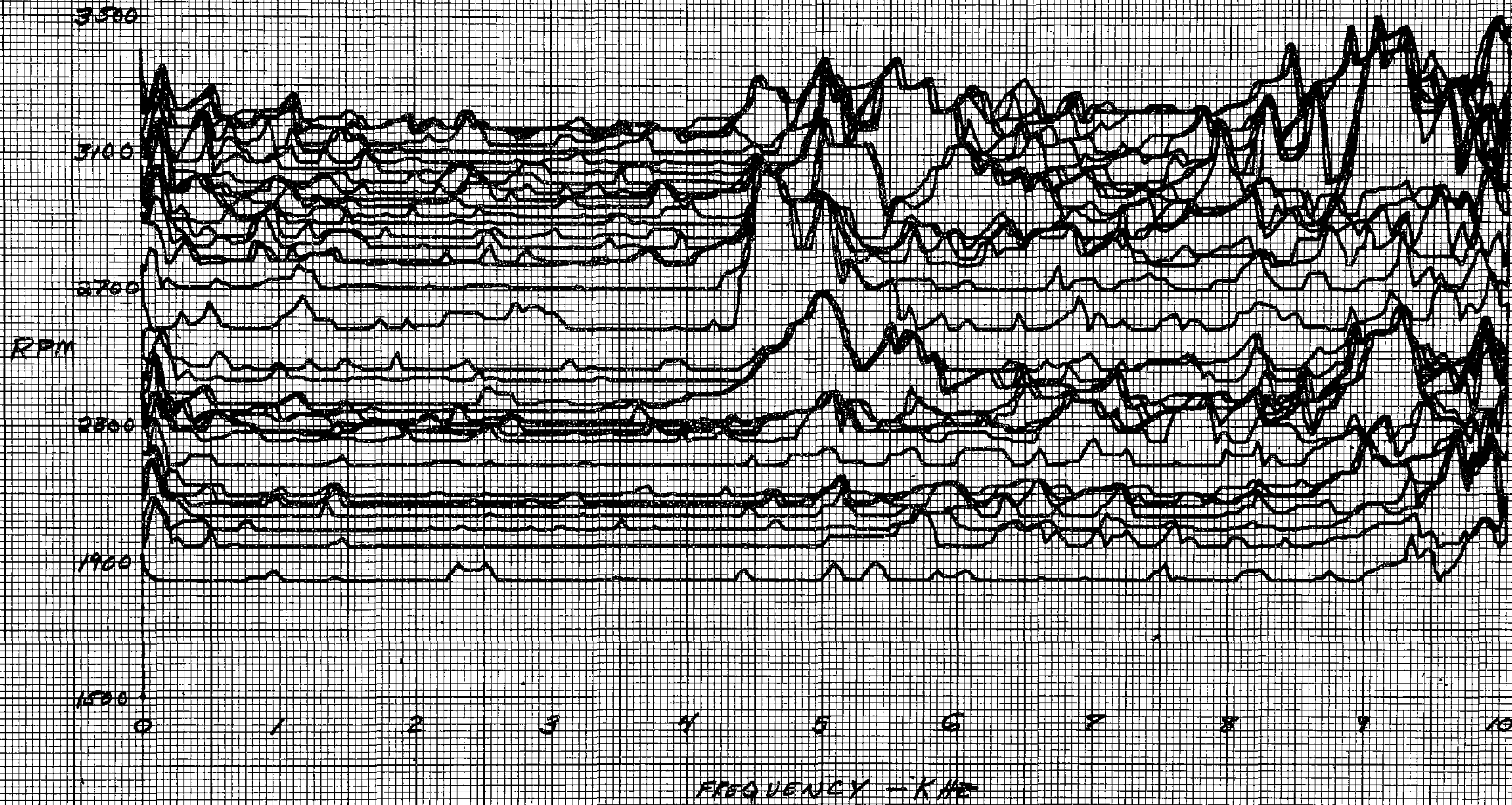

PLOT 8-2
LEFT HEAD - FRONT PERPENDICULAR
KNOCK DETECTION TEST II
1600 TO 3200 RPM ACCL.
SEQ 8
78 RON
VERY LIGHT KNOCK
SCALE 1g/MAJOR DIV.
3500
3100
2700
RPM
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10
FREQUECY - KHZ
ERE 3-4-76
T.W. BROWN


PLOT 8-3
OIL PAN (INSIDE) PERPENDICULAR KNOCK DETECTION TEST II
1600 TO 3200 RPM
SEQ #8
78 RON
VERY LIGHT
SCALE 1.0 g/MAJOR DIV.
3500
3100
2700
RPM
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY -KHZ

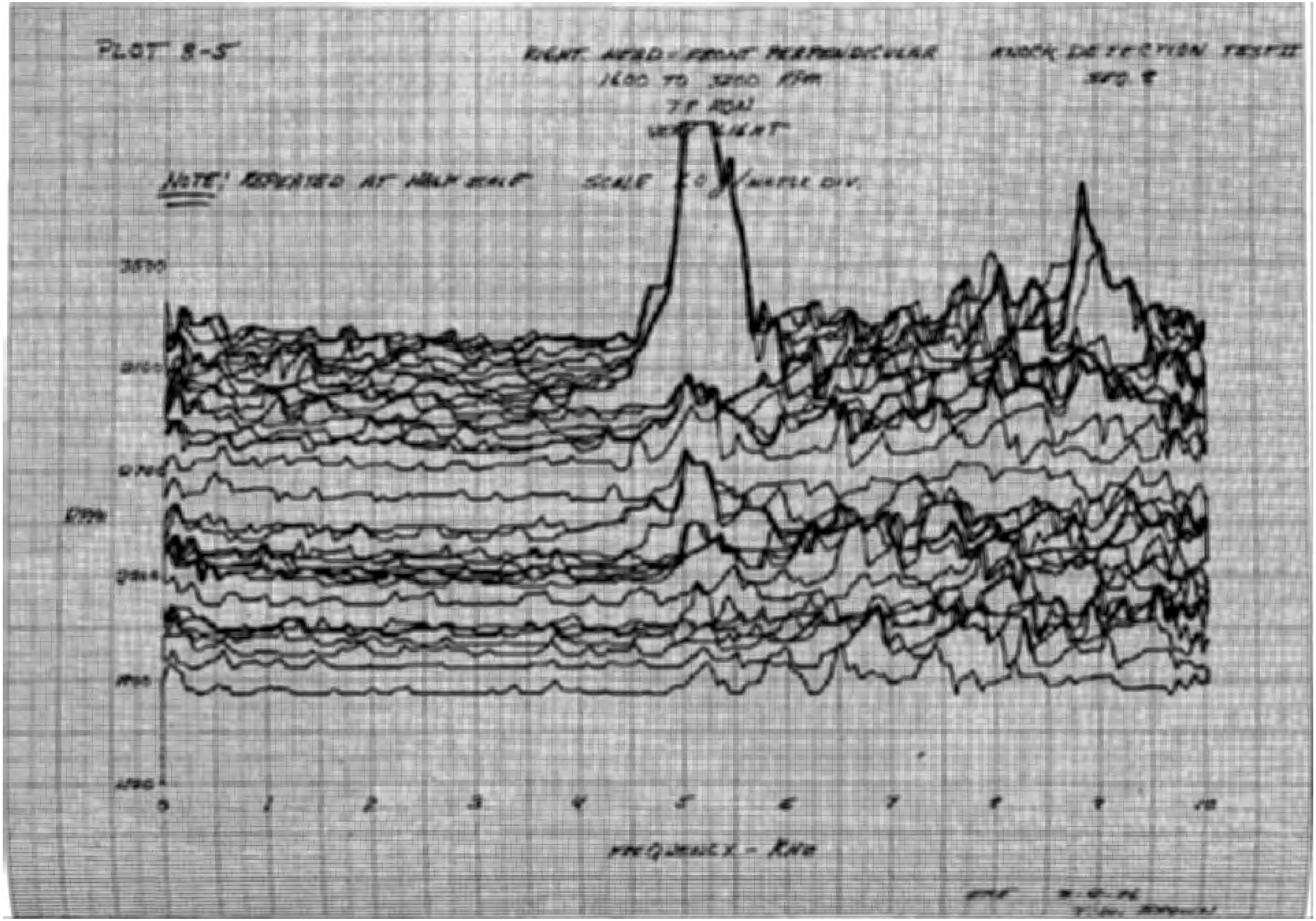
PLOT 8-4

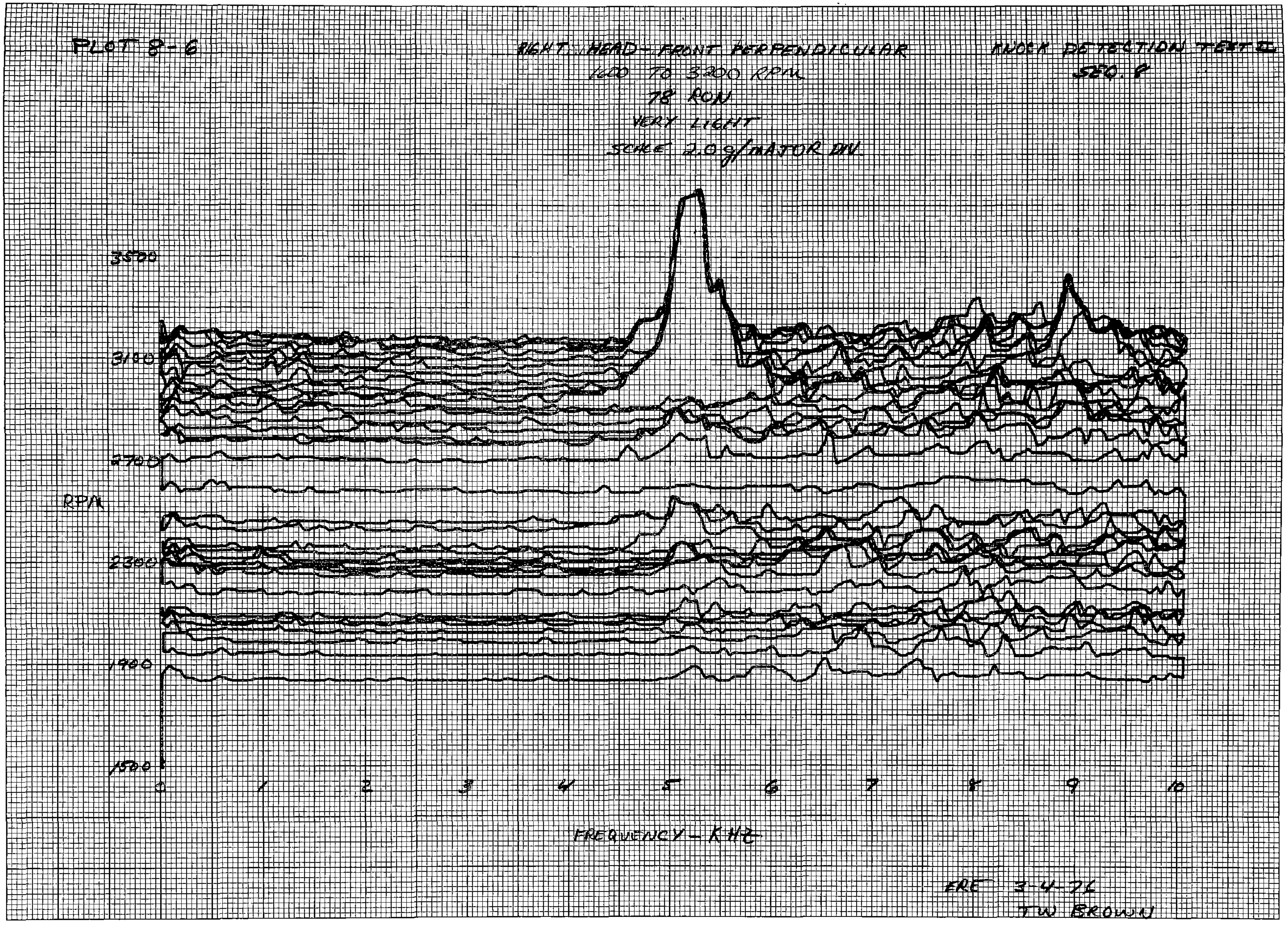
RIGHT HEAD — REAR PERPENDICULAR KNOCK DETECTION TEST II
1600 TO 3200 RPM SEQ 8
78 RON
VERY LIGHT

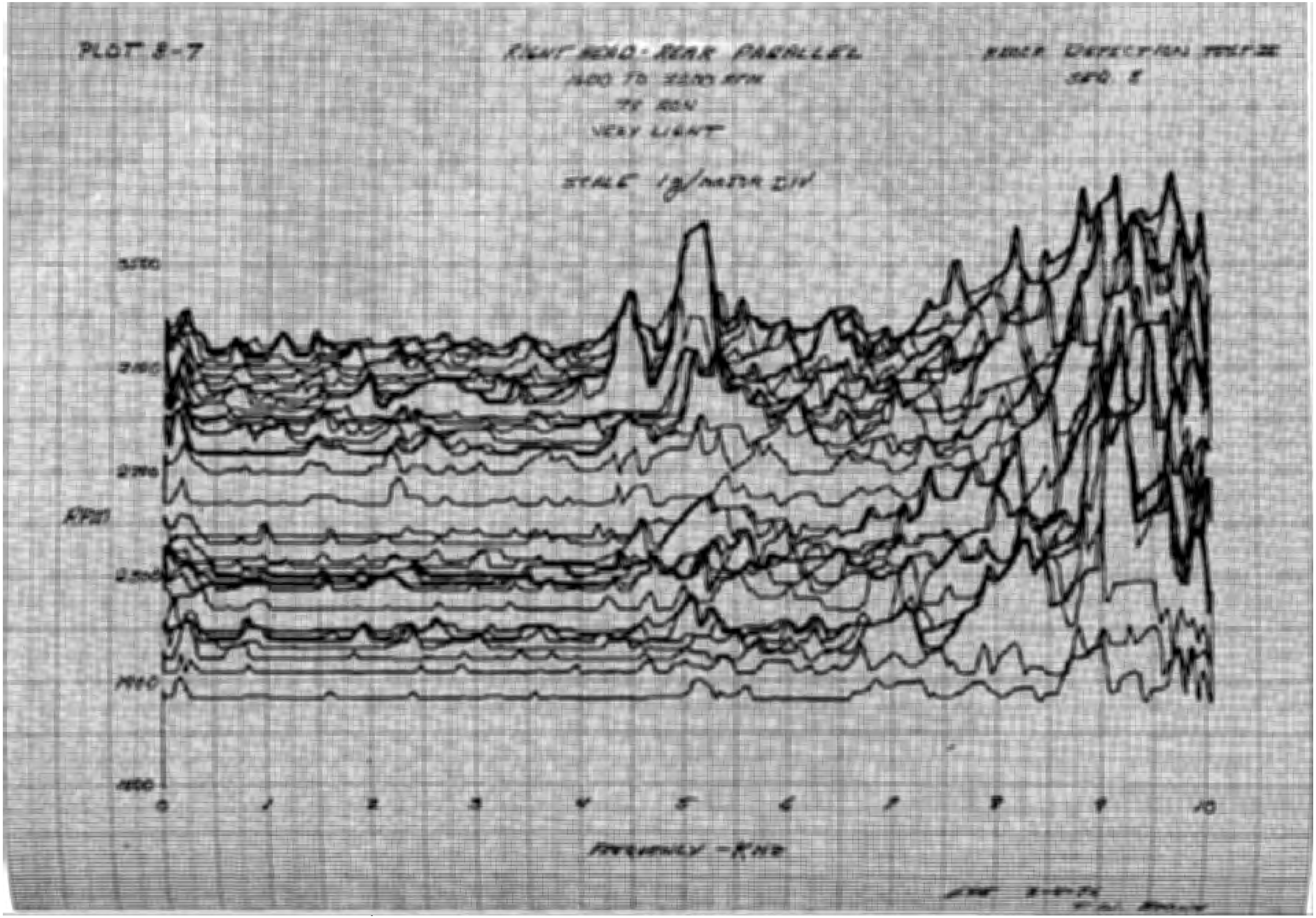
SCALE 1.0 g/MAJOR DIV.



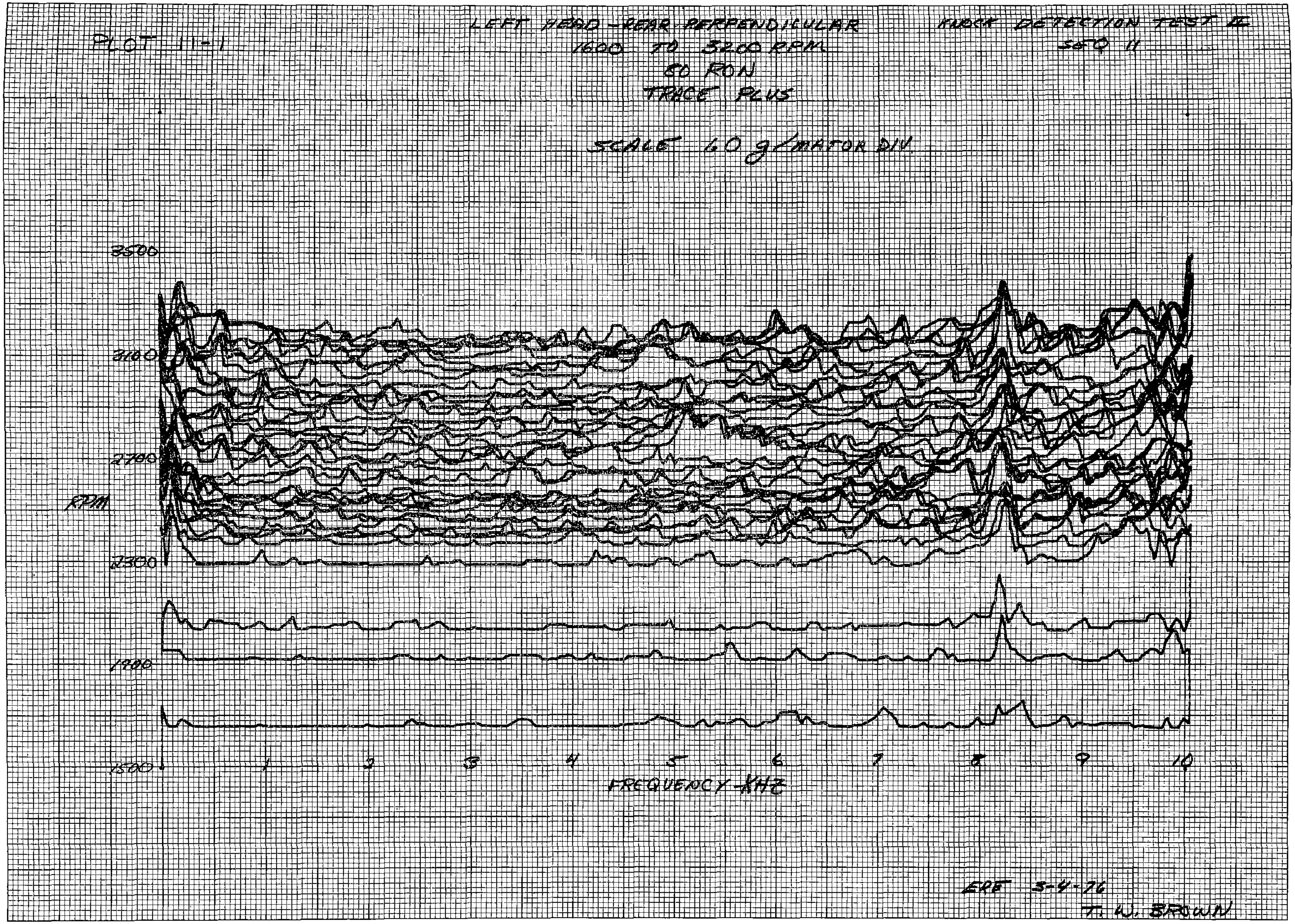

ERC 3-4-76
T. W. BROWN


PLOT 8-5
RIGHT HEAD - FRONT PERPENDICULAR
1600 TO 3200 RPM
KNOCK DETECTION TEST II
NOTE: REPEATED AT HALF SCALE
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ

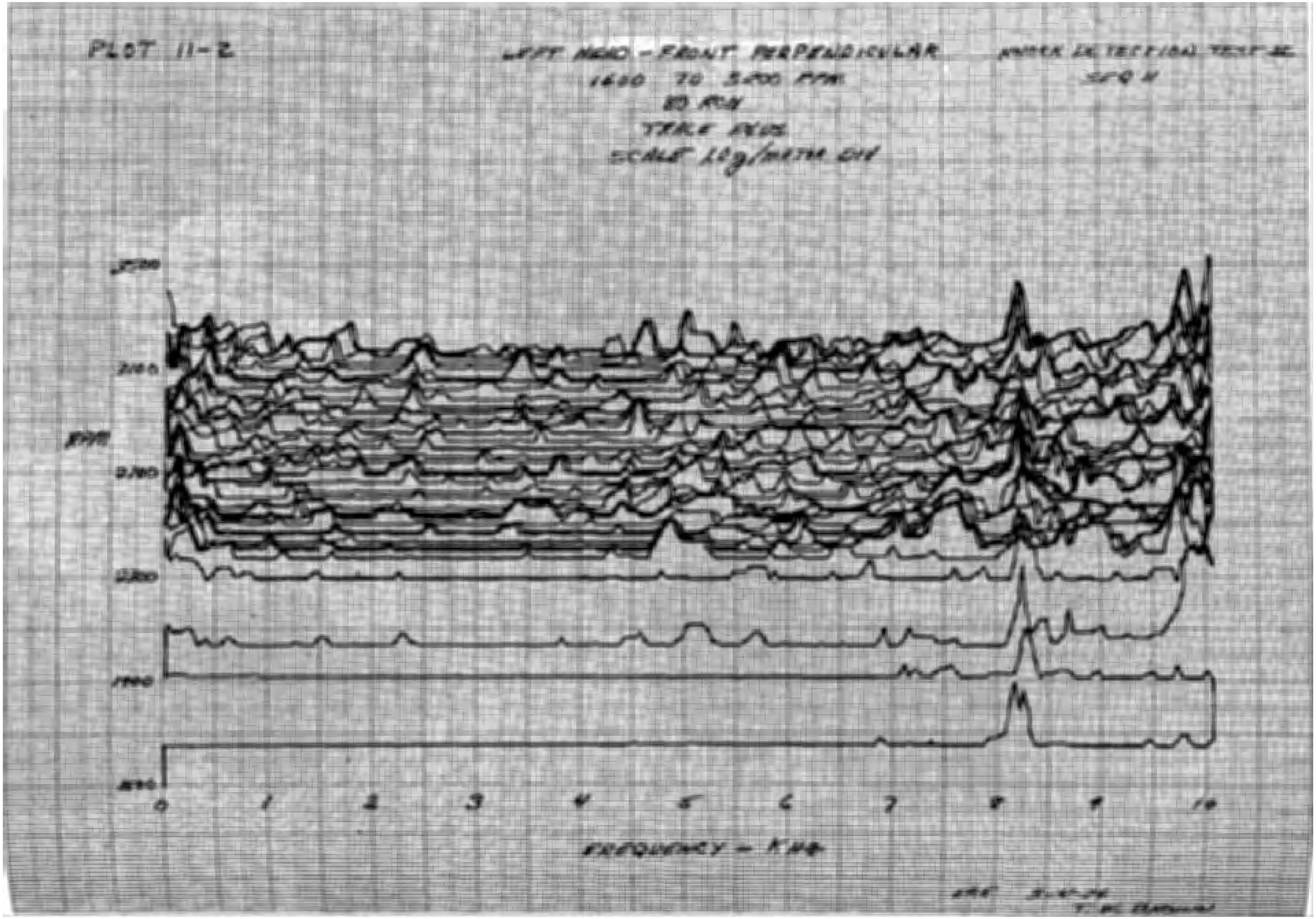

PLOT 8-6
RIGHT HEAD - FRONT PERPENDICULAR
1600 TO 3200 RPM
78 RON
VERY LIGHT
SCALE 2.0 g/MAJOR DIV.
KNOCK DETECTION TEST II
SEQ. 8
3500
3100
2700
RPM
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ
ERE 3-4-76
T W BROWN

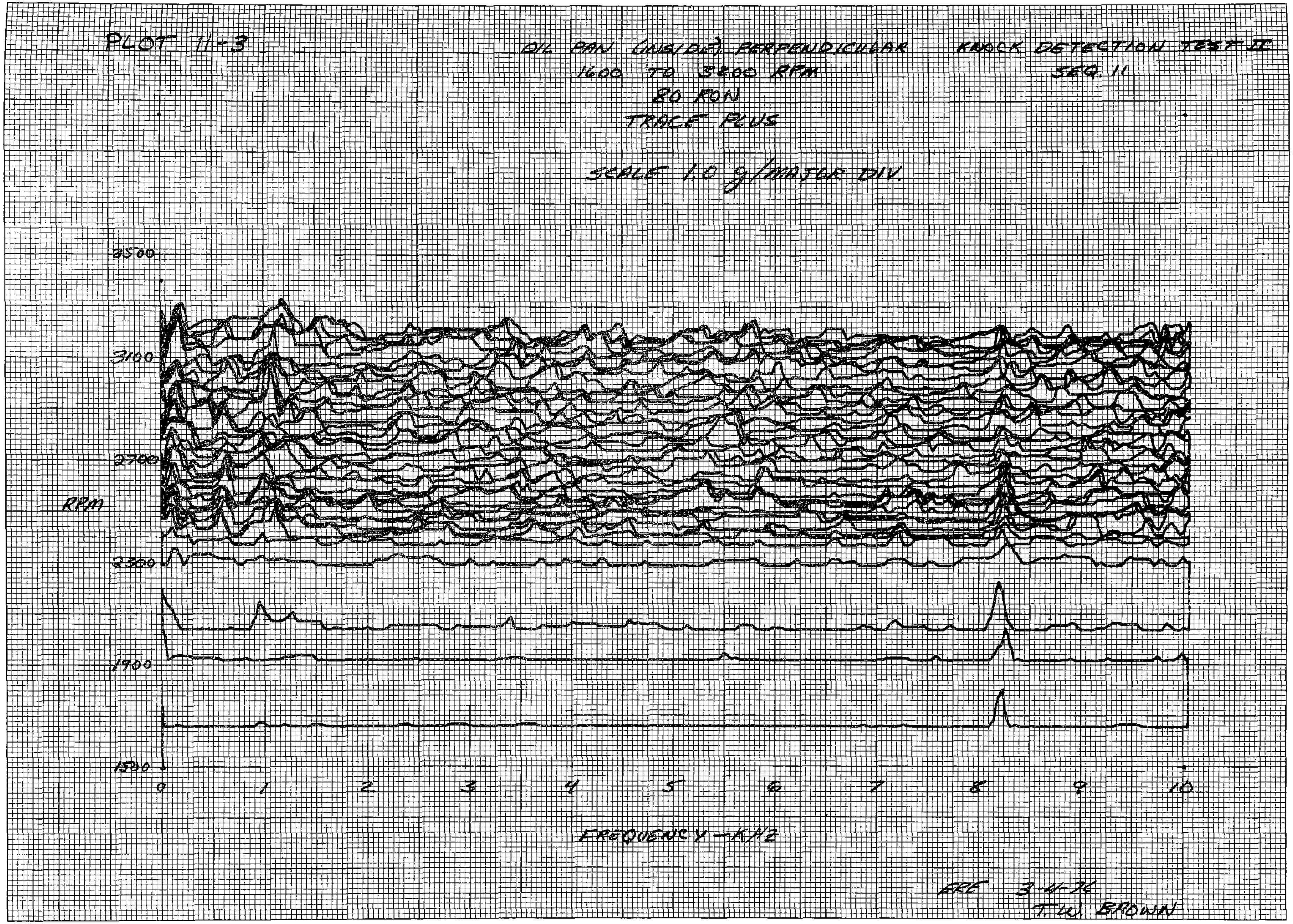


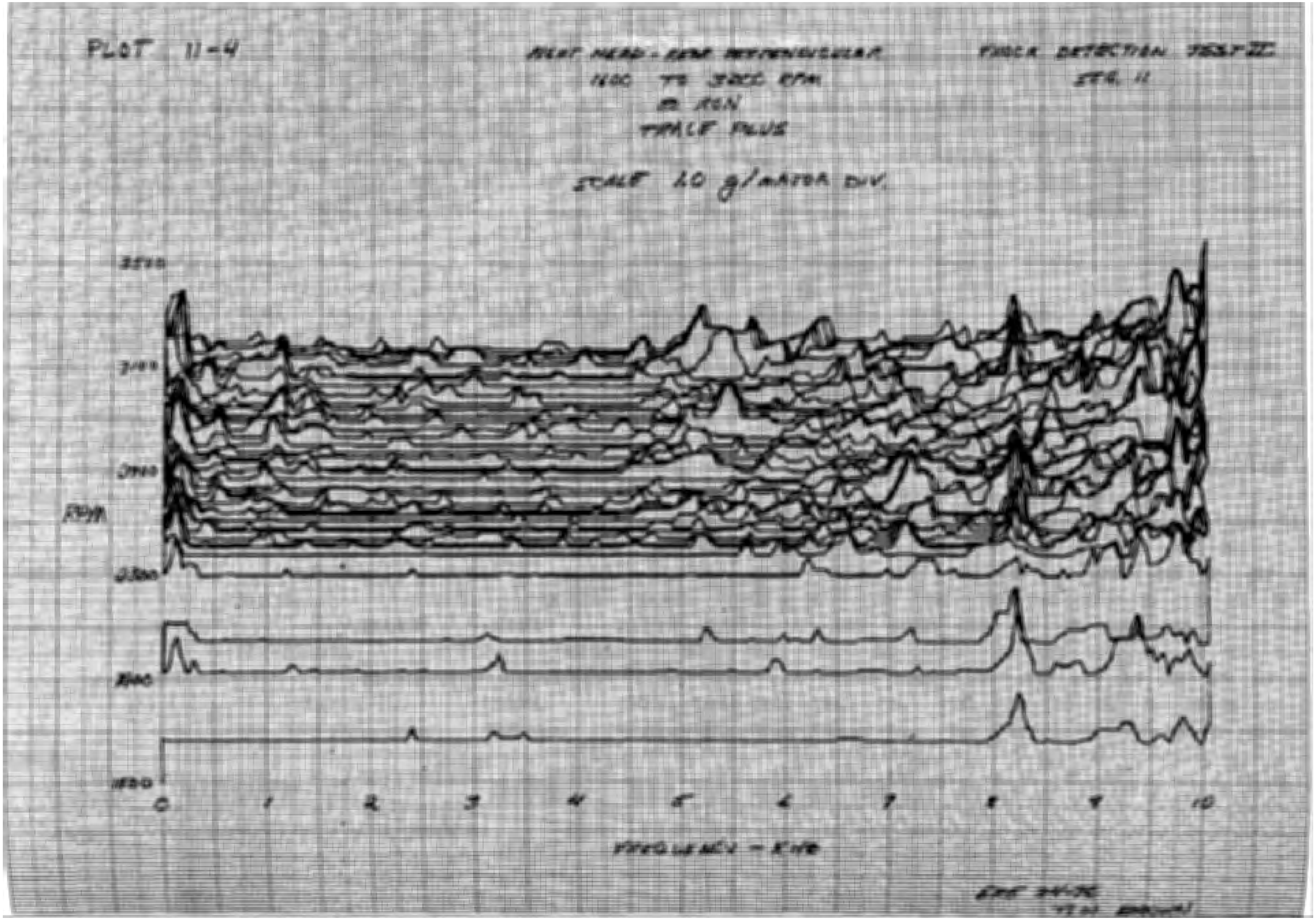
PLOT 8-7
RIGHT HEAD - REAR PARALLEL
VERY LIGHT
SCALE 1g/MAJOR DIV
RPM
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHz

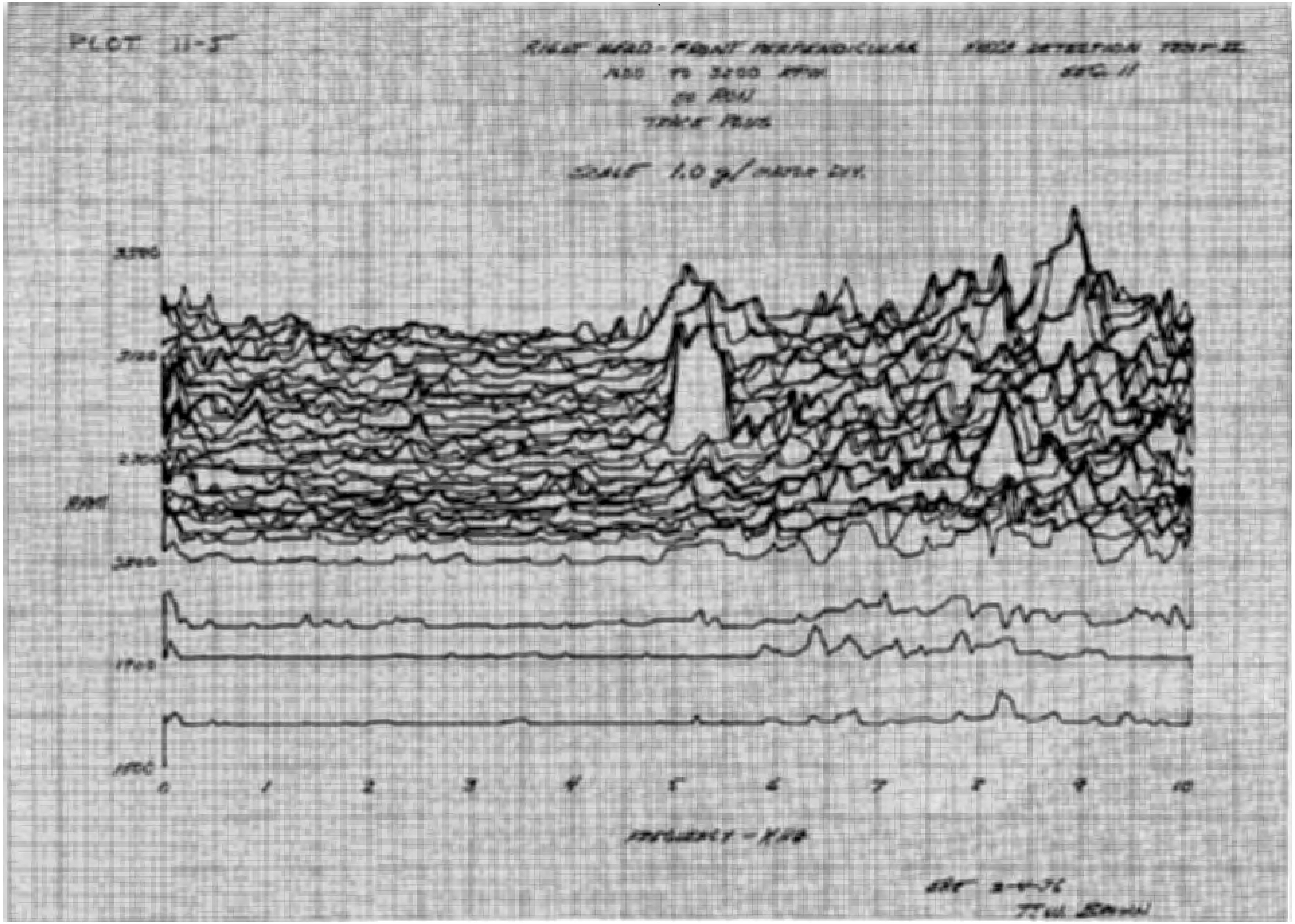


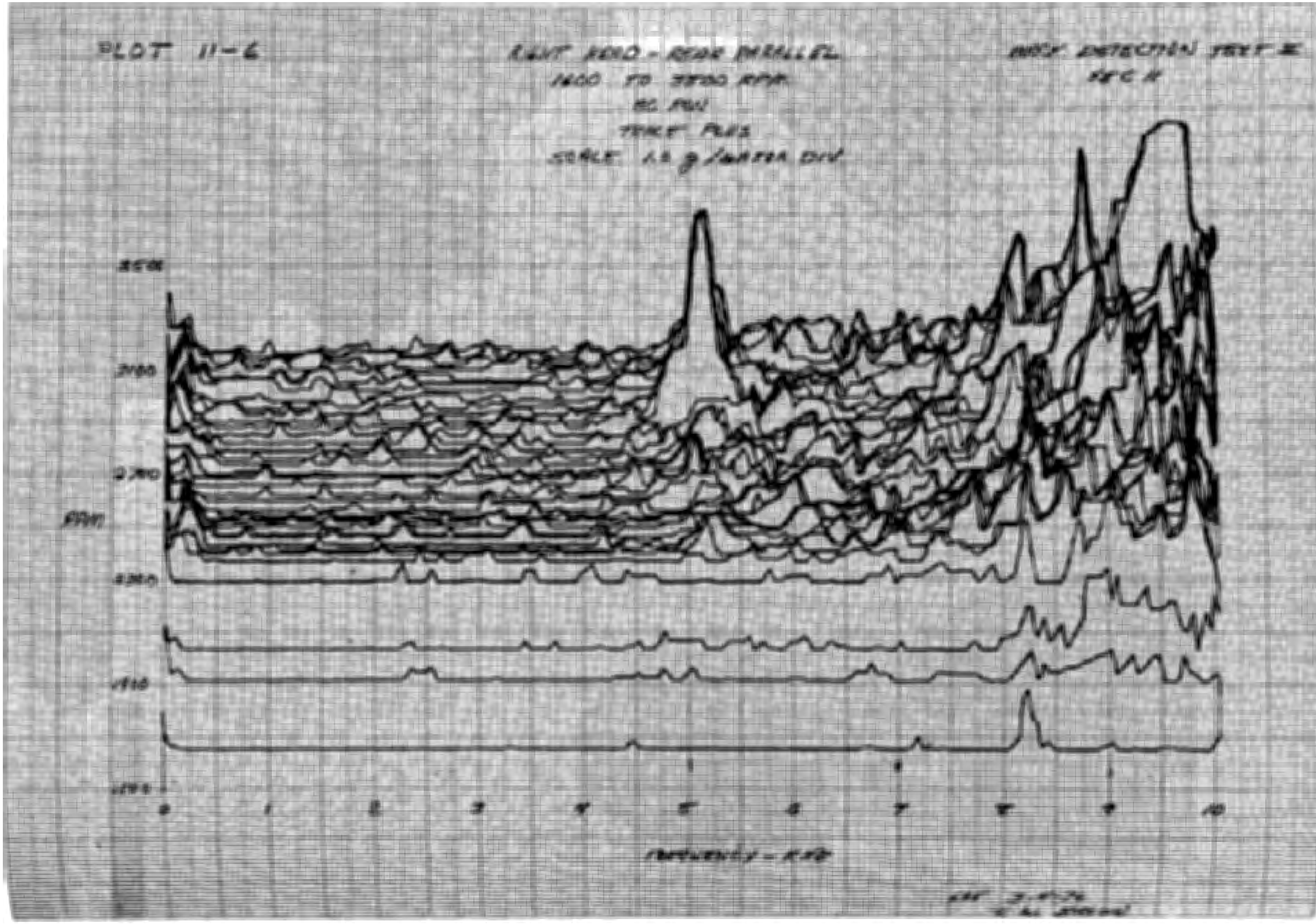
PLOT 11-1
LEFT HEAD - REAR - PERPENDICULAR
1600 TO 3200 RPM
80 RON
TRACE PLUS
KNOCK DETECTION TEST II
SEQ 11
SCALE 1.0 g/MAJOR DIV.
3500
3100
2700
RPM
2300
1900
1500
1
2
3
4
5
6
7
8
9
10
FREQUENCY-KHZ
ERE 3-4-76
T. W. BROWN


PLOT 11-2
FRONT PERPENDICULAR
0
1
2
3
4
5
6
7
8
9
10

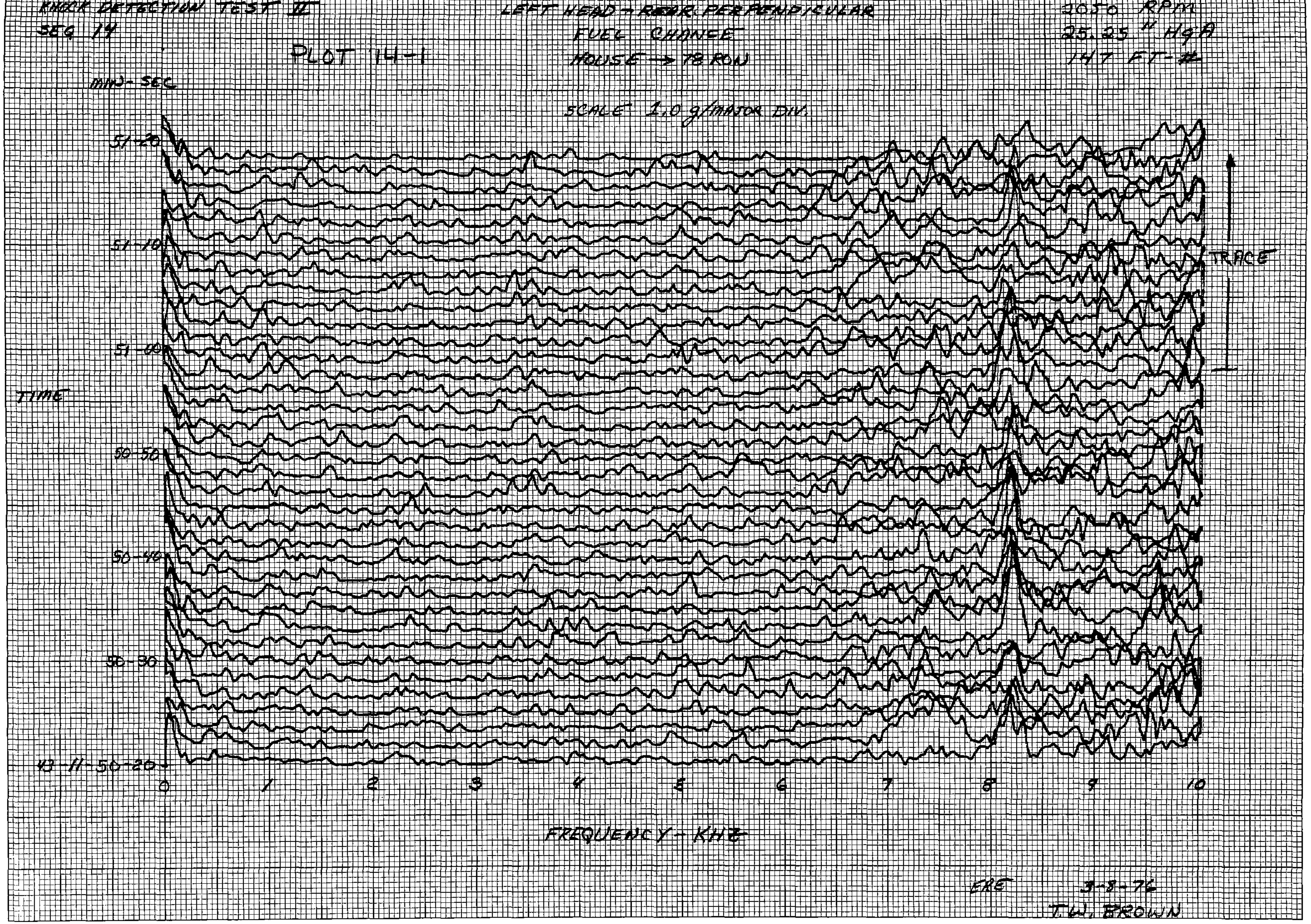

PLOT 11-3
OIL PAN (INSIDE) PERPENDICULAR
1600 TO 3500 RPM
80 RON
TRACE PLUS
KNOCK DETECTION TEST II
SEQ. 11
SCALE 1.0 g/MAJOR DIV.
3500
3100
2700
RPM
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY — KHZ
FRF 3-4-76
T. W. BROWN

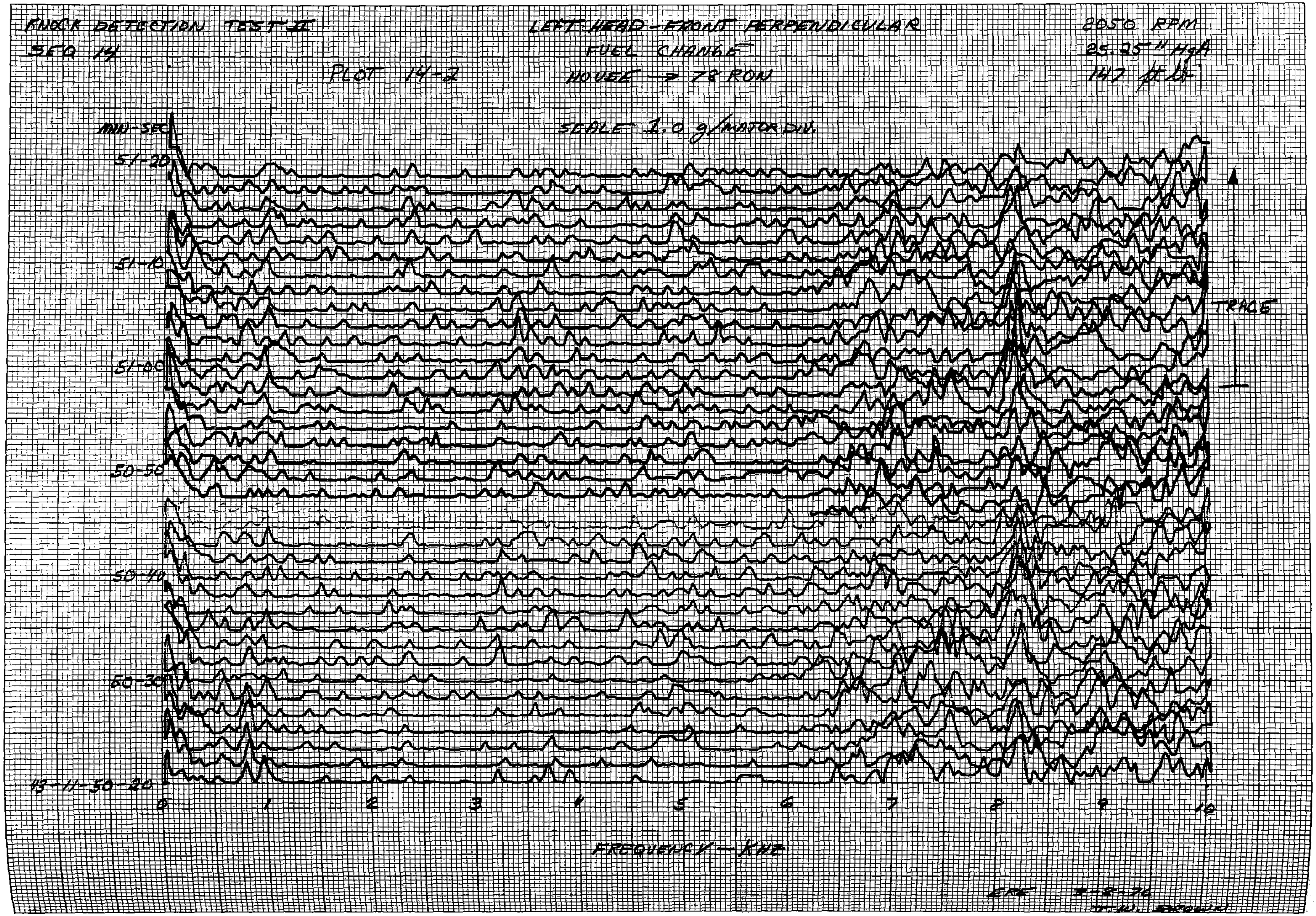

PLOT 11-4
SCALE 1.0 g/MAJOR DIV.
RPM
0
1
2
3
4
5
6
7
8
9
10

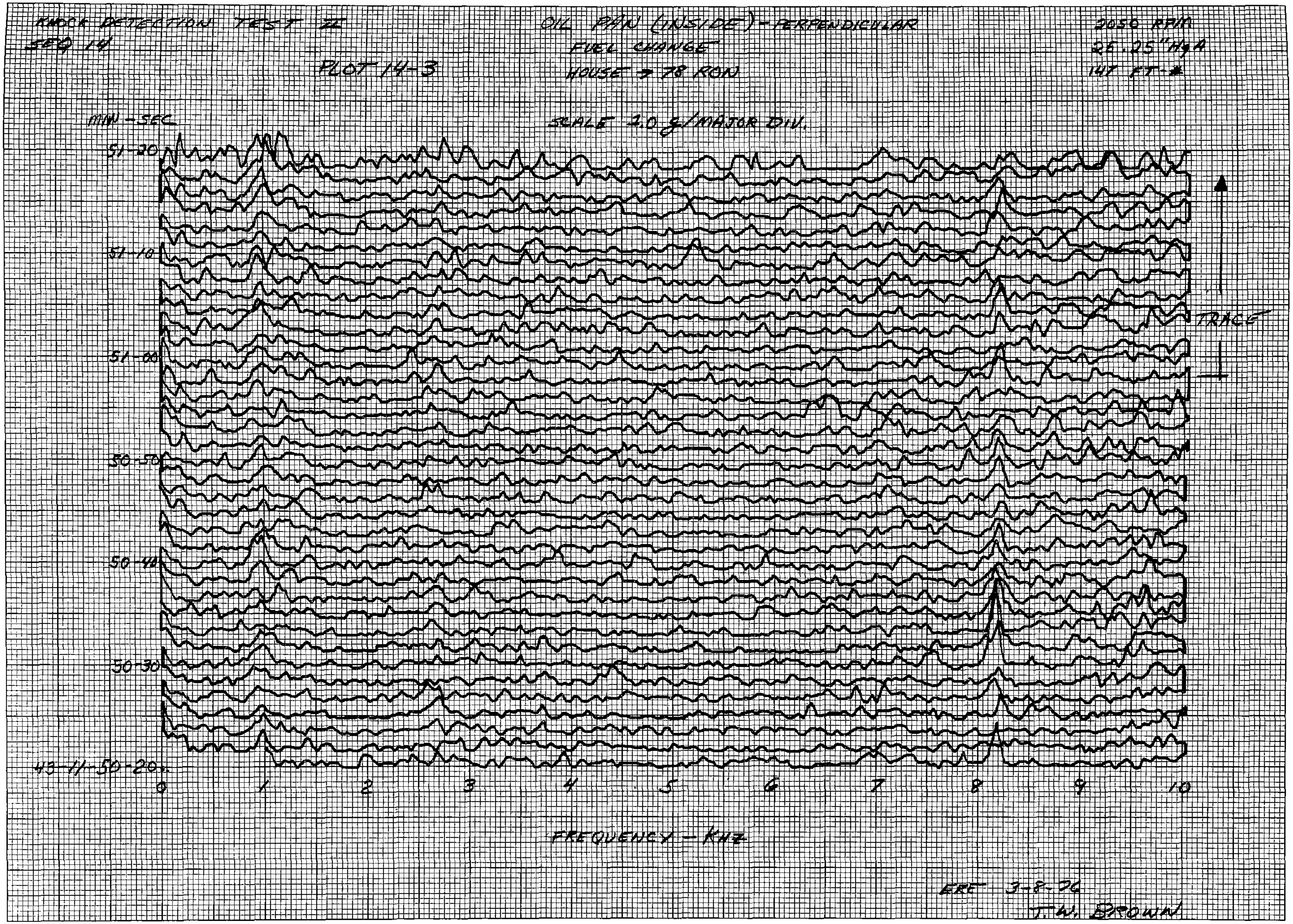

PLOT 11-5
1400 TO 3200 RPM
SCALE 1.0 g/ MAJOR DIV.
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ

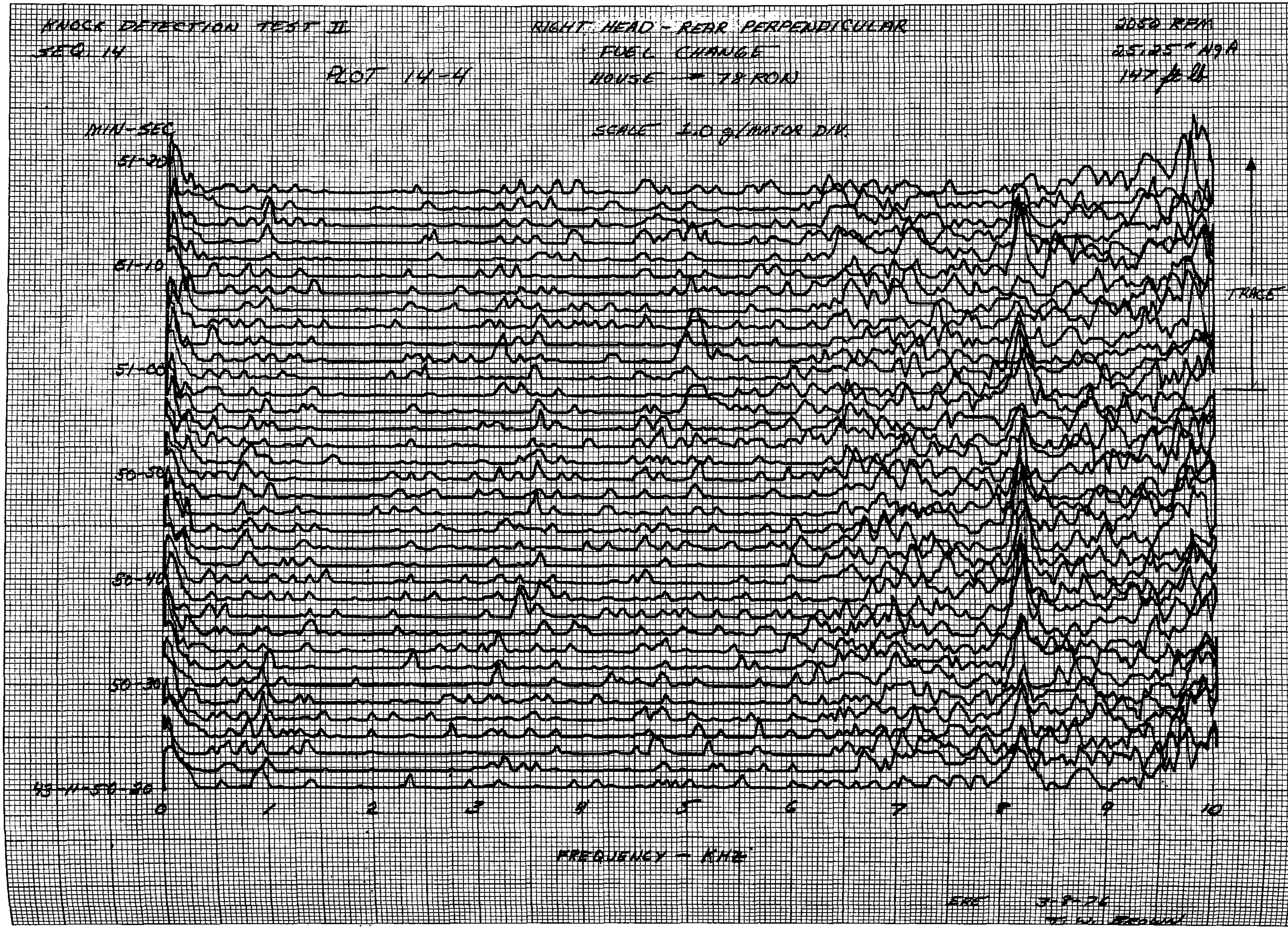

PLOT 11-6

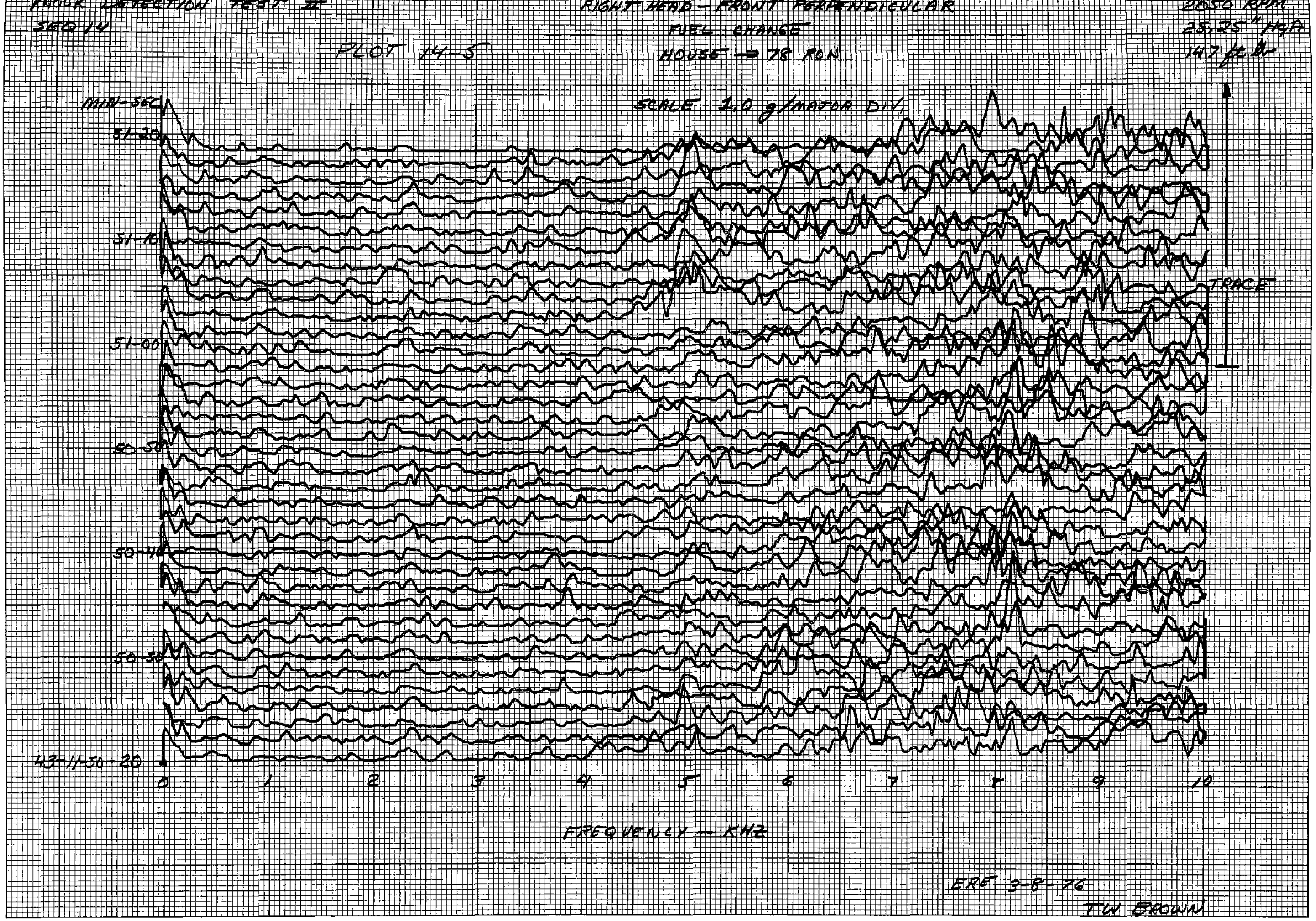
14-1

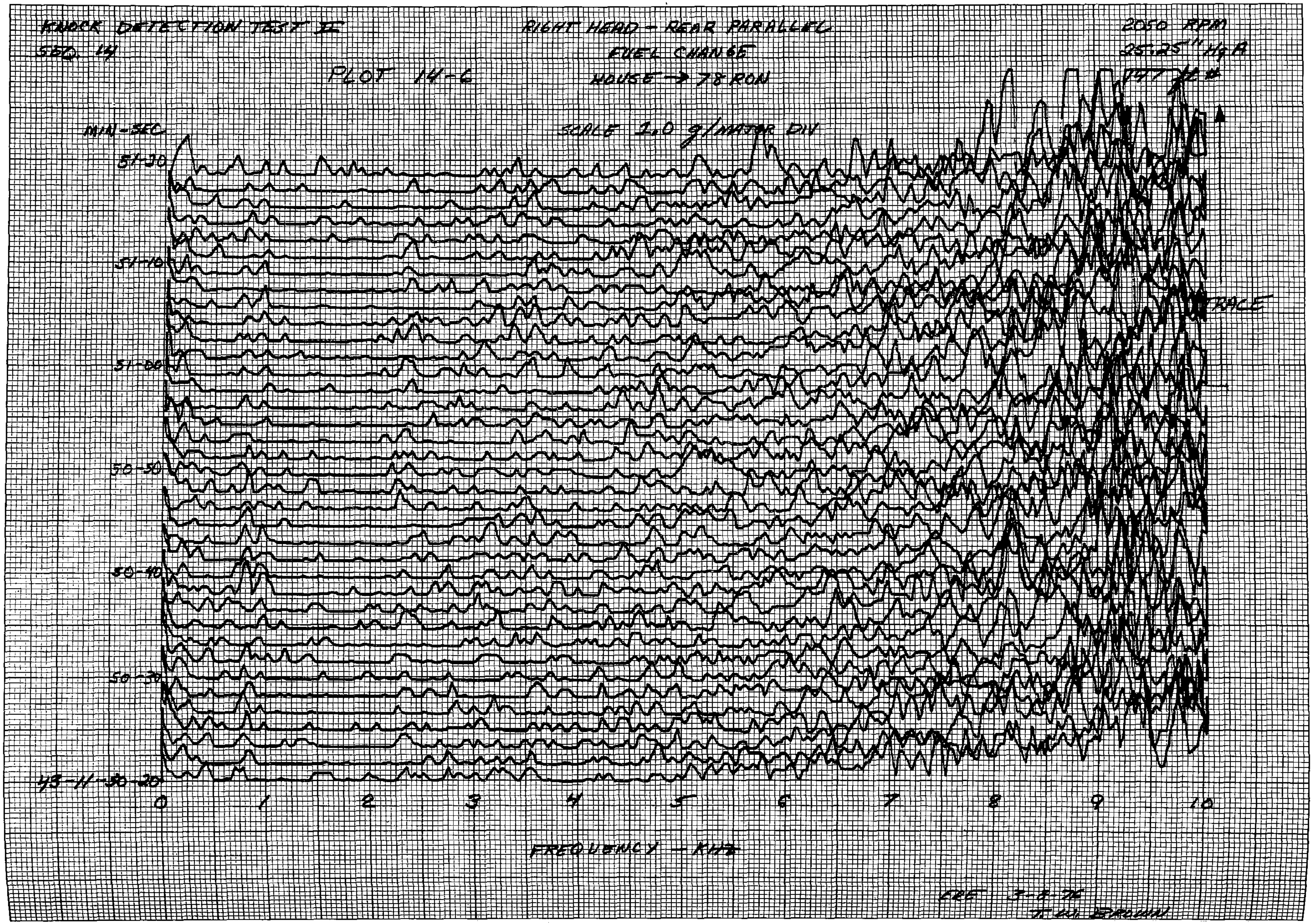

KNOCK DETECTION TEST II
SEG 14
PLOT 14-1
LEFT HEAD – REAR PERPENDICULAR
FUEL CHANGE
HOUSE → 78 RON
2050 RPM
25.25 " HgA
147 FT-#
MIN-SEC
SCALE 1.0 g/MAJOR DIV.
51-20
51-10
51-00
TIME
50-50
50-40
50-30
43-11-50-20
TRACE
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ
EKE 3-8-76
T.W. BROWN

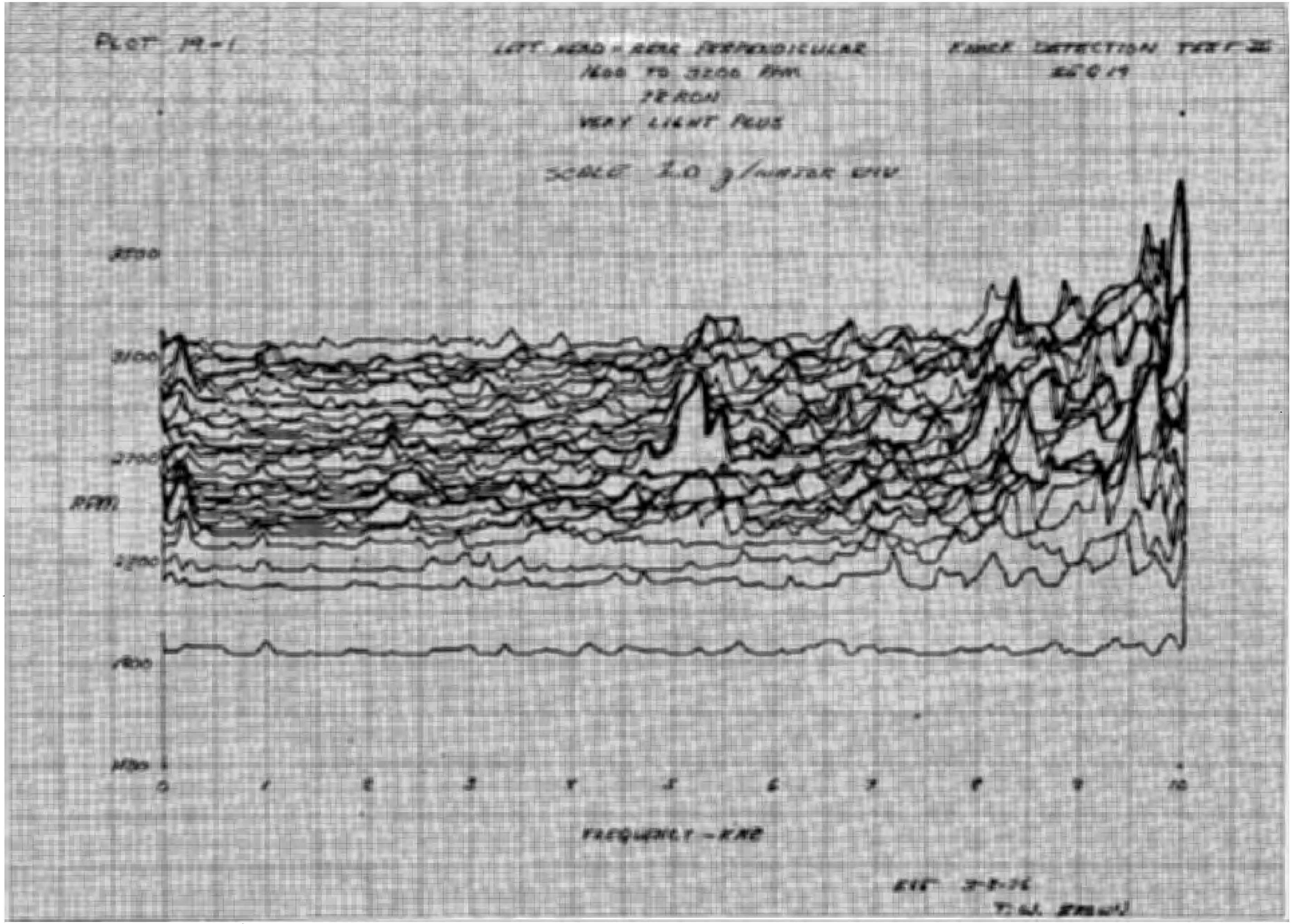

KNOCK DETECTION TEST II
SEQ 14
PLOT 14-2
LEFT HEAD - FRONT PERPENDICULAR
FUEL CHANGE
HOUSE → 78 RON
8050 RPM
25.25" HgA
SCALE 1.0 g/MAJOR DIV.
MIN-SEC
51-20
51-10
51-00
50-50
50-40
50-30
43-11-50-20
TRACE
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY — KHZ
ERE
T.W. BROWN

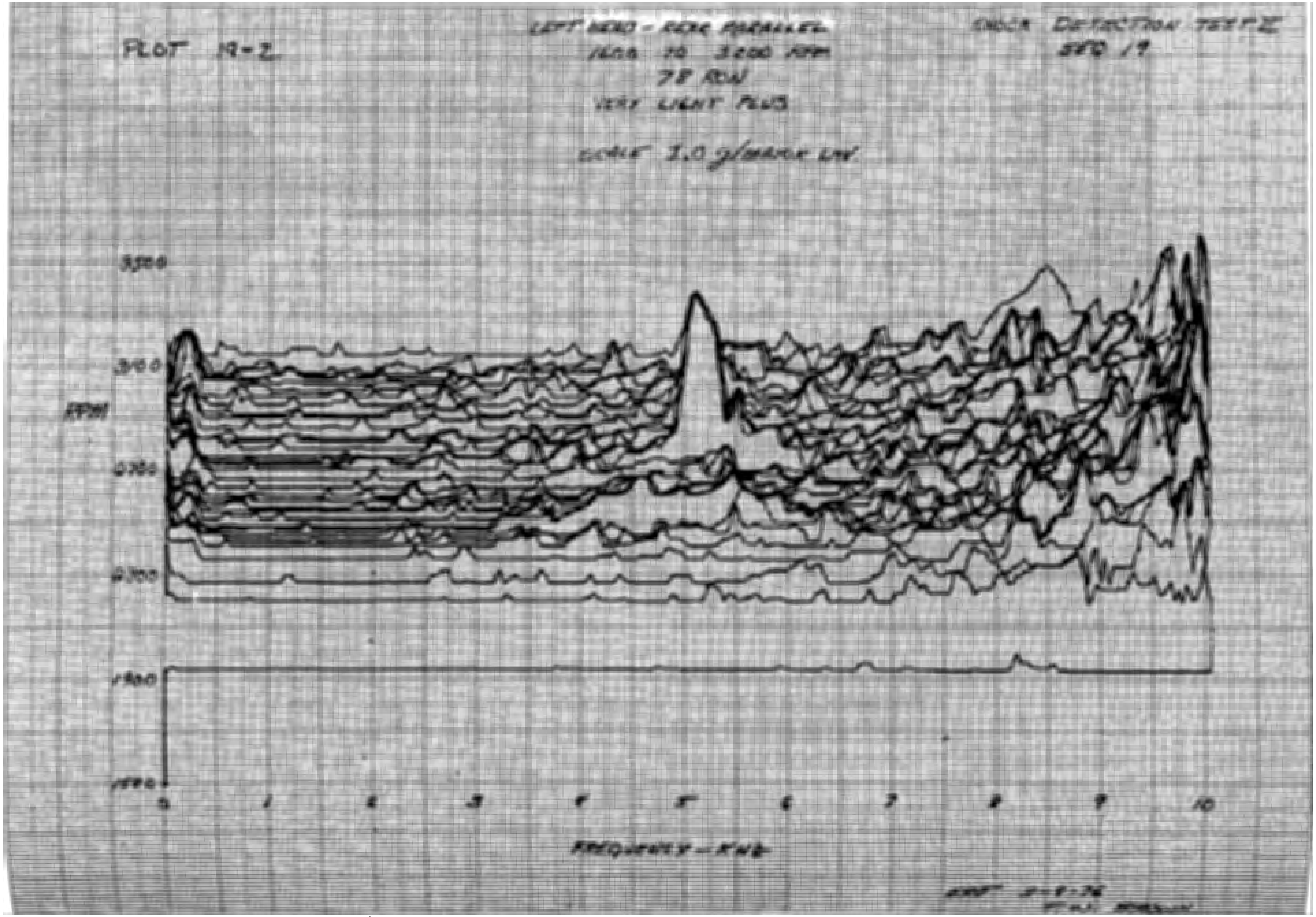

KNOCK DETECTION TEST II
SEQ 14
PLOT 14-3
OIL PAN (INSIDE) - PERPENDICULAR
FUEL CHANGE
HOUSE → 78 RON
2050 RPM
25.25" HgA
147 FT-#
MIN-SEC
SCALE 2.0 g/MAJOR DIV.
51-20
51-10
51-00
50-50
50-40
50-30
43-11-50-20
TRACE
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ
ERE 3-8-76
T.W. BROWN


KNOCK DETECTION TEST II
SEQ. 14
PLOT 14-4
RIGHT HEAD - REAR PERPENDICULAR
FUEL CHANGE
HOUSE → 78 RON
2050 RPM
MIN-SEC
SCALE 1.0 g/MAJOR DIV.
51-20
51-10
51-00
50-50
50-40
50-30
TRACE
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ


KNOCK DETECTION TEST II
SEQ 14
PLOT 14-5
RIGHT HEAD — FRONT PERPENDICULAR
FUEL CHANGE
HOUSE → 78 RON
2050 RPM
25.25" HgA
147 ft lb
SCALE 1.0 g/MAJOR DIV.
MIN-SEC
51-20
51-10
51-00
50-50
50-40
50-30
43-11-50-20
TRACE
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY — KHZ
ERE 3-8-76
TW BROWN


KNOCK DETECTION TEST II
SEQ. 14
RIGHT HEAD – REAR PARALLEL
FUEL CHANGE
HOUSE → 78 RON
PLOT 14-6
2050 RPM
25.25" Hg A
MIN-SEC
SCALE 1.0 g/MAJOR DIV
51-20
51-10
51-00
50-50
50-40
50-30
50-20
0
1
2
3
4
5
6
7
8
9
10
TRACE
FREQUENCY — KHZ


LEFT HEAD - REAR PERPENDICULAR
1600 TO 3200 RPM
VERY LIGHT PLUG
KNOCK DETECTION
SCALE 2.0 g/MAJOR DIV
RPM
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ



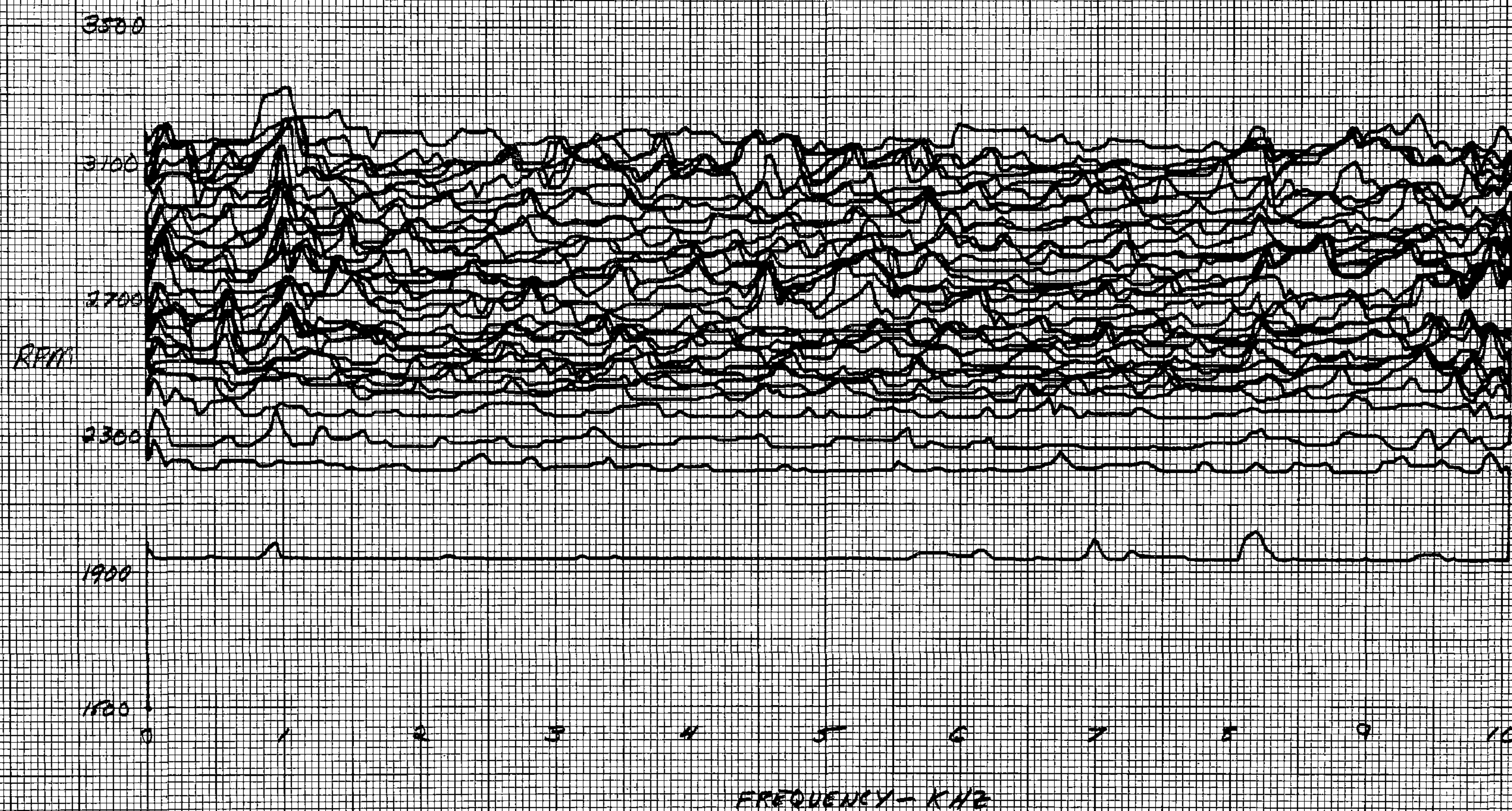
PLOT 19-2
LEFT HEAD - REAR PARALLEL
1600 TO 3200 RPM
78 RON
VERY LIGHT PLUG
SCALE 1.0 g/MARK DIV.
KNOCK DETECTION TEST II
3500
3100
RPM
2700
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHz

PLOT 19-3

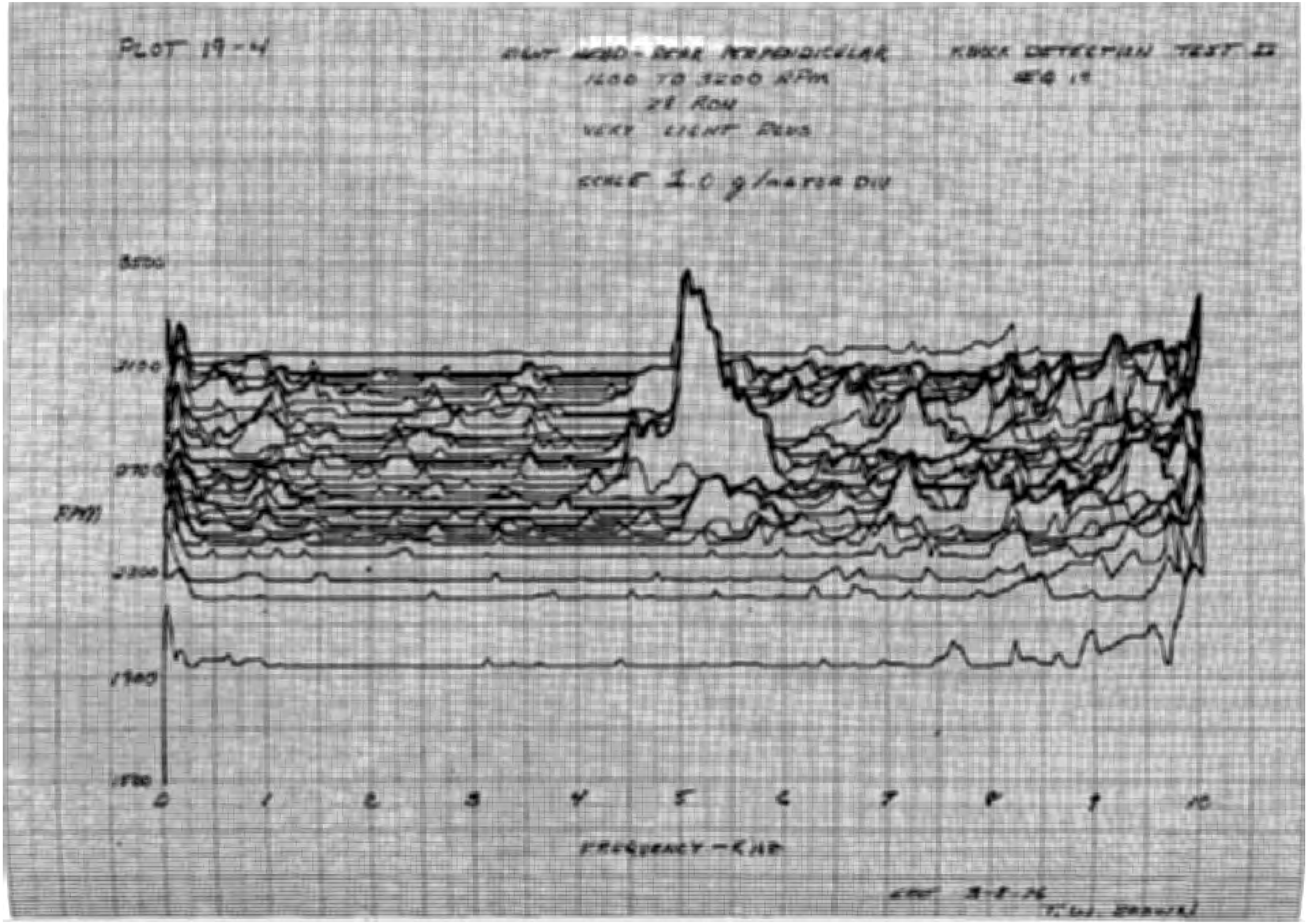
OIL PAN (INSIDE) PERPENDICULAR
1600 TO 3200 RPM
78 RON
VERY LIGHT PLUS

KNOCK DETECTION TEST II
SEQ 19

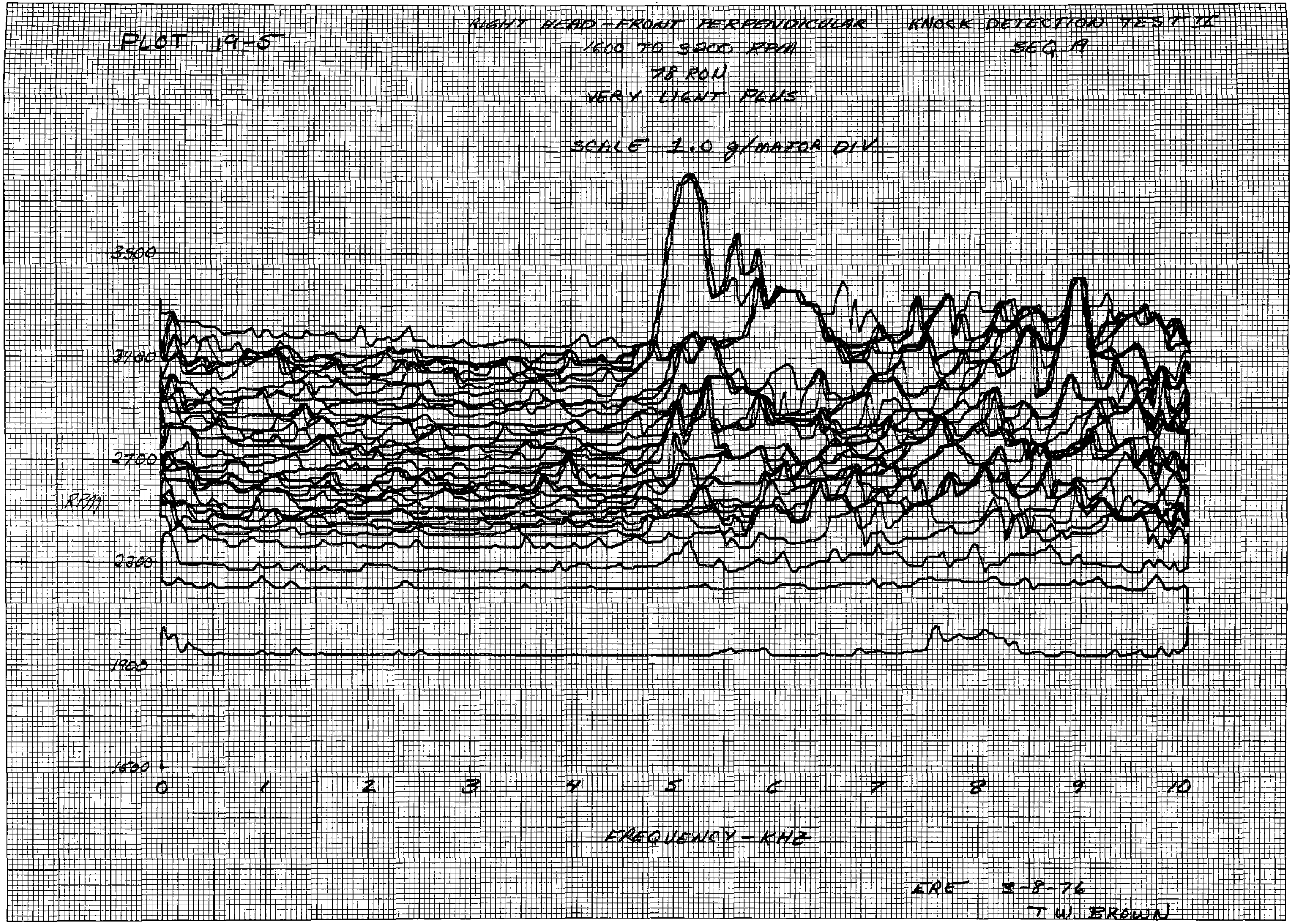
SCALE 1.0 g/MAJOR DIV

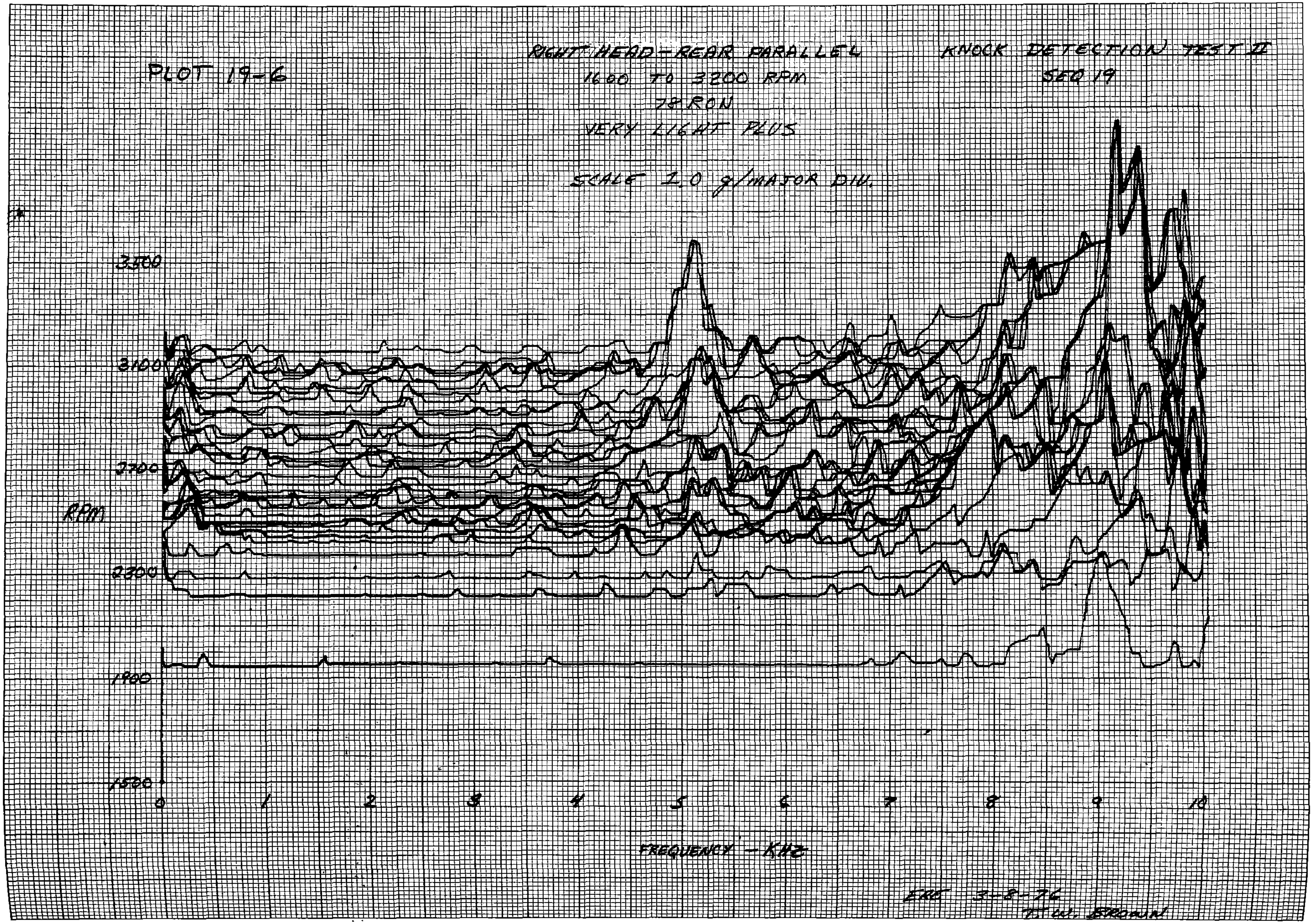


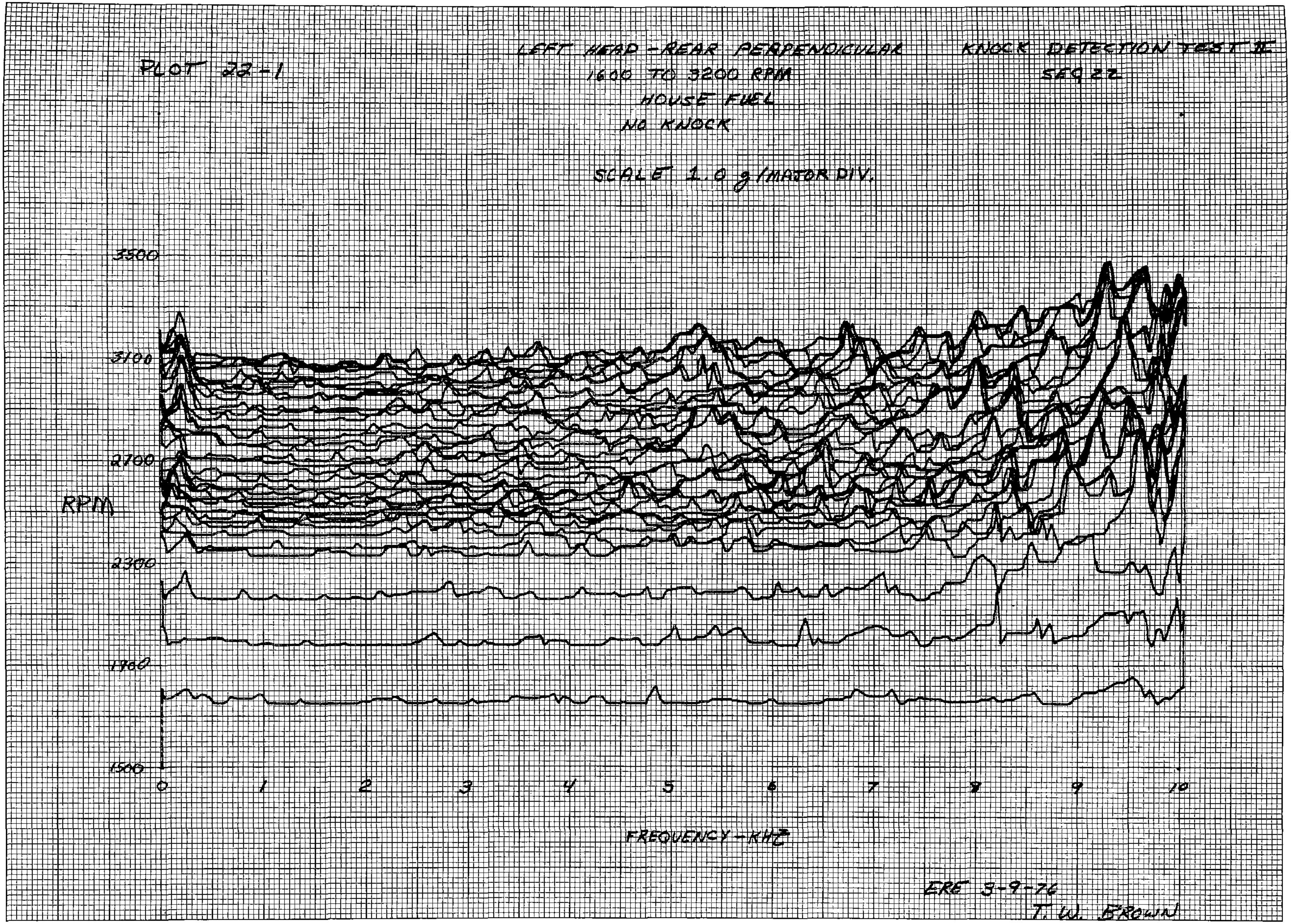

ERE 3-8-76
T.W. BROWN

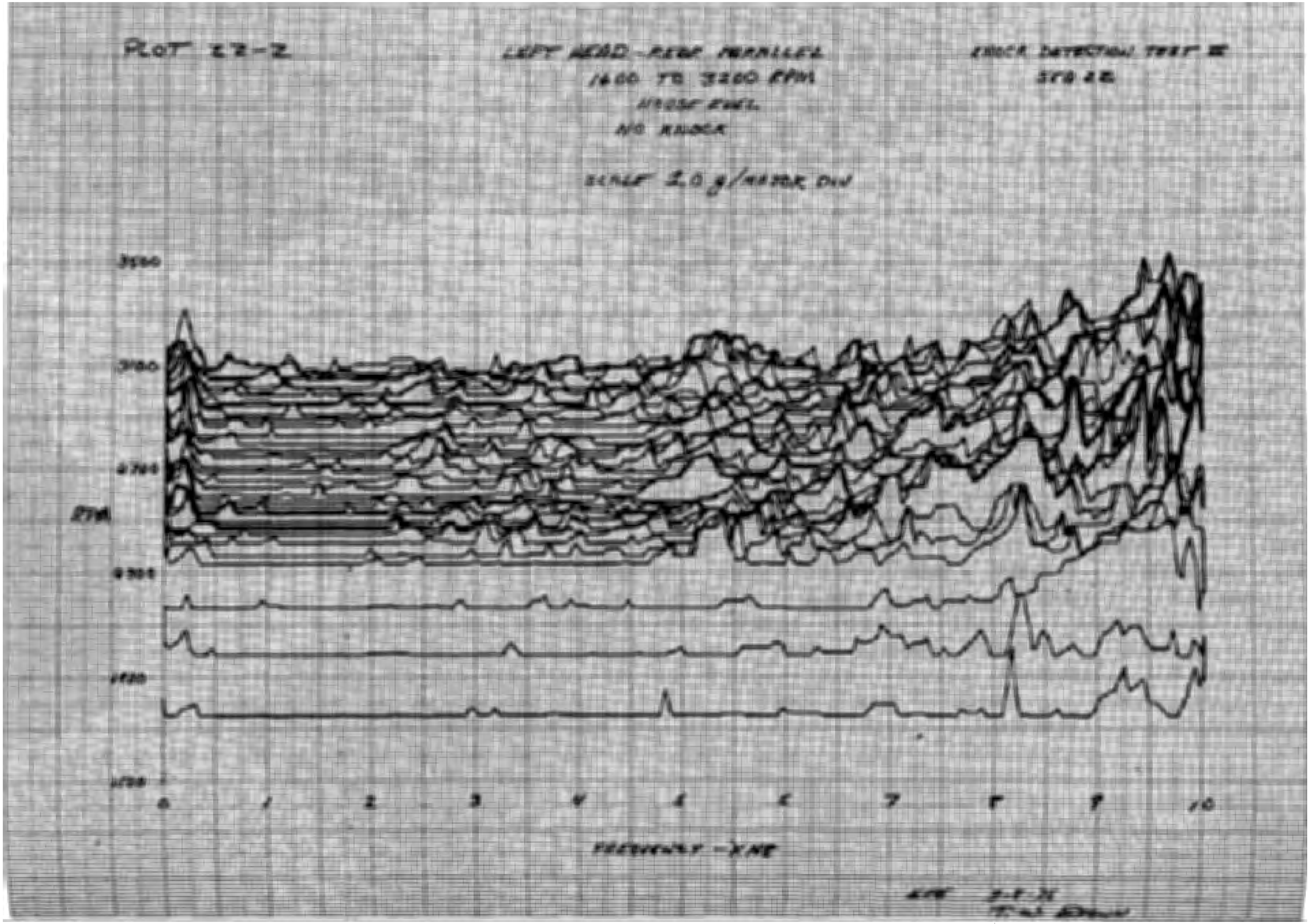


PLOT 19-4
KNOCK DETECTION TEST II
1600 TO 3200 RPM
VERY LIGHT KNOCK
SCALE 1.0 g/MAJOR DIV
RPM
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY – KHZ

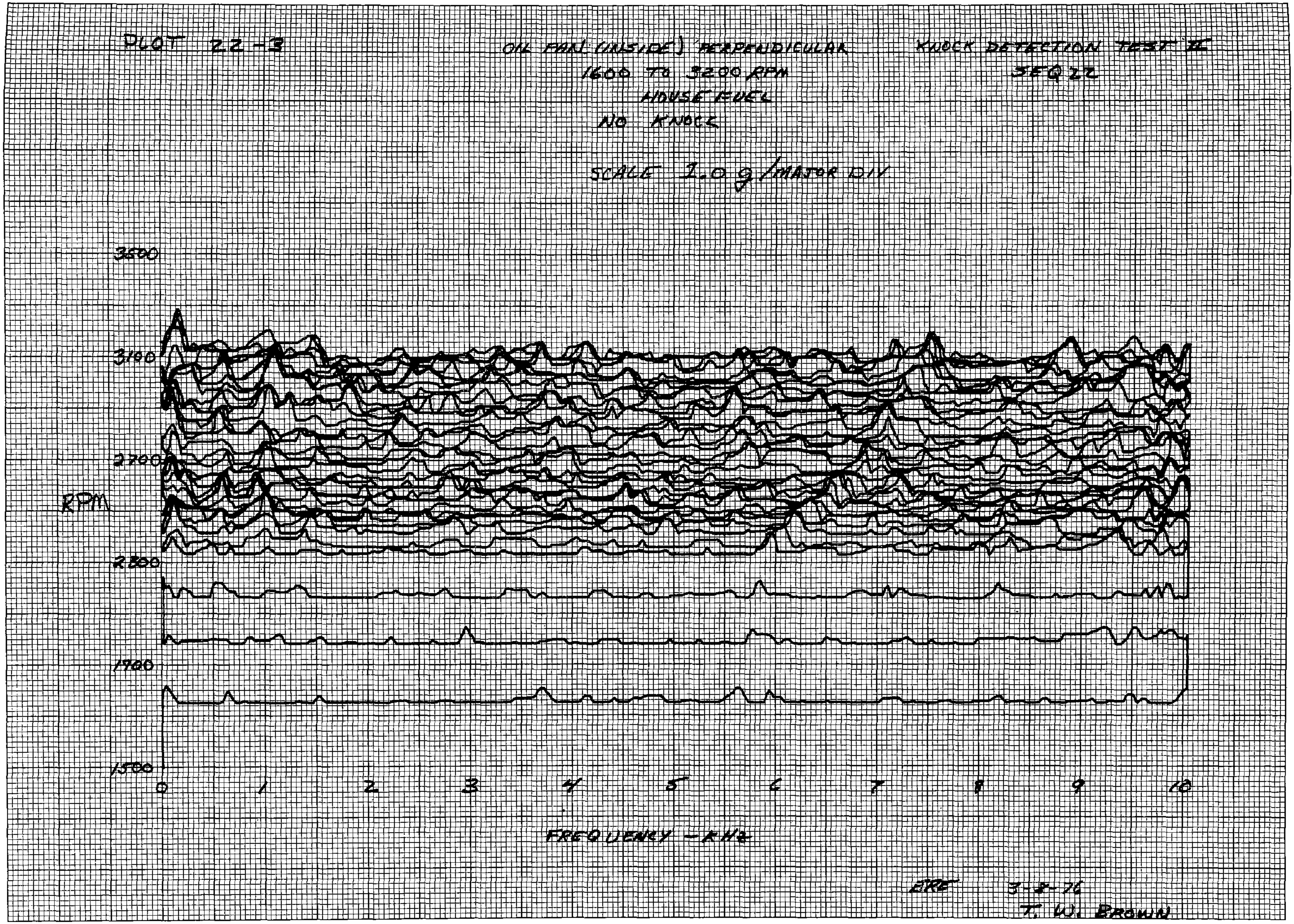

PLOT 19-5
RIGHT HEAD - FRONT PERPENDICULAR
KNOCK DETECTION TEST II
1600 TO 3200 RPM
SEQ 19
78 RON
VERY LIGHT PLUS
SCALE 1.0 g/MAJOR DIV
3500
3100
2700
RPM
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ
ERE 3-8-76
T.W. BROWN

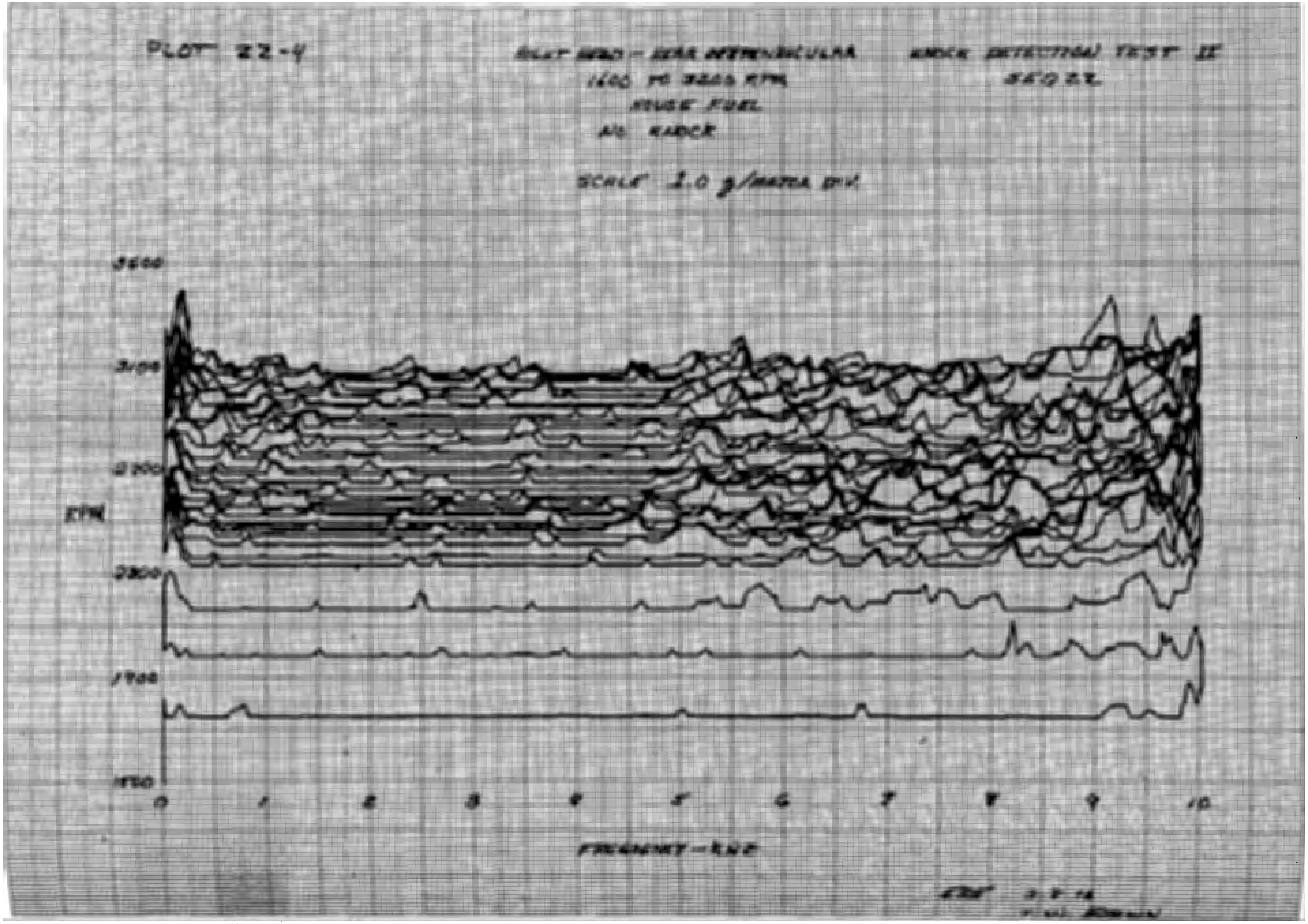

PLOT 19-6
RIGHT HEAD - REAR PARALLEL
1600 TO 3200 RPM
78 RON
VERY LIGHT PLUS
SCALE 1.0 g/MAJOR DIV.
KNOCK DETECTION TEST II
SEQ 19
3500
3100
2700
2300
1900
1500
RPM
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ
ERC 3-8-76
T.W. BROWN

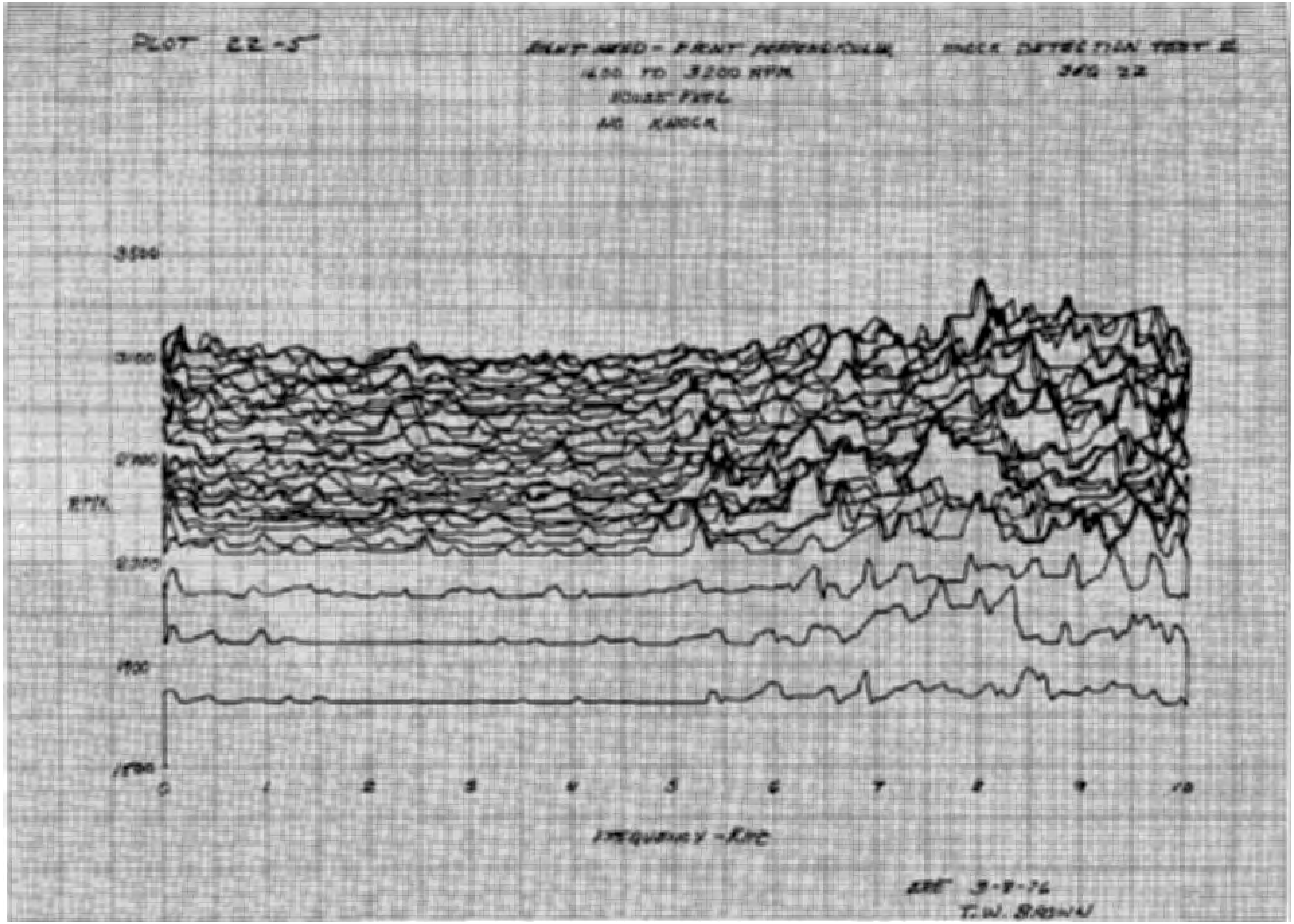

PLOT 22-1
LEFT HEAD - REAR PERPENDICULAR
1600 TO 3200 RPM
HOUSE FUEL
NO KNOCK
KNOCK DETECTION TEST II
SEQ 22
SCALE 1.0 g/MAJOR DIV.
3500
3100
2700
RPM
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ
ERE 3-9-76
T. W. BROWN



PLOT 22-2
1600 TO 3200 RPM
NO KNOCK
KNOCK DETECTION TEST
RPM
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ

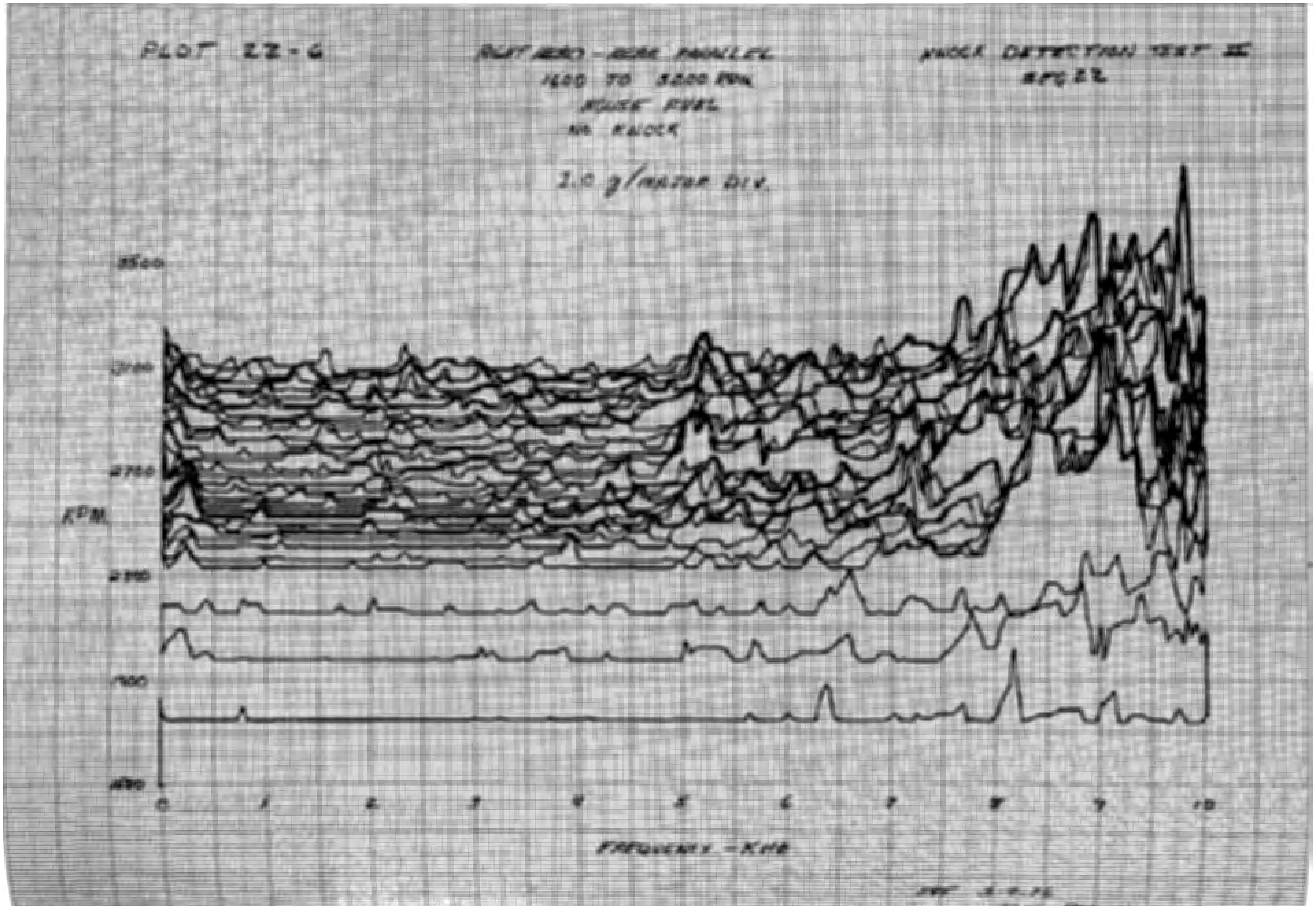

PLOT 22-3
OIL PAN (INSIDE) PERPENDICULAR
1600 TO 3200 RPM
HOUSE FUEL
NO KNOCK
KNOCK DETECTION TEST II
SEQ 22
SCALE 1.0 g/MAJOR DIV
3500
3100
2700
RPM
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY - KHZ
3-8-76
T. W. BROWN


PLOT 22-4
RPM
0
1
2
3
4
5
6
7
8
9
10
FREQUENCY – KHZ



PLOT 22-5
NO KNOCK
3500
3100
2700
RPM
2300
1900
1500
0
1
2
3
4
5
6
7
8
9
10
T.W. BROWN


- 261 -


PLOT 22-6
KNOCK DETECTION TEST II
1600 TO 3200 RPM
NO KNOCK
2.0 g/MAJOR DIV.
RPM
FREQUENCY - KHZ

# APPENDIX B

## EMISSIONS AND FUEL ECONOMY OF 1975 CHEVROLET NOVA

# APPENDIX B-1

## EMISSIONS OF 1975 NOVA

| Test Cycle | Mileage (miles/km) | Emissions - g/mile | | |
|---|---|---|---|---|
| | | CO | HC | $NO_x$ |
| CVS-CH | 564/907 | 2.97 | 0.47 | 2.64 |
| EPA-H | 575/925 | 0.41 | 0.35 | 3.75 |
| CVS-CH | 585/941 | 3.73 | 0.54 | 2.39 |
| EPA-H | 596/959 | 0.14 | 0.22 | 3.71 |
| CVS-CH | 606/975 | 4.42 | 0.70 | 2.30 |
| EPA-H | 617/993 | 0.27 | 0.13 | 3.53 |
| CVS-CH | 6860/11,040 | 3.47 | 0.41 | 1.77 |
| EPA-H | 6871/11,058 | 0.50 | 0.28 | 3.34 |
| CVS-CH | 6882/11,076 | 4.09 | 0.39 | 1.84 |
| EPA-H | 6893/11,093 | 0.53 | 0.24 | 3.34 |
| CVS-CH | 8903/14,328 | 4.34 | 0.49 | 1.80 |
| EPA-H | 8915/14,347 | 0.27 | 0.14 | 3.81 |
| CVS-CH | 8925/14,363 | 4.96 | 0.43 | 1.61 |
| EPA-H | 8936/14,381 | 0.37 | 0.20 | 3.36 |
| CVS-CH | 11,025/17,743 | 6.16 | 0.48 | 2.33 |
| EPA-H | 11,036/17,761 | 0.70 | 0.23 | 4.58 |
| CVS-CH | 11,046/17,777 | 4.96 | 0.49 | 2.02 |
| EPA-H | 11,058/17,796 | 0.31 | 0.14 | 3.71 |
| CVS-CH | 13,148/21,160 | 4.32 | 0.49 | 2.23 |
| EPA-H | 13,159/21,177 | 0.62 | 0.21 | 5.73 |
| CVS-CH | 13,170/21,195 | 4.33 | 0.44 | 2.18 |
| EPA-H | 13,181/21,213 | 0.68 | 0.17 | 4.74 |
| CVS-CH | 13,191/21,229 | 5.50 | 0.51 | 2.34 |
| EPA-H | 13,202/21,247 | 0.71 | 0.23 | 4.93 |

APPENDIX B-2

| Test No. | Test Cycle | Mileage (Miles/km) | Emissions - g/Mile CO | HC | $NO_x$ | Remarks |
|---|---|---|---|---|---|---|
| 1 | CVS-CH | 13,947/22,441 | 34.8 | 2.37 | 2.27 | Engine Out |
| | HFET | 13,958/22,458 | 45.4 | 1.22 | 2.30 | " " |
| 2 | CVS-CH | 13,968/22,475 | 30.9 | 2.19 | 1.92 | " " |
| | HFET | 13,979/22,492 | 18.0 | 0.75 | 2.83 | " " |
| 3 | CVS-CH | 13,994/22,516 | 40.1 | 1.97 | 1.77 | " " |
| | HFET | 14,005/22,534 | 39.6 | 1.37 | 1.96 | " " |
| 4 | CVS-CH | 14,015/22,550 | 3.99 | 0.57 | 1.76 | With Catalyst |
| | HFET | 14,026/22,568 | 0.09 | 0.08 | 1.66 | " " |
| 5 | CVS-CH | 14,048/22,603 | 4.83 | 0.58 | 1.79 | " " |
| | HFET | 14,059/22,621 | 0.45 | 0.12 | 1.95 | " " |
| 6 | CVS-CH | 14,072/22,642 | 7.23 | 0.51 | 1.51 | " " |
| | HFET | 14,082/22,658 | 0.36 | 0.10 | 1.59 | " " |
| 7 | CVS-CH | 14,094/22,677 | 7.86 | 0.50 | 1.63 | " " |
| | HFET | 14,105/22,695 | 0.21 | 0.09 | 1.64 | " " |
| 8 | CVS-CH | 14,234/22,902 | 9.22 | 0.71 | 2.45 | Catalyst, 9:1 C.R. |
| | HFET | 14,245/22,920 | 0.22 | 0.11 | 2.08 | " " |
| 9 | CVS-CH | 14,257/22,940 | 9.00 | 0.66 | 2.55 | " " |
| | HFET | 14,268/22,957 | 0.23 | 0.11 | 2.16 | " " |
| 10 | CVS-CH | 14,280/22,977 | 8.62 | 0.59 | 2.20 | " " |
| | HFET | 14,290/22,993 | 0.46 | 0.15 | 1.92 | " " |
| 11 | CVS-CH | 14,457/23,261 | 5.60 | 0.50 | 1.76 | " " |
| | HFET | 14,468/23,279 | 0.15 | 0.11 | 1.64 | " " |

# APPENDIX B-3

| | | Mileage (miles/km) | Emissions - g/Mile CO | HC | $NO_x$ | Remarks |
|---|---|---|---|---|---|---|
| | CVS-CH | 14,234 to | 8.11 | 0.62 | 2.24 | Average of 4 Tests with |
| | HFET | 14,468 | 0.26 | 0.12 | 1.95 | Standard Recycle |
| 1 | CVS-CH | 14,480/23,303 | 5.41 | 0.50 | 1.94 | GM Proportional EGR Valve |
| | HFET | 14,491/23,320 | 0.15 | 0.10 | 1.76 | with 1/4 inch Orifice |
| 2 | CVS-CH | 14,503/23,340 | 10.53 | 0.61 | 2.08 | GM Proportional EGR Valve |
| | HFET | 14,514/23,357 | 0.39 | 0.12 | 1.86 | with 1/4 inch Orifice |
| 3 | CVS-CH | 14,525/23,375 | 9.11 | 0.62 | 2.26 | GM Proportional EGR Valve |
| | HFET | 14,536/23,393 | 0.32 | 0.12 | 1.76 | with 1/4 inch Orifice |
| | CVS-CH | | 8.35 | 0.58 | 2.09 | Average of Tests 1 to 3 |
| | HFET | | 0.29 | 0.11 | 1.79 | Average of Tests 1 to 3 |
| 4 | CVS-CH | 14,549/23,414 | 1.75 | 0.41 | 2.16 | Prop. EGR, Leaner Choke, |
| | HFET | 14,560/23,431 | 0.12 | 0.11 | 1.71 | Intake Man. Air Leak |
| 5 | CVS-CH | 14,572/23,451 | 1.47 | 0.36 | 2.49 | Prop. EGR, Leaner Choke, |
| | HFET | 14,583/23,468 | 0.05 | 0.11 | 2.23 | Intake Man. Air Leak |
| 6 | CVS-CH | 14,640/23,560 | 3.84 | 0.48 | 1.63 | Prop. EGR, 21/64 inch Orifice |
| | HFET | 14,651/23,578 | 0.23 | 0.12 | 1.40 | Leaner Choke |
| 7 | CVS-CH | 14,842/23,885 | 3.35 | 0.51 | 1.76 | Prop. EGR, 21/64 inch Orifice |
| | HFET | 14,853/23,903 | 0.22 | 0.12 | 1.47 | Leaner Choke |
| 8 | CVS-CH | 15,141/24,366 | 4.56 | 0.54 | 1.78 | Prop. EGR, 21/64 inch Orifice |
| | HFET | 15,152/24,384 | 0.48 | 0.16 | 1.33 | Leaner Choke |
| | CVS-CH | | 3.92 | 0.51 | 1.72 | Average of Tests 6 to 8 |
| | HFET | | 0.31 | 0.13 | 1.40 | |

## APPENDIX B-4

| Cycle | Mileage (miles/km) | Emissions - g/mile CO | HC | $NO_x$ | Remarks |
|---|---|---|---|---|---|
| CVS-CH | 16,549/26,627 | 6.83 | 0.95 | 2.32 | Pistons replaced, 350 mi. |
| HFET | 16,560/26,645 | 0.28 | 0.23 | 2.06 | break-in, prop. EGR valve |
| CVS-CH | 16,576/26,671 | 5.24 | 0.87 | 2.66 | Richer idle mixture. |
| HFET | 16,587/26,688 | 0.37 | 0.18 | 2.46 | Sample valves on intake manifold plugged. |

APPENDIX B-5

| Cycle | (Miles/km) | Emissions - g/mile CO | HC | $NO_x$ | Remarks |
|---|---|---|---|---|---|
| CVS-CH | 16,784/27,005 | 7.01 | 0.69 | 2.45 | New intake manifold gasket. |
| HFET | 16,795/27,023 | 0.37 | 0.17 | 2.65 | |
| CVS-CH | 16,824/27,070 | 6.05 | 0.92 | 2.96 | Fresh oxidation catalyst. |
| HFET | 16,835/27,088 | 0.43 | 0.26 | 2.58 | Idle mixture reset. |
| CVS-CH | 18,283/29,417 | 6.57 | 0.72 | 2.01 | Put back old piston, |
| HFET | 18,294/29,435 | 0.32 | 0.11 | 1.79 | 1200 mi. break-in. |
| CVS-CH | 18,304/29,451 | 6.28 | 0.70 | 1.83 | Repeat. |
| HFET | 18,315/29,469 | 0.26 | 0.11 | 1.57 | |

## APPENDIX B-6

| Test | Cycle | Miles/km | Emissions - g/mile CO | HC | $NO_x$ | Remarks |
|---|---|---|---|---|---|---|
| 1 | CVS-CH | 18,328/29,490 | 4.68 | 0.96 | 2.05 | Leaner choke; two stalls |
| | HFET | 18,339/29,507 | 0.42 | 0.18 | 2.04 | |
| 2 | CVS-CH | 18,357/29,536 | 6.12 | 1.16 | 1.83 | Deposits cleaned, richer choke, false start |
| | HFET | 18,368/29,554 | 0.24 | 0.12 | 1.85 | |
| 3 | CVS-CH | 18,378/29,570 | 8.52 | 0.72 | 1.83 | Fast idle increased, 1 stall |
| | HFET | 18,389/29,588 | 0.67 | 0.16 | 1.53 | |
| 4 | CVS-CH | 18,449/29,684 | 6.89 | 0.60 | 1.87 | Carburetor rebuilt |
| | HFET | 18,461/29,704 | 0.35 | 0.15 | 1.85 | |
| 5 | CVS-CH | 18,475/29,726 | 4.39 | 0.59 | 2.11 | Leaner choke |
| | HFET | 18,486/29,744 | 0.20 | 0.13 | 2.01 | |
| 6 | CVS-CH | 18,581/29,897 | 5.36 | 0.65 | 1.91 | Repeat - Weekend Soak |
| | HFET | 18,592/29,915 | 0.20 | 0.14 | 1.90 | |
| 7 | CVS-CH | 18,665/30,032 | 3.16 | 0.53 | 2.07 | Repeat |
| | HFET | 18,676/30,050 | 0.22 | 0.13 | 2.03 | |
| 8 | CVS-CH | 18,723/30,125 | 2.94 | 0.45 | 2.08 | Repeat |
| | HFET | 18,734/30,143 | 0.50 | 0.44 | 2.25 | |

APPENDIX B-7

| Cycle | Miles/km | Emissions, g/mile CO | HC | $NO_x$ | Remarks |
|---|---|---|---|---|---|
| CVS-CH | 18,774/30,207 | 4.09 | 0.62 | 1.86 | Repeat of Previous Run |
| HFET | 18,785/30,225 | 0.25 | 0.14 | 1.96 | |
| CVS-CH | 19,689/31,680 | 4.74 | 0.76 | 1.58 | Knock Sensor on - Retarded |
| HFET | 19,700/31,697 | 0.42 | 0.35 | 1.82 | 3 times on CVS-CH, 8 times on HFET |

# APPENDIX B-8

| Cycle | Miles/km | Emissions g/Mile CO | HC | $NO_x$ | Remarks |
|---|---|---|---|---|---|
| CVS-CH | 21,638/34,816 | 6.48 | 0.81 | 1.07 | New heads installed |
| HFET | | 0.55 | 0.25 | 1.08 | |
| CVS-CH | 21,765/35,020 | 7.09 | 1.30 | 1.46 | Hard starting |
| HFET | | 0.85 | 0.56 | 1.70 | |
| CVS-CH | 21,803/35,081 | 4.28 | 0.84 | 2.41 | 1/4" EGR orifice |
| HFET | | 0.75 | 0.26 | 3.00 | |
| CVS-CH | 21,886/35,215 | 3.48 | 0.81 | 2.64 | 1/4" EGR orifice, choke richer |
| HFET | | 0.51 | 0.24 | 2.64 | |
| CVS-CH | 21,947/35,313 | 5.49 | 0.90 | 1.86 | 5/16" EGR orifice, false start |
| HFET | | 0.66 | 0.25 | 1.92 | |
| CVS-CH | 21,976/35,359 | 10.00 | 3.46 | 1.90 | 5/16" EGR orifice, false start |
| HFET | | 0.51 | 0.19 | 1.96 | |
| CVS-CH | 22,039/35,461 | 5.29 | 0.89 | 2.15 | New carb. needle and seat 5/16" EGR |
| HFET | | 0.29 | 0.15 | 2.19 | |
| CVS-CH | 22,088/35,540 | 4.05 | 0.71 | 2.07 | Repeat - 5/16" EGR |
| HFET | | 0.42 | 0.24 | 2.08 | |

# APPENDIX B-9

| Cycle | Miles/km | Emissions - g/Mile CO | HC | $NO_x$ | Remarks |
|---|---|---|---|---|---|
| CVS-CH | 22,141/35,625 | 4.81 | 0.64 | 1.95 | 21/64" EGR orifice |
| HFET | 22,152/35,643 | 0.30 | 0.26 | 2.32 | |
| CVS-CH | 22,435/36,098 | 5.34 | 0.97 | 1.77 | Repeat, 1 stall |
| HFET | 22,446/36,116 | 0.29 | 0.19 | 2.04 | |
| CVS-CH | 22,459/36,137 | 5.72 | 0.66 | 1.86 | Repeat |
| HFET | 22,470/36,154 | 0.40 | 0.36 | 2.12 | |
| CVS-CH | 22,613/36,384 | 3.38 | 0.82 | 1.84 | Repeat |
| HFET | 22,624/36,402 | 0.10 | 0.16 | 2.13 | |
| CVS-CH | | 4.81 | 0.77 | 1.86 | Average |
| HFET | | 0.27 | 0.24 | 2.15 | Average |
| CVS-CH | | 5.98 | 0.54 | 1.67 | Average 8:1 Base Case |
| HFET | | 0.28 | 0.10 | 1.71 | Average 8:1 Base Case |

## APPENDIX B-10

| Cycle | Miles/km | Emissions - g/Mile CO | HC | $NO_x$ | Remarks |
|---|---|---|---|---|---|
| CVS-CH | 29,233/47,036 | 10.99 | 0.68 | 1.31 | (6K) No retards |
| HFET | 29,244/47,054 | 1.78 | 0.16 | 1.19 | 1 Retard - 55 mph cruise |
| CVS-CH | 29,310/47,160 | 12.44 | 0.71 | 1.62 | (6K) No retards |
| HFET | 29,321/47,178 | 2.01 | 0.20 | 1.36 | 1 Retard - 55 mph cruise |
| CVS-CH | 31,223/50,238 | 3.78 | 0.55 | 1.52 | (8K) Idle CO leaned, carburetor |
| HFET | 31,234/50,256 | 1.40 | 0.21 | 1.65 | cleaned, No retards |
| CVS-CH | 31,245/50,273 | 5.67 | 0.57 | 1.47 | (8K) No retards |
| HFET | 31,256/50,291 | 1.61 | 0.22 | 1.29 | No retards |
| CVS-CH | 33,494/53,892 | 6.46 | 1.33 | 1.73 | (10K) No retards - 2 stalls |
| HFET | 33,505/53,910 | 2.38 | 0.31 | 1.51 | No retards |
| CVS-CH | 33,516/53,927 | 6.99 | 0.89 | 1.73 | (10K) No retards |
| HFET | 33,527/53,945 | 2.26 | 0.34 | 1.57 | No retards |
| CVS-CH | 35,159/56,571 | 5.03 | 0.66 | 2.09 | (12K) New spark plugs, |
| HFET | 35,170/56,589 | 2.37 | 0.28 | 1.65 | No retards |
| CVS-CH | 35,180/56,605 | 5.10 | 0.75 | 1.96 | (12K) No retards |
| HFET | 35,191/56,623 | 2.54 | 0.30 | 1.50 | |

APPENDIX B-11

| Cycle | Miles | CO | HC | $NO_x$ | Remarks |
|---|---|---|---|---|---|
| CVS-CH | 35,341 | 4.27 | 0.63 | 1.96 | 12 K - No retards |
| HFET | 35,352 | 2.23 | 0.24 | 1.56 | 12 K - No retards |
| CVS-CH | 35,963 | 6.39 | 0.54 | 2.06 | CX-82 - No retards |
| HFET | 35,974 | 2.35 | 0.22 | 1.70 | CX-82 - No retards |
| CVS-CH | 35,985 | 7.85 | 0.43 | 1.66 | CX-82 - Lots of retard |
| HFET | 35,996 | 2.02 | 0.15 | 1.33 | CX-82 - Accelerometer Malfunction |
| CVS-CH | 36,244 | 5.32 | 0.53 | 1.87 | C-82 - No retards |
| HFET | 36,255 | 3.35 | 0.53 | 1.46 | C-82 - No retards |
| CVS-CH | 36,285 | 5.19 | 0.57 | 1.81 | C-82 - No retards |
| HFET | 36,296 | 3.24 | 0.26 | 1.46 | Delay 128, Delay - 4,100 mV threshold |
| CVS-CH | 40,667 | 12.06 | 0.80 | 1.82 | 4 K AMA Cycle |
| HFET | 40,678 | 5.48 | 0.34 | 1.46 | No retards; 128 X 4 Delay, 100 mV threshold |
| CVS-CH | 40,829 | 6.76 | 0.69 | 1.56 | No retards; 128 X 4 Delay, 100 mV threshold |
| HFET | 40,840 | 4.92 | 0.40 | 1.41 | No retards; 128 X 4 Delay, 100 mV threshold |
| CVS-CH | 40,872 | 6.34 | 0.64 | 1.64 | No retards; 128 X 4 Delay, 100 mV threshold |
| HFET | 40,883 | 4.79 | 0.30 | 1.35 | No retards; 128 X 4 Delay, 100 mV threshold |
| CVS-CH | 40,910 | 5.95 | 0.73 | 2.39 | CX-86 - 12° BTC Timing |
| HFET | 40,921 | 5.53 | 0.37 | 2.08 | 128 X 4 Delay, 100 mV threshold No retards |
| CVS-CH | 40,957 | 10.43 | 1.02 | 2.51 | 128 X 4 Delay, 100 mV threshold No retards |
| HFET | 40,968 | 4.95 | 0.64 | 2.39 | 128 X 4 Delay, 100 mV threshold No retards |

APPENDIX B-12

FUEL ECONOMY OF 1975 NOVA

| Test Cycle | Mileage (miles/km) | Fuel Economy - MPG/km per litre From Emissions | From Weight |
|---|---|---|---|
| CVS-CH | 564/907 | 12.12/5.15 | 12.72/5.41 |
| EPA-H | 575/925 | 17.24/7.33 | 17.56/7.46 |
| CVS-CH | 585/941 | 11.58/4.92 | 12.01/5.11 |
| EPA-H | 596/959 | 16.36/6.95 | 16.35/6.95 |
| CVS-CH | 606/975 | 11.81/5.02 | 12.36/5.25 |
| EPA-H | 617/993 | 16.40/6.97 | 17.23/7.32 |
| CVS-CH | 6860/11,040 | 12.00/5.10 | 12.30/5.23 |
| EPA-H | 6871/11,058 | 16.27/6.92 | 15.27/6.49 |
| CVS-CH | 6882/11,076 | 12.19/15.19 | 12.13/5.16 |
| EPA-H | 6893/11,093 | 16.39/6.97 | 15.56/6.61 |
| CVS-CH | 8903/14,328 | 11.11/4.73 | 11.14/4.74 |
| EPA-H | 8915/14,347 | 15.49/6.59 | 14.91/6.34 |
| CVS-CH | 8925/14,363 | 11.62/4.94 | 11.91/5.06 |
| EPA-H | 8936/14,381 | 15.87/6.75 | 15.16/6.44 |
| CVS-CH | 11,025/17,743 | 12.55/5.34 | 12.11/5.15 |
| EPA-H | 11,036/17,761 | 18.63/7.92 | 15.95/6.78 |
| CVS-CH | 11,046/17,777 | 12.72/5.41 | 12.15/5.17 |
| EPA-H | 11,058/17,796 | 19.71/8.38 | 16.35/6.95 |
| CVS-CH | 13,148/21,160 | 11.94/5.08 | 12.24/5.20 |
| EPA-H | 13,159/21,177 | 15.95/6.78 | 15.75/6.70 |
| CVS-CH | 13,170/21,195 | 11.95/5.08 | 12.58/5.35 |
| EPA-H | 13,181/21,213 | 16.74/7.12 | 16.11/6.85 |
| CVS-CH | 13,191/21,229 | 11.93/5.07 | 12.45/5.29 |
| EPA-H | 13,202/21,247 | 16.39/6.97 | 16.03/6.81 |

## APPENDIX B-13

| Miles/km | Fuel Economy - mpg/kmpL: CVS - CH: Emissions | Weight | Flowmeter | Fuel Economy Cycle: Emissions | Weight | Flowmeter |
|---|---|---|---|---|---|---|
| 13,947/22,441 | 11.10/4.72 | 11.32/4.81 | - | 16.11/6.85 | 16.90/7.18 | - |
| 13,968/22,475 | 11.17/4.75 | 11.38/4.84 | - | 15.91/6.76 | 16.71/7.10 | - |
| 13,994/22,516 | 11.56/4.91 | 11.95/5.08 | - | 16.31/6.93 | 16.52/7.02 | - |
| 14,015/22,550 | 10.89/4.63 | 11.18/4.75 | - | 16.48/7.01 | 17.00/7.23 | - |
| 14,048/22,603 | 11.19/4.76 | 11.42/4.85 | - | 15.87/6.75 | 16.66/7.08 | - |
| 14,072/22,642 | 11.59/4.93 | 11.34/4.82 | 11.26/4.79 | 16.52/7.02 | 16.33/6.94 | 16.03/6.81 |
| 14,094/22,677 | 11.88/5.05 | 11.54/4.91 | 11.43/4.86 | 17.32/7.36 | 16.33/6.94 | 16.14/6.86 |
| 14,234/22,902 | 12.66/5.38 | 11.88/5.05 | 11.69/4.97 | 19.18/8.15 | 17.51/7.44 | 17.13/7.28 |
| 14,257/22,940 | 12.14/5.16 | 11.73/4.99 | 11.64/4.95 | 17.75/7.55 | 17.20/7.31 | 16.97/7.21 |
| 14,280/22,977 | 12.51/5.32 | 11.95/5.08 | 11.84/5.03 | 17.90/7.61 | 17.25/7.33 | 17.03/7.24 |
| 14,457/23,261 | 11.78/5.01 | 11.86/5.04 | 11.71/4.98 | 17.46/7.42 | 17.15/7.29 | 16.87/7.17 |

## APPENDIX B-14

| Test No. | Mileage Miles/km | Fuel Economy - mpg/kmpl: CVS-CH Emissions | CVS-CH Weight | CVS-CH Flowmeter | Highway Fuel Economy Emissions | Highway Fuel Economy Weight | Highway Fuel Economy Flowmeter |
|---|---|---|---|---|---|---|---|
| | Averages: | | | | | | |
| | 8:1 C.R. | 11.34/4.82 | 11.45/4.87 | - | 16.36/6.96 | 16.64/7.07 | - |
| | 9:1 C.R. | 12.27/5.22 | 11.86/5.04 | 11.72/4.98 | 18.07/7.68 | 17.28/7.35 | 17.00/7.23 |
| 1 | 14,480/23,303 | 11.95/5.08 | 12.61/5.36 | 12.46/5.30 | 17.90/7.61 | 17.46/7.42 | 17.12/7.28 |
| 2 | 14,503/23,340 | 12.47/5.30 | 12.56/5.34 | 12.41/5.28 | 17.70/7.52 | 17.46/7.42 | 17.25/7.33 |
| 3 | 14,525/23,375 | 12.35/5.25 | 12.61/5.36 | 12.47/5.30 | 17.46/7.42 | 17.67/7.51 | 17.43/7.41 |
| | Average: | | | | | | |
| | Tests 1 to 3 | 12.26/5.21 | 12.59/5.35 | 12.45/5.29 | 17.69/7.52 | 17.53/7.45 | 17.27/7.34 |
| 4 | 14,549/23,414 | 13.17/5.60 | 12.88/5.48 | 12.79/5.44 | 17.70/7.52 | 17.56/7.46 | 17.35/7.38 |
| 5 | 14,572/23,451 | 13.12/5.58 | 12.99/5.52 | 13.05/5.55 | 18.57/7.89 | 18.33/7.79 | 18.08/7.69 |
| 6 | 14,640/23,560 | 13.04/5.54 | 12.61/5.36 | 12.42/5.28 | 17.66/7.51 | 17.35/7.38 | 17.12/7.28 |
| 7 | 14,842/23,885 | 13.25/5.63 | 12.91/5.49 | 12.87/5.47 | 18.36/7.80 | 17.78/7.56 | 17.55/7.46 |
| 8 | 15,141/24,366 | 12.53/5.33 | 11.97/5.09 | 11.87/5.05 | 17.80/7.57 | 17.51/7.44 | 17.23/7.32 |
| | Average: | | | | | | |
| | Tests 6 to 8 | 12.94/5.50 | 12.50/5.31 | 12.39/5.27 | 17.94/7.63 | 17.55/7.46 | 17.30/7.35 |

## APPENDIX B-15

| Mileage (miles/km) | Fuel Economy (mpg/kmpg) | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| | CVS-CH | | | HFET | | |
| | Emissions | Weight | Flowmeter | Emissions | Weight | Flowmeter |
| 16,549/26,627 | 11.83/5.03 | 11.30/4.80 | 11.24/4.78 | 18.57/7.89 | 16.42/6.98 | 15.98/7.27 |
| 16,576/26,671 | 11.78/5.01 | 11.75/4.99 | 11.70/4.97 | 19.90/8.46 | 17.56/7.46 | 17.30/7.35 |

APPENDIX B-16

| Mileage (miles/km) | Fuel Economy (mpg/kmpl) CVS-CH | | | HFET | | |
|---|---|---|---|---|---|---|
| | Emissions | Weight | Flowmeter | Emissions | Weight | Flowmeter |
| 16,784/27,005 | 12.75/5.42 | 11.95/5.09 | 11.77/5.00 | 20.21/8.59 | 18.28/7.77 | 17.90/7.61 |
| 16,824/27,070 | 12.25/5.21 | 12.34/5.24 | 12.15/5.16 | 20.47/8.70 | 18.05/7.67 | 17.87/7.59 |
| 18,283/29.417 | 12.56/5.34 | 12.23/5.20 | ---- | 17.66/7.50 | 17.83/7.58 | ---- |
| 18,304/29,451 | 13.20/5.61 | 12.88/5.47 | --- | 19.24/8.18 | 18.63/7.92 | ---- |

## APPENDIX B-17

| Test | Miles/km | Fuel Economy (mpg/kmpl) CVS-CH Emissions | CVS-CH Weight | CVS-CH Flowmeter | HFET Emissions | HFET Weight | HFET Flowmeter |
|---|---|---|---|---|---|---|---|
| 1 | 18,328/29,490 | 12.68/5.39 | 11.56/4.91 | 11.75/4.99 | 18.36/7.80 | 16.80/7.14 | 16.82/7.15 |
| 2 | 18,357/29,536 | 12.16/5.17 | 13.33/5.67 | 11.48/4.88 | 18.47/7.85 | 20.24/8.60 | 18.18/7.73 |
| 3 | 18,378/29,570 | 10.89/4.63 | 10.37/4.41 | 10.50/4.46 | 17.61/7.48 | 16.11/6.85 | 16.18/6.88 |
| 4 | 18,449/29,684 | 12.17/5.17 | 11.40/4.85 | 11.58/4.92 | 17.80/7.57 | 17.00/7.23 | 17.03/7.24 |
| 5 | 18,475/29,726 | 11.61/4.93 | 11.62/4.94 | 11.79/5.01 | 18.21/7.74 | 17.25/7.33 | 17.12/17.28 |
| 6 | 18,581/29,897 | 12.31/5.23 | 11.58/4.92 | 11.73/4.99 | 19.84/8.18 | 17.83/7.58 | 17.79/7.56 |
| 7 | 18,665/30,032 | 11.97/5.09 | 12.13/5.16 | 12.29/5.22 | 18.47/7.85 | 18.16/7.72 | 18.20/7.74 |
| 8 | 18,723/30,125 | 12.33/5.24 | 11.97/5.09 | 12.15/5.16 | 19.13/8.13 | 17.72/7.53 | 17.83/7.58 |
| | 5-8 Average (9:1) | 12.06/5.13 | 11.83/5.03 | 11.99/5.10 | 18.91/8.04 | 17.74/7.54 | 17.74/7.54 |
| | Average (8:1) | 11.34/4.82 | 11.45/4.87 | 11.35/4.82 | 16.36/6.95 | 16.44/6.99 | 16.09/6.84 |
| | % Improvement | 6.3 | 3.3 | 5.6 | 15.6 | 7.9 | 10.3 |

## APPENDIX B-18

| Miles/km | Fuel Economy (mpg/kmpl) | | | | | |
|---|---|---|---|---|---|---|
| | CVS-CH | | | HFET | | |
| | Emissions | Weight | Flowmeter | Emissions | Weight | Flowmeter |
| 18,774/30,207 | 12.45/5.29 | 11.93/5.07 | 12.05/5.12 | 19.24/8.18 | 17.83/7.58 | 17.90/7.61 |
| 19,689/31,680 | 12.11/5.15 | 11.56/4.91 | 11.49/4.88 | 18.05/7.67 | 17.35/7.37 | 17.22/7.32 |

# APPENDIX B-19

| Miles/km | Fuel Economy (mpg/kmph) | | | | | |
|---|---|---|---|---|---|---|
| | CVS - CH | | | HFET | | |
| | Emissions | Weight | Flowmeter | Emissions | Weight | Flowmeter |
| 21,638/34,816 | 11.18/4.75 | 11.44/4.86 | 11.38/4.84 | 17.61/7.48 | 16.95/7.20 | 16.89/7.18 |
| 21,765/35,020 | 11.07/4.70 | 10.86/4.62 | 11.00/4.68 | 16.65/7.08 | 16.02/6.81 | 16.13/6.86 |
| 21,803/35,081 | 11.21/4.76 | 11.44/4.86 | 11.71/4.98 | 17.75/7.54 | 16.56/7.04 | 16.70.7.10 |
| 21,886/35,215 | 12.11/5.15 | 12.15/5.16 | 12.29/5.22 | 17.85/7.59 | 17.46/7.42 | 17.42/7.40 |
| 21,947/35,313 | 11.40/4.85 | 11.62/4.94 | 11.79/5.01 | 17.14/7.28 | 16.82/7.15 | 16.11/6.85 |
| 21,976/35,359 | 10.91/4.64 | 11.39/4.84 | 12.03/5.11 | 17.18/7.30 | 16.85/7.16 | 16.75/7.12 |
| 22,039/35,461 | 11.28/4.79 | 11.42/4.85 | 11.58/4.92 | 17.46/7.42 | 16.90/7.18 | 16.97/7.21 |
| 22,088/35,540 | 11.29/4.80 | 11.67/4.96 | 11.83/5.03 | 18.05/7.67 | 16.84/7.16 | 16.77/7.13 |

## APPENDIX B-20

| Miles/km | Fuel Economy (mpg/kmpl) CVS-CH Emissions | CVS-CH Weight | CVS-CH Flowmeter | HFET Emissions | HFET Weight | HFET Flowmeter |
|---|---|---|---|---|---|---|
| 22,141/35,625 | 11.79/5.01 | 11.73/4.99 | 11.87/5.05 | 17.56/7.46 | 17.25/7.33 | 17.21/7.31 |
| 22,435/36,098 | 11.32/4.81 | 11.22/4.77 | 11.33/4.82 | 17.51/7.44 | 16.71/7.10 | 16.62/7.06 |
| 22,459/36,137 | 10.98/4.67 | 11.24/4.78 | 11.06/4.70 | 17.90/7.61 | 16.85/7.16 | 17.09/7.26 |
| 22,613/36,384 | 11.51/4.89 | 11.60.4.93 | 11.76/5.00 | 18.47/7.85 | 17.05/7.25 | 17.12/7.28 |
| Average | 11.40/4.85 | 11.45/4.87 | 11.51/4.89 | 17.86/7.59 | 16.97/7.21 | 17.01/7.23 |

## APPENDIX B-21

| | Fuel Economy (mpg/kmpl) | | | | | |
|---|---|---|---|---|---|---|
| | CVS-CH | | | HFET | | |
| Miles/km | Emissions | Weight | Flowmeter | Emissions | Weight | Flowmeter |
| (6K) 29,233/47,036 | 11.25/4.78 | 11.01/4.68 | --- | 17.28/7.34 | 16.02/6.81 | 16.23/6.90 |
| (6K) 29,310/46,160 | 10.50/4.46 | 10.99/4.67 | 11.07/4.70 | 16.35/6.95 | 15.93/6.77 | 15.92/6.77 |
| (8K) 31,223/50,238 | 11.67/4.96 | 11.84/5.03 | 11.88/5.05 | 17.70/7.52 | 16.42/6.98 | 16.42/6.98 |
| (8K) 31,245/50,273 | 11.45/4.87 | 11.44/4.86 | 11.50/4.89 | 17.51/7.44 | 16.11/6.85 | 16.16/6.87 |
| (10K) 33,494/53,892 | 10.98/4.67 | 10.99/4.67 | 11.10/4.72 | 17.66/7.51 | 16.56/7.04 | 16.78/7.13 |
| (10K) 33,516/53,927 | 11.26/4.79 | 11.50/4.89 | 11.54/4.90 | 17.56/7.46 | 16.47/7.00 | 16.52/7.02 |
| (12K) 35,159/56,571 | 12.07/5.13 | 11.82/5.02 | 11.90/5.06 | 18.10/7.69 | 16.71/7.10 | 16.79/7.14 |
| (12K) 35,180/56,605 | 11.40/4.85 | 11.42/4.85 | 11.44/4.86 | 17.75/7.54 | 16.52/7.02 | 16.57/7.04 |

APPENDIX B-22

Fuel Economy (mpg/kmpℓ)

| Miles | CVS-CH Emissions | CVS-CH Weight | CVS-CH Flowmeter | HFET Emissions | HFET Weight | HFET Flowmeter |
|---|---|---|---|---|---|---|
| (12 K)35,341 | 11.94/5.07 | 11.95/5.08 | 12.03/5.11 | 17.66/7.51 | 17.20/7.31 | 17.30/7.35 |
| 35,963 | 12.20/5.19 | 11.42/4.85 | 11.81/5.02 | 18.04/7.67 | 16.90/7.18 | 17.37/7.38 |
| 35,985 | 11.54/4.90 | 10.86/4.61 | 11.17/4.75 | 17.54/7.45 | 15.97/6.79 | 16.39/6.97 |
| 36,244 | 13.26/5.64 | 11.19/4.76 | 11.30/4.80 | 20.17/8.57 | 16.67/7.08 | 16.85/7.16 |
| 36,285 | 11.89/5.05 | 11.56/4.91 | 11.66/4.96 | 18.40/7.82 | 16.87/7.17 | 16.72/7.11 |
| (4 K AMA)40,667 | 12.12/5.15 | 11.22/4.77 | 11.36/4.83 | 19.22/8.17 | 16.71/7.10 | 16.77/7.13 |
| (4 K AMA)40,829 | 11.88/5.05 | 11.52/4.90 | 11.64/4.95 | 18.40/7.82 | 16.71/7.10 | 16.73/7.11 |
| (4 K AMA)40,872 | 12.06/5.13 | 11.32/4.81 | 11.45/4.87 | 18.67/7.93 | 16.71/7.10 | 16.72/7.11 |
| 40,910 | 13.05/5.55 | 12.42/5.28 | 12.41/5.27 | 18.83/8.00 | 17.38/7.39 | 17.12/7.28 |
| 40,957 | 12.75/5.42 | 12.23/5.20 | 12.18/5.18 | 18.48/7.85 | 17.23/7.32 | -- |

DATE 7-9-75
STAND 3
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 564

MAKE NOVA

WET BULB TEMP 80
DRY BULB TEMP 89
BAROMETRIC PRES. 754.

ABSOLUTE HUMIDITY 140.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 67.0 PCT
PUMP INLET PRES. 20.80 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 442.50 | 1.00 | 3.00 | 1.00 | 17.00 | 2.00 |
| HC,PPM C6 | 14.20 | 1.60 | 3.00 | 1.70 | 5.60 | 1.86 |
| NOX,PPM | 47.50 | 0.48 | 16.00 | 0.68 | 45.50 | 0.41 |
| CO2,PCT | 1.44 | 0.04 | 1.00 | 0.04 | 1.35 | 0.05 |
| PUMP REV | 13392. | | 22972. | | 13392. | |

TEMP 130. F
PUMP CAPACITY 0.3115 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3517. | 6033. | 3517. |
| DF | 8.95 | 13.30 | 9.88 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 48.67 | 0.39 | 1.67 |
| HC | 4.40 | 0.84 | 1.35 |
| NOX | 8.96 | 5.02 | 8.59 |
| CO2 | 2570.46 | 3028.22 | 2380.05 |
| CARBON | 726.14 | 827.28 | 651.38 |
| FUEL LBS/BAG | 1.84 | 2.10 | 1.65 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.73 MILES/GAL | 4.989 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.33 | 5.242 |
| OVERALL TEST MILEAGE | 12.12 12.72 | 5.156 |
| WEIGHTED TEST MILEAGE | 12.06 | 5.130 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 2.970 G/MILE | 1.845 G/KM |
| HC | 0.467 | 0.290 |
| NOX | 1.837 | 1.141 |
| CORRECTED NOX | 2.645 | 1.643 |
| CO2 | 732.020 | 454.856 |

DATE 7-10-75
STAND 3
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 585

MAKE NOVA

WET BULB TEMP 77
DRY BULB TEMP 82
BAROMETRIC PRES. 755.

ABSOLUTE HUMIDITY 133.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 79.0 PCT
PUMP INLET PRES. 20.90 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 592.50 | 7.00 | 8.75 | 8.00 | 3.00 | 3.00 |
| HC,PPM C6 | 22.00 | 2.04 | 2.90 | 1.92 | 3.70 | 1.74 |
| NOX,PPM | 41.50 | 0.20 | 15.00 | 0.43 | 45.00 | 0.45 |
| CO2,PCT | 1.57 | 0.05 | 1.03 | 0.04 | 1.37 | 0.04 |
| SO2,PPM | 1.00 | | 0.50 | | 0.00 | |

PUMP REV 13435. 22885. 13435.
TEMP 130. F
PUMP CAPACITY 0.3115 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3532. | 6017. | 3532. |
| DF | 8.15 | 12.97 | 9.72 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 64.45 | 0.22 | 0.02 |
| HC | 6.99 | 0.66 | 0.74 |
| NOX | 7.90 | 4.75 | 8.53 |
| CO2 | 2804.50 | 3081.14 | 2442.92 |
| CARBON | 799.02 | 841.49 | 667.30 |
| SO2 | 0.27 | 0.23 | 0.00 |
| FUEL LBS/BAG | 2.03 | 2.14 | 1.69 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.11 MILES/GAL | 4.724 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.08 | 5.137 |
| OVERALL TEST MILEAGE | 11.58 | 4.926 |
| WEIGHTED TEST MILEAGE | 11.64 | 4.951 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 3.728 G/MILE | 2.316 G/KM |
| HC | 0.545 | 0.339 |
| NOX | 1.736 | 1.078 |
| CORRECTED NOX | 2.387 | 1.483 |
| CO2 | 757.273 | 470.547 |
| SO2 | 0.046 | 0.029 |
| SO2 | 0.045 | 0.028 UNWEIGHTED |

DATE 7-11-75 VEHICLE NO. 26 MAKE NOVA
STAND 3 ODOMETER 606.4
FUEL INDOLENE

WET BULB TEMP 75 ABSOLUTE HUMIDITY 119.0 GRNS/LBS DRY AIR
DRY BULB TEMP 83 RELATIVE HUMIDITY 69.0 PCT
BAROMETRIC PRES. 755. PUMP INLET PRES. 21.00 INCHES OF H20

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 680.00 | 3.00 | 8.00 | 6.00 | 10.20 | 3.00 |
| HC,PPM C6 | 30.00 | 1.30 | 2.20 | 1.36 | 3.00 | 1.02 |
| NOX,PPM | 37.00 | 0.22 | 15.80 | 0.17 | 51.00 | 0.10 |
| CO2,PCT | 1.50 | 0.05 | 1.00 | 0.04 | 1.37 | 0.03 |
| SO2,PPM | 2.00 | | 1.00 | | 1.00 | |

PUMP REV 13468. 22874. 13446.
TEMP 130. F
PUMP CAPACITY 0.3115 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3539. | 6011. | 3533. |
| DF | 8.46 | 13.30 | 9.72 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 74.98 | 0.44 | 0.82 |
| HC | 10.00 | 0.55 | 0.72 |
| NOX | 7.05 | 5.09 | 9.74 |
| CO2 | 2671.81 | 3009.90 | 2455.11 |
| CARBON | 769.94 | 822.05 | 670.96 |
| SO2 | 0.54 | 0.46 | 0.27 |

| | | | |
|---|---|---|---|
| FUEL LBS/BAG | 1.95 | 2.09 | 1.70 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.45 MILES/GAL | 4.868 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.21 | 5.191 |
| OVERALL TEST MILEAGE | 11.81 | 5.023 |
| WEIGHTED TEST MILEAGE | 11.87 | 5.047 |

WEIGHTED MASS EMISSIONS

| | | | | |
|---|---|---|---|---|
| | CO | 4.421 G/MILE | 2.747 G/KM | |
| | HC | 0.702 | 0.436 | |
| | NOX | 1.824 | 1.133 | |
| CORRECTED | NOX | 2.299 | 1.428 | |
| | CO2 | 741.092 | 460.493 | |
| | SO2 | 0.114 | 0.070 | |
| | SO2 | 0.116 | 0.072 | UNWEIGHTED |

DATE 8-19-75 | VEHICLE NO. 26 | MAKE NOVA
STAND 3 | ODOMETER 6860.25
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 68 | ABSOLUTE HUMIDITY | 80.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 82 | RELATIVE HUMIDITY | 48.0 PCT |
| BAROMETRIC PRES. | 764. | PUMP INLET PRES. | 20.60 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 485.00 | 3.00 | 8.00 | 3.00 | 28.00 | 3.00 |
| HC,PPM C6 | 13.00 | 1.60 | 2.80 | 1.60 | 4.00 | 1.30 |
| NOX,PPM | 46.50 | 0.22 | 15.50 | 0.09 | 36.50 | 0.40 |
| CO2,PCT | 1.41 | 0.05 | 1.03 | 0.04 | 1.31 | 0.04 |
| SO2,PPM | 1.00 | | 0.50 | | 1.50 | |

PUMP REV 13435. 22961. 13446.
TEMP 130. F
PUMP CAPACITY 0.3115 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3575. | 6110. | 3578. |
| DF | 9.13 | 12.97 | 10.12 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 54.41 | 1.00 | 2.85 |
| HC | 4.05 | 0.79 | 0.99 |
| NOX | 8.96 | 5.10 | 7.00 |
| CO2 | 2534.98 | 3140.42 | 2375.05 |
| CARBON | 718.62 | 858.11 | 650.21 |
| SO2 | 0.27 | 0.23 | 0.41 |
| FUEL LBS/BAG | 1.82 | 2.18 | 1.65 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.56 MILES/GAL | 4.915 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.08 | 5.138 |
| OVERALL TEST MILEAGE | 12.00 12.30 | 5.104 |
| WEIGHTED TEST MILEAGE | 11.85 | 5.040 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 3.471 G/MILE | 2.156 G/KM | |
| HC | 0.413 | 0.256 | |
| NOX | 1.726 | 1.072 | |
| CORRECTED NOX | 1.768 | 1.098 | |
| CO2 | 744.566 | 462.651 | |
| SO2 | 0.078 | 0.049 | |
| SO2 | 0.084 | 0.052 | UNWEIGHTED |

DATE 8-20-75 | VEHICLE NO. 26 | MAKE NOVA
STAND 3 | ODOMETER 6881.6
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 67 | ABSOLUTE HUMIDITY | 78.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 80 | RELATIVE HUMIDITY | 51.0 PCT |
| BAROMETRIC PRES. | 766. | PUMP INLET PRES. | 20.80 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 603.00 | 3.00 | 3.00 | 2.00 | 18.80 | 1.00 |
| HC,PPM C6 | 12.60 | 1.12 | 2.20 | 1.10 | 3.60 | 1.38 |
| NOX,PPM | 52.50 | 0.25 | 16.10 | 0.25 | 36.00 | 0.47 |
| CO2,PCT | 1.41 | 0.04 | 0.97 | 0.04 | 1.31 | 0.04 |
| SO2,PPM | 1.00 | | 0.50 | | 1.00 | |
| PUMP REV | 13489. | | 22885. | | 13468. | |

TEMP 130. F
PUMP CAPACITY 0.3115 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3597. | 6103. | 3592. |
| DF | 9.07 | 13.72 | 10.13 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 68.09 | 0.21 | 2.02 |
| HC | 4.09 | 0.70 | 0.82 |
| NOX | 10.18 | 5.24 | 6.92 |
| CO2 | 2557.59 | 2962.42 | 2384.26 |
| CARBON | 730.68 | 809.12 | 652.23 |
| SO2 | 0.27 | 0.23 | 0.27 |
| FUEL LBS/BAG | 1.85 | 2.05 | 1.65 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.84 MILES/GAL | 5.033 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.47 | 5.304 |
| OVERALL TEST MILEAGE | 12.19 12.13 | 5.186 |
| WEIGHTED TEST MILEAGE | 12.19 | 5.184 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 4.086 G/MILE | 2.539 G/KM | |
| HC | 0.391 | 0.243 | |
| NOX | 1.809 | 1.124 | |
| CORRECTED NOX | 1.835 | 1.140 | |
| CO2 | 722.829 | 449.145 | |
| SO2 | 0.068 | 0.042 | |
| SO2 | 0.071 | 0.044 | UNWEIGHTED |

DATE 8-25-75 | VEHICLE NO. 26 | MAKE NOVA
STAND 3 | ODOMETER 8903
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 79 | ABSOLUTE HUMIDITY | 140.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 85 | RELATIVE HUMIDITY | 76.5 PCT |
| BAROMETRIC PRES. | 761. | PUMP INLET PRES. | 20.80 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 637.00 | 4.50 | 8.00 | 3.00 | 20.50 | 3.00 |
| HC,PPM C6 | 17.60 | 2.20 | 3.20 | 1.90 | 4.00 | 1.80 |
| NOX,PPM | 39.50 | 0.30 | 11.00 | 0.33 | 24.00 | 0.30 |
| CO2,PCT | 1.51 | 0.05 | 1.12 | 0.04 | 1.41 | 0.05 |
| SO2,PPM | 1.00 | | 0.20 | | 0.80 | |
| PUMP REV | 13543. | | 22928. | | 13435. | |

TEMP 130. F
PUMP CAPACITY 0.3115 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3587. | 6073. | 3558. |
| DF | 8.42 | 11.93 | 9.41 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 70.81 | 0.99 | 1.97 |
| HC | 5.50 | 0.86 | 0.83 |
| NOX | 7.62 | 3.51 | 4.57 |
| CO2 | 2743.36 | 3394.08 | 2535.82 |
| CARBON | 783.77 | 927.39 | 693.57 |
| SO2 | 0.27 | 0.09 | 0.22 |
| FUEL LBS/BAG | 1.99 | 2.35 | 1.76 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.65 MILES/GAL | 4.529 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.24 | 4.781 |
| OVERALL TEST MILEAGE | 11.11 11.14 | 4.727 |
| WEIGHTED TEST MILEAGE | 10.98 | 4.670 |

WEIGHTED MASS EMISSIONS

| | | | | |
|---|---|---|---|---|
| | CO | 4.342 G/MILE | 2.698 G/KM | |
| | HC | 0.494 | 0.307 | |
| | NOX | 1.253 | 0.779 | |
| CORRECTED | NOX | 1.805 | 1.121 | |
| | CO2 | 802.552 | 498.682 | |
| | SO2 | 0.045 | 0.028 | |
| | SO2 | 0.053 | 0.033 | UNWEIGHTED |

DATE 8-26-75 | VEHICLE NO. 26 | MAKE NOVA
STAND 3 | ODOMETER 8925
FUEL INDOLENE

WET BULB TEMP 77 | ABSOLUTE HUMIDITY 136.0 GRNS/LBS DRY AIR
DRY BULB TEMP 80 | RELATIVE HUMIDITY 88.0 PCT
BAROMETRIC PRES. 763. | PUMP INLET PRES. 20.60 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 754.00 | 7.00 | 10.20 | 8.00 | 21.80 | 6.00 |
| HC,PPM C6 | 15.80 | 2.60 | 3.40 | 2.40 | 4.40 | 2.10 |
| NOX,PPM | 33.20 | 0.62 | 11.20 | 0.85 | 23.00 | 0.92 |
| CO2,PCT | 1.47 | 0.05 | 1.03 | 0.05 | 1.41 | 0.04 |
| SO2,PPM | 1.50 | | 0.50 | | 1.00 | |
| PUMP REV | 13414. | | 22928. | | 13424. | |

TEMP 130. F
PUMP CAPACITY 0.3115 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3567. | 6098. | 3570. |
| DF | 8.61 | 12.97 | 9.45 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 82.94 | 0.50 | 1.80 |
| HC | 4.71 | 0.70 | 0.88 |
| NOX | 6.30 | 3.43 | 4.28 |
| CO2 | 2638.61 | 3096.25 | 2537.79 |
| CARBON | 759.71 | 845.77 | 694.08 |
| SO2 | 0.41 | 0.23 | 0.27 |
| FUEL LBS/BAG | 1.93 | 2.15 | 1.76 |

| | INDOLENE MILEAGE | | |
|---|---|---|---|
| AVERAGE COLD START MILEAGE | 11.35 MILES/GAL | | 4.827 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.84 | | 5.033 |
| OVERALL TEST MILEAGE | 11.62 | 11.91 MPG | 4.943 |
| WEIGHTED TEST MILEAGE | 11.62 | | 4.943 |

WEIGHTED MASS EMISSIONS

| | | G/MILE | G/KM | |
|---|---|---|---|---|
| | CO | 4.960 G/MILE | 3.082 G/KM | |
| | HC | 0.432 | 0.268 | |
| | NOX | 1.146 | 0.712 | |
| CORRECTED | NOX | 1.607 | 0.998 | |
| | CO2 | 756.986 | 470.369 | |
| | SO2 | 0.076 | 0.047 | |
| | SO2 | 0.084 | 0.052 | UNWEIGHTED |

DATE 9-3-75
STAND 3
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 11024.9

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 61 | ABSOLUTE HUMIDITY | 66.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 70 | RELATIVE HUMIDITY | 60.0 PCT |
| BAROMETRIC PRES. | 760. | PUMP INLET PRES. | 20.80 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 902.50 | 6.00 | 6.00 | 2.00 | 39.50 | 1.00 |
| HC,PPM C6 | 16.80 | 1.10 | 2.30 | 1.10 | 3.60 | 1.10 |
| NOX,PPM | 67.00 | 0.72 | 22.00 | 0.48 | 52.00 | 0.40 |
| CO2,PCT | 1.35 | 0.05 | 0.98 | 0.04 | 1.26 | 0.04 |
| SO2,PPM | 3.00 | | 1.20 | | 2.00 | |
| PUMP REV | 13360. | | 22864. | | 13500. | |

TEMP 130. F
PUMP CAPACITY 0.3115 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3533. | 6047. | 3570. |
| DF | 9.26 | 13.64 | 10.58 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 99.77 | 0.78 | 4.34 |
| HC | 5.47 | 0.75 | 0.91 |
| NOX | 12.70 | 7.06 | 9.98 |
| CO2 | 2391.90 | 2956.83 | 2265.84 |
| CARBON | 700.25 | 807.89 | 620.98 |
| SO2 | 0.81 | 0.56 | 0.55 |
| FUEL LBS/BAG | 1.78 | 2.05 | 1.57 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.08 MILES/GAL | 5.139 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.75 | 5.424 |
| OVERALL TEST MILEAGE | 12.55 12.11 | 5.339 |
| WEIGHTED TEST MILEAGE | 12.46 | 5.298 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 6.155 G/MILE | 3.824 G/KM | |
| HC | 0.484 | 0.301 | |
| NOX | 2.428 | 1.509 | |
| CORRECTED NOX | 2.329 | 1.447 | |
| CO2 | 703.584 | 437.186 | |
| SO2 | 0.163 | 0.101 | |
| SO2 | 0.175 | 0.109 | UNWEIGHTED |

DATE 9-4-75 | VEHICLE NO. 26 | MAKE NOVA
STAND 3 | ODOMETER 11046.45
FUEL INDOLENE

| | | | | |
|---|---|---|---|---|
| WET BULB TEMP | 65 | ABSOLUTE HUMIDITY | 81.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 72 | RELATIVE HUMIDITY | 68.0 PCT |
| BAROMETRIC PRES. | 762. | PUMP INLET PRES. | 20.50 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 718.00 | 7.00 | 8.00 | 3.00 | 32.00 | 3.00 |
| HC,PPM C6 | 15.00 | 1.60 | 3.40 | 1.70 | 4.00 | 1.40 |
| NOX,PPM | 52.00 | 0.35 | 17.30 | 0.33 | 44.00 | 0.52 |
| CO2,PCT | 1.32 | 0.04 | 0.98 | 0.04 | 1.23 | 0.05 |
| SO2,PPM | 2.00 | | 1.50 | | 1.50 | |
| PUMP REV | 13446. | | 22907. | | 13478. | |

TEMP 130. F
PUMP CAPACITY 0.3116 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3570. | 6082. | 3578. |
| DF | 9.58 | 13.63 | 10.84 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 79.79 | 0.99 | 3.28 |
| HC | 4.74 | 1.08 | 0.95 |
| NOX | 9.99 | 5.59 | 8.43 |
| CO2 | 2377.32 | 2973.87 | 2198.23 |
| CARBON | 687.08 | 812.91 | 602.12 |
| SO2 | 0.55 | 0.70 | 0.41 |
| FUEL LBS/BAG | 1.74 | 2.06 | 1.53 |

| | INDOLENE MILEAGE | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.15 MILES/GAL | 5.167 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.88 | 5.477 |
| OVERALL TEST MILEAGE | 12.72 12.15 | 5.408 |
| WEIGHTED TEST MILEAGE | 12.56 | 5.339 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 4.957 G/MILE | 3.080 G/KM | |
| HC | 0.489 | 0.304 | |
| NOX | 1.960 | 1.218 | |
| CORRECTED NOX | 2.017 | 1.253 | |
| CO2 | 699.881 | 434.886 | |
| SO2 | 0.157 | 0.097 | |
| SO2 | 0.152 | 0.094 | UNWEIGHTED |

DATE 9/8/75 | VEHICLE NO. 7526 | MAKE NOVA
STAND 3 | ODOMETER 13,148.0
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 78 | ABSOLUTE HUMIDITY | 134.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 85 | RELATIVE HUMIDITY | 73.0 PCT |
| BAROMETRIC PRES. | 765. | PUMP INLET PRES. | 23.10 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 648.00 | 3.00 | 6.00 | 2.00 | 13.00 | 2.00 |
| HC,PPM C6 | 16.80 | 2.30 | 3.60 | 2.20 | 4.80 | 2.20 |
| NOX,PPM | 43.00 | 0.50 | 14.70 | 0.40 | 35.50 | 0.40 |
| CO2,PCT | 1.48 | 0.05 | 1.00 | 0.05 | 1.35 | 0.05 |
| SO2,PPM | 1.50 | | 0.00 | | 0.50 | |
| PUMP REV | 13446. | | 22961. | | 13424. | |

TEMP 130. F
PUMP CAPACITY 0.3115 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3560. | 6079. | 3554. |
| DF | 8.63 | 13.36 | 9.89 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 71.79 | 0.78 | 1.24 |
| HC | 5.15 | 0.93 | 0.98 |
| NOX | 8.20 | 4.71 | 6.76 |
| CO2 | 2650.33 | 3006.34 | 2405.06 |
| CARBON | 758.50 | 821.55 | 657.70 |
| SO2 | 0.41 | 0.00 | 0.13 |
| FUEL LBS/BAG | 1.92 | 2.08 | 1.67 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.53 MILES/GAL | 4.905 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.32 | 5.239 |
| OVERALL TEST MILEAGE | 11.94 12.24 | 5.080 |
| WEIGHTED TEST MILEAGE | 11.97 | 5.090 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 4.315 G/MILE | 2.681 G/KM | |
| HC | 0.494 | 0.307 | |
| NOX | 1.613 | 1.002 | |
| CORRECTED NOX | 2.232 | 1.387 | |
| CO2 | 735.583 | 457.070 | |
| SO2 | 0.034 | 0.021 | |
| SO2 | 0.050 | 0.031 | UNWEIGHTED |

DATE 9/9/75 | VEHICLE NO. 26 | MAKE NOVA
STAND 3 | ODOMETER 13,169.6
FUEL INDOLENE

WET BULB TEMP 63 | ABSOLUTE HUMIDITY 67.0 GRNS/LBS DRY AIR
DRY BULB TEMP 75 | RELATIVE HUMIDITY 52.0 PCT
BAROMETRIC PRES. 768. | PUMP INLET PRES. 20.60 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 592.00 | 3.00 | 4.50 | 1.00 | 45.00 | 2.00 |
| HC,PPM C6 | 12.40 | 1.40 | 2.50 | 1.04 | 4.20 | 1.08 |
| NOX,PPM | 61.50 | 0.37 | 19.80 | 0.32 | 48.00 | 0.35 |
| CO2,PCT | 1.41 | 0.04 | 1.00 | 0.04 | 1.32 | 0.04 |
| SO2,PPM | 1.00 | | 0.50 | | 0.00 | |

| | | | |
|---|---|---|---|
| PUMP REV | 13576. | 22961. | 13489. |
| TEMP | 130. F | | |
| PUMP CAPACITY | 0.3115 CF/REV | | |

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3632. | 6143. | 3609. |
| DF | 9.09 | 13.37 | 10.09 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 67.47 | 0.69 | 4.91 |
| HC | 3.97 | 0.92 | 1.14 |
| NOX | 12.03 | 6.49 | 9.32 |
| CO2 | 2588.76 | 3067.75 | 2402.92 |
| CARBON | 738.82 | 838.26 | 658.83 |
| SO2 | 0.28 | 0.23 | 0.00 |
| FUEL LBS/BAG | 1.87 | 2.13 | 1.67 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.56 MILES/GAL | 4.914 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.17 | 5.177 |
| OVERALL TEST MILEAGE | 11.95 12.58 | 5.084 |
| WEIGHTED TEST MILEAGE | 11.90 | 5.061 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 4.334 G/MILE | 2.693 G/KM | |
| HC | 0.437 | 0.272 | |
| NOX | 2.263 | 1.406 | |
| CORRECTED NOX | 2.181 | 1.355 | |
| CO2 | 740.078 | 459.863 | |
| SO2 | 0.047 | 0.029 | |
| SO2 | 0.047 | 0.029 | UNWEIGHTED |

DATE 9/9/10/7
STAND 3
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 13,191.2

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 64 | ABSOLUTE HUMIDITY | 68.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 77 | RELATIVE HUMIDITY | 49.0 PCT |
| BAROMETRIC PRES. | 767. | PUMP INLET PRES. | 20.90 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 742.50 | 3.00 | 6.00 | 2.00 | 73.50 | 3.00 |
| HC,PPM C6 | 14.20 | 0.90 | 2.90 | 1.46 | 5.60 | 1.22 |
| NOX,PPM | 69.50 | 0.44 | 20.00 | 0.28 | 52.50 | 0.22 |
| CO2,PCT | 1.44 | 0.04 | 0.98 | 0.04 | 1.35 | 0.04 |
| SO2,PPM | 1.00 | | 0.00 | | 0.50 | |
| PUMP REV | 13414. | | 22961. | | 13392. | |

TEMP 130. F
PUMP CAPACITY 0.3115 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3581. | 6130. | 3575. |
| DF | 8.81 | 13.64 | 9.85 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 83.55 | 0.80 | 7.99 |
| HC | 4.70 | 0.92 | 1.57 |
| NOX | 13.40 | 6.55 | 10.12 |
| CO2 | 2608.37 | 2997.43 | 2436.34 |
| CARBON | 751.70 | 819.12 | 669.65 |
| SO2 | 0.27 | 0.00 | 0.13 |
| FUEL LBS/BAG | 1.91 | 2.08 | 1.70 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.60 MILES/GAL | 4.934 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.24 | 5.206 |
| OVERALL TEST MILEAGE | 11.93 12.45 | 5.074 |
| WEIGHTED TEST MILEAGE | 11.96 | 5.085 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 5.504 G/MILE | 3.420 G/KM | |
| HC | 0.513 | 0.319 | |
| NOX | 2.412 | 1.499 | |
| CORRECTED NOX | 2.335 | 1.451 | |
| CO2 | 734.366 | 456.314 | |
| SO2 | 0.026 | 0.016 | |
| SO2 | 0.037 | 0.023 | UNWEIGHTED |

DATE 9-8-76
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 13947.2

MAKE NOVA

WET BULB TEMP 80
DRY BULB TEMP 90
BAROMETRIC PRES. 763.

ABSOLUTE HUMIDITY 140.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 60.0 PCT
PUMP INLET PRES. 6.80 INCHES OF H20

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1600.00 | 1.50 | 800.00 | 1.50 | 1760.00 | 3.00 |
| HC,PPM C6 | 44.00 | 1.16 | 18.00 | 1.00 | 34.00 | 1.14 |
| NOX,PPM | 48.00 | 0.12 | 17.00 | 0.10 | 54.00 | 0.27 |
| CO2,PCT | 1.84 | 0.01 | 1.23 | 0.03 | 1.88 | 0.03 |

PUMP REV 9530. 16370. 9560.
TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2715. | 4663. | 2723. |
| DF | 6.64 | 10.17 | 6.48 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 135.26 | 117.50 | 149.03 |
| HC | 11.44 | 7.81 | 8.81 |
| NOX | 7.04 | 4.27 | 7.93 |
| CO2 | 2578.30 | 2908.89 | 2619.06 |
| CARBON | 771.51 | 850.97 | 786.26 |
| FUEL LBS/BAG | 1.96 | 2.16 | 1.99 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.23 MILES/GAL | 4.777 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.13 | 4.734 |
| OVERALL TEST MILEAGE | 11.10 | 4.719 |
| WEIGHTED TEST MILEAGE | 11.17 | 4.752 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 34.749 G/MILE | 21.592 G/KM |
| HC | 2.367 | 1.471 |
| NOX | 1.576 | 0.979 |
| CORRECTED NOX | 2.269 | 1.410 |
| CO2 | 734.724 | 456.536 |

DATE 9-10-76 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 13968
FUEL TK 90

WET BULB TEMP 73 | ABSOLUTE HUMIDITY 116.0 GRNS/LBS DRY AIR
DRY BULB TEMP 77 | RELATIVE HUMIDITY 83.0 PCT
BAROMETRIC PRES. 756. | PUMP INLET PRES. 6.75 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 2250.00 | 5.00 | 760.00 | 4.00 | 880.00 | 5.00 |
| HC,PPM C6 | 46.00 | 1.39 | 18.30 | 1.60 | 26.00 | 2.10 |
| NOX,PPM | 48.00 | 0.22 | 14.50 | 0.15 | 60.50 | 0.70 |
| CO2,PCT | 1.91 | 0.03 | 1.23 | 0.03 | 1.88 | 0.04 |
| PUMP REV | 9610. | | 16380. | | 9590. | |

TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2712. | 4623. | 2706. |
| DF | 6.23 | 10.20 | 6.77 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 188.07 | 109.47 | 73.22 |
| HC | 11.91 | 7.63 | 6.42 |
| NOX | 7.02 | 3.59 | 8.78 |
| CO2 | 2645.07 | 2873.04 | 2584.87 |
| CARBON | 812.78 | 837.58 | 742.35 |
| FUEL LBS/BAG | 2.06 | 2.13 | 1.88 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.04 MILES/GAL | 4.696 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.53 | 4.906 |
| OVERALL TEST MILEAGE | 11.17 | 4.751 |
| WEIGHTED TEST MILEAGE | 11.32 | 4.813 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 30.943 G/MILE | 19.227 G/KM |
| HC | 2.189 | 1.360 |
| NOX | 1.549 | 0.963 |
| CORRECTED NOX | 1.919 | 1.192 |
| CO2 | 731.174 | 454.330 |

DATE 9-15-76 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 13994
FUEL TK 90

| | | | |
|---|---|---|---|
| WET BULB TEMP | 72 | ABSOLUTE HUMIDITY | 110.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 77 | RELATIVE HUMIDITY | 79.0 PCT |
| BAROMETRIC PRES. | 768. | PUMP INLET PRES. | 6.80 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 2500.00 | 5.00 | 932.00 | 6.00 | 1500.00 | 4.00 |
| HC,PPM C6 | 41.00 | 1.00 | 16.00 | 1.16 | 22.00 | 1.14 |
| NOX,PPM | 56.50 | 0.30 | 15.30 | 0.20 | 43.50 | 0.23 |
| CO2,PCT | 1.89 | 0.04 | 1.16 | 0.04 | 1.63 | 0.04 |
| PUMP REV | 9570. | | 16370. | | 9590. | |

TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2744. | 4694. | 2750. |
| DF | 6.22 | 10.64 | 7.50 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 211.82 | 136.53 | 127.97 |
| HC | 10.79 | 6.87 | 5.66 |
| NOX | 8.36 | 3.84 | 6.45 |
| CO2 | 2642.99 | 2735.50 | 2275.02 |
| CARBON | 821.43 | 811.00 | 680.61 |
| FUEL LBS/BAG | 2.08 | 2.06 | 1.73 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.16 MILES/GAL | 4.748 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.22 | 5.196 |
| OVERALL TEST MILEAGE | 11.56 | 4.914 |
| WEIGHTED TEST MILEAGE | 11.74 | 4.993 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 40.076 G/MILE | 24.902 G/KM |
| HC | 1.966 | 1.221 |
| NOX | 1.482 | 0.920 |
| CORRECTED NOX | 1.773 | 1.102 |
| CO2 | 689.167 | 428.228 |

DATE 9-16-76  
STAND 2  
FUEL INDOLENE

VEHICLE NO. 26  
ODOMETER 14015.4

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 73 | ABSOLUTE HUMIDITY | 118.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 76 | RELATIVE HUMIDITY | 87.0 PCT |
| BAROMETRIC PRES. | 767. | PUMP INLET PRES. | 6.80 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 775.00 | 3.00 | 8.25 | 3.00 | 33.00 | 3.00 |
| HC,PPM C6 | 25.00 | 1.36 | 2.90 | 1.46 | 6.80 | 1.52 |
| NOX,PPM | 45.00 | 0.18 | 13.50 | 0.15 | 51.50 | 0.27 |
| CO2,PCT | 1.95 | 0.00 | 1.31 | 0.00 | 2.10 | 0.00 |
| PUMP REV | 9540. | | 16360. | | 9590. | |

TEMP 125. F  
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2709. | 4645. | 2723. |
| DF | 6.57 | 10.20 | 6.35 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 64.45 | 0.79 | 2.53 |
| HC | 6.32 | 0.72 | 1.47 |
| NOX | 6.58 | 3.36 | 7.56 |
| CO2 | 2739.03 | 3155.50 | 2965.18 |
| CARBON | 780.58 | 862.07 | 811.54 |
| FUEL LBS/BAG | 1.98 | 2.19 | 2.06 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.09 MILES/GAL | 4.718 KM/LITRE |
| AVERAGE HOT START MILEAGE | 10.89 | 4.631 |
| OVERALL TEST MILEAGE | 10.89 | 4.632 |
| WEIGHTED TEST MILEAGE | 10.98 | 4.668 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 3.994 G/MILE | 2.481 G/KM |
| HC | 0.570 | 0.354 |
| NOX | 1.400 | 0.870 |
| CORRECTED NOX | 1.755 | 1.090 |
| CO2 | 803.125 | 499.038 |

DATE 9-17-76 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 14048.2
FUEL TK 90

WET BULB TEMP 75 | ABSOLUTE HUMIDITY 126.0 GRNS/LBS DRY AIR
DRY BULB TEMP 78 | RELATIVE HUMIDITY 87.0 PCT
BAROMETRIC PRES. 764. | PUMP INLET PRES. 6.70 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 920.00 | 4.00 | 4.00 | 2.00 | 70.00 | 3.00 |
| HC,PPM C6 | 28.00 | 2.30 | 3.90 | 2.40 | 6.00 | 2.40 |
| NOX,PPM | 49.50 | 0.16 | 14.60 | 0.10 | 41.50 | 0.15 |
| CO2,PCT | 2.04 | 0.04 | 1.38 | 0.03 | 1.84 | 0.03 |
| PUMP REV | 9550. | | 16380. | | 9550. | |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2701. | 4634. | 2701. |
| DF | 6.23 | 9.69 | 7.24 |
| **MASS EMISSIONS, GRAMS/BAG** | | | |
| CO | 76.13 | 0.31 | 5.61 |
| HC | 6.90 | 0.79 | 1.04 |
| NOX | 7.22 | 3.64 | 6.05 |
| CO2 | 2817.70 | 3240.34 | 2535.32 |
| CARBON | 807.55 | 885.08 | 695.17 |
| FUEL LBS/BAG | 2.05 | 2.25 | 1.76 |

| | INDOLENE MILEAGE | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.77 MILES/GAL | 4.579 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.53 | 4.905 |
| OVERALL TEST MILEAGE | 11.19 | 4.761 |
| WEIGHTED TEST MILEAGE | 11.19 | 4.759 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 4.833 G/MILE | 3.003 G/KM |
| HC | 0.580 | 0.360 |
| NOX | 1.359 | 0.844 |
| CORRECTED NOX | 1.788 | 1.111 |
| CO2 | 786.279 | 488.571 |

DATE 9-20-76
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 14071.8

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 70 | ABSOLUTE HUMIDITY | 102.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 75 | RELATIVE HUMIDITY | 78.0 PCT |
| BAROMETRIC PRES. | 756. | PUMP INLET PRES. | 6.70 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1350.00 | 3.00 | 4.00 | 3.00 | 135.00 | 1.50 |
| HC,PPM C6 | 23.00 | 1.71 | 3.00 | 1.74 | 6.20 | 1.44 |
| NOX,PPM | 49.00 | 0.17 | 16.30 | 0.15 | 34.50 | 0.11 |
| CO2,PCT | 2.03 | 0.04 | 1.30 | 0.04 | 1.80 | 0.03 |
| PUMP REV | 9540. | | 16380. | | 9580. | |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2670. | 4584. | 2681. |
| DF | 6.17 | 10.29 | 7.37 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 110.99 | 0.17 | 11.10 |
| HC | 5.64 | 0.64 | 1.30 |
| NOX | 7.06 | 4.01 | 4.99 |
| CO2 | 2764.11 | 3004.45 | 2466.48 |
| CARBON | 806.78 | 820.52 | 678.97 |
| FUEL LBS/BAG | 2.05 | 2.08 | 1.72 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.20 MILES/GAL | 4.763 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.15 | 5.169 |
| OVERALL TEST MILEAGE | 11.59 | 4.929 |
| WEIGHTED TEST MILEAGE | 11.72 | 4.986 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 7.231 G/MILE | 4.493 G/KM |
| HC | 0.508 | 0.315 |
| NOX | 1.319 | 0.820 |
| CORRECTED NOX | 1.511 | 0.939 |
| CO2 | 746.522 | 463.867 |

36 Hour Soak

DATE 9-21-76 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 14094
FUEL TK 90

| | | | |
|---|---|---|---|
| WET BULB TEMP | 68 | ABSOLUTE HUMIDITY | 96.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 72 | RELATIVE HUMIDITY | 82.0 PCT |
| BAROMETRIC PRES. | 751. | PUMP INLET PRES. | 6.70 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1500.00 | 4.00 | 4.00 | 3.00 | 136.00 | 3.00 |
| HC,PPM C6 | 25.00 | 1.17 | 2.22 | 1.10 | 4.60 | 0.95 |
| NOX,PPM | 57.00 | 0.24 | 18.30 | 0.18 | 37.50 | 0.23 |
| CO2,PCT | 1.95 | 0.03 | 1.29 | 0.03 | 1.77 | 0.04 |
| PUMP REV | 9520. | | 16390. | | 9550. | |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2646. | 4556. | 2655. |
| DF | 6.36 | 10.33 | 7.50 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 122.22 | 0.17 | 10.96 |
| HC | 6.22 | 0.54 | 0.98 |
| NOX | 8.14 | 4.47 | 5.36 |
| CO2 | 2635.50 | 2984.88 | 2388.89 |
| CARBON | 777.01 | 815.10 | 657.46 |
| FUEL LBS/BAG | 1.97 | 2.07 | 1.67 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.45 MILES/GAL | 4.868 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.38 | 5.263 |
| OVERALL TEST MILEAGE | 11.88 | 5.053 |
| WEIGHTED TEST MILEAGE | 11.96 | 5.086 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 7.863 G/MILE | 4.886 G/KM |
| HC | 0.504 | 0.313 |
| NOX | 1.471 | 0.914 |
| CORRECTED NOX | 1.632 | 1.014 |
| CO2 | 730.643 | 454.000 |

DATE 9-28-76
STAND 2
FUEL TK 90

VEHICLE NO. 26
ODOMETER 14233

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 62 | ABSOLUTE HUMIDITY | 74.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 68 | RELATIVE HUMIDITY | 73.0 PCT |
| BAROMETRIC PRES. | 759. | PUMP INLET PRES. | 6.80 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1850.00 | 6.00 | 4.00 | 2.00 | 46.00 | 3.00 |
| HC,PPM C6 | 34.00 | 0.74 | 2.10 | 0.66 | 6.10 | 0.73 |
| NOX,PPM | 85.00 | 0.20 | 29.50 | 0.13 | 68.50 | 0.22 |
| CO2,PCT | 1.78 | 0.03 | 1.22 | 0.03 | 1.53 | 0.03 |
| PUMP REV | 9560. | | 16450. | | 9570. | |

TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2709. | 4661. | 2711. |
| DF | 6.76 | 10.95 | 8.68 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 155.21 | 0.31 | 3.66 |
| HC | 8.85 | 0.68 | 1.44 |
| NOX | 12.44 | 7.41 | 10.03 |
| CO2 | 2465.40 | 2874.28 | 2114.85 |
| CARBON | 747.01 | 785.09 | 579.95 |
| FUEL LBS/BAG | 1.90 | 1.99 | 1.47 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.89 MILES/GAL | 5.059 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.35 | 5.678 |
| OVERALL TEST MILEAGE | 12.66 | 5.382 |
| WEIGHTED TEST MILEAGE | 12.68 | 5.394 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 9.219 G/MILE | 5.728 G/KM |
| HC | 0.709 | 0.440 |
| NOX | 2.465 | 1.531 |
| CORRECTED NOX | 2.453 | 1.524 |
| CO2 | 685.315 | 425.835 |

DATE 9-29-76
STAND 2
FUEL TK 90

VEHICLE NO. 26
ODOMETER 14256

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 58 | ABSOLUTE HUMIDITY | 64.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 63 | RELATIVE HUMIDITY | 74.0 PCT |
| BAROMETRIC PRES. | 762. | PUMP INLET PRES. | 6.70 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1800.00 | 2.00 | 3.00 | 2.00 | 50.00 | 2.00 |
| HC,PPM C6 | 32.00 | 0.68 | 2.00 | 0.62 | 5.40 | 0.64 |
| NOX,PPM | 102.00 | 0.27 | 30.00 | 0.35 | 74.00 | 0.45 |
| CO2,PCT | 1.97 | 0.03 | 1.21 | 0.04 | 1.61 | 0.04 |

PUMP REV 9550. 16400. 9540.
TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2717. | 4667. | 2714. |
| DF | 6.20 | 11.06 | 8.28 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 151.17 | 0.16 | 4.07 |
| HC | 8.36 | 0.65 | 1.28 |
| NOX | 14.98 | 7.50 | 10.82 |
| CO2 | 2734.69 | 2840.08 | 2216.88 |
| CARBON | 818.34 | 775.67 | 607.83 |
| FUEL LBS/BAG | 2.08 | 1.97 | 1.54 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.43 MILES/GAL | 4.862 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.17 | 5.602 |
| OVERALL TEST MILEAGE | 12.14 | 5.163 |
| WEIGHTED TEST MILEAGE | 12.36 | 5.258 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 8.999 G/MILE | 5.591 G/KM |
| HC | 0.665 | 0.413 |
| NOX | 2.681 | 1.666 |
| CORRECTED NOX | 2.549 | 1.584 |
| CO2 | 703.950 | 437.414 |

DATE 9-30-76 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 14279
FUEL TK 90

| | | | |
|---|---|---|---|
| WET BULB TEMP | 62 | ABSOLUTE HUMIDITY | 76.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 66.5 | RELATIVE HUMIDITY | 78.0 PCT |
| BAROMETRIC PRES. | 760. | PUMP INLET PRES. | 6.75 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1750.00 | 16.00 | 12.00 | 10.50 | 39.50 | 13.50 |
| HC,PPM C6 | 28.00 | 1.18 | 2.70 | 1.17 | 4.80 | 1.02 |
| NOX,PPM | 79.50 | 0.55 | 24.70 | 0.50 | 63.50 | 0.31 |
| CO2,PCT | 1.83 | 0.05 | 1.21 | 0.04 | 1.61 | 0.04 |
| PUMP REV | 9600. | | 16360. | | 9570. | |

TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2724. | 4642. | 2715. |
| DF | 6.66 | 11.04 | 8.28 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 146.50 | 0.32 | 2.30 |
| HC | 7.20 | 0.74 | 1.03 |
| NOX | 11.66 | 6.09 | 9.30 |
| CO2 | 2525.02 | 2825.25 | 2217.64 |
| CARBON | 758.12 | 771.77 | 607.06 |
| FUEL LBS/BAG | 1.92 | 1.96 | 1.54 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.91 MILES/GAL | 5.066 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.22 | 5.621 |
| OVERALL TEST MILEAGE | 12.51 | 5.319 |
| WEIGHTED TEST MILEAGE | 12.62 | 5.368 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 8.617 G/MILE | 5.354 G/KM |
| HC | 0.591 | 0.367 |
| NOX | 2.188 | 1.359 |
| CORRECTED NOX | 2.198 | 1.366 |
| CO2 | 690.009 | 428.751 |

DATE 10-12-76
STAND 2
FUEL TK 90

VEHICLE NO. 26
ODOMETER 14457

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 61 | ABSOLUTE HUMIDITY | 66.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 70 | RELATIVE HUMIDITY | 60.0 PCT |
| BAROMETRIC PRES. | 771. | PUMP INLET PRES. | 6.80 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1100.00 | 5.00 | 5.00 | 3.00 | 37.00 | 3.00 |
| HC,PPM C6 | 21.00 | 1.61 | 2.80 | 1.33 | 6.20 | 1.13 |
| NOX,PPM | 71.00 | 0.38 | 20.00 | 0.17 | 51.00 | 0.28 |
| CO2,PCT | 1.92 | 0.05 | 1.31 | 0.06 | 1.76 | 0.06 |
| PUMP REV | 9560. | | 16360. | | 9570. | |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2729. | 4670. | 2731. |
| DF | 6.56 | 10.17 | 7.58 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 93.01 | 0.32 | 2.92 |
| HC | 5.25 | 0.73 | 1.39 |
| NOX | 10.44 | 5.02 | 7.51 |
| CO2 | 2663.97 | 3053.33 | 2419.29 |
| CARBON | 771.41 | 834.00 | 662.67 |
| FUEL LBS/BAG | 1.96 | 2.12 | 1.68 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.35 MILES/GAL | 4.828 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.18 | 5.178 |
| OVERALL TEST MILEAGE | 11.78 | 5.012 |
| WEIGHTED TEST MILEAGE | 11.81 | 5.022 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 5.598 G/MILE | 3.478 G/KM |
| HC | 0.504 | 0.313 |
| NOX | 1.839 | 1.142 |
| CORRECTED NOX | 1.764 | 1.096 |
| CO2 | 743.711 | 462.121 |

DATE 10-13-76 VEHICLE NO. 26 MAKE NOVA
STAND 2 ODOMETER 14479
FUEL TK 90

WET BULB TEMP 62 ABSOLUTE HUMIDITY 70.0 GRNS/LBS DRY AIR
DRY BULB TEMP 70 RELATIVE HUMIDITY 64.0 PCT
BAROMETRIC PRES. 761. PUMP INLET PRES. 6.75 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 980.00 | 4.00 | 10.00 | 5.00 | 102.00 | 3.00 |
| HC,PPM C6 | 22.00 | 0.90 | 2.20 | 0.87 | 5.40 | 0.86 |
| NOX,PPM | 70.00 | 0.21 | 25.00 | 0.29 | 52.00 | 0.15 |
| CO2,PCT | 1.97 | 0.06 | 1.28 | 0.06 | 1.76 | 0.05 |
| PUMP REV | 9550. | | 16380. | | 9540. | |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2690. | 4614. | 2687. |
| DF | 6.44 | 10.38 | 7.54 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 81.54 | 0.77 | 8.31 |
| HC | 5.59 | 0.63 | 1.22 |
| NOX | 10.17 | 6.18 | 7.55 |
| CO2 | 2684.59 | 2951.02 | 2395.82 |
| CARBON | 772.42 | 806.20 | 658.43 |
| FUEL LBS/BAG | 1.96 | 2.05 | 1.67 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.54 MILES/GAL | 4.910 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.44 | 5.292 |
| OVERALL TEST MILEAGE | 11.95 | 5.081 |
| WEIGHTED TEST MILEAGE | 12.04 | 5.120 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 5.411 G/MILE | 3.362 G/KM |
| HC | 0.499 | 0.310 |
| NOX | 1.981 | 1.231 |
| CORRECTED NOX | 1.936 | 1.203 |
| CO2 | 729.470 | 453.271 |

DATE 10-14-76
STAND 2
FUEL TK 90

VEHICLE NO. 26
ODOMETER 14503

MAKE NOVA

WET BULB TEMP 65
DRY BULB TEMP 76
BAROMETRIC PRES. 753.

ABSOLUTE HUMIDITY 75.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 56.0 PCT
PUMP INLET PRES. 6.70 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 2100.00 | 10.50 | 5.00 | 3.50 | 87.00 | 1.50 |
| HC,PPM C6 | 28.00 | 0.94 | 2.30 | 0.86 | 6.20 | 0.78 |
| NOX,PPM | 69.00 | 0.20 | 29.50 | 0.08 | 49.50 | 0.18 |
| CO2,PCT | 1.88 | 0.04 | 1.19 | 0.04 | 1.67 | 0.04 |

PUMP REV 9550. 16390. 9570.
TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2662. | 4568. | 2667. |
| DF | 6.39 | 11.24 | 7.96 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 173.55 | 0.25 | 7.15 |
| HC | 7.09 | 0.67 | 1.44 |
| NOX | 9.92 | 7.28 | 7.12 |
| CO2 | 2548.48 | 2732.78 | 2261.63 |
| CARBON | 776.02 | 746.45 | 621.50 |
| FUEL LBS/BAG | 1.97 | 1.89 | 1.58 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.97 MILES/GAL | 5.091 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.32 | 5.666 |
| OVERALL TEST MILEAGE | 12.47 | 5.302 |
| WEIGHTED TEST MILEAGE | 12.71 | 5.403 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 10.527 G/MILE | 6.541 G/KM |
| HC | 0.607 | 0.377 |
| NOX | 2.081 | 1.293 |
| CORRECTED NOX | 2.081 | 1.293 |
| CO2 | 682.368 | 424.003 |

DATE 10-15-76 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 14525
FUEL TK 90

| | | | |
|---|---|---|---|
| WET BULB TEMP | 65 | ABSOLUTE HUMIDITY | 76.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 75 | RELATIVE HUMIDITY | 58.0 PCT |
| BAROMETRIC PRES. | 759. | PUMP INLET PRES. | 6.75 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1600.00 | 10.50 | 14.00 | 6.00 | 215.00 | 1.50 |
| HC,PPM C6 | 29.00 | 0.91 | 2.40 | 0.76 | 5.30 | 0.65 |
| NOX,PPM | 72.50 | 0.50 | 32.00 | 0.40 | 55.00 | 0.18 |
| CO2,PCT | 1.88 | 0.05 | 1.25 | 0.04 | 1.65 | 0.05 |
| PUMP REV | 9550. | | 16390. | | ~~14270.~~ 9580 | |

TEMP 128. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 | |
|---|---|---|---|---|
| VMIX | 2669. | 4581. | 3989. | 3989 x 9580 / 14270 = 2678 |
| DF | 6.54 | 10.69 | 8.00 | |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 | x 2678 / 3989 |
|---|---|---|---|---|
| CO | 132.33 | 1.21 | 26.68 | = 17.911 |
| HC | 7.38 | 0.76 | 1.84 | = 1.235 |
| NOX | 10.42 | 7.85 | 11.84 | = 7.949 |
| CO2 | 2543.78 | 2883.50 | 3322.39 | = 2230.45 |
| CARBON | 757.31 | 788.07 | 919.69 | = 617.46 |
| FUEL LBS/BAG | 1.92 | 2.00 | 2.33 | = 1.564 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.79 MILES/GAL | 5.015 KM/LITRE |
| AVERAGE HOT START MILEAGE | 10.67 | 4.538 |
| OVERALL TEST MILEAGE | 10.84 = 12.354 | 4.611 |
| WEIGHTED TEST MILEAGE | 11.13 | 4.732 |

WEIGHTED MASS EMISSIONS

| | G/MILE | | G/KM |
|---|---|---|---|
| CO | ~~9.777~~ | 9.109 | 6.075 |
| HC | 0.666 | 0.618 | 0.414 |
| NOX | 2.544 | 2.248 | 1.581 |
| CORRECTED NOX | 2.556 | 2.259 | 1.588 |
| CO2 | 782.813 | 699.824 | 486.417 |

DATE 10-20-76 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 14549
FUEL TK 90

| | | | |
|---|---|---|---|
| WET BULB TEMP | 66 | ABSOLUTE HUMIDITY | 84.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 73 | RELATIVE HUMIDITY | 69.0 PCT |
| BAROMETRIC PRES. | 766. | PUMP INLET PRES. | 6.85 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 310.00 | 10.50 | 8.00 | 6.00 | 44.50 | 6.00 |
| HC,PPM C6 | 16.80 | 1.50 | 2.60 | 1.32 | 5.50 | 1.10 |
| NOX,PPM | 69.50 | 0.47 | 27.00 | 0.42 | 53.00 | 0.33 |
| CO2,PCT | 1.84 | 0.05 | 1.16 | 0.05 | 1.57 | 0.05 |
| PUMP REV | 9540. | | 16380. | | 9550. | |

TEMP 123. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2714. | 4660. | 2717. |
| DF | 7.13 | 11.52 | 8.49 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 25.35 | 0.35 | 3.31 |
| HC | 4.12 | 0.63 | 1.20 |
| NOX | 10.15 | 6.71 | 7.75 |
| CO2 | 2529.12 | 2692.78 | 2149.79 |
| CARBON | 704.62 | 735.54 | 589.12 |
| FUEL LBS/BAG | 1.79 | 1.87 | 1.49 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.65 MILES/GAL | 5.382 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.76 | 5.851 |
| OVERALL TEST MILEAGE | 13.17 | 5.602 |
| WEIGHTED TEST MILEAGE | 13.26 | 5.639 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 1.752 G/MILE | 1.088 G/KM |
| HC | 0.413 | 0.256 |
| NOX | 2.067 | 1.284 |
| CORRECTED NOX | 2.159 | 1.341 |
| CO2 | 667.425 | 414.718 |

DATE 10-21-76 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 14571
FUEL TK 90

| | | | |
|---|---|---|---|
| WET BULB TEMP | 65 | ABSOLUTE HUMIDITY | 73.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 77 | RELATIVE HUMIDITY | 53.0 PCT |
| BAROMETRIC PRES. | 753. | PUMP INLET PRES. | 6.70 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 243.00 | 1.50 | 5.00 | 2.00 | 38.00 | ~~1.00~~ 1.50 |
| HC,PPM C6 | 13.40 | 0.80 | 2.20 | 0.76 | 4.70 | 0.68 |
| NOX,PPM | 83.00 | 0.13 | 33.00 | 0.17 | 65.00 | 0.16 |
| CO2,PCT | 1.86 | 0.03 | 1.15 | 0.04 | 1.59 | 0.04 |
| PUMP REV | 9560. | | 16390. | | 9570. | |

TEMP 120. F
PUMP CAPACITY 0.3180 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2696. | 4622. | 2699. |
| DF | 7.08 | 11.63 | 8.39 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 20.34 | 0.45 | 3.14 |
| HC | 3.35 | 0.68 | 1.08 |
| NOX | 12.10 | 8.22 | 9.48 |
| CO2 | 2564.45 | 2668.87 | 2176.00 |
| CARBON | 711.45 | 729.10 | 596.10 |
| FUEL LBS/BAG | 1.80 | 1.85 | 1.51 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.65 MILES/GAL | 5.380 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.75 | 5.849 |
| OVERALL TEST MILEAGE | 13.12 | 5.581 |
| WEIGHTED TEST MILEAGE | 13.26 | 5.638 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 1.466 G/MILE | 0.911 G/KM |
| HC | 0.365 | 0.227 |
| NOX | 2.511 | 1.560 |
| CORRECTED NOX | 2.487 | 1.545 |
| CO2 | 668.254 | 415.234 |

DATE 10-26-76
STAND 2
FUEL TK 90

VEHICLE NO. 26
ODOMETER 14640

MAKE NOVA

WET BULB TEMP 63
DRY BULB TEMP 72
BAROMETRIC PRES. 756.

ABSOLUTE HUMIDITY 72.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 62.0 PCT
PUMP INLET PRES. 6.75 INCHES OF H20

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 698.00 | 3.50 | 3.50 | 1.50 | 77.50 | 2.00 |
| HC,PPM C6 | 19.80 | 1.02 | 2.60 | 0.94 | 5.50 | 0.88 |
| NOX,PPM | 63.00 | 0.17 | 20.50 | 0.13 | 42.00 | 0.14 |
| CO2,PCT | 1.82 | 0.04 | 1.16 | 0.04 | 1.65 | 0.04 |
| PUMP REV | 9540. | | 16400. | | 9560. | |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2669. | 4589. | 2675. |
| DF | 7.06 | 11.53 | 8.06 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 57.79 | 0.30 | 6.33 |
| HC | 4.95 | 0.78 | 1.23 |
| NOX | 9.08 | 5.06 | 6.06 |
| CO2 | 2471.93 | 2673.57 | 2240.30 |
| CARBON | 703.64 | 730.40 | 615.15 |
| FUEL LBS/BAG | 1.78 | 1.85 | 1.56 |

| | INDOLENE MILEAGE | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.71 MILES/GAL | 5.405 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.54 | 5.760 |
| OVERALL TEST MILEAGE | 13.04 | 5.547 |
| WEIGHTED TEST MILEAGE | 13.17 | 5.602 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| | CO | 3.835 G/MILE | 2.383 G/KM |
| | HC | 0.482 | 0.299 |
| | NOX | 1.657 | 1.030 |
| CORRECTED | NOX | 1.634 | 1.015 |
| | CO2 | 668.464 | 415.364 |

DATE 10-29-76 VEHICLE NO. 26 MAKE NOVA
STAND 2 ODOMETER 14841
FUEL TK 90

WET BULB TEMP 63 ABSOLUTE HUMIDITY 65.0 GRNS/LBS DRY AIR
DRY BULB TEMP 76 RELATIVE HUMIDITY ~~47.0~~ PCT 48.0
BAROMETRIC PRES. 765. PUMP INLET PRES. 6.90 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 570.00 | 6.00 | 9.00 | 3.50 | 73.50 | 1.50 |
| HC,PPM C6 | 22.00 | 1.02 | 2.40 | 0.90 | 5.10 | 0.88 |
| NOX,PPM | 62.00 | 0.22 | 24.30 | 0.16 | 44.50 | 0.08 |
| CO2,PCT | 1.73 | 0.05 | 1.15 | 0.04 | 1.59 | 0.04 |
| PUMP REV | 9550. | | 16380. | | 9540. | |

TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2727. | 4677. | 2724. |
| DF | 7.45 | 11.62 | 8.37 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 48.30 | 0.85 | 6.18 |
| HC | 5.64 | 0.72 | 1.15 |
| NOX | 9.12 | 6.11 | 6.55 |
| CO2 | 2385.19 | 2700.60 | 2196.32 |
| CARBON | 676.50 | 737.96 | 603.01 |
| FUEL LBS/BAG | 1.72 | 1.87 | 1.53 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.88 MILES/GAL | 5.479 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.59 | 5.780 |
| OVERALL TEST MILEAGE | 13.25 | 5.634 |
| WEIGHTED TEST MILEAGE | 13.28 | 5.647 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 3.353 G/MILE | 2.083 G/KM |
| HC | 0.507 | 0.315 |
| NOX | 1.837 | 1.141 |
| CORRECTED NOX | 1.755 | 1.090 |
| CO2 | 663.752 | 412.436 |

DATE 11-5-76
STAND 2
FUEL TK 90

VEHICLE NO. 26
ODOMETER 15140

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 62.5 | ABSOLUTE HUMIDITY | 66.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 74 | RELATIVE HUMIDITY | 53.0 PCT |
| BAROMETRIC PRES. | 761. | PUMP INLET PRES. | 6.80 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 745.00 | 5.00 | 10.50 | 3.00 | 130.00 | 3.00 |
| HC,PPM C6 | 25.00 | 1.60 | 2.60 | 1.10 | 6.10 | 2.10 |
| NOX,PPM | 59.00 | 0.28 | 27.00 | 0.23 | 41.50 | 0.22 |
| CO2,PCT | 1.84 | 0.05 | 1.25 | 0.05 | 1.65 | 0.05 |
| PUMP REV | 9560. | | 16380. | | 9570. | |

TEMP 122. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2706. | 4638. | 2709. |
| DF | 6.95 | 10.69 | 8.04 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 62.62 | 1.13 | 10.81 |
| HC | 6.26 | 0.72 | 1.13 |
| NOX | 8.61 | 6.73 | 6.06 |
| CO2 | 2522.48 | 2897.08 | 2256.80 |
| CARBON | 720.64 | 791.70 | 621.48 |
| FUEL LBS/BAG | 1.83 | 2.01 | 1.58 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.05 MILES/GAL | 5.125 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.90 | 5.484 |
| OVERALL TEST MILEAGE | 12.53 | 5.327 |
| WEIGHTED TEST MILEAGE | 12.52 | 5.324 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 4.563 G/MILE | 2.835 G/KM |
| HC | 0.542 | 0.337 |
| NOX | 1.852 | 1.150 |
| CORRECTED NOX | 1.776 | 1.104 |
| CO2 | 702.418 | 436.462 |

DATE 3-4-77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 16548

MAKE NOVA

WET BULB TEMP 58
DRY BULB TEMP 67
BAROMETRIC PRES. 768.

ABSOLUTE HUMIDITY 58.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 58.0 PCT
PUMP INLET PRES. 7.00 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1230.00 | 7.00 | 5.30 | 3.50 | 127.00 | 3.00 |
| HC,PPM C6 | 38.00 | 1.12 | 3.80 | 1.24 | 13.00 | 2.80 |
| NOX,PPM | 68.00 | 0.68 | 37.00 | 0.56 | 62.00 | 0.48 |
| CO2,PCT | 1.88 | 0.05 | 1.29 | 0.05 | 1.73 | 0.05 |
| PUMP REV | 9550. | | 16450. | | 9540. | |

TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2737. | 4715. | 2734. |
| DF | 6.63 | 10.32 | 7.65 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 104.39 | 0.30 | 10.62 |
| HC | 9.93 | 1.23 | 2.83 |
| NOX | 9.99 | 9.32 | 9.12 |
| CO2 | 2608.20 | 3055.78 | 2391.35 |
| CARBON | 765.12 | 835.10 | 659.59 |
| FUEL LBS/BAG | 1.94 | 2.12 | 1.67 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.39 MILES/GAL | 4.843 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.19 | 5.185 |
| OVERALL TEST MILEAGE | 11.83 | 5.030 |
| WEIGHTED TEST MILEAGE | 11.83 | 5.033 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 6.833 G/MILE | 4.245 G/KM |
| HC | 0.949 | 0.590 |
| NOX | 2.508 | 1.559 |
| CORRECTED NOX | 2.323 | 1.443 |
| CO2 | 738.718 | 459.018 |

DATE 3-8-77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 16576

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 60 | ABSOLUTE HUMIDITY | 61.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 71 | RELATIVE HUMIDITY | 55.0 PCT |
| BAROMETRIC PRES. | 769. | PUMP INLET PRES. | 7.10 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 853.00 | 5.90 | 5.30 | 1.50 | 157.50 | 3.00 |
| HC,PPM C6 | 36.00 | 1.06 | 5.20 | 2.60 | 8.70 | 1.37 |
| NOX,PPM | 86.00 | 0.41 | 37.50 | 0.23 | 75.00 | 0.20 |
| CO2,PCT | 1.86 | 0.05 | 1.31 | 0.04 | 1.77 | 0.05 |
| PUMP REV | 9550. | | 16370. | | 9540. | |

TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2740. | 4697. | 2737. |
| DF | 6.82 | 10.20 | 7.48 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 72.49 | 0.57 | 13.24 |
| HC | 9.42 | 1.31 | 2.01 |
| NOX | 12.71 | 9.48 | 11.09 |
| CO2 | 2582.29 | 3102.85 | 2450.92 |
| CARBON | 743.93 | 848.13 | 676.26 |
| FUEL LBS/BAG | 1.89 | 2.15 | 1.72 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.45 MILES/GAL | 4.868 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.96 | 5.084 |
| OVERALL TEST MILEAGE | 11.78 | 5.011 |
| WEIGHTED TEST MILEAGE | 11.73 | 4.989 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 5.240 G/MILE | 3.256 G/KM |
| HC | 0.868 | 0.539 |
| NOX | 2.837 | 1.762 |
| CORRECTED NOX | 2.661 | 1.654 |
| CO2 | 748.034 | 464.807 |

DATE 4 22 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 16784

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 60 | ABSOLUTE HUMIDITY | 66.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 67 | RELATIVE HUMIDITY | 67.0 PCT |
| BAROMETRIC PRES. | 754. | PUMP INLET PRES. | 7.00 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1275.00 | 8.80 | 7.90 | 3.00 | 133.00 | 3.00 |
| HC,PPM C6 | 29.00 | 1.18 | 3.30 | 1.00 | 7.30 | 1.06 |
| NOX,PPM | 74.00 | 0.50 | 36.00 | 0.45 | 68.50 | 0.50 |
| CO2,PCT | 1.81 | 0.04 | 1.19 | 0.03 | 1.62 | 0.04 |
| PUMP REV | 9560. | | 16380. | | 9540. | |

TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2689. | 4608. | 2683. |
| DF | 6.84 | 11.22 | 8.16 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 106.00 | 0.74 | 10.91 |
| HC | 7.37 | 1.07 | 1.67 |
| NOX | 10.71 | 8.88 | 9.89 |
| CO2 | 2483.07 | 2769.58 | 2212.54 |
| CARBON | 729.45 | 757.05 | 609.91 |
| FUEL LBS/BAG | 1.85 | 1.92 | 1.55 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.26 MILES/GAL | 5.214 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.33 | 5.670 |
| OVERALL TEST MILEAGE | 12.75 | 5.422 |
| WEIGHTED TEST MILEAGE | 12.85 | 5.464 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 7.006 G/MILE | 4.353 G/KM |
| HC | 0.694 | 0.431 |
| NOX | 2.550 | 1.584 |
| CORRECTED NOX | 2.447 | 1.520 |
| CO2 | 679.793 | 422.404 |

DATE 3 23 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 16824

MAKE NOVA

WET BULB TEMP 58
DRY BULB TEMP 67
BAROMETRIC PRES. 752.

ABSOLUTE HUMIDITY 58.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 58.0 PCT
PUMP INLET PRES. 6.90 INCHES OF H20

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1100.00 | 3.00 | 11.50 | 5.00 | 105.50 | 2.00 |
| HC,PPM C6 | 37.00 | 1.12 | 3.50 | 1.02 | 11.60 | 0.80 |
| NOX,PPM | 76.00 | 0.29 | 52.00 | 0.20 | 76.50 | 0.38 |
| CO2,PCT | 1.88 | 0.04 | 1.32 | 0.04 | 1.59 | 0.04 |

| | | | |
|---|---|---|---|
| PUMP REV | 9550. | 16390. | 9550. |

TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2680. | 4599. | 2680. |
| DF | 6.65 | 10.08 | 8.33 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 91.62 | 0.99 | 8.70 |
| HC | 9.46 | 1.16 | 2.86 |
| NOX | 10.99 | 12.90 | 11.05 |
| CO2 | 2575.07 | 3063.43 | 2155.93 |
| CARBON | 750.20 | 837.42 | 594.55 |
| FUEL LBS/BAG | 1.90 | 2.12 | 1.51 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.48 MILES/GAL | 4.882 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.73 | 5.412 |
| OVERALL TEST MILEAGE | 12.25 | 5.209 |
| WEIGHTED TEST MILEAGE | 12.16 | 5.171 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 6.048 G/MILE | 3.758 G/KM |
| HC | 0.915 | 0.568 |
| NOX | 3.191 | 1.983 |
| CORRECTED NOX | 2.955 | 1.836 |
| CO2 | 719.945 | 447.353 |

DATE 4 11 77
STAND 3
FUEL TK90

VEHICLE NO. 26
ODOMETER 18283.4

MAKE NOVA

WET BULB TEMP 62
DRY BULB TEMP 72
BAROMETRIC PRES. 773.

ABSOLUTE HUMIDITY 67.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 57.0 PCT
PUMP INLET PRES. 21.90 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 947.50 | 3.00 | 6.00 | 3.00 | 98.00 | 3.00 |
| HC,PPM C6 | 27.00 | 0.74 | 2.50 | 1.06 | 5.00 | 0.76 |
| NOX,PPM | 41.50 | 0.37 | 26.50 | 0.26 | 40.00 | 0.17 |
| CO2,PCT | 1.42 | 0.00 | 0.95 | 0.00 | 1.27 | 0.00 |

| | | | |
|---|---|---|---|
| PUMP REV | 12270. | 21240. | 12370. |

TEMP 120. F
PUMP CAPACITY 0.3120 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3357. | 5811. | 3384. |
| DF | 8.74 | 14.07 | 10.38 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 99.77 | 0.58 | 10.16 |
| HC | 8.66 | 0.86 | 1.43 |
| NOX | 7.48 | 8.26 | 7.30 |
| CO2 | 2482.10 | 2862.42 | 2242.62 |
| CARBON | 727.63 | 782.13 | 617.59 |

| | | | |
|---|---|---|---|
| FUEL LBS/BAG | 1.85 | 1.98 | 1.57 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.07 MILES/GAL | 5.134 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.02 | 5.537 |
| OVERALL TEST MILEAGE | 12.56 | 5.343 |
| WEIGHTED TEST MILEAGE | 12.59 | 5.356 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 6.570 G/MILE | 4.082 G/KM |
| HC | 0.720 | 0.447 |
| NOX | 2.086 | 1.296 |
| CORRECTED NOX | 2.010 | 1.249 |
| CO2 | 694.404 | 431.482 |

DATE 4 12 77
STAND 3
FUEL CK31175

VEHICLE NO. 26
ODOMETER 18304.4

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 63.0 | ABSOLUTE HUMIDITY | 66.5 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 75.0 | RELATIVE HUMIDITY | 51.0 PCT |
| BAROMETRIC PRES. | 768. | PUMP INLET PRES. | 21.80 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 930.00 | 8.75 | 7.00 | 3.00 | 75.50 | 5.00 |
| HC,PPM C6 | 25.60 | 0.68 | 2.40 | 0.63 | 4.36 | 0.72 |
| NOX,PPM | 40.50 | 0.16 | 23.60 | 0.00 | 36.50 | 0.07 |
| CO2,PCT | 1.45 | 0.04 | 0.90 | 0.04 | 1.27 | 0.04 |

PUMP REV 12430. 21220. 12430.
TEMP 120. F
PUMP CAPACITY 0.3107 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 3364. | 5744. | 3364. |
| DF | 8.57 | 14.85 | 10.40 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 97.73 | 0.75 | 7.53 |
| HC | 8.24 | 1.02 | 1.22 |
| NOX | 7.35 | 7.34 | 6.64 |
| CO2 | 2482.11 | 2569.50 | 2166.64 |
| CARBON | 726.39 | 702.40 | 595.55 |
| FUEL LBS/BAG | 1.84 | 1.78 | 1.51 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.76 MILES/GAL | 5.424 KM/LITRE |
| AVERAGE HOT START MILEAGE | 14.04 | 5.971 |
| OVERALL TEST MILEAGE | 13.20 | 5.615 |
| WEIGHTED TEST MILEAGE | 13.46 | 5.723 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 6.277 G/MILE | 3.900 G/KM |
| HC | 0.701 | 0.435 |
| NOX | 1.905 | 1.183 |
| CORRECTED NOX | 1.832 | 1.138 |
| CO2 | 649.573 | 403.626 |

DATE 4 19 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 18328

MAKE NOVA

WET BULB TEMP 63
DRY BULB TEMP 76
BAROMETRIC PRES. 767.

ABSOLUTE HUMIDITY 66.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 48.0 PCT
PUMP INLET PRES. 6.90 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 800.00 | 5.00 | 4.00 | 1.00 | 115.50 | 2.00 |
| HC,PPM C6 | 49.00 | 1.06 | 2.80 | 1.08 | 6.60 | 0.94 |
| NOX,PPM | 61.00 | 0.17 | 30.00 | 0.21 | 55.50 | 0.25 |
| CO2,PCT | 1.85 | 0.04 | 1.15 | 0.04 | 1.65 | 0.04 |

PUMP REV 9540. 16380. 9530.
TEMP 122. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2722. | 4674. | 2719. |
| DF | 6.83 | 11.62 | 8.02 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 67.74 | 0.45 | 9.71 |
| HC | 12.82 | 0.83 | 1.53 |
| NOX | 8.97 | 7.54 | 8.14 |
| CO2 | 2571.58 | 2700.91 | 2282.83 |
| CARBON | 741.93 | 737.97 | 628.46 |
| FUEL LBS/BAG | 1.88 | 1.87 | 1.59 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 12.31 MILES/GAL | 5.237 KM/LITRE |
| AVERAGE HOT START MILEAGE | 13.34 | 5.672 |
| OVERALL TEST MILEAGE | 12.68 | 5.392 |
| WEIGHTED TEST MILEAGE | 12.88 | 5.477 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 4.682 G/MILE | 2.909 G/KM |
| HC | 0.963 | 0.598 |
| NOX | 2.139 | 1.329 |
| CORRECTED NOX | 2.052 | 1.275 |
| CO2 | 681.054 | 423.187 |

DATE 4 29 77 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 18356
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 56 | ABSOLUTE HUMIDITY | 48.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 68 | RELATIVE HUMIDITY | 47.0 PCT |
| BAROMETRIC PRES. | 767. | PUMP INLET PRES. | 6.90 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 939.00 | 5.00 | 7.00 | 2.00 | 215.00 | 10.50 |
| HC,PPM C6 | 58.00 | 0.88 | 2.40 | 0.72 | 8.00 | 0.56 |
| NOX,PPM | 62.00 | 0.14 | 28.00 | 0.13 | 52.00 | 0.15 |
| CO2,PCT | 1.81 | 0.04 | 1.27 | 0.03 | 1.62 | 0.04 |
| PUMP REV | 9790. | | 16380. | | 9570. | |

TEMP 123. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2788. | 4666. | 2726. |
| DF | 6.91 | 10.46 | 8.11 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 81.62 | 0.75 | 17.61 |
| HC | 15.64 | 0.79 | 2.00 |
| NOX | 9.34 | 7.04 | 7.65 |
| CO2 | 2573.61 | 3015.40 | 2247.41 |
| CARBON | 750.87 | 823.89 | 622.59 |
| FUEL LBS/BAG | 1.90 | 2.09 | 1.58 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.57 MILES/GAL | 4.922 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.60 | 5.358 |
| OVERALL TEST MILEAGE | 12.16 | 5.173 |
| WEIGHTED TEST MILEAGE | 12.14 | 5.161 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 6.119 G/MILE | 3.802 G/KM |
| HC | 1.155 | 0.718 |
| NOX | 2.057 | 1.278 |
| CORRECTED NOX | 1.825 | 1.134 |
| CO2 | 720.410 | 447.642 |

DATE 5 2 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 18377

MAKE NOVA

WET BULB TEMP 65
DRY BULB TEMP 72
BAROMETRIC PRES. 767.

ABSOLUTE HUMIDITY 82.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 69.0 PCT
PUMP INLET PRES. 7.00 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1200.00 | 6.00 | 31.00 | 5.00 | 366.00 | 6.00 |
| HC,PPM C6 | 31.00 | 1.26 | 3.20 | 1.30 | 8.00 | 1.30 |
| NOX,PPM | 48.50 | 0.25 | 28.00 | 0.24 | 40.00 | 0.27 |
| CO2,PCT | 2.07 | 0.04 | 1.44 | 0.04 | 1.85 | 0.04 |

PUMP REV 9590. 16380. 9580.
TEMP 128. F
PUMP CAPACITY 0.3160 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2699. | 4610. | 2696. |
| DF | 6.06 | 9.26 | 7.06 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 99.71 | 3.81 | 30.20 |
| HC | 7.92 | 0.92 | 1.81 |
| NOX | 7.06 | 6.93 | 5.80 |
| CO2 | 2857.30 | 3351.37 | 2542.45 |
| CARBON | 829.35 | 916.99 | 708.34 |
| FUEL LBS/BAG | 2.10 | 2.33 | 1.80 |

| | INDOLENE MILEAGE | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.44 MILES/GAL | 4.438 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.21 | 4.768 |
| OVERALL TEST MILEAGE | 10.89 | 4.631 |
| WEIGHTED TEST MILEAGE | 10.86 | 4.621 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 8.520 G/MILE | 5.294 G/KM |
| HC | 0.715 | 0.444 |
| NOX | 1.771 | 1.100 |
| CORRECTED NOX | 1.831 | 1.138 |
| CO2 | 803.895 | 499.517 |

DATE 5 5 77 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 18448.8
FUEL K90

| | | | |
|---|---|---|---|
| WET BULB TEMP | 63 | ABSOLUTE HUMIDITY | 75.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 70 | RELATIVE HUMIDITY | 68.0 PCT |
| BAROMETRIC PRES. | 758. | PUMP INLET PRES. | 6.90 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1150.00 | 6.00 | 16.00 | 14.00 | 210.00 | 7.87 |
| HC,PPM C6 | 25.00 | 1.10 | 3.40 | 1.60 | 7.00 | 1.48 |
| NOX,PPM | 50.00 | 0.30 | 27.50 | 0.28 | 48.50 | 0.45 |
| CO2,PCT | 1.90 | 0.04 | 1.26 | 0.04 | 1.65 | 0.04 |
| PUMP REV | 9600. | | 16380. | | 9570. | |

TEMP 120. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2716. | 4634. | 2707. |
| DF | 6.59 | 10.57 | 7.97 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 96.49 | 0.43 | 17.13 |
| HC | 6.40 | 0.88 | 1.51 |
| NOX | 7.31 | 6.83 | 7.05 |
| CO2 | 2633.24 | 2939.35 | 2269.58 |
| CARBON | 765.51 | 803.08 | 628.01 |
| FUEL LBS/BAG | 1.94 | 2.04 | 1.59 |

| | INDOLENE MILEAGE | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.62 MILES/GAL | 4.941 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.73 | 5.416 |
| OVERALL TEST MILEAGE | 12.17 | 5.175 |
| WEIGHTED TEST MILEAGE | 12.23 | 5.201 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 6.892 G/MILE | 4.282 G/KM |
| HC | 0.600 | 0.373 |
| NOX | 1.867 | 1.160 |
| CORRECTED NOX | 1.867 | 1.160 |
| CO2 | 715.374 | 444.512 |

DATE 5 6 77
STAND 2
FUEL K-90

VEHICLE NO. 26
ODOMETER 18475.4

MAKE NOVA

WET BULB TEMP 70
DRY BULB TEMP 76
BAROMETRIC PRES. 757.

ABSOLUTE HUMIDITY 101.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 74.0 PCT
PUMP INLET PRES. 6.90 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 647.50 | 3.00 | 14.00 | 8.75 | 193.75 | 8.75 |
| HC,PPM C6 | 25.00 | 2.20 | 4.40 | 2.60 | 7.30 | 2.20 |
| NOX,PPM | 49.00 | 0.40 | 28.00 | 0.33 | 46.50 | 0.35 |
| CO2,PCT | 1.98 | 0.05 | 1.40 | 0.05 | 1.69 | 0.04 |

| | | | |
|---|---|---|---|
| PUMP REV | 9570. | 16390. | 9560. |
| TEMP | 120. F | | |
| PUMP CAPACITY | 0.3170 CF/REV | | |

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2703. | 4630. | 2701. |
| DF | 6.50 | 9.54 | 7.79 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 53.92 | 0.86 | 15.61 |
| HC | 6.13 | 0.94 | 1.42 |
| NOX | 7.12 | 6.94 | 6.75 |
| CO2 | 2720.83 | 3254.10 | 2322.19 |
| CARBON | 770.92 | 889.20 | 641.63 |
| FUEL LBS/BAG | 1.96 | 2.26 | 1.63 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.98 MILES/GAL | 4.669 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.90 | 5.063 |
| OVERALL TEST MILEAGE | 11.61 | 4.939 |
| WEIGHTED TEST MILEAGE | 11.49 | 4.885 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 4.393 G/MILE | 2.729 G/KM |
| HC | 0.585 | 0.363 |
| NOX | 1.848 | 1.148 |
| CORRECTED NOX | 2.106 | 1.308 |
| CO2 | 766.362 | 476.195 |

DATE 5 9 77
STAND 2
FUEL K-90

VEHICLE NO. 26
ODOMETER 18581.2

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 57 | ABSOLUTE HUMIDITY | 53.5 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 67 | RELATIVE HUMIDITY | 53.5 PCT |
| BAROMETRIC PRES. | 749. | PUMP INLET PRES. | 6.80 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 907.50 | 6.00 | 6.00 | 3.00 | 153.00 | 5.00 |
| HC,PPM C6 | 31.00 | 1.20 | 3.30 | 1.62 | 5.60 | 1.28 |
| NOX,PPM | 60.00 | 0.33 | 30.00 | 0.15 | 56.00 | 0.17 |
| CO2,PCT | 1.90 | 0.05 | 1.31 | 0.04 | 1.59 | 0.04 |
| PUMP REV | 9610. | | 16370. | | 9600. | |

TEMP 120. F
PUMP CAPACITY 0.3175 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2690. | 4583. | 2688. |
| DF | 6.65 | 10.18 | 8.32 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 75.72 | 0.46 | 12.52 |
| HC | 7.90 | 0.82 | 1.17 |
| NOX | 8.70 | 7.41 | 8.13 |
| CO2 | 2602.90 | 3023.04 | 2162.38 |
| CARBON | 749.62 | 825.88 | 596.49 |
| FUEL LBS/BAG | 1.90 | 2.10 | 1.51 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.57 MILES/GAL | 4.919 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.81 | 5.449 |
| OVERALL TEST MILEAGE | 12.31 | 5.234 |
| WEIGHTED TEST MILEAGE | 12.25 | 5.208 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 5.355 G/MILE | 3.327 G/KM |
| HC | 0.652 | 0.405 |
| NOX | 2.105 | 1.308 |
| CORRECTED NOX | 1.912 | 1.188 |
| CO2 | 716.646 | 445.303 |

DATE 5 10 77
STAND 2
FUEL K 90

VEHICLE NO. 26
ODOMETER 18665.5

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 58 | ABSOLUTE HUMIDITY | 56.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 68 | RELATIVE HUMIDITY | 54.0 PCT |
| BAROMETRIC PRES. | 754. | PUMP INLET PRES. | 6.90 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 565.00 | 2.00 | 6.00 | 2.00 | 58.62 | 6.00 |
| HC,PPM C6 | 22.00 | 1.15 | 3.00 | 1.16 | 5.60 | 1.18 |
| NOX,PPM | 61.50 | 0.15 | 32.50 | 0.15 | 59.00 | 0.22 |
| CO2,PCT | 1.87 | 0.04 | 1.37 | 0.04 | 1.66 | 0.04 |
| PUMP REV | 9630. | | 16380. | | 9590. | |

TEMP 120. F
PUMP CAPACITY 0.3175 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2714. | 4616. | 2702. |
| DF | 6.90 | 9.72 | 7.99 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 47.70 | 0.60 | 4.50 |
| HC | 5.58 | 0.88 | 1.20 |
| NOX | 9.02 | 8.09 | 8.60 |
| CO2 | 2590.58 | 3205.51 | 2281.78 |
| CARBON | 732.24 | 875.78 | 625.66 |
| FUEL LBS/BAG | 1.86 | 2.22 | 1.59 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.33 MILES/GAL | 4.820 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.14 | 5.162 |
| OVERALL TEST MILEAGE | 11.97 | 5.089 |
| WEIGHTED TEST MILEAGE | 11.78 | 5.009 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 3.158 G/MILE | 1.962 G/KM |
| HC | 0.530 | 0.329 |
| NOX | 2.250 | 1.398 |
| CORRECTED NOX | 2.066 | 1.283 |
| CO2 | 749.343 | 465.620 |

DATE 5 11 77 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 18723.0
FUEL K 90

| | | | |
|---|---|---|---|
| WET BULB TEMP | 59 | ABSOLUTE HUMIDITY | 56.5 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 70 | RELATIVE HUMIDITY | 51.0 PCT |
| BAROMETRIC PRES. | 761. | PUMP INLET PRES. | 6.95 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 540.00 | 5.00 | 7.00 | 5.00 | 46.00 | 3.00 |
| HC,PPM C6 | 19.60 | 1.39 | 2.80 | 1.34 | 4.80 | 1.16 |
| NOX,PPM | 61.00 | 0.23 | 32.00 | 0.15 | 60.50 | 0.15 |
| CO2,PCT | 1.87 | 0.03 | 1.29 | 0.04 | 1.59 | 0.04 |
| PUMP REV | 9560. | | 16380. | | 9600. | |

TEMP 120. F
PUMP CAPACITY 0.3175 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2719. | 4659. | 2730. |
| DF | 6.91 | 10.32 | 8.38 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 45.49 | 0.34 | 3.71 |
| HC | 4.90 | 0.72 | 1.01 |
| NOX | 8.95 | 8.04 | 8.92 |
| CO2 | 2602.34 | 3042.24 | 2202.98 |
| CARBON | 733.91 | 830.98 | 603.64 |
| FUEL LBS/BAG | 1.86 | 2.11 | 1.53 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.65 MILES/GAL | 4.953 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.70 | 5.402 |
| OVERALL TEST MILEAGE | 12.33 | 5.242 |
| WEIGHTED TEST MILEAGE | 12.23 | 5.199 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 2.937 G/MILE | 1.825 G/KM |
| HC | 0.454 | 0.282 |
| NOX | 2.264 | 1.406 |
| CORRECTED NOX | 2.083 | 1.294 |
| CO2 | 722.260 | 448.792 |

DATE 5 13 77 VEHICLE NO. 26 MAKE NOVA
STAND 2 ODOMETER 18774.4
FUEL K 90

WET BULB TEMP 63 ABSOLUTE HUMIDITY 71.5 GRNS/LBS DRY AIR
DRY BULB TEMP 72 RELATIVE HUMIDITY 61.0 PCT
BAROMETRIC PRES. 755. PUMP INLET PRES. 6.90 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 600.00 | 2.00 | 4.00 | 1.00 | 180.25 | 1.00 |
| HC,PPM C6 | 25.00 | 1.22 | 3.20 | 1.27 | 7.50 | 1.28 |
| NOX,PPM | 52.00 | 0.10 | 26.50 | 0.12 | 52.00 | 0.15 |
| CO2,PCT | 1.89 | 0.04 | 1.25 | 0.04 | 1.62 | 0.04 |
| PUMP REV | 9570. | | 16370. | | 9560. | |

TEMP 120. F
PUMP CAPACITY 0.3175 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2700. | 4620. | 2698. |
| DF | 6.82 | 10.70 | 8.13 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 50.28 | 0.44 | 15.14 |
| HC | 6.34 | 0.92 | 1.68 |
| NOX | 7.59 | 6.60 | 7.57 |
| CO2 | 2601.11 | 2907.54 | 2224.25 |
| CARBON | 736.88 | 794.44 | 614.93 |
| FUEL LBS/BAG | 1.87 | 2.02 | 1.56 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.90 MILES/GAL | 5.061 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.93 | 5.499 |
| OVERALL TEST MILEAGE | 12.45 | 5.296 |
| WEIGHTED TEST MILEAGE | 12.47 | 5.302 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 4.093 G/MILE | 2.543 G/KM |
| HC | 0.615 | 0.382 |
| NOX | 1.891 | 1.175 |
| CORRECTED NOX | 1.861 | 1.156 |
| CO2 | 705.846 | 438.592 |

DATE 6 1 77
STAND 2
FUEL K90

VEHICLE NO. 26
ODOMETER 19689.1

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 70 | ABSOLUTE HUMIDITY | 102.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 75 | RELATIVE HUMIDITY | 78.0 PCT |
| BAROMETRIC PRES. | 758. | PUMP INLET PRES. | 6.90 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 737.50 | 8.75 | 8.75 | 4.00 | 190.50 | 6.00 |
| HC,PPM C6 | 33.00 | 1.56 | 4.00 | 1.60 | 8.00 | 1.62 |
| NOX,PPM | 35.00 | 0.30 | 20.00 | 0.20 | 39.00 | 0.25 |
| CO2,PCT | 1.90 | 0.04 | 1.26 | 0.05 | 1.77 | 0.04 |

| | | | |
|---|---|---|---|
| PUMP REV | 9560. | 16380. | 9550. |

TEMP 125. F
PUMP CAPACITY 0.3175 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2685. | 4601. | 2683. |
| DF | 6.71 | 10.57 | 7.46 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 60.62 | 0.72 | 15.40 |
| HC | 8.33 | 1.15 | 1.73 |
| NOX | 5.05 | 4.93 | 5.63 |
| CO2 | 2609.72 | 2908.02 | 2412.32 |
| CARBON | 745.38 | 794.88 | 666.41 |
| FUEL LBS/BAG | 1.89 | 2.02 | 1.69 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.83 MILES/GAL | 5.032 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.47 | 5.304 |
| OVERALL TEST MILEAGE | 12.11 | 5.151 |
| WEIGHTED TEST MILEAGE | 12.19 | 5.183 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 4.743 G/MILE | 2.947 G/KM |
| HC | 0.763 | 0.474 |
| NOX | 1.376 | 0.855 |
| CORRECTED NOX | 1.576 | 0.979 |
| CO2 | 720.697 | 447.820 |

DATE 8 25 77
STAND 3
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 21,638

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 62.5 | ABSOLUTE HUMIDITY | 72.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 70 | RELATIVE HUMIDITY | 65.0 PCT |
| BAROMETRIC PRES. | 767. | PUMP INLET PRES. | 10.70 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 977.50 | 6.00 | 17.00 | 1.00 | 301.30 | 3.00 |
| HC,PPM C6 | 33.00 | 1.46 | 4.00 | 1.00 | 10.50 | 1.10 |
| NOX,PPM | 34.50 | 0.23 | 16.50 | 0.22 | 28.50 | 0.16 |
| CO2,PCT | 2.17 | 0.05 | 1.50 | 0.05 | 1.89 | 0.04 |
| PUMP REV | 8250. | | 14120. | | 8290. | |

TEMP 70. F
PUMP CAPACITY 0.3150 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2544. | 4355. | 2557. |
| DF | 5.86 | 8.90 | 6.95 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 76.44 | 2.19 | 23.73 |
| HC | 7.92 | 1.32 | 2.39 |
| NOX | 4.72 | 3.84 | 3.92 |
| CO2 | 2815.02 | 3287.07 | 2463.04 |
| CARBON | 807.84 | 899.11 | 684.39 |
| FUEL LBS/BAG | 2.05 | 2.28 | 1.74 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.68 MILES/GAL | 4.540 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.51 | 4.894 |
| OVERALL TEST MILEAGE | 11.18 | 4.753 |
| WEIGHTED TEST MILEAGE | 11.14 | 4.736 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 6.479 G/MILE | 4.025 G/KM |
| HC | 0.813 | 0.505 |
| NOX | 1.082 | 0.672 |
| CORRECTED NOX | 1.067 | 0.663 |
| CO2 | 786.862 | 488.933 |

DATE 8 30 77 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 21,765
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 74 | ABSOLUTE HUMIDITY | 118.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 80 | RELATIVE HUMIDITY | 76.0 PCT |
| BAROMETRIC PRES. | 766. | PUMP INLET PRES. | 6.85 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 745.00 | 5.00 | 46.00 | 4.00 | 438.80 | 4.00 |
| HC,PPM C6 | 31.00 | 2.70 | 5.50 | 2.90 | 37.00 | 2.70 |
| NOX,PPM | 32.50 | 0.24 | 16.80 | 0.18 | 31.00 | 0.34 |
| CO2,PCT | 2.05 | 0.04 | 1.38 | 0.04 | 1.90 | 0.05 |
| PUMP REV | 9550. | | 16380. | | 9650. | |

TEMP 130. F
PUMP CAPACITY 0.3160 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2676. | 4590. | 2704. |
| DF | 6.24 | 9.60 | 6.79 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 61.16 | 6.07 | 36.43 |
| HC | 7.53 | 1.30 | 9.19 |
| NOX | 4.68 | 4.13 | 4.49 |
| CO2 | 2803.59 | 3207.88 | 2615.80 |
| CARBON | 797.83 | 879.14 | 737.42 |
| FUEL LBS/BAG | 2.02 | 2.23 | 1.87 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.87 MILES/GAL | 4.622 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.27 | 4.794 |
| OVERALL TEST MILEAGE | 11.07 | 4.708 |
| WEIGHTED TEST MILEAGE | 11.09 | 4.719 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 7.085 G/MILE | 4.402 G/KM |
| HC | 1.304 | 0.810 |
| NOX | 1.161 | 0.721 |
| CORRECTED NOX | 1.456 | 0.904 |
| CO2 | 787.257 | 489.179 |

DATE 8 31 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 21,803

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 74 | ABSOLUTE HUMIDITY | 117.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 80 | RELATIVE HUMIDITY | 76.0 PCT |
| BAROMETRIC PRES. | 769. | PUMP INLET PRES. | 6.90 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 552.50 | 3.00 | 12.50 | 2.00 | 212.50 | 5.00 |
| HC,PPM C6 | 29.00 | 2.00 | 5.80 | 2.10 | 10.10 | 2.10 |
| NOX,PPM | 50.00 | 0.23 | 28.50 | 0.25 | 49.50 | 0.19 |
| CO2,PCT | 1.95 | 0.04 | 1.42 | 0.04 | 1.80 | 0.04 |
| PUMP REV | 10010. | | 16400. | | 9570. | |

TEMP 130. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2825. | 4628. | 2700. |
| DF | 6.63 | 9.36 | 7.33 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 48.03 | 1.54 | 17.42 |
| HC | 7.55 | 1.77 | 2.19 |
| NOX | 7.62 | 7.08 | 7.21 |
| CO2 | 2800.48 | 3325.87 | 2466.40 |
| CARBON | 791.37 | 909.81 | 682.43 |
| FUEL LBS/BAG | 2.01 | 2.31 | 1.73 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.71 MILES/GAL | 4.556 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.45 | 4.868 |
| OVERALL TEST MILEAGE | 11.21 | 4.769 |
| WEIGHTED TEST MILEAGE | 11.12 | 4.728 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 4.284 G/MILE | 2.662 G/KM |
| HC | 0.837 | 0.520 |
| NOX | 1.930 | 1.199 |
| CORRECTED NOX | 2.405 | 1.494 |
| CO2 | 791.457 | 491.788 |

DATE 9 1 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 21,886

MAKE NOVA

WET BULB TEMP 74
DRY BULB TEMP 79
BAROMETRIC PRES. 769.

ABSOLUTE HUMIDITY 119.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 79.0 PCT
PUMP INLET PRES. 6.85 INCHES OF H20

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 533.80 | 3.00 | 6.00 | 2.00 | 136.00 | 1.00 |
| HC,PPM C6 | 22.00 | 2.60 | 4.90 | 2.50 | 19.40 | 2.40 |
| NOX,PPM | 59.50 | 0.27 | 29.00 | 0.18 | 57.00 | 0.23 |
| CO2,PCT | 1.90 | 0.04 | 1.27 | 0.04 | 1.72 | 0.04 |
| PUMP REV | 9550. | | 16380. | | 9590. | |

TEMP 130. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2695. | 4623. | 2706. |
| DF | 6.79 | 10.45 | 7.65 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 44.26 | 0.60 | 11.34 |
| HC | 5.22 | 1.19 | 4.59 |
| NOX | 8.65 | 7.22 | 8.32 |
| CO2 | 2613.18 | 2977.06 | 2375.15 |
| CARBON | 736.62 | 813.71 | 657.00 |
| FUEL LBS/BAG | 1.87 | 2.06 | 1.67 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.75 MILES/GAL | 4.999 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.39 | 5.270 |
| OVERALL TEST MILEAGE | 12.11 | 5.150 |
| WEIGHTED TEST MILEAGE | 12.11 | 5.150 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 3.480 G/MILE | 2.162 G/KM |
| HC | 0.807 | 0.502 |
| NOX | 2.091 | 1.299 |
| CORRECTED NOX | 2.637 | 1.638 |
| CO2 | 727.276 | 451.908 |

DATE 9 6 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 21,947

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 72 | ABSOLUTE HUMIDITY | 112.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 76 | RELATIVE HUMIDITY | 83.0 PCT |
| BAROMETRIC PRES. | 762. | PUMP INLET PRES. | 6.90 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 860.00 | 5.00 | 9.50 | 2.00 | 200.00 | 3.00 |
| HC,PPM C6 | 33.00 | 1.50 | 5.00 | 1.18 | 9.80 | 1.08 |
| NOX,PPM | 42.50 | 0.23 | 21.50 | 0.25 | 43.00 | 0.27 |
| CO2,PCT | 1.96 | 0.04 | 1.40 | 0.04 | 1.80 | 0.04 |
| PUMP REV | 9590. | | 16360. | | 9550. | |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2704. | 4613. | 2693. |
| DF | 6.48 | 9.54 | 7.34 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 71.35 | 1.10 | 16.44 |
| HC | 8.40 | 1.78 | 2.33 |
| NOX | 6.19 | 5.31 | 6.23 |
| CO2 | 2703.51 | 3252.73 | 2459.29 |
| CARBON | 775.65 | 889.66 | 680.20 |
| FUEL LBS/BAG | 1.97 | 2.26 | 1.73 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.94 MILES/GAL | 4.654 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.61 | 4.937 |
| OVERALL TEST MILEAGE | 11.40 | 4.846 |
| WEIGHTED TEST MILEAGE | 11.31 | 4.811 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 5.487 G/MILE | 3.410 G/KM |
| HC | 0.897 | 0.557 |
| NOX | 1.538 | 0.955 |
| CORRECTED NOX | 1.862 | 1.157 |
| CO2 | 775.605 | 481.938 |

DATE 9 7 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 21,976

MAKE NOVA

WET BULB TEMP 63
DRY BULB TEMP 72
BAROMETRIC PRES. 766.

ABSOLUTE HUMIDITY 72.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 62.0 PCT
PUMP INLET PRES. 6.95 INCHES OF H20

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 1770.00 | 7.00 | 10.50 | 2.00 | 200.00 | 1.00 |
| HC,PPM C6 | 194.00 | 1.12 | 4.30 | 0.96 | 15.60 | 0.84 |
| NOX,PPM | 51.00 | 0.19 | 27.50 | 0.17 | 52.50 | 0.25 |
| CO2,PCT | 1.95 | 0.04 | 1.42 | 0.04 | 1.80 | 0.04 |
| PUMP REV | 9600. | | 16380. | | 9560. | |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2721. | 4643. | 2710. |
| DF | 6.00 | 9.37 | 7.32 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 149.15 | 1.26 | 16.81 |
| HC | 51.48 | 1.56 | 3.94 |
| NOX | 7.49 | 6.87 | 7.67 |
| CO2 | 2704.54 | 3347.25 | 2480.79 |
| CARBON | 846.61 | 915.33 | 687.62 |
| FUEL LBS/BAG | 2.15 | 2.32 | 1.74 |

| | INDOLENE MILEAGE | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.34 MILES/GAL | 4.399 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.37 | 4.835 |
| OVERALL TEST MILEAGE | 10.91 | 4.640 |
| WEIGHTED TEST MILEAGE | 10.90 | 4.637 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 9.998 G/MILE | 6.212 G/KM |
| HC | 3.460 | 2.150 |
| NOX | 1.929 | 1.199 |
| CORRECTED NOX | 1.903 | 1.182 |
| CO2 | 789.901 | 490.821 |

DATE 9 8 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 22,039

MAKE NOVA

WET BULB TEMP 68
DRY BULB TEMP 77
BAROMETRIC PRES. 767.

ABSOLUTE HUMIDITY 88.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 64.0 PCT
PUMP INLET PRES. 7.00 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 915.00 | 5.00 | 7.00 | 2.00 | 123.00 | 1.00 |
| HC,PPM C6 | 40.00 | 1.18 | 3.80 | 1.16 | 7.60 | 1.44 |
| NOX,PPM | 55.00 | 0.20 | 29.50 | 0.19 | 51.50 | 0.17 |
| CO2,PCT | 1.98 | 0.04 | 1.40 | 0.03 | 1.77 | 0.03 |

| | | | |
|---|---|---|---|
| PUMP REV | 9590. | 16390. | 9560. |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2721. | 4651. | 2713. |
| DF | 6.40 | 9.55 | 7.48 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 76.90 | 0.75 | 10.32 |
| HC | 10.40 | 1.25 | 1.68 |
| NOX | 8.08 | 7.38 | 7.54 |
| CO2 | 2750.96 | 3301.22 | 2451.72 |
| CARBON | 792.70 | 902.29 | 674.94 |
| FUEL LBS/BAG | 2.01 | 2.29 | 1.71 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.75 MILES/GAL | 4.572 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.55 | 4.914 |
| OVERALL TEST MILEAGE | 11.28 | 4.796 |
| WEIGHTED TEST MILEAGE | 11.19 | 4.761 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 5.294 G/MILE | 3.289 G/KM |
| HC | 0.892 | 0.554 |
| NOX | 2.022 | 1.256 |
| CORRECTED NOX | 2.153 | 1.338 |
| CO2 | 784.215 | 487.289 |

DATE 9 9 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 22,088

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 66 | ABSOLUTE HUMIDITY | 80.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 76 | RELATIVE HUMIDITY | 58.0 PCT |
| BAROMETRIC PRES. | 767. | PUMP INLET PRES. | 6.90 INCHES OF H20 |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 730.00 | 5.00 | 9.60 | 5.00 | 70.80 | 5.00 |
| HC,PPM C6 | 26.00 | 1.06 | 4.00 | 1.33 | 8.80 | 1.41 |
| NOX,PPM | 55.50 | 0.25 | 28.00 | 0.20 | 55.50 | 0.35 |
| CO2,PCT | 2.00 | 0.05 | 1.40 | 0.04 | 1.80 | 0.04 |
| PUMP REV | 9590. | | 16380. | | 9610. | |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2722. | 4650. | 2728. |
| DF | 6.41 | 9.54 | 7.39 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 61.39 | 0.73 | 5.64 |
| HC | 6.69 | 1.27 | 2.02 |
| NOX | 8.15 | 7.00 | 8.15 |
| CO2 | 2769.35 | 3278.44 | 2491.20 |
| CARBON | 787.86 | 896.08 | 684.00 |
| FUEL LBS/BAG | 2.00 | 2.27 | 1.73 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.82 MILES/GAL | 4.603 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.53 | 4.905 |
| OVERALL TEST MILEAGE | 11.29 | 4.800 |
| WEIGHTED TEST MILEAGE | 11.22 | 4.770 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 4.046 G/MILE | 2.514 G/KM |
| HC | 0.708 | 0.440 |
| NOX | 2.021 | 1.256 |
| CORRECTED NOX | 2.070 | 1.286 |
| CO2 | 785.233 | 487.921 |

DATE 9 13 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 22,141.3

MAKE NOVA

WET BULB TEMP 63
DRY BULB TEMP 70
BAROMETRIC PRES. 765.

ABSOLUTE HUMIDITY 75.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 68.0 PCT
PUMP INLET PRES. 6.95 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 948.00 | 8.80 | 4.00 | 1.00 | 33.00 | 1.00 |
| HC,PPM C6 | 26.00 | 0.82 | 3.50 | 1.00 | 5.60 | 0.84 |
| NOX,PPM | 59.50 | 0.15 | 24.50 | 0.15 | 57.00 | 0.15 |
| CO2,PCT | 1.98 | 0.04 | 1.29 | 0.04 | 1.72 | 0.04 |
| PUMP REV | 9600. | | 16290. | | 9610. | |

TEMP 125. F
PUMP CAPACITY 0.3175 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2722. | 4619. | 2724. |
| DF | 6.41 | 10.34 | 7.73 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 79.31 | 0.44 | 2.72 |
| HC | 6.74 | 1.17 | 1.29 |
| NOX | 8.75 | 6.09 | 8.39 |
| CO2 | 2745.21 | 3010.19 | 2390.84 |
| CARBON | 789.00 | 822.66 | 654.73 |
| FUEL LBS/BAG | 2.00 | 2.09 | 1.66 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.31 MILES/GAL | 4.809 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.34 | 5.246 |
| OVERALL TEST MILEAGE | 11.79 | 5.016 |
| WEIGHTED TEST MILEAGE | 11.87 | 5.049 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 4.813 G/MILE | 2.991 G/KM |
| HC | 0.642 | 0.399 |
| NOX | 1.952 | 1.213 |
| CORRECTED NOX | 1.952 | 1.213 |
| CO2 | 740.455 | 460.097 |

DATE 9 16 77 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 22435.7
FUEL INDOLENE TK.90

| | | | |
|---|---|---|---|
| WET BULB TEMP | 66.0 | ABSOLUTE HUMIDITY | 86.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 72.0 | RELATIVE HUMIDITY | 74.0 PCT |
| BAROMETRIC PRES. | 772. | PUMP INLET PRES. | 6.95 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 830.00 | 1.00 | 16.00 | 1.00 | 168.50 | 1.00 |
| HC,PPM C6 | 44.00 | 2.00 | 4.20 | 1.30 | 8.00 | 1.10 |
| NOX,PPM | 46.00 | 0.11 | 23.20 | 0.12 | 47.00 | 0.17 |
| CO2,PCT | 2.02 | 0.04 | 1.37 | 0.03 | 1.77 | 0.04 |
| PUMP REV | 9560. | | 16390. | | 9550. | |

TEMP 130. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2708. | 4643. | 2705. |
| DF | 6.29 | 9.71 | 7.47 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 69.38 | 2.19 | 14.08 |
| HC | 11.23 | 1.38 | 1.86 |
| NOX | 6.73 | 5.80 | 6.86 |
| CO2 | 2796.62 | 3237.17 | 2438.75 |
| CARBON | 802.65 | 885.53 | 673.17 |
| FUEL LBS/BAG | 2.04 | 2.25 | 1.71 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.79 MILES/GAL | 4.591 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.69 | 4.972 |
| OVERALL TEST MILEAGE | 11.32 | 4.814 |
| WEIGHTED TEST MILEAGE | 11.29 | 4.801 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 5.340 G/MILE | 3.318 G/KM |
| HC | 0.969 | 0.602 |
| NOX | 1.682 | 1.045 |
| CORRECTED NOX | 1.773 | 1.102 |
| CO2 | 777.308 | 482.996 |

DATE 9 19 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 22,459

MAKE NOVA

WET BULB TEMP 71
DRY BULB TEMP 78
BAROMETRIC PRES. 757.

ABSOLUTE HUMIDITY 103.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 72.0 PCT
PUMP INLET PRES. 6.85 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 907.50 | 6.00 | 7.00 | 4.00 | 232.50 | 3.00 |
| HC,PPM C6 | 23.00 | 2.00 | 5.20 | 2.10 | 8.90 | 1.66 |
| NOX,PPM | 51.50 | 0.30 | 21.80 | 0.29 | 45.00 | 0.32 |
| CO2,PCT | 2.31 | 0.04 | 1.37 | 0.03 | 1.81 | 0.04 |
| PUMP REV | 9600. | | 16380. | | 9550. | |

TEMP 130. F
PUMP CAPACITY 0.3160 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2658. | 4535. | 2644. |
| DF | 5.55 | 9.71 | 7.25 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 73.72 | 0.47 | 18.87 |
| HC | 5.56 | 1.47 | 1.93 |
| NOX | 7.37 | 5.29 | 6.40 |
| CO2 | 3142.95 | 3159.94 | 2440.99 |
| CARBON | 894.12 | 863.80 | 675.89 |
| FUEL LBS/BAG | 2.27 | 2.19 | 1.71 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10.37 MILES/GAL | 4.409 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.84 | 5.034 |
| OVERALL TEST MILEAGE | 10.98 | 4.671 |
| WEIGHTED TEST MILEAGE | 11.16 | 4.745 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 5.723 G/MILE | 3.556 G/KM |
| HC | 0.662 | 0.411 |
| NOX | 1.615 | 1.003 |
| CORRECTED NOX | 1.860 | 1.155 |
| CO2 | 787.037 | 489.042 |

DATE 9 27 77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 22,613

MAKE NOVA

WET BULB TEMP 62.5
DRY BULB TEMP 70
BAROMETRIC PRES. 755.

ABSOLUTE HUMIDITY 72.0 GRNS/LBS DRY AIR
RELATIVE HUMIDITY 66.0 PCT
PUMP INLET PRES. 7.05 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO,PPM | 587.50 | 3.00 | 7.00 | 2.00 | 83.50 | 1.00 |
| HC,PPM C6 | 34.00 | 1.20 | 4.40 | 1.36 | 7.80 | 1.14 |
| NOX,PPM | 53.50 | 0.17 | 23.80 | 0.15 | 59.00 | 0.22 |
| CO2,PCT | 2.05 | 0.04 | 1.35 | 0.04 | 1.81 | 0.04 |
| PUMP REV | 9550. | | 16390. | | 9550. | |

TEMP 126. F
PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2662. | 4569. | 2662. |
| DF | 6.28 | 9.84 | 7.33 |
| MASS EMISSIONS, GRAMS/BAG | | | |
| CO | 48.21 | 0.73 | 6.84 |
| HC | 8.60 | 1.42 | 1.77 |
| NOX | 7.69 | 5.85 | 8.48 |
| CO2 | 2794.64 | 3132.31 | 2456.54 |
| CARBON | 790.76 | 856.33 | 674.84 |
| FUEL LBS/BAG | 2.01 | 2.17 | 1.71 |

| | INDOLENE MILEAGE | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.06 MILES/GAL | 4.705 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.90 | 5.062 |
| OVERALL TEST MILEAGE | 11.51 | 4.896 |
| WEIGHTED TEST MILEAGE | 11.53 | 4.902 |

WEIGHTED MASS EMISSIONS

| | | |
|---|---|---|
| CO | 3.382 G/MILE | 2.102 G/KM |
| HC | 0.818 | 0.508 |
| NOX | 1.866 | 1.159 |
| CORRECTED NOX | 1.840 | 1.143 |
| CO2 | 764.565 | 475.078 |

SAVED
READY
EXEC (LUNT2)
MEMBER LUNT2 NOT IN DATASET CLIST
READY
EXEC (LUNT4)

DATE 10/20/77 VEHICLE NO. 26 MAKE NOVA
STAND 2 ODOMETER 29233.00
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 62.0 | ABSOLUTE HUMIDITY | 68.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 70.0 | RELATIVE HUMIDITY | 60.0 PCT |
| BAROMETRIC PRES. | 758. | PUMP INLET PRES. | 6.95 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 1275.00 | 5.00 | 45.30 | 3.00 | 665.00 | 4.00 |
| HC, PPM C6 | 23.00 | 1.44 | 4.40 | 1.62 | 10.40 | 1.84 |
| NOX, PPM | 40.00 | 0.40 | 20.00 | 0.27 | 34.50 | 0.30 |
| CO2, PCT | 2.10 | 0.05 | 1.31 | 0.05 | 1.89 | 0.04 |
| SO2, PPM | 0.0 | | 0.0 | | 0.0 | |

***

| | | | |
|---|---|---|---|
| PUMP REV | 9550. | 16370. | 9560. |
| TEMP | 127 F | | |
| PUMP CAPACITY | 0.3160 CF/REV | | |

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2661. | 4561. | 2664. |
| DF | 6.00 | 10.15 | 6.83 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 104.81 | 6.11 | 54.85 |
| HC | 5.68 | 1.31 | 2.30 |
| NOX | 5.72 | 4.88 | 4.94 |
| CO2 | 2845.64 | 3009.30 | 2565.98 |
| CARBON | 826.42 | 824.97 | 725.75 |
| SO2 | 0.0 | 0.0 | 0.0 |

| | | | |
|---|---|---|---|
| FUEL LBS/BAG | 2.10 | 2.10 | 1.85 |

***



| | INDOLENE MILEAGE | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.04 MILES/GAL | 4.694 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11.76 | 4.998 |
| OVERALL TEST MILEAGE | 11.25 | 4.782 |
| WEIGHTED TEST MILEAGE | 11.44 | 4.863 |

WEIGHTED MASS EMISSIONS

| | | | | |
|---|---|---|---|---|
| | CO | 10.992 G/MILE | 6.830 G/KM | |
| | HC | 0.676 | 0.420 | |
| | NOX | 1.354 | 0.841 | |
| CORRECTED | NOX | 1.311 | 0.815 | |
| | CO2 | 759.404 | 471.872 | |
| | SO2 | 0.0 | 0.0 | |
| | SO2 | 0.0 | 0.0 | UNWEIGHTED |

READY

SAVED
READY
EXEC (LUNT4)

DATE 10/21/77 VEHICLE NO. 26 MAKE NOVA
STAND 2 ODOMETER 29310.
FUEL INDOLENE

WET BULB TEMP 62.0 ABSOLUTE HUMIDITY 70.0 GRNS/LBS DRY AIR
DRY BULB TEMP 70.0 RELATIVE HUMIDITY 64.0 PCT
BAROMETRIC PRES. 767. PUMP INLET PRES. 7 10 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 1275.00 | 7 00 | 64.00 | 5.00 | 823.00 | 1.00 |
| HC, PPM C6 | 22.00 | 1.26 | 4.20 | 1.20 | 10.80 | 0.98 |
| NOX, PPM | 44.00 | 0.25 | 27.00 | 0.31 | 36.50 | 0.19 |
| CO2, PCT | 2.10 | 0.05 | 1.52 | 0.04 | 1.88 | 0.04 |
| SO2, PPM | 0.0 | | 0.0 | | 0.0 | |
| PUMP REV | 9540. | | 16370. | | 9560. | |
| TEMP | 127 F | | | | | |

***
PUMP CAPACITY 0.3160 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2689. | 4615. | 2695. |
| DF | 6.00 | 8.74 | 6.84 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 105.64 | 8.59 | 68.90 |
| HC | 5.52 | 1.42 | 2.63 |
| NOX | 6.38 | 6.68 | 5.30 |
| CO2 | 2875.93 | 3564.08 | 2578.21 |
| CARBON | 834.90 | 977 52 | 735.40 |
| SO2 | 0.0 | 0.0 | 0.0 |
| FUEL LBS/BAG | 2.12 | 2.49 | 1.87 |

INDOLENE MILEAGE
AVERAGE COLD START MILEAGE 10.06 MILES/GAL 4.277 KM/LITRE

****

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 10.64 | 4.525 |
| OVERALL TEST MILEAGE | 10.50 | 4.462 |
| WEIGHTED TEST MILEAGE | 10.38 | 4.415 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 12.438 G/MILE | 7.729 G/KM | |
| HC | 0.706 | 0.438 | |
| NOX | 1.659 | 1.031 | |
| CORRECTED NOX | 1.621 | 1.007 | |
| CO2 | 836.041 | 519.492 | |
| NO2 | 0.0 | 0.0 | |
| SO2 | 0.0 | 0.0 | UNWEIGHTED |

SAVED
READY
EXEC (LUNT4)

DATE 10/25/77 VEHICLE NO. 26 MAKE NOVA
STAND 2 ODOMETER 31223.
FUEL INDOLENE

WET BU[illegible]MP 63. 0 ABSOLUTE HUMIDITY 68. 5 GRNS/LBS DRY AIR
DRY BU[illegible]MP 74. 0 RELATIVE HUMIDITY 54. 0 PCT
BAROMETRIC PRES. 775. PUMP INLET PRES. 7 15 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 438. 80 | 5. 00 | 43. 50 | 3. 00 | 130. 00 | 1. 00 |
| HC, PPM C6 | 15. 30 | 1. 60 | 4. 20 | 1. 28 | 8. 40 | 1. 20 |
| NOX, PPM | 50. 00 | 0. 35 | 19. 30 | 0. 17 | 43. 50 | 0. 25 |
| CO2, PCT | 1. 95 | 0. 05 | 1. 34 | 0. 05 | 1. 73 | 0. 04 |
| SO2, PPM | 0. 0 | | 0. 0 | | 0. 0 | |
| PUMP REV | 9560. | | 16370. | | 9550. | |
| TEMP | 124. F | | | | | |

***
PUMP CAPACITY 0. 3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2746. | 4702. | 2743. |
| DF | 6. 70 | 9. 97 | 7. 68 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 37 16 | 6. 04 | 11. 08 |
| HC | 3. 75 | 1. 40 | 1. 98 |
| NOX | 7. 39 | 4. 88 | 6. 43 |
| CO2 | 2721. 75 | 3161. 98 | 2406. 70 |
| CARBON | 761. 93 | 866. 69 | 663. 24 |
| SO2 | 0. 0 | 0. 0 | 0. 0 |
| FUEL LBS/BAG | 1. 94 | 2. 20 | 1. 69 |

INDOLENE MILEAGE
AVERAGE COLD START MILEAGE 11. 19 MILES/GAL 4. 759 KM/LITRE

***

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 11.92 | 5.066 |
| OVERALL TEST MILEAGE | 11.67 | 4.960 |
| WEIGHTED TEST MILEAGE | 11.60 | 4.930 |

WEIGHTED MASS EMISSIONS

| | | | | | |
|---|---|---|---|---|---|
| CO | 3.778 | G/MILE | 2.348 | G/KM | |
| HC | 0.553 | | 0.343 | | |
| NOX | 1.563 | | 0.971 | | |
| CORRECTED NOX | 1.516 | | 0.942 | | |
| CO2 | 760.552 | | 472.585 | | |
| SO2 | 0.0 | | 0.0 | | |
| SO2 | 0.0 | | 0.0 | | UNWEIGHTED |

READY

SAVED
READY
EXEC (LUNT4)

DATE 10/26/77 VEHICLE NO. 2 MAKE NOVA
STAND 2 ODOMETER 31245.
FUEL INDOLENE

WET BULB TEMP 65. 0 ABSOLUTE HUMIDITY 81. 0 GRNS/LBS DRY AIR
DRY BULB TEMP 72. 0 RELATIVE HUMIDITY 68. 0 PCT
BAROMETRIC PRES. 767 PUMP INLET PRES. 7. 10 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 612. 50 | 7. 90 | 50. 00 | 8. 80 | 310. 00 | 7. 90 |
| HC, PPM C6 | 17. 40 | 2. 20 | 4. 90 | 2. 20 | 9. 80 | 2. 40 |
| NOX, PPM | 48. 50 | 0. 57 | 19. 20 | 0. 50 | 35. 50 | 0. 55 |
| CO2, PCT | 1. 98 | 0. 06 | 1. 40 | 0. 05 | 1. 77 | 0. 05 |
| SO2, PPM | 0. 0 | | 0. 0 | | 0. 0 | |
| PUMP REV | 9550. | | 16380. | | 9560. | |

TEMP 125. F

***
PUMP CAPACITY 0. 3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2710. | 4648. | 2713. |
| DF | 6. 53 | 9. 52 | 7 41 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 50. 85 | 6. 11 | 25. 57 |
| HC | 4. 13 | 1. 33 | 2. 05 |
| NOX | 7. 05 | 4. 72 | 5. 15 |
| CO2 | 2717. 21 | 3257. 44 | 2428. 07 |
| CARBON | 766. 86 | 892. 70 | 675. 35 |
| SO2 | 0 0 | 0. 0 | 0. 0 |
| FUEL LBS/BAG | 1. 95 | 2. 27 | 1. 72 |

INDOLENE MILEAGE

AVERAGE COLD START MILEAGE 10. 99 MILES/GAL 4. 671 KM/LITRE

***

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 11.63 | 4.943 |
| OVERALL TEST MILEAGE | 11.45 | 4.869 |
| WEIGHTED TEST MILEAGE | 11.34 | 4.822 |

WEIGHTED MASS EMISSIONS

| | | | | | |
|---|---|---|---|---|---|
| | CO | 5.673 | G/MILE | 3.525 | G/KM |
| | HC | 0.571 | | 0 354 | |
| | NOX | 1.425 | | 0.885 | |
| CORRECTED | NOX | 1.466 | | 0.911 | |
| | CO2 | 774.644 | | 481.341 | |
| | SO2 | 0.0 | | 0.0 | |
| | SO2 | 0.0 | | 0.0 | UNWEIGHTED |

READY

SAVED
READY
EXEC (LUNT4)

DATE 11/3/77 — VEHICLE NO. 26 — MAKE NOVA
STAND 2 — ODOMETER 33494.
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 64. 0 | ABSOLUTE HUMIDITY | 76. 0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 72. 5 | RELATIVE HUMIDITY | 65. 0 PCT |
| BAROMETRIC PRES. | 772. | PUMP INLET PRES. | 7. 35 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 702. 50 | 3. 00 | 67. 50 | 2. 00 | 276. 30 | 2. 00 |
| HC, PPM C6 | 52. 00 | 1. 34 | 5. 90 | 0. 98 | 12. 60 | 0. 95 |
| NOX, PPM | 51. 00 | 0. 32 | 22. 60 | 0. 26 | 49. 00 | 0. 27 |
| CO2, PCT | 2. 02 | 0. 05 | 1. 39 | 0. 05 | 1. 91 | 0. 05 |
| SO2, PPM | 0. 0 | | 0. 0 | | 0. 0 | |
| PUMP REV | 9660. | | 16350. | | 9550. | |
| TEMP | 125. F | | | | | |

***
PUMP CAPACITY 0. 3160 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2749. | 4653. | 2718. |
| DF | 6. 31 | 9. 59 | 6. 90 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 59. 62 | 9. 59 | 23. 18 |
| HC | 13. 70 | 2. 29 | 3. 14 |
| NOX | 7. 55 | 5. 64 | 7. 18 |
| CO2 | 2832. 21 | 3251. 11 | 2634. 25 |
| CARBON | 810. 33 | 893. 30 | 731. 52 |
| SO2 | 0. 0 | 0. 0 | 0. 0 |
| FUEL LBS/BAG | 2. 06 | 2. 27 | 1. 86 |

INDOLENE MILEAGE
AVERAGE COLD START MILEAGE 10. 70 MILES/GAL 4. 550 KM/LITRE

****

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 11.22 | 4.771 |
| OVERALL TEST MILEAGE | 10.98 | 4.668 |
| WEIGHTED TEST MILEAGE | 10.99 | 4.673 |

WEIGHTED MASS EMISSIONS

| | | | | |
|---|---|---|---|---|
| CO | 6.459 G/MILE | 4.013 G/KM | |
| HC | 1.329 | 0.826 | |
| NOX | 1.730 | 1.075 | |
| CORRECTED NOX | 1.738 | 1.080 | |
| CO2 | 796.063 | 494.650 | |
| SO2 | 0.0 | 0.0 | |
| SO2 | 0.0 | 0.0 | UNWEIGHTED |

READY

SAVED
READY
EXEC (LUNT4)

| | | |
|---|---|---|
| DATE 11/4/77 | VEHICLE NO. 26 | MAKE NOVA |
| STAND 2 | ODOMETER 33516. | |
| FUEL INDOLENE | | |

| | | | |
|---|---|---|---|
| WET BULB TEMP | 68. 0 | ABSOLUTE HUMIDITY | 96. 0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 73. 0 | RELATIVE HUMIDITY | 78. 0 PCT |
| BAROMETRIC PRES | 771. | PUMP INLET PRES. | 7. 30 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 677. 50 | 9. 60 | 83. 50 | 9. 60 | 380. 00 | 7. 00 |
| HC, PPM C6 | 21. 00 | 1. 66 | 7. 20 | 1. 48 | 13. 60 | 1. 76 |
| NOX, PPM | 49. 50 | 0. 34 | 22. 00 | 0. 48 | 39. 00 | 0. 45 |
| CO2, PCT | 2. 04 | 0. 05 | 1. 43 | 0. 05 | 1. 77 | 0. 05 |
| SO2, PPM | 0. 0 | | 0. 0 | | 0. 0 | |
| PUMP REV | 9560. | | 16370. | | 9540. | |
| TEMP | 130. F | | | | | |

***
PUMP CAPACITY 0. 3160 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2694. | 4613. | 2688. |
| DF | 6. 33 | 9. 32 | 7. 38 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 55. 60 | 10. 76 | 31. 16 |
| HC | 5. 17 | 2. 66 | 3. 18 |
| NOX | 7. 18 | 5. 39 | 5. 62 |
| CO2 | 2798. 14 | 3304. 18 | 2411. 27 |
| CARBON | 791. 91 | 908. 60 | 674. 14 |
| SO2 | 0. 0 | 0. 0 | 0. 0 |
| FUEL LBS/BAG | 2. 01 | 2. 31 | 1. 71 |

INDOLENE MILEAGE
AVERAGE COLD START MILEAGE 10. 72 MILES/GAL 4. 558 KM/LITRE

***

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 11.52 | 4.897 |
| OVERALL TEST MILEAGE | 11.26 | 4.787 |
| WEIGHTED TEST MILEAGE | 11.16 | 4.745 |

WEIGHTED MASS EMISSIONS

| | | | | | |
|---|---|---|---|---|---|
| | CO | 6.991 | G/MILE | 4.344 | G/KM |
| | HC | 0.893 | | 0.555 | |
| | NOX | 1.558 | | 0.968 | |
| CORRECTED | NOX | 1.728 | | 1.074 | |
| | CO2 | 784.240 | | 487.304 | |
| | SO2 | 0.0 | | 0.0 | |
| | SO2 | 0.0 | | 0.0 | UNWEIGHTED |

READY

QE

SAVED
READY
EXEC (LUNT4)
DATE 11/9/77
STAND 2
FUEL INDOLENE

VEHICLE NO. 26
ODOMETER 35158.

MAKE NOVA

| | | | |
|---|---|---|---|
| WET BULB TEMP | 68. 0 | ABSOLUTE HUMIDITY | 90. 0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 76. 0 | RELATIVE HUMIDITY | 67. 0 PCT |
| BAROMETRIC PRES. | 764. | PUMP INLET PRES. | 7. 25 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 600. 00 | 10. 50 | 75. 50 | 7. 00 | 144. 50 | 3. 00 |
| HC, PPM C6 | 19. 20 | 1. 46 | 5. 30 | 1. 47 | 9. 00 | 1. 32 |
| NOX, PPM | 65. 00 | 0. 47 | 26. 50 | 0. 41 | 50. 00 | 0. 40 |
| CO2, PCT | 1. 95 | 0. 05 | 1. 34 | 0. 04 | 1. 65 | 0. 04 |
| SO2, PPM | 0. 0 | | 0. 0 | | 0. 0 | |
| PUMP REV | 9560. | | 16380. | | 9570. | |
| TEMP | 130. F | | | | | |

***

PUMP CAPACITY 0. 3160 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2670. | 4574. | 2672. |
| DF | 6. 64 | 9. 94 | 8. 01 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 48. 92 | 9. 92 | 11. 82 |
| HC | 4. 70 | 1. 78 | 2. 05 |
| NOX | 9. 34 | 6. 47 | 7. 19 |
| CO2 | 2646. 20 | 3087. 89 | 2243. 29 |
| CARBON | 747. 17 | 848. 46 | 619. 03 |
| SO2 | 0. 0 | 0. 0 | 0. 0 |
| FUEL LBS/BAG | 1. 90 | 2. 16 | 1. 57 |

INDOLENE MILEAGE

AVERAGE COLD START MILEAGE 11. 43 MILES/GAL 4. 858 KM/LITRE

***

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 12.42 | 5.282 |
| OVERALL TEST MILEAGE | 12.07 | 5.133 |
| WEIGHTED TEST MILEAGE | 11.97 | 5.091 |

## WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 5.025 G/MILE | 3.123 G/KM | |
| HC | 0.663 | 0.412 | |
| NOX | 1.945 | 1.208 | |
| CORRECTED NOX | 2.092 | 1.300 | |
| CO2 | 733.923 | 456.039 | |
| SO2 | 0.0 | 0.0 | |
| SO2 | 0.0 | 0.0 | UNWEIGHTED |

READY

EXEC (LUNT4)
DATE 11/10/77 VEHICLE NO. 26 MAKE NOVA
STAND 2 ODOMETER 35180.
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 67 0 | ABSOLUTE HUMIDITY | 90. 0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 73. 0 | RELATIVE HUMIDITY | 74. 0 PCT |
| BAROMETRIC PRES. | 757. | PUMP INLET PRES. | 7. 15 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 593. 80 | 1. 00 | 67 50 | 1. 00 | 168. 50 | 1. 00 |
| HC, PPM C6 | 19. 60 | 1. 20 | 6. 00 | 0. 98 | 9. 40 | 1. 02 |
| NOX, PPM | 58. 50 | 0. 23 | 25. 00 | 0. 20 | 48. 50 | 0. 20 |
| CO2, PCT | 2. 06 | 0. 05 | 1. 41 | 0. 04 | 1. 80 | 0. 05 |
| SO2, PPM | 0. 0 | | 0. 0 | | 0. 0 | |
| PUMP REV | 9560. | | 16380. | | 9560. | |

TEMP 128. F
PUMP CAPACITY 0. 3160 CF/REV

***

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2654. | 4548. | 2654. |
| DF | 6. 30 | 9. 42 | 7. 36 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 48. 59 | 9. 47 | 13. 81 |
| HC | 4. 83 | 2. 28 | 2. 22 |
| NOX | 8. 38 | 6. 11 | 6. 95 |
| CO2 | 2780. 23 | 3247. 64 | 2423. 75 |
| CARBON | 783. 73 | 892. 30 | 669. 26 |
| SO2 | 0. 0 | 0. 0 | 0. 0 |
| FUEL LBS/BAG | 1. 99 | 2. 27 | 1. 70 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10. 88 MILES/GAL | 4. 625 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11. 68 | 4. 964 |
| OVERALL TEST MILEAGE | 11. 40 | 4. 847 |
| WEIGHTED TEST MILEAGE | 11. 32 | 4. 812 |

***

WEIGHTED MASS EMISSIONS

| | | | | |
|---|---|---|---|---|
| | CO | 5.098 G/MILE | 3.168 G/KM | |
| | HC | 0.750 | 0.466 | |
| | NOX | 1.824 | 1.133 | |
| CORRECTED | NOX | 1.962 | 1.219 | |
| | CO2 | 776.623 | 482.571 | |
| | SO2 | 0.0 | 0.0 | |
| | SO2 | 0.0 | 0.0 | UNWEIGHTED |

READY

SAVED
READY
EXEC (LUNT4)

DATE 11/22/77 VEHICLE NO. 26 MAKE NOVA
STAND 2 ODOMETER 35963.
FUEL CX-82

| | | | |
|---|---|---|---|
| WET BULB TEMP | 60.0 | ABSOLUTE HUMIDITY | 58.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 72.0 | RELATIVE HUMIDITY | 50.0 PCT |
| BAROMETRIC PRES. | 773. | PUMP INLET PRES. | 7.30 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 930.00 | 7.00 | 49.00 | 3.00 | 140.00 | 3.00 |
| HC, PPM C6 | 17.60 | 1.04 | 3.60 | 1.00 | 6.40 | 1.14 |
| NOX, PPM | 64.00 | 0.31 | 29.50 | 0.35 | 60.50 | 0.30 |
| CO2, PCT | 1.93 | 0.06 | 1.28 | 0.05 | 1.67 | 0.06 |
| SO2, PPM | 0.0 | | 0.0 | | 0.0 | |
| PUMP REV | 9590. | | 16350. | | 9560. | |
| TEMP | 120. F | | | | | |

***

PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2765. | 4714. | 2756. |
| DF | 6.61 | 10.43 | 7.95 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 79.73 | 6.89 | 11.88 |
| HC | 4.53 | 1.25 | 1.46 |
| NOX | 9.55 | 7.45 | 8.99 |
| CO2 | 2695.09 | 3004.56 | 2310.79 |
| CARBON | 773.58 | 823.96 | 636.95 |
| SO2 | 0.0 | 0.0 | 0.0 |
| FUEL LBS/BAG | 1.97 | 2.10 | 1.62 |

2234.49 g C / .860 = 2598.2
× 1 lb / 454 g × 1 gal / 6.0721 lb = 0.943

INDOLENE MILEAGE
AVERAGE COLD START MILEAGE 11.41 MILES/GAL 4.852 KM/LITRE
***

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 12.48 | 5.306 |
| OVERALL TEST MILEAGE | 11.97 | 5.088 |
| WEIGHTED TEST MILEAGE | 12.00 | 5.101 |

WEIGHTED MASS EMISSIONS

| | | | | | |
|---|---|---|---|---|---|
| CO | 6.393 | G/MILE | 3.972 | G/KM | |
| HC | 0.537 | | 0.333 | | |
| NOX | 2.224 | | 1.382 | | |
| CORRECTED NOX | 2.060 | | 1.280 | | |
| CO2 | 730.746 | | 454.064 | | |
| SO2 | 0.0 | | 0.0 | | |
| SO2 | 0.0 | | 0.0 | | UNWEIGHTED |

READY

SAVED
READY
EXEC (LUNT4)
DATE 11/23/77 VEHICLE NO. 26 MAKE NOVA
STAND 2 ODOMETER 35985.
FUEL CX-82

| | | | |
|---|---|---|---|
| WET BULB TEMP | 62. 0 | ABSOLUTE HUMIDITY | 67. 0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 72. 0 | RELATIVE HUMIDITY | 57. 0 PCT |
| BAROMETRIC PRES. | 770. | PUMP INLET PRES. | 7. 30 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 587. 50 | 7. 00 | 77. 50 | 8. 80 | 577. 50 | 7. 90 |
| HC, PPM C6 | 14. 40 | 1. 80 | 4. 00 | 2. 40 | 7. 60 | 1. 90 |
| NOX, PPM | 57. 50 | 0. 75 | 23. 30 | 0. 57 | 43. 00 | 0. 29 |
| CO2, PCT | 1. 98 | 0. 05 | 1. 40 | 0. 05 | 1. 80 | 0. 05 |
| SO2, PPM | 0. 0 | | 0. 0 | | 0. 0 | |

| | | | |
|---|---|---|---|
| PUMP REV | 9560. | 16370. | 9590. |
| TEMP | 125. F | | |
| PUMP CAPACITY | 0. 3160 CF/REV | | |

***

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2714. | 4647. | 2722. |
| DF | 6. 55 | 9. 50 | 7. 21 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 49. 07 | 10. 15 | 48. 48 |
| HC | 3. 42 | 0. 84 | 1. 59 |
| NOX | 8. 36 | 5. 74 | 6. 30 |
| CO2 | 2725. 67 | 3256. 51 | 2485. 81 |
| CARBON | 767. 82 | 893. 76 | 700. 52 — 2362.1 g C = .996 gal |
| SO2 | 0. 0 | 0. 0 | 0. 0 |
| FUEL LBS/BAG | 1. 95 | 2. 27 | 1. 78 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 10. 97 MILES/GAL | 4. 665 KM/LITRE |
| AVERAGE HOT START MILEAGE | 11. 44 | 4. 862 |

***

| | | |
|---|---|---|
| OVERALL TEST MILEAGE | 11.32 | 4.813 |
| WEIGHTED TEST MILEAGE | 11.23 | 4.775 |

WEIGHTED MASS EMISSIONS

| | | | | |
|---|---|---|---|---|
| CO | 7 851 G/MILE | 4.878 G/KM | |
| HC | 0.430 | 0.267 | |
| NOX | 1.723 | 1.071 | |
| CORRECTED NOX | 1.660 | 1.032 | |
| CO2 | 779.393 | 484.292 | |
| SO2 | 0.0 | 0.0 | |
| SO2 | 0.0 | 0.0 | UNWEIGHTED |

READY

? Rerun

SAVED
READY
EXEC (LUNT4)
DATE 11/29/77
STAND 2
FUEL C-82

VEHICLE NO. 26
ODOMETER 36244.

MAKE NOVA

| | | | | |
|---|---|---|---|---|
| WET BULB TEMP | 57.5 | ABSOLUTE HUMIDITY | 54.0 | GRNS/LBS DRY AIR |
| DRY BULB TEMP | 68.0 | RELATIVE HUMIDITY | 53.0 | PCT |
| BAROMETRIC PRES. | 778. | PUMP INLET PRES. | 7.30 | INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 593.80 | 5.00 | 70.00 | 4.00 | 170.50 | 3.00 |
| HC, PPM C6 | 16.60 | 2.00 | 4.60 | 2.20 | 8.70 | 2.00 |
| NOX, PPM | 67 50 | 0.53 | 26.00 | 0.62 | 54.50 | 0.40 |
| CO2, PCT | 1.82 | 0.05 | 1.19 | 0.05 | 1.50 | 0.05 |
| SO2, PPM | 0.0 | | 0.0 | | 0.0 | |
| PUMP REV | 9590. | | 16390. | | 9600. | |
| TEMP | 125. F | | | | | |

***

PUMP CAPACITY 0.3160 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2751 | 4701. | 2754. |
| DF | 7.11 | 11.16 | 8.81 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 50.66 | 9.86 | 14.53 |
| HC | 4.01 | 1.20 | 1.87 |
| NOX | 9.99 | 6.48 | 8.08 |
| CO2 | 2528.29 | 2783.44 | 2078.43 |
| CARBON | 715.15 | 764.84 | 575.04 |
| SO2 | 0.0 | 0.0 | 0.0 |
| FUEL LBS/BAG | 1.82 | 1.95 | 1.46 |

.4536 kg/lb

– 2055.03 g Carbon
4.53 lb. Carbon
.859 ?
5.274 lb fuel.

INDOLENE MILEAGE

AVERAGE COLD START MILEAGE 12.32 MILES/GAL 5.237 KM/LITRE

= .8687 g/cc

13.24 mpg

***

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 13.61 | 5.785 |
| OVERALL TEST MILEAGE | 13.01 | 5.532 |
| WEIGHTED TEST MILEAGE | 13.02 | 5.536 |

WEIGHTED MASS EMISSIONS

| | | | | |
|---|---|---|---|---|
| | CO | 5.324 G/MILE | 3.308 G/KM | |
| | HC | 0.532 | 0.330 | |
| | NOX | 2.050 | 1.274 | |
| CORRECTED | NOX | 1.866 | 1.159 | |
| | CO2 | 674.041 | 418.829 | |
| | SO2 | 0.0 | 0.0 | |
| | SO2 | 0.0 | 0.0 | UNWEIGHTED |

READY

SAVED
READY
XEC (LUNT4)
DATE 11/30/77 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 36285.
FUEL C-82

WET BULB TEMP 62.0 | ABSOLUTE HUMIDITY 67 0 GRNS/LBS DRY AIR
DRY BULB TEMP 72.0 | RELATIVE HUMIDITY 57 0 PCT
BAROMETRIC PRES. 772. | PUMP INLET PRES. 7 25 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 479.00 | 5.00 | 81.50 | 5.00 | 215.00 | 5.00 |
| HC, PPM C6 | 15.00 | 1.66 | 4.90 | 1.64 | 9.00 | 1.64 |
| NOX, PPM | 63.50 | 0.42 | 23.50 | 0.42 | 50.00 | 0.39 |
| CO2, PCT | 2.04 | 0.05 | 1.36 | 0.06 | 1.67 | 0.06 |
| SO2, PPM | 0.0 | | 0.0 | | 0.0 | |

| | 1 | 2 | 3 |
|---|---|---|---|
| PUMP REV | 9580. | 16360. | 9570. |

TEMP 125. F
PUMP CAPACITY 0.3170 CF/REV
***

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2735. | 4671. | 2733. |
| DF | 6.40 | 9.80 | 7.91 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 40.33 | 11.31 | 18.00 |
| HC | 3.64 | 1.57 | 2.03 |
| NOX | 9.35 | 5.85 | 7.35 |
| CO2 | 2827.28 | 3145.37 | 2291.46 |
| CARBON | 792.00 | 864.56 | 634.80 |
| SO2 | 0.0 | 0.0 | 0.0 |
| FUEL LBS/BAG | 2.01 | 2.20 | 1.61 |

— 2291.36 g
5.05 lb C. / .859 = 5.88 lb fuel
= .96860 gal
11.87 mpg.

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.01 MILES/GAL | 4.679 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.16 | 5.170 |

***

| | | |
|---|---|---|
| OVERALL TEST MILEAGE | 11.67 | 4.961 |
| WEIGHTED TEST MILEAGE | 11.64 | 4.947 |

WEIGHTED MASS EMISSIONS

| | | | | |
|---|---|---|---|---|
| | CO | 5.189 G/MILE | 3.225 G/KM | |
| | HC | 0.572 | 0.355 | |
| | NOX | 1.875 | 1.165 | |
| CORRECTED | NOX | 1.807 | 1.123 | |
| | CO2 | 755.631 | 469.527 | |
| | SO2 | 0.0 | 0.0 | |
| | SO2 | 0.0 | 0.0 | UNWEIGHTED |

READY

SAVED
READY
:XEC (LUNT4)

| | | |
|---|---|---|
| DATE 12/9/77 | VEHICLE NO. 26 | MAKE NOVA |
| STAND 2 | ODOMETER 40667. | |
| FUEL TK90 | | |

| | | | |
|---|---|---|---|
| WET BULB TEMP | 60. 0 | ABSOLUTE HUMIDITY | 58. 0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 74. 0 | RELATIVE HUMIDITY | 50. 0 PCT |
| BAROMETRIC PRES. | 754. | PUMP INLET PRES. | 7. 10 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 1600. 00 | 20. 00 | 115. 50 | 4. 00 | 366. 30 | 1. 00 |
| HC, PPM C6 | 23. 00 | 1. 18 | 5. 50 | 1. 24 | 11. 20 | 0. 80 |
| NOX, PPM | 63. 00 | 0. 57 | 26. 00 | 0. 35 | 54. 00 | 0. 30 |
| CO2, PCT | 1. 95 | 0. 05 | 1. 25 | 0. 05 | 1. 66 | 0. 04 |
| SO2, PPM | 0. 0 | | 0. 0 | | 0. 0 | |
| PUMP REV | 9570. | | 16390. | | 9590. | |
| TEMP | 124. F | | | | | |

***

PUMP CAPACITY 0. 3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2673. | 4578. | 2679. |
| DF | 6. 34 | 10. 60 | 7. 87 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 131. 99 | 16. 20 | 30. 72 |
| HC | 5. 76 | 1. 96 | 2. 76 |
| NOX | 9. 05 | 6. 37 | 7. 80 |
| CO2 | 2644. 50 | 2870. 59 | 2257. 20 |
| CARBON | 783. 25 | 792. 01 | 631. 53 |
| SO2 | 0. 0 | 0. 0 | 0. 0 |
| FUEL LBS/BAG | 1. 99 | 2. 01 | 1. 61 |

INDOLENE MILEAGE

AVERAGE COLD START MILEAGE 11. 57 MILES/GAL 4. 921 KM/LITRE

***

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 12.81 | 5.445 |
| OVERALL TEST MILEAGE | 12.12 | 5.152 |
| WEIGHTED TEST MILEAGE | 12.25 | 5.206 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 12.061 G/MILE | 7.495 G/KM | |
| HC | 0.802 | 0.498 | |
| NOX | 1.961 | 1.218 | |
| CORRECTED NOX | 1.816 | 1.128 | |
| CO2 | [illegible] | 436.633 | |
| SO2 | 0.0 | 0.0 | |
| SO2 | [illegible] | 0.0 | UNWEIGHTED |

READY

SAVED
READY
EXEC (LUNT4)

DATE 12/13/77 | VEHICLE NO. 26 | MAKE NOVA
STAND 2 | ODOMETER 40829
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 58.0 | ABSOLUTE HUMIDITY | 52.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 70.5 | RELATIVE HUMIDITY | 48.0 PCT |
| BAROMETRIC PRES. | 771. | PUMP INLET PRES. | 7.20 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 577.50 | 10.50 | 126.00 | 14.00 | 271.30 | 3.00 |
| HC, PPM C6 | 18.40 | 1.50 | 5.40 | 1.76 | 10.80 | 1.42 |
| NOX, PPM | 54.50 | 0.47 | 22.00 | 0.52 | 48.00 | 0.29 |
| CO2, PCT | 1.98 | 0.05 | 1.31 | 0.06 | 1.65 | 0.05 |
| SO2, PPM | 0.0 | | 0.0 | | 0.0 | |
| PUMP REV | 9560. | | 16360. | | 9580. | |
| TEMP | 124. F | | | | | |

***

PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2731. | 4674. | 2737. |
| DF | 6.54 | 10.09 | 7.95 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 48.42 | 16.71 | 23.09 |
| HC | 4.58 | 1.75 | 2.56 |
| NOX | 8.00 | 5.45 | 7.08 |
| CO2 | 2743.28 | 3055.18 | 2285.05 |
| CARBON | 773.35 | 842.41 | 635.69 |
| SO2 | 0.0 | 0.0 | 0.0 |
| FUEL LBS/BAG | 1.97 | 2.14 | 1.62 |

INDOLENE MILEAGE
AVERAGE COLD START MILEAGE 11.28 MILES/GAL 4.797 KM/LITRE
***

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 12.33 | 5.244 |
| OVERALL TEST MILEAGE | 11.88 | 5.049 |
| WEIGHTED TEST MILEAGE | 11.86 | 5.042 |

WEIGHTED MASS EMISSIONS

| | | | | |
|---|---|---|---|---|
| | CO | 6.759 G/MILE | 4.200 G/KM | |
| | HC | 0.690 | 0.429 | |
| | NOX | 1.723 | 1.071 | |
| CORRECTED | NOX | 1.555 | 0.966 | |
| | CO2 | 738.302 | 458.760 | |
| | SO2 | 0.0 | 0.0 | |
| | SO2 | 0.0 | 0.0 | UNWEIGHTED |

READY

QE LUNT

SAVED
READY
EXEC (LUNT4)
DATE 12/14/77 VEHICLE NO. 26 MAKE NOVA
STAND-2 ODOMETER 40872.
FUEL INDOLENE

| | | | |
|---|---|---|---|
| WET BULB TEMP | 64.0 | ABSOLUTE HUMIDITY | 73.0 GRNS/LBS DRY AIR |
| DRY BULB TEMP | 74.0 | RELATIVE HUMIDITY | 58.0 PCT |
| BAROMETRIC PRES. | 766. | PUMP INLET PRES. | 7 10 INCHES OF H2O |

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 463.80 | 20.00 | 126.00 | 7 00 | 292.50 | 8.80 |
| HC, PPM C6 | 15.00 | 1.44 | 5.40 | 1.28 | 9.40 | 1.34 |
| NOX, PPM | 50.00 | 0.53 | 22.00 | 0.50 | 46.50 | 0.52 |
| CO2, PCT | 1.91 | 0.05 | 1.35 | 0.05 | 1.63 | 0.05 |
| SO2, PPM | 0.0 | | 0.0 | | 0.0 | |
| PUMP REV | 3610. | | 16400. | | 9570. | |
| TEMP | 125. F | | | | | |

***

PUMP CAPACITY 0.3170 CF/REV

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2723. | 4647 | 2712. |
| DF | 6.83 | 9.84 | 8.08 |

MASS EMISSIONS, GRAMS/BAG

| | 1 | 2 | 3 |
|---|---|---|---|
| CO | 37.83 | 17.50 | 24.17 |
| HC | 3.67 | 1.94 | 2.19 |
| NOX | 7.31 | 5.42 | 6.76 |
| CO2 | 2629.02 | 3126.51 | 2218.43 |
| CARBON | 736.84 | 862.38 | 617 65 |
| SO2 | 0.0 | 0.0 | 0.0 |
| FUEL LBS/BAG | 1.87 | 2.19 | 1.57 |

INDOLENE MILEAGE
AVERAGE COLD START MILEAGE 11.40 MILES/GAL 4.847 KM/LITRE
***

| | | |
|---|---|---|
| AVERAGE HOT START MILEAGE | 12.32 | 5.237 |
| OVERALL TEST MILEAGE | 12.06 | 5.128 |
| WEIGHTED TEST MILEAGE | 11.91 | 5.062 |

WEIGHTED MASS EMISSIONS

| | | | | |
|---|---|---|---|---|
| | CO | 6.339 G/MILE | 3.939 G/KM | |
| | HC | 0.635 | 0.394 | |
| | NOX | 1.656 | 1.029 | |
| CORRECTED | NOX | 1.641 | 1.020 | |
| | CO2 | 736.199 | 457.453 | |
| | SO2 | 0.0 | 0.0 | |
| | SO2 | 0.0 | 0.0 | UNWEIGHTED |

READY

SAVED
READY
EXEC (LUNT4)
DATE 12/15/77 VEHICLE NO. 26 MAKE NOVA
STAND 2 ODOMETER 40910
FUEL CX-86

WET BULB TEMP 67.0 ABSOLUTE HUMIDITY 81.0 GRNS/LBS DRY AIR
DRY BULB TEMP 78.0 RELATIVE HUMIDITY 56.0 PCT
BAROMETRIC PRES. 758. PUMP INLET PRES 7.10 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 348.80 | 3.00 | 142.50 | 3.00 | 260.00 | 3.00 |
| HC, PPM C6 | 17.40 | 0.84 | 5.80 | 0.90 | 10.00 | 0.96 |
| NOX, PPM | 71.00 | 0.30 | 31.00 | 0.26 | 67.00 | 0.40 |
| CO2, PCT | 1.88 | 0.04 | 1.36 | 0.04 | 1.63 | 0.04 |
| SO2, PPM | 0.0 | | 0.0 | | 0.0 | |

| | | | |
|---|---|---|---|
| PUMP REV | 9570. | 16400. | 9560. |
| TEMP | 128. F | | |
| PUMP CAPACITY | 0.3160 CF/REV | | |

***

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2661. | 4560. | 2658. |
| DF | 6.98 | 9.76 | 8.09 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 28.72 | 20.08 | 21.44 |
| HC | 4.35 | 2.23 | 2.39 |
| NOX | 10.20 | 7.60 | 9.60 |
| CO2 | 2539.69 | 3121.26 | 2191.39 |
| CARBON | 709.15 | 862.31 | 609.27 |
| SO2 | 0.0 | 0.0 | 0.0 |
| FUEL LBS/BAG | 1.80 | 2.19 | 1.55 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.60 MILES/GAL | 4.933 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.39 | 5.267 |

***

| | | |
|---|---|---|
| OVERALL TEST MILEAGE | 12.26 | 5.213 |
| WEIGHTED TEST MILEAGE | 12.04 | 5.118 |

WEIGHTED MASS EMISSIONS

| | | | |
|---|---|---|---|
| CO | 5.953 G/MILE | 3.699 G/KM | |
| HC | 0.728 | 0.452 | |
| NOX | 2.327 | 1.446 | |
| CORRECTED NOX | 2.394 | 1.488 | |
| CO2 | 728.322 | 452.558 | |
| SO2 | 0.0 | 0.0 | |
| SO2 | 0.0 | 0.0 | UNWEIGHTED |

READY

EXEC (LUNT4)
DATE 12/16/77 VEHICLE NO. 26 MAKE NOVA
STAND 2. ODOMETER 40956.95
FUEL CX86

WET BULB TEMP 59.0 ABSOLUTE HUMIDITY 55.0 GRNS/LBS DRY AIR
DRY BULB TEMP 71.0 RELATIVE HUMIDITY 48.5 PCT
BAROMETRIC PRES. 767 PUMP INLET PRES. 7 00 INCHES OF H2O

MEASURED CONCENTRATIONS

| BAG | 1 | AIR(1) | 2 | AIR(2) | 3 | AIR(3) |
|---|---|---|---|---|---|---|
| CO, PPM | 1325.00 | 8.90 | 128.30 | 7 00 | 275.00 | 4.30 |
| HC, PPM C6 | 23.00 | 1.28 | 5.80 | 1.47 | 22.00 | 1.34 |
| NOX, PPM | 89.50 | 0.55 | 35.50 | 0.43 | 76.00 | 0.55 |
| CO2, PCT | 1.92 | 0.04 | 1.31 | 0.04 | 1.65 | 0.04 |
| SO2, PPM | 0.0 | | 0.0 | | 0.0 | |

| | | | |
|---|---|---|---|
| PUMP REV | 9560. | 16360. | 9550. |

TEMP 130. F
PUMP CAPACITY 0.3165 CF/REV

***

RESULTS

| BAG | 1 | 2 | 3 |
|---|---|---|---|
| VMIX | 2686. | 4597 | 2683. |
| DF | 6.51 | 10.11 | 7.93 |

MASS EMISSIONS, GRAMS/BAG

| | | | |
|---|---|---|---|
| CO | 110.51 | 17.71 | 22.85 |
| HC | 5.77 | 2.02 | 5.48 |
| NOX | 12.95 | 8.74 | 10.98 |
| CO2 | 2624.58 | 3032.08 | 2244.57 |
| CARBON | 768.61 | 836.77 | 627 07 |
| SO2 | 0.0 | 0.0 | 0.0 |

– 2232.455 C = .902 gal

| | | | |
|---|---|---|---|
| FUEL LBS/BAG | 1.95 | 2.13 | 1.59 |

INDOLENE MILEAGE

| | | |
|---|---|---|
| AVERAGE COLD START MILEAGE | 11.36 MILES/GAL | 4.828 KM/LITRE |
| AVERAGE HOT START MILEAGE | 12.45 | 5.295 |
| OVERALL TEST MILEAGE | 11.98 | 5.092 |
| WEIGHTED TEST MILEAGE | 11.96 | 5.084 |

***

WEIGHTED MASS EMISSIONS

| | | | | | |
|---|---|---|---|---|---|
| | CO | 10.434 | G/MILE | 6.483 | G/KM |
| | HC | 1.016 | | 0.631 | |
| | NOX | 2.742 | | 1.704 | |
| CORRECTED | NOX | 2.507 | | 1.558 | |
| | CO2 | 725.340 | | 450.705 | |
| | SO2 | 0.0 | | 0.0 | |
| | SO2 | 0.0 | | 0.0 | UNWEIGHTED |

READY

# APPENDIX C

## OCTANE REQUIREMENT INFORMATION

C-1 Technique for Determination of Octane Number Requirements of Passenger Cars (CRC E-15-78)

C-2 RON and RON for Full-Boiling Range Octane Rating Fuels

C-3 through C-11 Octane Rating Data for Vehicle with Knock-Sensor Spark Retard System

APPENDIX C-1

# TECHNIQUE FOR DETERMINATION OF OCTANE NUMBER REQUIREMENTS OF PASSENGER CARS

(CRC Designation E-15-78)

Revised
June 1977

# TECHNIQUE FOR DETERMINATION OF OCTANE NUMBER REQUIREMENTS OF PASSENGER CARS

(CRC Designation E-15-78)

## A. GENERAL

The technique provides for the determination of octane number requirements of a vehicle in terms of borderline spark knock or surface ignition knock, regardless of throttle position, on one or more series of full-boiling range reference fuels as well as on primary reference fuels. It also provides octane requirements throughout the speed range on primary reference fuels.

Spark knock, surface ignition and after-run characteristics of tank fuel will also be described.

## B. DEFINITION OF TERMS

1. The following definitions of knock were approved by the CFR and CLR Committees on June 8, 1954, and will be used in this technique.

   Knock is the noise associated with autoignition* of a portion of the fuel-air mixture ahead of the advancing flame front. The flame front is presupposed to be moving at normal velocity. With this definition the source of the normal flame front is immaterial--it may be the result of surface ignition or spark ignition.

   a. Spark Knock: A knock which is recurrent and repeatable in terms of audibility. It is controllable by the spark advance; advancing the spark increases the knock intensity and retarding the spark reduces the intensity. This definition does not include surface ignition induced knock.

   b. Surface Ignition Knock: Knock which has been preceded by a surface ignition. It is not controllable by spark advance.** It may or may not be recurrent and repeatable.

---

* Autoignition: The spontaneous ignition and the resulting very rapid reaction of a portion or all of the fuel-air mixture. The flame speed is many, many times greater than that which follows normal spark ignition. There is no time reference for autoignition.

** For the purpose of this program, it is not intended that surface ignition knock be identified by manipulation of the spark advance.

2. The following definitions of knock intensity were specifically adopted for use in this technique:

   a. No Knock: This means no spark knock or surface ignition knock.

   b. Borderline Knock: This means spark knock of lowest audible intensity, recurrent surface ignition knock of borderline intensity, or infrequent (three or less) surface ignition knocks regardless of intensity.

   c. Above Borderline Knock: This means greater than borderline spark knock, recurrent surface ignition knock greater than borderline intensity, or frequent (four or more) surface ignition knocks regardless of intensity.

   d. After-Run: The engine continues to operate after the ignition is turned off.

3. Definition of Accelerations

   Accelerations are made at full-throttle and part-throttle conditions which are defined below:

   a. Full-Throttle Acceleration: Full throttle consists of accelerations carried out under maximum or wide-open throttle as specified in the following procedure:

      1) Maximum Throttle: The throttle is depressed and held at detent throughout the acceleration at a position of minimum manifold vacuum for the desired gear (highest gear or passing gear operation for automatic transmissions). The minimum manifold vacuum obtainable on a given model is determined by the transmission characteristics.

      2) Wide-Open Throttle: The throttle is depressed through the downshift point on automatic transmissions and held at the limit of pedal travel throughout the acceleration.

   b. Part-Throttle Acceleration: The throttle is depressed and regulated throughout the acceleration to maintain a desired constant manifold vacuum. This constant manifold vacuum will exceed that obtained at "maximum throttle" and will be within the specified vacuum range of investigation for this program.

## C. VEHICLE PREPARATION

The following vehicle preparation steps should be completed before any octane tests are run. Detailed procedures for each adjustment can be found in the manufacturers' shop manuals.

1. Record vehicle identification number and emission control type, Federal, Altitude or California. Fill in heading on data sheet DFMF-11-1178.

2. Inspect all vacuum lines and air pump hoses for appropriate connections. Also check to see if PCV valve, distributor vacuum delay valve, EGR valve and heated inlet air mechanism are functioning. Engine must be warmed up for these checks. If manufacturers' procedures are not provided, check distributor vacuum delay according to Figure 1.

3. Record engine idle speed and observe anti-dieseling solenoid operation. Adjust to manufacturers' recommended specifications as specified on the under-hood decal.

4. Observe and record basic spark timing at recommended engine speed. Adjust to manufacturers' recommended setting as specified on the under-hood decal.

5. Crankcase oil, radiator coolant, automatic transmission fluid, and battery fluid levels shall be maintained as recommended by the manufacturer.

6. A calibrated tachometer graduated in 100 rpm (or smaller) increments and capable of indicating engine speed from 0-5000 rpm shall be installed on each vehicle.

7. One calibrated vacuum gage, graduated in one-half inch of mercury (or smaller) increments and capable of indicating vacuum from 0-24 inches of mercury shall be connected to the intake manifold.

8. An auxiliary fuel system shall be provided to supply test fuels to the engine. Caution shall be taken to avoid placing auxiliary fuel lines in locations which promote vapor lock. If cars with carbureted engines have tank return fuel lines, this return line should be blocked off. Evaporative control systems should be isolated by disconnecting line from fuel tank and the carburetor float bowl if the car is so equipped. Instructions for fuel handling with fuel injection systems is shown in the Appendix.

9. Before starting the octane number requirements tests, a sample of the tank gasoline shall be withdrawn for determination of Research and Motor method octane number ratings.

# D. TEST PROCEDURE

## 1. Engine Warm-Up

a. To stabilize engine temperatures, a minimum of ten miles of warm-up is required. The test vehicle should be operated at 55 mph in top gear with a minimum of full-throttle operation.

b. During the warm-up period, the general mechanical condition of the vehicle should be checked to insure satisfactory and safe operation during test work.

## 2. Fuel Change-Over

Caution: Because of the installation of catalytic devices on these cars, permanent damage may result if the engine runs over lean or stalls. Therefore, change-over from one fuel to another must be accomplished without running the carburetor or fuel injection system dry. Fuel handling procedures for cars equipped with fuel injection systems are explained in Attachment 1.

To eliminate contamination of the new fuel with residual amounts of the previous fuel, the car will be operated under the following conditions after charging with the new fuel: operate car for 2 miles at a maximum speed of 55 mph during which time four part-throttle accelerations at approximately 4" Hg manifold vacuum are made.

After fuel change-over, make one preliminary acceleration before beginning Vehicle Rating Procedure.

## 3. Details of Observations

### a. Operating Conditions

All octane number requirements will be determined under level road acceleration conditions. Cars equipped with free wheeling or overdrive units shall be tested with this unit (free wheeling or overdrive) locked out of operation. Cars with three-speed and four-speed transmissions shall be run in highest gear. Five-speed transmissions shall be run in fourth gear and automatic transmissions shall be run in "Drive". Test accelerations will be made as described below under 3 d.

Tests will be conducted on moderately dry days preferably at ambient temperatures above 60°F. Tests should not be conducted during periods of high humidity such as prevail when rain is threatening or during or immediately after a rain storm. Laboratories with control capabilities should target for 70°F air temperature and 50 grains of water per pound of dry air whenever possible.

Air conditioned cars will be tested with air conditioner set at the temperature setting to assure continuous compressor operation and on low fan position.

b. Order of Fuel Testing

1. Tank
2. FBRSU
3. FBRU
4. Primary

c. Determination of Knock Intensity

Octane requirements will be established by evaluating the occurrence of knock in terms of knock intensity: "N" for none, "B" for borderline, and "A" for above borderline. Establishment of representative knock intensity for a given fuel will be accomplished with the fewest number of accelerations possible. As defined below, the first two duplicating accelerations are sufficient with "N" and "B" knock intensity.

| Number of Accelerations | | | Representative Rating |
|---|---|---|---|
| 1 | 2 | 3 | |
| N | N | – | N |
| N | B | N | N |
| N | B | B | B |
| B | N | B | B |
| B | B | – | B |
| B | A | – | A |
| A | – | – | A |

All subsequent accelerations will normally be discontinued when "A" knock intensity is experienced and testing continued with a higher octane number fuel in that series. An exception will be made if "A" knock is experienced on the highest octane fuel which knocks in the engine. In this case, it may be necessary to run additional accelerations to determine the speed of maximum knock intensity. If "A" knock is experienced at initiation of acceleration, as limited by transmission characteristics, this speed will be considered the speed of maximum knock. Otherwise, the mid-point between knock-in and knock-out will be considered the speed of maximum knock. When establishing knock-in and knock-out, back off on the throttle between points to eliminate "A" knock.

d. Determination of Maximum Octane Requirement

1) Vehicle Operating Procedure (for driver)

a) For establishment of transmission characteristics, obtain downshift engine rpm and manifold vacuum at 20, 30, 40 and 50 mph by movement of the throttle through the detent position. Record both engine rpm and manifold vacuum at the downshift point for each speed. The vehicle brakes may be applied lightly, if necessary, to maintain vehicle speed. The minimum speeds obtained here will be used for starting speeds for the accelerations in (b), (c) and (e) below.

b) For maximum throttle requirements, accelerate at maximum throttle from minimum obtainable speed as determined in (a)* up to 3500 rpm if necessary in order to define requirements. Tests should be run to 70 mph unless required to terminate at 55 mph because of legal speed limits. If 3500 rpm cannot be attained in top gear, accelerations shall be discontinued and resumed in the next highest gear from 500 rpm below the engine speed at which top gear accelerations were discontinued.

c) For wide-open throttle requirements in passing gear for vehicles with automatic transmissions, accelerate from minimum obtainable engine speed up to 3500 rpm if necessary in order to define requirements. Tests should be run to 70 mph unless required to terminate at 55 mph because of legal speed limits. In some cases it may be necessary to use maximum throttle to the detent position up to the point where wide-open throttle can be obtained.

---

* Starting speed for accelerations on manual transmission cars should be the lowest speed from which the vehicle will accelerate smoothly and at an acceptable rate, or 750 rpm, whichever is the greater.

d) For those cars with vacuum delay devices, to stablilize vacuum advance before starting each part-throttle acceleration, operate at road load for 40 seconds at the minimum vehicle speed obtainable before downshift from the highest gear for the manifold vacuum under investigation.

e) For part-throttle requirements, accelerate at constant critical manifold vacuum from minimum obtainable speed to 70 mph unless required to terminate at 55 mph because of legal speed limits or until vehicle ceases to accelerate. To obtain critical part-throttle vacuum, operate at road load for 40 seconds at 30 mph and at 50 mph. At each speed move the throttle from 10 inches vacuum or maximum road load vacuum, whichever is lowest, down to 4 inches vacuum in from 3 to 5 seconds for automatic transmissions. Move the throttle from 10 inches vacuum or maximum road load vacuum, whichever is lowest, down to 2 inches vacuum for manual transmissions. Observe the manifold vacuum for maximum knock and use this critical vacuum for all subsequent part-throttle accelerations.

f) Determination of After-Run Characteristics

Determination of the occurrence of after-run will be evaluated on tank fuel. Following the engine warm-up, moderately brake the vehicle to a stop (foot off throttle) and place automatic transmission cars in park position, manual transmission cars in neutral. Immediately turn key to the off position. Note on the data sheet if after-run occurs.

2) Vehicle Rating Procedure (for rater)

Knock rating should be performed while in a normal seated position with floor mats in place.

Step 1 - Using an estimated non-knocking fuel in a given fuel series, investigate for incidence of knock under conditions as described in 3d (1) (b), and 3d (1) (c) above.

Step 2 - If no knock occurs, go to a lower octane number blend in that series and repeat Step 1.

Step 3 - If knock occurs at one or more of the operating conditions in Step 1, then continue investigation at the critical condition(s) with higher octane blends until highest octane fuel giving knock is determined within one octane number or one blend.

Record maximum knock intensity on all fuels and speed of maximum knock intensity on highest octane fuel that knocks.

Step 4 - Using the highest octane blend that knocked in Step 3 (or lowest octane blend in fuel series if no knock), investigate for incidence of part-throttle knock as described in 3d(1)(e).

Step 5 - If no knock occurs with:

<u>FBRU Fuel</u>, investigate for knock with lower octane fuels until maximum part-throttle requirement is defined down to the limit of the lowest octane fuel available.

The above rating procedure is given in arrow diagram form on page 18.

e. <u>Determination of Supplemental Requirement</u>

1) <u>Tank Fuel Observations</u>

Investigate for full-throttle and part-throttle knock as detailed in Item 3d(1). Define maximum knock intensity as per Item 3c. Record maximum knock intensity, speed of maximum knock intensity and manifold vacuum at each operating condition. Determine after-run characteristics as described in Item 3d(1)(f).

2) <u>Octane Number Requirement Over Speed Range</u>

Octane requirements over the speed range will be obtained on primary reference fuels only. These will be established by recording the knock-in and knock-out points during maxi mum throttle acceleration with each incremental fuel investigated. It may be necessary to test one or two additional lower octane fuels to describe the knocking characteristics over the speed range from minimum obtainable up to 3500 rpm if necessary in order to find the knock-out point. Accelerate at maximum throttle from minimum obtainable speed as determined in 3d(1)(a) up to 3500 rpm if necessary in order to define requirements. Tests should be run to 70 mph unless required to terminate at 55 mph because of legal speed limits. If 3500 rpm cannot be attained in top gear, accelerations shall be discontinued and resumed in the next highest gear from 500 rpm below the engine speed at which top gear accelerations were discontinued.

When "A" knock is experienced, continue the acceleration but back off on the throttle to maintain "B" knock until just prior to the knock-out point.

## E. INTERPRETATION OF DATA

The data will be recorded on data sheet (DFMF-11 1178). Maximum octane requirements for all reference fuels shall be determined as follows:

1. If the knock intensity of the highest fuel giving knock is borderline, the requirement shall be reported as the octane number of that fuel.

2. If the knock intensity of the highest fuel giving knock is above borderline, the requirement shall be reported as one-half the difference between the fuel giving knock and the next highest fuel.

Speed range data shall be reported on data sheet (DFMF-11-1178) as the engine speed of knock-in and knock-out for the octane number of the primary reference fuel tested.

When transferring data to the summary report form, record "no" data as well as "yes" data.

Record data on all fuels tested, even though knock was not encountered. When transferring data to the summary report form (DFMF-15-1178), record results on all fuel series for each throttle condition investigated. Use proper letter designation (see footnotes on summary sheet) to designate requirements outside of the reference fuel limits.

Requirements for the various engine speeds will be determined by fitting a smooth curve through the knock-in and knock-out points on work form (DFMF-12-1178). Primary reference fuel requirements at various engine speeds should be reported to the nearest one-half octane number and recorded on the special speed range summary sheets, (DFMF-25-1178).

It is important that the serial number (or other identifying number) of each vehicle tested be recorded on all data and summary sheets to provide a means of cross-indexing.

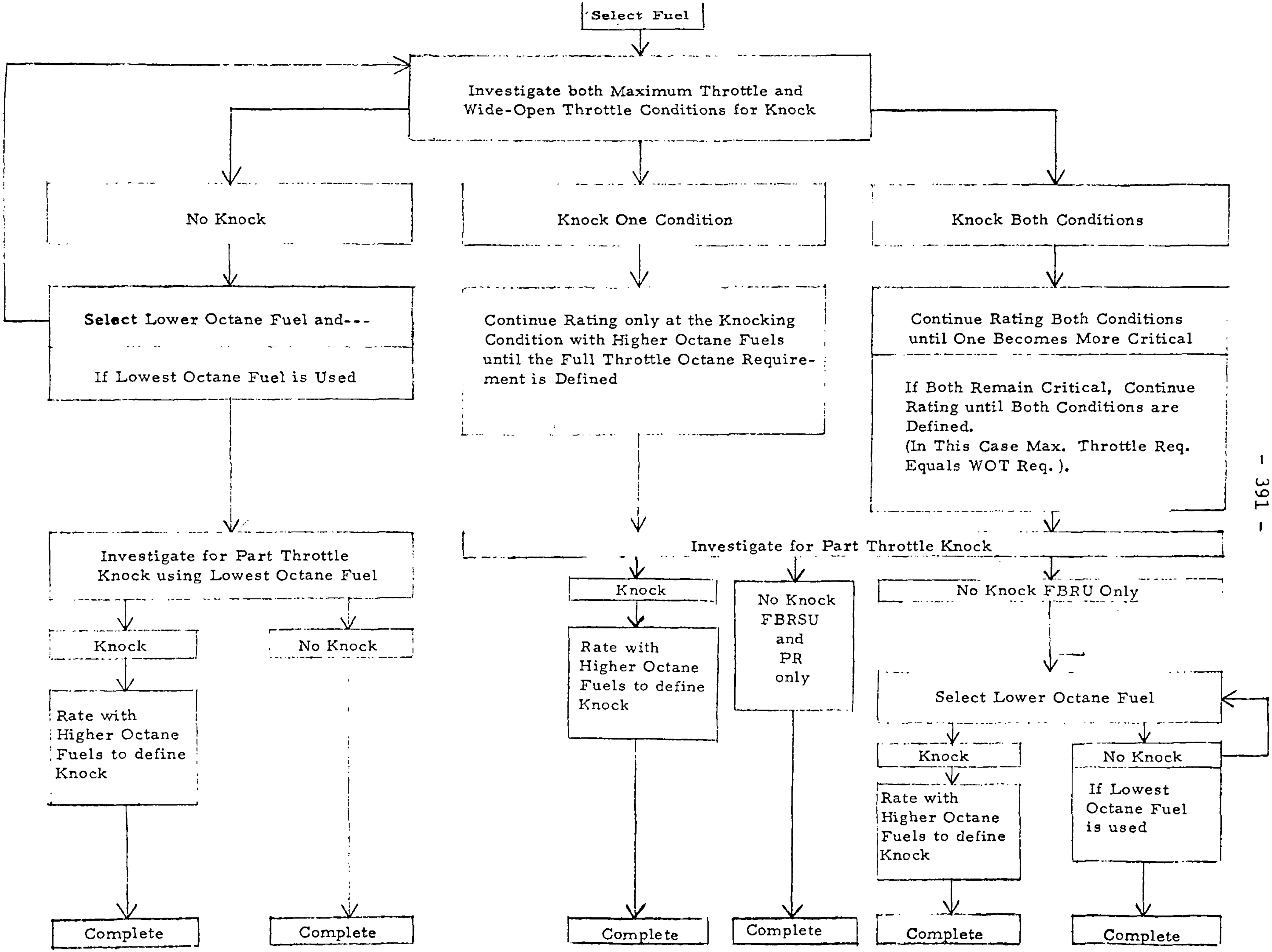
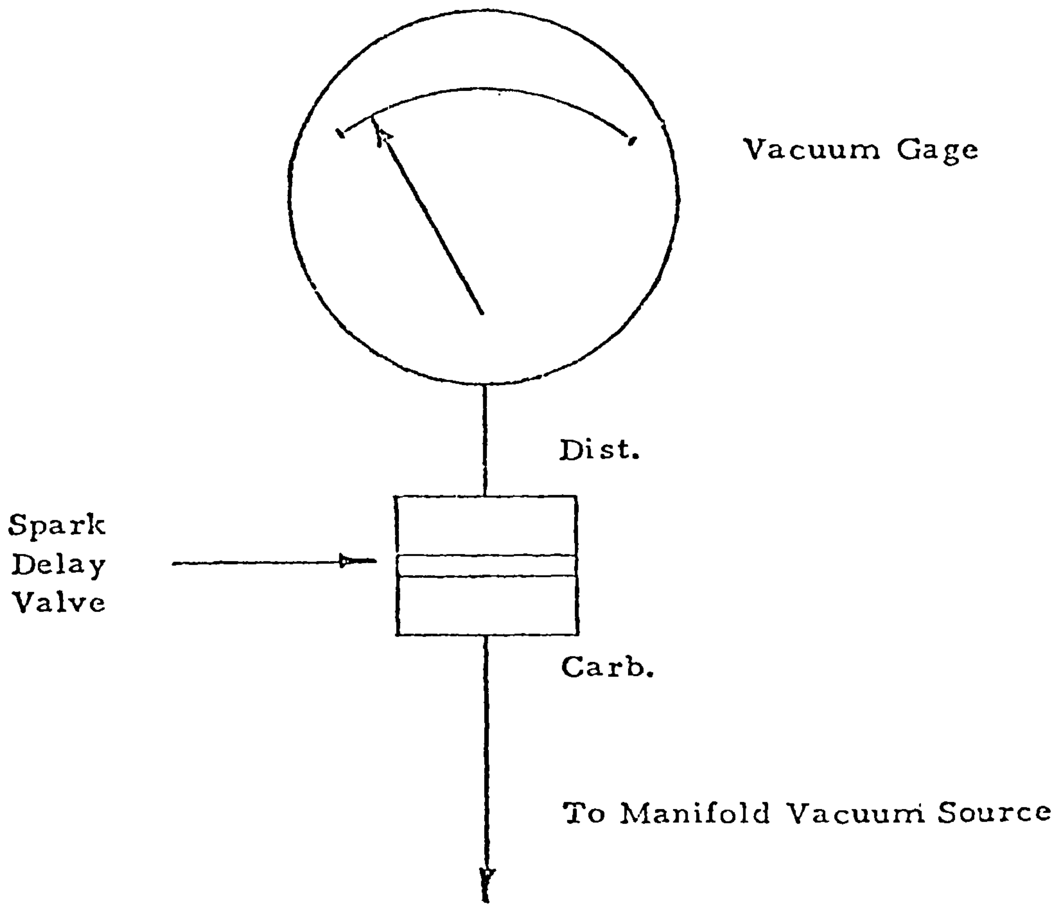

Select Fuel
Investigate both Maximum Throttle and Wide-Open Throttle Conditions for Knock
No Knock
Knock One Condition
Knock Both Conditions
Select Lower Octane Fuel and---
If Lowest Octane Fuel is Used
Continue Rating only at the Knocking Condition with Higher Octane Fuels until the Full Throttle Octane Requirement is Defined
Continue Rating Both Conditions until One Becomes More Critical
If Both Remain Critical, Continue Rating until Both Conditions are Defined. (In This Case Max. Throttle Req. Equals WOT Req.).
Investigate for Part Throttle Knock using Lowest Octane Fuel
Investigate for Part Throttle Knock
Knock
No Knock
Rate with Higher Octane Fuels to define Knock
Complete
Complete
Knock
No Knock FBRSU and PR only
No Knock FBRU Only
Rate with Higher Octane Fuels to define Knock
Select Lower Octane Fuel
Knock
No Knock
Rate with Higher Octane Fuels to define Knock
If Lowest Octane Fuel is used
Complete
Complete
Complete
Complete

Figure 1

SPARK DELAY VALVE FUNCTIONAL TEST




Determine vacuum spark control delay function during tune-up by attaching vacuum gage to distributor side and applying manifold vacuum of at least 10" Hg to carburetor side of device.

APPENDIX
CRC E-15-78

PROCEDURE FOR SETTING UP VEHICLES AND HANDLING REFERENCE FUELS ON VEHICLES EQUIPPED WITH FUEL INJECTION.

1. To run octane requirements on fuel injected vehicles it is necessary to run an external fuel line to the inlet of the vehicle fuel injection pump.

2. The fuel return line from the engine to the fuel tank must be disconnected after the fuel pressure regulator (in engine compartment) and before the fuel tank. An auxiliary line long enough to reach the cans must be added to the fuel return line.

3. Make certain that the fuel tank connections are plugged, this means both the normal fuel pump inlet line and the normal fuel return line connection. On vehicles with an in-tank booster pump, this pump must be shut off so it cannot run during the time the vehicle is operating on the external fuel system. If this pump is not disconnected it will be destroyed.

4. An electric fuel pump (Bendix type acceptable) must be used to draw fuel from the reference fuel can to supply the fuel injection pump on the vehicle. Caution must be exercised to keep the fuel line between the reference fuel cans and the vehicle fuel injection pump full of fuel. If very much air gets into this line, the fuel injection system will become air bound and it is difficult to get the air out of the system.

5. As soon as the fuel injection pump line and fuel return lines have been removed from the vehicle fuel tank, the vehicle can no longer be run on the fuel tank. Any subsequent engine operations will have to be done from an auxiliary fuel tank.

6. It is possible to use three-way valves in the fuel line between the fuel pump and the fuel tank and between the return line and the fuel tank. If they are used, the operator must change the return line valve to the auxiliary fuel system while the engine is shut down to avoid building up excessive pressure in the return line which could do damage to both the fuel pressure regulator and the fuel injection pump.

7. After switching fuel lines to the external fuel cans, the vehicle can no longer be operated on the vehicle fuel tank and all subsequent operations will have to be done from the external system.

8. When changing from one reference fuel to another, the following steps must be followed.

a. Put fuel inlet line in reference fuel tank with the return line going to a slop fuel can. Do not keep fuel inlet line out of a fuel can any longer than is necessary to move it from one can to the next. DO NOT RUN OUT OF FUEL.

b. Observe the fuel stream in the fuel return line. As soon as a steady flow of fuel is observed, move the fuel return line to an empty one quart can. Allow one quart of fuel to flow into this can before inserting the return line into the chosen reference fuel can. This operation should take about 60 seconds.

c. When going to the next reference fuel, it will be necessary to repeat steps a. and b.

The fuel injection pumps on most vehicles pump between 30 and 50 gallons of fuel per hour; therefore, steps a. and b. should be followed very closely or there will be gross reference fuel contamination or you will use a lot more reference fuel than is required to run each test. If steps a. and b. are followed exactly, you will be discarding to slop about two quarts of reference fuel each time you change reference fuels. The two quarts to slop will be at least as much fuel as is consumed to get the reference fuel rating.

# OWNER'S QUESTIONNAIRE

# CRC OCTANE NUMBER REQUIREMENT SURVEY

OWNER:

Your car is being tested for fuel octane number requirements by the Coordinating Research Council activity. To help analyze the data, we would like the person who has recently been driving the car to answer the following questions:

1. Has any engine knock (or ping) been encountered recently?

   ☐ Yes ☐ Occasionally

   ☐ No ☐ Frequently

2. If "yes", was it during any of these conditions?

   ☐ Low Speed ☐ Hill Climbing ☐ Acceleration

   ☐ High Speed ☐ Towing Trailer

3. Did you consider the knock objectionable?

   ☐ Yes ☐ No

4. Did the knock (or ping) occur on the fuel that is now in the tank?

   ☐ Yes ☐ No

5. Does the engine continue to run after the key is turned off?

   ☐ Yes ☐ No

Car Make ______________________ License No. ______________

Serial No. ______________________

## APPENDIX C-2

### RON AND MON FOR FULL-BOILING RANGE OCTANE RATING FUELS

| Nominal | High Sensitivity Fuel "CX" | | Lower Sensitivity Fuel "C" | |
|---|---|---|---|---|
| RON | RON | MON | RON | MON |
| 78 | 78.0 | 71.6 | 77.9 | 72.6 |
| 79 | --- | --- | 78.9 | 73.4 |
| 80 | 80.0 | 73.4 | 80.1 | 74.5 |
| 81 | --- | --- | 81.0 | 75.3 |
| 82 | 82.1 | 74.8 | 81.9 | 75.9 |
| 83 | --- | --- | 83.0 | 76.8 |
| 84 | 84.0 | 76.4 | 84.1 | 77.7 |
| 85 | 85.3 | 77.1 | 85.0 | 78.5 |
| 86 | 86.2 | 77.5 | 86.1 | 79.2 |
| 87 | 87.3 | 78.1 | 87.0 | 80.0 |
| 88 | 88.3 | 79.0 | 88.1 | 80.5 |
| 89 | 89.2 | 79.5 | 89.0 | 81.3 |
| 90 | 90.0 | 80.2 | 90.1 | 82.2 |
| 91 | 91.1 | 80.7 | 91.1 | 83.0 |
| 92 | 92.0 | 81.4 | 92.1 | 83.7 |
| 93 | 93.0 | 82.2 | 93.1 | 84.3 |
| 94 | 94.2 | 83.0 | 94.1 | 85.0 |
| 95 | 95.2 | 84.0 | 95.0 | 85.8 |
| 96 | 96.1 | 84.3 | 96.1 | 86.8 |
| 97 | 97.2 | 85.2 | 97.1 | 87.5 |
| 98 | 98.1 | 86.1 | 98.0 | 88.4 |
| 99 | 99.1 | 87.1 | 99.0 | 89.4 |
| 100 | 100.0 | 88.0 | 100.0 | 90.1 |
| 101 | 101.0 | 89.0 | 100.9 | 91.2 |

# APPENDIX C-3

## Zero Mile (Clean Engine Octane Ratings - MAD

| | | Box Off | | Box On | | |
|---|---|---|---|---|---|---|
| Series | RON | Rating | 40-70 mph Acceleration Time (Sec) | Rating | °Retard | 40-70 mph Acceleration Time (Sec) |
| CX | 86 | NK | 16.6 | NK | 2.5° | 16.5 |
| | 85 | $T^-$ | 16.2 | NK | 2.5-4° | 17.0 |
| | 84 | T | 16.2 | $T^-$ | 4° | 17.0 |
| | 82 | $VL^-$ | 16.0 | $T^-$ | 7° | 18.0 |
| | 80 | | | T | 8.5° | 18.7 |
| C | 85 | NK | 16.5 | NK | 2.5° | 16.6 |
| | 84 | $T^-$ | 16.4 | $T^-$ | 2.5° | 16.6 |
| | 83 | T | 16.7 | $T^-$ | 4-5.5° | 18.0 |
| | 82 | $T^+$ | 17.4 | $T^-$ | 4.7° | 18.5 |
| | 81 | $VL^-$ | 16.0 | $T^-$ | 5.5° | 18.0 |
| | 80 | | | T | 8.5° | 19.0 |
| | 79 | | | $T^+$ | 8.5-10° | 19.2 |
| P | 83 | NK | 19.8 | NK | 0-2.5° | 19.6 |
| | 82 | $T^-$ | 18.4 | $T^-$ | 4-5.5° | 20.5 |
| | 81 | T | 18.7 | $T^-$ | 5.5° | 20.8 |
| | 80 | $VL^-$ | 17.8 | T | 5.5-10° | 21.8 |

## APPENDIX C-4

### Zero Mile (Clean Engine) Octane Ratings - Track (Road)

| | | Box Off | | Box On | | |
|---|---|---|---|---|---|---|
| Series | RON | Rating | 40-70 mph Acceleration Time (Sec) | Rating | °Retard | 40-70 mph Acceleration Time (Sec) |
| CX | 86 | NK | 13.7 | NK | 0° | 13.8 |
| | 85 | T⁻ | 13.6 | T⁻ | 0° | 13.7 |
| | 84 | T | 13.8 | T⁻ | 2.5-4° | 14.1 |
| | 82 | | | T⁻ | 5.5-7° | 16.0 |
| | 80 | | | T | 8.5-10° | 18.0 |
| C | 84 | NK | 14.5 | NK | 0° | 14.2 |
| | 83 | T⁻ | 14.2 | NK | 2.5-4° | 14.9 |
| | 82 | T | 14.5 | T⁻ | 5.5° | 15.3 |
| | 80 | | | T⁻ | 7° | 16.3 |
| | 79 | | | T⁻ | 8.5° | 16.9 |
| | 78 | | | T | 8.5-10° | 17.2 |
| P | 83 | NK | 15.2 | NK | 2.5° | 16.2 |
| | 82 | T⁻ | 14.9 | NK | 2.5-4° | 15.9 |
| | 81 | T | 15.0 | T⁻ | 4-5.5° | 16.5 |
| | 80 | | | T⁻ | 5.5° | 16.5 |
| | 79 | | | T | 8.5-10° | 17.5 |

## APPENDIX C-6

### OCTANE REQUIREMENT OF VEHICLE ON MAD DURING MILEAGE ACCUMULATION

#### 6,000 Miles

| | Uncontrolled Spark | | Controlled Spark | | |
|---|---|---|---|---|---|
| Fuel RON | Rating | Acc. Time (sec) | Rating | ° Retard | Acc. Time (sec) |
| C 85 | NK | 17.5 | NK | 0 | 17.5 |
| 83 | T⁻ | 17.7 | T⁻ | 0 | 17.8 |
| 82 | T | 17.7 | T⁻ | 5.5 | 19.8 |
| 81 | T⁺ | 17.2 | T- | 7 | 20.0 |
| 80 | | | T | 8.5-10 | 22.3 |

#### 8,000 Miles

| Fuel RON | Rating | Acc. Time (sec) | Rating | ° Retard | Acc. Time (sec) |
|---|---|---|---|---|---|
| 87 | NK | 15.1 | NK | 0 | 15.0 |
| 86 | T⁻ | 15.5 | NK | 2.5 | 16.0 |
| 85 | T | 15.1 | T⁻ | 4 | 16.0 |
| 84 | | | T⁻ | 4 | 16.5 |
| 83 | | | T- | 5.5-7 | 17.3 |
| 82 | | | T⁻ | 4-7 | 16.8 |
| 81 | | | T | 8.5 | 17.5 |
| 80 | | | T⁺ | 8.5-10 | 18.7 |

#### 10,000 Miles

| Fuel RON | Rating | Acc. Time (sec) | Rating | ° Retard | Acc. Time (sec) |
|---|---|---|---|---|---|
| 88 | NK | 15.8 | NK | 0 | 15.8 |
| 87 | T⁻ | 15.3 | NK | 2.5 | 15.4 |
| 86 | T- | 15.6 | T- | 2.5-4 | 16.0 |
| 85 | T | 15.4 | T⁻ | 5.5 | 16.5 |
| 84 | T⁺ | 15.8 | T⁻ | 5.5 | 16.9 |
| 83 | | | T⁻ | 5.5-7 | 17.3 |
| 82 | | | T | 7° | 18.1 |
| 81 | | | T⁺ | 8.5 | 18.3 |

## APPENDIX C-7

### Octane Requirement of Vehicle on MAD @ 12,000 Miles

| Series | RON | Uncontrolled Spark Rating | Uncontrolled Spark Acc. Time(sec.) | Controlled Spark Rating | Controlled Spark ° Retard | Controlled Spark Acc. Time |
|---|---|---|---|---|---|---|
| CX | 88 | NK | 16.3 | NK | 0 | 16.6 |
| | 87 | T⁻ | 16.2 | NK | 2.5 | 16.8 |
| | 86 | T⁻ | 16.3 | NK | 2.5 | 16.5 |
| | 84 | | | T⁻ | 4-5.5 | 17.5 |
| | 82 | | | T | 7-8.5 | 19.0 |
| C | 88 | NK | 15.6 | NK | 0 | 15.7 |
| | 87 | T⁻ | 16.2 | T⁻ | 0° | 15.8 |
| | 86 | T | 16.2 | T⁻ | 4° | 17.0 |
| | 85 | T⁺ | 16.8 | T⁻ | 4° | 17.2 |
| | 84 | | | T | 4° | 17.0 |
| | 83 | | | T | 5.5 | 17.0 |
| | 82 | | | T | 7-8.5 | 18.7 |
| | 81 | | | T⁺ | 8.5 | 18.2 |
| P | 85 | NK | 17.0 | NK | 0 | 17.2 |
| | 84 | T⁻ | 17.1 | NK | 0-2.5 | 17.3 |
| | 83 | | | NK | 2.5-4 | 17.9 |
| | 82 | | | T⁻ | 4 | 18.4 |
| | 81 | | | T | 4-7 | 19.2 |
| | 80 | | | T | 5.5-7 | 19.7 |

# APPENDIX C-8

## Octane Requirement of Vehicle on Road @ 12,000 Miles

| | | Uncontrolled | | Controlled Spark | | |
|---|---|---|---|---|---|---|
| Series | RON | Rating | Acc. Time(sec.) | Rating | ° Retard | Acc. Time(sec.) |
| CX | 85 | NK | 14.7 | NK | 0 | 15.0 |
| | 84 | $T^-$ | 14.6 | $T^-$ | 0 | 14.3 |
| | 82 | $T^+$ | 14.5 | $T^-$ | 0-4° | 14.8 |
| | 80 | | | $T^+$ | 5.5-7 | 16.0 |
| | 78 | | | VL | 5.5-8.5 | 17.0 |
| C | 83 | NK | 15.3 | NK | 0 | 15.5 |
| | 81 | $T^-$ | 15.1 | NK | 2.5-4 | 16.0 |
| | 80 | T | 15.3 | $T^-$ | 2.5-4 | 16.4 |
| | 79 | $T^+$ | 15.5 | T | 4-7 | 16.7 |
| | 78 | | | T | 5.5-7 | 17.2 |
| P | 82 | NK | 15.5 | NK | 0 | 15.5 |
| | 81 | $T^-$ | 15.1 | NK | 0-2.5 | 15.3 |
| | 80 | T | 15.1 | NK | 2.5-4 | 15.5 |
| | 78 | | | T | 5.5 | 16.5 |
| | 77 | | | $T^+$ | 7-8.5 | 18.5 |

## APPENDIX C-9

### Vehicle Octane Requirement on MAD After 4,000 Mile AMA Cycle*

| | | Uncontrolled Spark | | Controlled Spark | | |
|---|---|---|---|---|---|---|
| Fuel | RON | Rating | Acc. Time(sec) | Rating | ° Retard | Acc. Time(sec) |
| C | 88 | NK | 16.8 | NK | 0 | 16.0 |
| | 87 | $T^-$ | 15.8 | NK | 4° | 16.2 |
| | 86 | $T^-$ | 16.0 | $T^-$ | 4° | 16.2 |
| | 84 | T | 16.1 | $T^-$ | 2.5 | 16.0 |
| | 83 | $T^+$ | 15.4 | $T^-$ | 4° | 15.7 |
| | 81 | VL | 15.4 | T | 7° | 16.3 |
| P | 83 | NK | 17.7 | NK | 2.5 | 17.9 |
| | 82 | $T^-$ | 17.8 | $T^-$ | 2.5 | 17.8 |
| | 81 | T | 17.9 | $T^-$ | 4 | 18.2 |
| | 80 | | | T | 5.5 | 18.1 |
| | 78 | | | $T^+$ | 10° | 19.0 |

* Delay -1 is 128 Engine Revolution, Delay -2 is 32 revolutions. Threshold is 100 mV.

## APPENDIX C-10

### Vehicle Octane Requirement on Road After 4,000 Mile AMA Cycle*

| | | Uncontrolled Spark | | Controlled Spark | | |
|---|---|---|---|---|---|---|
| Fuel | RON | Rating | Acc. Time(sec) | Rating | ° Retard | Acc. Time(sec) |
| C | 84 | NK | 13.7 | NK | 2.5 | 14.0 |
| | 83 | $T^-$ | 13.9 | NK | 2.5-4 | 14.0 |
| | 82 | T | 13.6 | $T^-$ | 4-5.5 | 14.0 |
| | 80 | VL | 13.8 | T | 8.5 | 14.7 |
| | 79 | | | T | 8.5-10 | 14.7 |
| | 78 | | | $T^+$ | 8.5-10 | 14.9 |
| CX | 86 | NK | 13.9 | NK | 0 | 13.8 |
| | 85 | $T^-$ | 14.0 | NK | 4° | 14.2 |
| | 84 | T | 14.3 | NK | 4-5.5 | 14.1 |
| | 80 | | | T | 8.5-10 | 15.2 |
| P | 84 | NK | 14.4 | NK | 2.5 | 14.6 |
| | 83 | $T^-$ | 14.2 | NK | 2.5 | 14.6 |
| | 82 | T | 14.7 | $T^-$ | 4-5.5 | 14.7 |
| | 81 | $T^+$ | 14.6 | T | 4-7 | 14.7 |
| | 79 | | | T | 7-10 | 15.0 |
| | 77 | | | T | 10 | 15.2 |

* Delay -1 is 128 Engine Revolutions, Delay -2 is 32 Engine Revolutions. Threshold is 100 mV.

# APPENDIX C-11

## Vehicle Octane Requirement on MAD with 12° BTC Basic Timing*

| | | Uncontrolled Spark | | Controlled Spark | | |
|---|---|---|---|---|---|---|
| Fuel | RON | Rating | Acc. Time(sec) | Rating | ° Retard | Acc. Time(sec) |
| C | 90 | NK | 15.3 | NK | 0° | 15.1 |
| | 89 | $T^-$ | 15.4 | NK | 2.5 | 15.3 |
| | 88 | $T^-$ | 15.7 | NK | 2.5 | 15.7 |
| | 87 | T | 16.0 | $T^-$ | 2.5-4 | 16.1 |
| | 85 | VL | 15.4 | T | 5.5 | 15.9 |
| | 83 | | | T | 8.5-10 | 15.9 |

* Delay-1 is 128 engine revolutions; Delay-2 is 32 engine revclutions.
Threshold 100 mV.

# APPENDIX D

# DRIVEABILITY TESTING

D-1 Driveability Fuels

D-2 CRC Driveability Test Procedure

D-3 Driveability Test Results

## APPENDIX D-1

## DRIVEABILITY FUELS

| Fuel | D-1 | D-2 | D-3 | D-4 |
|---|---|---|---|---|
| RVP, psi | 7.03 | 6.87 | 11.92 | 11.18 |
| (D+L) at 158°F | 9.9 | 10.0 | 25.8 | 32.5 |
| (D+L) at 212°F | 47.7 | 65.7 | 46.5 | 64.5 |
| (D+L) at 302°F | 87.9 | 92.9 | 85.5 | 93.5 |
| RON | 93.5 | 94.2 | 98.2 | 95.0 |
| MON | 86.4 | 85.3 | 86.9 | 85.9 |

All fuels are unleaded

# APPENDIX D-2

## Proposed
## CRC Driveability Test Procedure
## (Adapted from AMA Procedure)

I. Cold Start and Driveaway Procedure (Data Sheets 1, 2, and 3)

A. Record all necessary vehicle and test information on data sheet 1.

B. Start engine per Owner's Manual Procedure and record start time.

C. Record engine speed, intake vacuum, and idle quality in Neutral or Park immediately after start, with foot removed from throttle pedal (fast idle cam).

D. If engine stalls, repeat steps B and C.

E. After 5 seconds from start, accelerate engine briefly, and again release throttle; record engine speed, intake vacuum, idle quality, and/or number of stalls. If engine stalls, repeat steps B through E.

F. After 10 seconds from start, apply brakes, shift to normal drive range, and record engine speed, intake vacuum, idle quality, and stalls.

G. After 15 seconds from start, make a light throttle acceleration to 25 mph at a constant throttle opening beginning at a predetermined intake vacuum.* Cruise at 25 mph for 0.1 mile (to check for choke loading), open throttle to detent* and accelerate from 25 to 35 mph at constant throttle in top gear. Decelerate to a stop and accelerate WOT to 35 mph. Decelerate to 10 mph and accelerate 10 to 25 mph constant throttle, beginning at a predetermined intake vacuum.

H. Observe and record any malfunctions such as the following:

1. Hesitations
2. Stumbles
3. Surge
4. Stalls
5. Backfires

I. At 0.5 miles from start, brake moderately to a stop. Idle for 30 seconds in drive range and record engine speed, intake vacuum, and idle quality.

J. Repeat steps G, H, and I through 1.5 miles from start (3 cycles).

---

* All light throttle accelerations are begun by opening the throttle to an initial vacuum which just precedes power enrichment, as indicated by carburetor flow curves. All detent accelerations are begun by opening the throttle to the downshift position as indicated by transmission shift characteristic curves.

K. Make a light throttle acceleration to 45 mph at constant vacuum beginning at a predetermined intake vacuum (crowd condition to check lean operation with choke off). Decelerate 45 to 25 mph, open throttle to detent and accelerate from 25 to 35 mph at constant throttle in top gear. Decelerate to a stop and accelerate WOT to 35 mph. Decelerate to 10 mph and accelerate 10 to 25 mph constant throttle, beginning at a predetermined intake vacuum. Repeat steps H and I above.

L. Repeat step K through 6.4 miles from start (7 cycles).

II. Warm Vehicle Driveability Procedure (Data Sheet 4)

A. Warm up vehicle for about 10 miles at 70 mph.

B. Evaluate curb idle in Neutral and Drive range. Record engine speed, intake vacuum, and idle quality.

C. With transmission in drive range, apply brakes securely and open throttle at a uniform rate to WOT (about 20 sec), allowing transmission torque converter to absorb all of the engine's power. Record any hesitation. stumble, surge, or stall.

D. Cruise at road load from 20 through 70 mph, and record stretchiness and surge.

E. Accelerate WOT from 0 to 30 mph at sudden, moderate, and slow throttle opening rates. Record hesitation, stumble, and surge.

F. Accelerate PT from 0 to 30 mph at constant throttle positions of 1/4, 1/2, and 3/4 throttle, beginning each acceleration at a predetermined intake vacuum. Record hesitation, stumble, and surge.

G. Part throttle crowds are evaluated in high gear at constant vacuum from the minimum speed attainable in high gear to 70 mph (or the maximum speed at each vacuum if less than 70 mph). Several runs are made at different vacuums to determine the worst surge condition. Also record hesitations and stumbles.

H. Evaluate "tip-in" characteristics by making several PT accelerations in high gear from 20 and 30 mph. Do not accelerate at a load which will cause the automatic transmission to downshift. Record hesitations and stumbles.

I. Accelerate WOT from 0 to 70 mph and record acceleration time. Drive 5 miles at 70 mph and brake moderately to a stop. Idle for 30 seconds, shut off engine, and soak for 15 minutes.

J. After hot soak, restart engine according to manufacturer's hot-start procedure (record start time and number of attempts), return to idle, maintain idle for 60 seconds in Neutral (record engine speed, intake vacuum, and idle quality). If engine stalls during the 60 sec. idle, repeat this hot-start and run procedure.

## Definitions of Driveability Terms

1. Road Load -- A fixed throttle position which maintains a constant vehicle speed on a level road.

2. Wide Open Throttle (WOT) Acceleration -- An acceleration made entirely at wide open throttle (from any speed).

3. Part Throttle (PT) Acceleration -- An acceleration made at any throttle position less than WOT.

4. Tip-In -- A maneuver to evaluate vehicle response (up to two seconds in duration) to the initial opening of the throttle.

5. Crowd -- An acceleration made at a constant intake vacuum (continually increasing throttle opening).

6. Idle Quality -- An evaluation of vehicle smoothness with the engine idling, as judged from the driver's seat.

7. Backfire -- An explosion in the induction or exhaust system.

8. Hesitation -- A temporary lack of initial response in acceleration rate.

9. Stumble -- A short, sharp reduction in acceleration rate.

10. Stretchiness -- A lack of anticipated response to throttle movement. This may occur on slight throttle movement from road load or during light to moderate accelerations.

11. Surge -- A continued condition of short, sharp fluctuations in power. These may be cyclic or random and can occur at any speed and/or load. Surge is usually caused by over-lean carburetor mixtures.

APPENDIX D-3

Date 10/12/75

Test Number 4

Fuel CR #29553-D-1

Proposed CRC

Driveability Test

Sheet 1 of 4

## Test Vehicle

Make CHEVROLET

Model NOVA #26

Year 1975

Transmission TURBO HYDRAMATIC

A/C NO PB NO PS YES

License No. 735 CPV N.J

Engine Type V-8

Displacement 350 CID

Nominal C.R. 8.5

Carb. Make ROCHESTER No. Bbls. 4

Emission Control System CAL

Odometer: Start 13857 Finish 13880

## Weather

C.T.R. ~~Ambient~~ Temp.: Start 20 °F Finish 69 °F

Observed Barom.: Start 30.03 in. Hg Finish 30.03 in. Hg

Relative Humidity: Start ___ % 68-56 Finish ___ % 69-58

CLAYTON ~~Road Conditions: Wet~~ ___
Dry ___

Time: Start 1:30 Finish 2:10

Soak Time (hrs.) 2½ HRS

Soak Temp. (°F) 70

## Test Crew

Driver WESLEY HOWARTH

Recorder SAMUEL IRWIN

Observers GEORGE BARNES

## Remarks

License 735 CPV N.J
#2 1975 NOVA #26



## Cold Start-Driveaway

T # 4

| Start Miles | Mode | | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Accel. or Cruise: Satis. | Accel. or Cruise: Hesit.* | Accel. or Cruise: Stumble* | Accel. or Cruise: Surge* | Accel. or Cruise: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start Time (sec.) | 5.0 | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Fast-Idle Cam | | 1300 | 20.1 | | T | | | | | | | |
| | Tap Th. (5 sec. from St.)N | | 1450 | 20.9 | ✓ | | | | | | | | |
| | (10 sec. from Start)Dr | | 900 | 15.9 | ✓ | | | | | | | | |
| ) | PT (0-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| ).1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| ).2 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| ).3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| ).4 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| ).5 | Idle (30 sec.): Dr | | 690 | 16.5 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| ).6 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| ).7 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| ).8 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| ).9 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .0 | Idle (30 sec.): Dr | | 690 | 16.2 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| .2 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| .3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| .4 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .5 | Idle (30 sec.): Dr | | 700 | 16.2 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | 12" | | | | | | ✓ | | | | | |
| .9 | PT (25-35): Th. to FULL Detent | | 4" | | | | | | T | | | | |
| .0 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| .1 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .2 | Idle (30 sec.): Dr | | 700 | 16.2 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | 12" | | | | | | ✓ | | | | | |
| .6 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| .7 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| .8 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |

License
735 CPV N.5
S#3 1975 NOVA #20



Cold Start-Driveaway

| Start Miles | T#4 Mode | Idle Engine Speed rpm | Idle Intake Vacuum in. Hg | Idle Satis. | Idle Rough* | Idle Stall | Acceleration Satis. | Acceleration Hesit.* | Acceleration Stumble* | Acceleration Surge* | Acceleration Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 700 | 16.2 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 4.3 | Idle (30 sec.): Dr | 700 | 16.2 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 700 | 16.2 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 700 | 16.2 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 6.1 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 700 | 16.2 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments:

License 735 CPV N.S

#4 1975 NOVA #26



## Warm Vehicle Evaluation

T#4

| Mode | | Accel. or Tip-In: Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load: Satis. | Stretchy | Surge* | Idle: Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 890 | 18.9 | ✓ | | | |
| | Dr | | | | | | | | | 690 | 16.0 | ✓ | | | |
| WOT Against T.C. | | ✓ | | | | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | ✓ | | | | | | | | |
| | 60 mph | | | | | | | | | | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | | | | | | | | | |
| PT Crowd (Min. ~~60~~ 20 or Max.) | 14 in.Hg | | | | | | | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | |
| | 6 in.Hg | ✓ | | | | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

50 TO 60 T SURGE

12"
9'
6"
20 MPH. MAX

0-60 mph WOT Acceleration (sec.) 8.5

Drive 5 miles at 60 mph; Idle 30 sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 4.0 | Idle in Neutral (60 sec.) | 700 | 17.0 | ✓ | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments:

Date 10/11/75
Test Number 1
Fuel CK #29552-D-2

Proposed CRC
Driveability Test
Sheet 1 of 4

#I

## Test Vehicle

Make CHEVROLET
Model NOVA #26
Year 1975
Transmission TURBO HYDRAMATIC
A/C NO PB NO PS YES
License No. 735 CPV. N.J

Engine Type V-8
Displacement 350 CID
Nominal C.R. 8.5
Carb. Make ROCHESTER No. Bbls. 4
Emission Control System CALF
Odometer: Start 13790 Finish 13813

## Weather

C.T.R ROOM ~~Ambient~~ Temp.: Start 70 °F, Finish 69 °F

Observed Barom.: Start 30.20 in. Hg, Finish 30.19 in. Hg

Relative Humidity: Start ____ % 69-60, Finish ____ % 68-57

CLAYTON ~~Road Conditions~~: ~~Wet~~ ____ Dry ✓

Time: Start 8:30, Finish 9:45

Soak Time (hrs.) 16 HRS
Soak Temp. (°F) 70°

## Test Crew

Driver WESLEY HOWARTH
Recorder SAMUEL IRWIN

Observers JOHN FOWLKS

## Remarks

License 735CPV

#2 1975 NOVA #26



Cold Start-Driveaway

T-#1

| Start Miles | Mode | | Idle | | | | | Accel. or Cruise | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Engine Speed rpm | Intake Vacuum in. Hg | Satis. | Rough* | Stall | Satis. | Hesit.* | Stumble* | Surge* | Stall | Backfire* |
| | Start Time (sec.) | 1.0 | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Fast-Idle Cam | | 1300 | 20.0 | ✓ | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | | 1500 | 21.0 | ✓ | | | | | | | | |
| | (10 sec. from Start)Dr | | 900 | 16.0 | ✓ | | | | | | | | |
| 0 | PT (0-25): Lt. Th. 12" | | | | | | | ✓ | | | | | |
| 0.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.2 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| 0.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.4 | PT (10-25): Lt. Th. 12" | | | | | | | ✓ | | | | | |
| 0.5 | Idle (30 sec.): Dr | | 650 | 16.5 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. 12" | | | | | | | ✓ | | | | | |
| 0.6 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.7 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| 0.8 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.9 | PT (10-25): Lt. Th. 12" | | | | | | | ✓ | | | | | |
| 1.0 | Idle (30 sec.): Dr | | 675 | 16.5 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. 12" | | | | | | | ✓ | | | | | |
| 1.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 1.2 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| 1.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 1.4 | PT (10-25): Lt. Th. 12" | | | | | | | ✓ | | | | | |
| 1.5 | Idle (30 sec.): Dr | | 675 | 16.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | | ✓ | | | | | |
| 1.9 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| 2.0 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.1 | PT (10-25): Lt. Th. 12" | | | | | | | ✓ | | | | | |
| 2.2 | Idle (30 sec.): Dr | | 675 | 16.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | | ✓ | | | | | |
| 2.6 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| 2.7 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.8 | PT (10-25): Lt. Th. 12" | | | | | | | ✓ | | | | | |

License 735CPV N.J



#3 1975 NOVA #26

## Cold Start-Driveaway

| Start Miles | T #1 Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Acceleration: Satis. | Acceleration: Hesit.* | Acceleration: Stumble* | Acceleration: Surge* | Acceleration: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 700 | 16.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 4.3 | Idle (30 sec.): Dr | 700 | 16.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 700 | 16.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 700 | 16.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12' | | | | | | ✓ | | | | | |
| 6.1 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 700 | 16.5 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments:

License 735 CPY NJ

#4 1975 NOVA #26



Warm Vehicle Evaluation

| T#1 Mode | | Accel. or Tip-In Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load Satis. | Stretchy | Surge* | Idle Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 880 | 19.1 | ✓ | | | |
| | Dr | | | | | | | | | 690 | 16.2 | ✓ | | | |
| WOT Against T.C. | | ✓ | | | | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | ✓ | | | | | | | | |
| | 60 mph | | | | | | ✓ | | | | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | 12" | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | 9" | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | 6" | | | | | | | | |
| PT Crowd (Min. 60 or Max.) 20 TO 60 | 14 in.Hg | | | | | | MAX 20MPH | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | |
| | 6 in.Hg | ✓ | | | | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

0-60 mph WOT Acceleration (sec.) 8.4

Drive 5 miles at 60 mph; Idle 30 sec. N; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 4.0 | Idle in Neutral (60 sec.) | 705 | 17.9 | ✓ | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments:

Date 10/12/75
Test Number 3
Fuel CK #29551-D-3

Proposed CRC
Driveability Test
Sheet 1 of 4

Test Vehicle

Make CHEVROLET
Model NOVA #26
Year 1975
Transmission TURBO HYDRAMATIC
A/C NO PB NO PS YES
License No. 735 CPV N.S.

Engine Type V-8
Displacement 350 CID
Nominal C.R. 8.5
Carb. Make ROCHESTER No. Bbls. 4
Emission Control System CAL
Odometer: Start 13832 Finish 13857

Weather

CTR. ~~Ambient~~ Temp.: Start 70 °F, Finish 69 °F

Observed Barom.: Start 30.05 in. Hg, Finish 30.03 in. Hg

Relative Humidity: Start ___ % 70-60, Finish ___ % 68-58

CLAYTON ~~Road Conditions: Wet~~ ___ Dry ___

Time: Start 8:55, Finish 10:05

Soak Time (hrs.) 16 HR
Soak Temp. (°F) 70

Test Crew

Driver WESLEY HOWARTH
Recorder SAMUEL IRWIN
Observers GEORGE BARNES

Remarks

License 735 CPV N.J
2 1975 NOVA #26



Cold Start-Driveaway

T#3

| Start Miles | Mode | | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Accel. or Cruise: Satis. | Accel. or Cruise: Hesit.* | Accel. or Cruise: Stumble* | Accel. or Cruise: Surge* | Accel. or Cruise: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start Time (sec.) | 2.0 | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Fast-Idle Cam | | 1150 | 19.0 | ✓ | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | | 1350 | 20.2 | ✓ | | | | | | | | |
| | (10 sec. from Start)Dr | | 900 | 15.5 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| .2 | PT (25-35): Th. to Detent | FULL | 4" | | | | | | ✓ | | | | ✓ |
| .3 | WOT Accel. (0-35) | | | | | | | | | | | ✓ | |
| .4 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .5 | Idle (30 sec.): Dr | | 680 | 16.2 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .6 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| .7 | PT (25-35): Th. to Detent | FULL | 4" | | | | | ✓ | | | | | |
| .8 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| .9 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .0 | Idle (30 sec.): Dr | | 690 | 16.0 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| .2 | PT (25-35): Th. to Detent | FULL | 4" | | | | | ✓ | | | | | |
| .3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| .4 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .5 | Idle (30 sec.): Dr | | 690 | 16.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | 12" | | | | | | ✓ | | | | | |
| .9 | PT (25-35): Th. to Detent | FULL | 4" | | | | | ✓ | | | | | |
| .0 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| .1 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| .2 | Idle (30 sec.): Dr | | 690 | 16.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | 13" | | | | | | | M | T | | | |
| .6 | PT (25-35): Th. to Detent | FULL | 4" | | | | | ✓ | | | | | |
| .7 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| .8 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |

License 735 CPV N.J

S#3 1975 NOVA #26

Cold Start-Driveaway

T#3

| Start Miles | Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Acceleration: Satis. | Acceleration: Hesit.* | Acceleration: Stumble* | Acceleration: Surge* | Acceleration: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 690 | 16.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 4.3 | Idle (30 sec.): Dr | 690 | 16.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 690 | 16.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 690 | 16.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 6.1 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 690 | 16.0 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments:

-ense 735CPV N.V.
#4 1975 NOVA #26



## Warm Vehicle Evaluation

T# 3

| Mode | | Accel. or Tip-In: Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load: Satis. | Stretchy | Surge* | Idle: Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 890 | 18.7 | ✓ | | | |
| | Dr | | | | | | | | | 690 | 15.9 | ✓ | | | |
| WOT Against T.C. | | ✓ | | | | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | ✓ | | | | | | | | |
| | 60 mph | | | | | | | | T | 50 TO 60 T SURGE | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | 12" | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | 9' | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | 6" | | | | | | | | |
| PT Crowd (Min. 60 or Max.) | 14 in.Hg | | | | | | MAX 20 MPH | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | |
| | 6 in.Hg | ✓ | | | | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

0-60 mph WOT Acceleration (sec.) 8.4

Drive 5 miles at 60 mph; Idle 30 sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 5.0 | Idle in Neutral (60 sec.) | 750 | 18.1 | | T | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments:

Date 10/11/75

Test Number 2

Fuel CK 29523-D4-1

Proposed CRC

Driveability Test

Sheet 1 of 4

S#I

## Test Vehicle

Make CHEVROLET

Model NOVA #26

Year 1975

Transmission TURBO HYDRAMATIC

A/C NO PB NO PS YES

License No. 735 CPV N.S

Engine Type V-8

Displacement 350CID

Nominal C.R. 8.5

Carb. Make ROCHESTER No. Bbls. 4

Emission Control System CALF.

Odometer: Start 13813 Finish 1383

## Weather

~~Ambient~~ C.T.R. ROOM Temp.: Start 70 °F, Finish 70 °F

Observed Barom.: Start 30.19 in. Hg, Finish 30.10 in. Hg

Relative Humidity: Start % 69-60, Finish % 71-61

~~Road Conditions: Wet~~ CLAYTON

Dry

Time: Start 1815, Finish 2:30

Soak Time (hrs.) 2 HRS

Soak Temp. (°F) 70

## Test Crew

Driver WESLEY HOWARTH

Recorder SAMUEL IRWIN

Observers JOHN FOWLKS

## Remarks

License 735 C PV NS

T-2 #2 NOVA 1975 #26



Cold Start-Driveaway

| Start Miles | T #2 Mode | | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Accel. or Cruise: Satis. | Accel. or Cruise: Hesit.* | Accel. or Cruise: Stumble* | Accel. or Cruise: Surge* | Accel. or Cruise: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start Time (sec.) | 1.0 | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Fast-Idle Cam | | 1200 | 20.0 | ✓ | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | | 1400 | 20.5 | ✓ | | | | | | | | |
| | (10 sec. from Start)Dr | | 900 | 16.0 | ✓ | | | | | | | | |
| 0 | PT (0-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| 0.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.2 | PT (25-35): Th. to FULL Detent | | 4 | | | | | ✓ | | | | | |
| 0.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.4 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| 0.5 | Idle (30 sec.): Dr | | 675 | 16.2 | | T | | | | | | | |
| | PT (0-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| 0.6 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.7 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| 0.8 | WOT Accel. (0-35) | | | | | | | | | ✓ | | | ✓ |
| 0.9 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| 1.0 | Idle (30 sec.): Dr | | 690 | 16.0 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| 1.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 1.2 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| 1.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 1.4 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| 1.5 | Idle (30 sec.): Dr | | 700 | 16.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | 12" | | | | | | ✓ | | | | | |
| 1.9 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| 2.0 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.1 | PT (10-25): Lt. Th. | 12" | | | | | | ✓ | | | | | |
| 2.2 | Idle (30 sec.): Dr | | 700 | 16.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | 12" | | | | | | ✓ | | | | | |
| 2.6 | PT (25-35): Th. to FULL Detent | | 4" | | | | | ✓ | | | | | |
| 2.7 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.8 | PT (10-25): Lt. Th. | 12" | | | | | | | | | | | |

License T#2 735 C PV N.J
S#3 NOVA 1975 #86



Cold Start-Driveaway

| Start Miles | T #2 Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Acceleration: Satis. | Acceleration: Hesit.* | Acceleration: Stumble* | Acceleration: Surge* | Acceleration: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 690 | 16.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 4.3 | Idle (30 sec.): Dr | 700 | 16.1 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 700 | 16.2 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 700 | 16.2 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 6.1 | PT (25-35): Th. to Detent FULL | 4" | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 700 | 16.1 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments:

License #2 735 CPV NJ
#4 NOVA 1975 - #26



Warm Vehicle Evaluation

T#2

| Mode | | Accel. or Tip-In: Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load: Satis. | Stretchy | Surge* | Idle: Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 850 | 19.5 | ✓ | | | | |
| | Dr | | | | | | | | | 680 | 16.0 | ✓ | | | | |
| WOT Against T.C. | | ✓ | | | | | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | | |
| | 50 mph | | | | | | | | M | | | | | | | 50 TO 60 SURGE |
| | 60 mph | | | | | | ✓ | | | | | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | | | | | | | | | | 13" |
| | 1/2 Th. | ✓ | | | | | | | | | | | | | | 9" |
| | 3/4 Th. | ✓ | | | | | | | | | | | | | | 6" |
| PT Crowd (Min. 60 or Max.) | 14 in.Hg | | | | | | | | | | | | | | | 20 M.P.R. MAX. |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | | |
| | 6 in.Hg | ✓ | | | | | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | | |

0-60 mph WOT Acceleration (sec.) 9.4

Drive 5 miles at 60 mph; Idle 30 N sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 4.0 | Idle in Neutral (60 sec.) | 700 | 17.9 | | T | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments: ______________________________

Date 9/19/77
Test Number 1
Fuel D-1

Proposed CRC
Driveability Test
Sheet 1 of 4

## Test Vehicle

Make NOVA
Model 2 door sedan
Year 1975
Transmission automatic
A/C NO PB ___ PS ___
License No. EPA 509

Engine Type V/8
Displacement 350 cu. in.
Nominal C.R. 9:1
Carb. Make Rochester No. Bbls. 4
Emission Control System stock - Knock sensor control
Odometer: Start 22480 Finish 22492

## Weather

Ambient Temp.: Start 84 °F; Finish ___ °F
Observed Barom.: Start 29.78 in. Hg; Finish ___ in. Hg
Relative Humidity: Start ___ %; Finish ___ %

Clayton #2
Road Conditions: Wet ___ Dry ___
Time: Start ___ Finish ___
Soak Time (hrs.) ___
Soak Temp. (°F) ___

## Test Crew

Driver R. Flynn
Recorder R. Hoernner

Observers L. HURST

## Remarks

## Cold Start-Driveaway

| Start Miles | Mode | | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Accel. or Cruise: Satis. | Accel. or Cruise: Hesit.* | Accel. or Cruise: Stumble* | Accel. or Cruise: Surge* | Accel. or Cruise: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start Time (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Fast-Idle Cam | | 2250 | 20.5 | ✓ | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | | 1800 | 20.5 | ✓ | | | | | | | | |
| | (10 sec. from Start)Dr | | 890 | 13.0 | ✓ | | | | | | | | |
| 0 | PT (0-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 0.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.2 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 0.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.4 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 0.5 | Idle (30 sec.): Dr | | 1100 | 11.5 | | T ✓ | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 0.6 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.7 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 0.8 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.9 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.0 | Idle (30 sec.): Dr | | 860 | 10.5 | | M ✓ | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 1.2 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 1.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 1.4 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.5 | Idle (30 sec.): Dr | | 670 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 1.9 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.0 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.1 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 2.2 | Idle (30 sec.): Dr | | 660 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 2.6 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.7 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.8 | PT (10-25): Lt. Th. | | | | | | | | | | T | | |
| 2.9 | Idle (30 sec.): Dr | | 665 | 18.0 | | | | | | | | | |

Cold Start-Driveaway

| Start Miles | Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Acceleration: Satis. | Acceleration: Hesit.* | Acceleration: Stumble* | Acceleration: Surge* | Acceleration: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 665 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 4.3 | Idle (30 sec.): Dr | 665 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 665 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 665 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 6.1 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 665 | 18.0 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments: ______________________________

## Warm Vehicle Evaluation

| Mode | | Accel. or Tip-In: Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load: Satis. | Stretchy | Surge* | Idle: Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 925 | 21.0 | | | | |
| | Dr | | | | | | | | | 675 | 17.5 | | | | |
| WOT Against T.C. | | ✓ | | | | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | | | T | | | | | | |
| | 60 mph | | | | | | | | T | | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | 12" | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | 9" | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | 6" | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | | | | | | | | | |
| 20-60 PT Crowd (Min.-70 or Max.) | 14 in.Hg | max 25 mph | | | | | | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | |
| | 6 in.Hg | ✓ | | | | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

0-~~70~~ 60 mph WOT Acceleration (sec.) 23.8

Drive 5 miles at 70 mph; Idle 30 sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 1.5 | Idle in Neutral (60 sec.) | 960 | 21.0 | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments:

Date 9/22/77

Test Number 2

Fuel D-2

Proposed CRC Driveability Test



## Test Vehicle

Make CHevy NOVA

Model 2 door sedan

Year 1975

Transmission Automatic

A/C NO PB NO PS yes

License No. EPA 509

Engine Type V-8

Displacement 350

Nominal C.R. 9:1

Carb. Make Roch. No. Bbls. 4

Emission Control System stock

Odometer: Start 22550 Finish 22560

## Weather

Ambient Temp.: Start 69 °F Finish ___ °F

Observed Barom.: Start 30.17 in. Hg Finish ___ in. Hg

Relative Humidity: Start 76 % Finish ___ %

Clayton #2 ~~Road Conditions~~: Wet ___ Dry ___

Time: Start ___ Finish ___

Soak Time (hrs.) ___

Soak Temp. (°F) ___

## Test Crew

Driver R. Flynn

Recorder R. Hoerner

Observers L. Hurst

## Remarks

Knock sensor Control in operation - NO Response observed during Test.

Cold Start-Driveaway

| Start Miles | Mode | | Idle | | | | | Accel. or Cruise | | | | | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Engine Speed rpm | Intake Vacuum in. Hg | Satis. | Rough* | Stall | Satis. | Hesit.* | Stumble* | Surge* | Stall | |
| | Start Time (sec.) | 1.0 | | | | | | | | | | | |
| | Restart (sec.) | Total start | very Hard start | | | | | | | | | | |
| | Restart (sec.) | Time ~ | 4 attempts needed To start | | | | | | | | | | |
| | Restart (sec.) | 1.5 min | | | | | | | | | | | |
| | Fast-Idle Cam | | 2500 | 22.0 | ✓ | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | | 2250 | 22.0 | ✓ | | | | | | | | |
| | (10 sec. from Start)Dr | | 940 | 14.0 | | T | | | | | | | |
| 0 | PT (0-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 0.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.2 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 0.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.4 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 0.5 | Idle (30 sec.): Dr | | 680 | 18.8 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 0.6 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.7 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 0.8 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.9 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.0 | Idle (30 sec.): Dr | | 690 | 18.5 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 1.2 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 1.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 1.4 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.5 | Idle (30 sec.): Dr | | 685 | 18.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 1.9 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.0 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.1 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 2.2 | Idle (30 sec.): Dr | | 685 | 18.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 2.6 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.7 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.8 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 2.9 | Idle (30 sec.): Dr | | 685 | 18.5 | ✓ | | | | | | | | |

## Cold Start-Driveaway

| Start Miles | Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Acceleration: Satis. | Acceleration: Hesit.* | Acceleration: Stumble* | Acceleration: Surge* | Acceleration: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. | | | | | | | • | | T | | |
| 3.6 | Idle (30 sec.): Dr | 680 | 18.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. | | | | | | | | | T | | |
| 4.3 | Idle (30 sec.): Dr | 675 | 18.5 | | T | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | T | | | | | |
| 4.7 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 670 | 18.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | T | | | | |
| 5.4 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 665 | 18.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | | | T | | |
| 6.1 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 665 | 18.5 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments: No Response from Knock Sensor

Test No. 2
License EPA 509





Warm Vehicle Evaluation

| Mode | | Accel. or Tip-In | | | | | Road Load | | | Idle | | | | | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Satis. | Hesit.* | Stumble* | Surge* | Stall | Satis. | Stretchy | Surge* | Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | |
| Idle | N | | | | | | | | | 900 | 21 | | | | |
| | Dr | | | | | | | | | 650 | 18.0 | | | | |
| WOT Against T.C. | | | | | T | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | | | T | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | ✓ | | | | | | | | |
| | 60 mph | | | | | | | | T | | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | | | | T | | 12" | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | 9" | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | 6" | | | | | | | | |
| PT Crowd (Min.-20 ~~60~~ or Max.) | 14 in.Hg | max speed 23 mph | | | | | | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | | | | T | | | | | | | | | | |
| | 8 in.Hg | | | | T | | | | | | | | | | |
| | 6 in.Hg | | | | T | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

0-60 mph WOT Acceleration (sec.) 20.6

Drive 5 miles at 70 mph; Idle 30 sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | | Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 1.0 | | Idle in Neutral (60 sec.) | 850 | 20.5 | | | | |
| Restart (sec.) | | | | | | | | | |
| Restart (sec.) | | | | | | | | | |
| Restart (sec.) | | | | | | | | | |

Comments:

Date 9/26/77

Test Number 3

Fuel D-3

Proposed CRC

Driveability Test

Sheet 1 of 4

## Test Vehicle

Make CHevy

Model NOVA

Year 1975

Transmission Auto

A/C NO PB NO PS yes

License No. EPA 509

Engine Type V-8

Displacement 350 cu. in.

Nominal C.R. 9:1

Carb. Make Rochester No. Bbls. 4

Emission Control System Stock - Knock sensor

Odometer: Start 22,594 Finish 22,602

## Weather

Ambient Temp.: Start 77 °F Finish ____ °F

Observed Barom.: Start 29.66 in. Hg Finish ____ in. Hg

Relative Humidity: Start 87 % Finish ____ %

Clayton #2 ~~Road Conditions:~~ Wet ____ Dry ____

Time: Start ____ Finish ____

Soak Time (hrs.) ____

Soak Temp. (°F) ____

## Test Crew

Driver R. Flynn

Recorder R. Hoerkner

Observers L. Hurst

## Remarks

Test No. 3
License EPA 509





Cold Start-Driveaway

| Start Miles | Mode | | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Accel. or Cruise: Satis. | Accel. or Cruise: Hesit.* | Accel. or Cruise: Stumble* | Accel. or Cruise: Surge* | Accel. or Cruise: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start Time (sec.) | 1.0 | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Fast-Idle Cam | | 2250 | 21.0 | | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | | 1750 | 20.5 | | T | | would idle but stall when put in drive | | | | | |
| | (10 sec. from Start)Dr | | 1250 | 18.0 | | | 6 | | | | | | 1 |
| 0 | PT (0-25): Lt. Th. | | 10" wouldn't make 25 @ 12" | | | | | | | T | | | |
| 0.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.2 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 0.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.4 | PT (10-25): Lt. Th. | | 10" wouldn't make 25 @12" | | | | | | T | | | | |
| 0.5 | Idle (30 sec.): Dr | | 655 | 17.5 | ✓ | | | | | | | | |
| - | PT (0-25): Lt. Th. | | | | | | | | | T | | | |
| 0.6 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.7 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 0.8 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.9 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.0 | Idle (30 sec.): Dr | | 645 | 17.5 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | | | | T | | |
| 1.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 1.2 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 1.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 1.4 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.5 | Idle (30 sec.): Dr | | 645 | 17.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 1.9 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.0 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.1 | PT (10-25): Lt. Th. | | | | | | | | | | T | | |
| 2.2 | Idle (30 sec.): Dr | | 645 | 17.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 2.6 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.7 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.8 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 2.9 | Idle (30 sec.): Dr | | 665 | 18.0 | ✓ | | | | | | | | |

Test No. 3
License EPA 509



## Cold Start-Driveaway

| Start Miles | Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Acceleration: Satis. | Acceleration: Hesit.* | Acceleration: Stumble* | Acceleration: Surge* | Acceleration: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 660 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. | | | | | | | | | T | | |
| 4.3 | Idle (30 sec.): Dr | 670 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 665 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 660 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | | | T | | |
| 6.1 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. | | | | | | | | | T | | |
| 6.4 | Idle (30 sec.): Dr | 660 | 18.0 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments: No Response from Knock sensor during cold start drive away.

Test No. 3
License EPA-509





## Warm Vehicle Evaluation

| Mode | | Accel. or Tip-In: Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load: Satis. | Stretchy | Surge* | Idle: Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 920 | 21.0 | ✓ | | | |
| | Dr | | | | | | | | | 670 | 18.0 | ✓ | | | |
| WOT Against T.C. | | | | T | T | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | ✓ | | | | | | | | |
| | 60 mph | | | | | | ✓ | | | | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | 12" | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | 9" | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | 6" | | | | | | | | |
| PT Crowd 20 (~~Min. - 70~~ 69 or Max.) | 14 in.Hg | max | speed | | 23 | mph | | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | |
| | 6 in.Hg | ✓ | | | | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

0-~~70~~60 mph WOT Acceleration (sec.) 22.5

Drive 5 miles at 70 mph; Idle 30 sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to idle

| | | | Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 1.8 | Idle in Neutral (60 sec.) | 800 | 20.0 | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments: No Response from Knock sensor.

Date 9-27-77
Test Number 4
Fuel D-4-1

Proposed CRC
Driveability Test
Sheet 1 of 4

## Test Vehicle

Make CHevy
Model NOVA
Year 1975
Transmission Auto
A/C NO PB NO PS yes
License No. EPA-509

Engine Type V-8
Displacement 350
Nominal C.R. 9:1
Carb. Make Rochester No. Bbls. 4
Emission Control System Stock-Knock
Odometer: Start 22,643 Finish ____

## Weather

Ambient Temp.: Start 74 °F, Finish ____ °F
Observed Barom.: Start 29.70 in. Hg, Finish ____ in. Hg
Relative Humidity: Start 58 %, Finish ____ %

~~Road Conditions~~ clayton #2: Wet X Dry X
Time: Start ____ Finish ____
Soak Time (hrs.) ____
Soak Temp. (°F) ____

## Test Crew

Driver R. Flynn
Recorder L. Hurst

Observers L. Hurst

## Remarks

Cold Start-Driveaway

| Start Miles | Mode | | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Accel. or Cruise: Satis. | Accel. or Cruise: Hesit.* | Accel. or Cruise: Stumble* | Accel. or Cruise: Surge* | Accel. or Cruise: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start Time (sec.) | 1.0 | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Fast-Idle Cam | | 2400 | 21.0 | | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | | 1500 | 19.0 | | | | | | | | | |
| | (10 sec. from Start)Dr | | 920 | 11.0 | | M | 1 | | | | | | |
| 0 | PT (0-25): Lt. Th. | | | | | 10° R | | | | | T | | |
| 0.1 | Cruise (25 mph) | | | | | 10° Retard | | | | T | T | | |
| 0.2 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 0.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.4 | PT (10-25): Lt. Th. | | | | | | | | | | T | | |
| 0.5 | Idle (30 sec.): Dr | | 680 | 17.0 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | | | | T | | |
| 0.6 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.7 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 0.8 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.9 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.0 | Idle (30 sec.): Dr | | 680 | 17.0 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | | | | T | | |
| 1.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 1.2 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 1.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 1.4 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.5 | Idle (30 sec.): Dr | | 680 | 17.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 1.9 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.0 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.1 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 2.2 | Idle (30 sec.): Dr | | 680 | 17.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 2.6 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.7 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.8 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 2.9 | Idle (30 sec.): Dr | | 680 | 17.0 | | | | | | | | | |

Cold Start-Driveaway

| Start Miles | Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Acceleration: Satis. | Acceleration: Hesit.* | Acceleration: Stumble* | Acceleration: Surge* | Acceleration: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 680 | 17.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 4.3 | Idle (30 sec.): Dr | 680 | 17.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. | | | | | | | | | T | | |
| 5.0 | Idle (30 sec.): Dr | 700 | 17.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 680 | 17.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 6.1 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 680 | 17.0 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments: Knock Sensor only Responded in cold engine condition

## Warm Vehicle Evaluation

| Mode | | Accel. or Tip-In: Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load: Satis. | Stretchy | Surge* | Idle: Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 990 | 20.5 | ✓ | | | |
| | Dr | | | | | | | | | 710 | 17.5 | ✓ | | | |
| WOT Against T.C. | | ✓ | | | | | Retard 4° | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | ✓ | | | | | | | | |
| | 60 mph | | | | | | | | T | | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | 12" | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | 9" | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | 6" | | | | | | | | |
| PT Crowd (~~Min.~~ 20 ~~70~~ 60 or Max.) | 14 in.Hg | Max | | 23 | MPH | | | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | |
| | 6 in.Hg | | | | T | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

0-~~70~~ 60 mph WOT Acceleration (sec.) 22.4

Drive 5 miles at 70 mph; Idle 30 sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 1.0 | Idle in Neutral (60 sec.) | 850 | 19.5 | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments: 

Date 12/13/77

Test Number 1

Fuel D-1

After 4000 mi durability miles

Proposed CRC

Driveability Test

Sheet 1 of 4

## Test Vehicle

Make CHEVY

Model NOVA

Year 1975

Transmission Automatic 3-speed

A/C NO PB NO PS yess

License No. EPA-509

Engine Type V-8

Displacement 350

Nominal C.R. 9:1.

Carb. Make Rochester No. Bbls. 4

Emission Control System standard

Odometer: Start 40,855.0 Finish 40,867.8

## Weather

Ambient Temp.: Start 74 °F, Finish 74 °F

Observed Barom.: Start 30.33 in. Hg, Finish 30.33 in. Hg

Relative Humidity: Start 54 %, Finish 54 %

Clayton #2 ~~Road Conditions~~: Wet ____ Dry ____

Time: Start ____ Finish ____

Soak Time (hrs.) ____

Soak Temp. (°F) ____

## Test Crew

Driver R. Flynn

Recorder L. Hurst

Observers ____

## Remarks

Test No. ____________
License ____________





## Cold Start-Driveaway

| Start Miles | Mode | | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Accel. or Cruise: Satis. | Accel. or Cruise: Hesit.* | Accel. or Cruise: Stumble* | Accel. or Cruise: Surge* | Accel. or Cruise: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start Time (sec.) | 1 | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Fast-Idle Cam | | 2060 | 27.0 | | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | | 1500 | 20.0 | | | | | | | | | |
| | (10 sec. from Start)Dr | | 990 | 12.0 | | T | 1 | | | | | | |
| 0 | PT (0-25): Lt. Th. 12" | | | | | | | | T | | | | |
| 0.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.2 | PT (25-35): Th. to Detent 4" | | | | | | | ✓ | | | | | |
| 0.3 | WOT Accel. (0-35) 4" | | | | | | | ✓ | | | | | |
| 0.4 | PT (10-25): Lt. Th. 12" | | | | | | | ✓ | | | | | |
| 0.5 | Idle (30 sec.): Dr | | 650 | 18.0 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 0.6 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.7 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 0.8 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.9 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.0 | Idle (30 sec.): Dr | | 660 | 18.0 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 1.2 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 1.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 1.4 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.5 | Idle (30 sec.): Dr | | 650 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | | ✓ | | | | | |
| 1.9 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.0 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.1 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 2.2 | Idle (30 sec.): Dr | | 660 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 2.6 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.7 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.8 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 2.9 | Idle (30 sec.): Dr | | 660 | 18.0 | ✓ | | | | | | | | |

License ____________



Cold Start-Driveaway

| Start Miles | Mode | Idle | | | | | Acceleration | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Engine Speed rpm | Intake Vacuum in. Hg | Satis. | Rough* | Stall | Satis. | Hesit.* | Stumble* | Surge* | Stall | Backfire* |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 660 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 4.3 | Idle (30 sec.): Dr | 660 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 650 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 650 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 6.1 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 650 | 18.0 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments: ____________________________________________

Test No. ______________
License ______________



## Warm Vehicle Evaluation

| Mode | | Accel. or Tip-In: Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load: Satis. | Stretchy | Surge* | Idle: Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 870 | 21.0 | | | | |
| | Dr | | | | | | | | | 650 | 18.0 | | | | |
| WOT Against T.C. | | ✓ | | | | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | ✓ | | | | | | | | |
| | 60 mph | | | | | | ✓ | | | | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | 12" | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | 9" | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | 6" | | | | | | | | |
| 20-60 PT Crowd (Min.-70 or Max.) | 14 in.Hg | ✓ | | | | | | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | |
| | 6 in.Hg | ✓ | | | | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

0-~~70~~ 60 mph WOT Acceleration (sec.) 21.5

Drive 5 miles at 70 mph; Idle 30 sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 0.8 | Idle in Neutral (60 sec.) | 760 | 19.5 | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments: ______________________________________________

6° BTC

Date 12-15-77
Test Number ____
Fuel D-2

Proposed CRC
Driveability Test
Sheet 1 of 4

## Test Vehicle

Make Chevy
Model NOVA 2-Door Sedan
Year 1975
Transmission AUTOMATIC
A/C NO PB NO PS NO
License No. EPA-509

Engine Type V-8
Displacement 350
Nominal C.R. 9:1
Carb. Make Rochester No. Bbls. 4
Emission Control System STOCK
Odometer: Start ____ Finish ____

## Weather

Ambient Temp.: Start 78 °F Finish ____ °F
Observed Barom.: Start 29.91 in. Hg Finish ____ in. Hg
Relative Humidity: Start ____ % Finish ____ %

Road Conditions: Clayton #2 Wet ____ Dry ____
Time: Start ____ Finish ____
Soak Time (hrs.) ____
Soak Temp. (°F) ____

## Test Crew

Driver R. Hoerner
Recorder R. Flynn/R. Krupa

Observers ____

## Remarks

## Cold Start-Driveaway

| Start Miles | Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Accel. or Cruise: Satis. | Accel. or Cruise: Hesit.* | Accel. or Cruise: Stumble* | Accel. or Cruise: Surge* | Accel. or Cruise: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start Time (sec.) 1 | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | |
| | Fast-Idle Cam | 2400 | 21.5 | ✓ | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | 1700 | 21 | ✓ | | | | | | | | |
| | (10 sec. from Start)Dr | 850 | 11 | ✓ | | | | | | | | |
| 0 | PT (0-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 0.1 | Cruise (25 mph) 30 seconds | | | | | | ✓ | | | | | |
| 0.2 | PT (25-35): Th. to Detent 4" | | | | | | ✓ | | | | | |
| 0.3 | WOT Accel. (0-35) 4" | | | | | | ✓ | | | | | |
| 0.4 | PT (10-25): Lt. Th. 12" | | | | | | ✓ | | | | | |
| 0.5 | Idle (30 sec.): Dr | 670 | 18 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | ✓ | | | | | |
| 0.6 | Cruise (25 mph) | | | | | | ✓ | | | | | |
| 0.7 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 0.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 0.9 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 1.0 | Idle (30 sec.): Dr | 670 | 18 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | ✓ | | | | | |
| 1.1 | Cruise (25 mph) | | | | | | ✓ | | | | | |
| 1.2 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 1.3 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 1.4 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 1.5 | Idle (30 sec.): Dr | 660 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. 12" | | | | | | ✓ | | | | | |
| 1.9 | PT (25-35): Th. to Detent | change | | | | | ✓ | | | | | |
| 2.0 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 2.1 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 2.2 | Idle (30 sec.): Dr | 660 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 2.6 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 2.7 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 2.8 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 2.9 | Idle (30 sec.): Dr | 660 | 18 | ✓ | | | | | | | | |

Test No. ________
License EPA-509



Cold Start-Driveaway

| Start Miles | Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Acceleration: Satis. | Acceleration: Hesit.* | Acceleration: Stumble* | Acceleration: Surge* | Acceleration: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 655 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 4.3 | Idle (30 sec.): Dr | 650 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 645 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 650 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 6.1 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 655 | 18 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments: ________

Test No.
License EPA-509



Warm Vehicle Evaluation

| Mode | | Accel. or Tip-In Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load Satis. | Stretchy | Surge* | Idle Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 890 | 20.5 | ✓ | | | |
| | Dr | | | | | | | | | 640 | 18 | ✓ | | | |
| WOT Against T.C. 4" | | ✓ | | | | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | ✓ | | | | | | | | |
| | 60 mph | | | | | | ✓ | | | | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | |
| WOT Accel. (0-30) (Retard →) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | | | | | | | | | |
| PT Crowd (Min.-70 or Max.) | 14 in.Hg | ✓ | | | | | | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | |
| | 6 in.Hg | ✓ | | | | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

0-~~70~~ 60 mph WOT 4" Acceleration (sec.) 21

Drive 5 miles at 70 mph; Idle 30 sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 1 | Idle in Neutral (60 sec.) | 790 | 19.5 | ✓ | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments:

Date 12-16-77

Test Number

Fuel D-3

6° BTC

Proposed CRC
Driveability Test
Sheet 1 of 4

## Test Vehicle

Make CHEVY

Model NOVA 2 DR. SEDAN

Year 1975

Transmission AUTOMATIC

A/C NO PB PS

License No. EPA 509

Engine Type V-8

Displacement 350 CU. IN.

Nominal C.R. 9:1

Carb. Make ROCHESTER No. Bbls. 4

Emission Control System STOCK- KNOCK SENS. CONTROL

Odometer: Start 40978.7 Finish 40999.

## Weather

Ambient Temp.: Start 78[redacted] °F
Finish 82[redacted] °F

Observed Barom.: Start 29.99 in. Hg
Finish in. Hg

Relative Humidity: Start %
Finish %

CLAYTON #2

Road Conditions: Wet
Dry

Time: Start
Finish

Soak Time (hrs.)
Soak Temp. (°F)

## Test Crew

Driver R. HOERRNER

Recorder R. KRUPA

Observers

## Remarks

Test No. ____________

License ____________





Cold Start-Driveaway

| Start Miles | Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Accel. or Cruise: Satis. | Accel. or Cruise: Hesit.* | Accel. or Cruise: Stumble* | Accel. or Cruise: Surge* | Accel. or Cruise: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start Time (sec.) 1 | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | |
| | Fast-Idle Cam | 2100 | 21.5 | ✓ | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | 1700 | 21 | ✓ | | | | | | | | |
| | (10 sec. from Start)Dr | 590 | 17 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | ✓ | | | | | |
| .1 | Cruise (25 mph) | | | | | | ✓ | | | | | |
| .2 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| .3 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| .4 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| .5 | Idle (30 sec.): Dr | 640 | 18 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | ✓ | | | | | |
| .6 | Cruise (25 mph) | | | | | | ✓ | | | | | |
| .7 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| .8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| .9 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| .0 | Idle (30 sec.): Dr | 645 | 18 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | ✓ | | | | | |
| .1 | Cruise (25 mph) | | | | | | ✓ | | | | | |
| .2 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| .3 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| .4 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| .5 | Idle (30 sec.): Dr | 650 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| .9 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| .0 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| .1 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| .2 | Idle (30 sec.): Dr | 650 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| .6 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| .7 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| .8 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| .9 | Idle (30 sec.): Dr | 650 | 18 | ✓ | | | | | | | | |

No. ____________
License ____________



Cold Start-Driveaway

| Start Miles | Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Acceleration: Satis. | Acceleration: Hesit.* | Acceleration: Stumble* | Acceleration: Surge* | Acceleration: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 660 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 4.3 | Idle (30 sec.): Dr | 655 | 17 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 660 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 660 | 18 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 6.1 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 660 | 18 | ✓ | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments: 1 STALL ON DROPPING INTO DRIVE - RESTART O.K.

Test No. ____________
License ____________



## Warm Vehicle Evaluation

| Mode | | Accel. or Tip-In: Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load: Satis. | Stretchy | Surge* | Idle: Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 890 | 20 | ✓ | | | |
| | Dr | | | | | | | | | 665 | 18 | ✓ | | | |
| WOT Against T.C. | | ✓ | | | | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | ✓ | | | | | | | | |
| | 60 mph | | | | | | ✓ | | | | | | | | |
| | ~~70~~ mph | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | | | | | | | | | |
| PT Crowd (Min.-70 or Max.) | 14 in.Hg | ✓ | | | | | | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | |
| | 6 in.Hg | ✓ | | | | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

0-~~70~~ 60 mph WOT Acceleration (sec.) 15

Drive 5 miles at ~~70~~ 60 mph; Idle 30 sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 2 | Idle in Neutral (60 sec.) | 660 | 17 | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments: ______________________________

Date 12/20/77
Test Number ____
Fuel D-4

Proposed CRC
Driveability Test
Sheet 1 of 4

Test Vehicle

Make CHevy
Model NOVA
Year 1975
Transmission Auto
A/C NO PB NO PS yes
License No. EPA -509

Engine Type V-8
Displacement 350
Nominal C.R. 9:1
Carb. Make Rochester No. Bbls. 4
Emission Control System G.M. EGR Valv
Odometer: Start 21028.5 Finish ____

Weather

Ambient Temp.: Start ____ °F
Finish ____ °F

Observed Barom.: Start ____ in. Hg
Finish ____ in. Hg

Relative Humidity: Start ____ %
Finish ____ %

~~Road Conditions~~ Clayton #2: Wet ____
Dry ____

Time: Start ____
Finish ____

Soak Time (hrs.) ____
Soak Temp. (°F) ____

Test Crew

Driver R. Hoerner
Recorder L. Hurst

Observers ____

Remarks

Test No. D-4
License EPA-509





Cold Start-Driveaway

| Start Miles | Mode | | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Accel. or Cruise: Satis. | Accel. or Cruise: Hesit.* | Accel. or Cruise: Stumble* | Accel. or Cruise: Surge* | Accel. or Cruise: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Start Time (sec.) | 1 | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Restart (sec.) | | | | | | | | | | | | |
| | Fast-Idle Cam | | 2100. | 21.0 | ✓ | | | | | | | | |
| | Tap Th. (5 sec. from St.)N | | 760 | 19.5 | | T | | | | | | | |
| | (10 sec. from Start)Dr | | 610. | 16.5 | | T | | | | | | | |
| 0 | PT (0-25): Lt. Th. 12" | | | | | | | ✓ | | | | | |
| 0.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.2 | PT (25-35): Th. to Detent 4" | | | | | | | ✓ | | | | | |
| 0.3 | WOT Accel. (0-35) 4 | | | | | | | ✓ | | | | | |
| 0.4 | PT (10-25): Lt. Th. | | | | | | | | | | T | | |
| 0.5 | Idle (30 sec.): Dr | | 680 | 17.5 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | | T | | | | |
| 0.6 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 0.7 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 0.8 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 0.9 | PT (10-25): Lt. Th. | | | | | | | | | | T | | |
| 1.0 | Idle (30 sec.): Dr | | 650 | 17.5 | ✓ | | | | | | | | |
| | PT (0-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.1 | Cruise (25 mph) | | | | | | | ✓ | | | | | |
| 1.2 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 1.3 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 1.4 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 1.5 | Idle (30 sec.): Dr | | 650 | 17.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 1.9 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.0 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.1 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 2.2 | Idle (30 sec.): Dr | | 640 | 17.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | | ✓ | | | | | |
| 2.6 | PT (25-35): Th. to Detent | | | | | | | ✓ | | | | | |
| 2.7 | WOT Accel. (0-35) | | | | | | | ✓ | | | | | |
| 2.8 | PT (10-25): Lt. Th. | | | | | | | ✓ | | | | | |
| 2.9 | Idle (30 sec.): Dr | | 650 | 17.5 | ✓ | | | | | | | | |

Test No. ____
License EPA-509
D-4



Cold Start-Driveaway

| Start Miles | Mode | Idle: Engine Speed rpm | Idle: Intake Vacuum in. Hg | Idle: Satis. | Idle: Rough* | Idle: Stall | Acceleration: Satis. | Acceleration: Hesit.* | Acceleration: Stumble* | Acceleration: Surge* | Acceleration: Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 3.3 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 3.4 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 3.5 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 3.6 | Idle (30 sec.): Dr | 650 | 17.5 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.0 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.1 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.2 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 4.3 | Idle (30 sec.): Dr | 640 | 17.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 4.7 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 4.8 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 4.9 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.0 | Idle (30 sec.): Dr | 660 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 5.4 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 5.5 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 5.6 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 5.7 | Idle (30 sec.): Dr | 650 | 18.0 | ✓ | | | | | | | | |
| | PT (0-45): Const. Vac. | | | | | | ✓ | | | | | |
| 6.1 | PT (25-35): Th. to Detent | | | | | | ✓ | | | | | |
| 6.2 | WOT Accel. (0-35) | | | | | | ✓ | | | | | |
| 6.3 | PT (10-25): Lt. Th. | | | | | | ✓ | | | | | |
| 6.4 | Idle (30 sec.): Dr | 660 | 18.0 | | | | | | | | | |

* T - Trace; M - Moderate; H - Heavy

Comments: ____

Test No. ______________________
License ______________________



## Warm Vehicle Evaluation

| Mode | | Accel. or Tip-In: Satis. | Hesit.* | Stumble* | Surge* | Stall | Road Load: Satis. | Stretchy | Surge* | Idle: Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Idle | N | | | | | | | | | 900 | 20.5 | ✓ | | | |
| | Dr | | | | | | | | | 660 | 17.5 | ✓ | | | |
| WOT Against T.C. | | ✓ | | | | | | | | | | | | | |
| Road Load | 20 mph | | | | | | ✓ | | | | | | | | |
| | 30 mph | | | | | | ✓ | | | | | | | | |
| | 40 mph | | | | | | ✓ | | | | | | | | |
| | 50 mph | | | | | | ✓ | | | | | | | | |
| | 60 mph | | | | | | ✓ | | | | | | | | |
| | ~~70 mph~~ | | | | | | | | | | | | | | |
| WOT Accel. (0-30) | Sudden | ✓ | | | | | | | | | | | | | |
| | Moderate | ✓ | | | | | | | | | | | | | |
| | Slow | ✓ | | | | | | | | | | | | | |
| PT Accel. (0-30) | 1/4 Th. | ✓ | | | | | 12" | | | | | | | | |
| | 1/2 Th. | ✓ | | | | | 9" | | | | | | | | |
| | 3/4 Th. | ✓ | | | | | 6" | | | | | | | | |
| PT Crowd (Min.-70 or Max.) 20 - 60 | 14 in.Hg | ✓ | | | | | | | | | | | | | |
| | 12 in.Hg | ✓ | | | | | | | | | | | | | |
| | 10 in.Hg | ✓ | | | | | | | | | | | | | |
| | 8 in.Hg | ✓ | | | | | | | | | | | | | |
| | 6 in.Hg | ✓ | | | | | | | | | | | | | |
| PT Tip-In (Top Gear) | From 20 | ✓ | | | | | | | | | | | | | |
| | From 30 | ✓ | | | | | | | | | | | | | |

0-~~70~~ 60 mph WOT @ 4" Acceleration (sec.) 22.0

Drive 5 miles at 70 mph; Idle 30 sec.; Soak 15 min.
After soak, start according to manufacturer's hot-start procedure; Return to Idle

| | | | Engine rpm | Vacuum in. Hg | Satis. | Rough* | Stall | Backfire* |
|---|---|---|---|---|---|---|---|---|
| Start Time (sec.) | 3 | Idle in Neutral (60 sec.) | 750 | 19.0 | | T | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |
| Restart (sec.) | | | | | | | | |

Comments: ______________________________________________

______________________________________________

______________________________________________

# APPENDIX E

## DUAL SPARK PLUG IGNITION TESTING

# APPENDIX E-1

## COMPARISON OF SINGLE AND DUAL IGNITION AT 10" MANIFOLD VACUUM

| RPM | Spark Timing P | Spark Timing S | Avg. Torque | Engine Out Emissions CO (%) | $NO_x$ (ppm) | HC (ppm) | Octane Req. (PRF) |
|---|---|---|---|---|---|---|---|
| 1500 | 23 | ---- | 138 | 0.5 | 730 | 180 | 81 |
| 1500 | 23 | 23.5 | 149 | 0.5 | 1150 | 210 | -- |
| 1500 | 16 | 16 | 138 | 0.5 | 620 | 170 | 83 |
| 1500 | 24 | ---- | 138 | 0.5 | 650 | 215 | -- |
| 1500 | 24 | 24 | 148 | 0.5 | 1000 | 225 | -- |
| 1500 | 16.5 | 16.5 | 138 | 0.5 | 550 | 175 | -- |
| 1500 | 16.5 | ---- | 125 | 0.5 | 350 | 140 | -- |
| 2000 | 29 | ---- | 150.5 | 0.9 | 1325 | 185 | 81 |
| 2000 | 29 | 29 | 153 | 1.0 | 1850 | 205 | -- |
| 2000 | 23 | 23 | 150.5 | 1.0 | 1300 | 180 | 85 |
| 2000 | 29 | -- | 148.5 | 1.0 | 970 | 165 | -- |
| 2000 | 29 | 29 | 153.5 | 1.0 | 1350 | 190 | -- |
| 2000 | 22 | 22 | 149 | 1.0 | 780 | 145 | -- |

P - Primary plugs.
S - Secondary plugs.
Fuel: Isooctane

# APPENDIX E-2

| RPM | Spark Timing P | Spark Timing S | Avg. Torque | Engine Out Emissions CO (%) | Engine Out Emissions $NO_x$ (ppm) | Engine Out Emissions HC (ppm) | Octane Req. (PRF) |
|---|---|---|---|---|---|---|---|
| 2000 | 30.5 | ---- | 142 | 1.0 | 1050 | 180 | -- |
| 2000 | 30.5 | 30.5 | 147 | 1.0 | 1425 | 200 | -- |
| 2000 | 22 | 22 | 142 | 1.0 | 800 | 160 | -- |
| 2000 | 22 | ---- | 131 | 1.0 | 550 | 125 | -- |
| 2500 | 31.5 | ---- | 148.5 | 1.2 | 1425 | 135 | 80 |
| 2500 | 31.5 | 31.5 | 153.5 | 1.6 | 2000 | 145 | -- |
| 2500 | 25.5 | 25.5 | 148.5 | 1.1 | 760 | 80 | 81 |
| 2500 | 33.5 | ---- | 144 | 1.6 | 975 | 145 | -- |
| 2500 | 33.5 | 33.5 | 149 | 1.6 | 1500 | 160 | -- |
| 2500 | 22.5 | 22.5 | 144 | 1.4 | 650 | 100 | -- |
| 2500 | 22.5 | ---- | 133.5 | 1.3 | 500 | 80 | -- |
| 3000 | 34.5 | ---- | 142.5 | 1.5 | 1150 | 75 | 81 |
| 3000 | 34.5 | 34.5 | 147 | 1.8 | 1700 | 110 | -- |
| 3000 | 25.5 | 25.5 | 142.5 | 1.6 | 950 | 75 | 80 |
| 3000 | 36 | ---- | 132.5 | 1.5 | 875 | 85 | -- |
| 3000 | 36 | 36 | 138 | 1.9 | 1250 | 110 | -- |
| 3000 | 27 | 27 | 132.5 | 1.6 | 700 | 120 | -- |
| 3000 | 27 | ---- | 124 | 1.4 | 525 | 55 | -- |

## APPENDIX E-3

## COMPARISON OF SINGLE AND DUAL IGNITION AT 2000 RPM, VARIABLE LOAD

| Manifold Vacuum (in. Hg) | Spark Timing P | Spark Timing S | Avg. Torque | Engine Out Emissions CO (%) | Engine Out Emissions $NO_x$ (ppm) | Engine Out Emissions HC (ppm) | Octane Req. (PRF) |
|---|---|---|---|---|---|---|---|
| 3 | 15.5 | -- | 256 | >5 | 710 | 325 | 98 |
| 3 | 16 | 16 | 260 | >5 | 720 | 320 | -- |
| 3 | 14 | 14 | 256 | >5 | 700 | 320 | >99 |
| 6 | 22.5 | -- | 190 | 1.7 | 650 | 140 | 89 |
| 6 | 22 | 22 | 195 | 1.7 | 980 | 170 | -- |
| 6 | 18 | 18 | 190 | 1.7 | 770 | 150 | 92 |
| 9 | 27 | -- | 160 | 1.1 | 925 | 165 | 84 |
| 9 | 27 | 27 | 166.5 | 1.2 | 1200 | 175 | -- |
| 9 | 22 | 22 | 160 | 1.2 | 900 | 145 | 86 |
| 12 | 34 | -- | 122.5 | 0.7 | 1075 | 180 | 75 |
| 12 | 34 | 34 | 125 | 0.7 | 1550 | 170 | -- |
| 12 | 26 | 26 | 123 | 0.7 | 1000 | 150 | 79 |

APPENDIX E-4

FUEL CONSUMPTION OF DUAL IGNITION ENGINE

| RPM | Manifold Vacuum (in.) | Spark Timing (°BTC) P | S | Average Torque (ft-lb) | Fuel Consumption (lb/min) | % Reduction |
|---|---|---|---|---|---|---|
| 1500 | 10.0 | 24.5 | ---- | 140 | 0.331 | |
| 1500 | 10.2 | 24.5 | 24.5 | 151.5 | 0.335 | |
| | | | | | | |
| 1500 | 10.0 | 24.5 | ---- | 141.5 | 0.335 | |
| 1500 | 9.9 | 17 | 17 | 141 | 0.333 | |
| | | | | | | |
| 1500 | 9.9 | 25 | ---- | 136 | 0.325 | |
| 1500 | 9.9 | 25 | 25 | 144.5 | ----- | |
| 1500 | 10.4 Throttle Adj. | 25 | 25 | 136 | 0.310 | 4.6% |
| | | | | | | |
| 1500 | 10.0 | 25 | ---- | 134.5 | 0.317 | |
| 1500 | 10.0 | 25 | 25 | 141 | ----- | |
| 1500 | 10.6 Throttle Adj. | 25 | 25 | 135 | 0.307 | 3.2% |
| | | | | | | |
| 2000 | 3.0 | 18 | ---- | 251 | 0.898 | |
| 2000 | 3.0 | 18 | 18 | 258 | ----- | |
| 2000 | 3.5 Throttle Adj. | 18 | 18 | 251 | 0.870 | 3.1% |
| | | | | | | |
| 2000 | 3.0 | 17.5 | ---- | 255 | 0.908 | |
| 2000 | 2.9 | 18 | 18 | 264 | ----- | |
| 2000 | 3.4 Throttle Adj. | 18 | 18 | 255 | 0.866 | 4.6% |
| | | | | | | |
| 2500 | 10.0 | 33 | ---- | 158.5 | 0.608 | |
| 2500 | 9.8 | 33 | 33 | 165 | ----- | |
| 2500 | 10.1 Throttle Adj. | 33 | 33 | 159 | 0.598 | 1.6% |

APPENDIX E-5

EFFECT OF INCREASED EGR FLOW ON OCTANE REQUIREMENT, FUEL CONSUMPTION, AND EMISSIONS OF DUAL IGNITION ENGINE USING GM PROPORTION RECYCLE VALVE (CONSTANT THROTTLE EXCEPT WHERE NOTED)

| | Description | Engine RPM | Manifold Vacuum | % EGR | Torque | Research Octane Requirement | CO(%) | HC(ppm) | $NO_x$(ppm) | Fuel Consumption (lb/min) |
|---|---|---|---|---|---|---|---|---|---|---|
| Test #1 | A. Single Ignition - (Base) | 1500 | 10.0 | 7.4 | 133 | 83 | 0.5 | 175 | 750 | 0.328 |
| Test #1 | B. Dual Ignition | 1500 | 10.0 | 7.4 | 143 | --- | --- | --- | --- | --- |
| Test #1 | C. Dual Ignition - Increased EGR | 1500 | 9.3 | 13.5 | 133 | 86 | 0.5 | 220 | 550 | 0.326 |
| Test #1 | Comparison of Single → Dual (A→C) at Equal Torque | | | | | +3 | 0 | +26% | -27% | -0.6% |
| Test #2 | A. Single Ignition - (Base) | 2000 | 10.0 | 5.7 | 134 | 80 | 0.95 | 200 | 900 | 0.442 |
| Test #2 | B. Dual Ignition | 2000 | 10.1 | 5.7 | 141 | --- | --- | --- | --- | --- |
| Test #2 | C. Dual Ignition - Increased EGR | 2000 | 9.0 | 11.9 | 134 | 86 | 0.95 | 230 | 680 | 0.430 |
| Test #2 | Comparison of Single → Dual (A→C) at Equal Torque | | | | | +6 | 0 | +15% | -24% | -2.7% |

* Octane requirements determined at steady state with Primary Reference Fuels (P Series). Emissions and fuel economy determined with isooctane fuel.

## APPENDIX E-6

### EFFECT OF INCREASED EGR ON OCTANE REQUIREMENT, FUEL CONSUMPTION, AND EMISSIONS OF DUAL IGNITION ENGINE

| | Description | Engine RPM | Manifold Vacuum | % EGR | Torque | Research Octane Requirement | CO(%) | HC(ppm) | $NO_x$(ppm) | Fuel Consumption (lb/min) |
|---|---|---|---|---|---|---|---|---|---|---|
| Test #3 | A. Single Ignition - (Base) | 2500 | 10.0 | 4.6 | 143 | 81 | 1.1 | 130 | 1300 | 0.584 |
| | B. Dual Ignition | 2500 | 10.0 | 4.6 | 145 | --- | --- | --- | --- | --- |
| | C. Dual Ignition - Increased EGR | 2500 | 9.3 | 10.2 | 142 | 88 | 1.1 | 180 | 1250 | 0.558 |
| | Comparison of Single → Dual (A→C) at Equal Torque | | | | | +7 | 0 | +38% | -4% | -4.5% |
| Test #4 | A. Single Ignition - (Base) | 2000 | 6.0 | 4.7 | 170 | 88 | 1.3 | 125 | 760 | 0.554 |
| | B. Dual Ignition | 2000 | 5.9 | 4.7 | 181 | --- | 1.3 | 165 | 750 | --- |
| | C. Dual Ignition - Increased EGR | 2000 | 5.4 | 8.8 | 170 | 92 | 1.4 | 190 | 450 | 0.545 |
| | Comparision of Single → Dual (A→C) at Equal Torque | | | | | +4 | +8% | +52% | -41% | -1.6% |

APPENDIX E-7

EFFECT OF INCREASED EGR ON OCTANE REQUIREMENT, FUEL CONSUMPTION, AND EMISSIONS OF DUAL IGNITION ENGINE

| Test | Description | Engine RPM | Manifold Vacuum | % EGR | Torque | Research Octane Requirement | CO(%) | HC(ppm) | $NO_x$(ppm) | Fuel Consumption (lb/min) |
|---|---|---|---|---|---|---|---|---|---|---|
| Test #5 | A. Single Ignition - (Base) | 2000 | 6.0 | 4.5 | 178 | 87 | 1.1 | 125 | 550 | 0.554 |
| Test #5 | B. Dual Ignition | 2000 | 6.0 | 4.5 | 190 | --- | 1.1 | 150 | 720 | --- |
| Test #5 | C. Dual Ignition - Increased EGR | 2000 | 5.6 | 7.5 | 180 | 92 | 1.3 | 160 | 560 | 0.544 |
| Test #5 | Comparison of Single → Dual (A→C) at Equal Torque | | | | | +5 | +18% | +28% | +2% | -1.8% |
| Test #5 | D. Dual Ignition - More EGR - Throttle Adjusted to Equalize Torque | 2000 | 4.5 | 12.6 | 179 | 87 | 2.3 | 155 | 300 | 0.568 |
| Test #5 | Comparison of Single → Dual (A→D) at Equal Torque | | | | | 0 | +109% | +24% | -45% | +2.5% |
| Test #6 | A. Single Ignition - (Base) | 2000 | 3.0 | < 0.5 | 246 | 91 | >5 | 325 | $NO_x$ Instrument Malfunction | 0.889 |
| Test #6 | B. Dual Ignition | 2000 | 3.0 | < 0.5 | 254 | --- | >5 | 325 | | --- |
| Test #6 | C. Dual Ignition - Increased EGR | 2000 | 2.7 | 6.1 | 246 | 99 | >5 | 330 | | 0.842 |
| Test #6 | Comparison of Single → Dual (A→C) at Equal Torque | | | | | +8 | | +2% | | -5.3% |
| Test #6 | D. Dual Ignition - More EGR - Throttle Adjusted to ≈ Equalize Torque | 2000 | 1.6 | 8.1 | 240 | >100 | >5 | 350 | | 0.834 |
| Test #6 | Comparison of Single → Dual (A→D) at Equal Torque | | | | | >+9 | | +7.7% | | -6.2% |

## APPENDIX E-8

### EFFECT OF INCREASED EGR ON OCTANE REQUIREMENT, FUEL CONSUMPTION, AND EMISSIONS OF DUAL IGNITION ENGINE

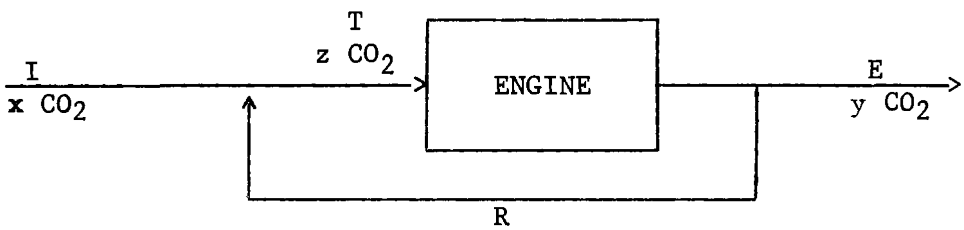
Test #7

| Description | Engine RPM | Manifold Vacuum | % EGR | Torque | Research Octane Requirement | CO(%) | HC(ppm) | $NO_x$(ppm) | Fuel Consumption (lb/min) |
|---|---|---|---|---|---|---|---|---|---|
| A. Single Ignition - (Base) | 2000 | 10.0 | 5.6 | 149 | 82 | 0.25 | 155 | 1800 | 0.446 |
| B. Dual Ignition | 2000 | 9.8 | 5.6 | 155 | --- | 0.25 | 180 | 2500 | --- |
| C. Dual Ignition - Increased EGR | 2000 | 9.0 | 13.0 | 149 | 90 | 0.25 | 175 | 1325 | 0.428 |
| Comparison of Single → Dual (A→C) at Equal Torque | | | | | +8 | 0 | +13% | -26% | -4.0% |
| D. Dual Ignition - More EGR - Throttle Adjusted to Equalize Torque | 2000 | 7.8 | 16.1 | 149 | 86 | 0.25 | 160 | 850 | 0.437 |
| Comparison of Single → Dual (A→D) at Equal Torque | | | | | +4 | 0 | +3% | -53% | -2.0% |

## APPENDIX E-9

### METHOD FOR CALCULATING PERCENTAGE EGR FLOW

EGR flow can be calculated from measurement of $CO_2$ concentrations in the exhaust and intake manifolds. The calculation procedure is outlined below.




The total flow into the engine consists of

(1) $I + R = T$. The $CO_2$ balance equation is

(2) $xI + yR = zT$

where x, y, and z are the fractional $CO_2$ concentrations in the intake air, exhaust manifold, and in the intake manifold respectively. Substitution of equation (1) into (2) gives

(3) $$\frac{R}{I} = \frac{z - x}{y - z}$$

Measurements of x, the $CO_2$ concentration in the intake air show it to be negligible. The basic combustion equation is given by

(4) $$CH_n + 3.76\ R\ N_2 + RO_2 + (7.63\ hR)\ H_2O \longrightarrow$$

$$CO_2 + \left(\frac{n}{2} + 7.63\ hR\right) H_2O + 3.76\ R\ N_2 + \left(R - \frac{n}{4} - 1\right) O_2$$

where n is the hydrogen/carbon ratio of the fuel, R is a measure of the intake air flow, and h is the humidity in lb $H_2O$/lb dry air. Since the $CO_2$ measurement procedure traps the $H_2O$ prior to measurement, the $CO_2$ concentration is on a dry basis and needs to be converted to a wet basis. From equation 3 the concentration of $CO_2$ (dry) in the exhaust is given by

(5) $$y_{(dry)} = \frac{1}{1 + 3.76\ R + \left(R - \frac{n}{4} - 1\right)}$$

Thus R can be estimated from the $CO_2$ concentration in the exhaust by rearrangement of equation 5.

(6) $$R = \frac{1}{4.76} \left(\frac{1}{y} + \frac{n}{4}\right)$$

The $CO_2$ concentration on a wet basis is given by

(7) $$y' \equiv y \text{ (wet)} = \frac{1}{1 + 3.76\ R + (R - \frac{n}{4} - 1) + (\frac{n}{2} + 7.63\ hR)}$$

y' can be expressed in terms of y using

(8) $$y' = \left(\frac{4.76\ R - \frac{n}{4}}{\frac{n}{4} + 7.63\ hR + 4.76\ R}\right) y$$

In general the $H_2O$ content of the intake manifold mixture is so low that no correction is necessary for Z, the intake manifold $CO_2$ concentration. However, for high levels of recycle some correction may be necessary and is given by

(9) $$z' \equiv z_{(wet)} = z \left(\frac{1}{1 + \frac{29}{18} h + [H_2O]_{EXH} \frac{[CO_2]_{IM}}{[CO_2]_{EXH}}}\right)$$

$$z' = z \left[\frac{1}{1 + \frac{29}{18} h + (1 - \frac{y'}{y}) (\frac{z}{y'})}\right]$$

With the $H_2O$ converted $CO_2$ concentrations calculated (z' and y'), equation 3 can be directly applied (ignoring the z term) to calculate R/I the fractional recycle flow.

# APPENDIX F

## FREQUENCY ANALYSIS OF ALTERNATE ENGINE

F-1 2.3 Liter Pinto L-4 Engine

F-2 2.8 Liter Ford V-6 Engine

## APPENDIX F-1

### Frequency Analysis Of 2.3 Liter, 4 Cylinder Pinto Engine

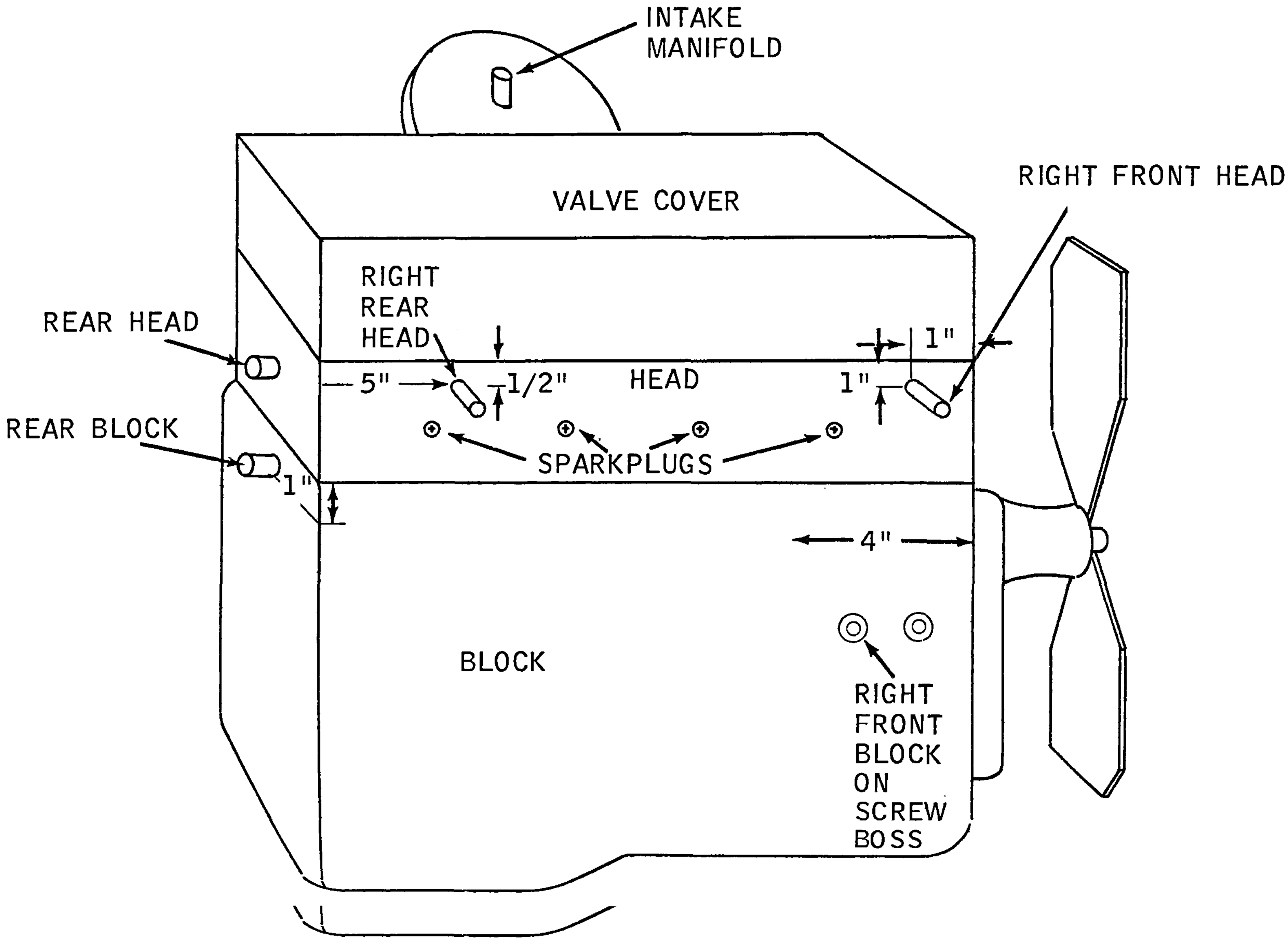
| Run No. | Accelerometer | Speed | Knock Rating |
|---|---|---|---|
| P 1 - 5 | Rear head | 2600 RPM Fuel Change | VL to NK |
| P 1 - 6 | Rear block | 2600 RPM Fuel Change | VL to NK |
| P 1 - 7 | Right front head | 2600 RPM Fuel Change | VL to NK |
| P 2 - 5 | Rear head | 2600 RPM Fuel Change | NK to VL |
| P 2 - 6 | Rear block | 2600 RPM Fuel Change | NK to VL |
| P 2 - 7 | Right front head | 2600 RPM Fuel Change | NK to VL |
| P 3 - 5 | Intake Manifold | 2600 RPM Fuel Change | NK to VL |
| P 3 - 6 | Right rear head | 2600 RPM Fuel Change | NK to VL |
| P 3 - 7 | Right front block | 2600 RPM Fuel Change | NK to VL |
| P 4 - 5 | Intake Manifold | 1600 RPM Fuel Change | VL to NK |
| P 4 - 6 | Right rear head | 1600 RPM Fuel Change | VL to NK |
| P 4 - 7 | Right front block | 1600 RPM Fuel Change | VL to NK |
| P 5 - 5 | Intake Manifold | 2600 RPM Fuel Change | NK to VL |
| P 5 - 6 | Right rear head | 2600 RPM Fuel Change | NK to VL |
| P 5 - 7 | Right front block | 2600 RPM Fuel Change | NK to VL |
| P 6 - 5 | Intake Manifold | 1600 RPM Fuel Change | NK to VL |
| P 6 - 6 | Right rear head | 1600 RPM Fuel Change | NK to VL |
| P 6 - 7 | Right front block | 1600 RPM Fuel Change | NK to VL |

| Run No. | Accelerometer | Speed | Knock Rating |
|---|---|---|---|
| P 10 - 5 | Rear head | 30 to 60 MPH Accel. | NK |
| P 10 - 6 | Rear block | 30 to 60 MPH Accel. | NK |
| P 10 - 7 | Right front head | 30 to 60 MPH Accel. | NK |
| P 11 - 5 | Intake Manifold | 30 to 60 MPH Accel. | NK |
| P 11 - 6 | Right rear head | 30 to 60 MPH Accel. | NK |
| P 11 - 7 | Right front block | 30 to 60 MPH Accel. | NK |
| P 12 - 5 | Intake Manifold | 30 to 60 MPH Accel. | VL |
| P 12 - 6 | Right rear head | 30 to 60 MPH Accel. | VL |
| P 12 - 7 | Right front block | 30 to 60 MPH Accel. | VL |
| P 13 - 5 | Rear head | 30 to 60 MPH Accel. | L |
| P 13 - 6 | Rear block | 30 to 60 MPH Accel. | L |
| P 13 - 7 | Right front head | 30 to 60 MPH Accel. | L |
| P 14 - 5 | Rear head | 30 to 60 MPH Accel. | NK |
| P 14 - 6 | Rear block | 30 to 60 MPH Accel. | NK |
| P 15 - 5 | Intake Manifold | 30 to 60 MPH Accel. | NK |
| P 15 - 6 | Right rear head | 30 to 60 MPH Accel. | NK |
| P 15 - 7 | Right front block | 30 to 60 MPH Accel. | NK |
| P 16 - 5 | Intake Manifold | 30 to 60 MPH Accel. | T- |
| P 16 - 6 | Right rear head | 30 to 60 MPH Accel. | T- |
| P 16 - 7 | Right front block | 30 to 60 MPH Accel. | T- |

| Run No. | Accelerometer | Speed | Knock Rating |
|---|---|---|---|
| P 17 - 5 | Rear head | 30 to 60 MPH Accel. | T- |
| P 17 - 6 | Rear block | 30 to 60 MPH Accel. | T- |
| P 17 - 7 | Right front head | 30 to 60 MPH Accel. | T- |
| P 18 - 5 | Rear head | 30 to 60 MPH Accel. | T /T+ |
| P 18 - 6 | Rear block | 30 to 60 MPH Accel. | T /T+ |
| P 18 - 7 | Right front head | 30 to 60 MPH Accel. | T /T+ |
| P 19 - 5 | Intake Manifold | 30 to 60 MPH Accel. | T /T+ |
| P 19 - 6 | Right rear head | 30 to 60 MPH Accel. | T /T+ |
| P 19 - 7 | Right front head | 30 to 60 MPH Accel. | T /T+ |
| P 20 - 5 | Rear head | 1600 RPM | T+ |
| P 20 - 6 | Rear block | 1600 RPM | T+ |
| P 20 - 7 | Right front head | 1600 RPM | T+ |
| P 21 - 5 | Intake Manifold | 1600 RPM | T+ |
| P 21 - 6 | Right rear head | 1600 RPM | T+ |
| P 21 - 7 | Right front block | 1600 RPM | T+ |
| P 22 5 | Intake manifold | 1600 RPM | T- |
| P 22 - 6 | Right rear head | 1600 RPM | T- |
| P 22 - 7 | Right front block | 1600 RPM | T- |
| P 23 - 5 | Rear head | 1600 RPM | T- |
| P 23 - 6 | Rear block | 1600 RPM | T- |
| P 23 - 7 | Right front head | 1600 RPM | T- |
| P 24 - 5 | Rear head | 2600 RPM | T+ |
| P 24 - 6 | Rear block | 2600 RPM | T+ |
| P 24 - 7 | Right front head | 2600 RPM | T+ |
| P 25 - 5 | Intake Manifold | 2600 RPM | T+ |
| P 25 - 6 | Right rear head | 2600 RPM | T+ |
| P 25 - 7 | Right front block | 2600 RPM | T+ |
| P 26 - 5 | Intake Manifold | 2600 RPM | T- |
| P 26 - 6 | Right rear head | 2600 RPM | T- |
| P 26 - 7 | Right front block | 2600 RPM | T- |

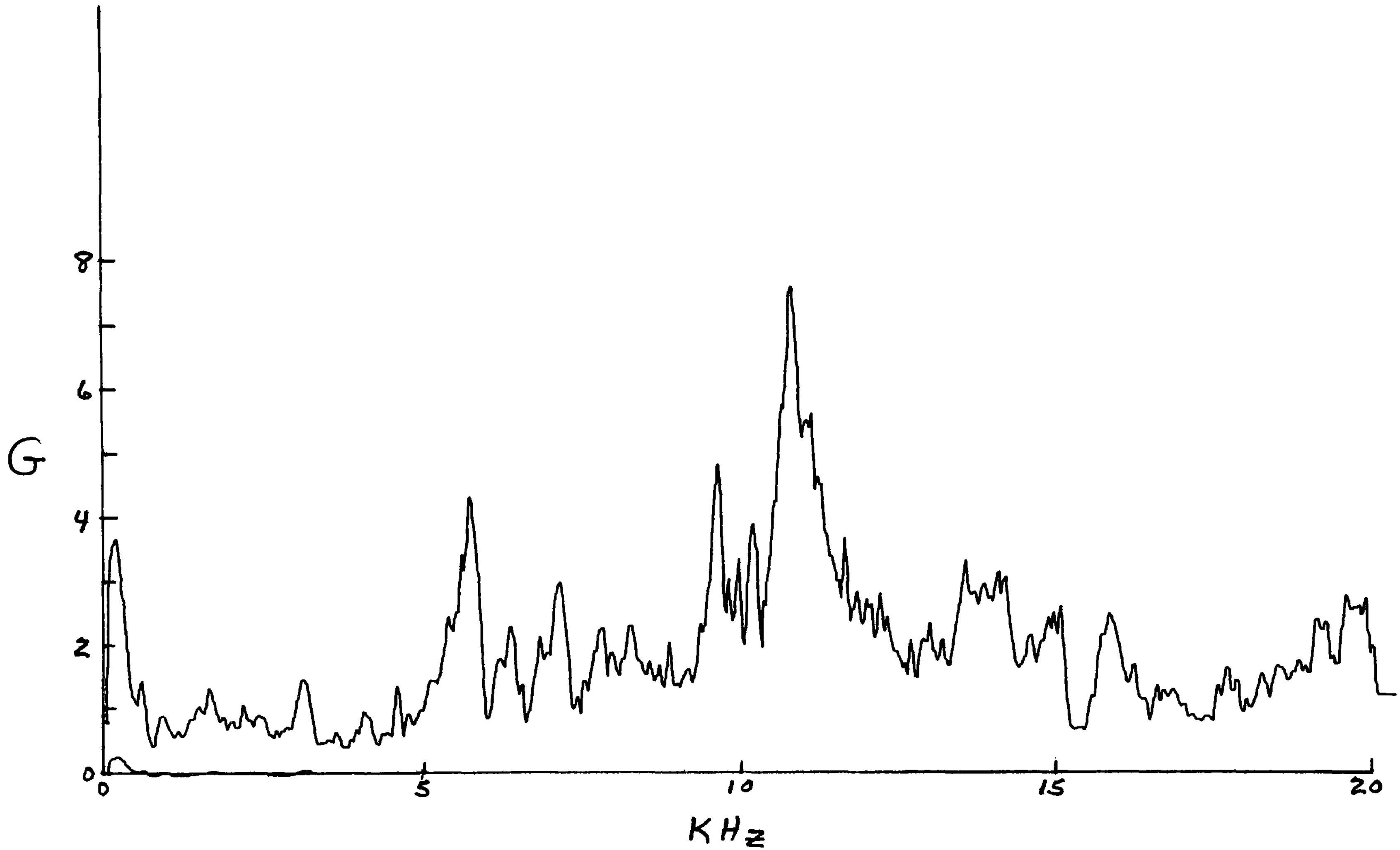
| Run No. | Accelerometer | Speed | Knock Rating |
|---|---|---|---|
| P 27 - 5 | Rear head | 2600 RPM | T- |
| P 27 - 6 | Rear block | 2600 RPM | T- |
| P 27 - 7 | Right front head | 2600 RPM | T- |
| P 28 - 5 | Rear head | 2600 RPM | NK |
| P 28 - 6 | Rear block | 2600 RPM | NK |
| P 28 - 7 | Right front head | 2600 RPM | NK |
| P 29 - 5 | Intake Manifold | 2600 RPM | NK |
| P 29 - 6 | Right rear head | 2600 RPM | NK |
| P 29 - 7 | Right front block | 2600 RPM | NK |
| P 30 - 5 | Intake Manifold | 2600 RPM | NK |
| P 30 - 6 | Right rear head | 2600 RPM | NK |
| P 30 - 7 | Right front block | 2600 RPM | NK |
| P 31 - 5 | Rear head | 2600 RPM | NK |
| P 31 - 6 | Rear block | 2600 RPM | NK |
| P 31 - 7 | Right front head | 2600 RPM | NK |
| P 32 - 5 | Rear head | 1600 RPM | NK |
| P 32 - 6 | Rear block | 1600 RPM | NK |
| P 32 - 7 | Right front head | 1600 RPM | NK |
| P 33 - 5 | Intake manifold | 1600 RPM | NK |
| P 33 - 6 | Right rear head | 1600 RPM | NK |
| P 33 - 7 | Right front block | 1600 RPM | NK |
| P 34 - 5 | Intake manifold | 1600 RPM | NK |
| P 34 - 6 | Right rear head | 1600 RPM | NK |
| P 34 - 7 | Right front block | 1600 RPM | NK |
| P 35 - 5 | Rear head | 1600 RPM | NK |
| P 35 - 6 | Rear block | 1600 RPM | NK |
| P 35 - 7 | Right front head | 1600 RPM | NK |

LOCATION OF ACCELEROMETERS ON
2.3 LITER 4 CYLINDER PINTO ENGINE (SIDE VIEW)



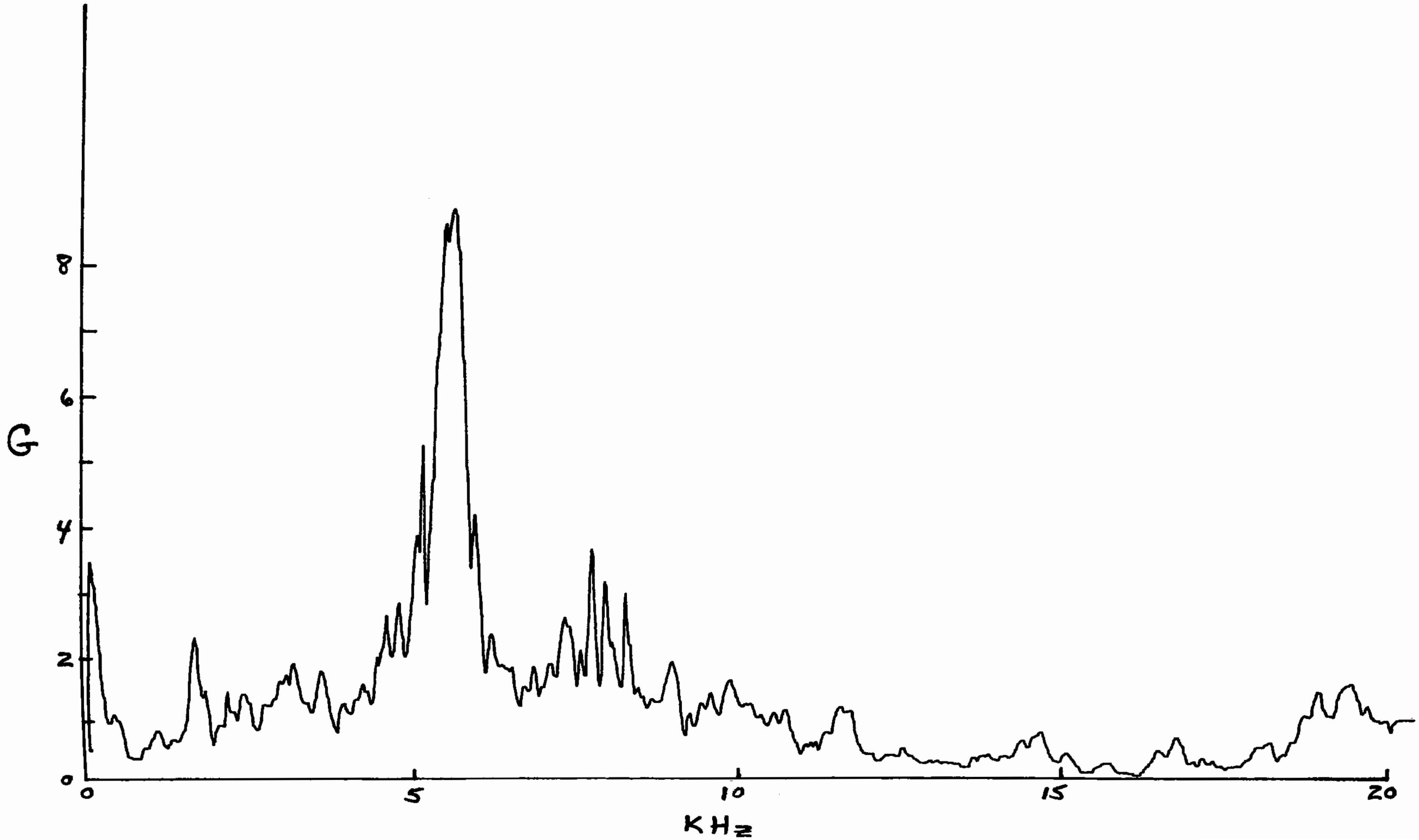
P1-5
160-190
record 3.16 IN
20DB
plot ODB

P1 - 5   2.3 L, 4 cyl.
Rear Head, C90, 2600 RPM
VL Knock to NK (TI 160/190)



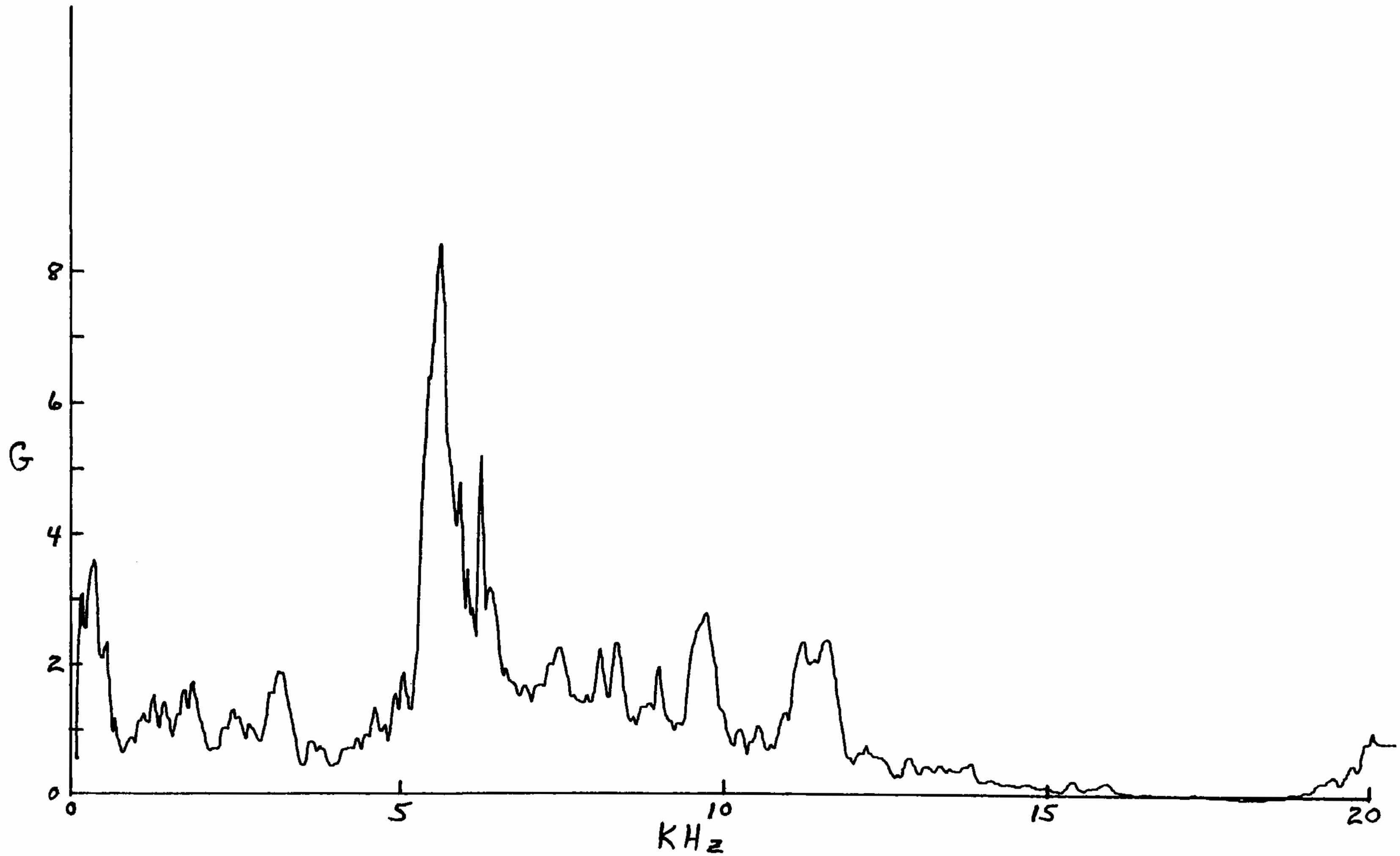
P1-6

P1 - 6   2.3 L, 4 cyl.
Rear Block, C90, 2600 RPM
VL Knock to NK (TI 160/190)



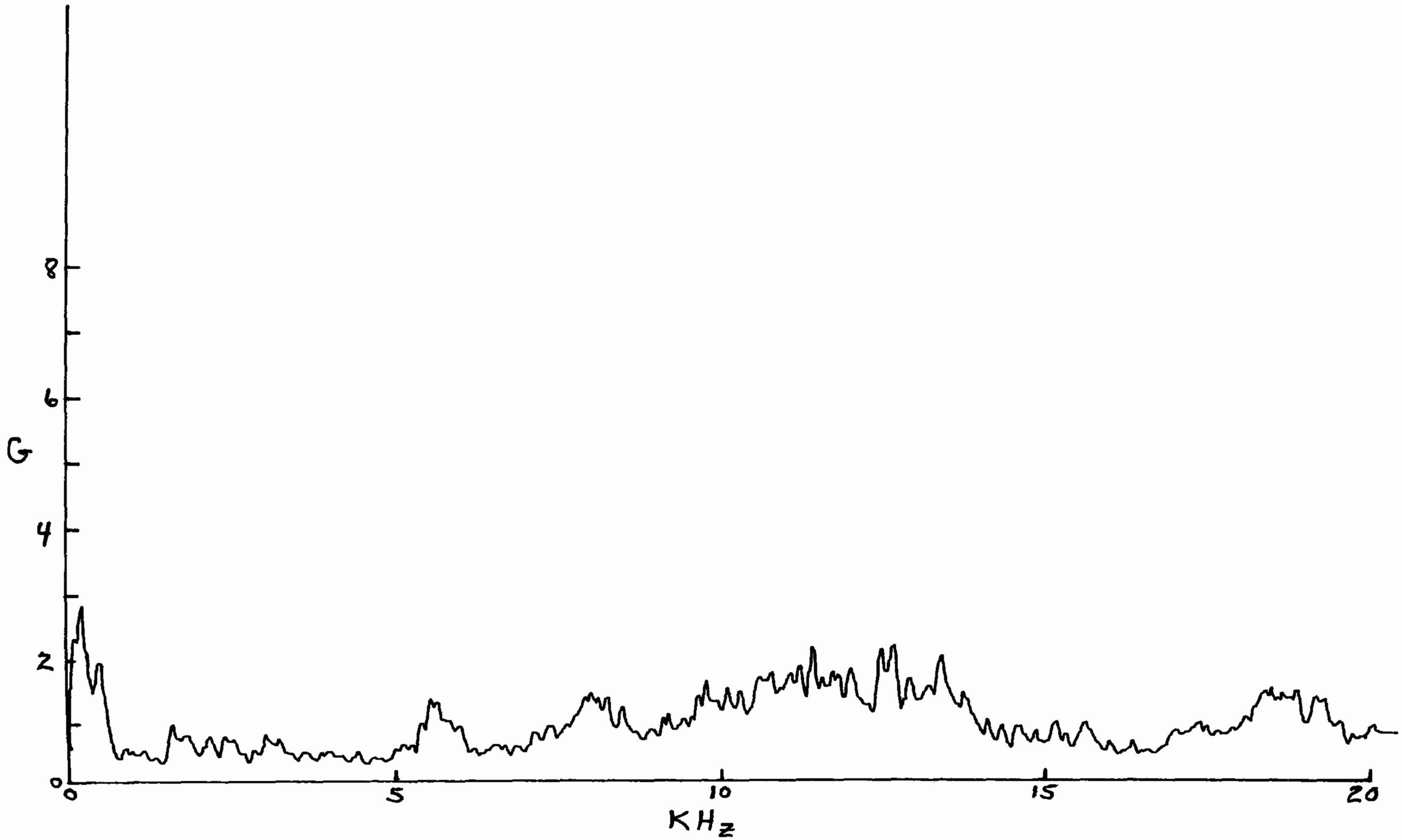
P1-7

P1 - 7   2.3 L, 4 cyl.
Right Front Head, C90, 2600
RPM VL Knock to NK (TI 160/190)



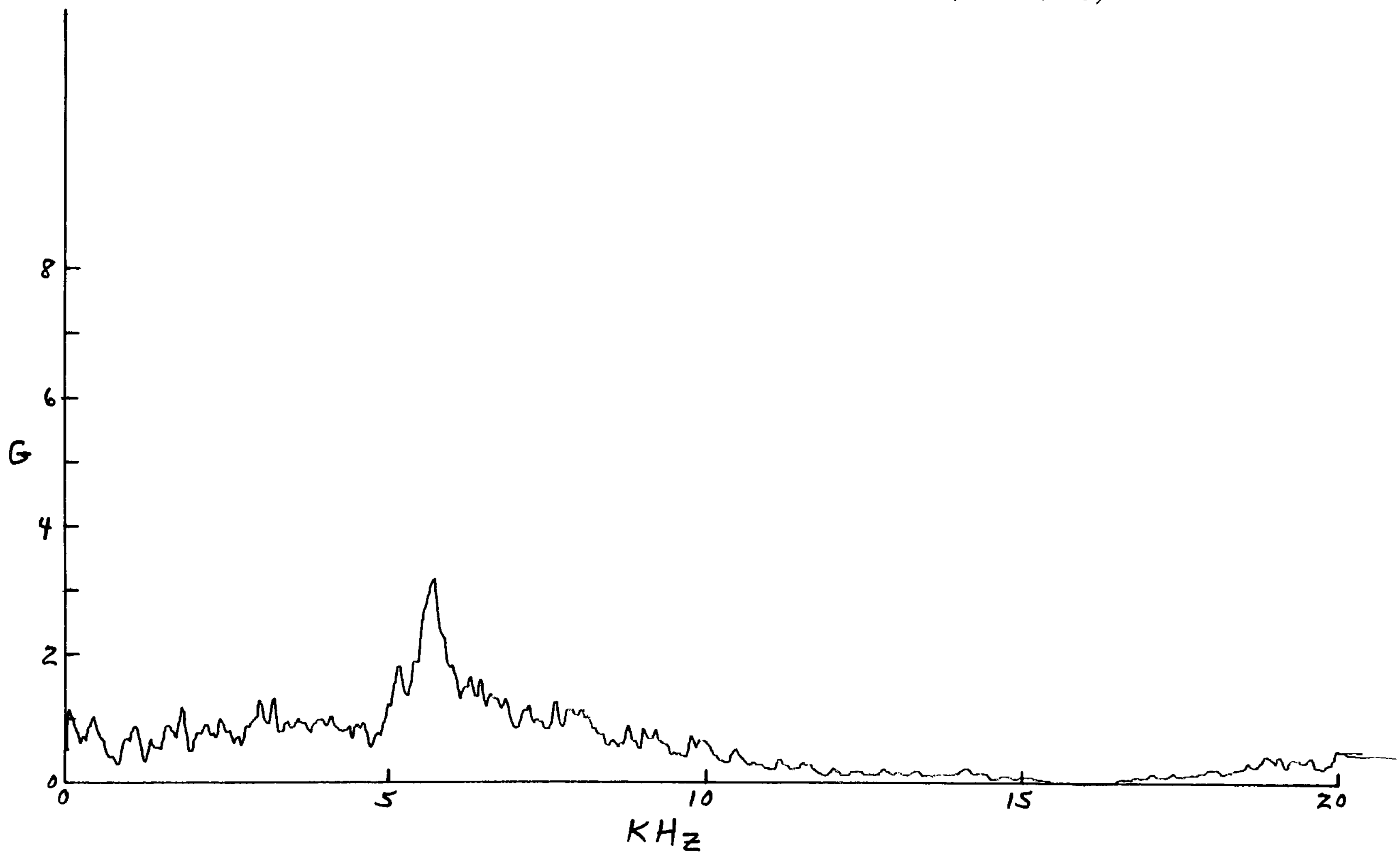
P2-5

P2 - 5   2.3 L, 4 cyl.
Rear Head, C90, 2600 RPM
NK to VL (TI 380/405)



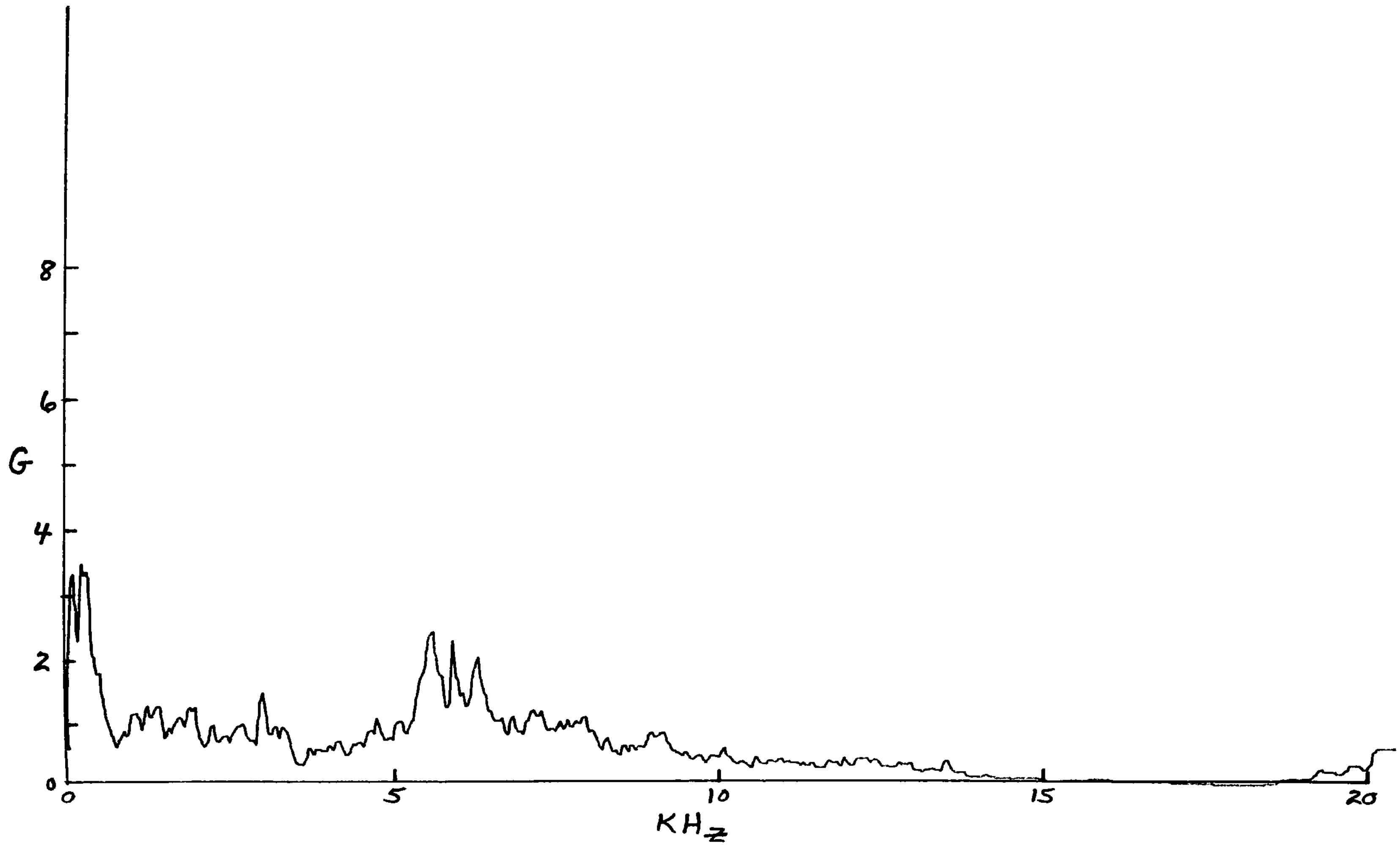
P2-6

P2 - 6   2.3 L, 4 cyl.
Rear Block, C90, 2600 RPM
NK to VL (TI 380/405)



P2-7

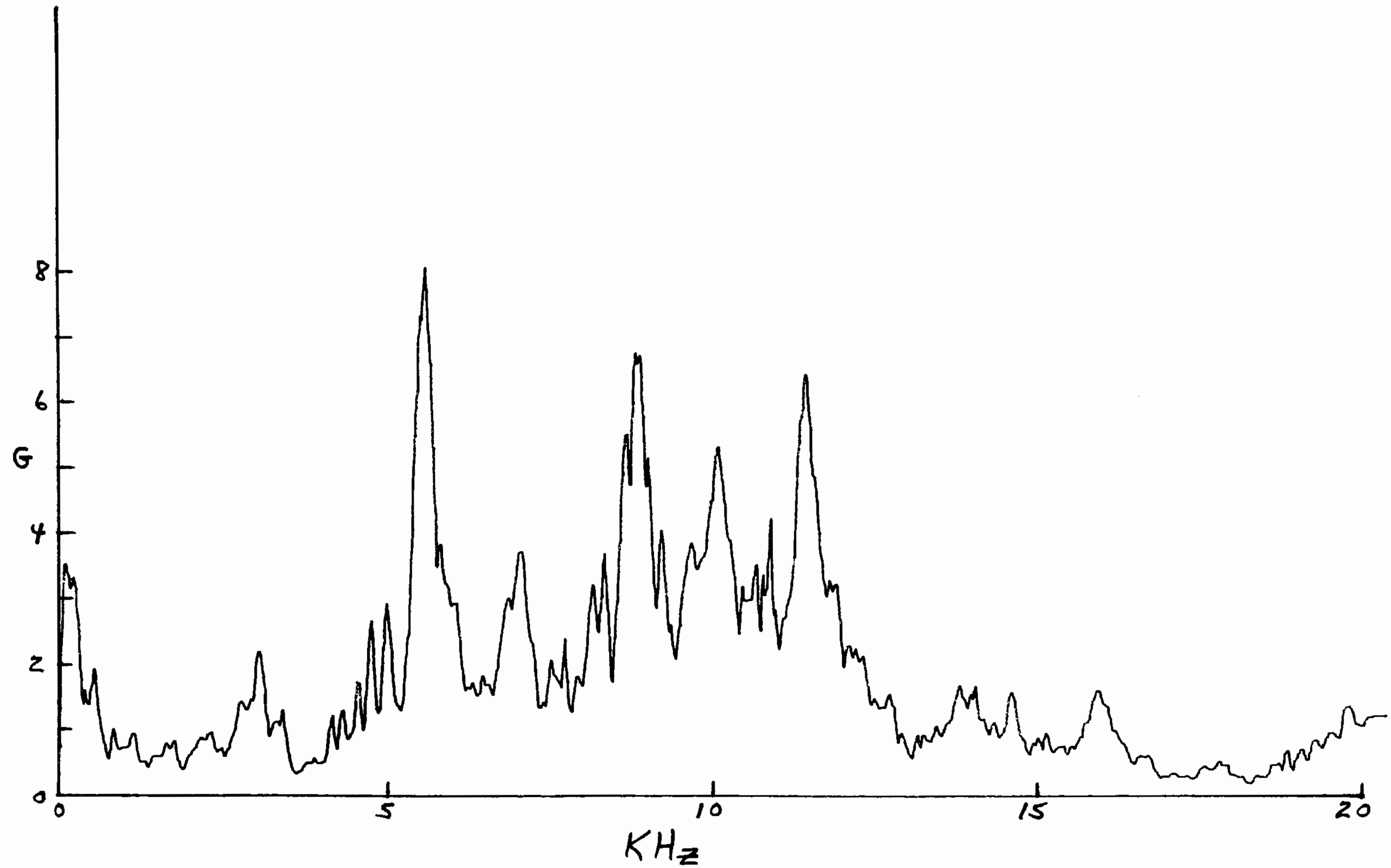
P2 - 7   2.3 L, 4 cyl.
Right Front Head, C90, 2600
RPM NK to VL (TI 380/405)



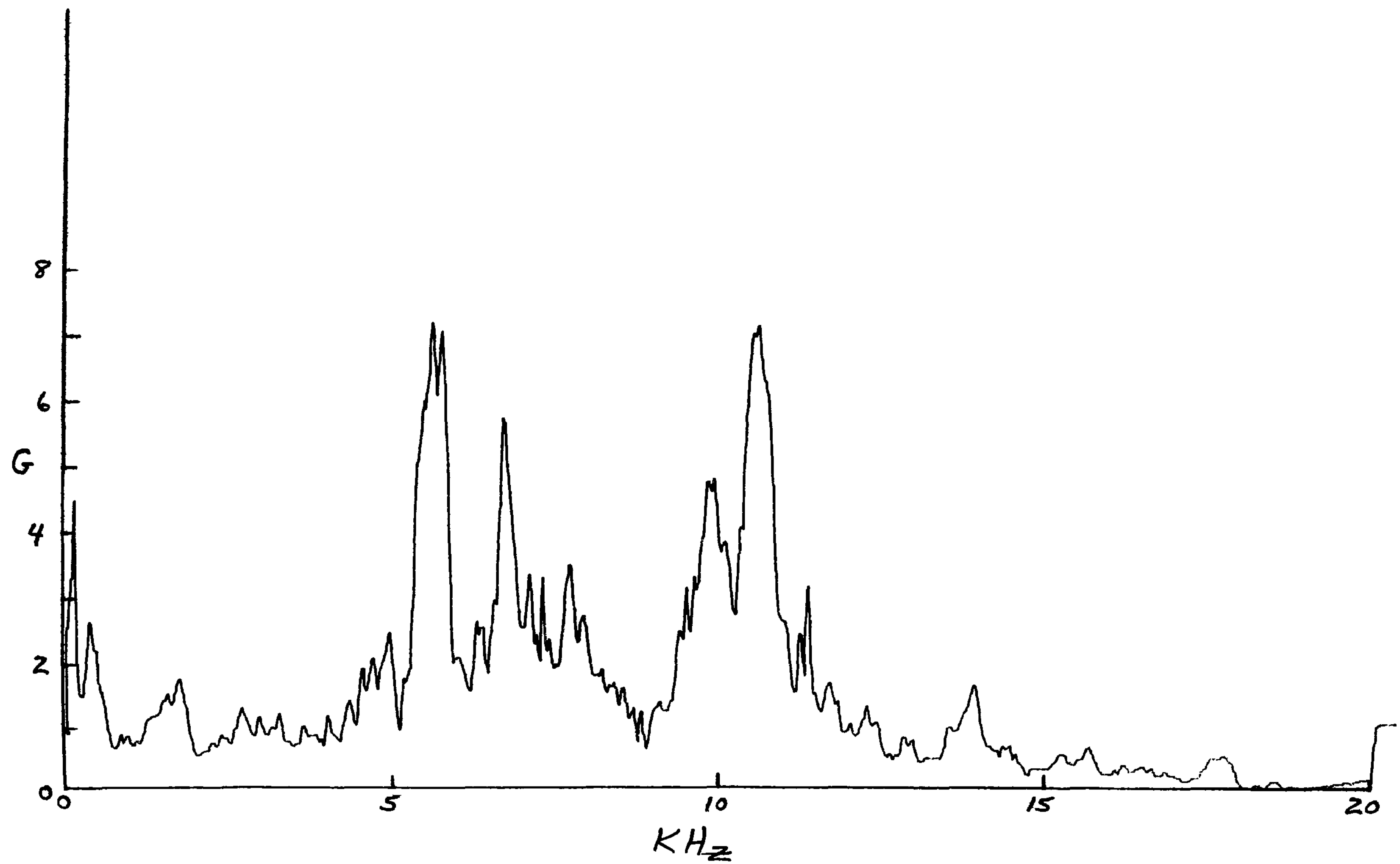

- 480 -

P3-5

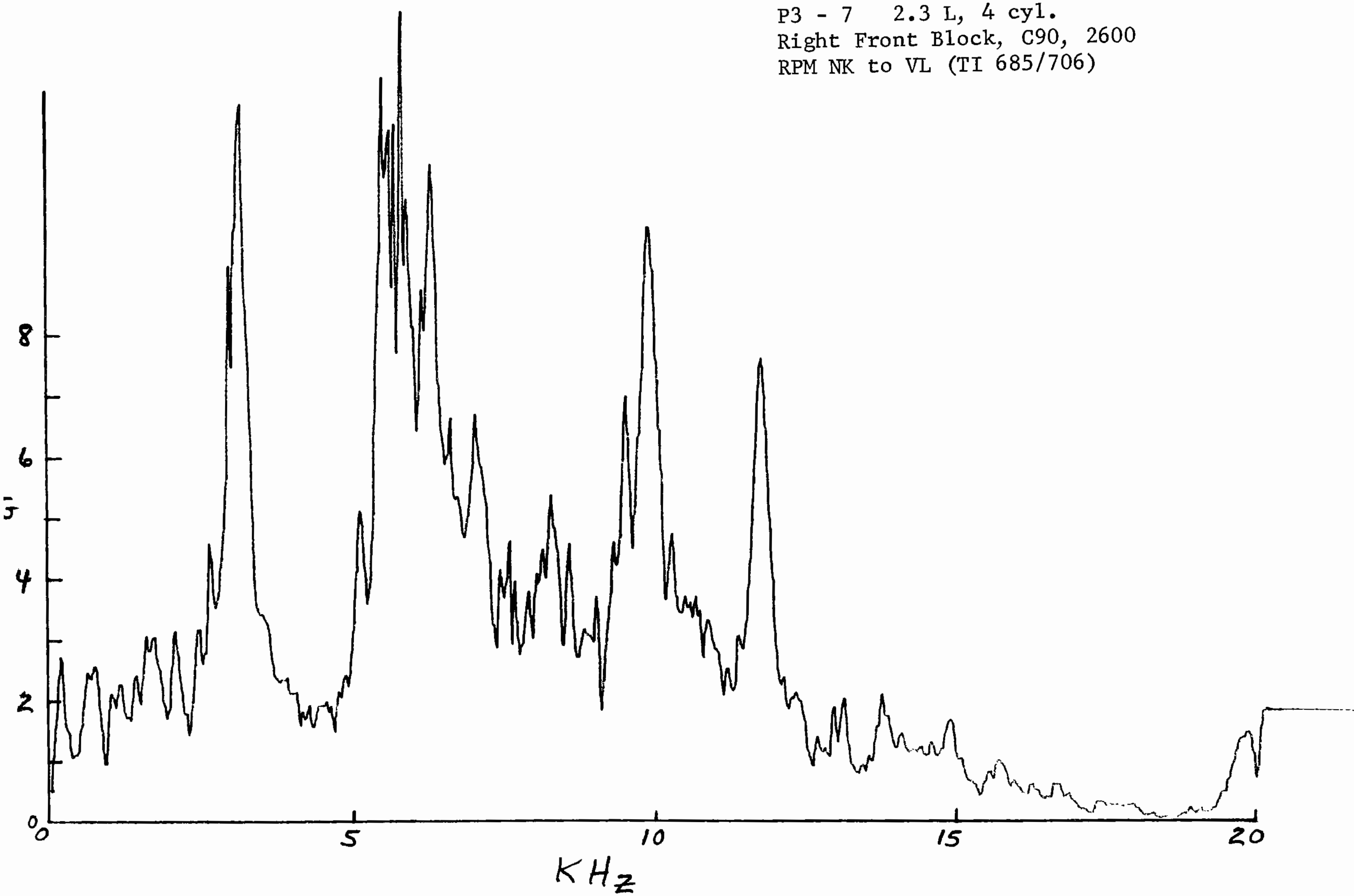
P3 - 5   2.3 L, 4 cyl.
Intake Manifold, C90, 2600
RPM NK to VL (TI 685/706)



P3 - 6   2.3 L, 4 cyl.
Right Rear Head, C90, 2600
RPM NK to VL (TI 685/706)



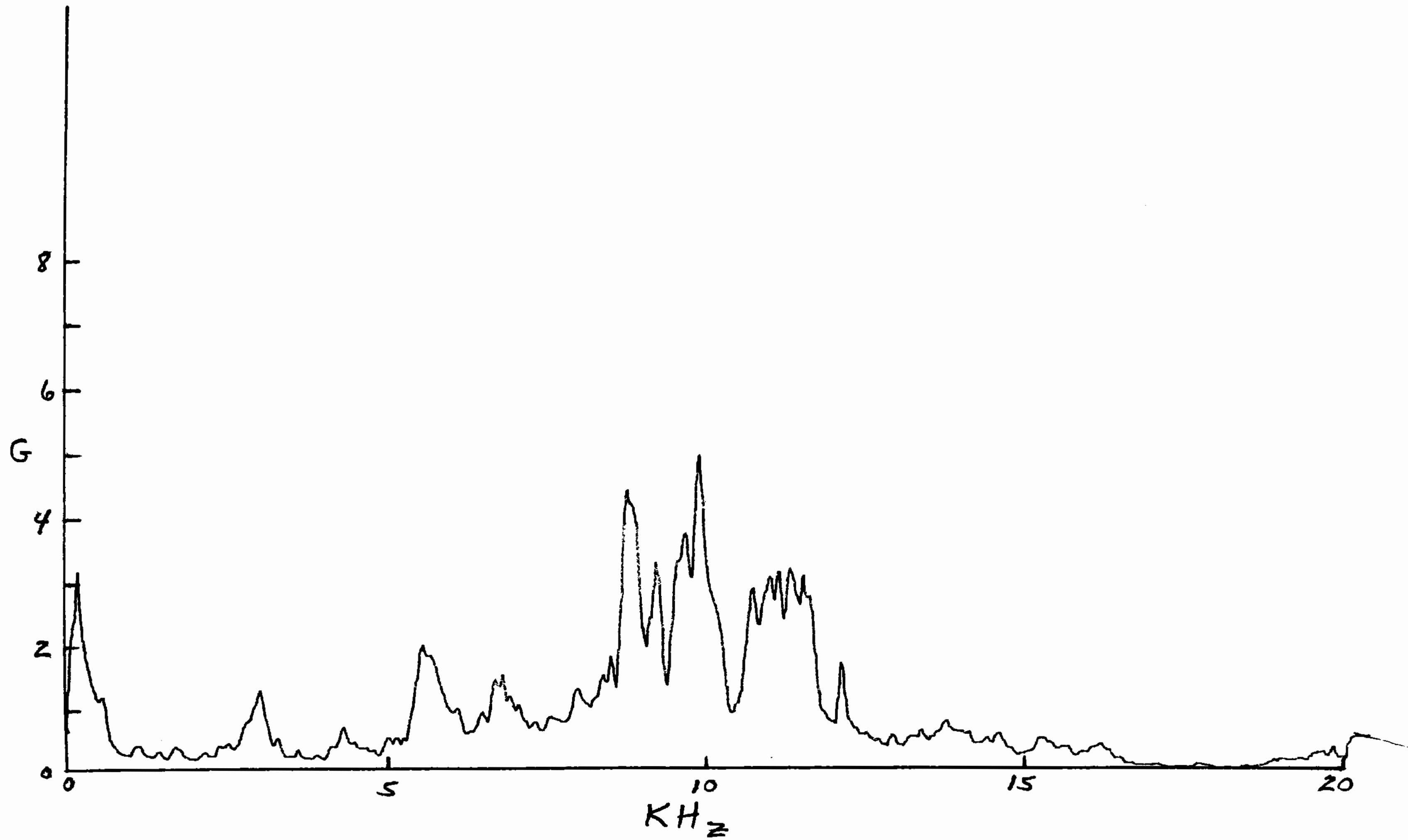
P3-7




P3 - 7 2.3 L, 4 cyl.
Right Front Block, C90, 2600
RPM NK to VL (TI 685/706)

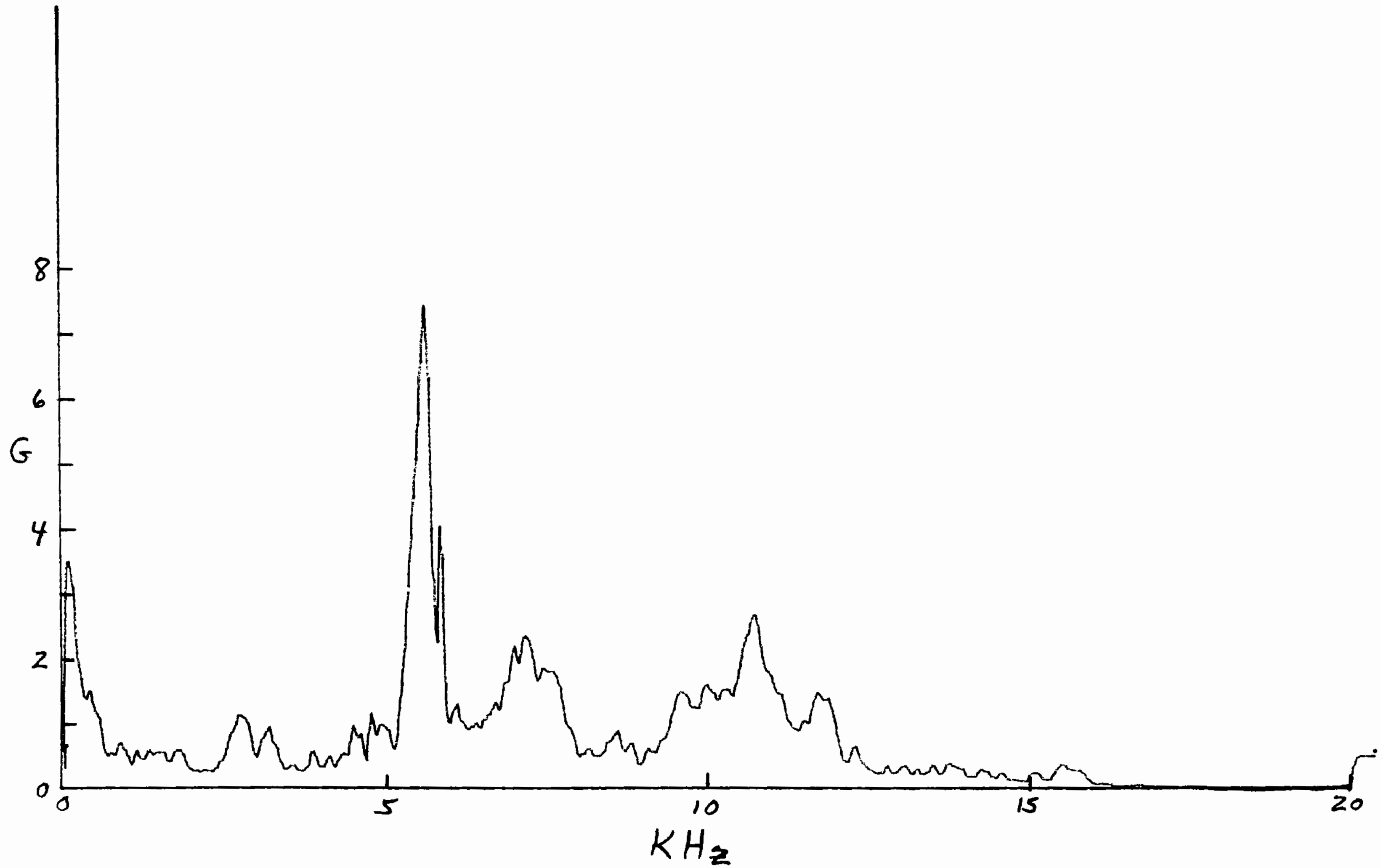
P4-5

P4 - 5 2.3 L, 4 cyl.
Intake Manifold, C90, 1600
RPM VL to NK (TI 870/888)



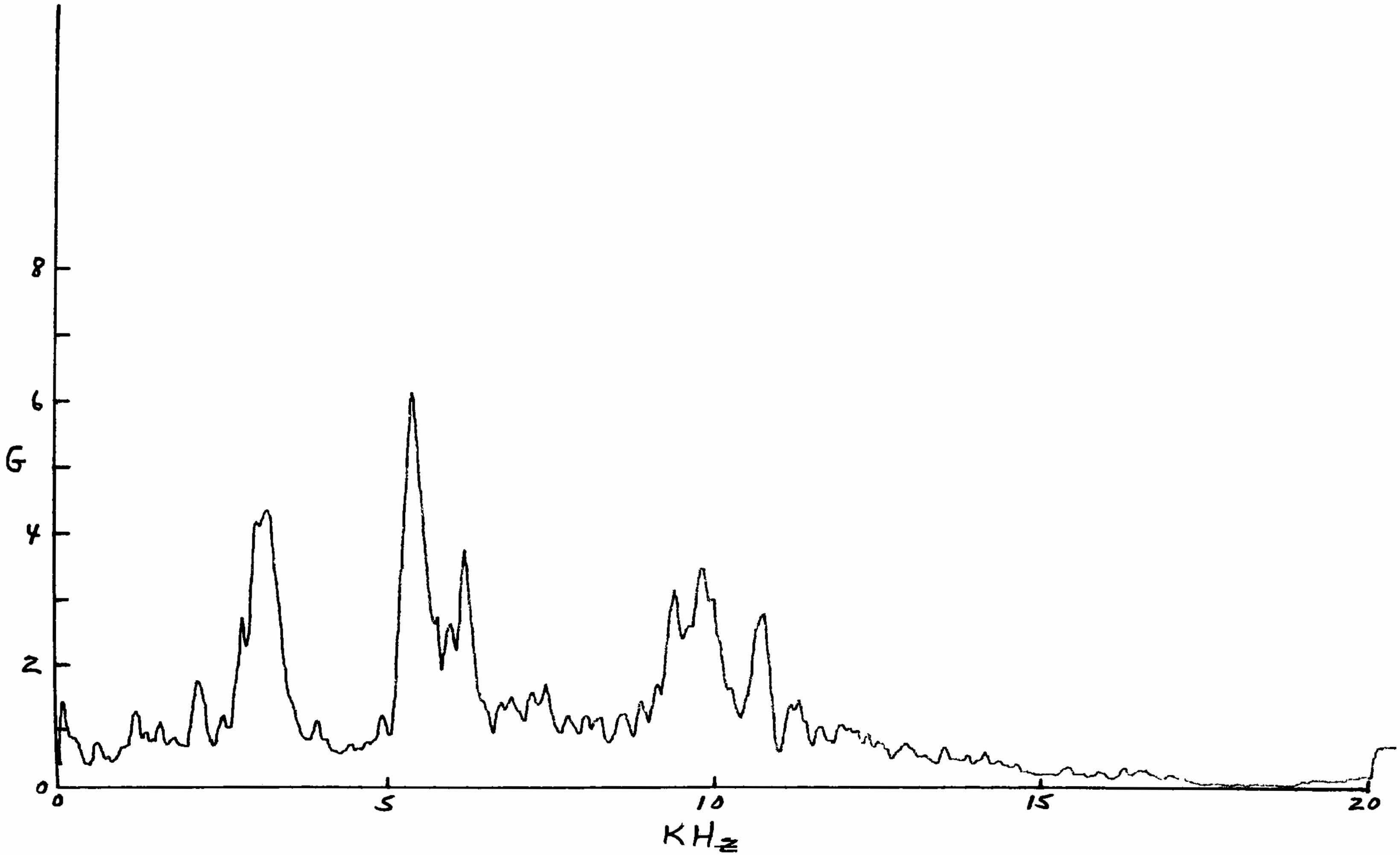
P4--

P4 - 6   2.3 L, 4 cyl.
RRH, C90, 1600 RPM
VL to NK (TI 870/888)

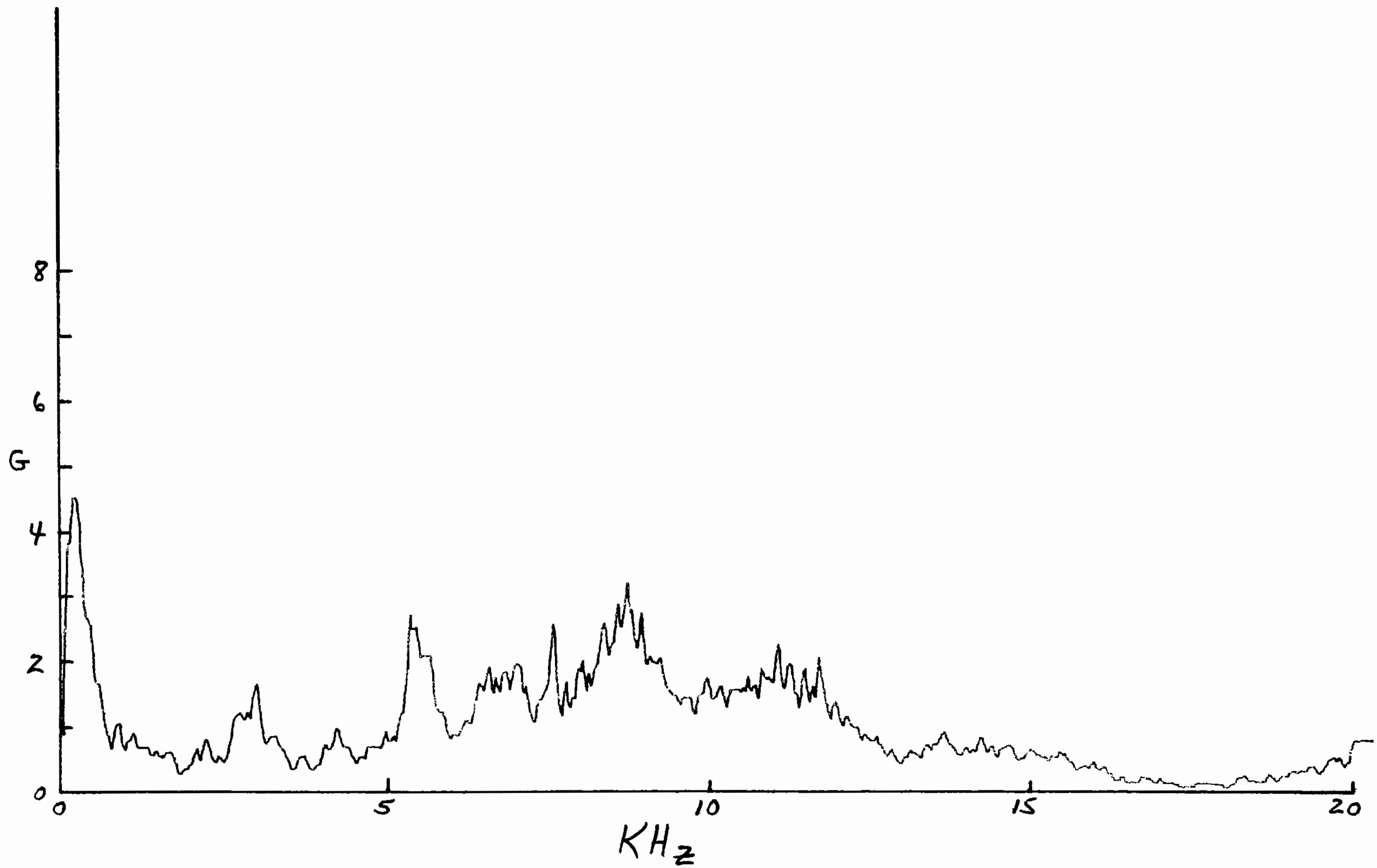


P4-7

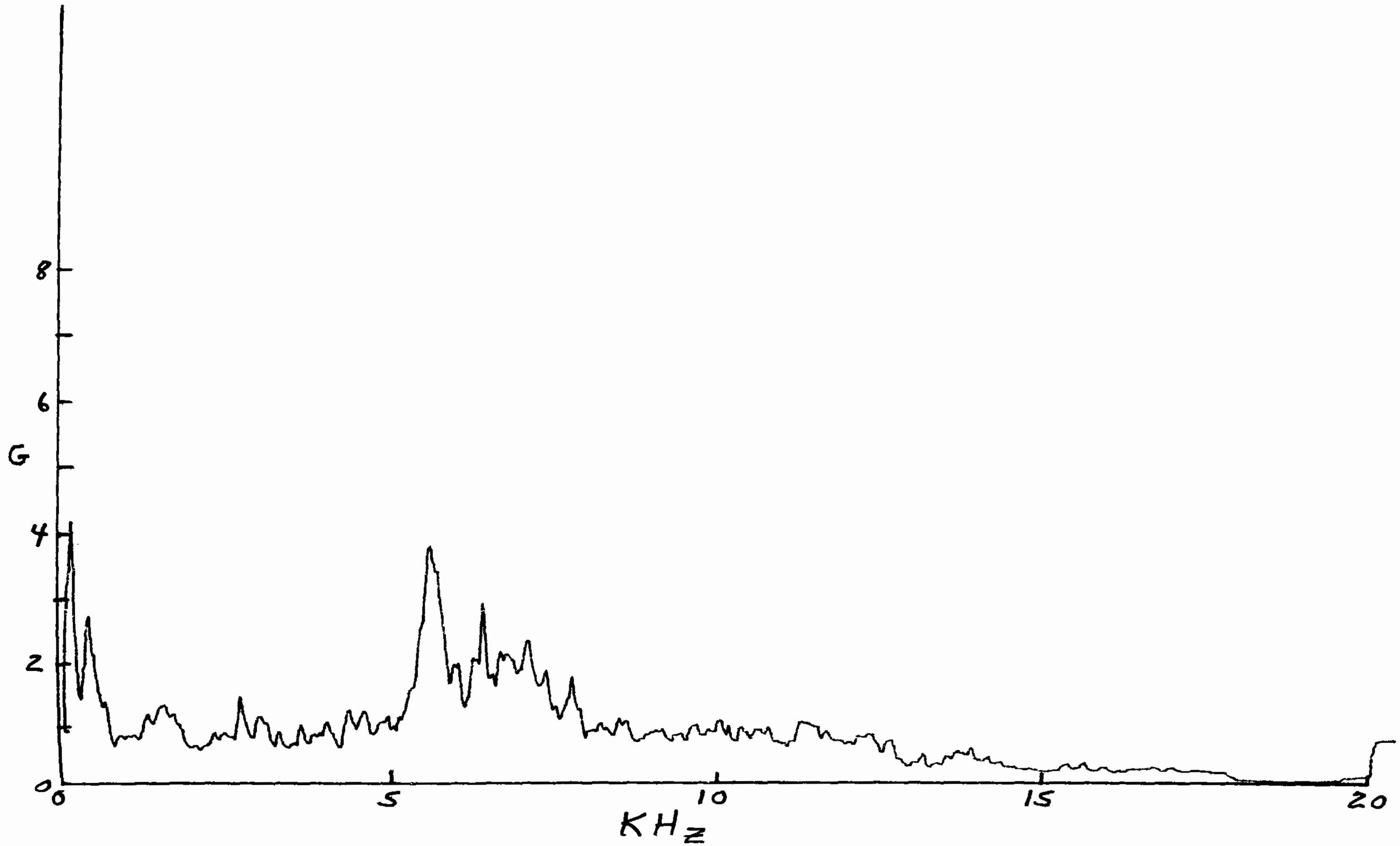
P4 - 7   2.3 L, 4 cyl.
RFB, C90, 1600 RPM
VL to NK (TI 870/888)



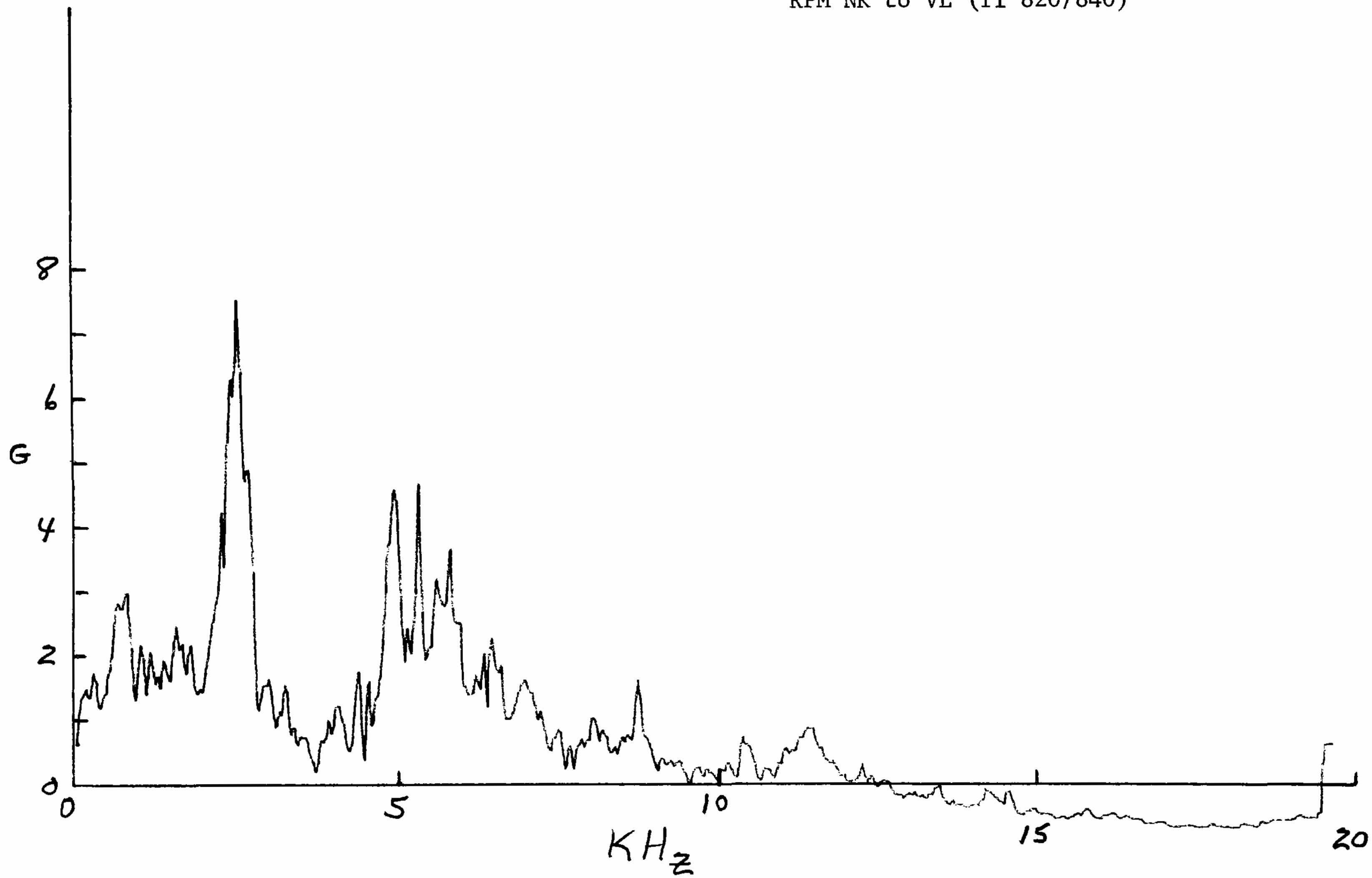
P5 - 5   2.3 L, 4 cyl.
Intake Manifold, C90, 2600
RPM No Knock to VL (TI 820/840)



P5 - 6   2.3 L, 4 cyl.
Right Rear Head, C90, 2600
RPM NK to VL (TI 820/840)

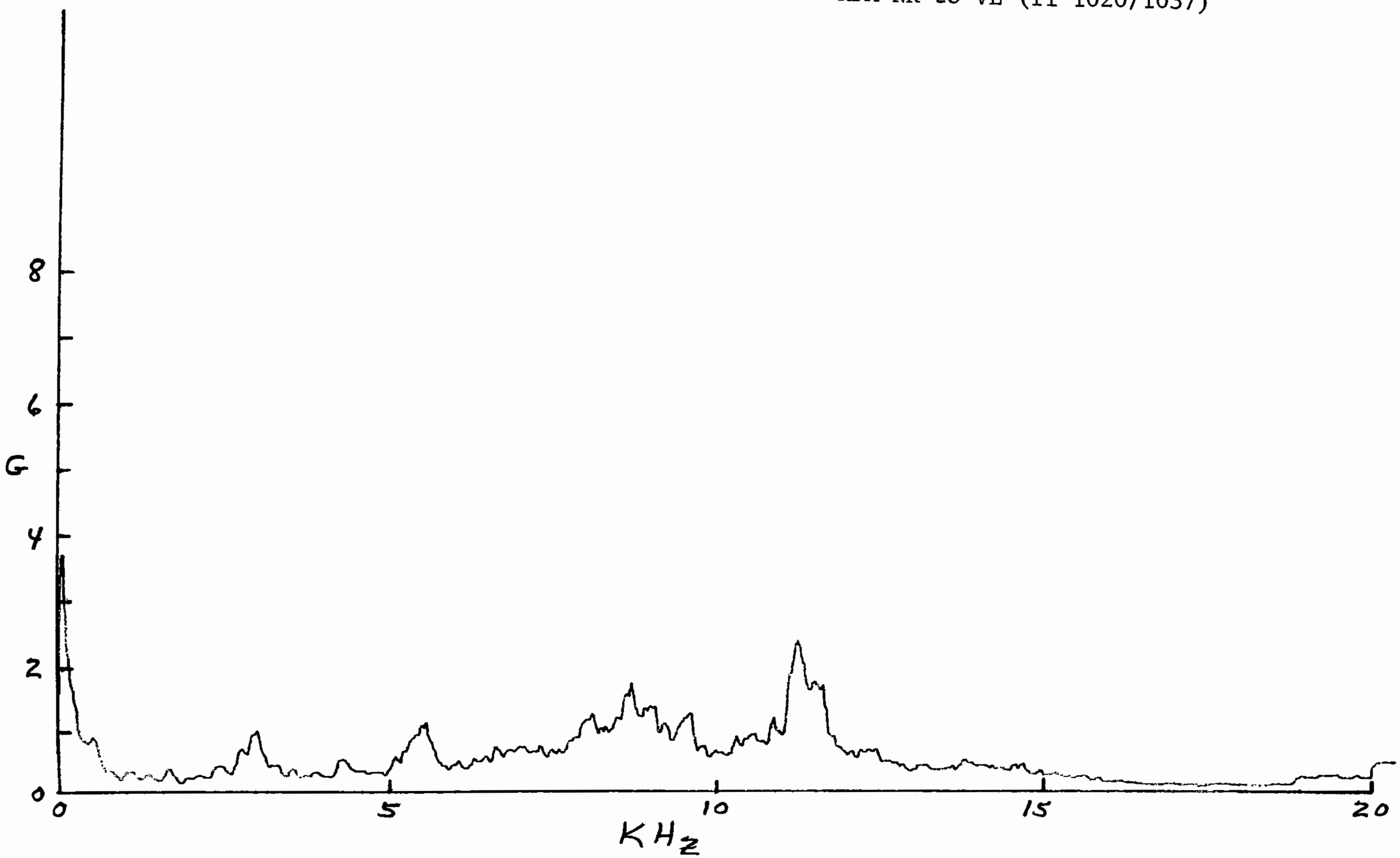


P5 - 7   2.3 L, 4 cyl.
Right Front Block, C90, 2600
RPM NK to VL (TI 820/840)



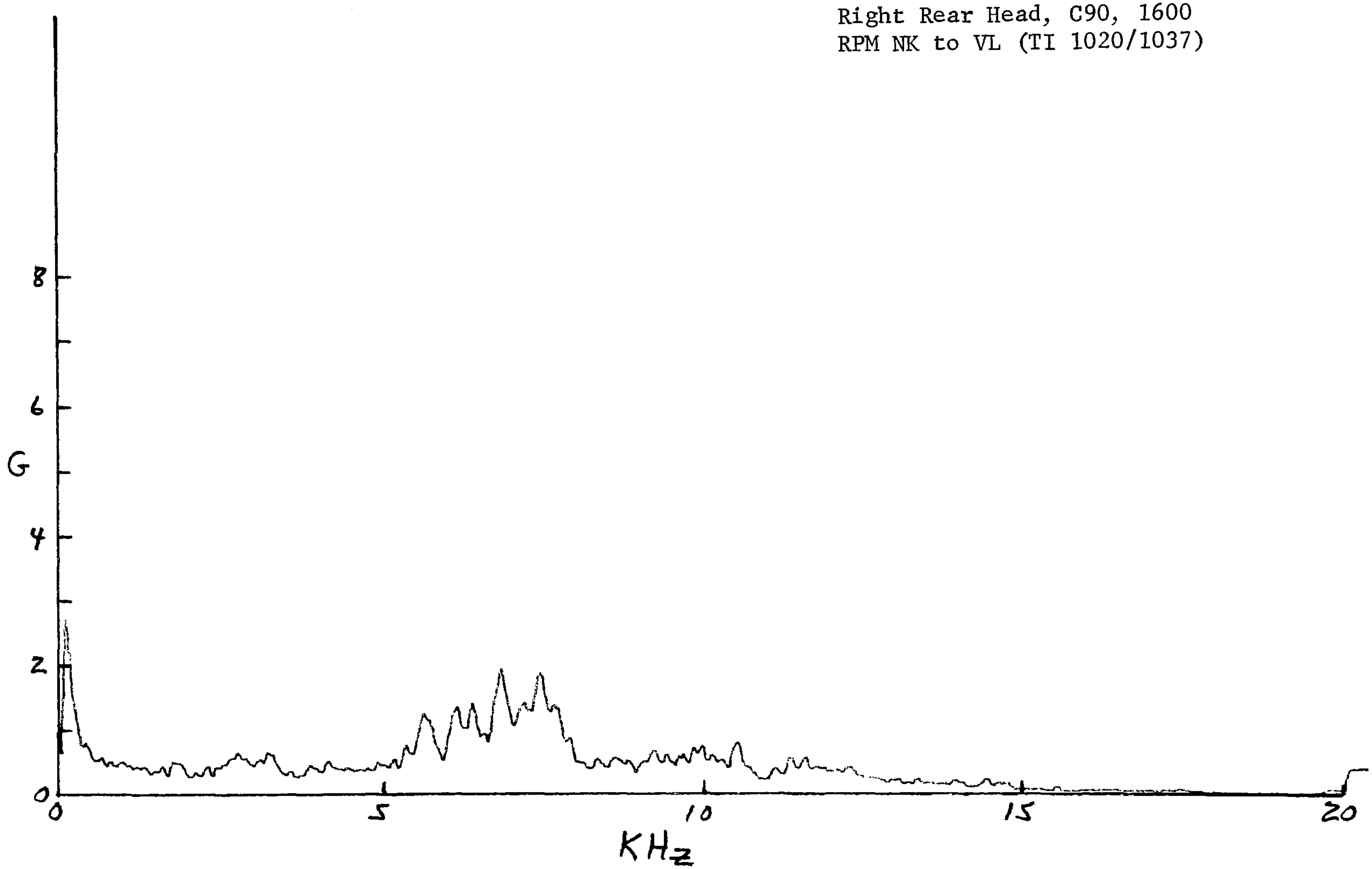
P6-5

P6 - 5   2.3 L, 4 cyl.
Intake Manifold, C90, 1600
RPM NK to VL (TI 1020/1037)



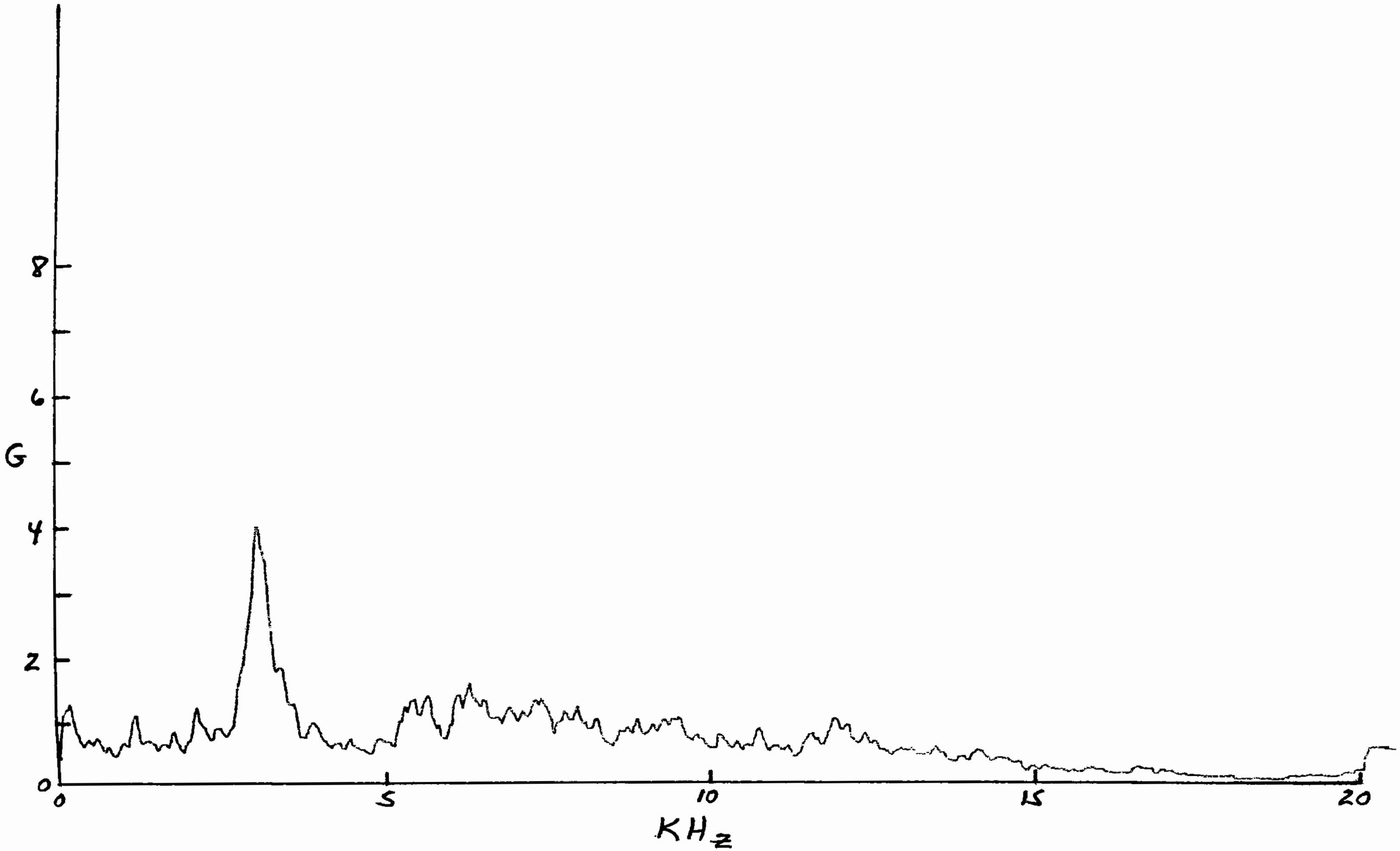
P6-6

P6 - 6 2.3 L, 4 cyl.
Right Rear Head, C90, 1600
RPM NK to VL (TI 1020/1037)

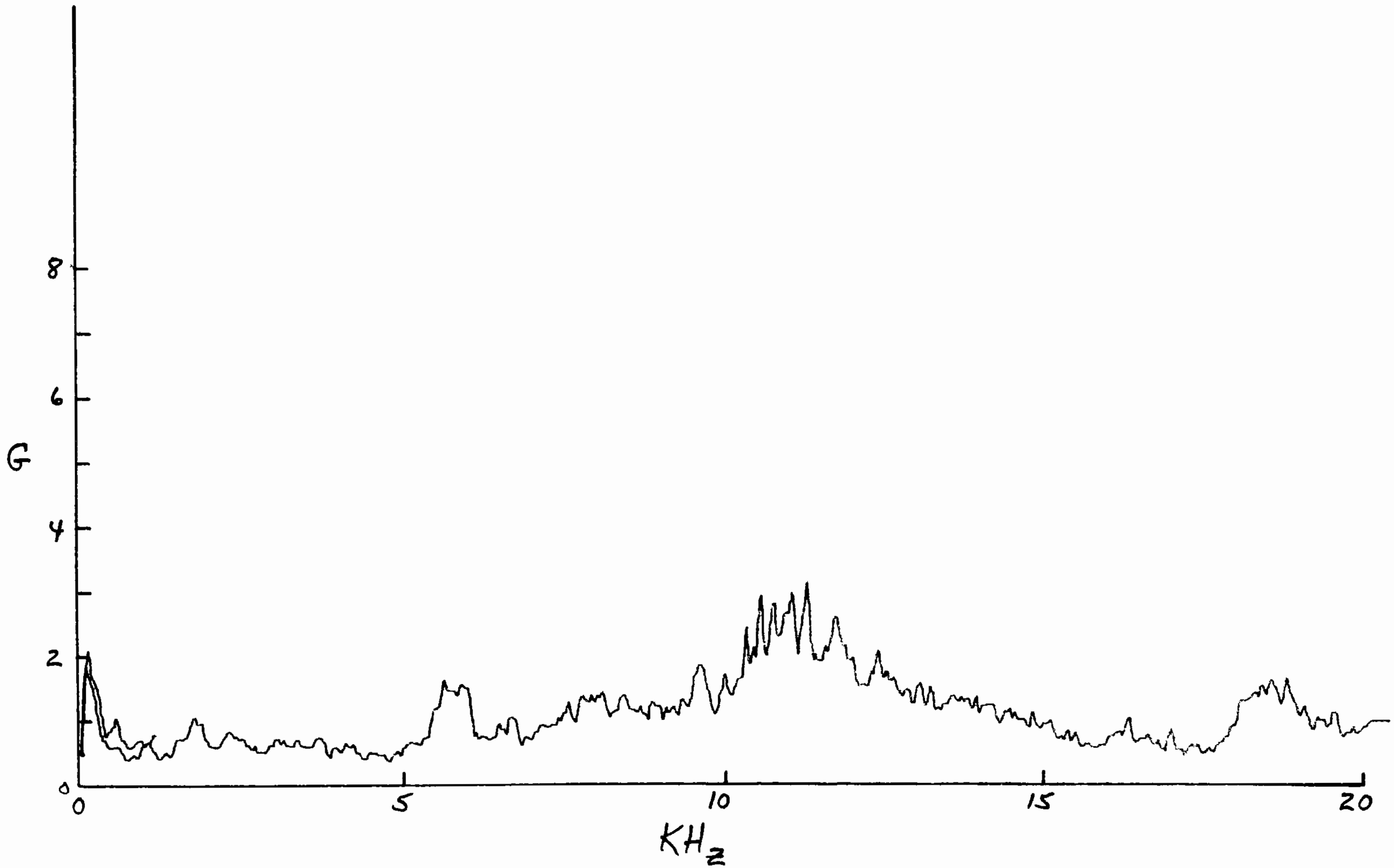


P6-7

P6 - 7 2.3 L, 4 cyl.
Right Front Block, C90, 1600
RPM NK to VL (TI 1020/1037)

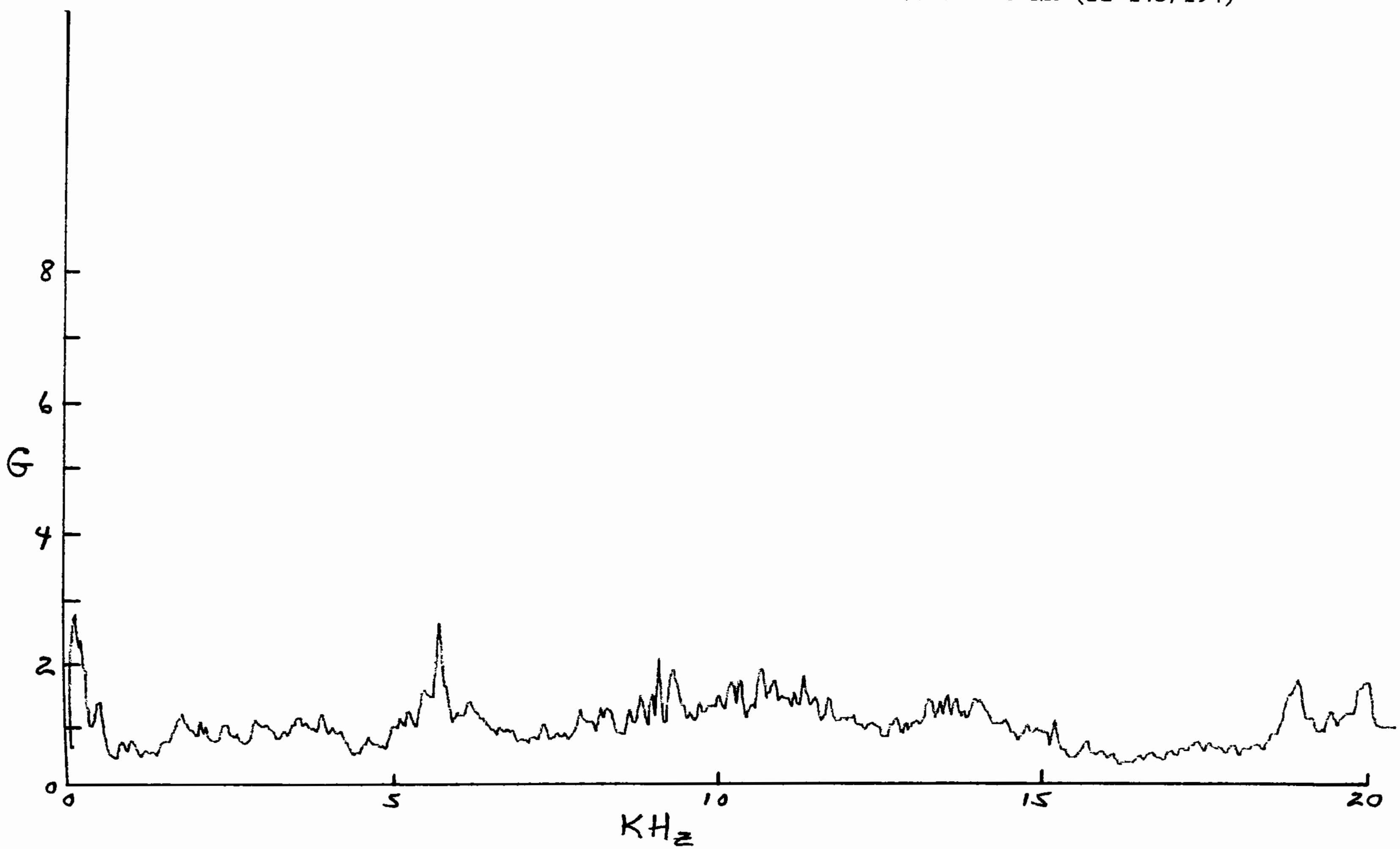


P10 - 5   2.3 L, 4 cyl.
Rear Head, Iso-Octane, 30 to
60 MPH Accel. NK (TI 143/194)



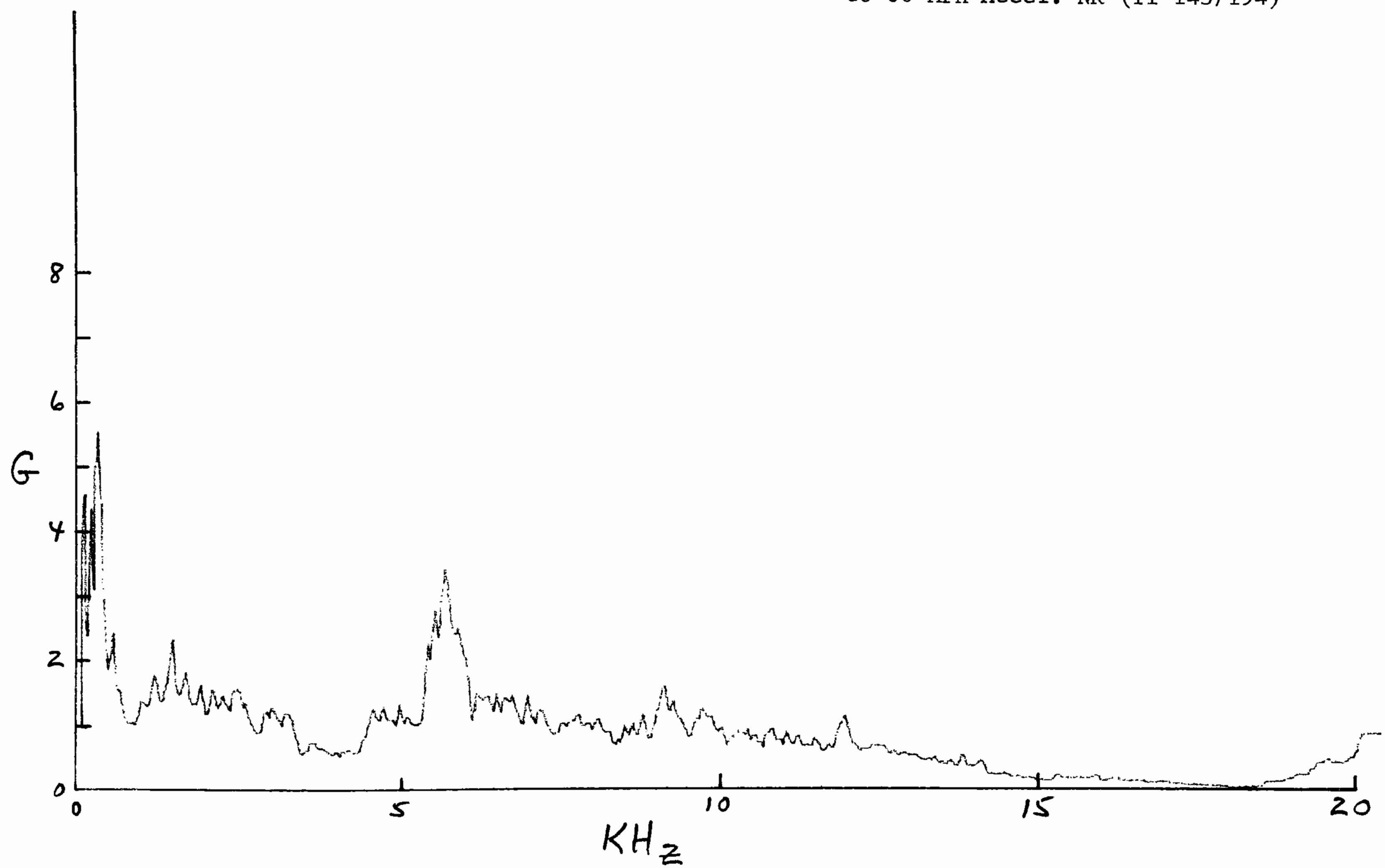
P10-6

P10 - 6   2.3 L, 4 cyl.
Rear Block, Iso-Octane, 30 to
60 MPH Accel. NK (TI 143/194)



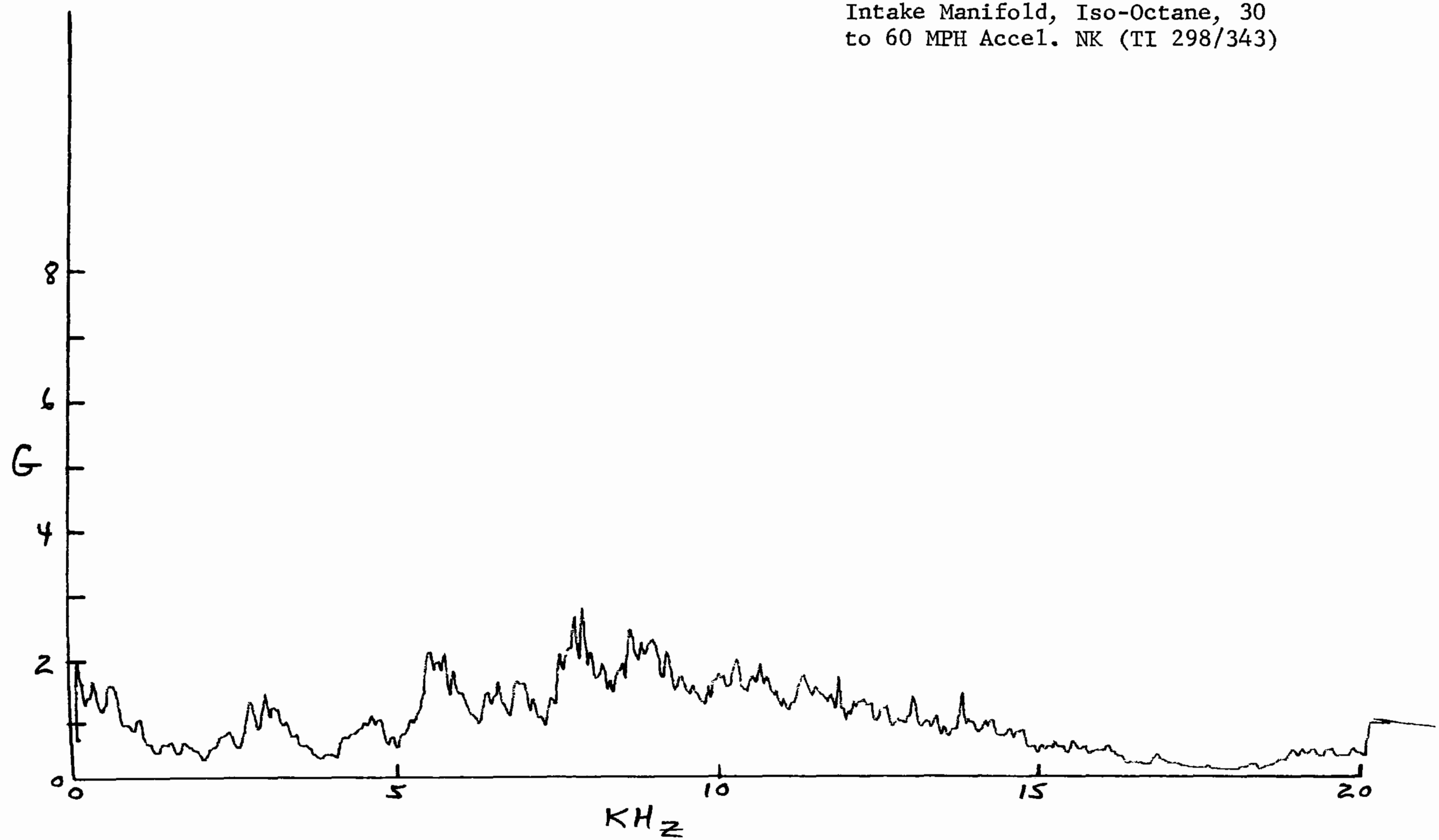
P10-7

P10 - 7 2.3 L, 4 cyl.
Right Front Head, Iso-Octane, 30
to 60 MPH Accel. NK (TI 143/194)



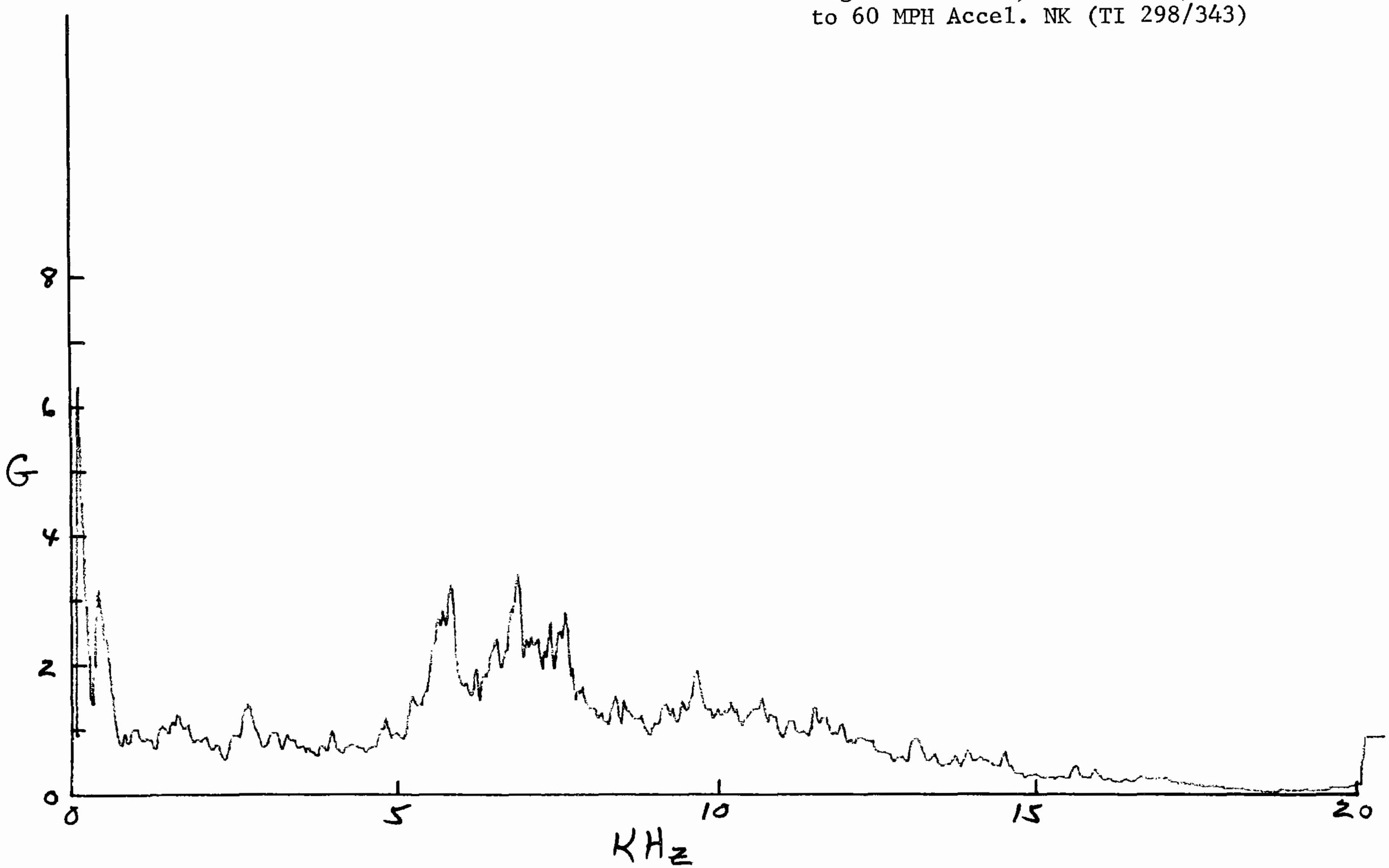
P11-5

P11 - 5   2.3 L, 4 cyl.
Intake Manifold, Iso-Octane, 30
to 60 MPH Accel. NK (TI 298/343)

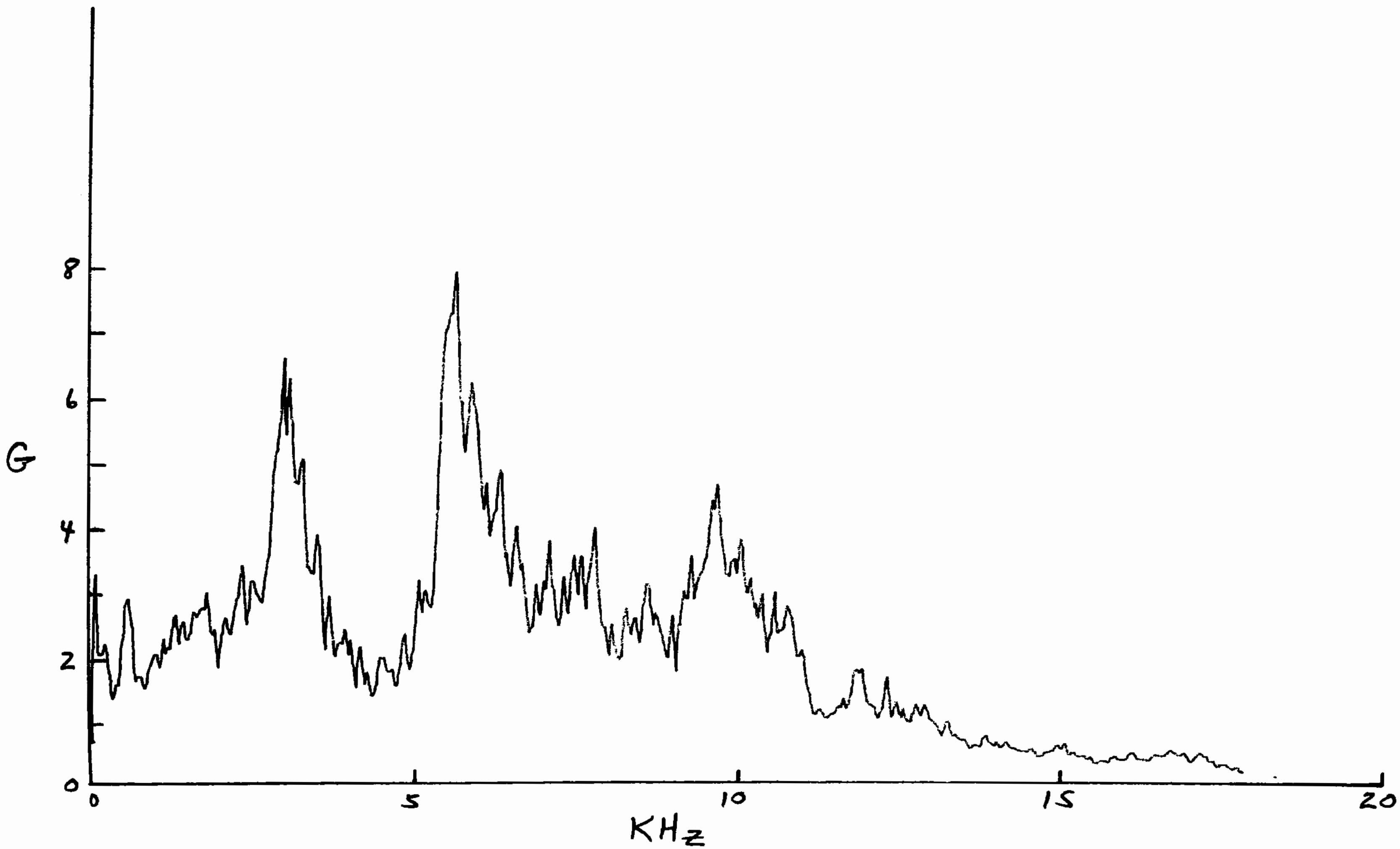


P11 - 6

P11 - 6 2.3 L, 4 cyl.
Right Rear Head, Iso-Octane, 30
to 60 MPH Accel. NK (TI 298/343)

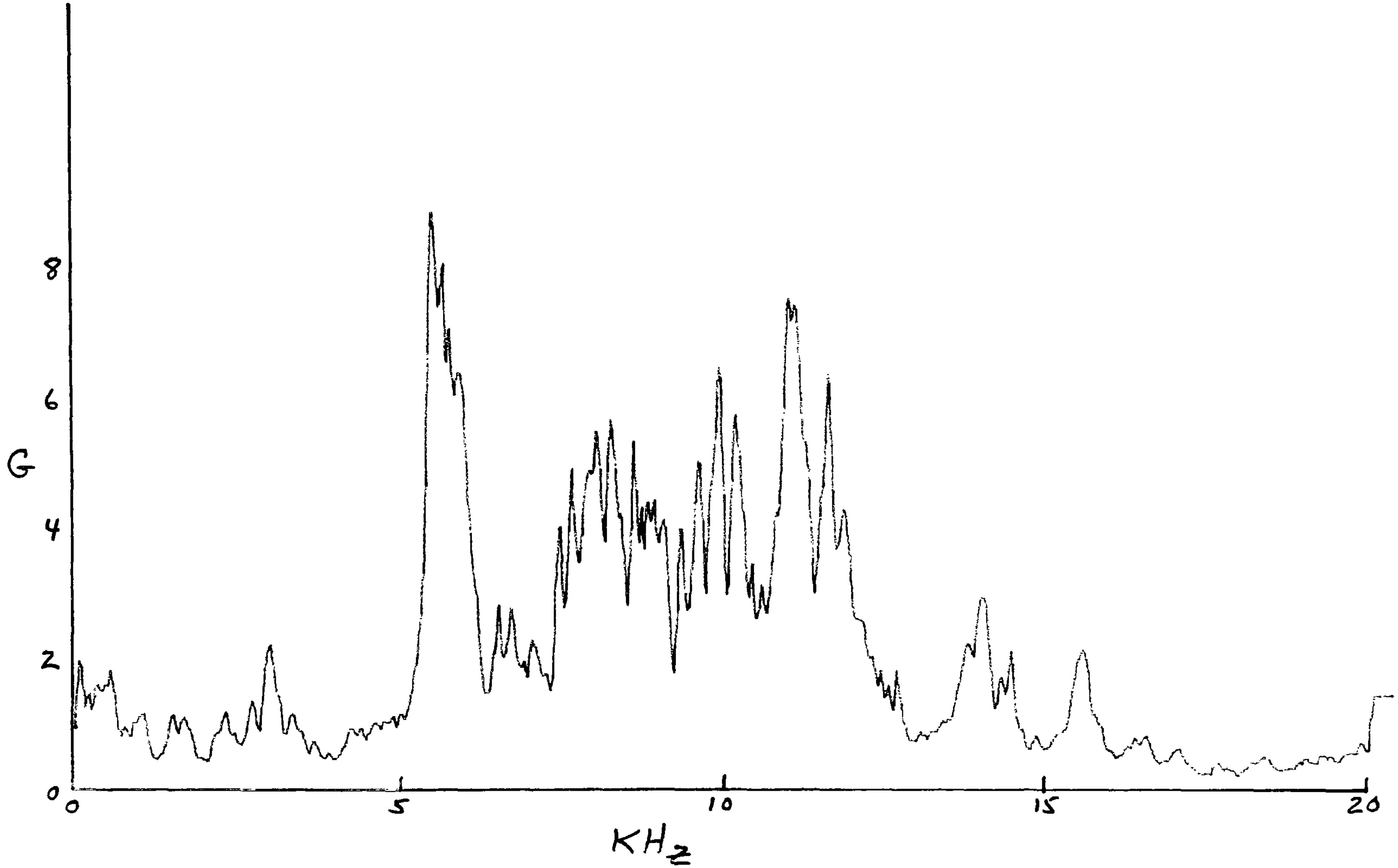


P11 - 7 2.3 L, 4 cyl.
Right Front Block, Iso-Octane, 30 to 60 MPH Accel. NK (TI 298/343)



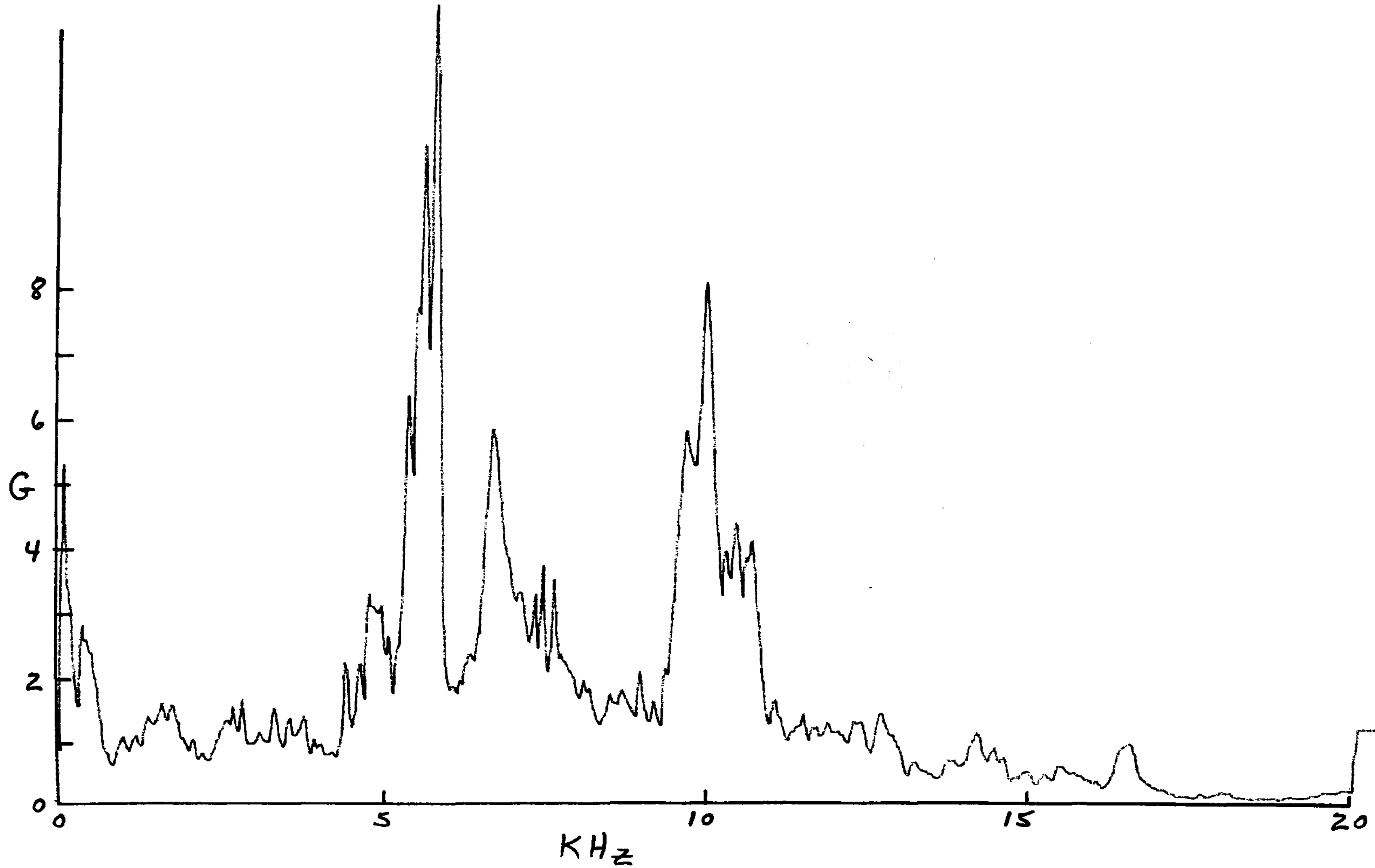
P12 - 5

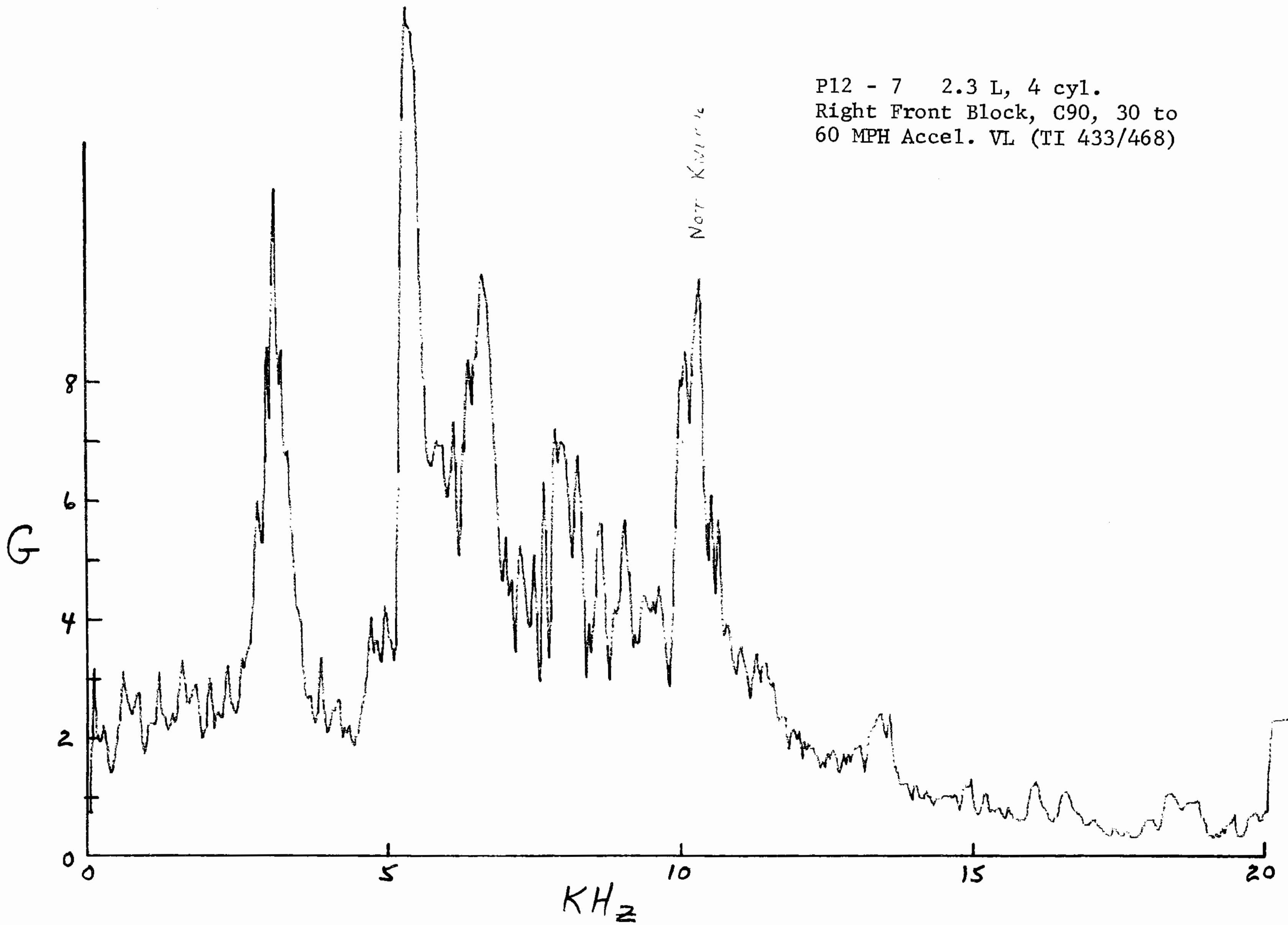
P12 - 5   2.3 L, 4 cyl.
Intake Manifold, C90, 30 to
60 MPH Accel. VL (TI 433/468)



P12-6

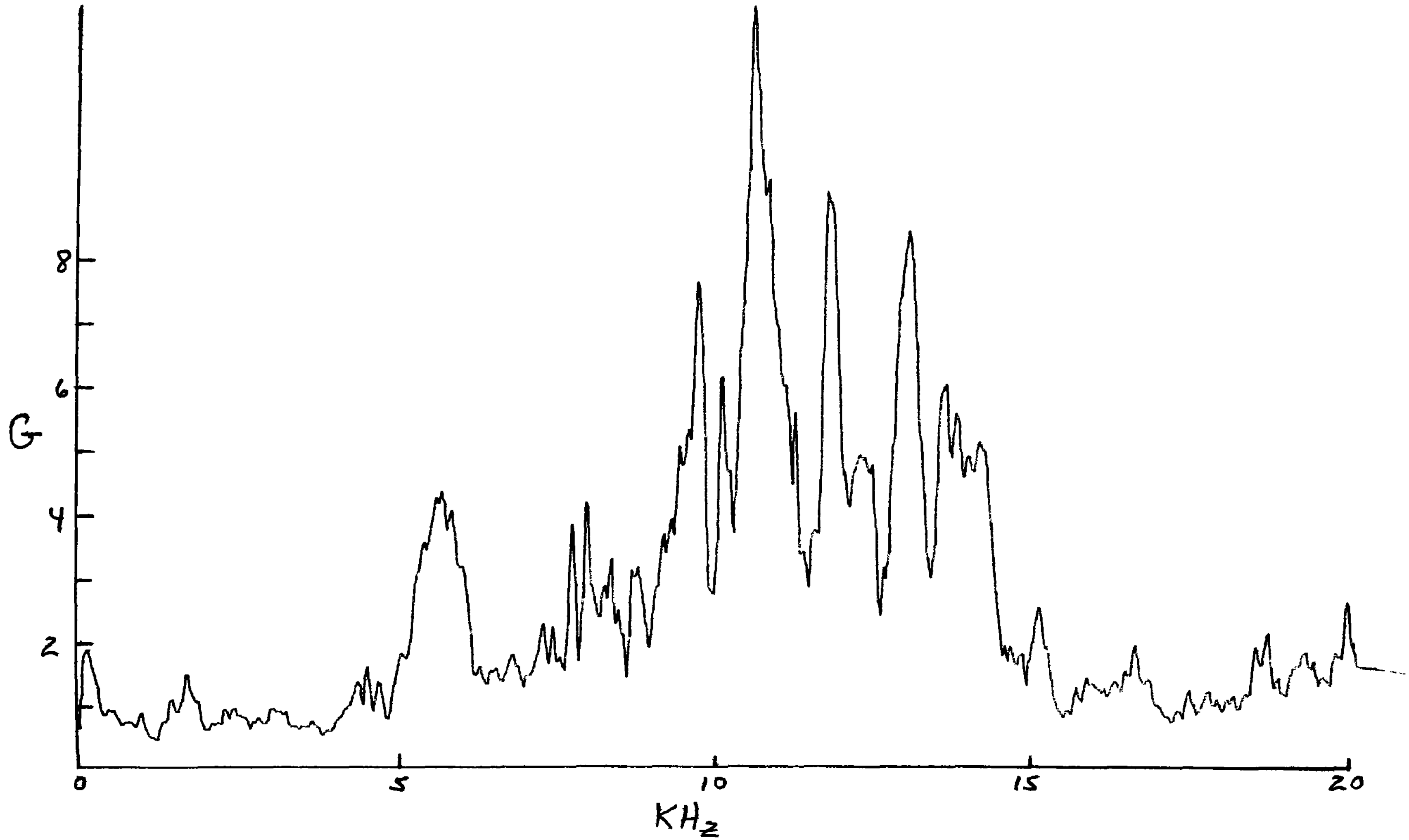
P12 - 6   2.3 L, 4 cyl.
Right Rear Head, C90, 30 to
60 MPH Accel. VL (TI 433/468)



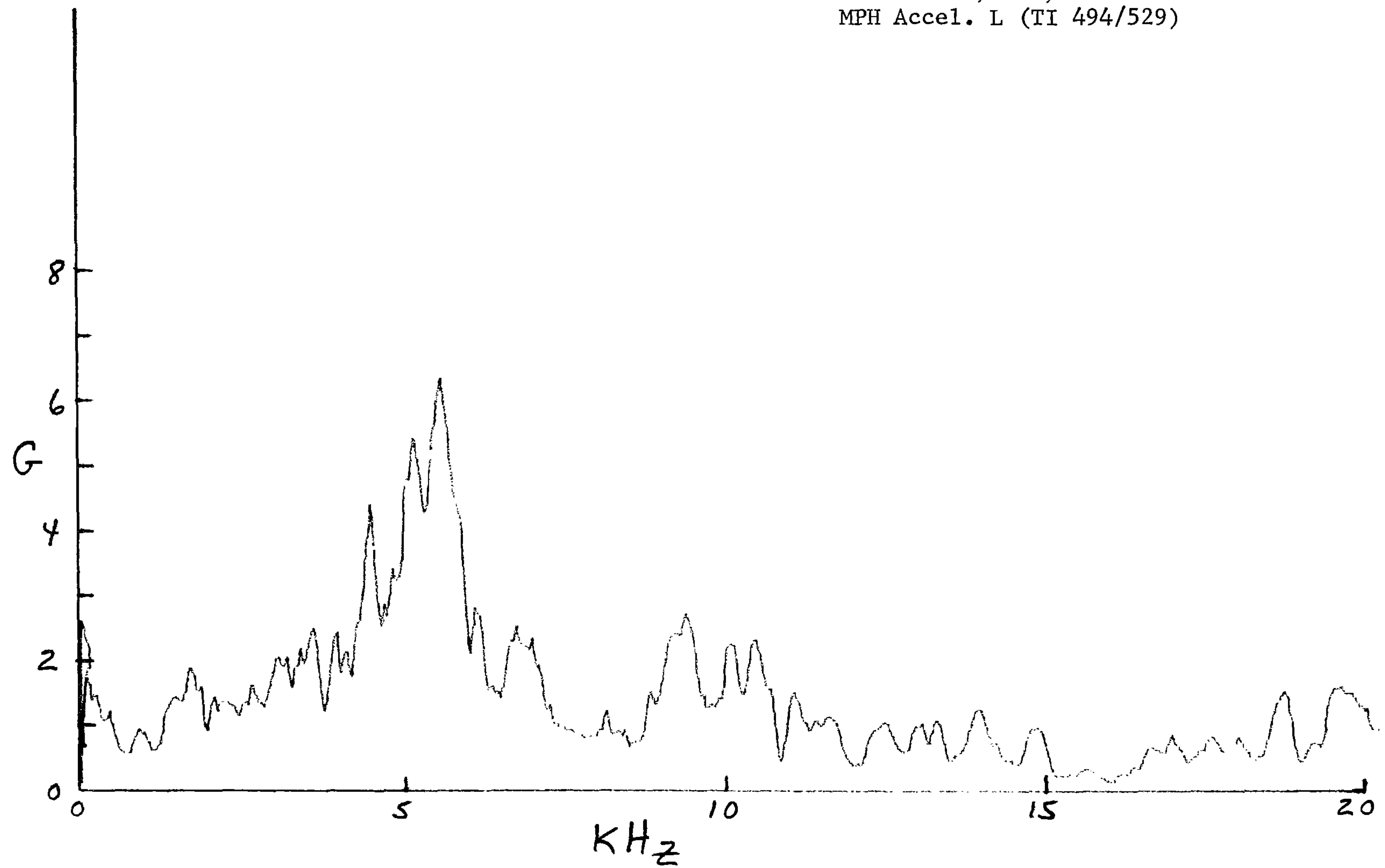

P12 - 7 2.3 L, 4 cyl.
Right Front Block, C90, 30 to
60 MPH Accel. VL (TI 433/468)
G
8
6
4
2
0
0
5
10
15
20
KHz

P13-5

P13 - 5   2.3 L, 4 cyl.
Rear Head, C90, 30 to 60
MPH Accel. L (TI 494/529)

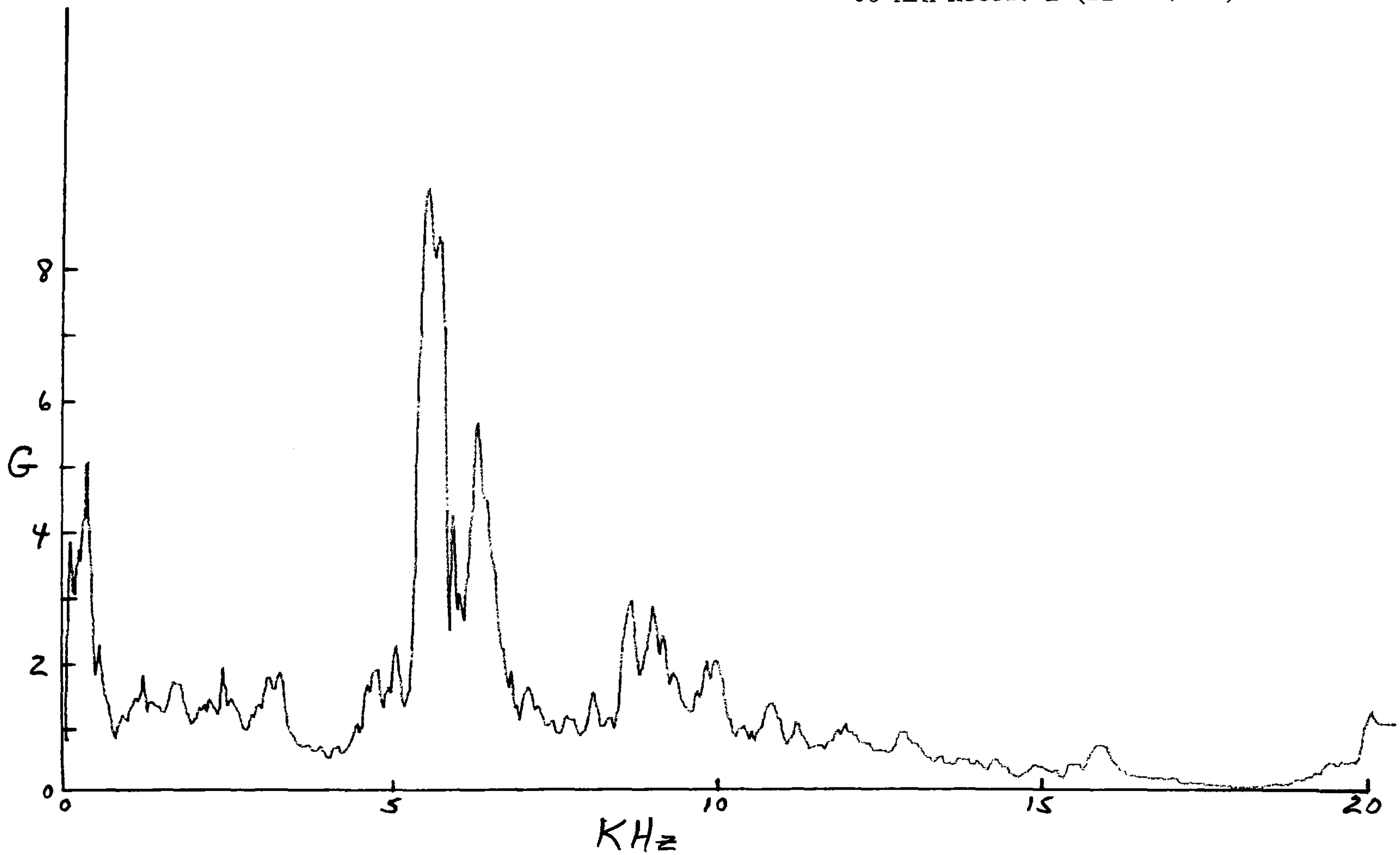


P13 - 6   2.3 L, 4 cyl.
Rear Block, C90, 30 to 60
MPH Accel. L (TI 494/529)



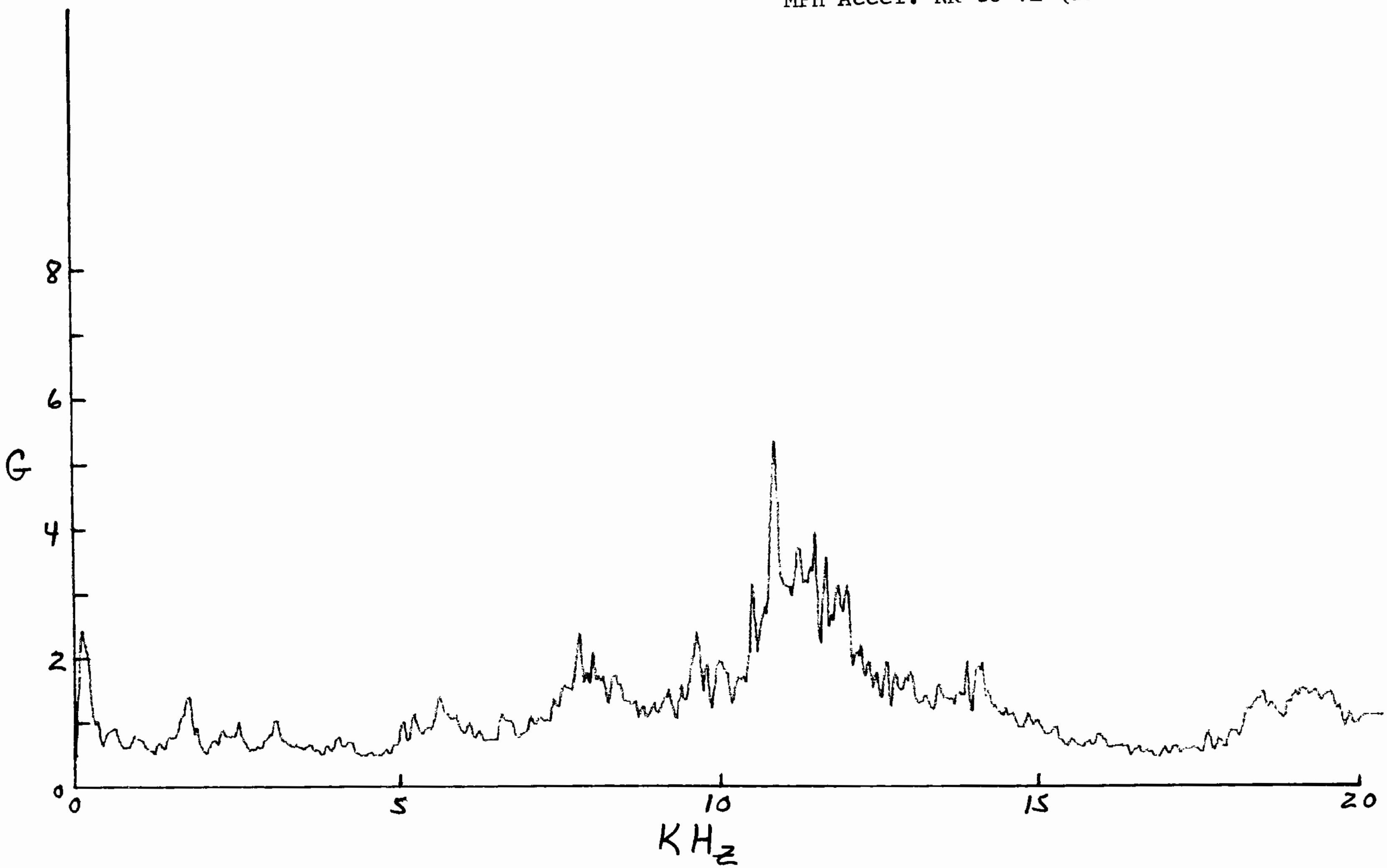
P13-7

P13 - 7   2.3 L, 4 cyl.
Right Front Head, C90, 30 to
60 MPH Accel. L (TI 494/529)



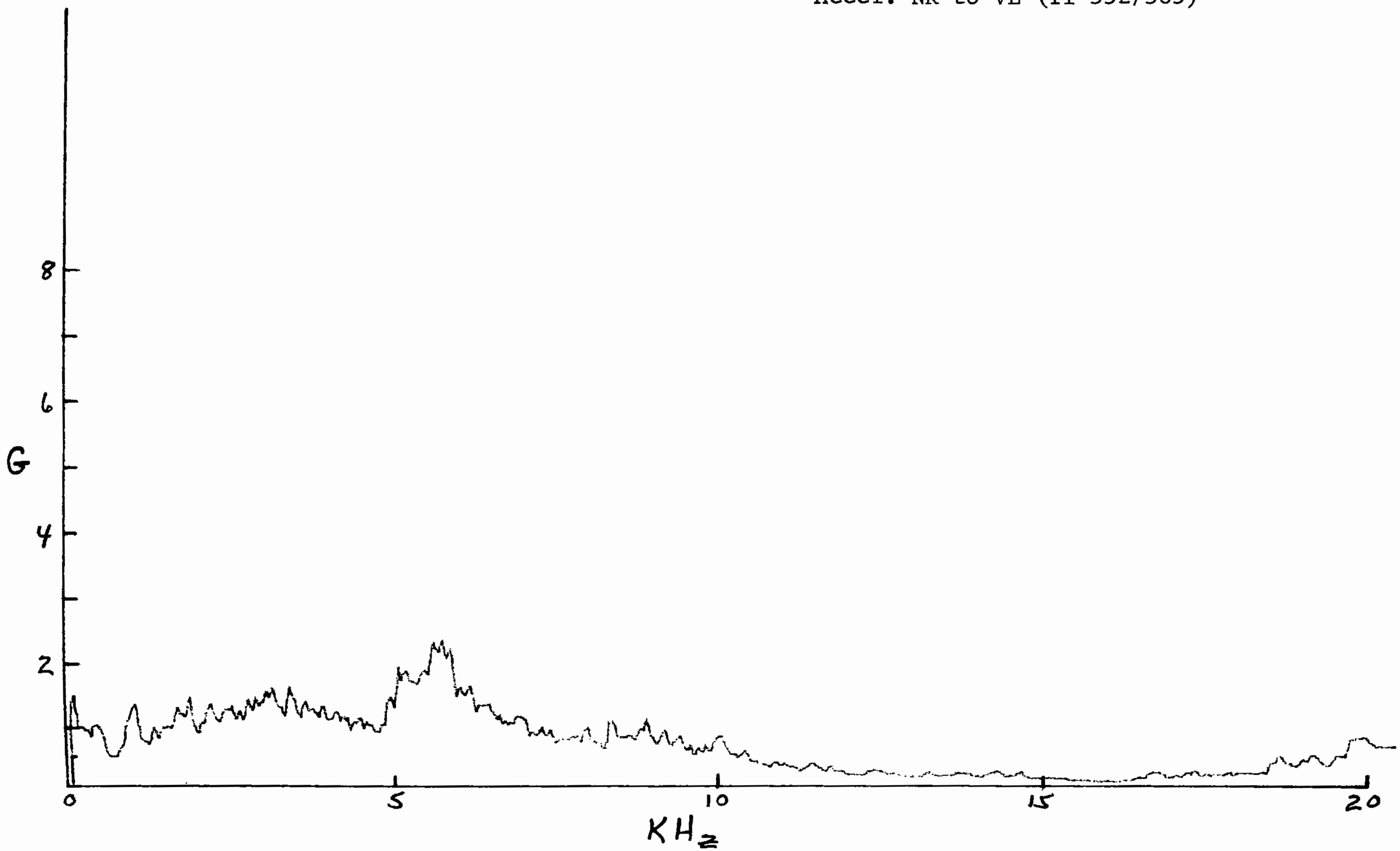
P14-5

P14 - 5   2.3 L, 4 cyl.
Rear Head, C-95, 30 to 60
MPH Accel. NK to VL (TI 552/585)

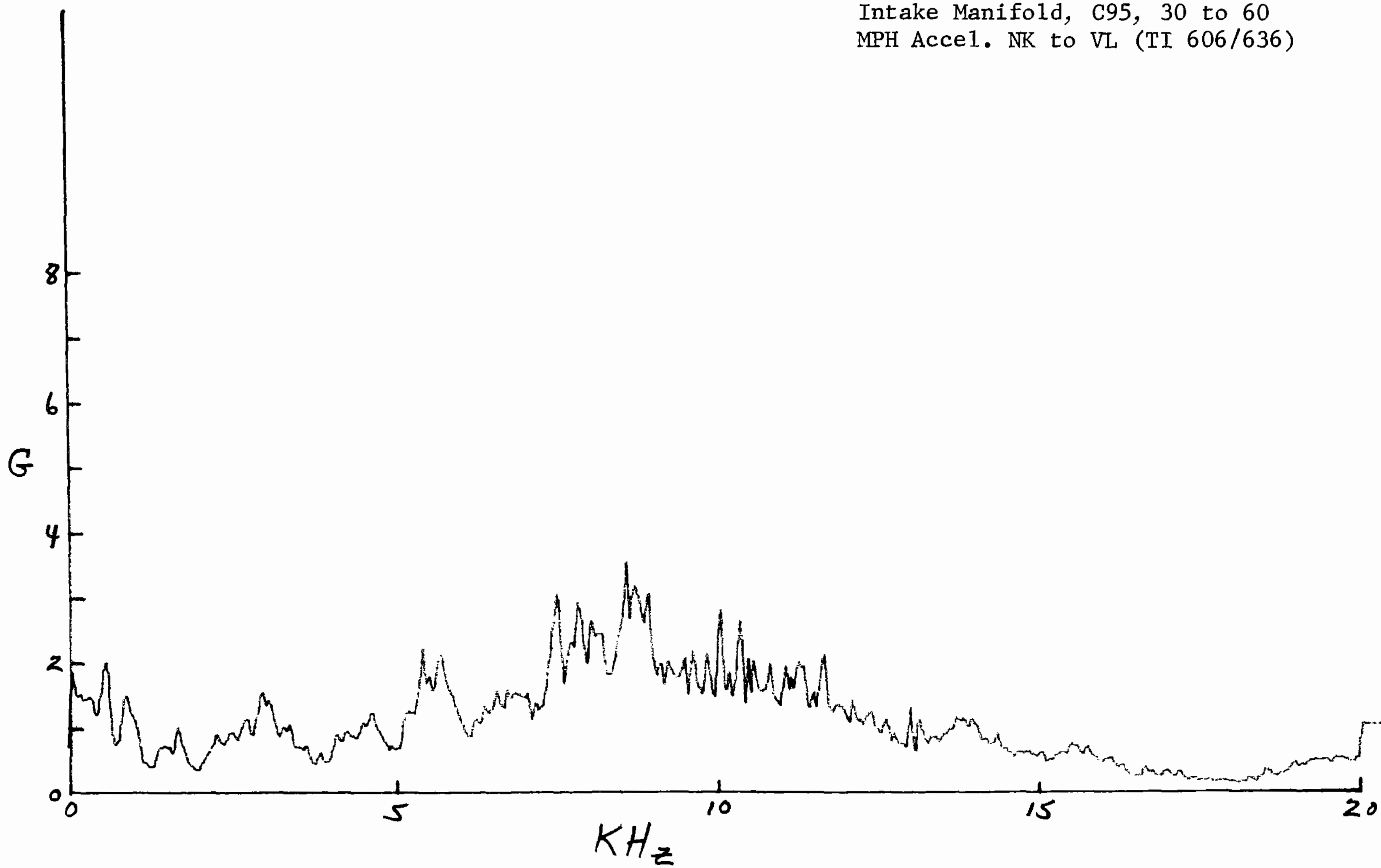


P14-6

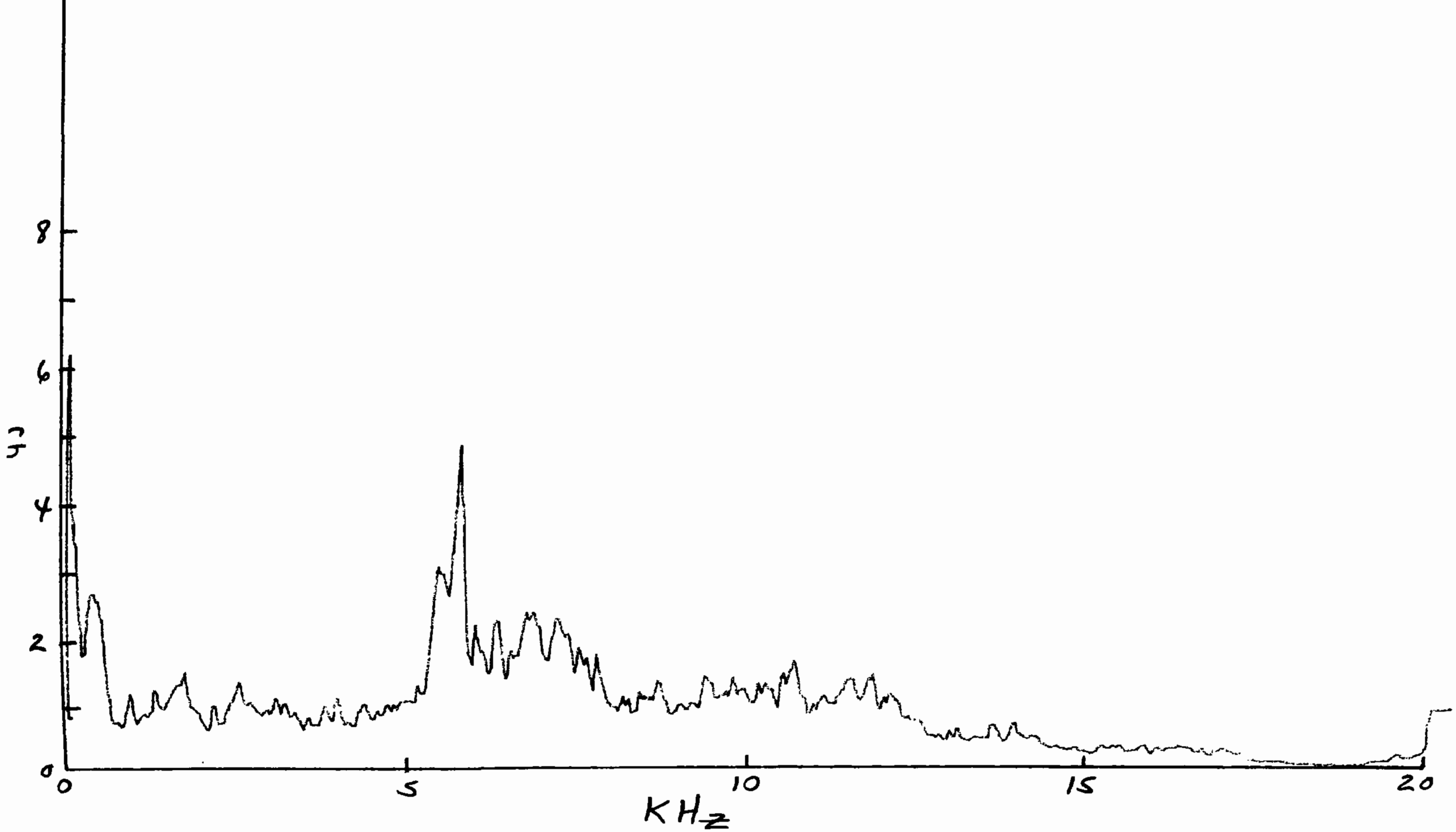
P14 - 6   2.3 L, 4 cyl.
Rear Block, C-95, 30 to 60 MPH
Accel. NK to VL (TI 552/585)



P15 - 5 2.3 L, 4 cyl.
Intake Manifold, C95, 30 to 60
MPH Accel. NK to VL (TI 606/636)

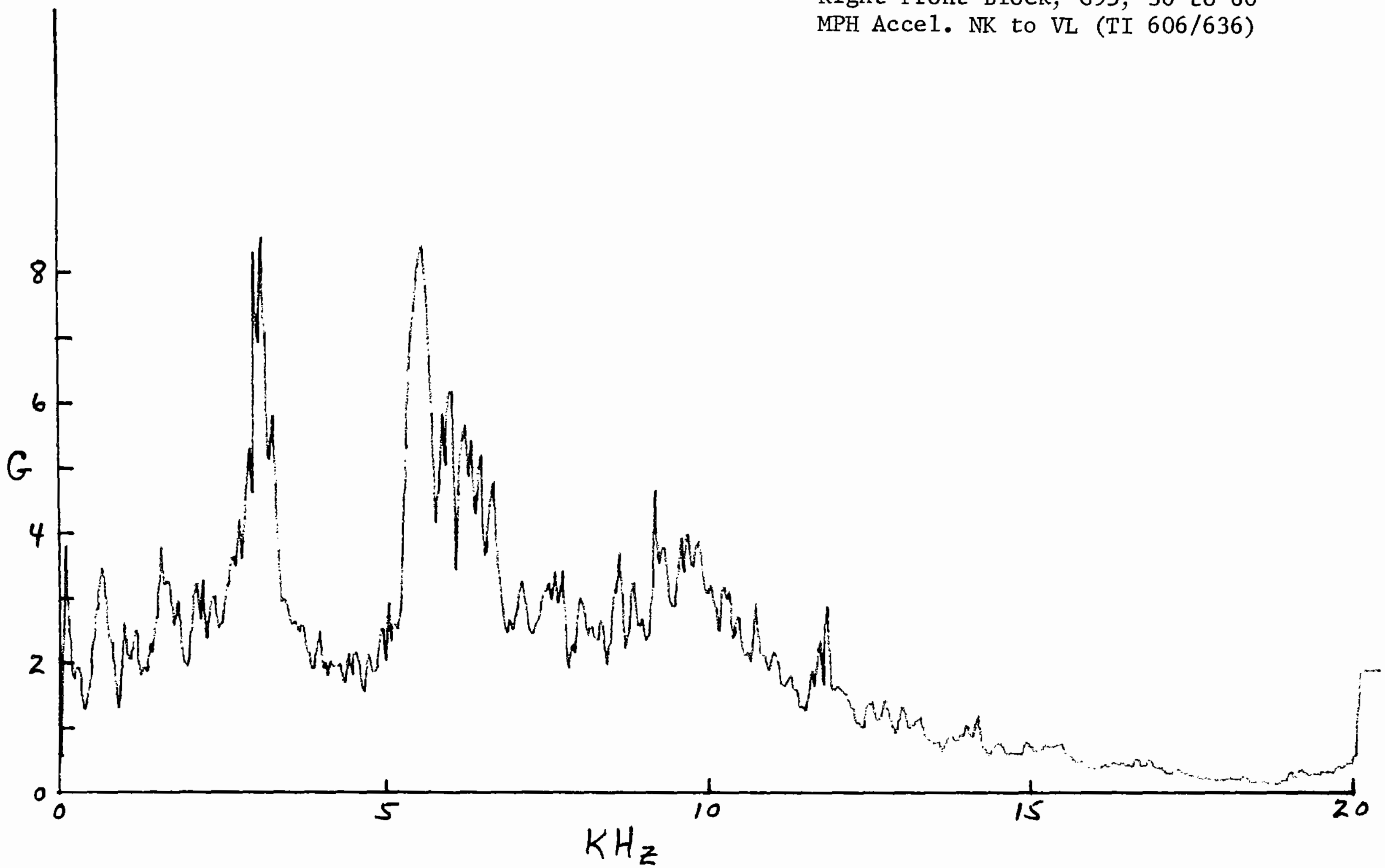


P15 - 6   2.3 L, 4 cyl.
Right Rear Head, C95, 30 to 60
MPH Accel. NK to VL (TI 606/636)



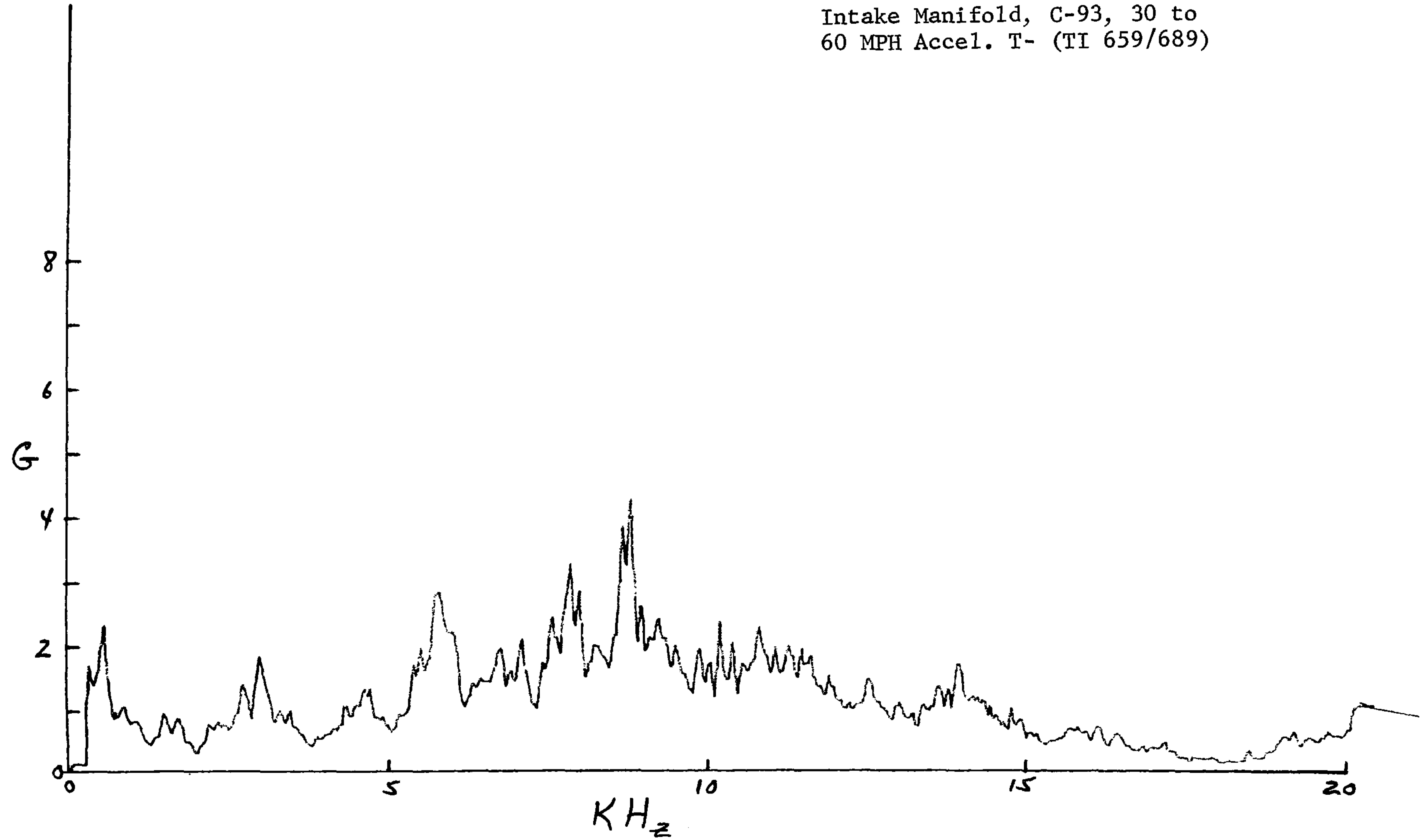
P15-7

P15 - 7 2.3 L, 4 cyl.
Right Front Block, C95, 30 to 60
MPH Accel. NK to VL (TI 606/636)



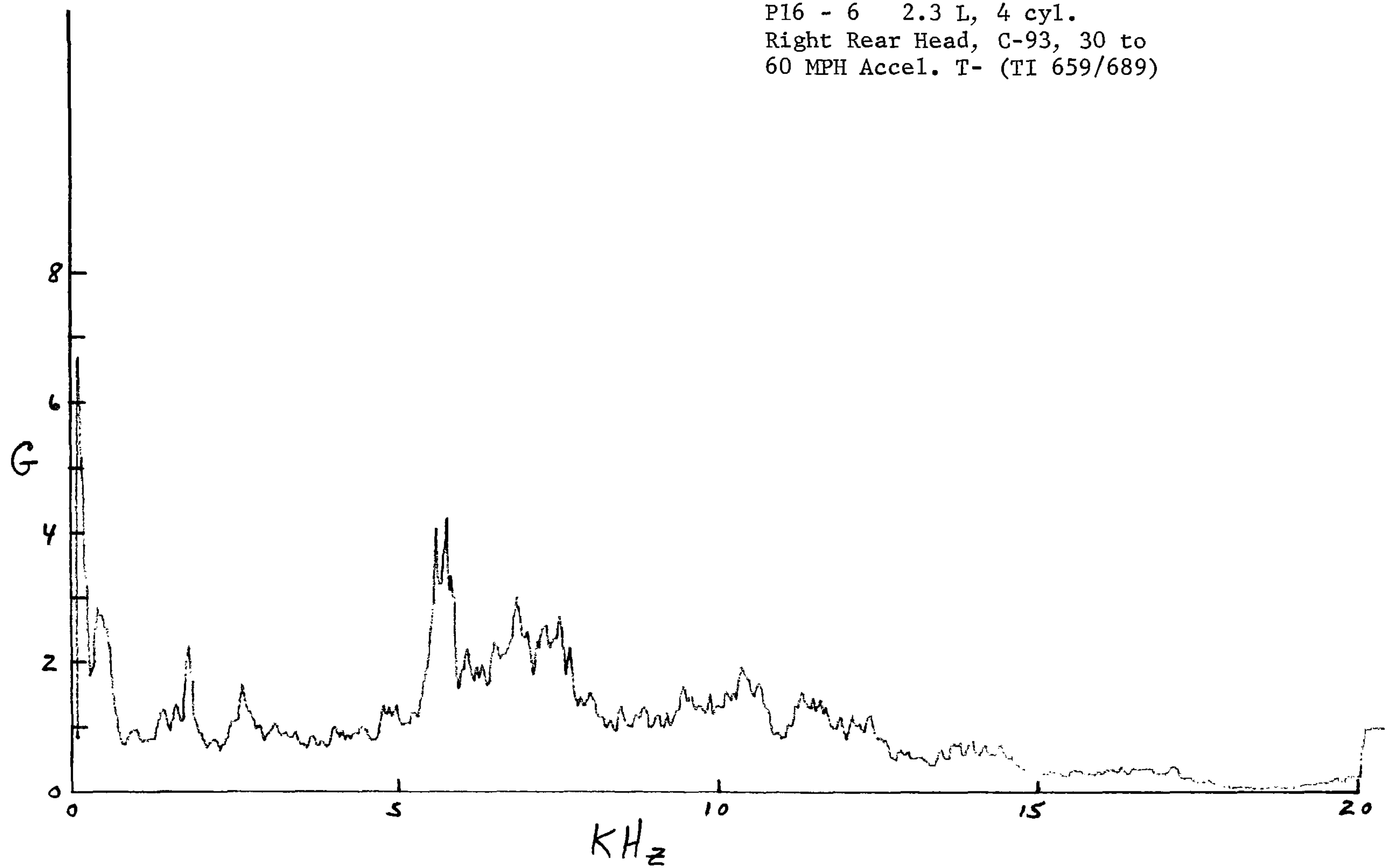
P16-5

P16 - 5 2.3 L, 4 cyl.
Intake Manifold, C-93, 30 to
60 MPH Accel. T- (TI 659/689)

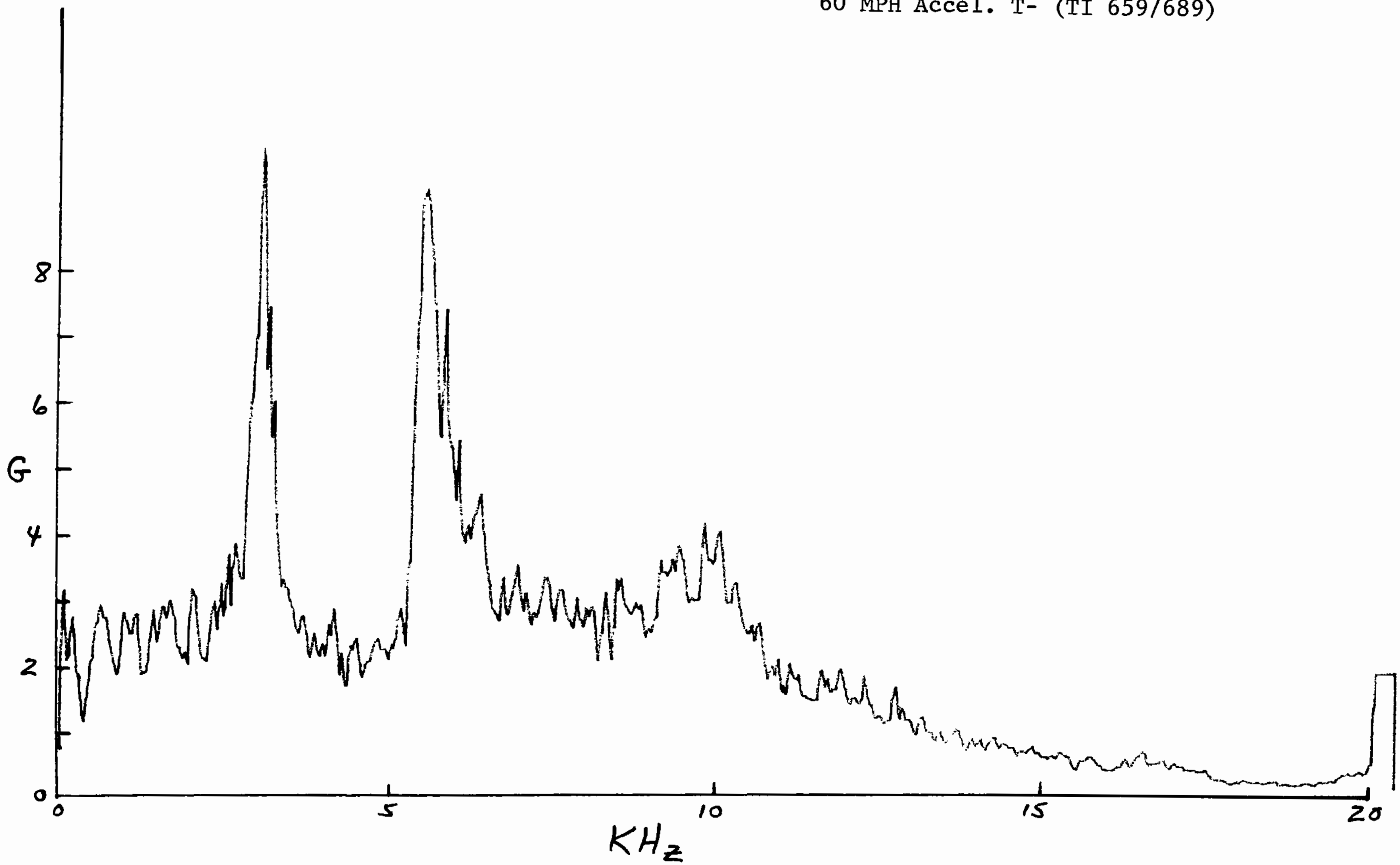


P16-6

P16 - 6 2.3 L, 4 cyl.
Right Rear Head, C-93, 30 to
60 MPH Accel. T- (TI 659/689)

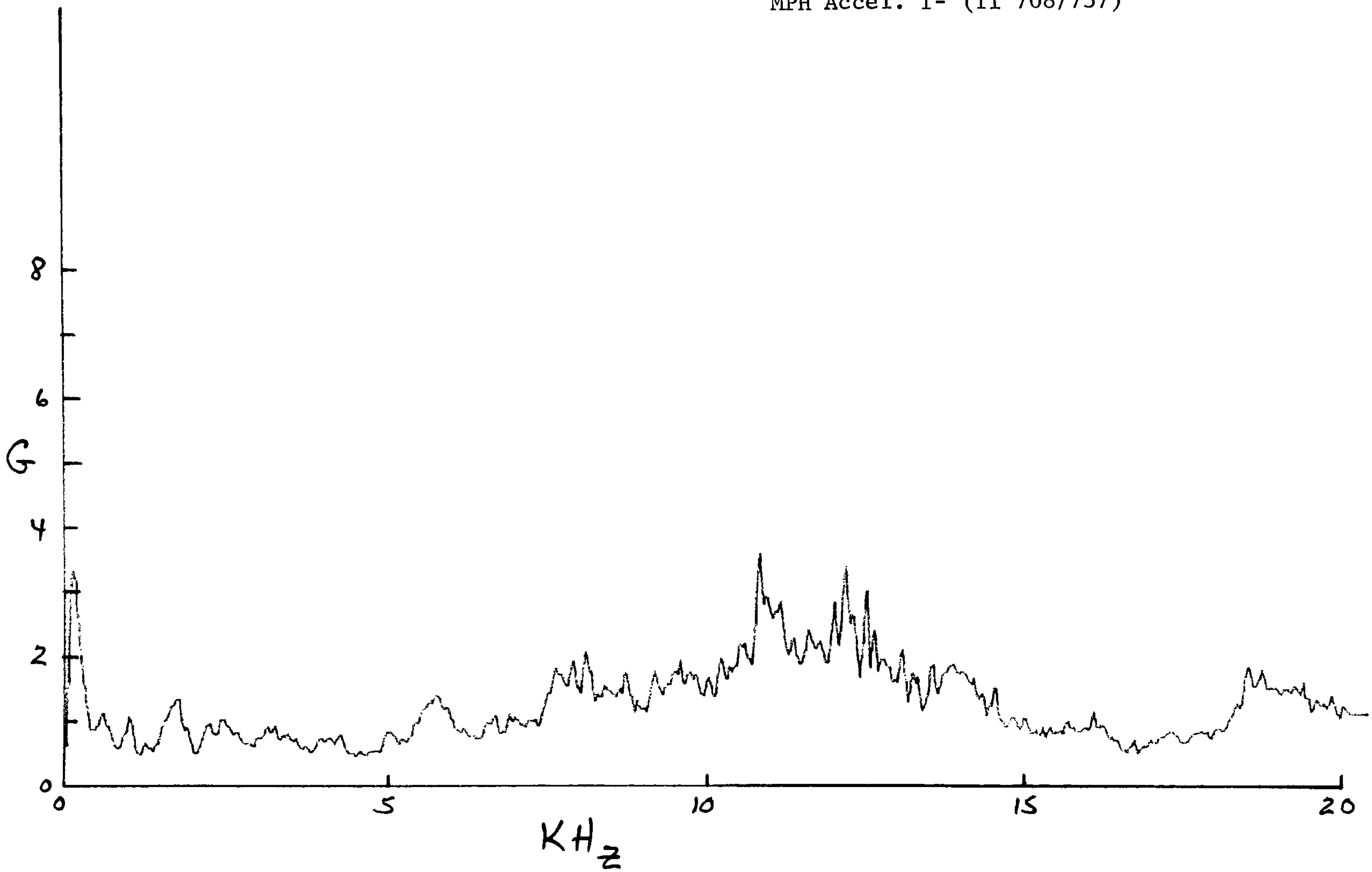


P16 - 7 2.3 L, 4 cyl.
Right Front Block, C-93, 30 to
60 MPH Accel. T- (TI 659/689)



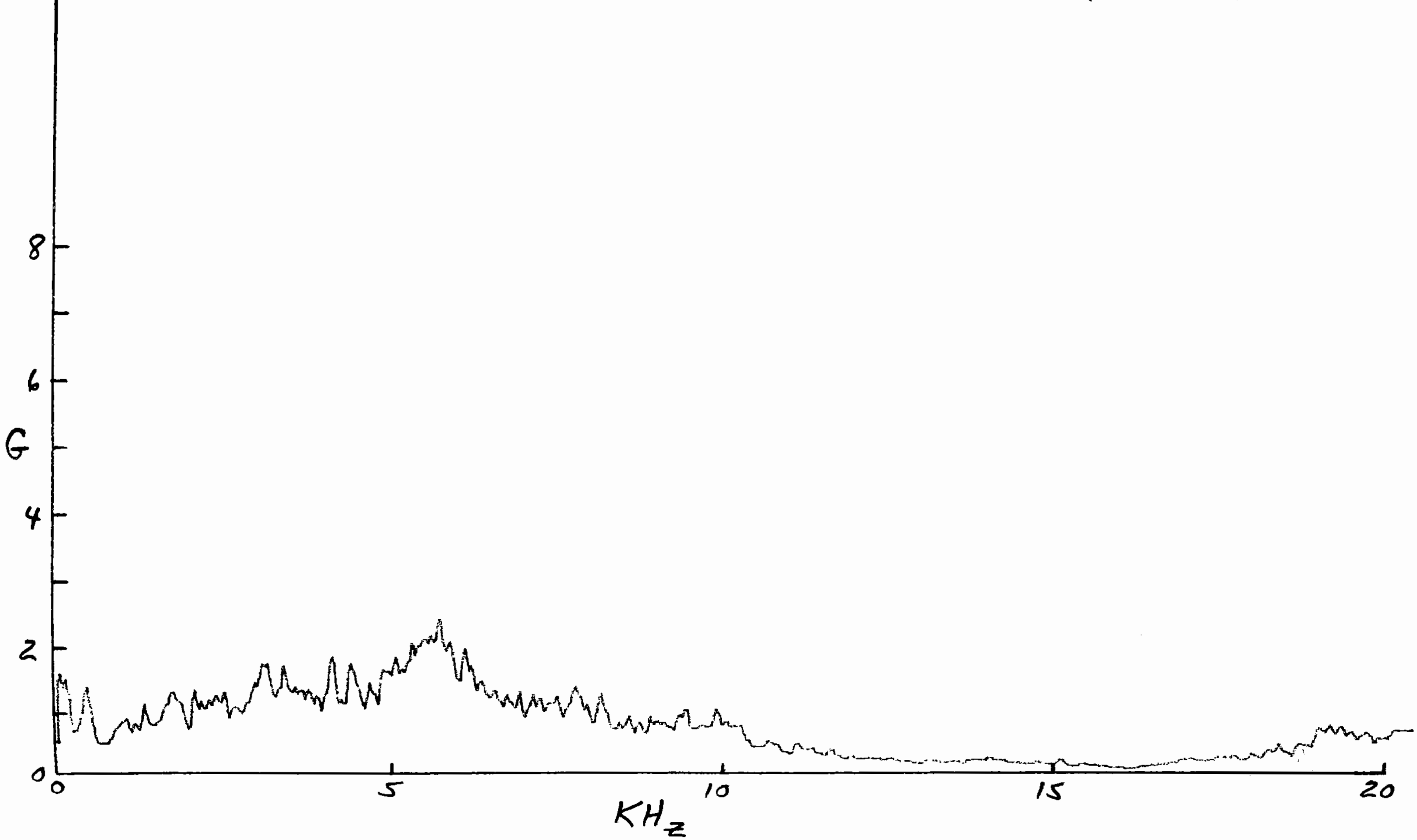
'Y17-5

P17 - 5   2.3 L, 4 cyl.
Rear Head, C-93, 30 to 60
MPH Accel. T- (TI 708/737)

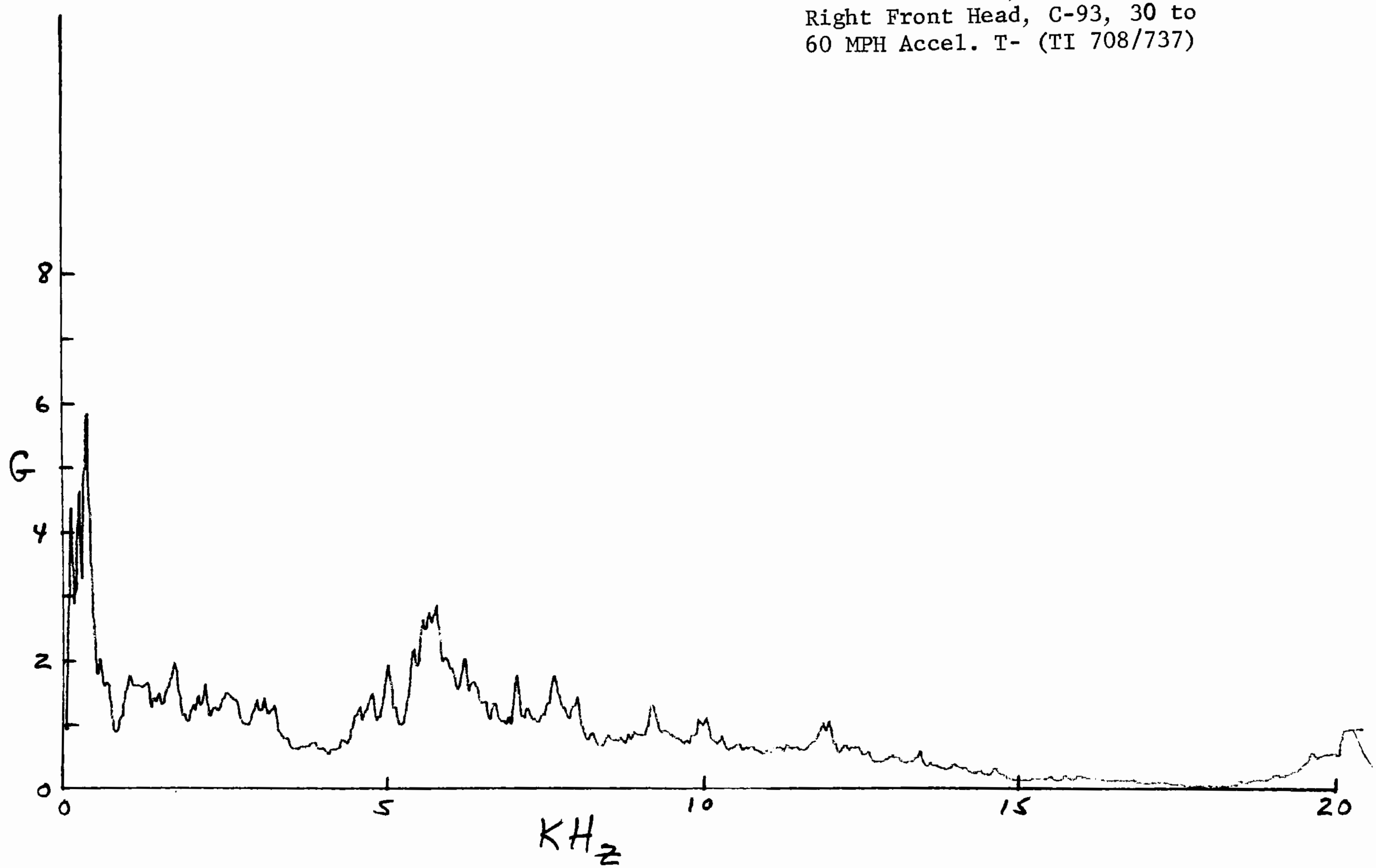


P17-6

P17 - 6 2.3 L, 4 cyl.
Rear Block, C-93, 30 to 60
MPH Accel. T- (TI 708/737)

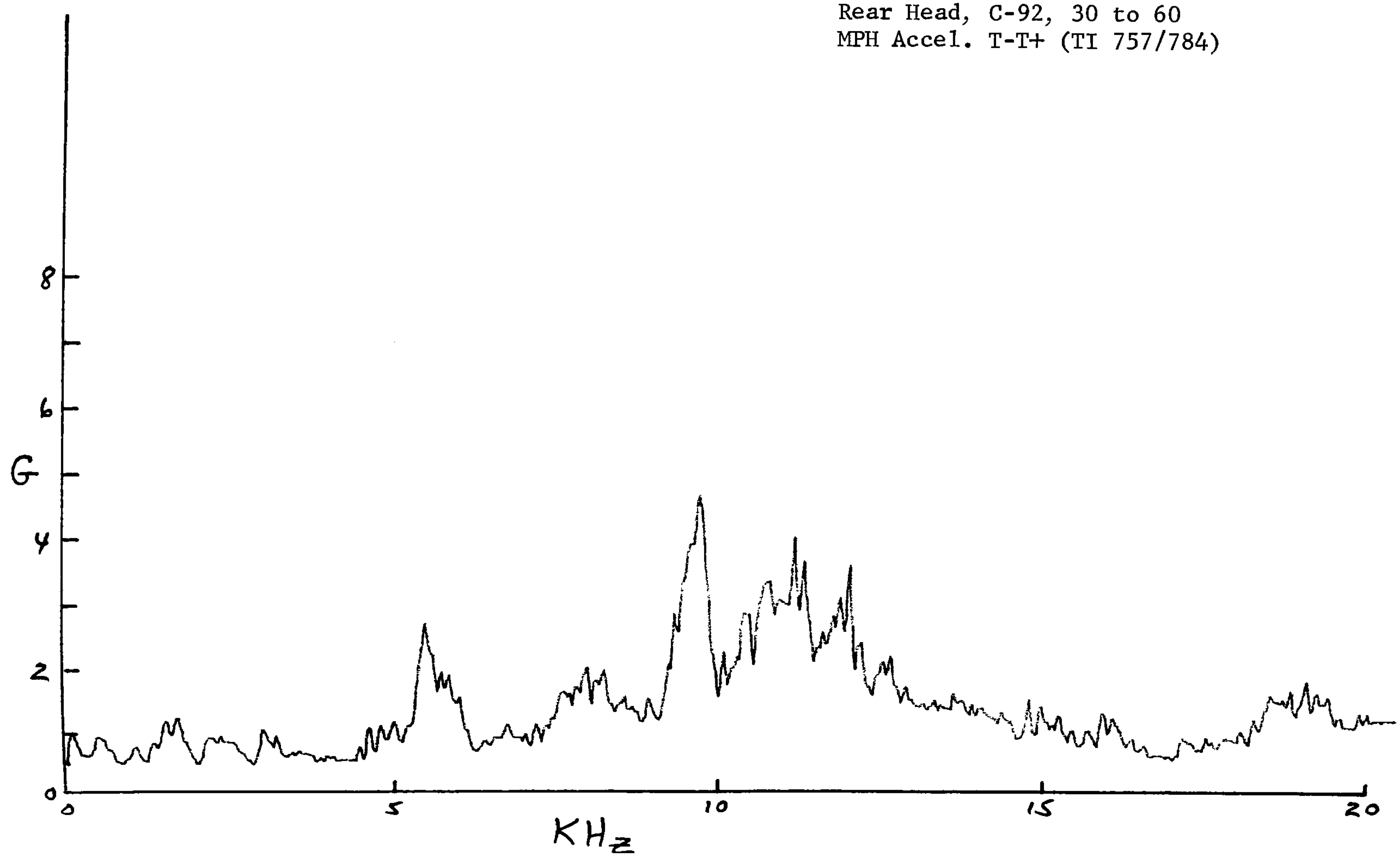


P17 - 7 2.3 L, 4 cyl.
Right Front Head, C-93, 30 to
60 MPH Accel. T- (TI 708/737)



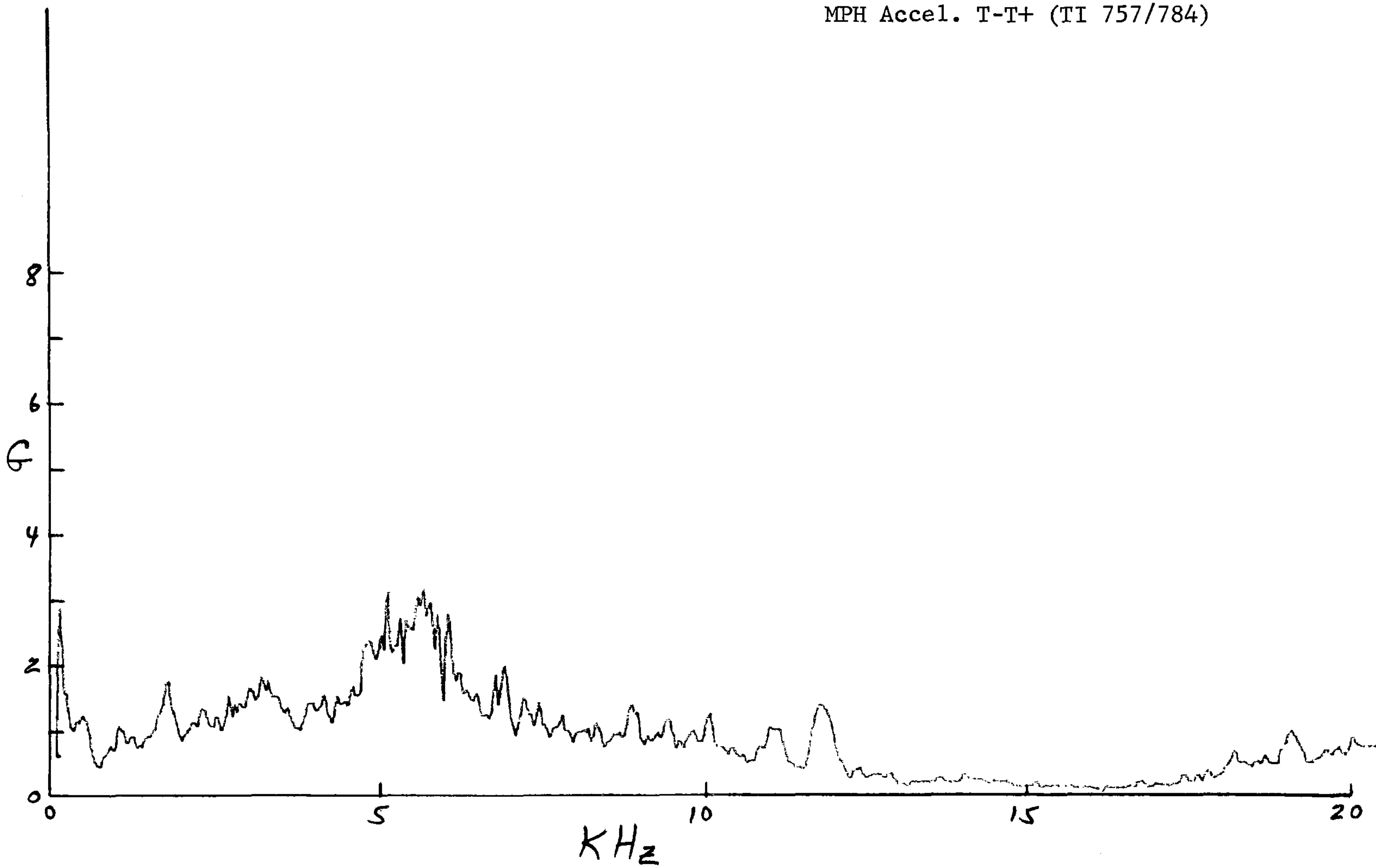
P18-5

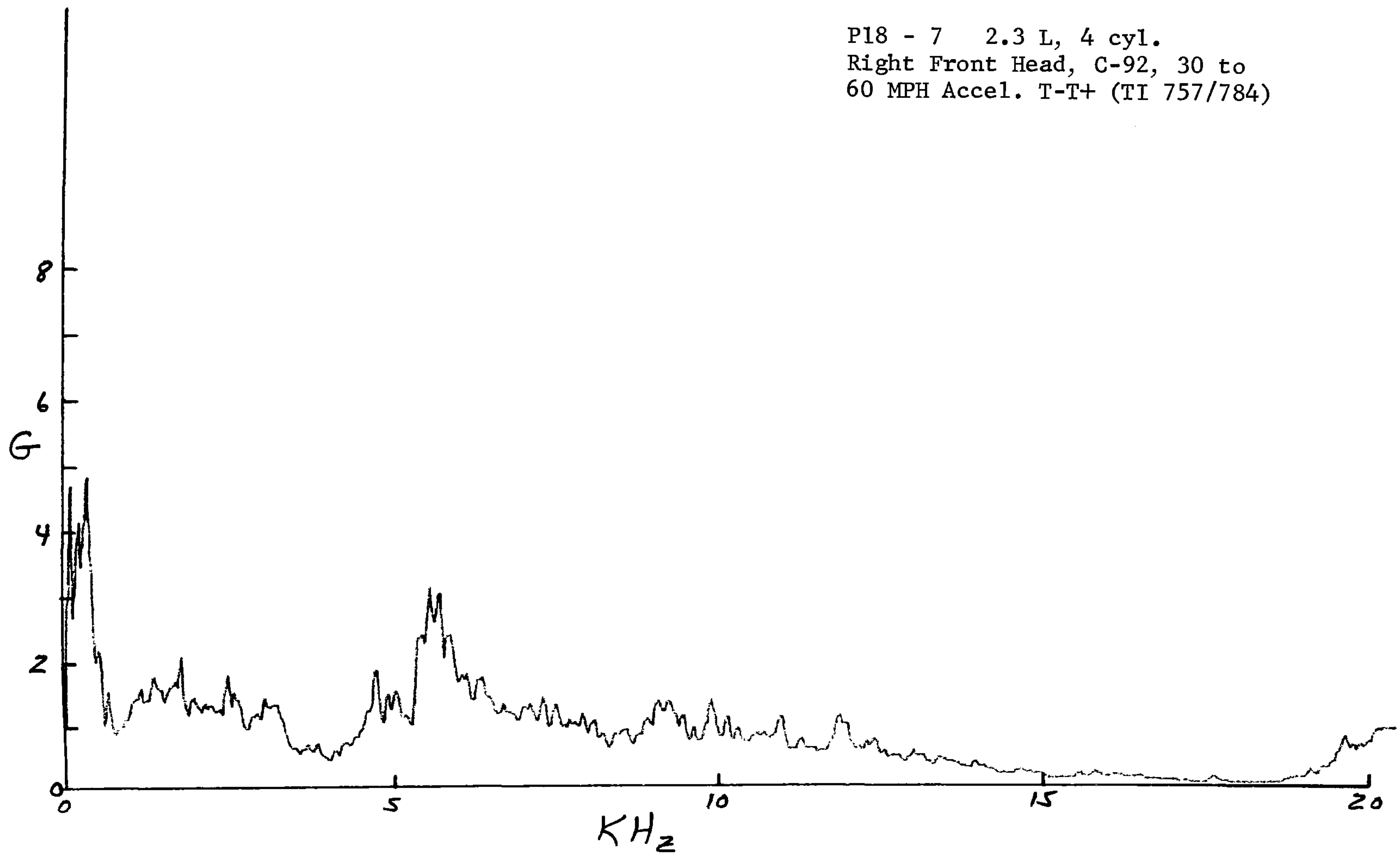
P18 - 5 2.3 L, 4 cyl.
Rear Head, C-92, 30 to 60
MPH Accel. T-T+ (TI 757/784)



P18-6

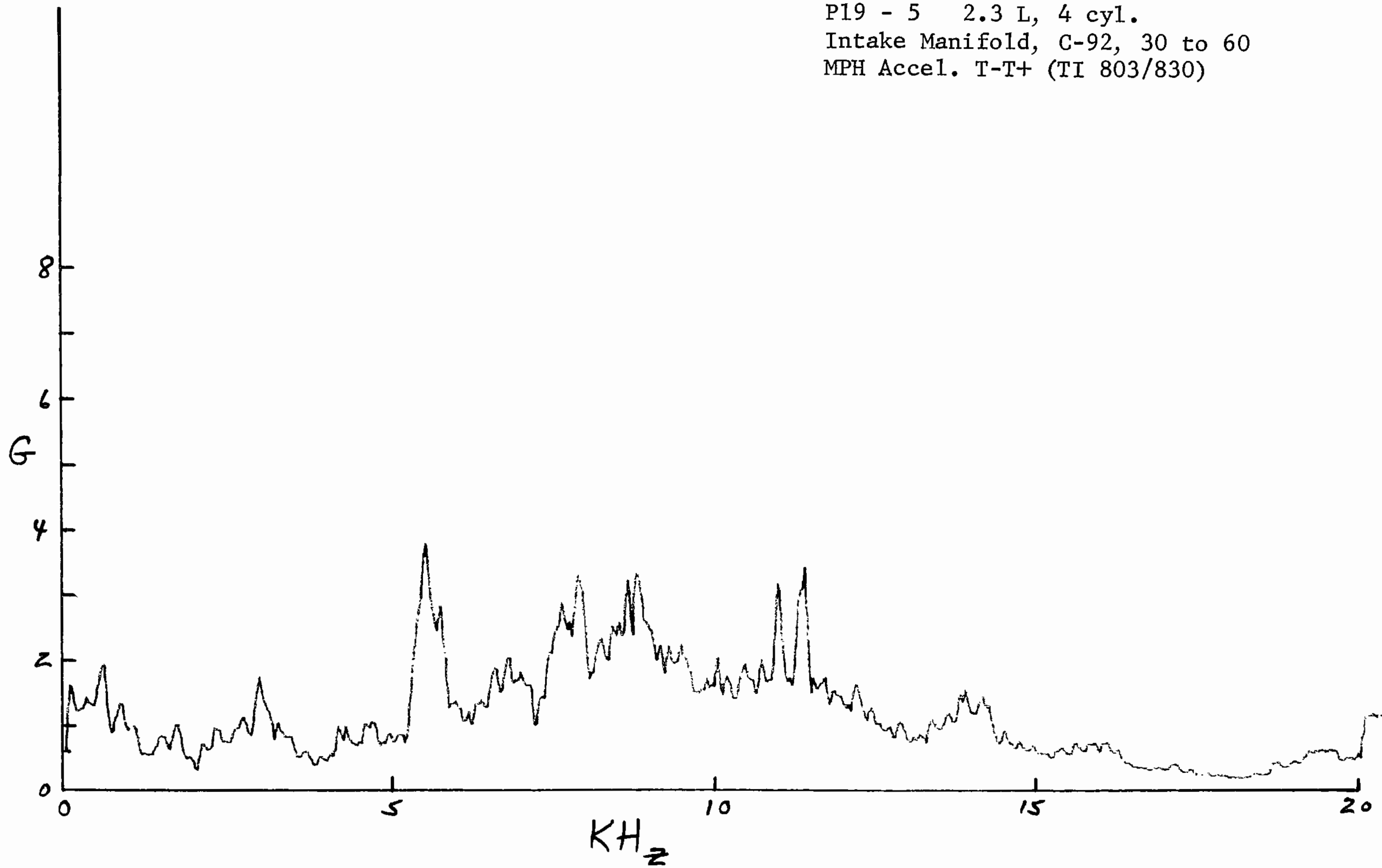
P18 - 6   2.3 L, 4 cyl.
Rear Block, C-92, 30 to 60
MPH Accel. T-T+ (TI 757/784)





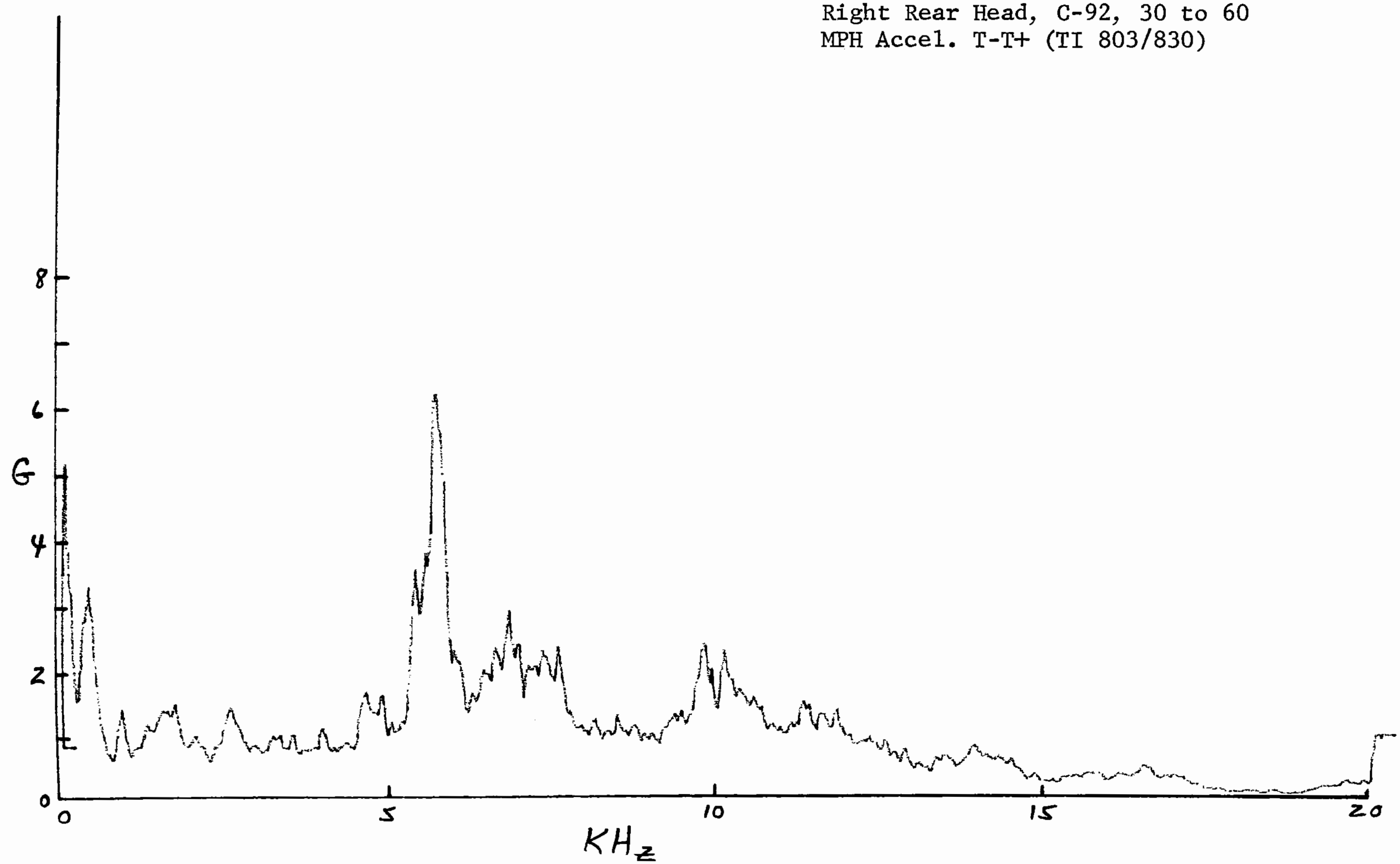

P18 - 7 2.3 L, 4 cyl.
Right Front Head, C-92, 30 to
60 MPH Accel. T-T+ (TI 757/784)

P19 - 5 2.3 L, 4 cyl.
Intake Manifold, C-92, 30 to 60
MPH Accel. T-T+ (TI 803/830)

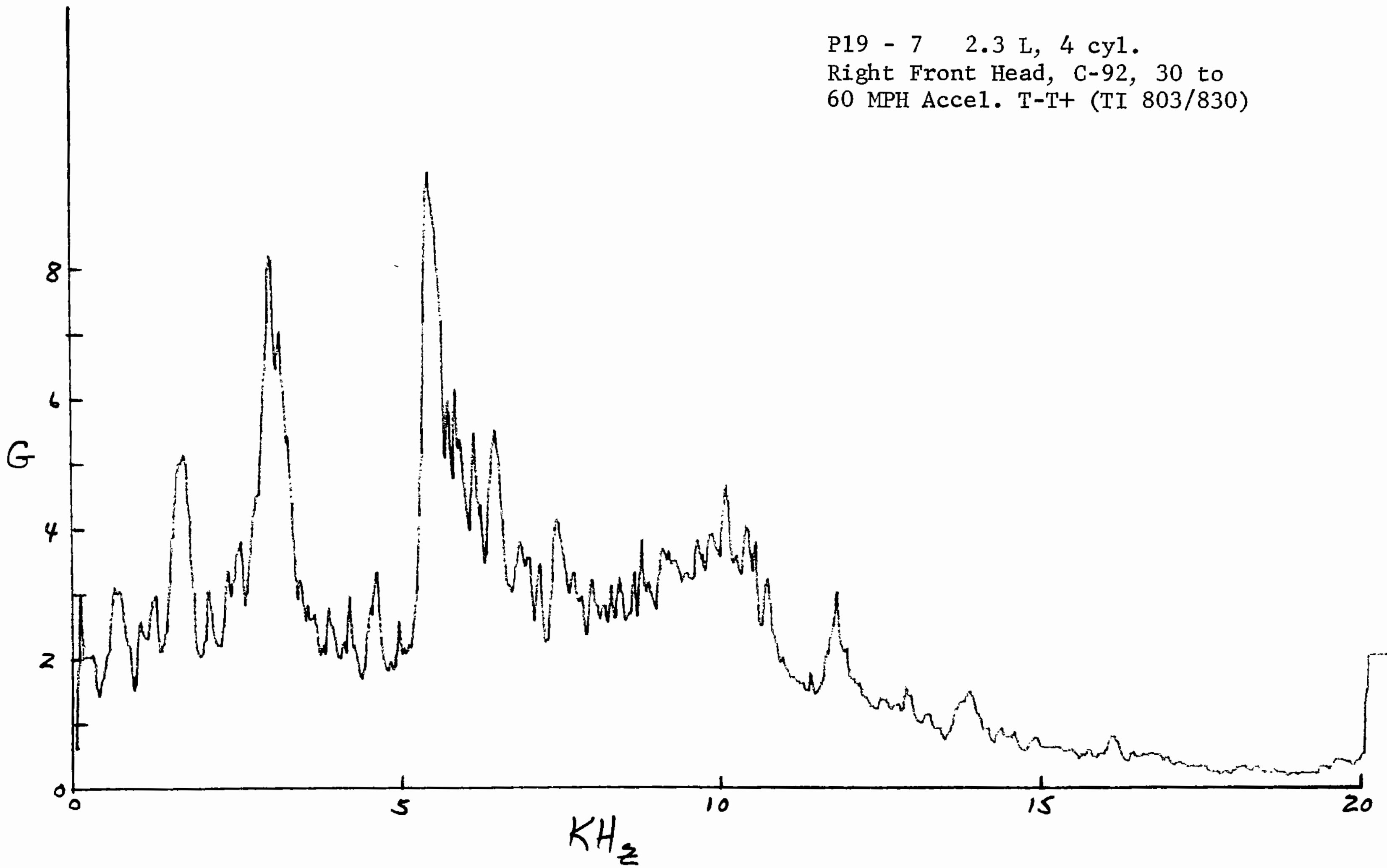


P19-6

P19 - 6   2.3 L, 4 cyl.
Right Rear Head, C-92, 30 to 60
MPH Accel. T-T+ (TI 803/830)



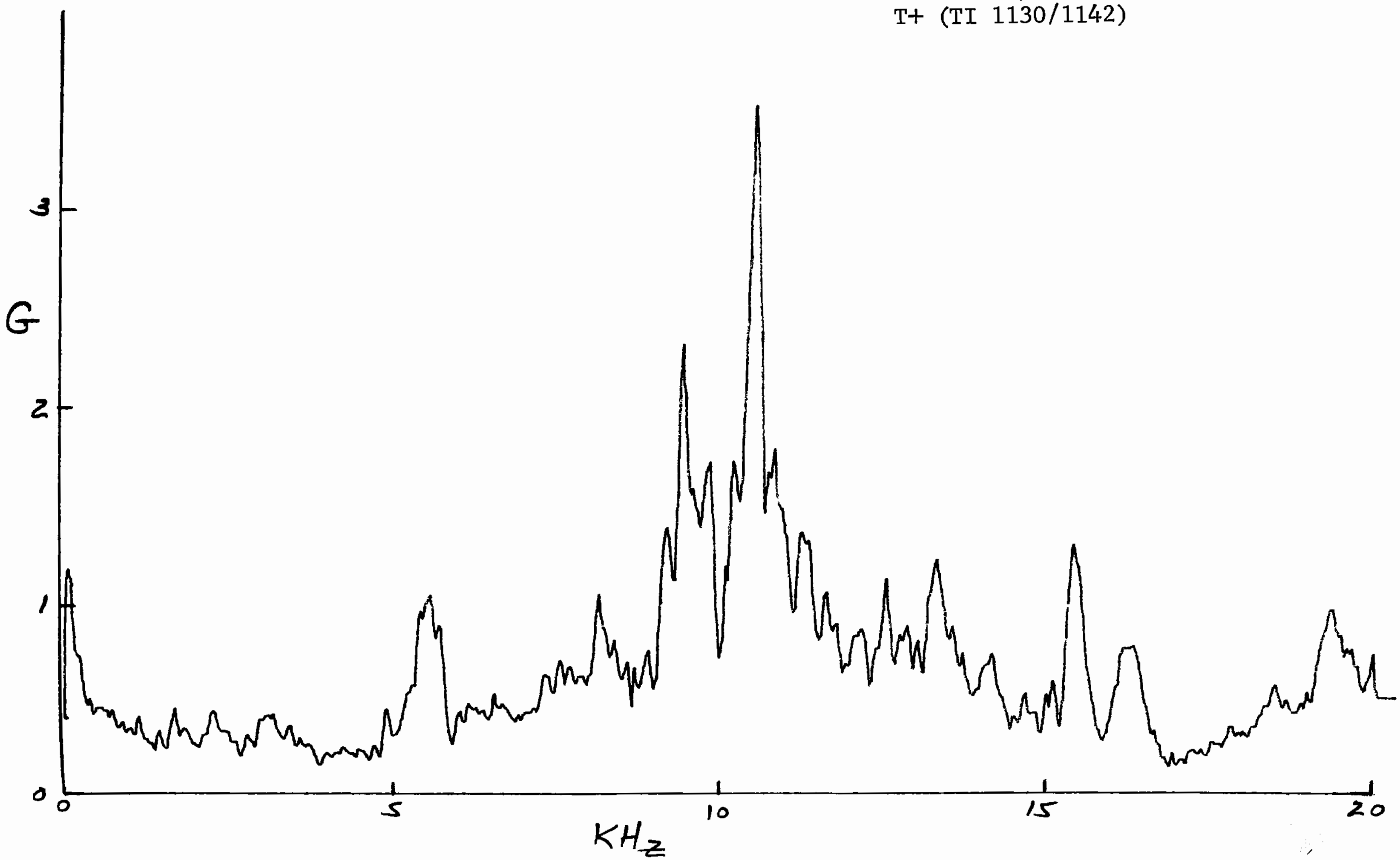
P19-1


P19 - 7 2.3 L, 4 cyl.
Right Front Head, C-92, 30 to
60 MPH Accel. T-T+ (TI 803/830)
G
8
6
4
2
0
0
5
10
15
20
KHz

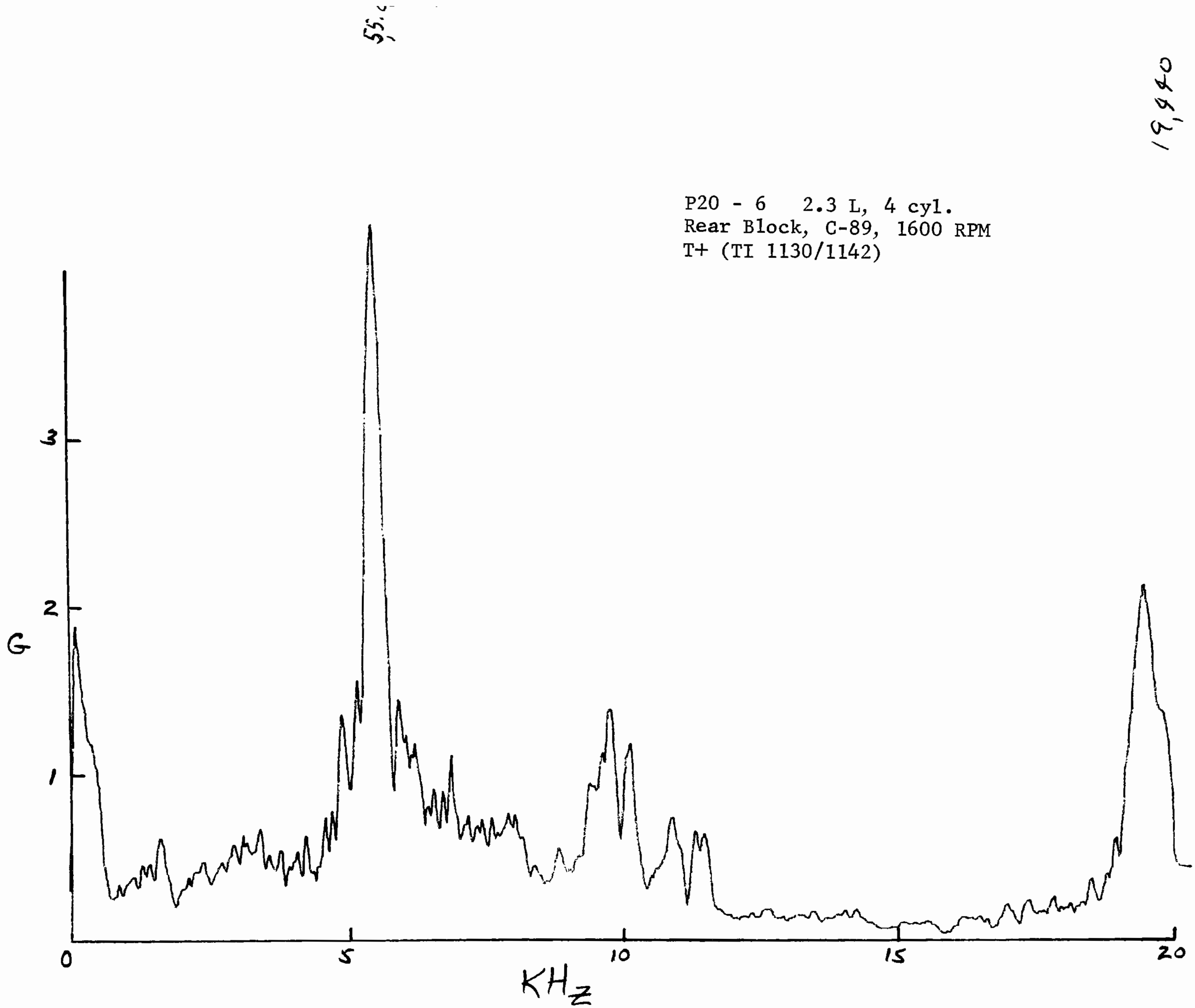
P20-5

10,600

P20 - 5   2.3 L, 4 cyl.
Rear Head, C-89, 1600 RPM
T+ (TI 1130/1142)

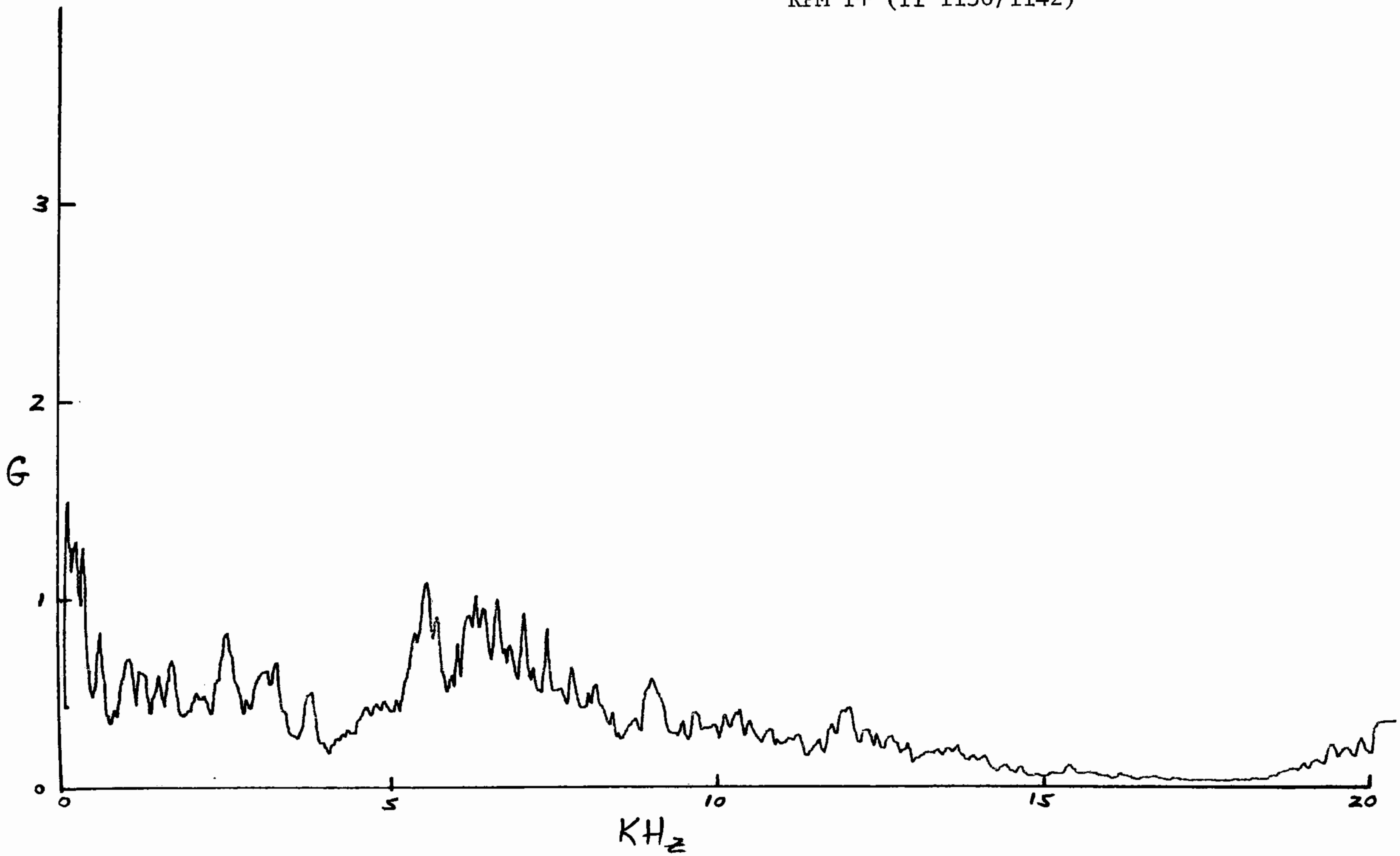


P20-6


19,940
P20 - 6   2.3 L, 4 cyl.
Rear Block, C-89, 1600 RPM
T+ (TI 1130/1142)
G
3
2
1
0
5
10
15
20
KHz

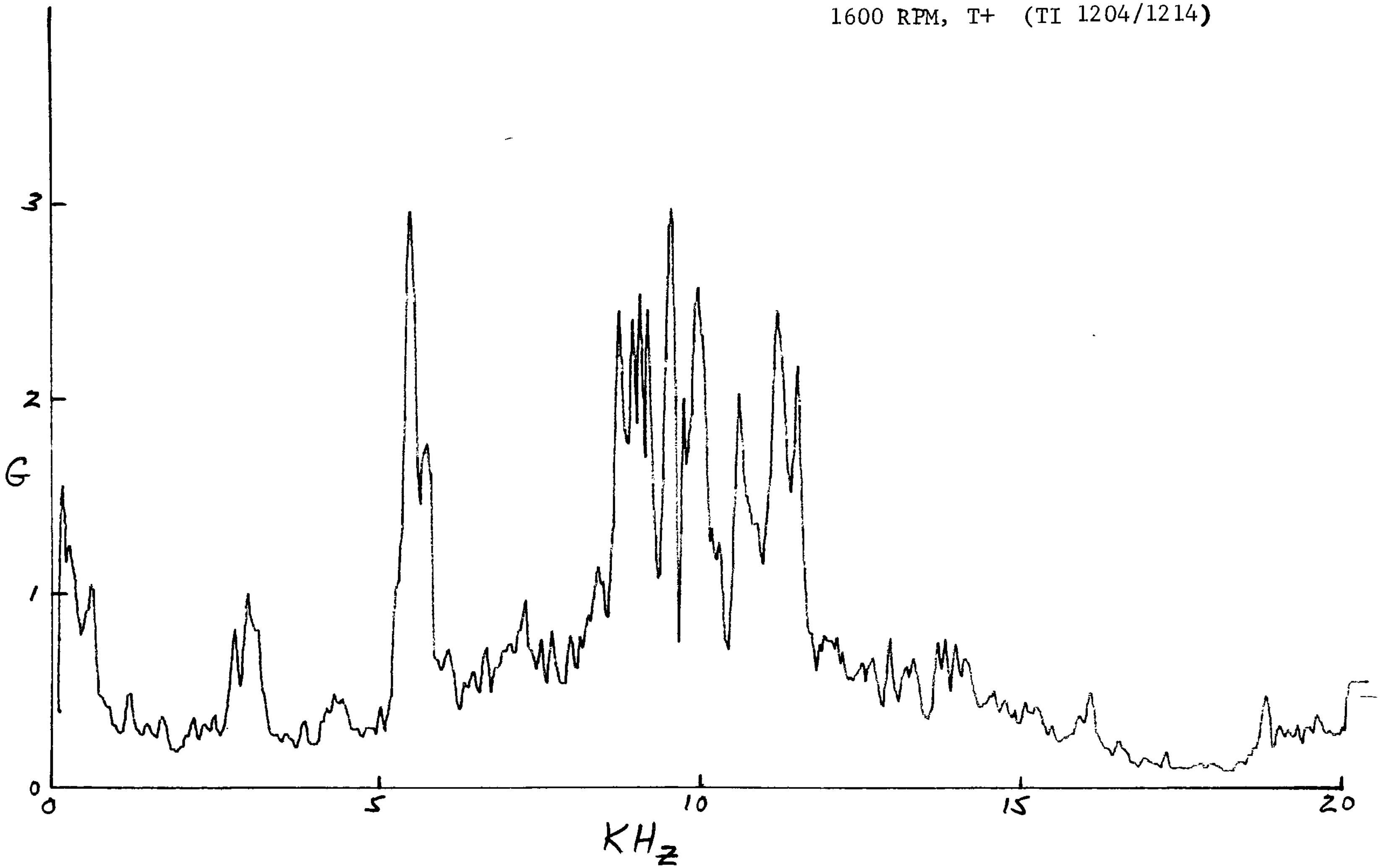
P20-7

P20 - 7   2.3 L, 4 cyl.
Right Front Head, C-89, 1600
RPM T+ (TI 1130/1142)



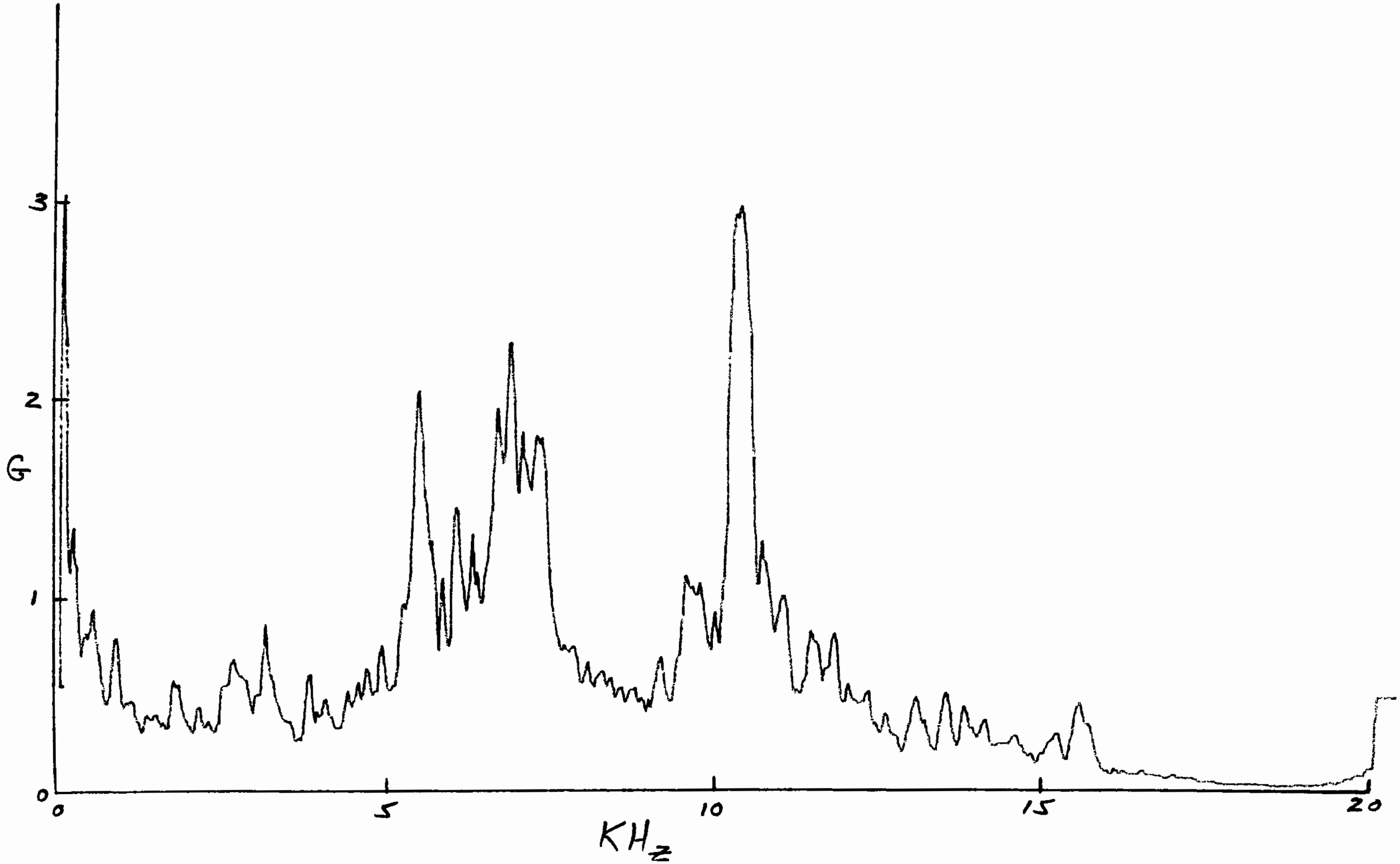
P21-5

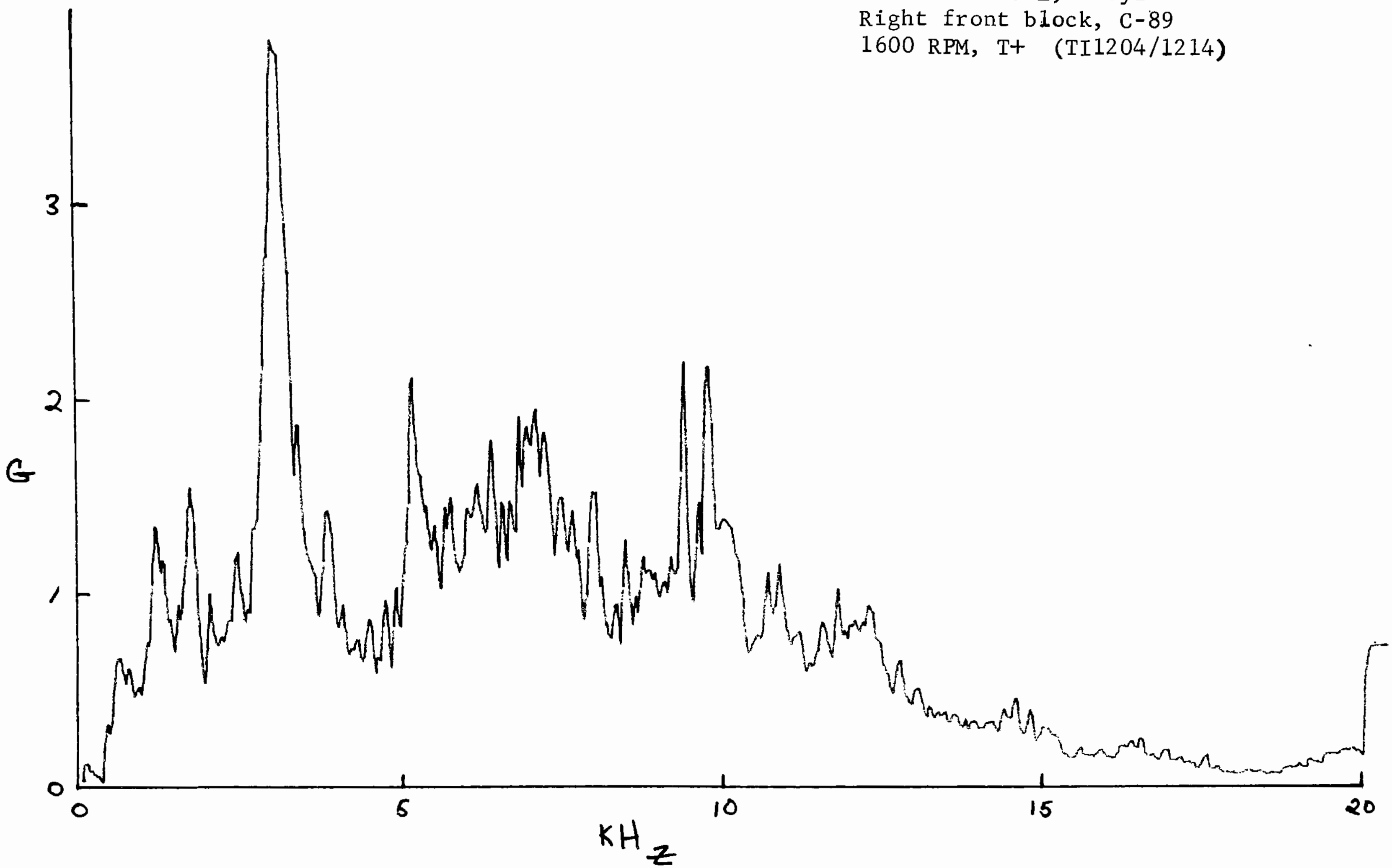
P21 - 5   2.3 L, 4 cyl.
Intake Manifold, C-89
1600 RPM, T+  (TI 1204/1214)



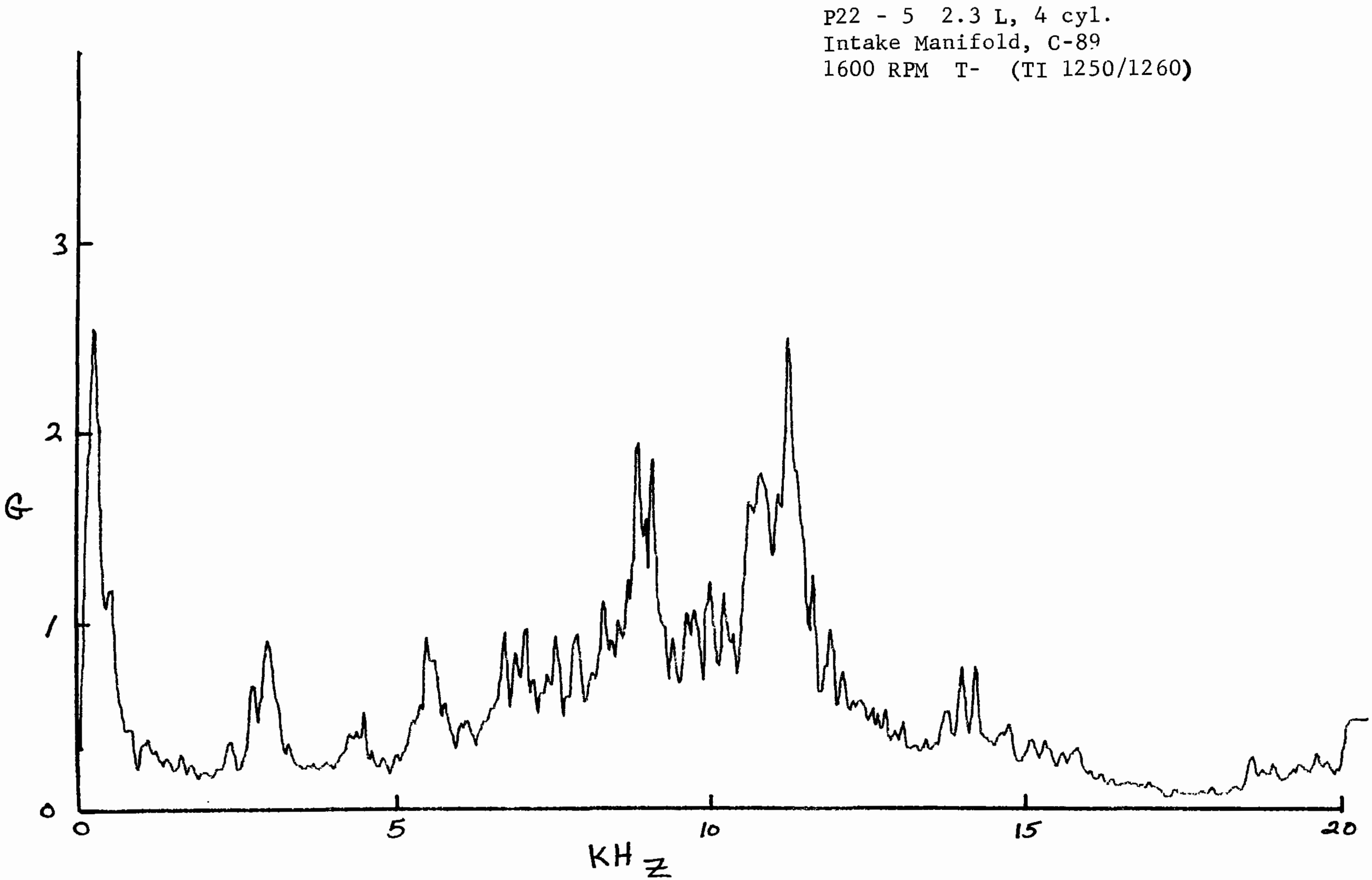
P21-6

P21 - 6  2.3 L, 4 cyl.
Right rear head, C-89
1600 RPM, T+  (TI 1204/1214)



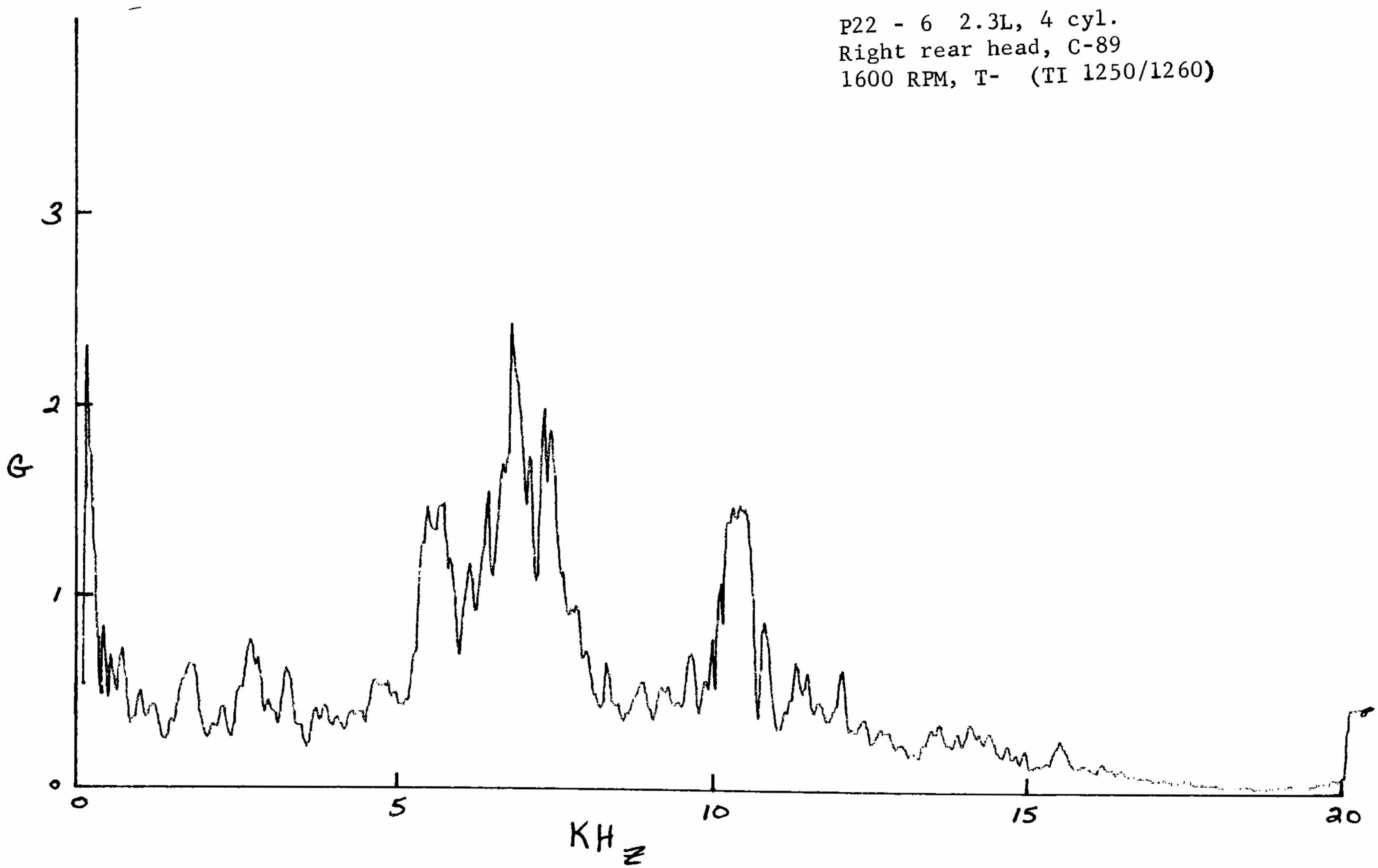

P21 - 7 2.3 L, 4cyl.
Right front block, C-89
1600 RPM, T+ (TI1204/1214)
G
3
2
1
0
0
5
10
15
20
KHz

P22-5

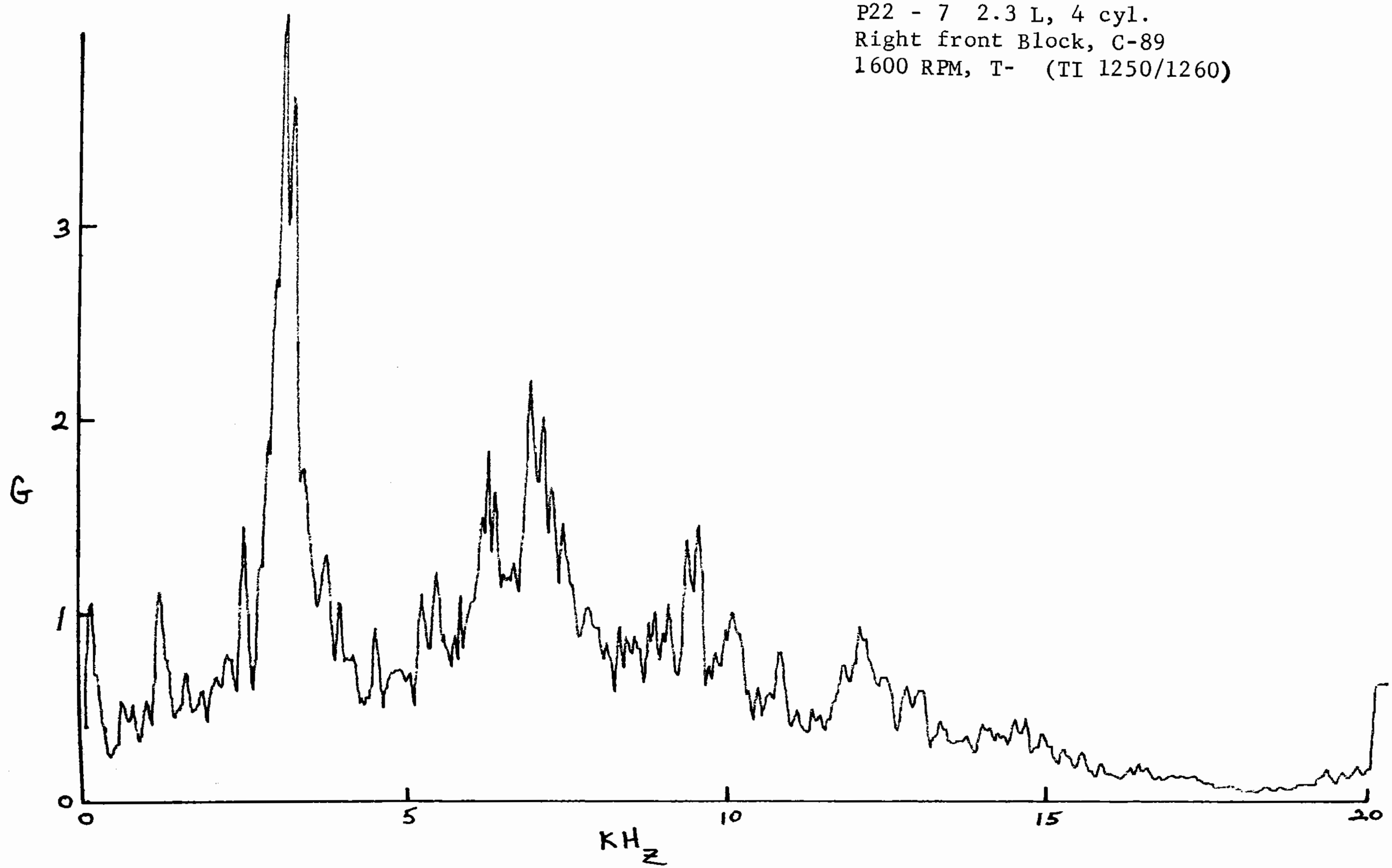


P22 - 5 2.3 L, 4 cyl.
Intake Manifold, C-89
1600 RPM T- (TI 1250/1260)
G
3
2
1
0
5
10
15
20
KHZ

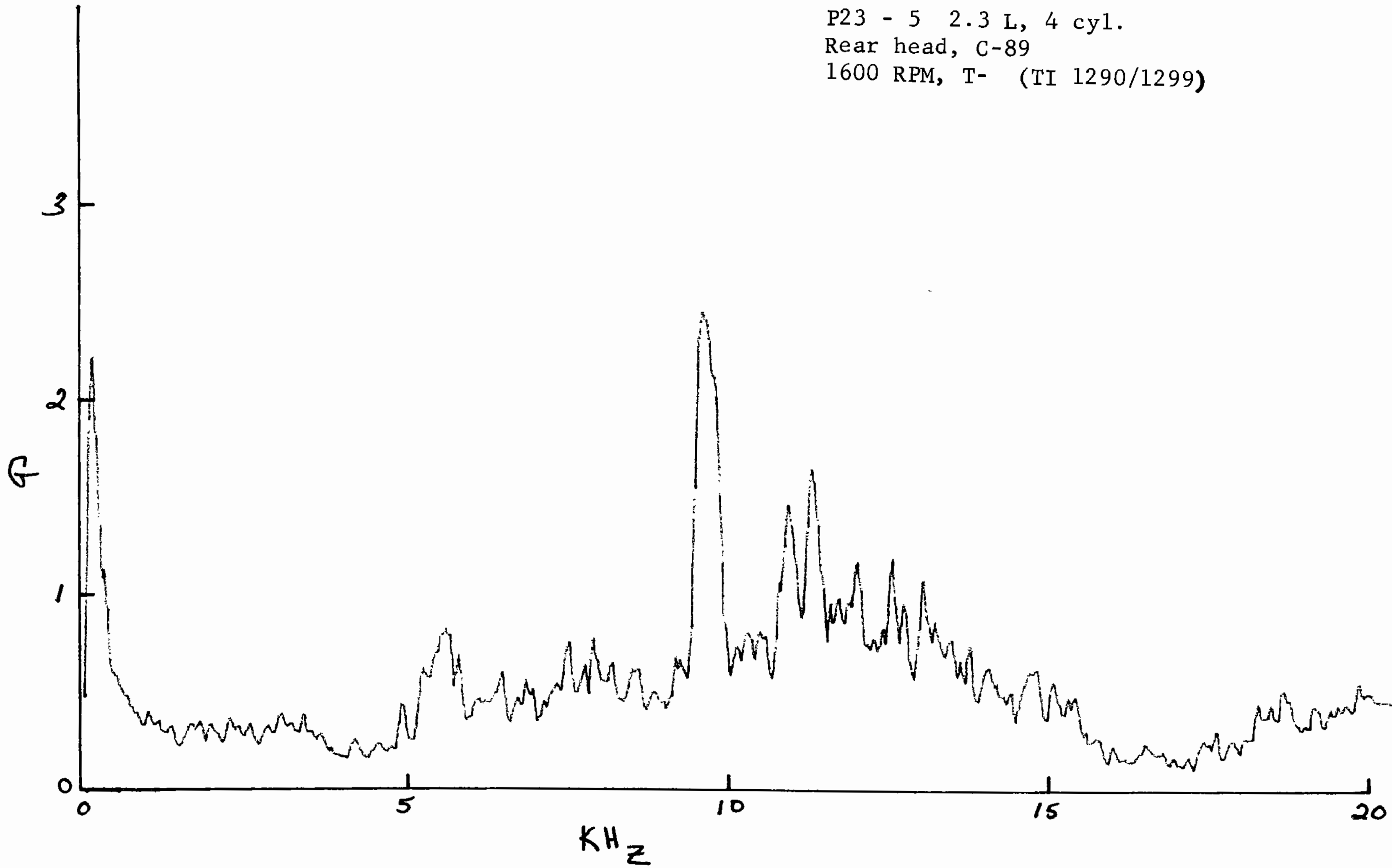
P22 - 6


P22 - 6 2.3L, 4 cyl.
Right rear head, C-89
1600 RPM, T- (TI 1250/1260)
G
0
1
2
3
0
5
10
15
20
KHz

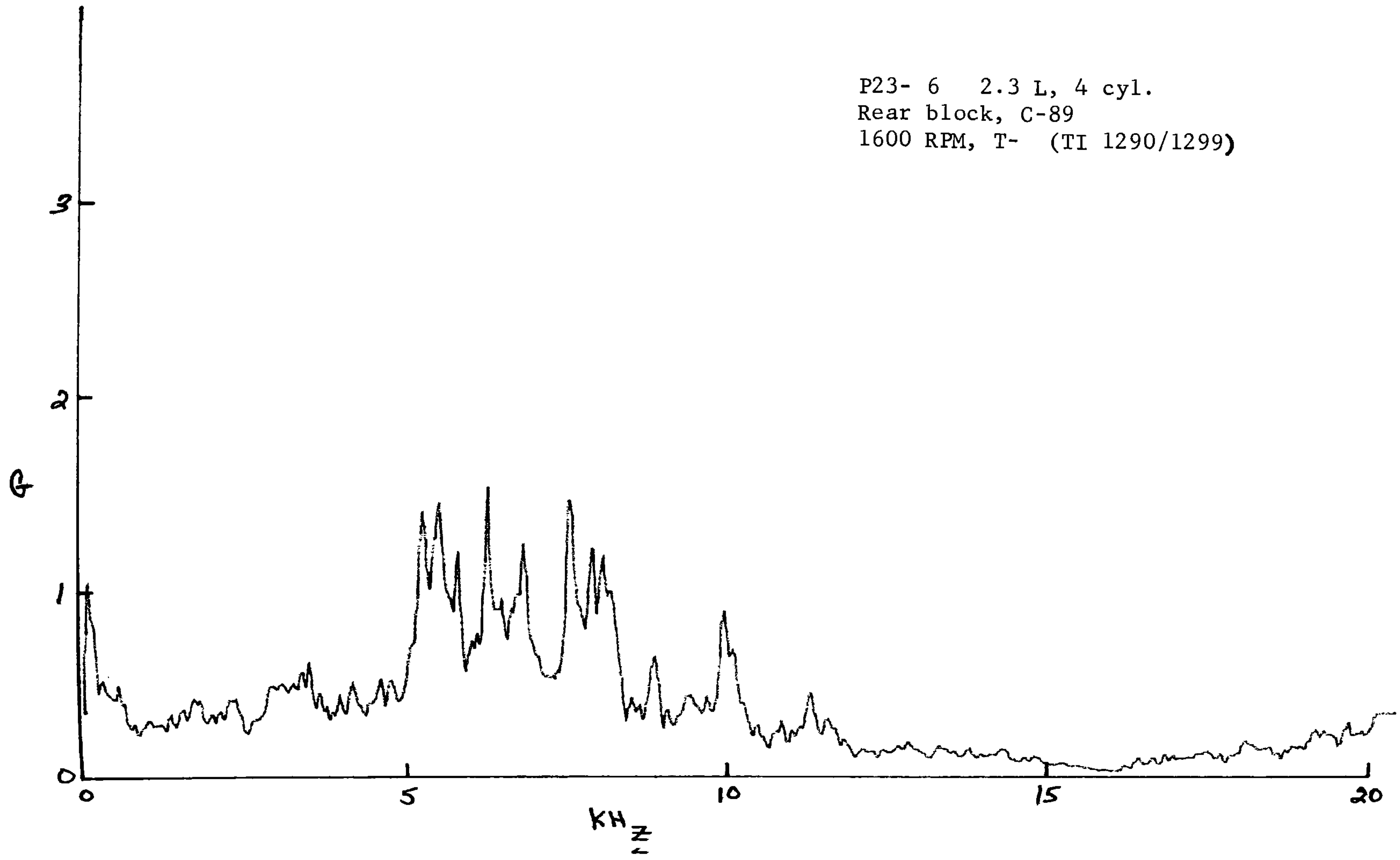
P22-7


P22 - 7 2.3 L, 4 cyl.
Right front Block, C-89
1600 RPM, T- (TI 1250/1260)
G
3
2
1
0
0
5
10
15
20
KHz

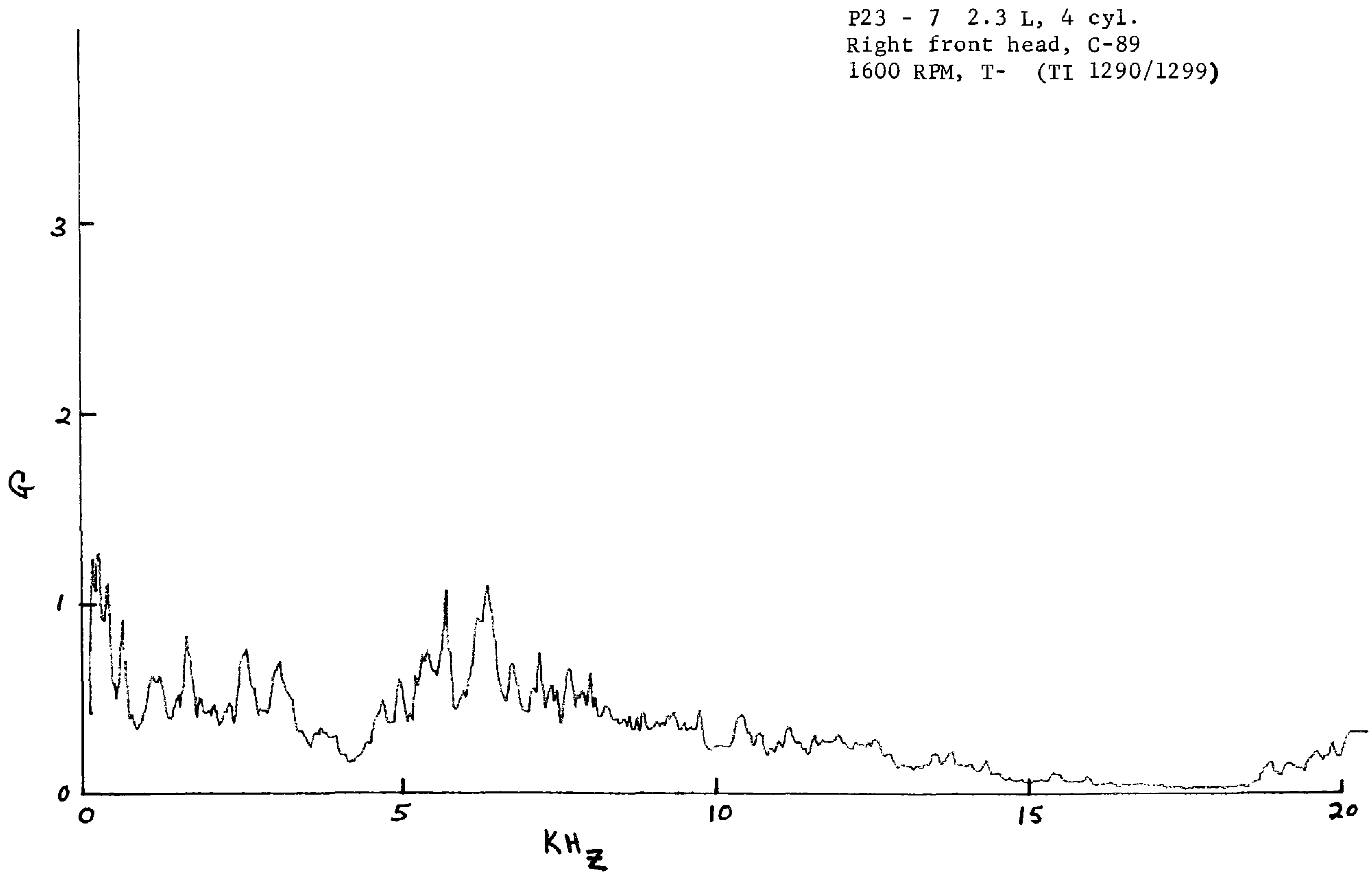
P23-5


P23 - 5 2.3 L, 4 cyl.
Rear head, C-89
1600 RPM, T- (TI 1290/1299)
G
3
2
1
0
0
5
10
15
20
KHz

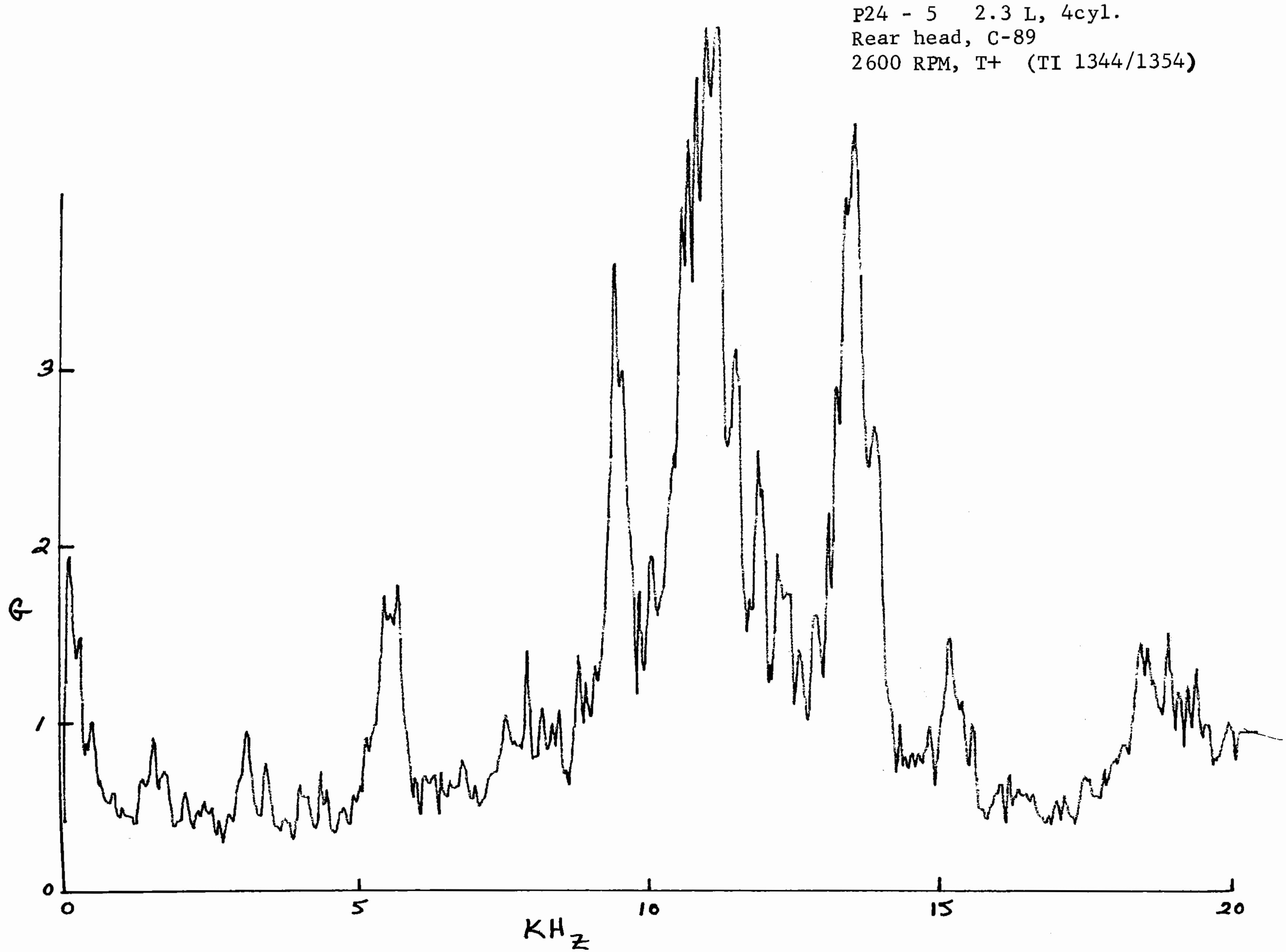
P23-6


P23- 6 2.3 L, 4 cyl.
Rear block, C-89
1600 RPM, T- (TI 1290/1299)
G
3
2
1
0
0
5
10
15
20
KHZ

P23-7

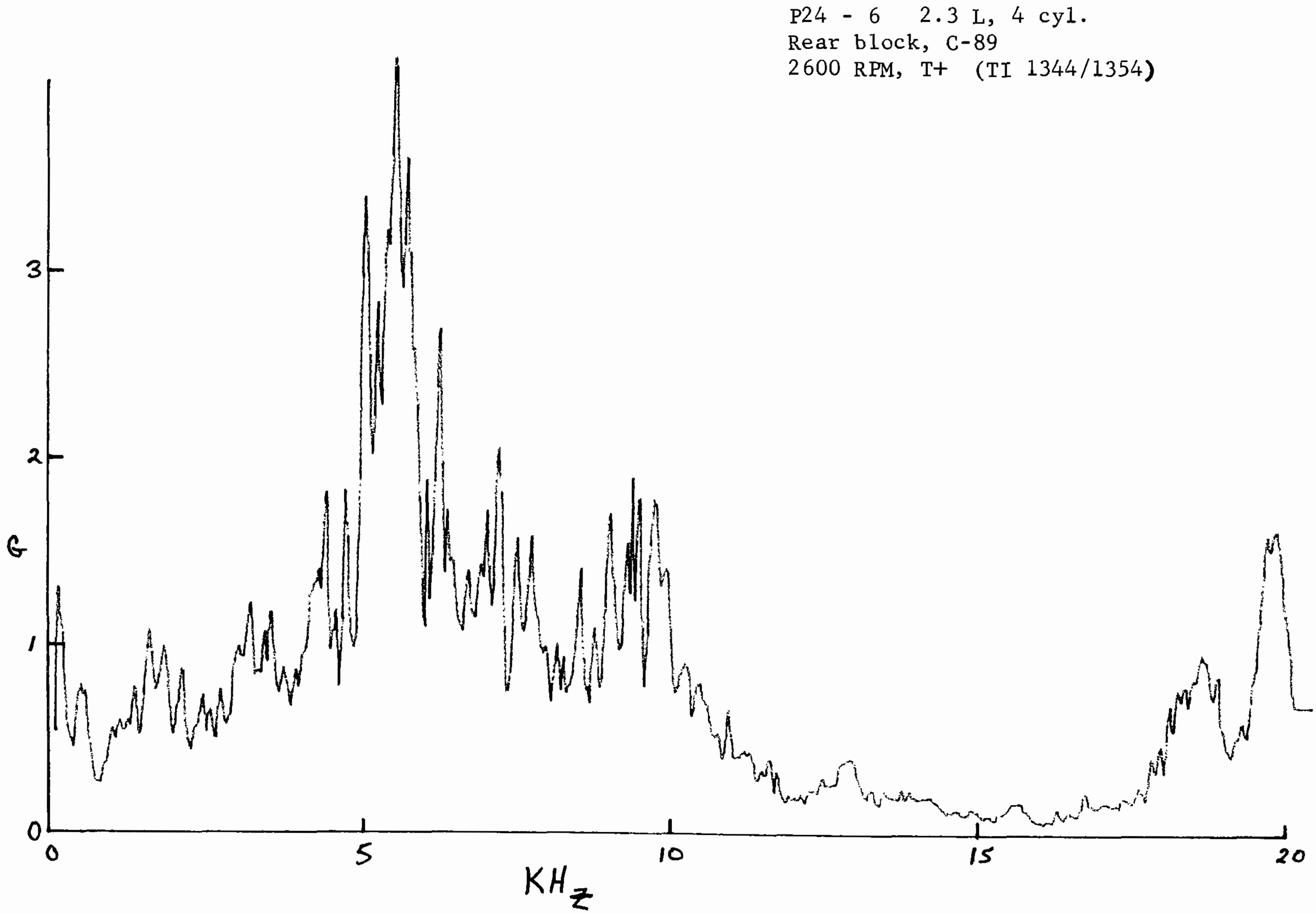

P23 - 7 2.3 L, 4 cyl.
Right front head, C-89
1600 RPM, T- (TI 1290/1299)
G
3
2
1
0
0
5
10
15
20
KHz

P24-5
RH


P24 - 5 2.3 L, 4cyl.
Rear head, C-89
2600 RPM, T+ (TI 1344/1354)
G
0
1
2
3
KHz
0
5
10
15
20

P24-6

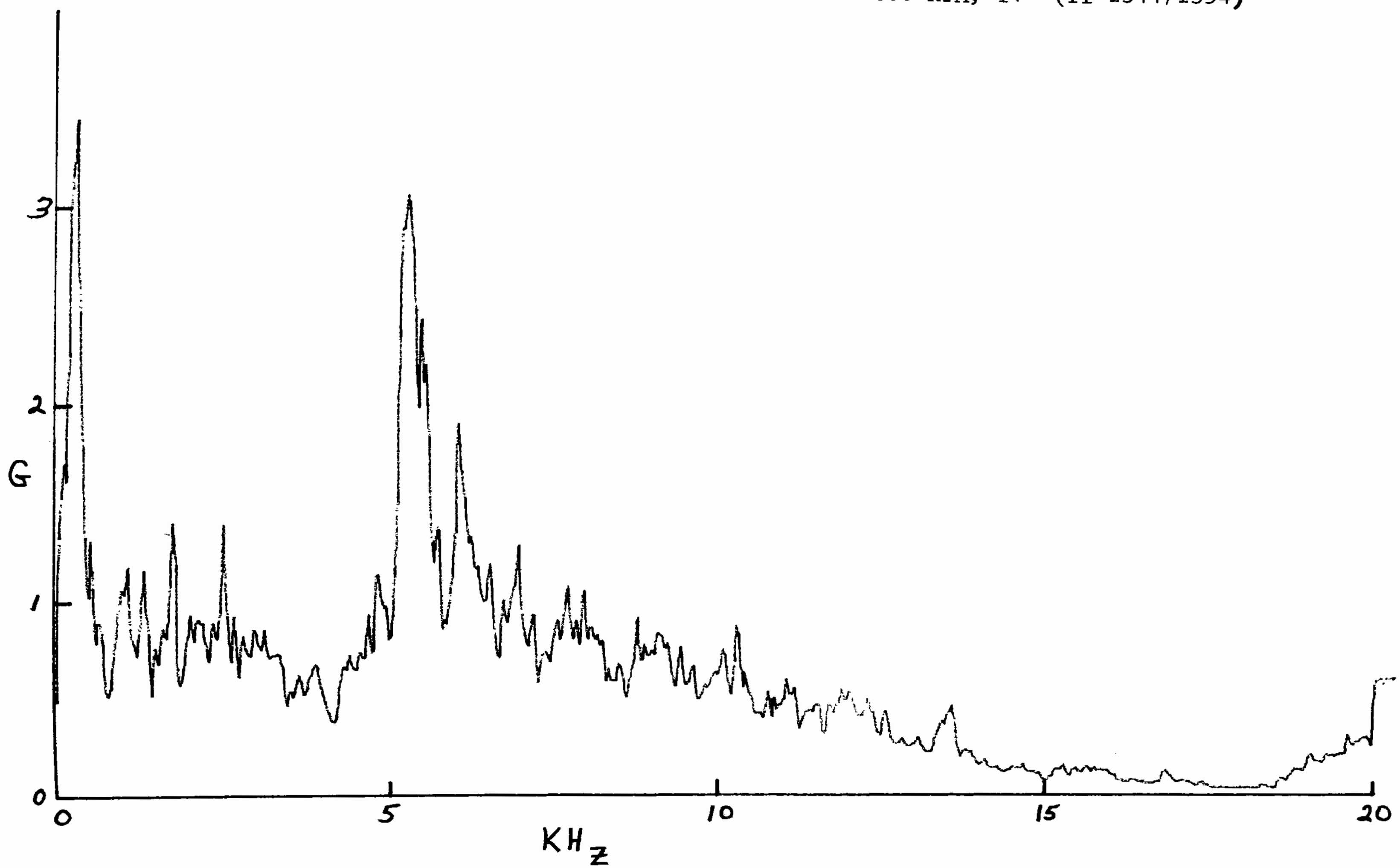
RB


P24 - 6 2.3 L, 4 cyl.
Rear block, C-89
2600 RPM, T+ (TI 1344/1354)
G
0
1
2
3
0
5
10
15
20
KHz

P24-7

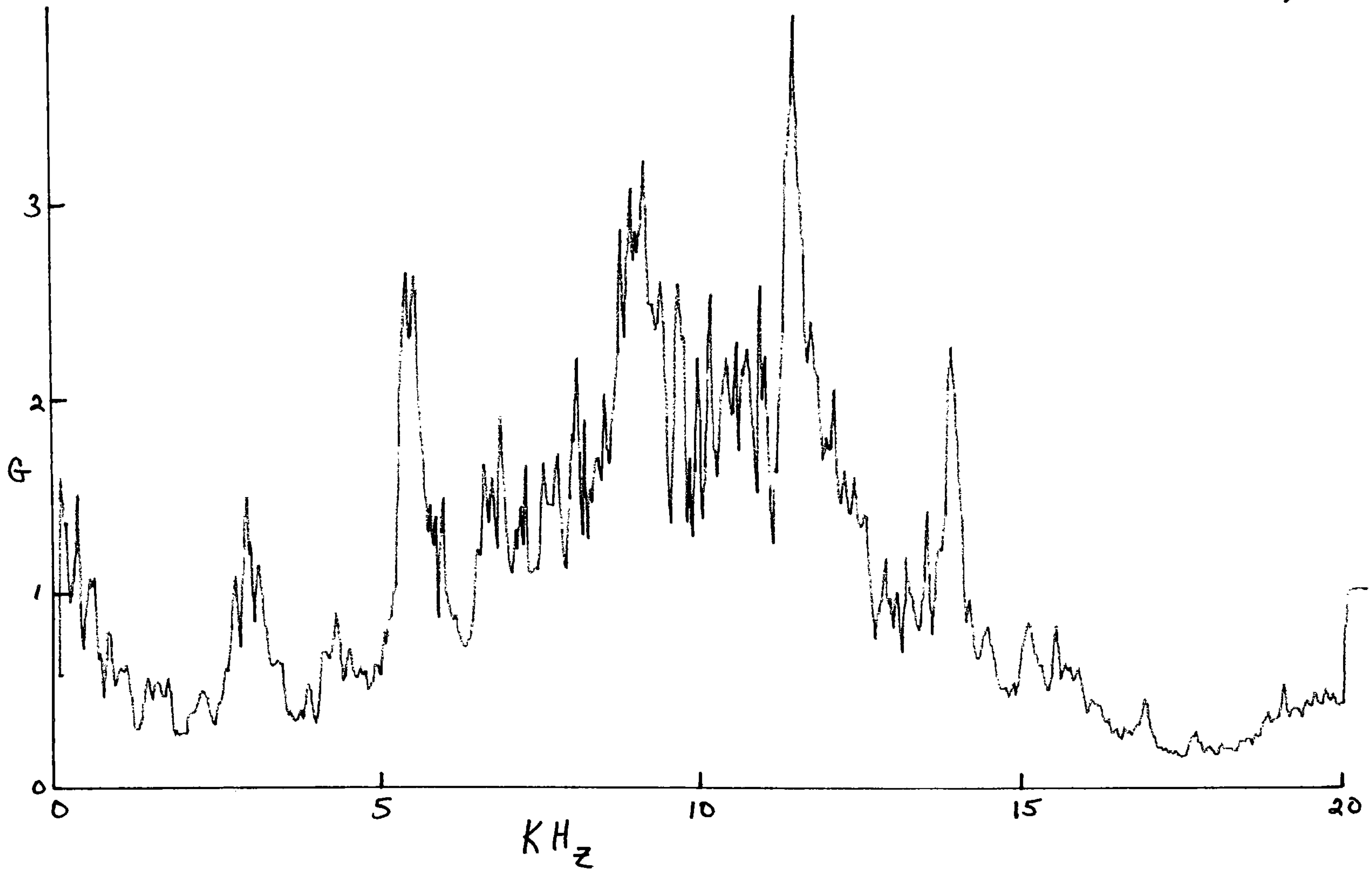
RFH

P24 - 7  2.3 L, 4 cyl.
Right front head, C-89
2600 RPM, T+  (TI 1344/1354)



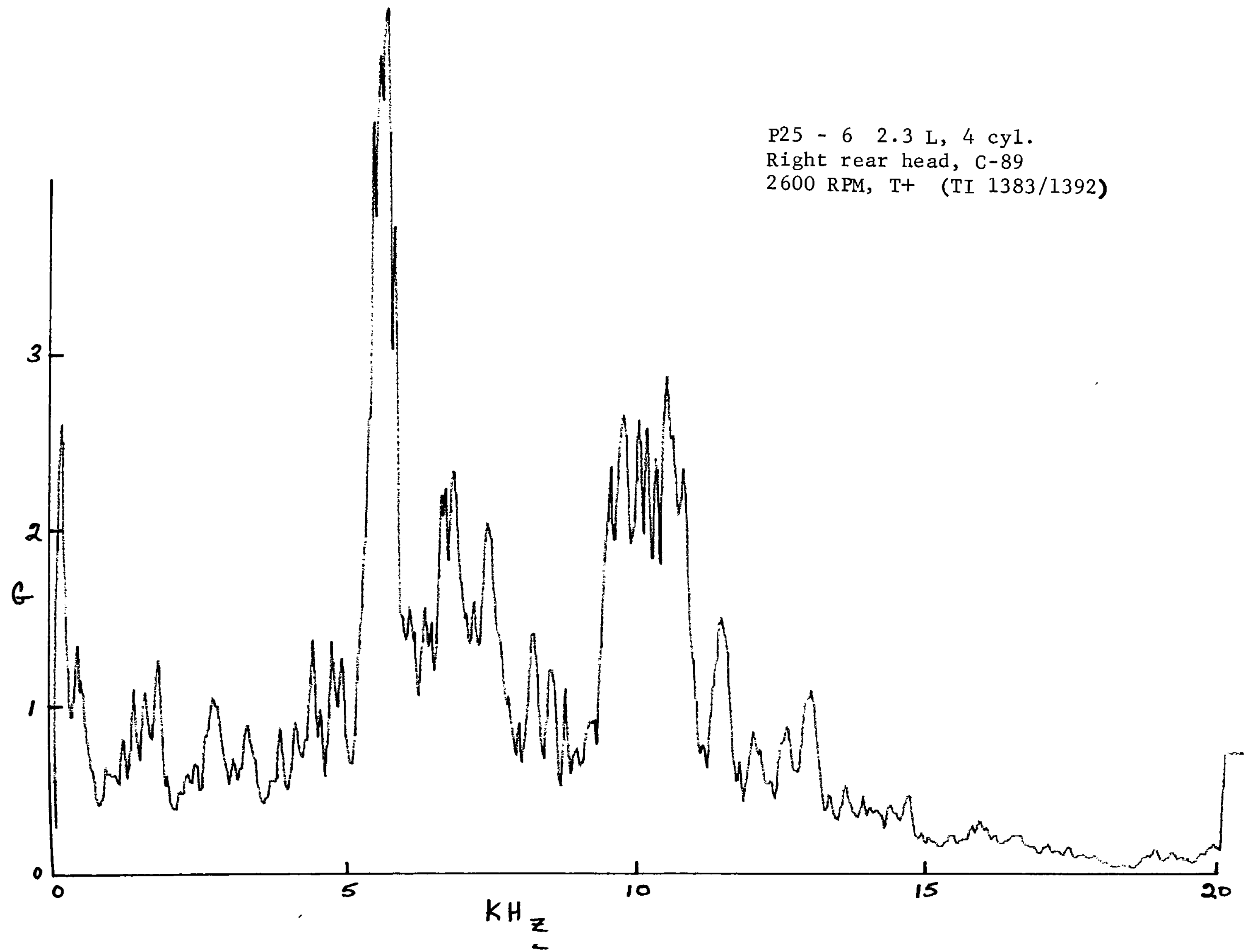
P25-5

P25 - 5 2.3 L, 4 cyl.
Intake Manifold, C-89
2600 RPM, T+ (TI 1383/1392)



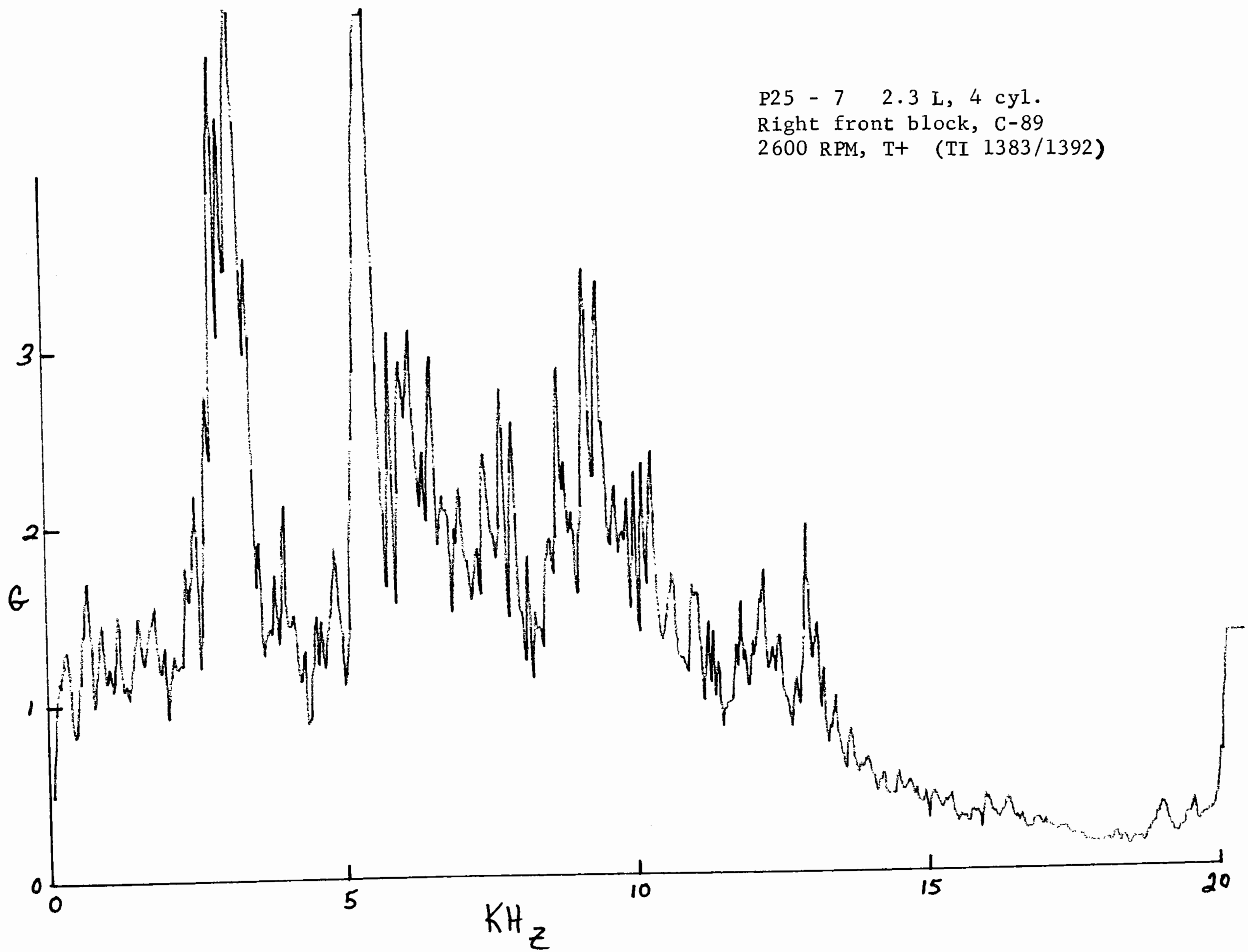
P25-6

RRH


P25 - 6 2.3 L, 4 cyl.
Right rear head, C-89
2600 RPM, T+ (TI 1383/1392)
G
3
2
1
0
0
5
10
15
20
KHz

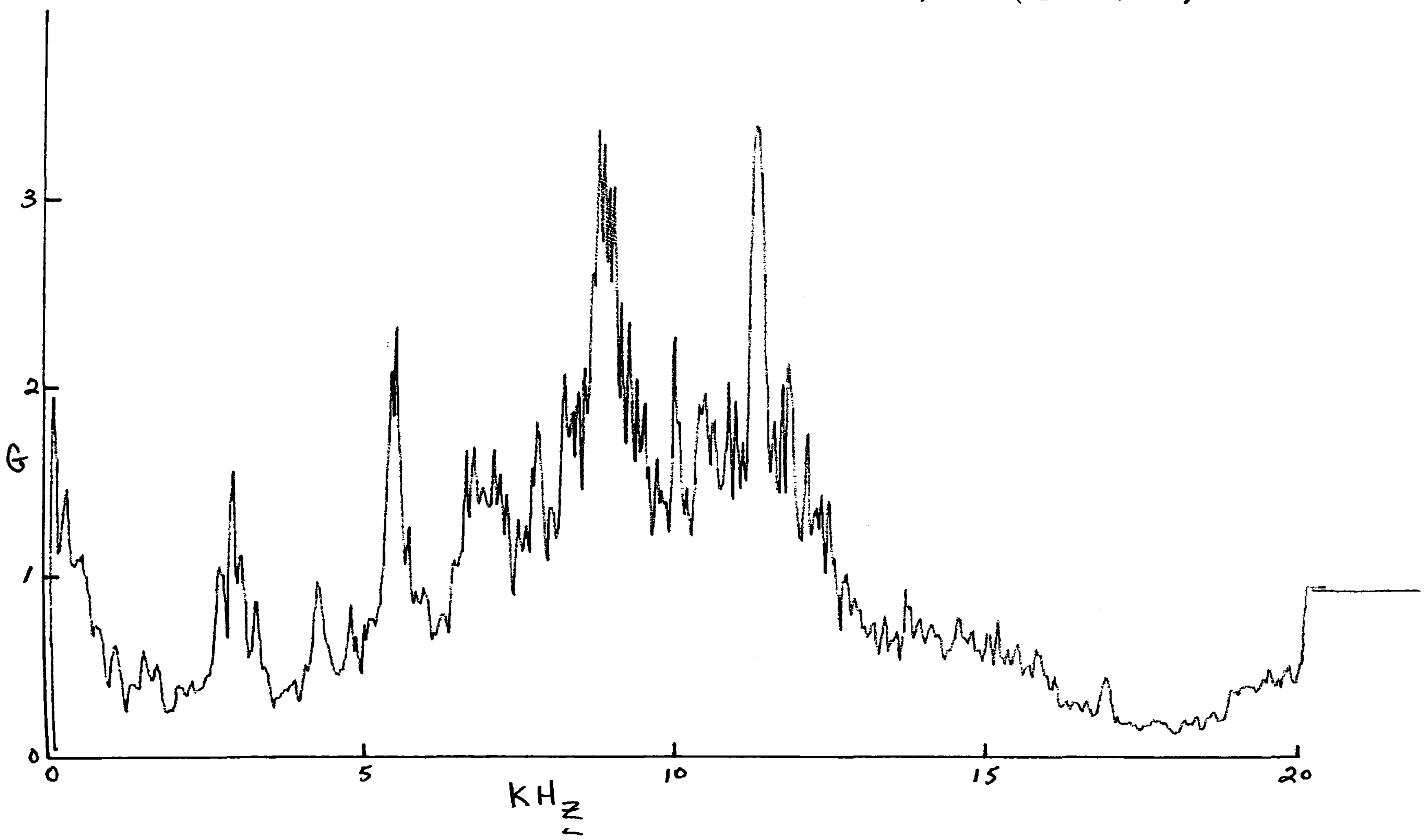
P25-7

RF 3

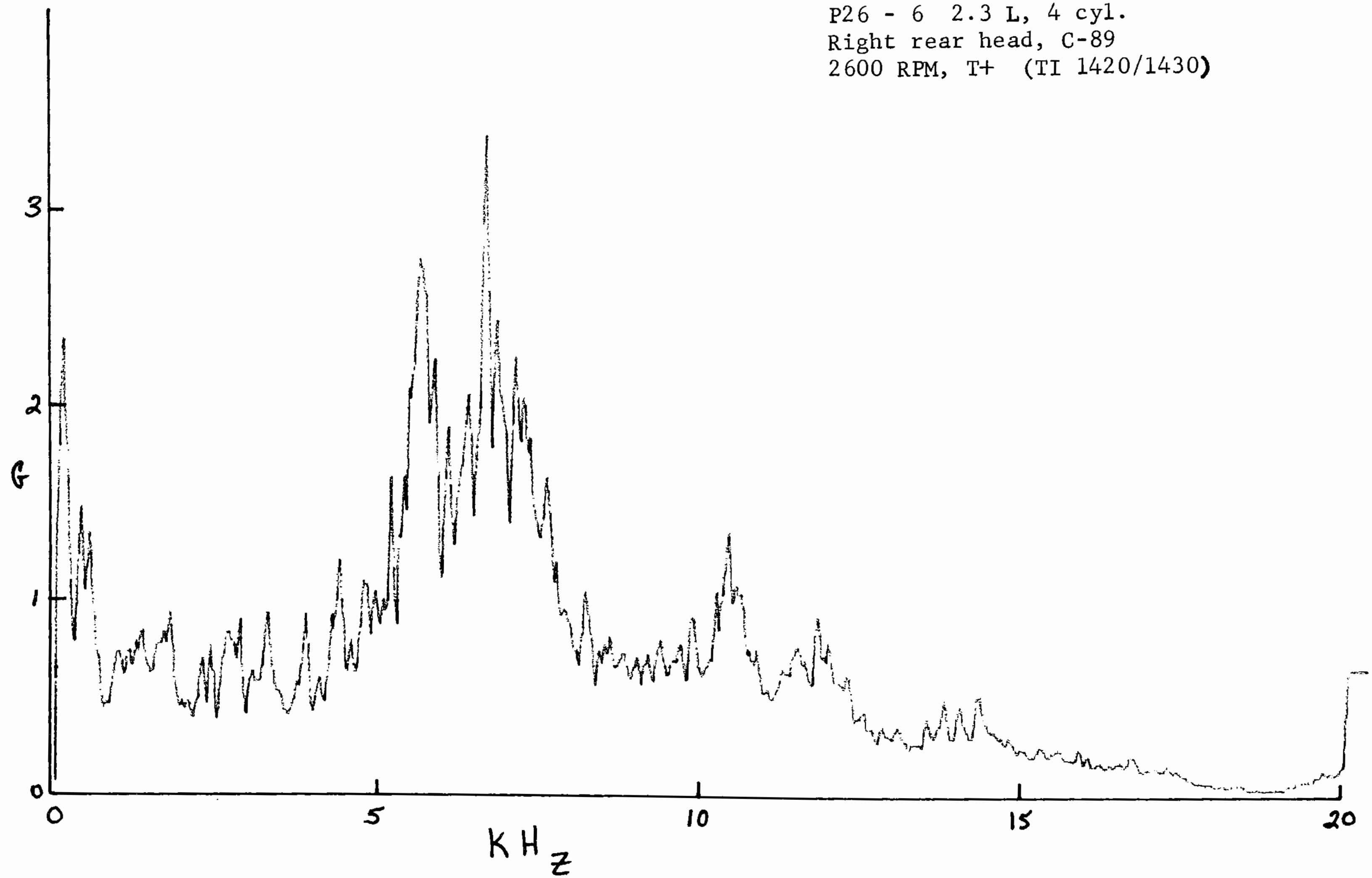

P25 - 7 2.3 L, 4 cyl.
Right front block, C-89
2600 RPM, T+ (TI 1383/1392)
G
0
1
2
3
0
5
10
15
20
KHz

P26-5

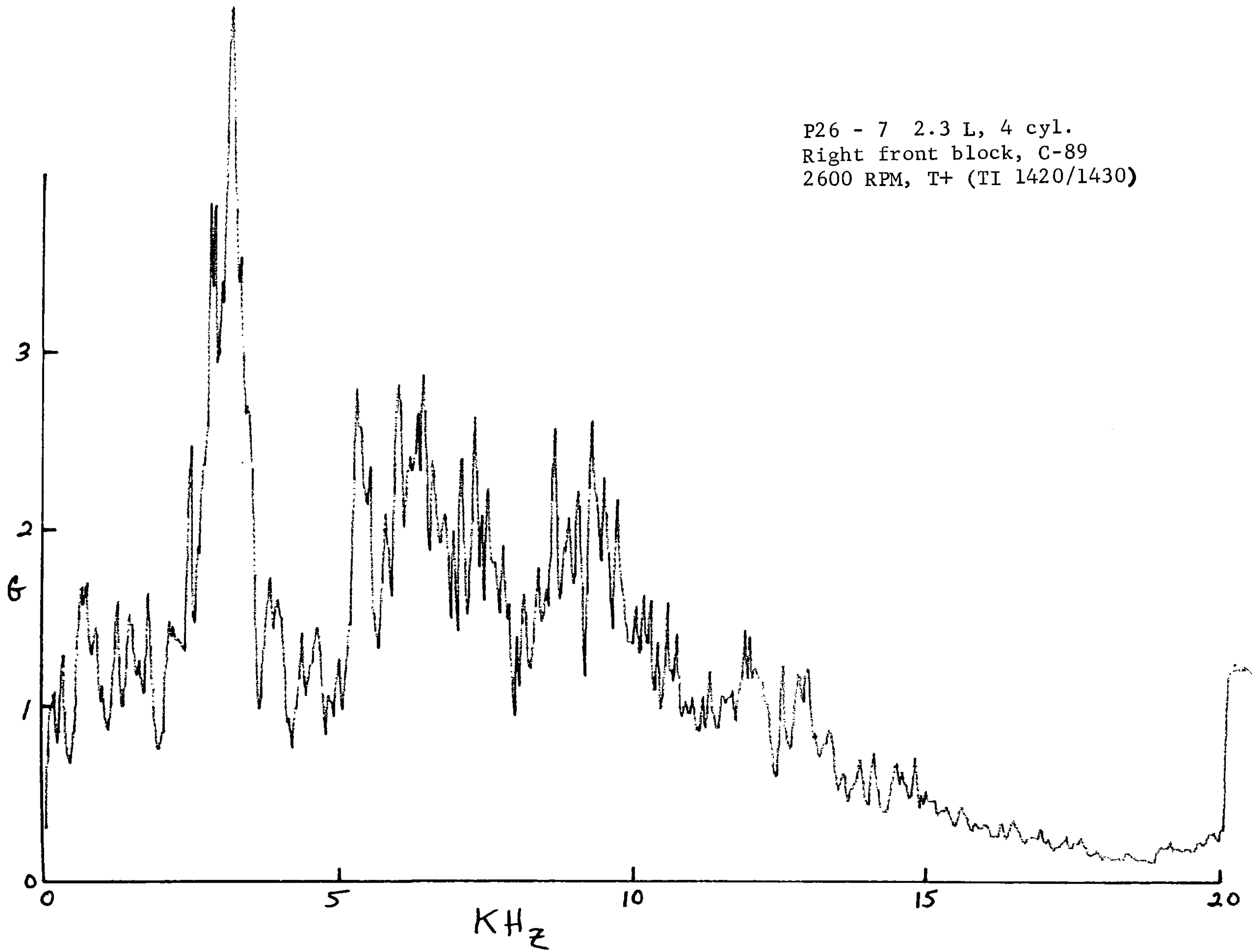
P26 - 5   2.3 L, 4 cyl.
Intake Manifold, C-89
2600 RPM,  T+  (TI 1420/1430)



P26-6

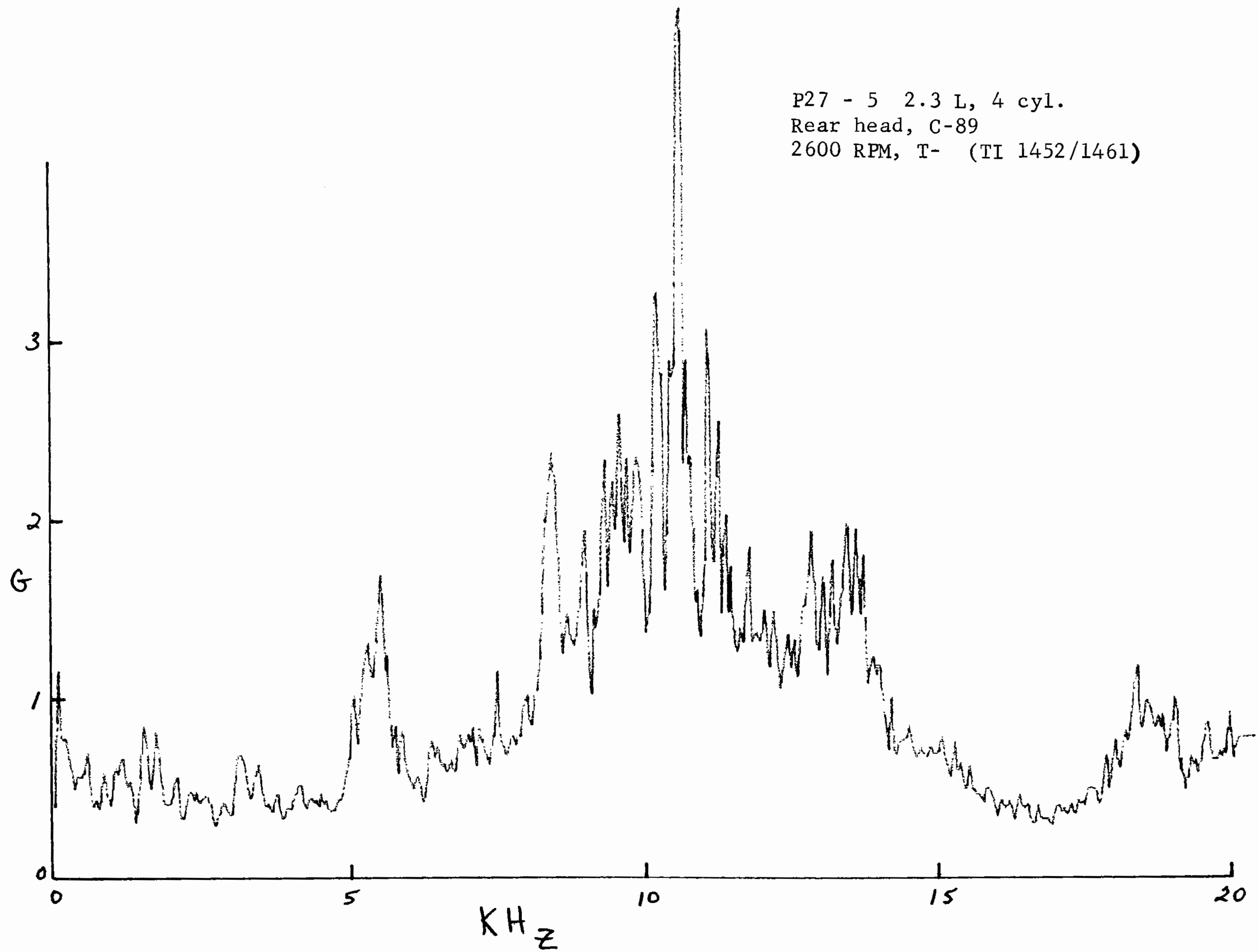

P26 - 6 2.3 L, 4 cyl.
Right rear head, C-89
2600 RPM, T+ (TI 1420/1430)
G
3
2
1
0
0
5
10
15
20
KHz

P26-7



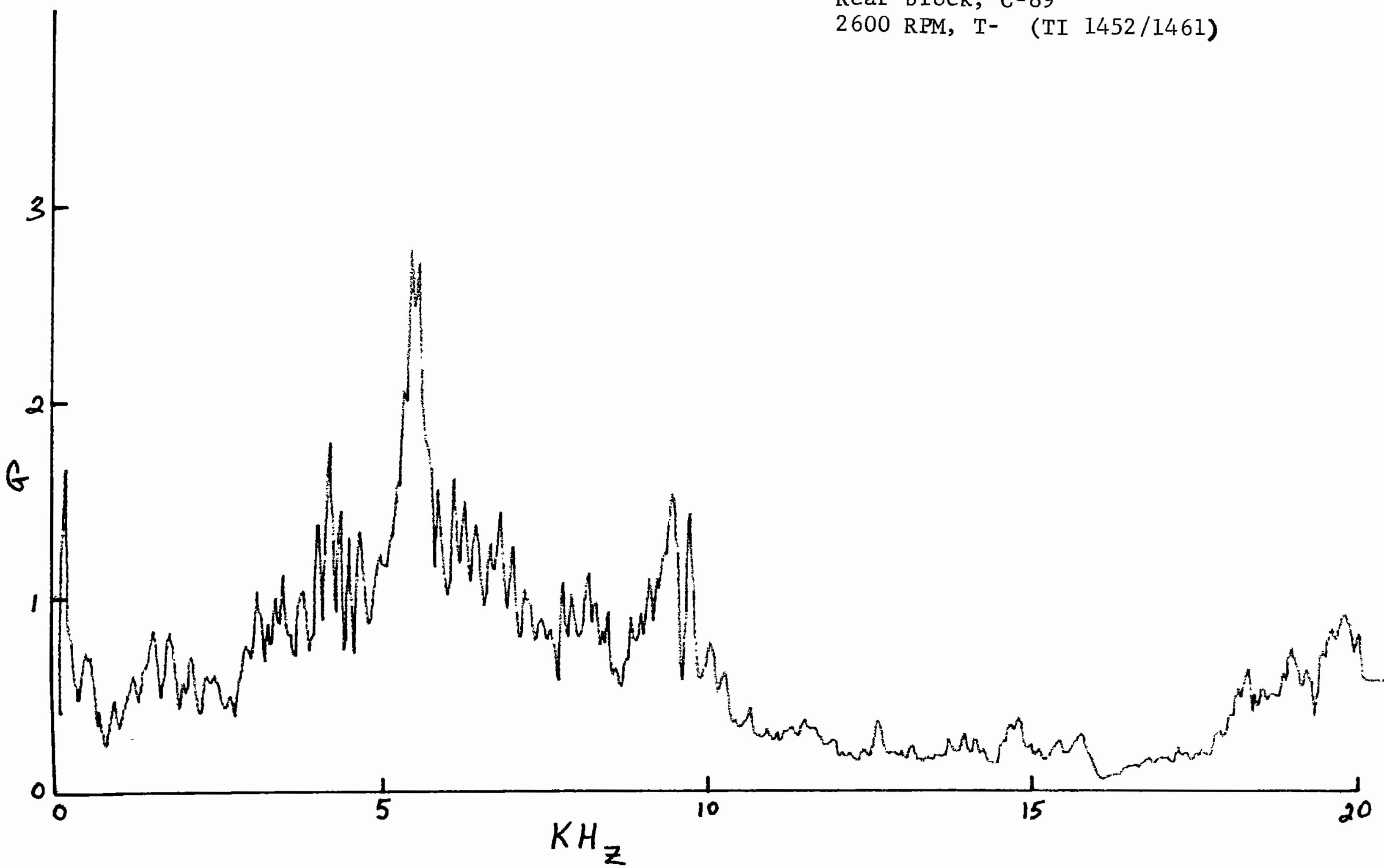
P26 - 7 2.3 L, 4 cyl.
Right front block, C-89
2600 RPM, T+ (TI 1420/1430)
G
0
1
2
3
0
5
10
15
20
KHz

P27-5


P27 - 5 2.3 L, 4 cyl.
Rear head, C-89
2600 RPM, T- (TI 1452/1461)
G
3
2
1
0
0
5
10
15
20
KHz

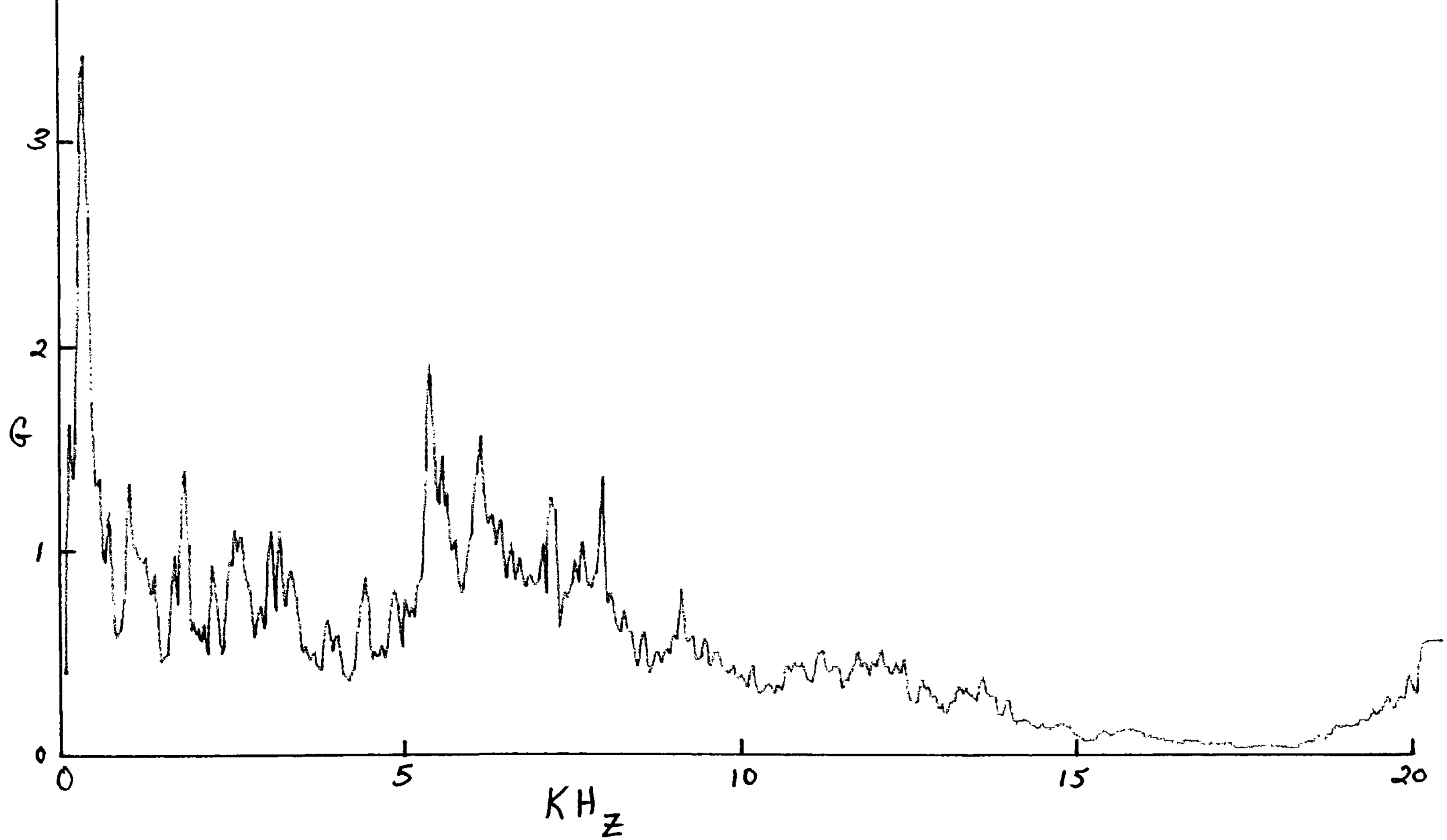
P27-6

P27 - 6 2.3 L, 4 cyl.
Rear block, C-89
2600 RPM, T- (TI 1452/1461)

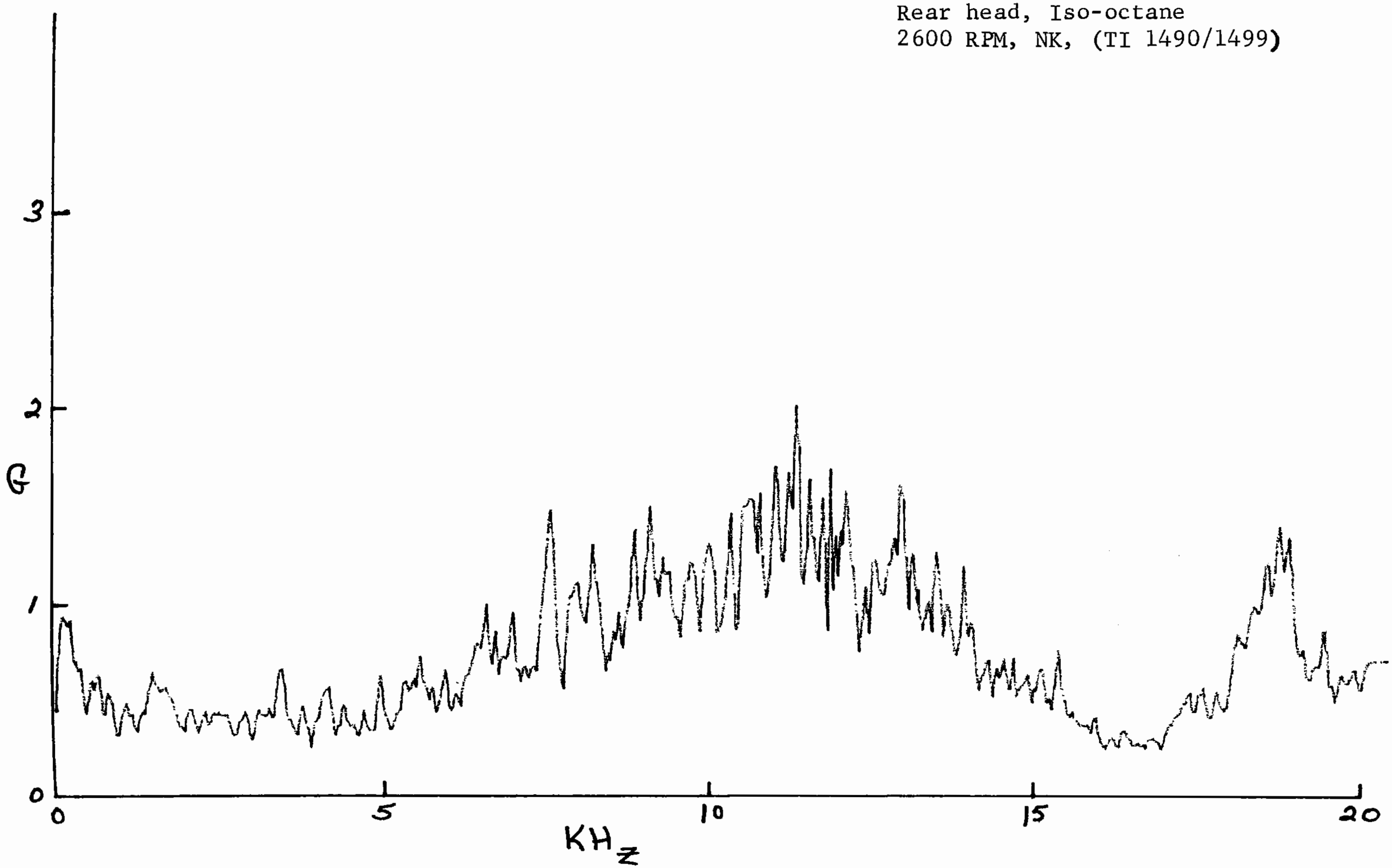


P27-7

P27 - 7   2.3 L, 4 cyl.
Right front head, C-89
2600 RPM, T-  (TI 1452/1461)

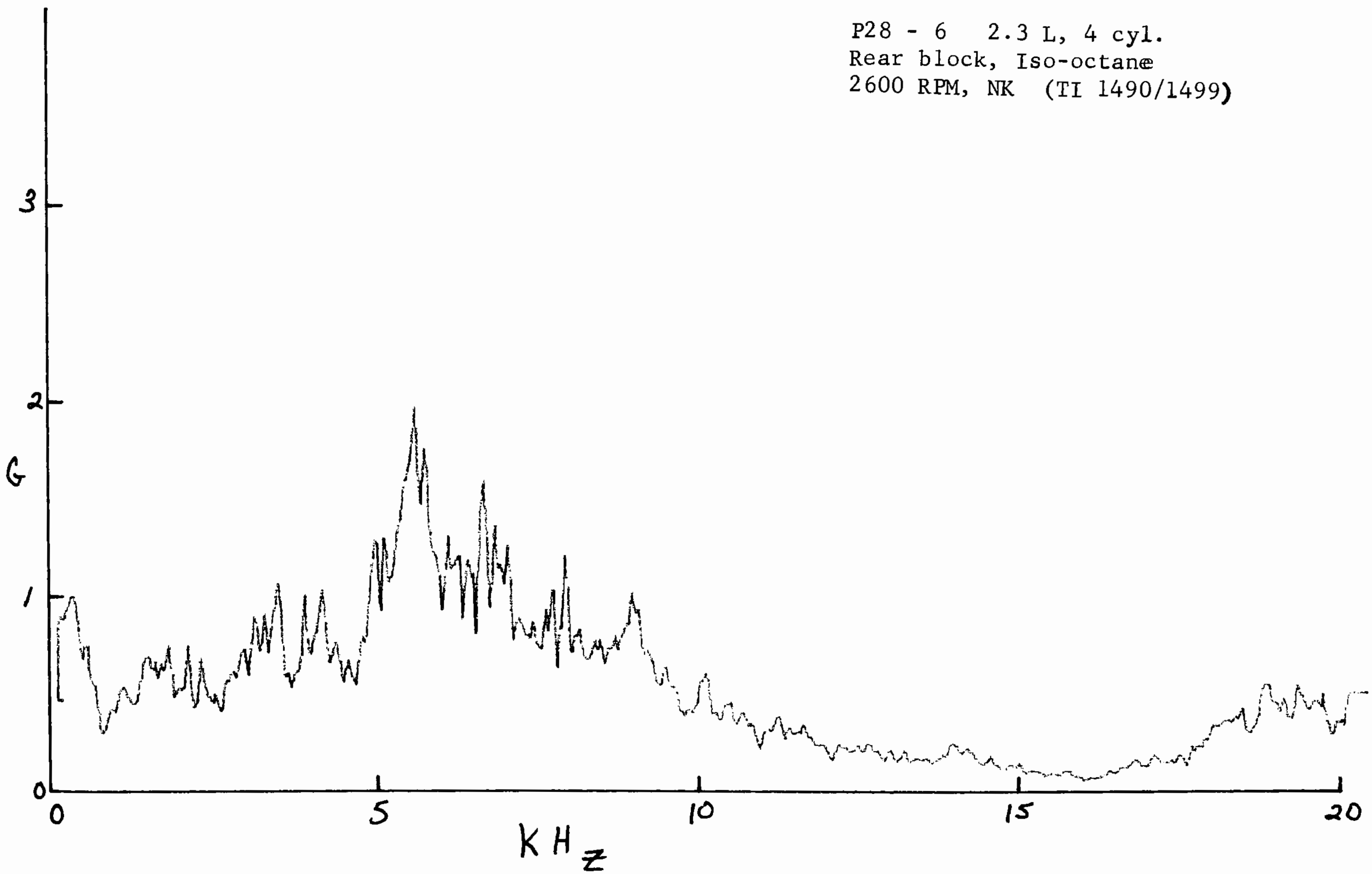


P28-5



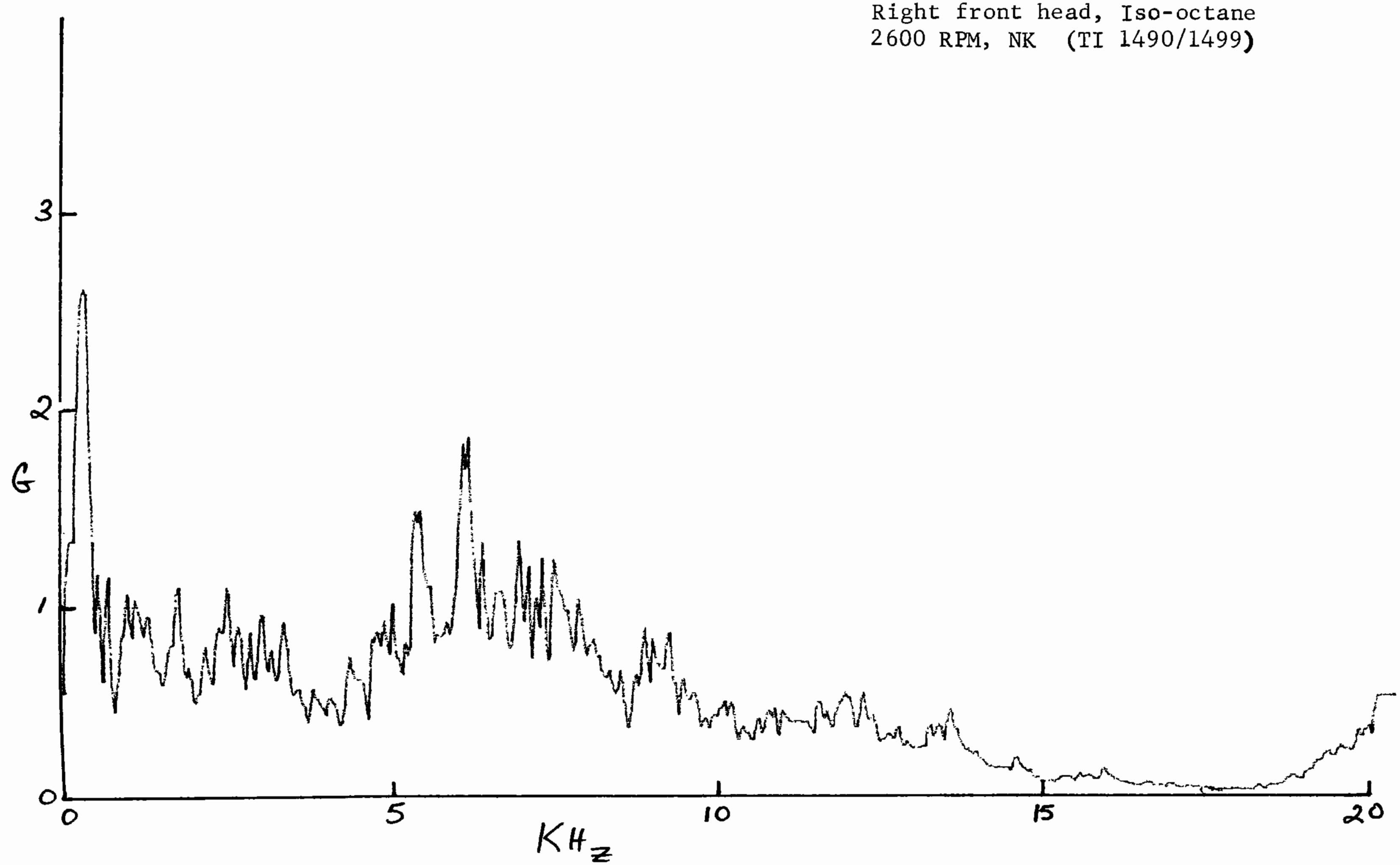

P28 - 5   2.3 L, 4 cyl.
Rear head, Iso-octane
2600 RPM, NK, (TI 1490/1499)

P28-6


P28 - 6   2.3 L, 4 cyl.
Rear block, Iso-octane
2600 RPM, NK  (TI 1490/1499)
G
3
2
1
0
0
5
10
15
20
KHz

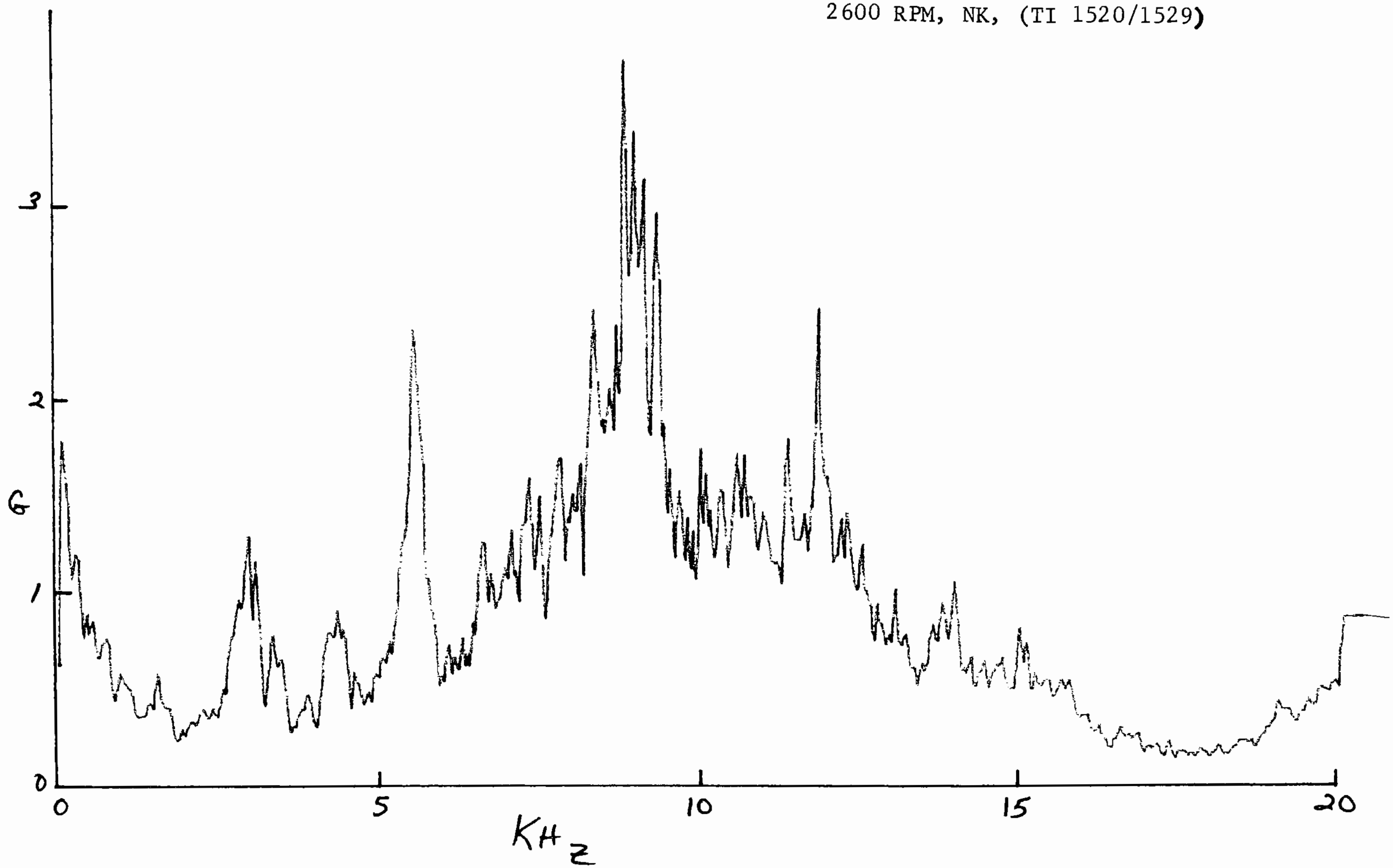
P28-7

P28 - 7  2.3 L, 4 cyl.
Right front head, Iso-octane
2600 RPM, NK  (TI 1490/1499)

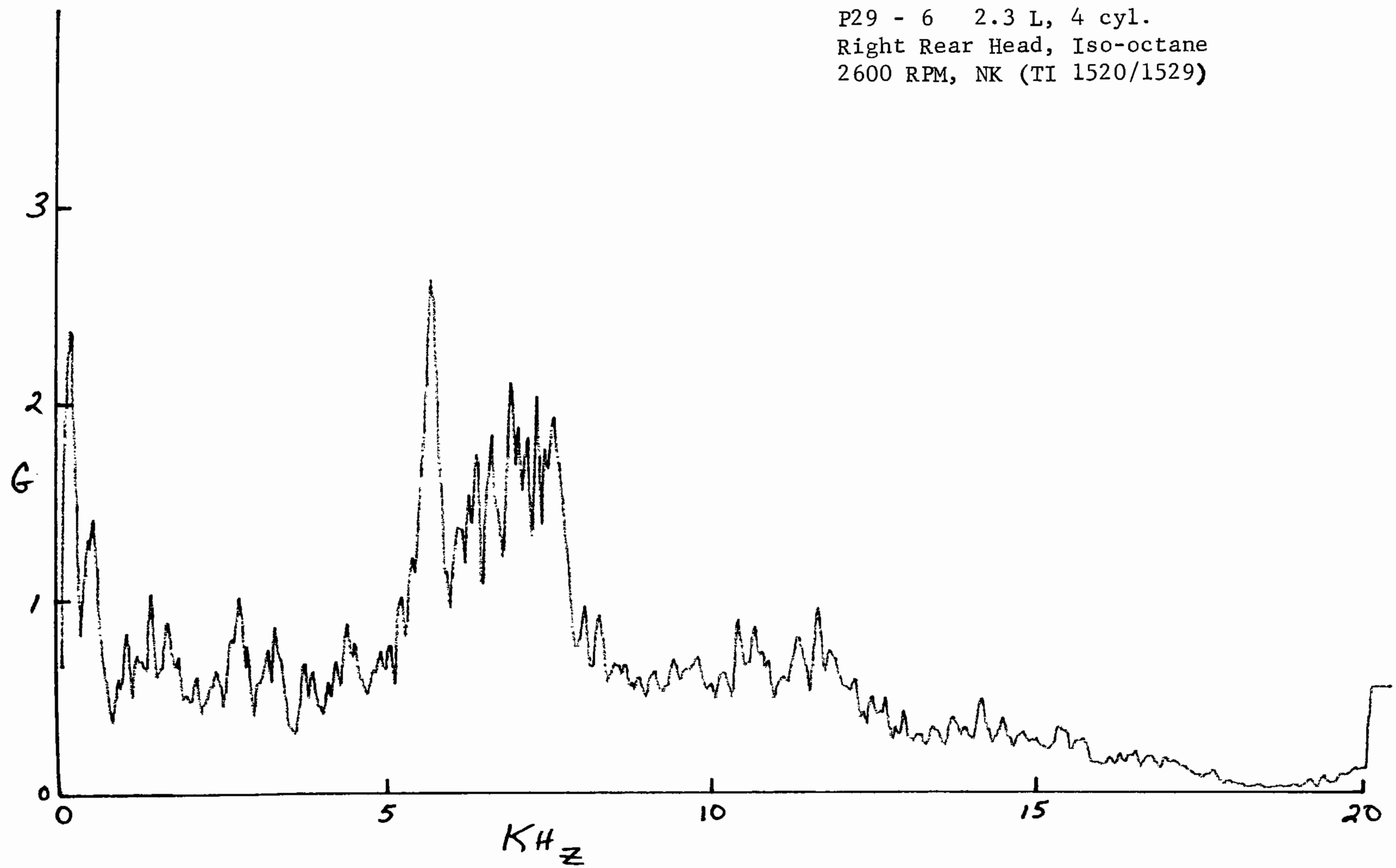


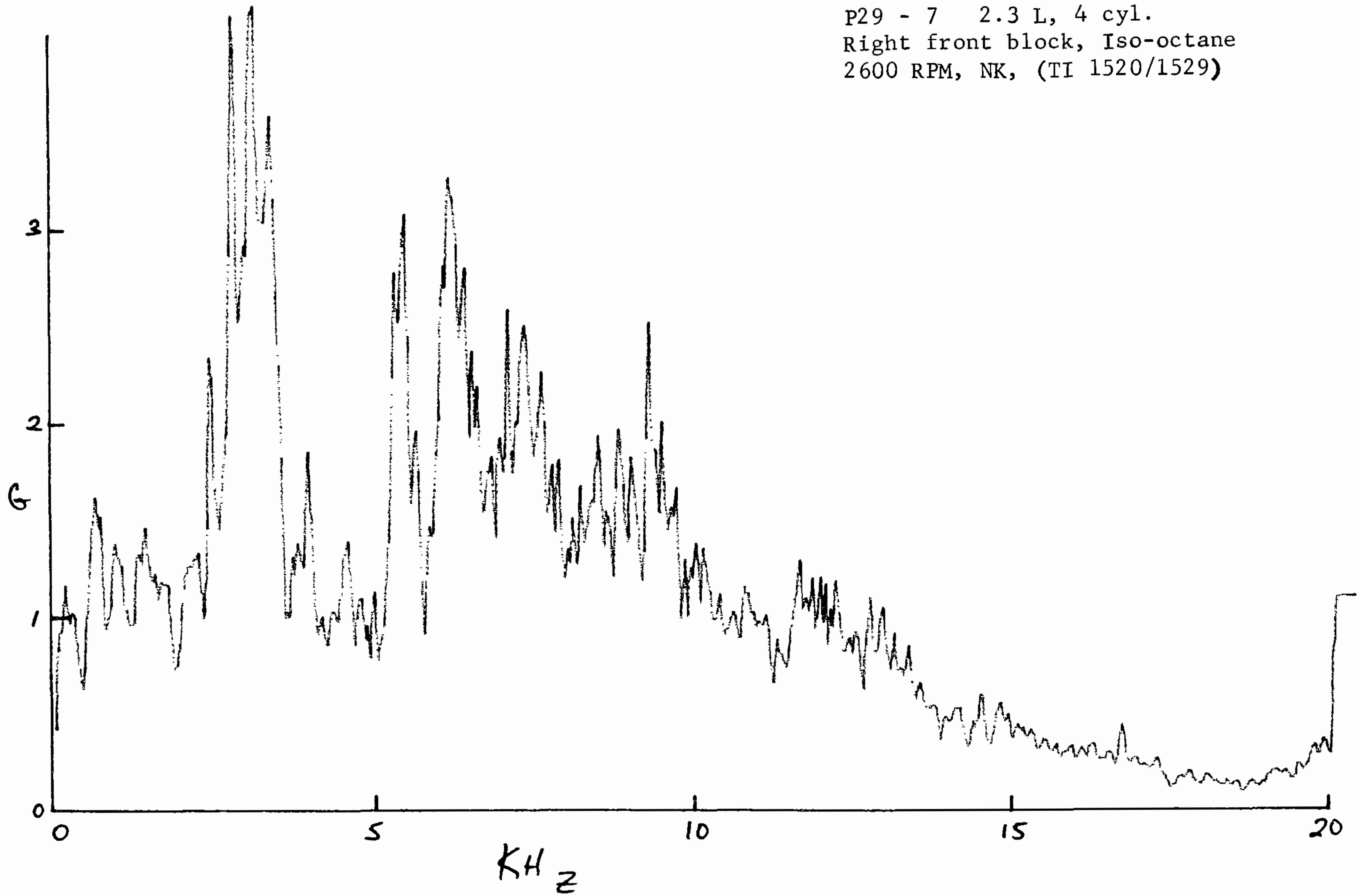
P29-5

P29 - 5 2.3 L, 4 cyl.
Intake Manifold, Iso-octane
2600 RPM, NK, (TI 1520/1529)

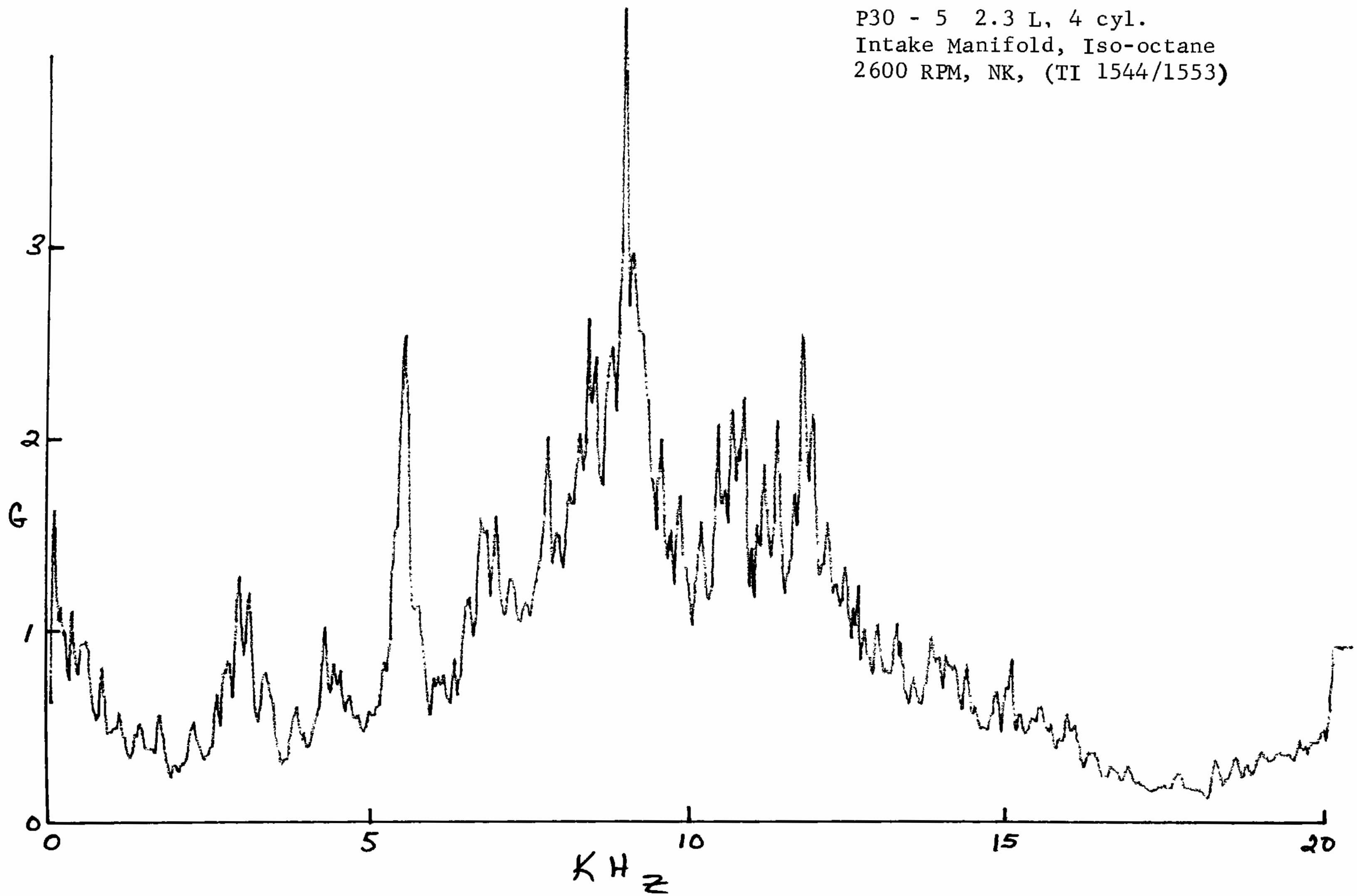


P29-6

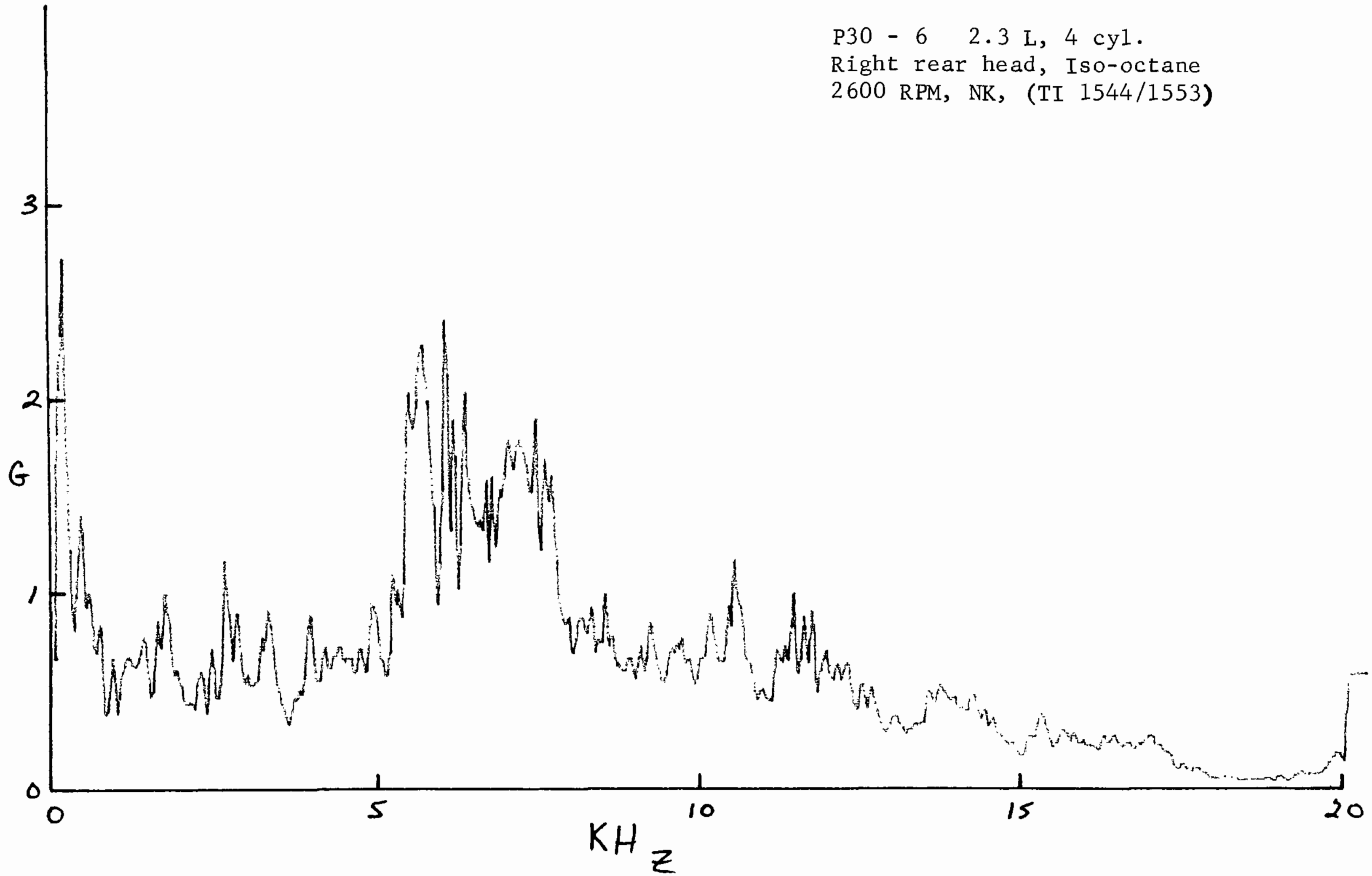

P29 - 6 2.3 L, 4 cyl.
Right Rear Head, Iso-octane
2600 RPM, NK (TI 1520/1529)
G
3
2
1
0
0
5
10
15
20
KHz


P29 - 7 2.3 L, 4 cyl.
Right front block, Iso-octane
2600 RPM, NK, (TI 1520/1529)
G
0
1
2
3
0
5
10
15
20
KHz

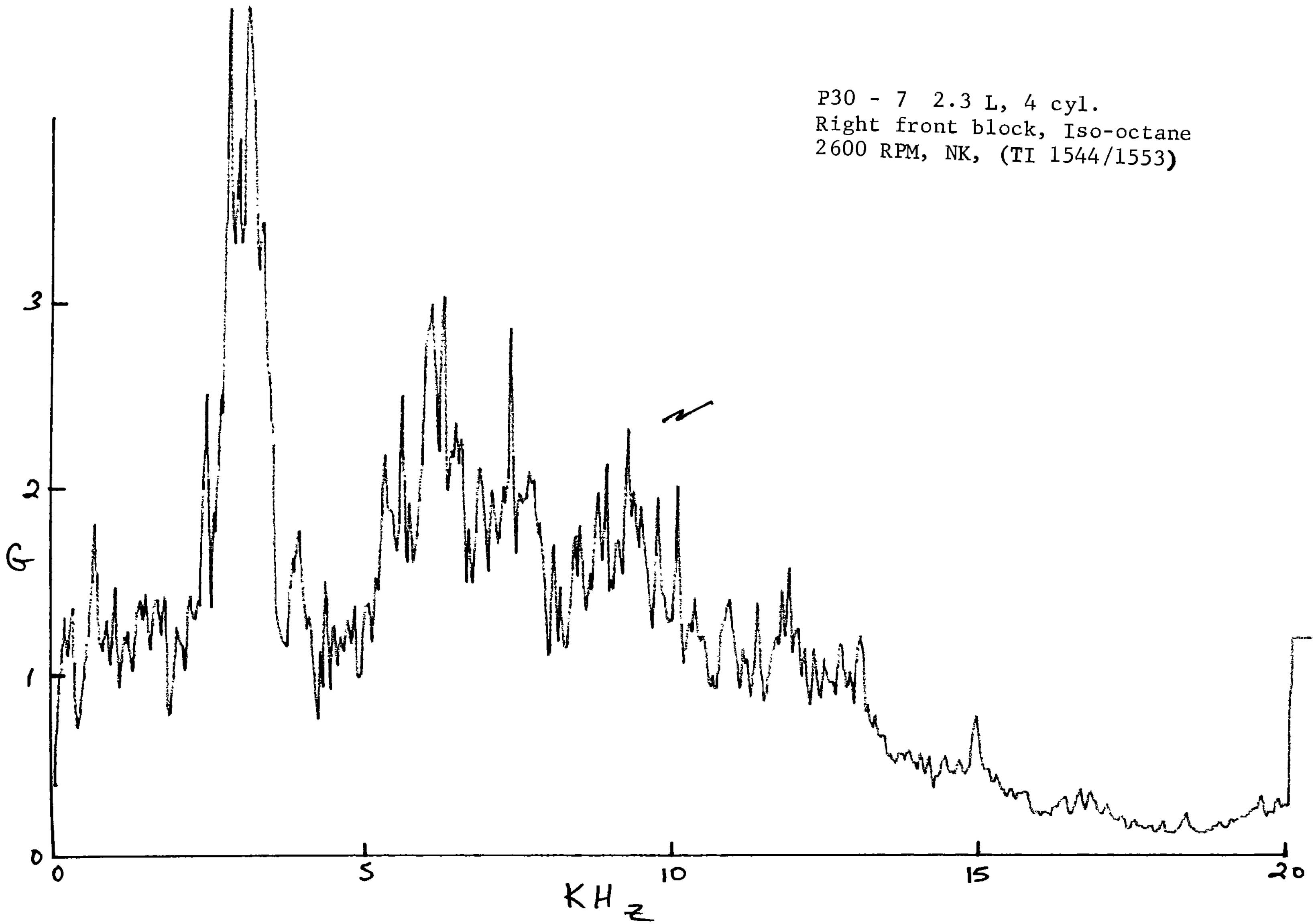
P30-5


P30 - 5 2.3 L, 4 cyl.
Intake Manifold, Iso-octane
2600 RPM, NK, (TI 1544/1553)
G
0
1
2
3
0
5
10
15
20
KHz

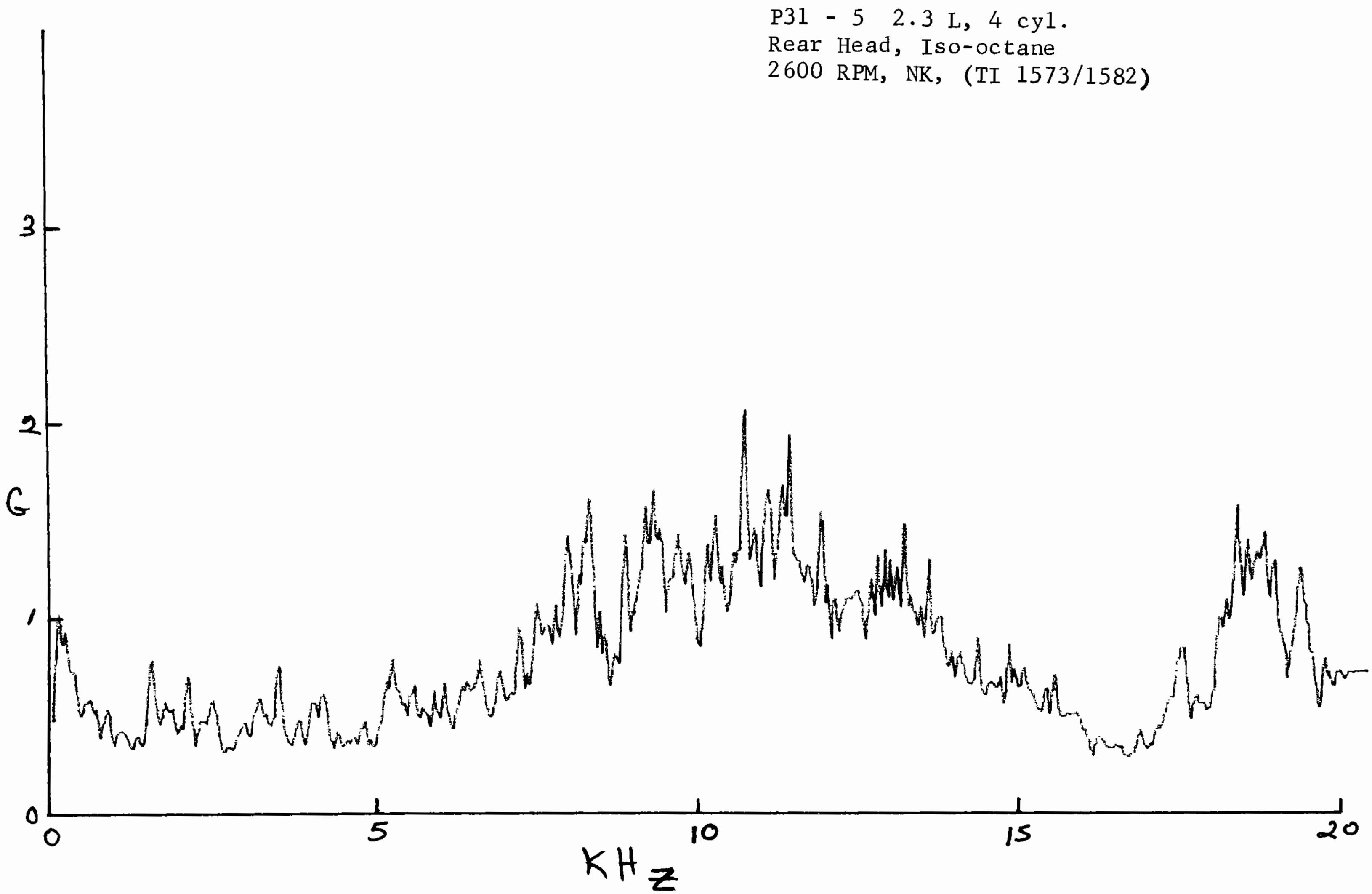
P30-6


P30 - 6 2.3 L, 4 cyl.
Right rear head, Iso-octane
2600 RPM, NK, (TI 1544/1553)
G
3
2
1
0
0
5
10
15
20
KHz

P30-7

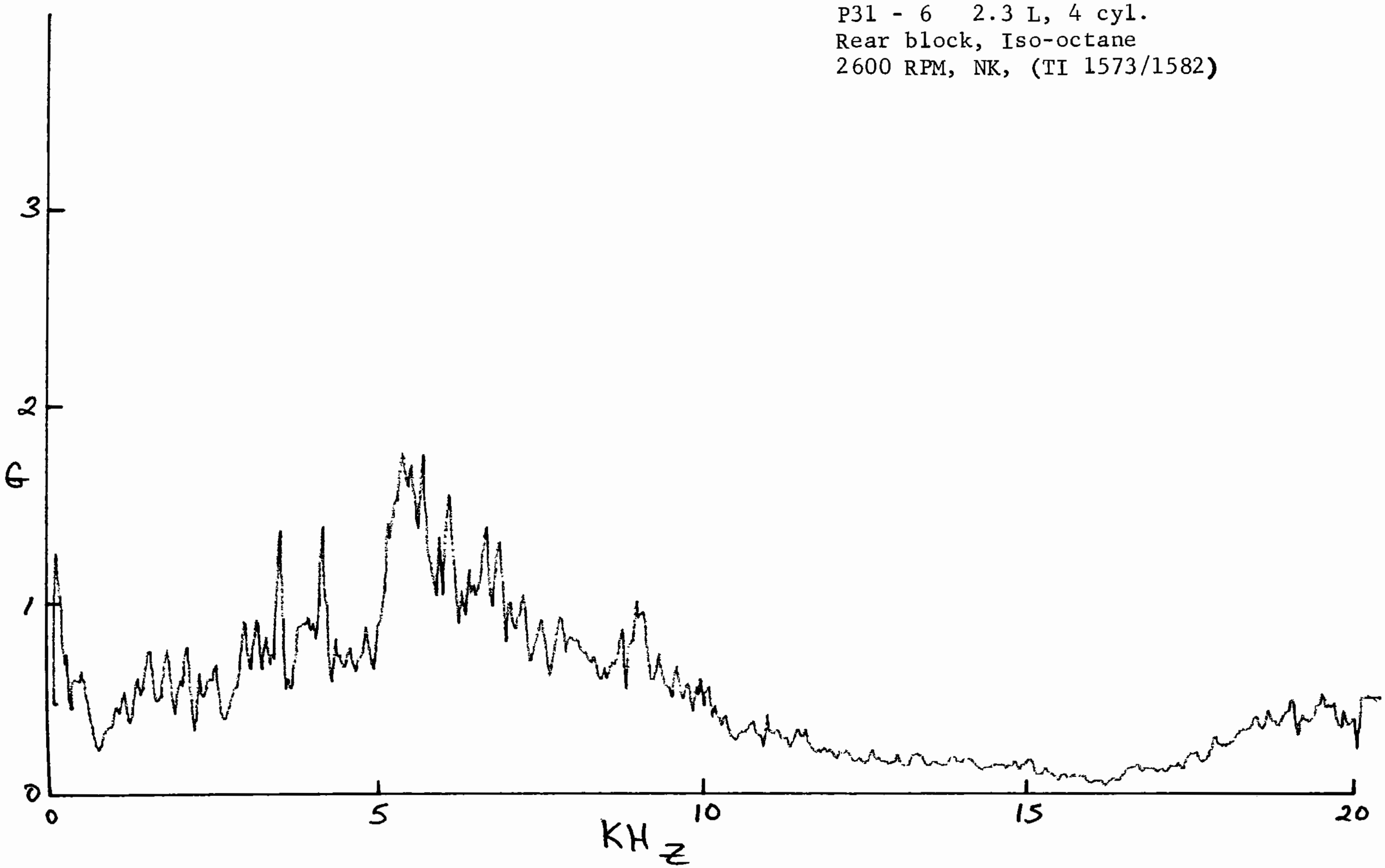

P30 - 7 2.3 L, 4 cyl.
Right front block, Iso-octane
2600 RPM, NK, (TI 1544/1553)
G
3
2
1
0
0
5
10
15
20
KHz

P31-5

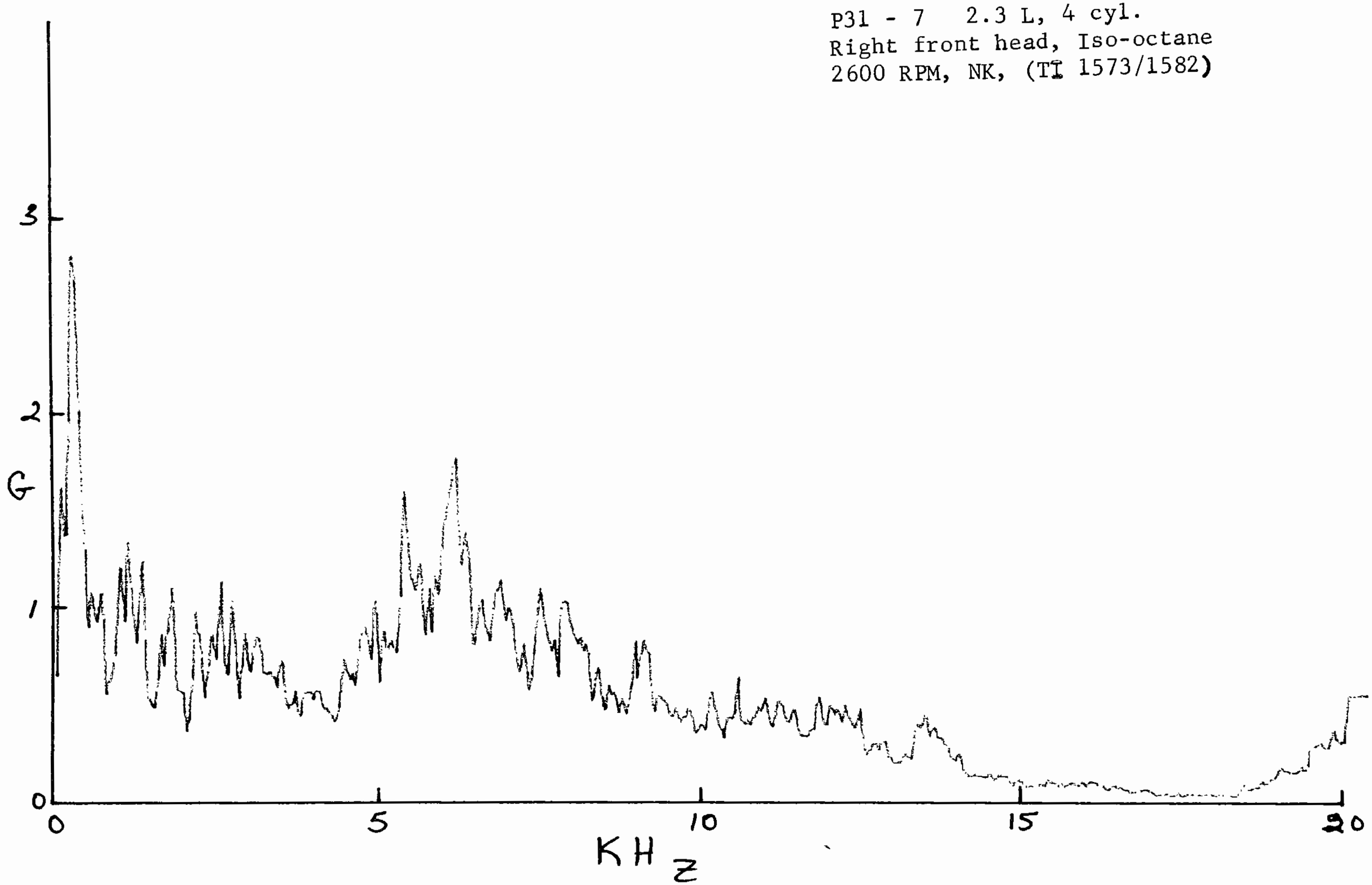


P31 - 5 2.3 L, 4 cyl.
Rear Head, Iso-octane
2600 RPM, NK, (TI 1573/1582)
G
3
2
1
0
5
10
15
20
KHz

P31-6

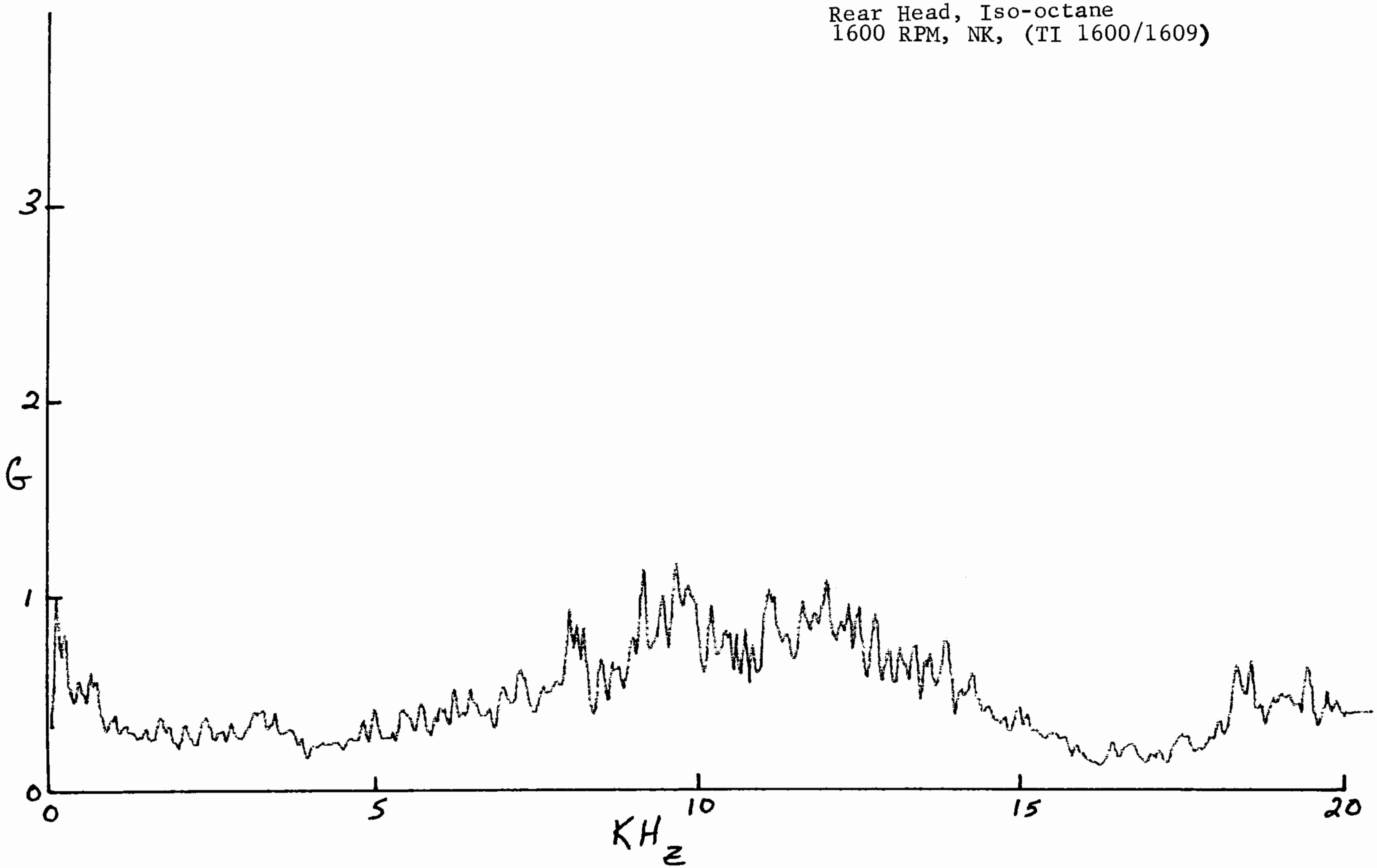

P31 - 6 2.3 L, 4 cyl.
Rear block, Iso-octane
2600 RPM, NK, (TI 1573/1582)
3
2
G
1
0
0
5
10
15
20
KHz

P31-7

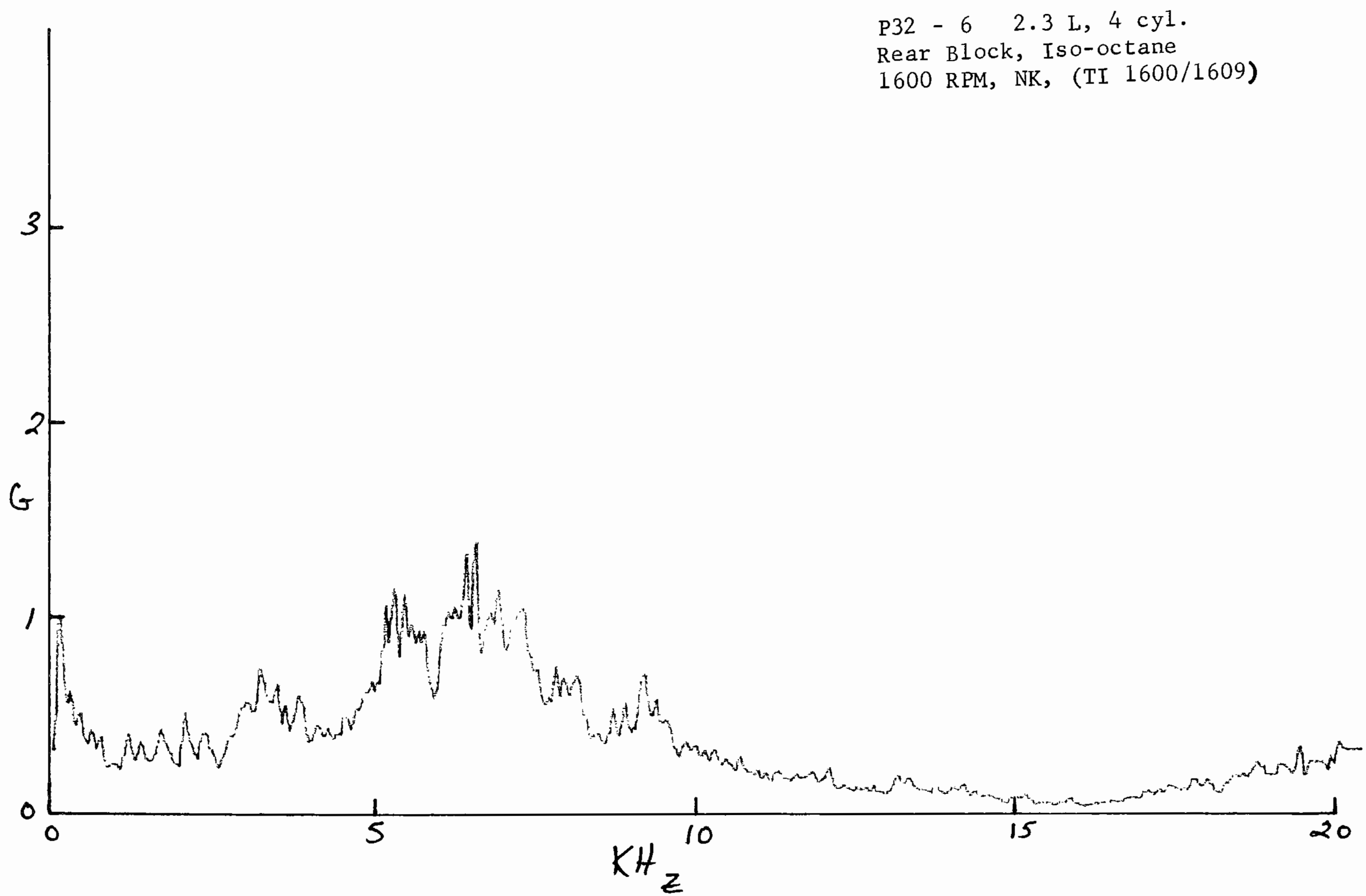

P31 - 7 2.3 L, 4 cyl.
Right front head, Iso-octane
2600 RPM, NK, (TI 1573/1582)
3
2
1
0
G
0
5
10
15
20
KHz

P32-5

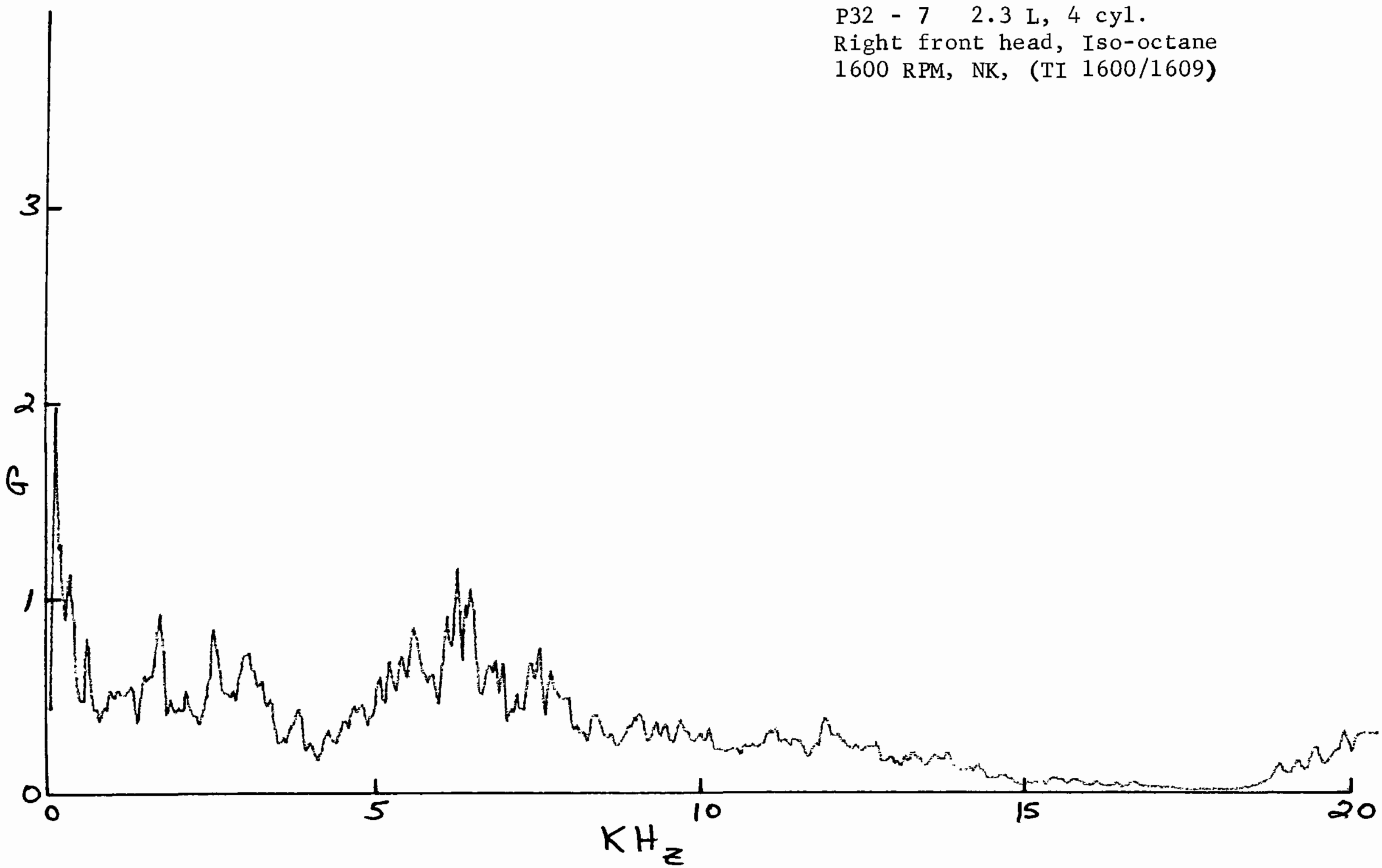
P32 - 5 2.3 L, 4 cyl.
Rear Head, Iso-octane
1600 RPM, NK, (TI 1600/1609)



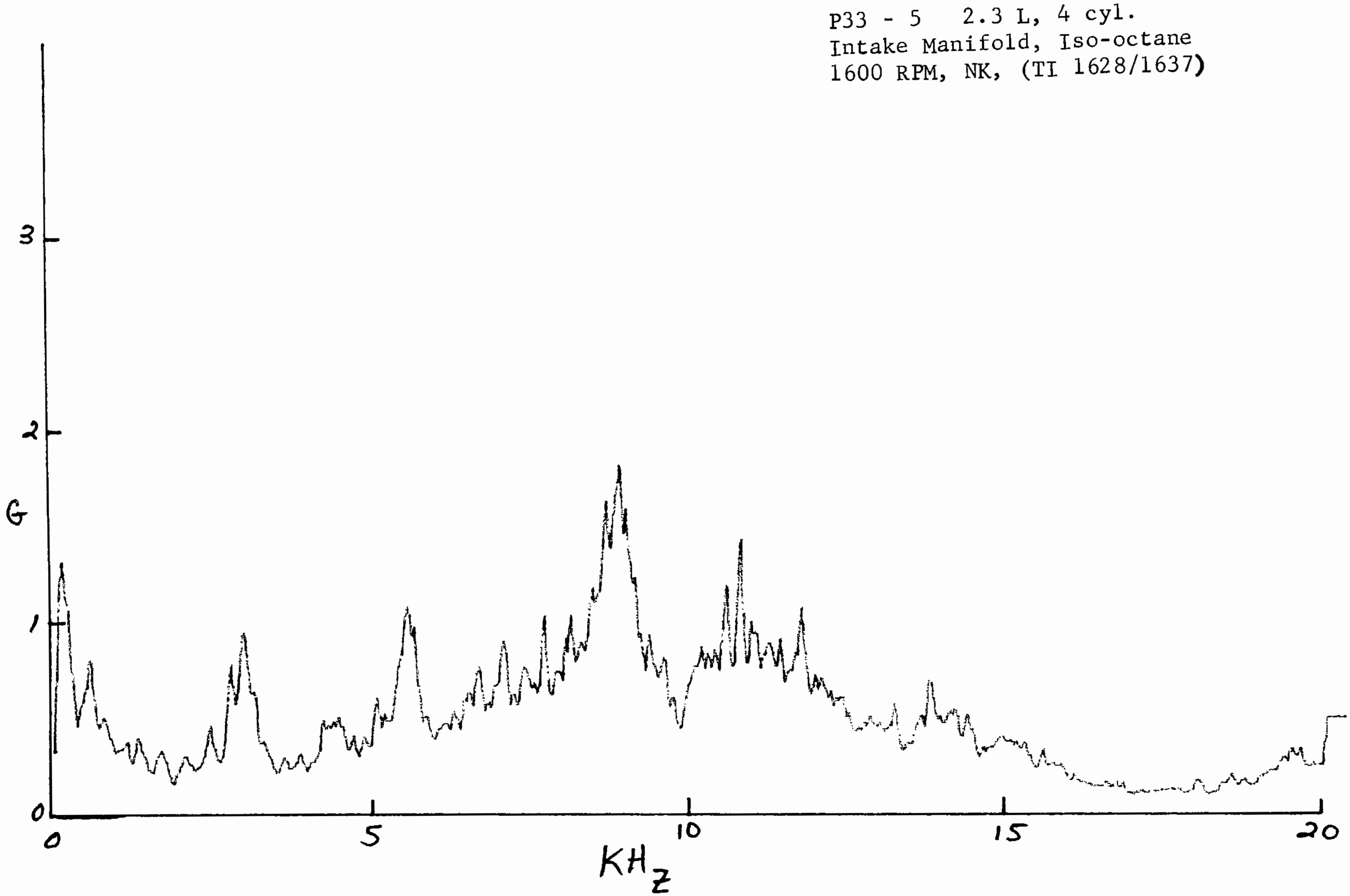
P32-6


P32 - 6 2.3 L, 4 cyl.
Rear Block, Iso-octane
1600 RPM, NK, (TI 1600/1609)
G
3
2
1
0
0
5
10
15
20
KHz

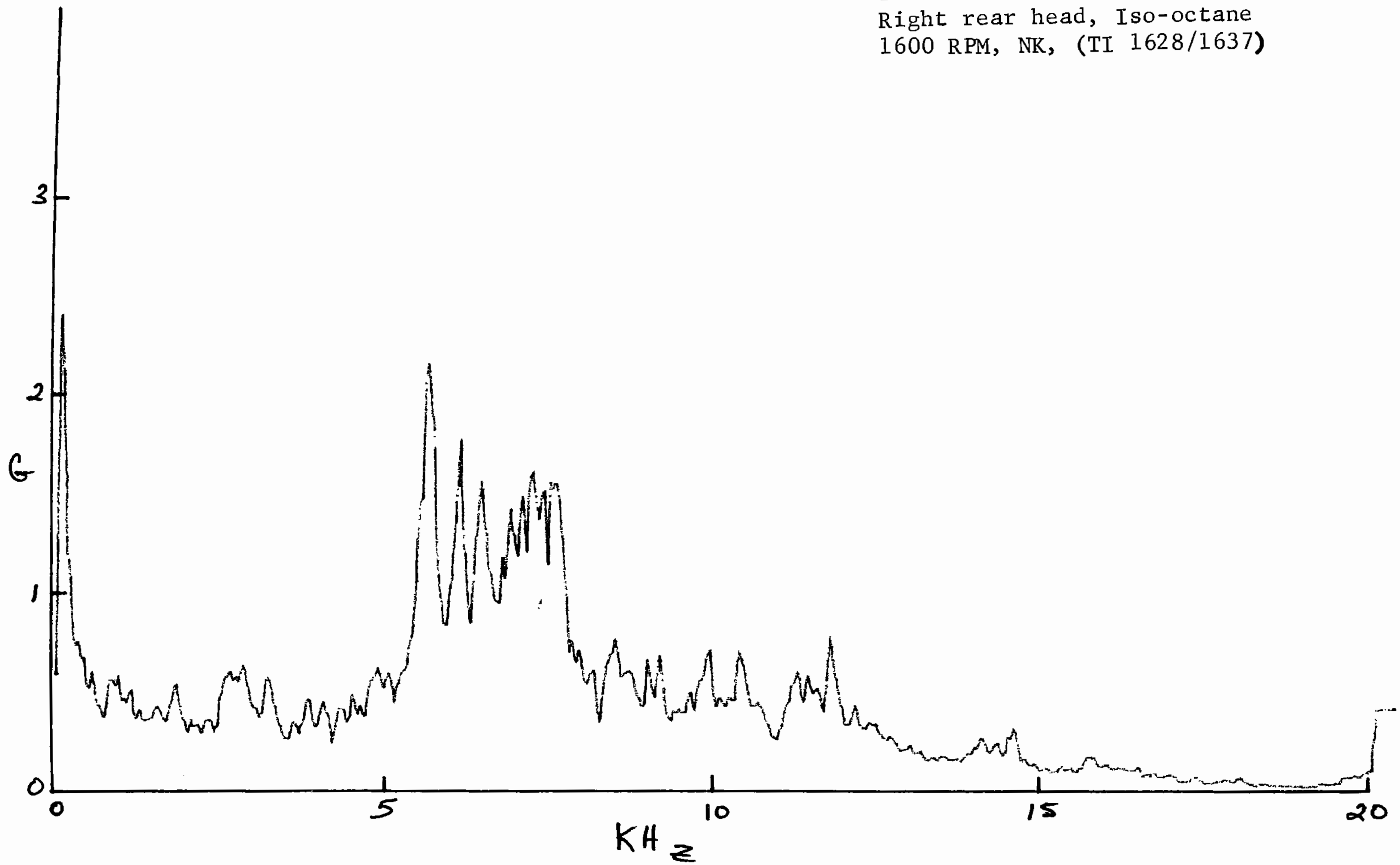
P32-7


P32 - 7 2.3 L, 4 cyl.
Right front head, Iso-octane
1600 RPM, NK, (TI 1600/1609)
G
3
2
1
0
0
5
10
15
20
KHz

P33-5


P33 - 5 2.3 L, 4 cyl.
Intake Manifold, Iso-octane
1600 RPM, NK, (TI 1628/1637)
G
3
2
1
0
0
5
10
15
20
KHz

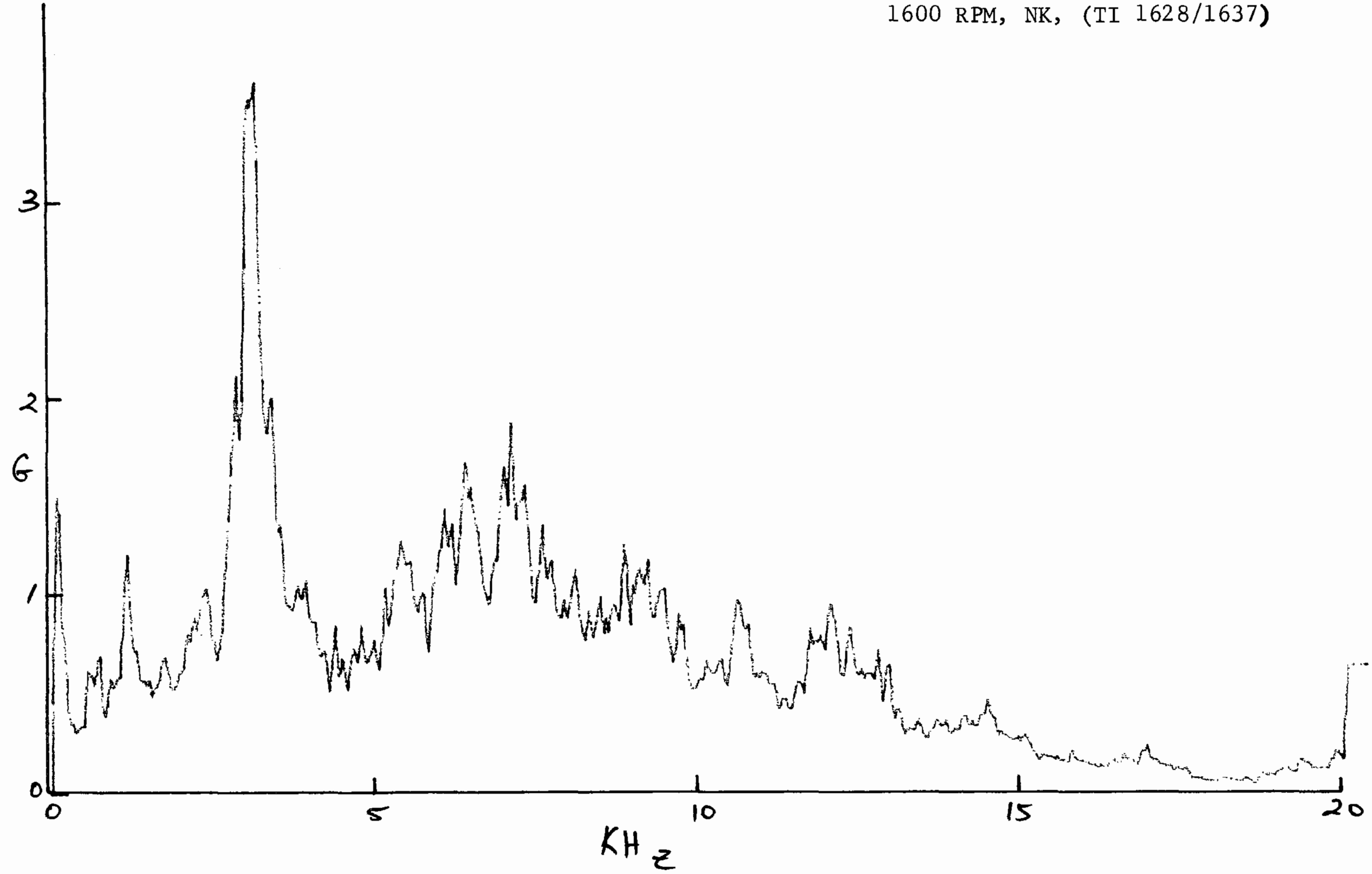
P33-6



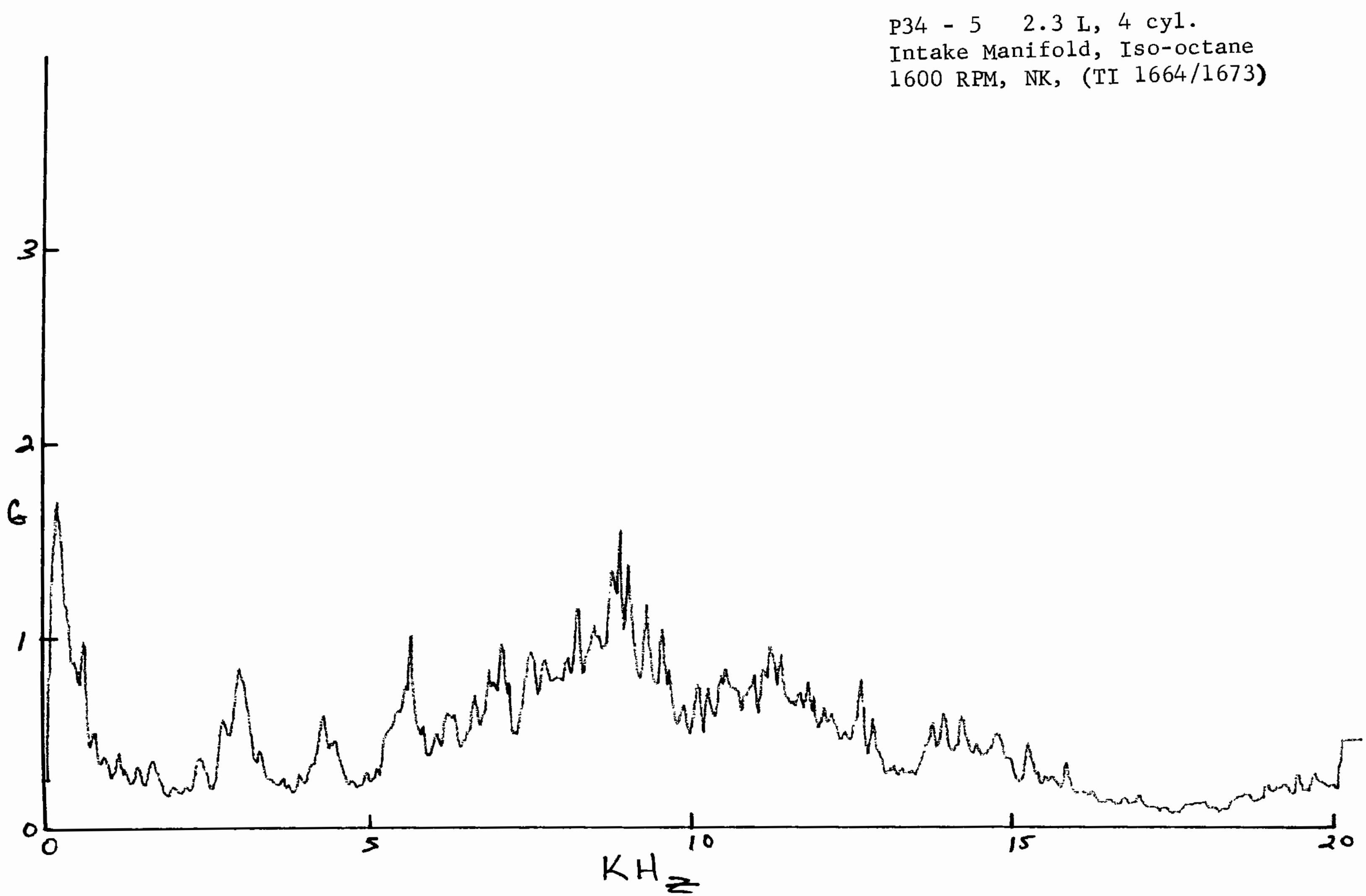

P33 - 6   2.3 L, 4 cyl.
Right rear head, Iso-octane
1600 RPM, NK, (TI 1628/1637)

P33-7

P33 - 7   2.3 L, 4 cyl.
Right front block, Iso-octane
1600 RPM, NK, (TI 1628/1637)

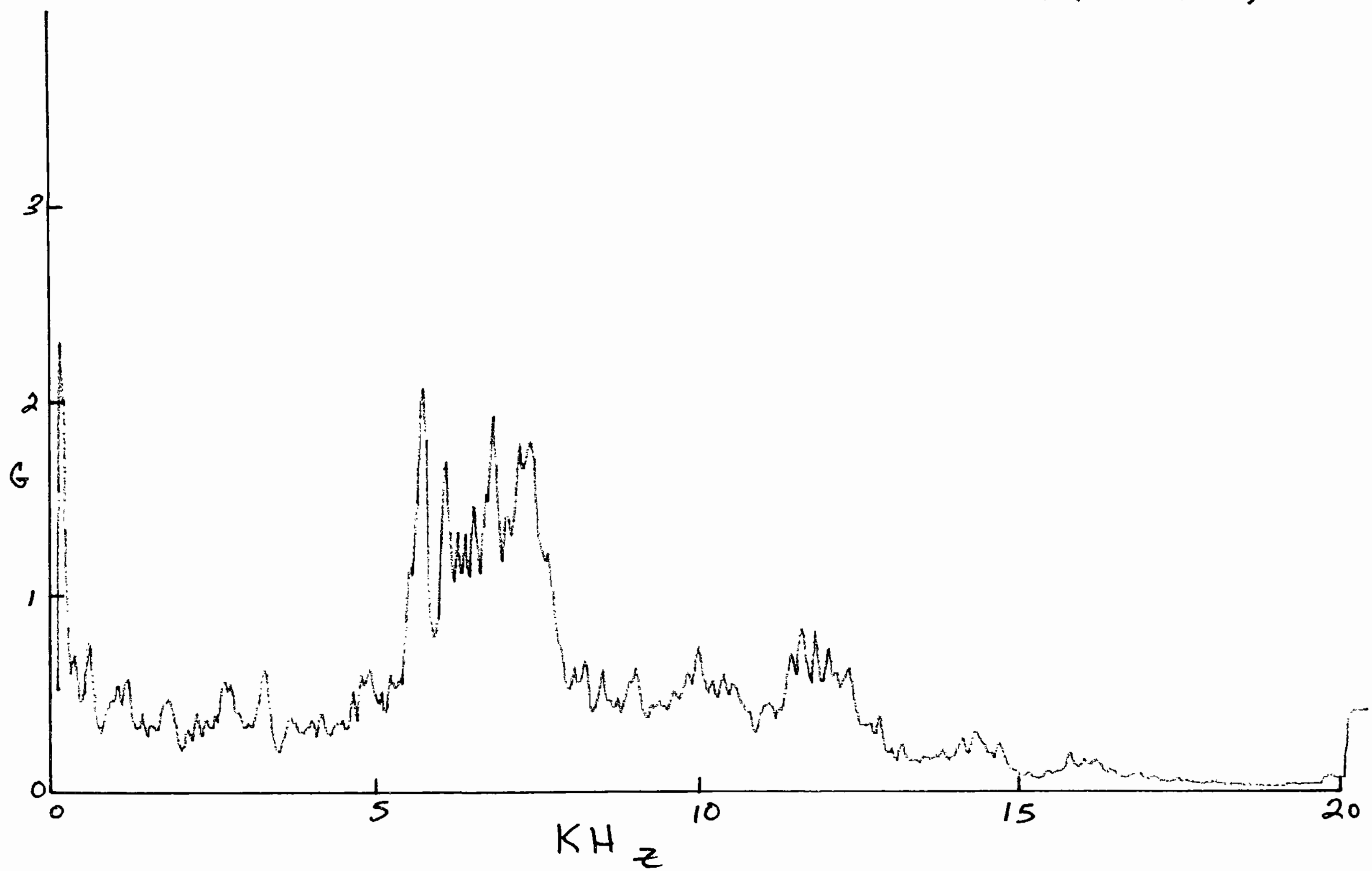


P34-5


P34 - 5 2.3 L, 4 cyl.
Intake Manifold, Iso-octane
1600 RPM, NK, (TI 1664/1673)
G
3
2
1
0
0
5
10
15
20
KHz

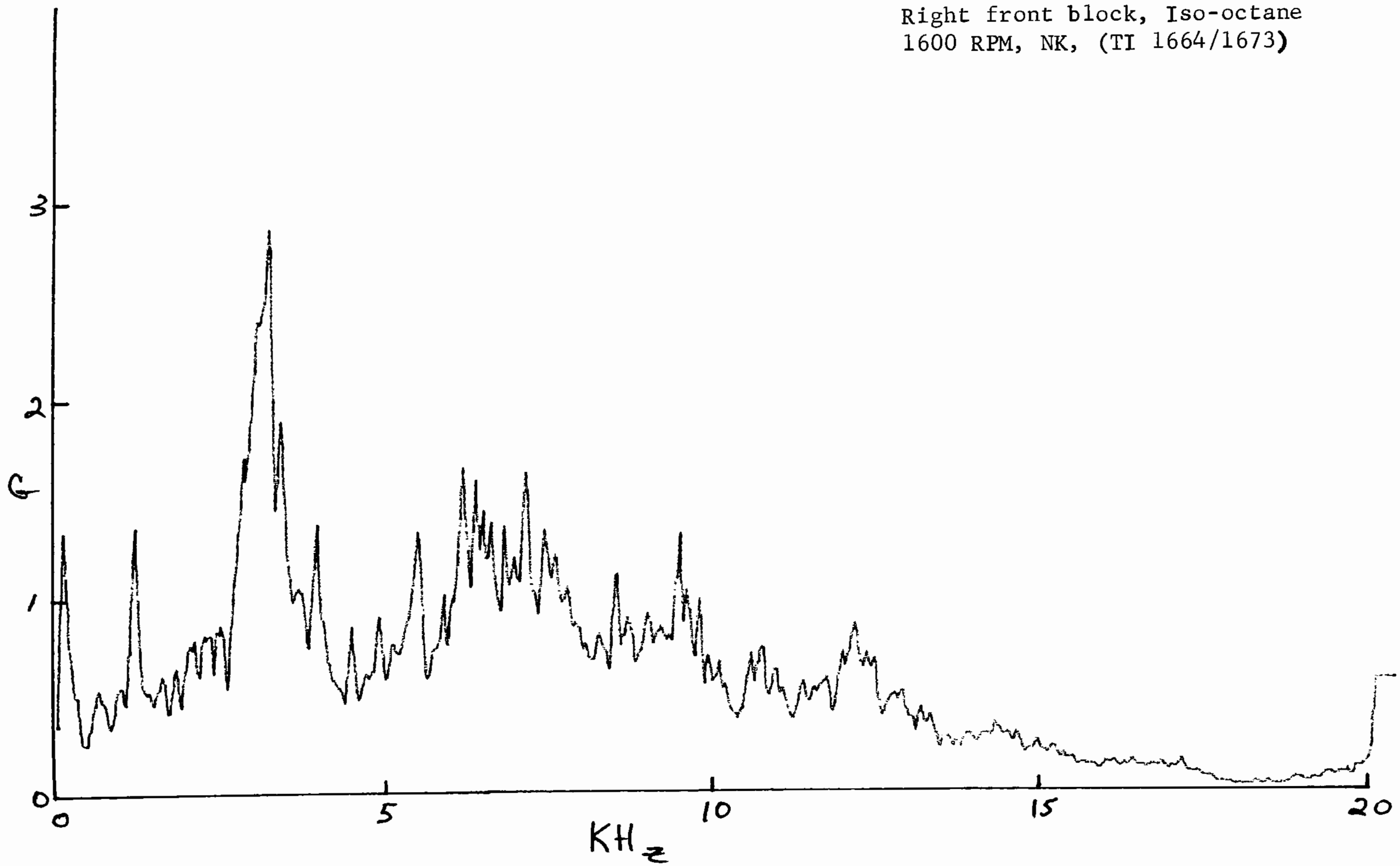
P34-6

P34 - 6   2.3 L, 4 cyl.
Right rear head, Iso-octane
1600 RPM, NK, (TI 1664/1673)



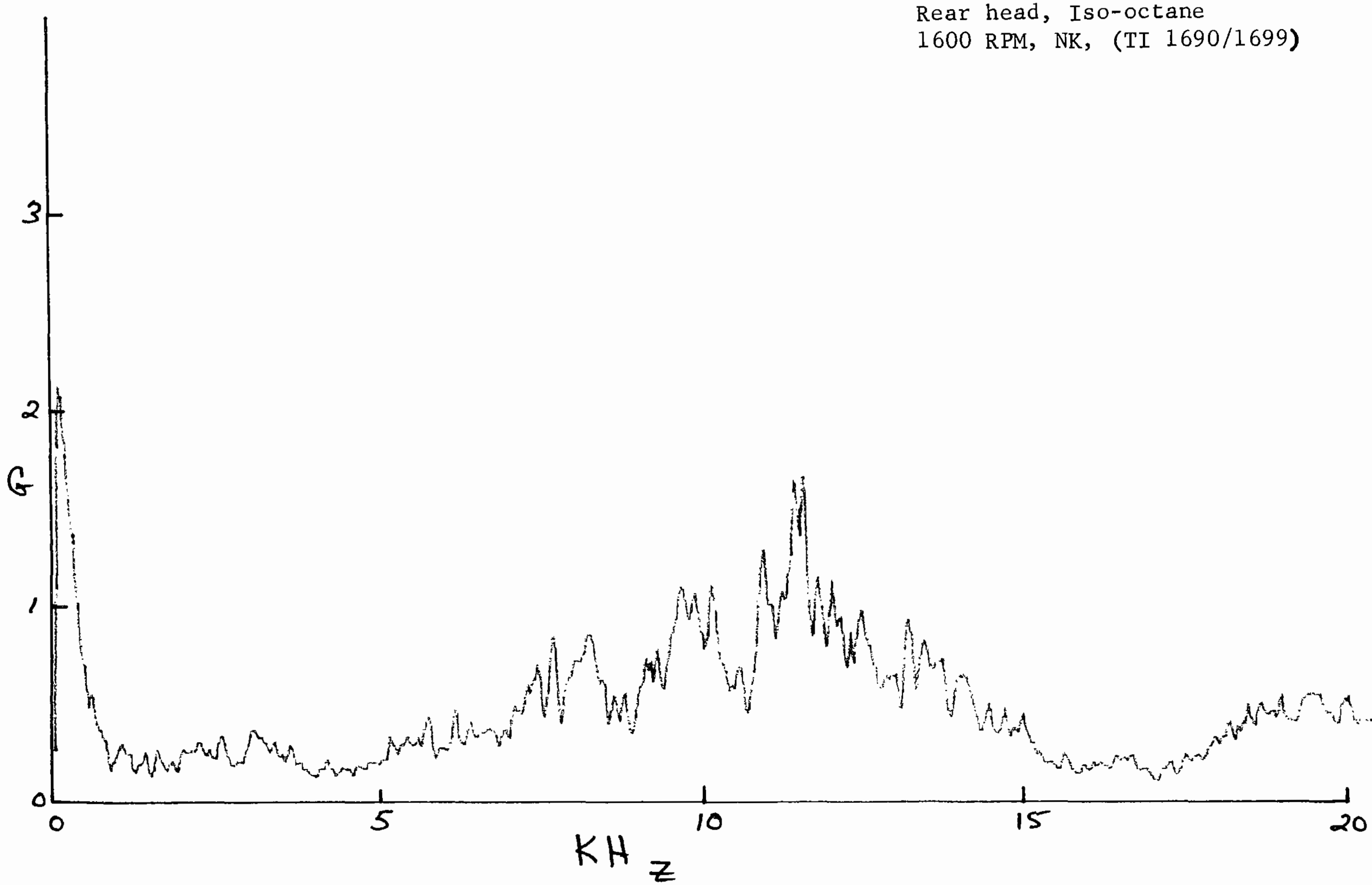
P34-7

P34 - 7 2.3 L, 4 cyl.
Right front block, Iso-octane
1600 RPM, NK, (TI 1664/1673)



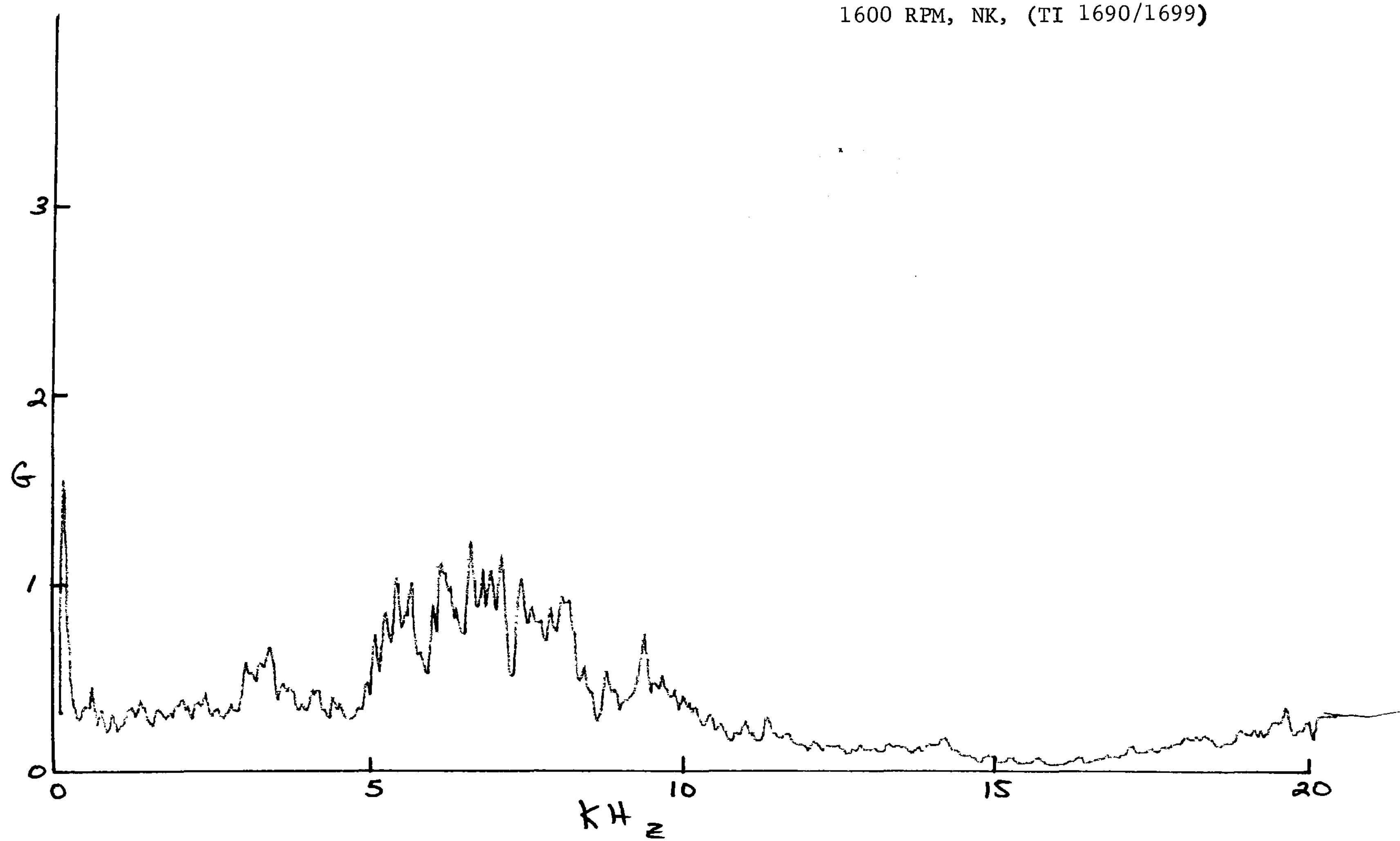
P35-5

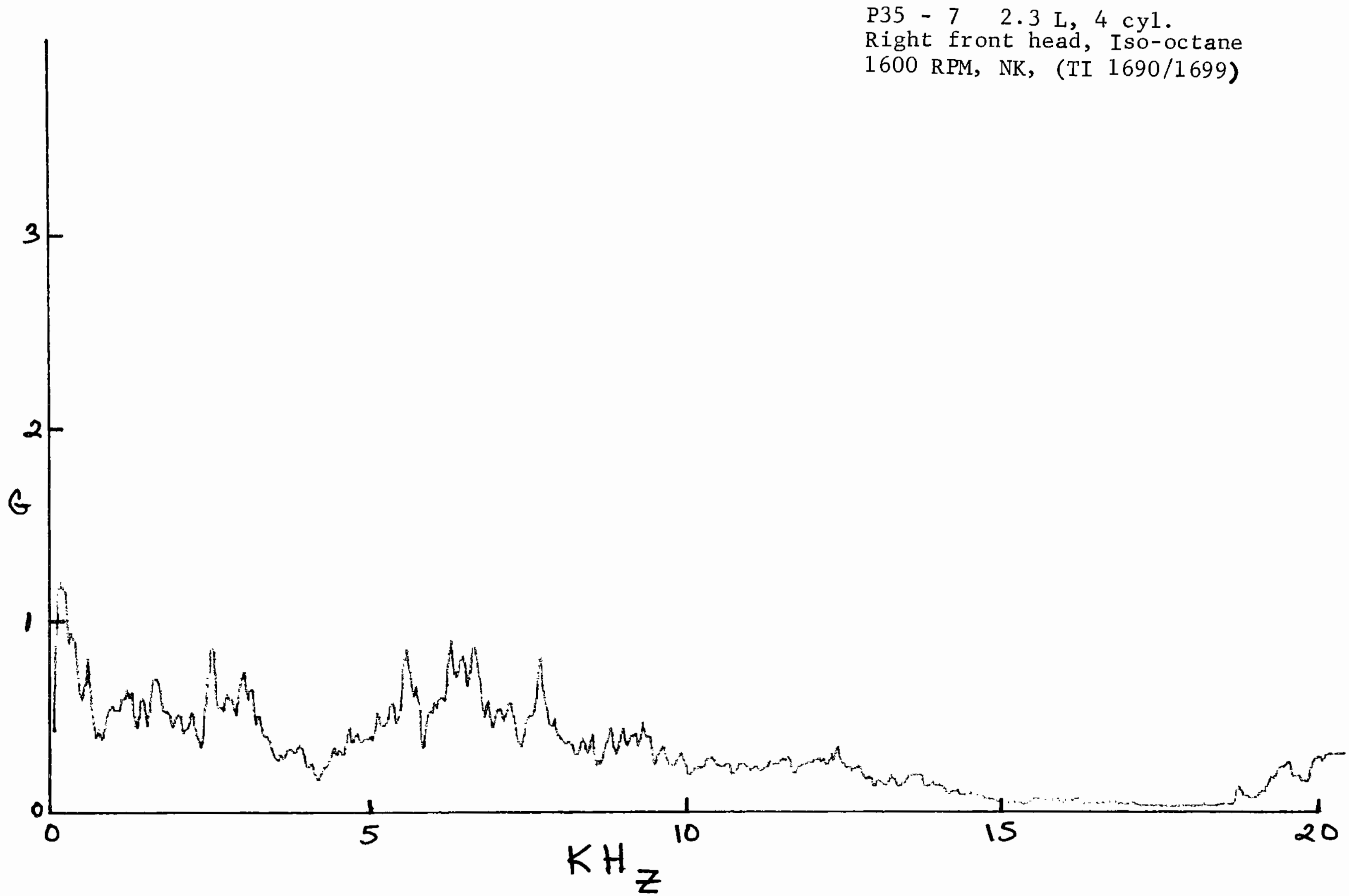
P35 - 5   2.3L, 4 cyl.
Rear head, Iso-octane
1600 RPM, NK, (TI 1690/1699)



P35-6

P35 - 6   2.3 L, 4 cyl.
Rear block, Iso-octane
1600 RPM, NK, (TI 1690/1699)




P35 - 7 2.3 L, 4 cyl.
Right front head, Iso-octane
1600 RPM, NK, (TI 1690/1699)
G
0
1
2
3
0
5
10
15
20
KHz

## APPENDIX F - 2

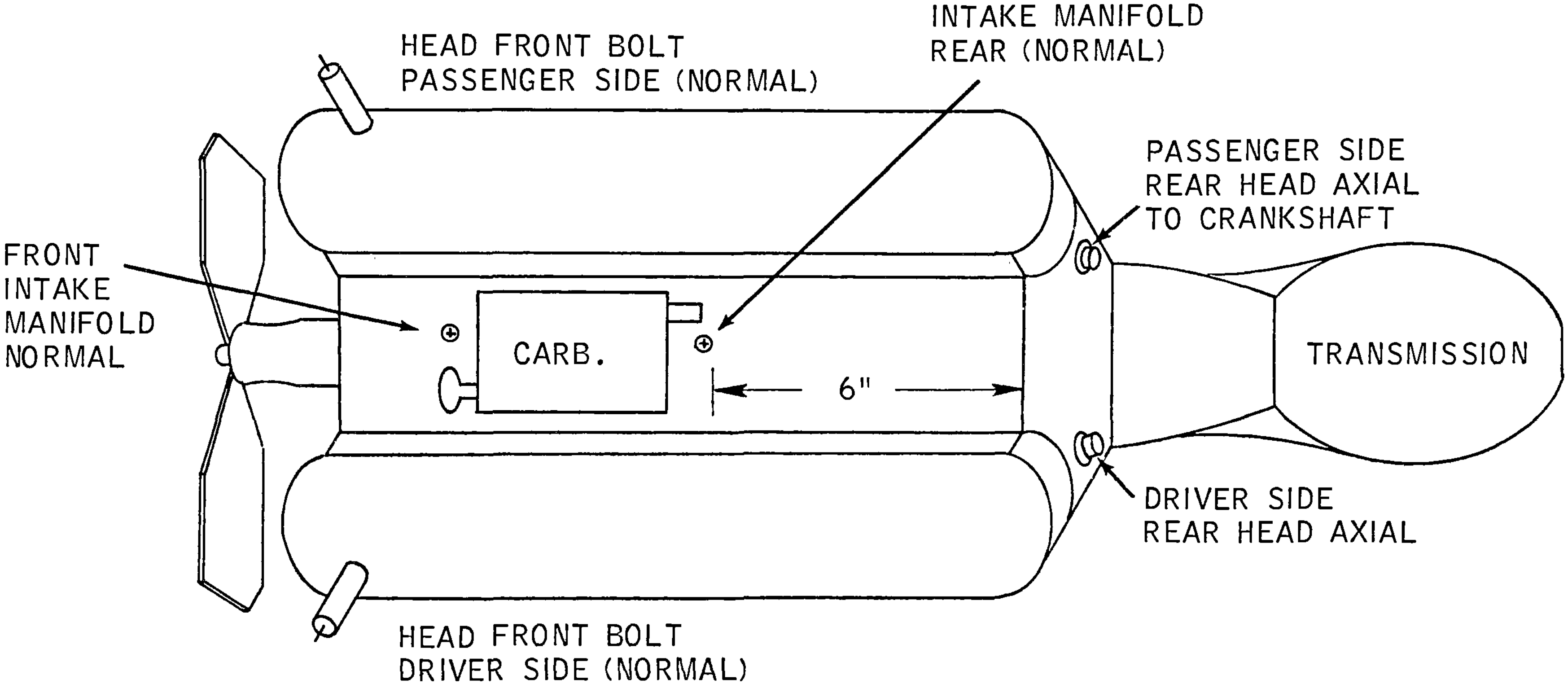
### Frequency Analysis Of 2.8 Liter, Ford V-6 Engine

| Run No. | Accelerometer | Speed | Knock Rating |
|---|---|---|---|
| FV 1 - 5 | Head front bolt<br>Driver side(normal) | 1600 RPM | NK |
| FV 1 - 6 | Passenger side<br>Rear head(axial) | 1600 RPM | NK |
| FV 1 - 7 | Head front bolt<br>Passenger side(normal) | 1600 RPM | NK |
| FV 2 - 5 | Intake manifold<br>Rear (normal) | 2550 RPM | NK |
| FV 2 - 6 | Intake manifold<br>Front (normal) | 2550 RPM | NK |
| FV 2 - 7 | Driver side<br>Rear head (axial) | 2550 RPM | NK |
| FV 3 - 5 | Head front bolt<br>Driver side (normal) | 1600 RPM | T+ |
| FV 3 - 6 | Passenger side<br>Rear head (axial) | 1600 RPM | T+ |
| FV 3 - 7 | Head front bolt<br>Passenger side(normal) | 1600 RPM | T+ |
| FV 4 - 5 | Intake manifold<br>Rear (normal) | 1600 RPM | T+ |
| FV 4 - 6 | Intake manifold<br>front (normal) | 1600 RPM | T+ |
| FV 4 - 7 | Driver side<br>rear head (axial) | 1600 RPM | T+ |
| FV 5 - 5 | Intake Manifold<br>rear (normal) | 1600 RPM | T- |
| FV 5 - 6 | Intake Manifold<br>front (normal) | 1600 RPM | T- |
| FV 5 - 7 | Driver side<br>rear head (axial) | 1600 RPM | T- |
| FV 6 - 5 | Head front bolt<br>Driver side (normal) | 1600 RPM | T- |
| FV 6 - 6 | Passenger side<br>Rear head (axial) | 1600 RPM | T- |
| FV 6 - 7 | Head front bolt<br>Passenger side(normal) | 1600 RPM | T- |

| Run No. | Accelerometer | Speed | Knock Rating |
|---|---|---|---|
| FV 7 - 5 | Head front bolt Driver side (normal) | 2550 RPM | T+ |
| FV 7 - 6 | Passenger side Rear head (axial) | 2550 RPM | T+ |
| FV 7 - 7 | Head front bolt Passenger side(normal) | 2550 RPM | T+ |
| FV 8 - 5 | Intake manifold Rear (normal) | 2560 RPM | T+ |
| FV 8 - 6 | Intake manifold Front (normal) | 2560 RPM | T+ |
| FV 8 - 7 | Driver side Rear head (axial) | 2560 RPM | T+ |
| FV 9 - 5 | Intake manifold rear (normal) | 2555 RPM | T- |
| FV 9 - 6 | Intake manifold Front (normal) | 2555 RPM | T- |
| FV 9 - 7 | Driver side Rear head (axial) | 2555 RPM | T- |
| FV 10 - 5 | Head front bolt Driver side (normal) | 2555 RPM | T- |
| FV 10 - 6 | Passenger side Rear head (axial) | 2555 RPM | T- |
| FV 10 - 7 | Head front bolt Passenger side(normal) | 2555 RPM | T- |
| FV 11 - 5 | Head front bolt Driver side (normal) | 40-70 MPH Accel. | NK |
| FV 11 - 6 | Passenger side Rear head (axial) | 40-70 MPH Accel. | NK |
| FV 11 - 7 | Head front bolt Passenger side(normal) | 40-70 MPH Accel. | NK |
| FV 12 - 5 | Intake manifold Rear (normal) | 40-70 MPH Accel. | NK |
| FV 12 - 6 | Intake manifold Front (normal) | 40-70 MPH Accel. | NK |
| FV 12 - 7 | Driver side Rear head (axial) | 40-70 MPH Accel. | NK |
| FV 13 - 5 | Intake manifold rear (normal) | 40-70 MPH Accel. | Heavy Knock |
| FV 13 - 6 | Intake manifold Front (normal) | 40-70 MPH Accel. | Heavy Knock |

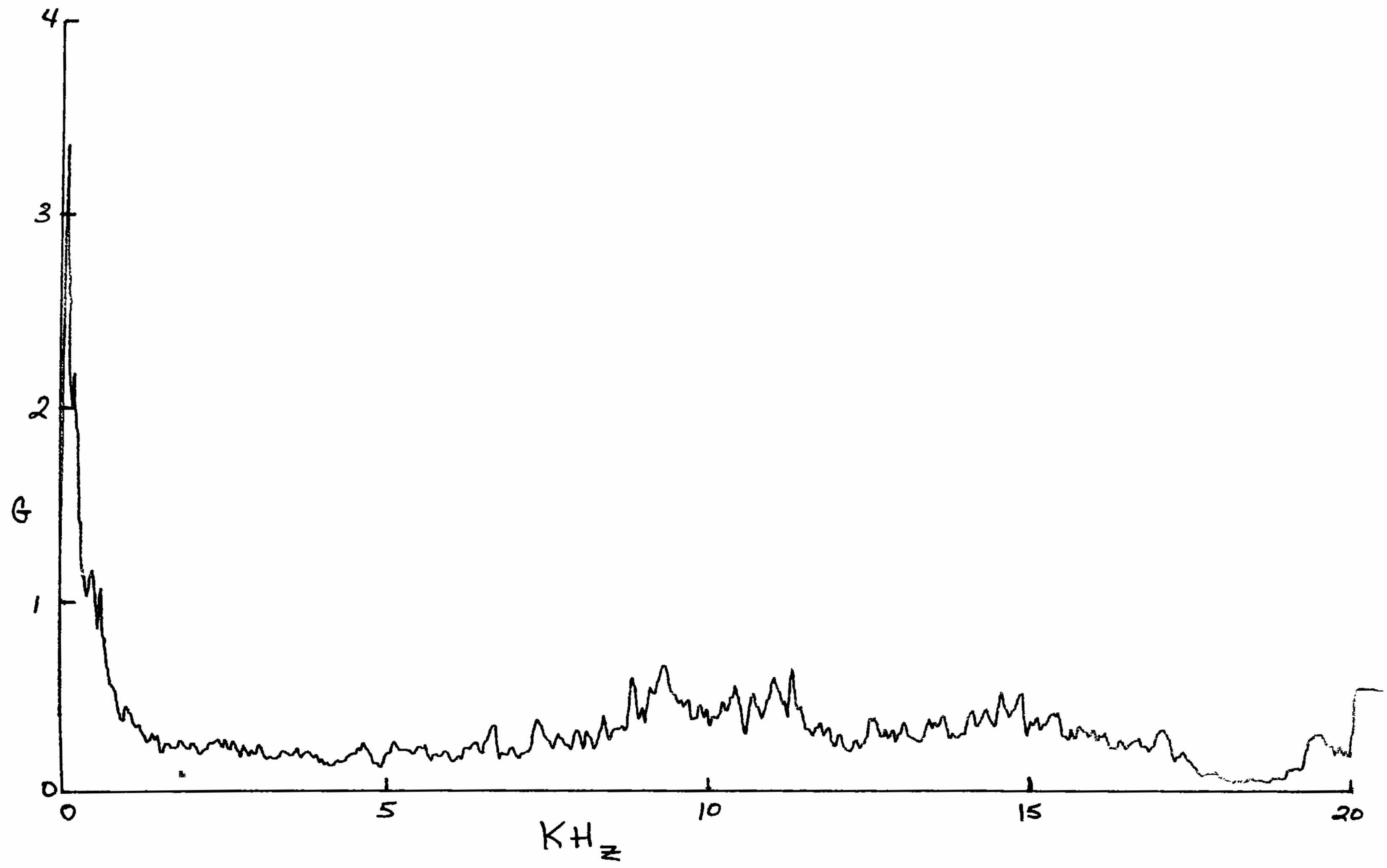
| Run No. | Accelerometer | Speed | Knock Rating |
|---|---|---|---|
| FV 14 - 5 | Intake manifold Rear (normal) | 40-70 MPH Accel. | VL+ |
| FV 14 - 6 | Intake manifold Front (normal) | 40-70 MPH Accel. | VL+ |
| FV 14 - 7 | Driver side rear head (axial) | 40-70 MPH Accel. | VL+ |
| FV 15 - 5 | Head front bolt Driver side (normal) | 40-70 MPH Accel. | VL+ |
| FV 15 - 6 | Passenger side Rear head (axial) | 40-70 MPH Accel. | VL+ |
| FV 15 - 7 | Head front bolt Passenger side(normal) | 40-70 MPH Accel. | VL+ |

LOCATION OF ACCELEROMETERS ON
FORD 2.8 LITER V6 ENGINE (TOP VIEW)



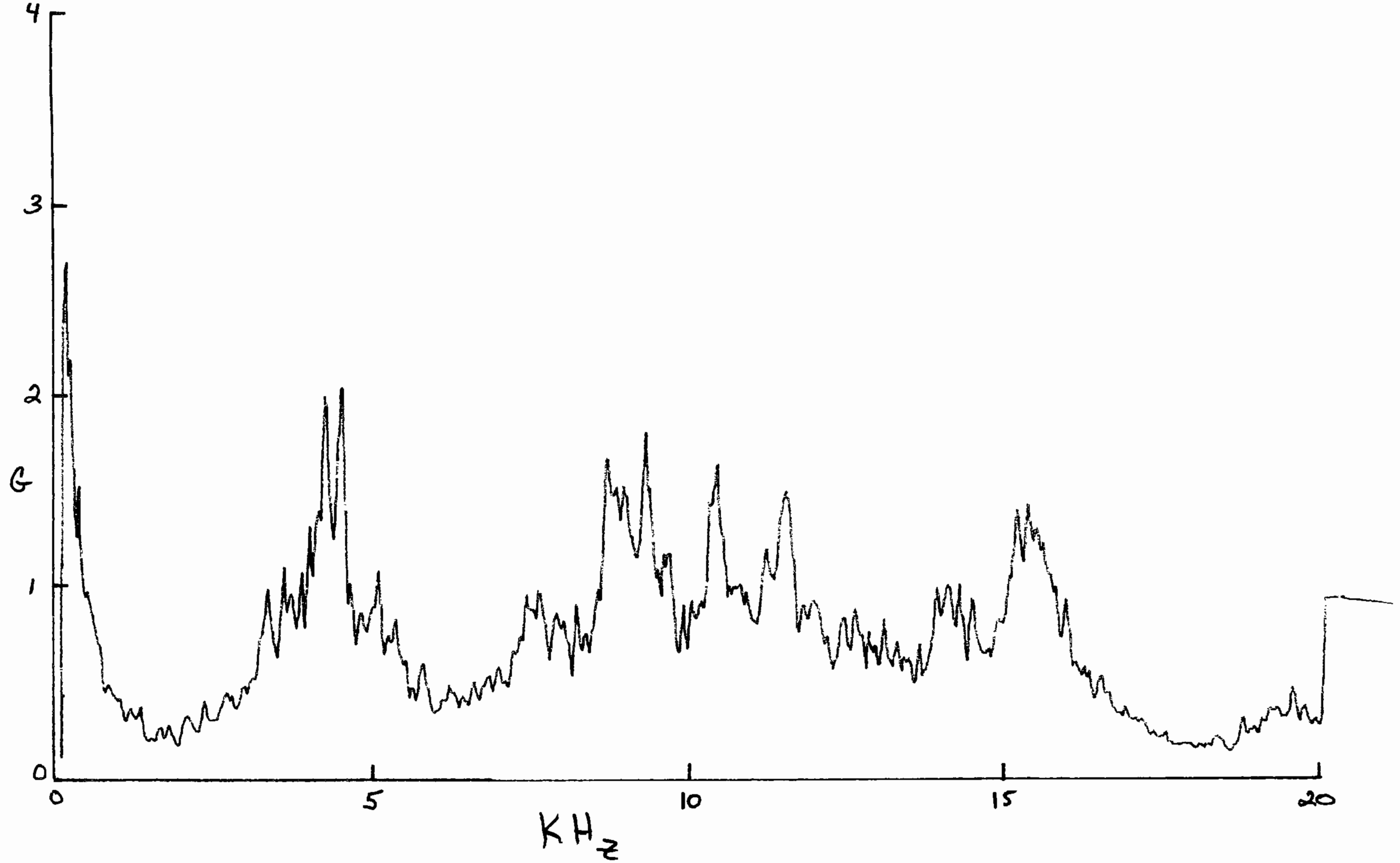
FV1-5

FV1 - 5 2.8 L, Ford V-6
Head front bolt driver side (normal)
Iso-octane, 1600 RPM, NK,
(TI 270/288)



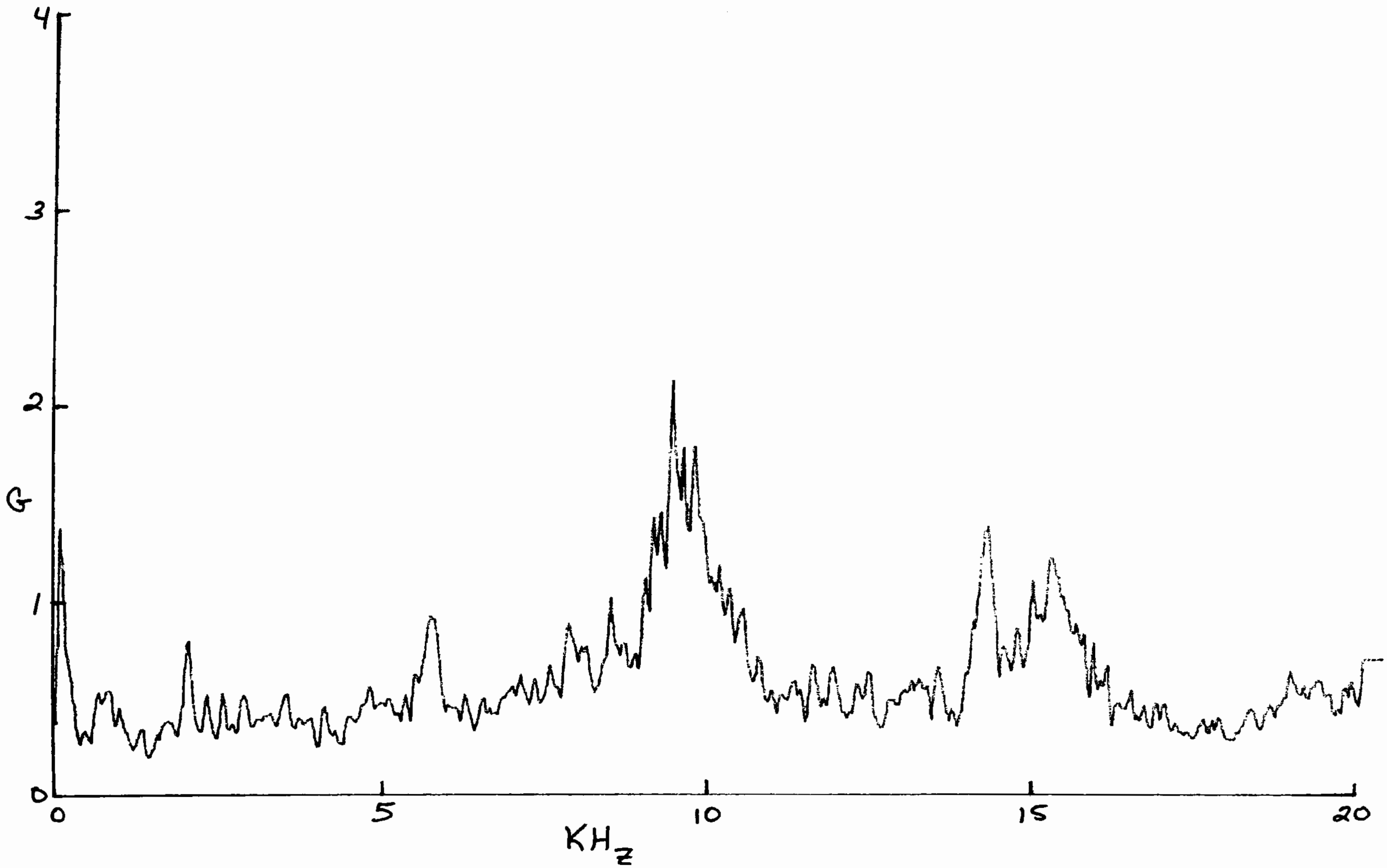
FV1-6

FVl - 6 2.8 L, Ford V-6
Passenger side rear head (axial)
Iso-octane, 1600 RPM, NK
(TI 270/288)



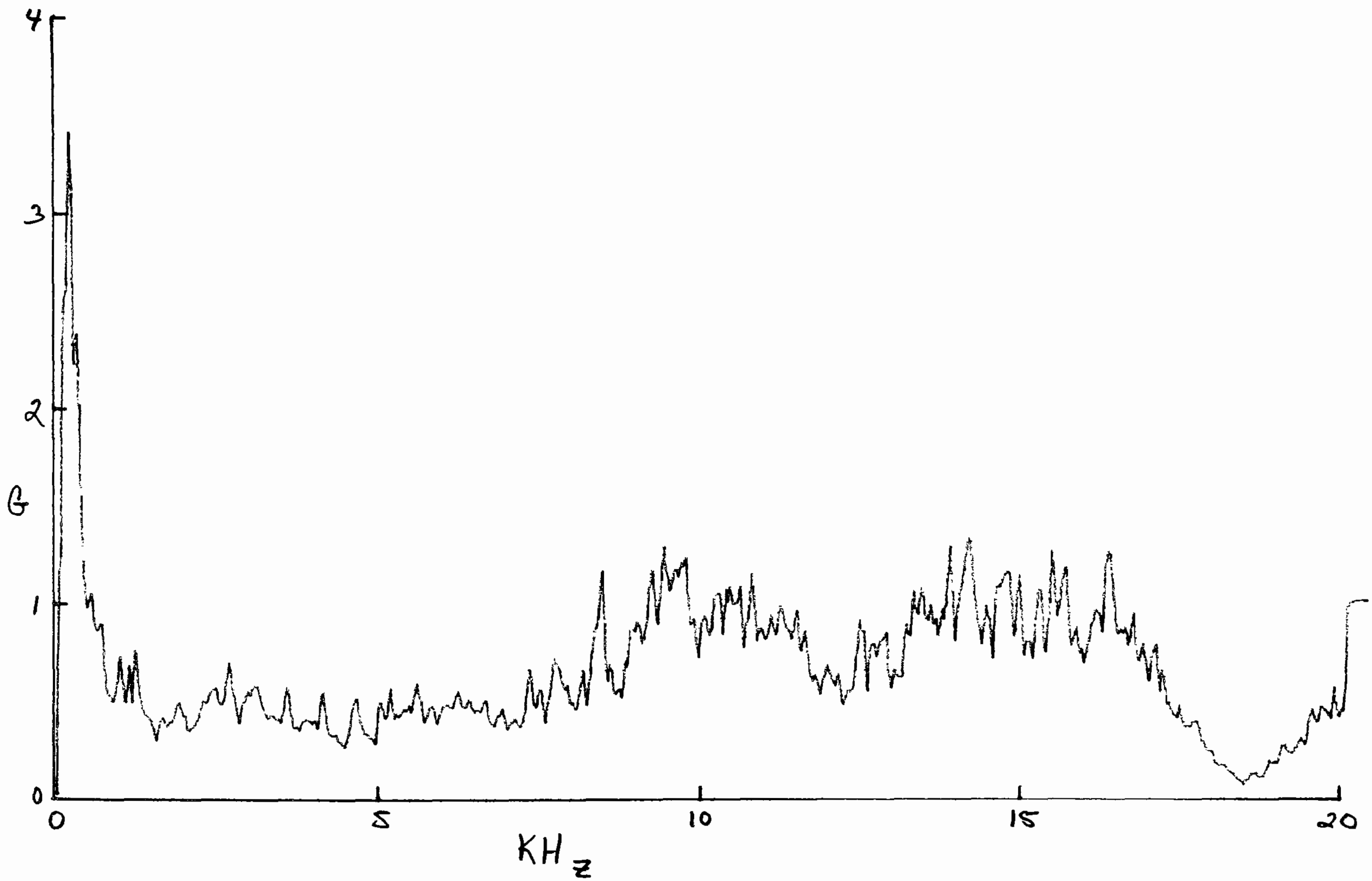
FV1-7

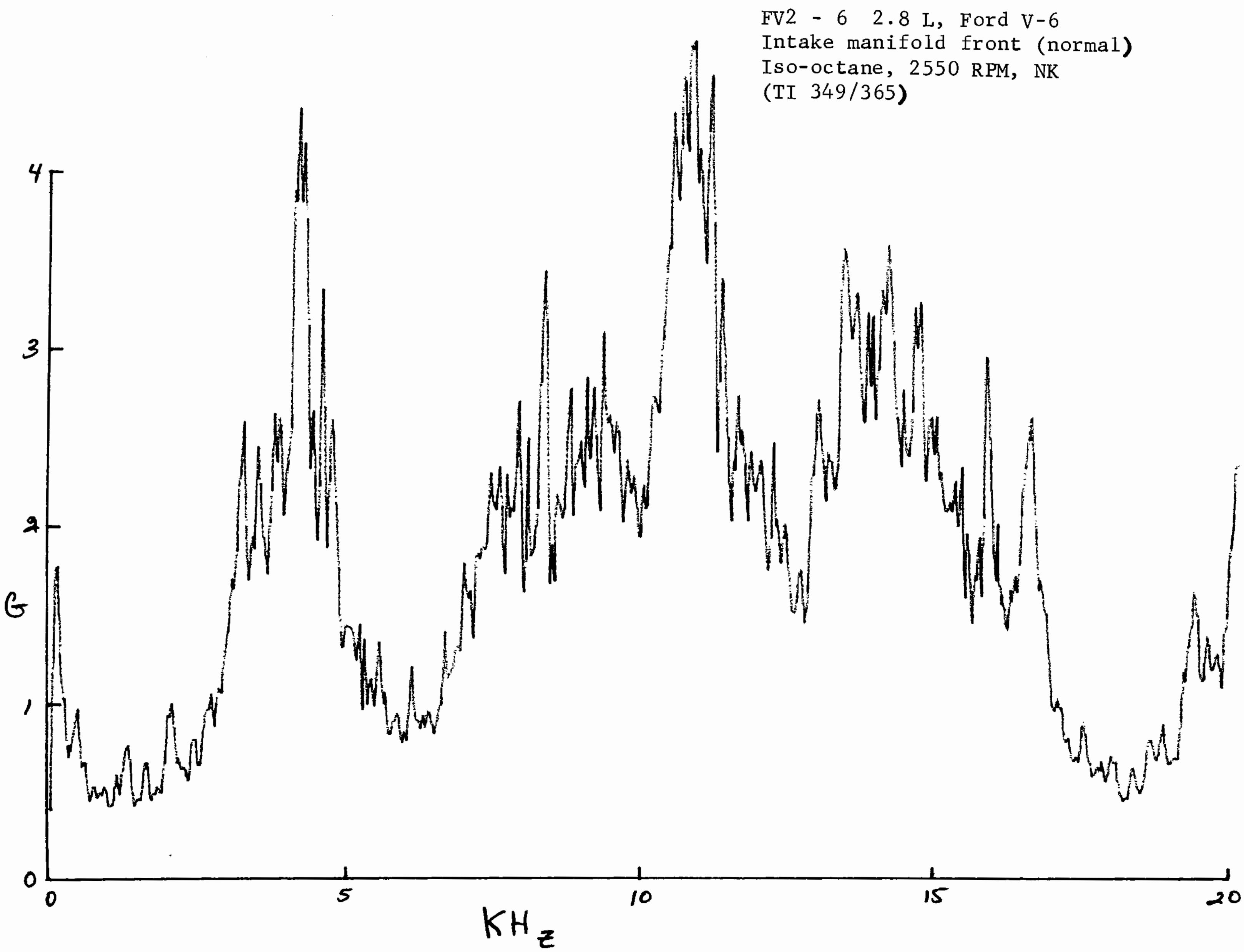
FV1 - 7   2.8 L, Ford V-6
Head front bolt passenger side(normal)
Iso-octane, 1600 RPM, NK
(TI 270/288)



FV2-5

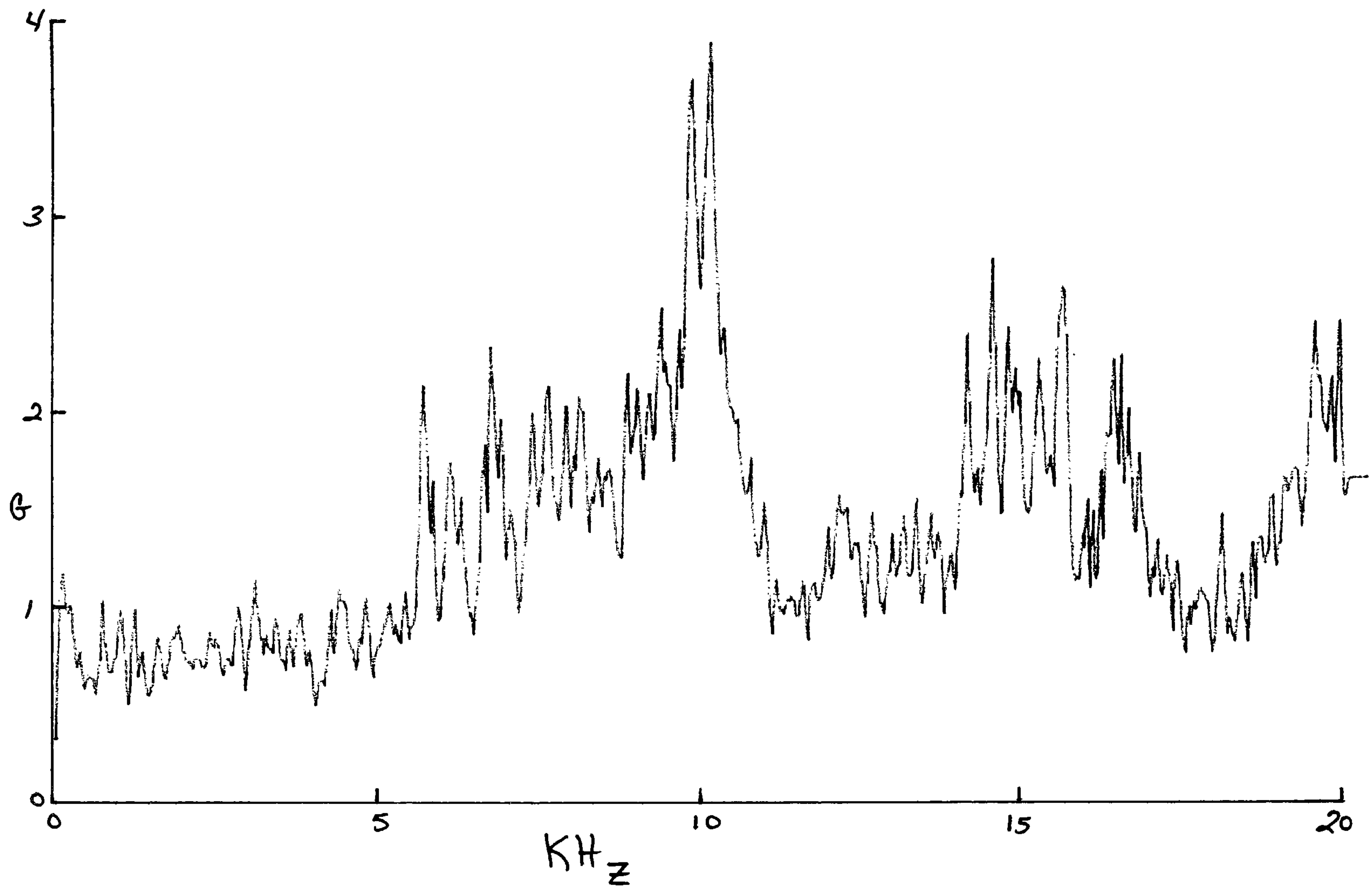
FV2 - 5 2.8 L, Ford V-6
Intake manifold rear (normal)
Iso-octane, 2550 RPM, NK
(TI 349/365)




FV2 - 6 2.8 L, Ford V-6
Intake manifold front (normal)
Iso-octane, 2550 RPM, NK
(TI 349/365)
4
3
2
1
0
G
0
5
10
15
20
KHz

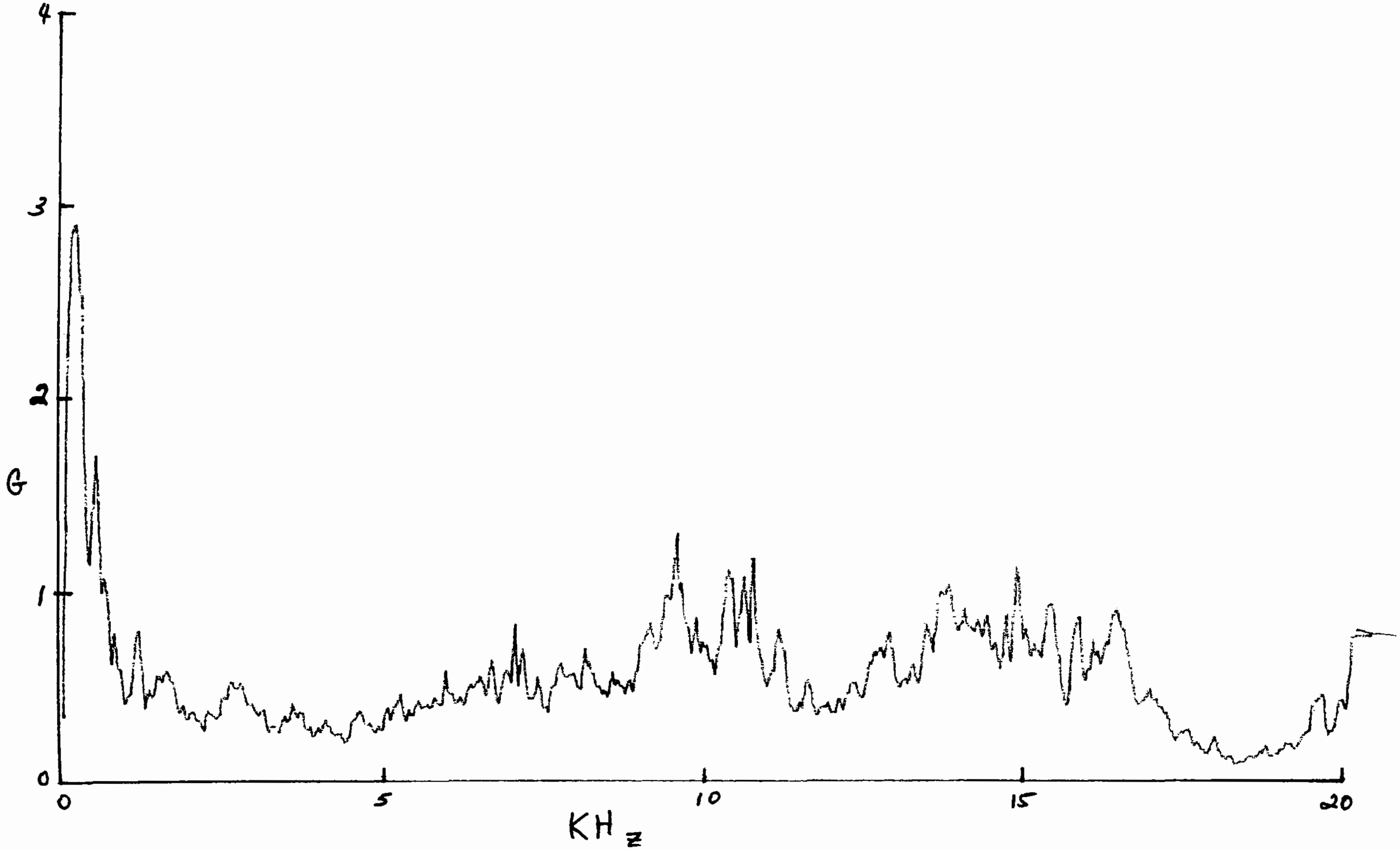
FV2-7

FV2 - 7   2.8 L, Ford V-6
Driver side rear head (axial)
Iso-octane, 2550 RPM, NK
(TI 349/365)



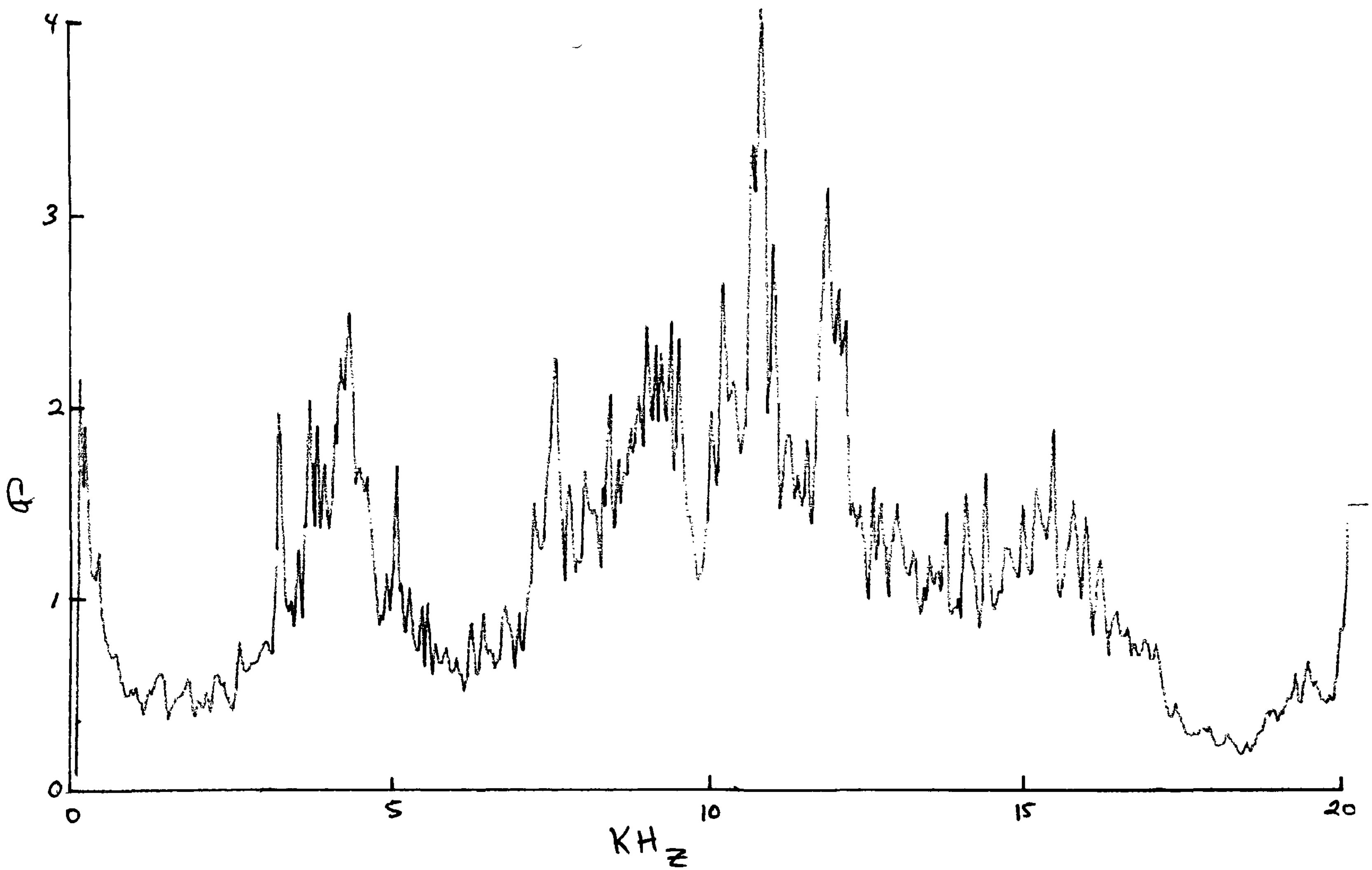
FV3-5

FV3 - 5 2.8 L, Ford V-6
Head front bolt driver side (normal)
C-85, 1600 RPM, T+
(TI 412/429)



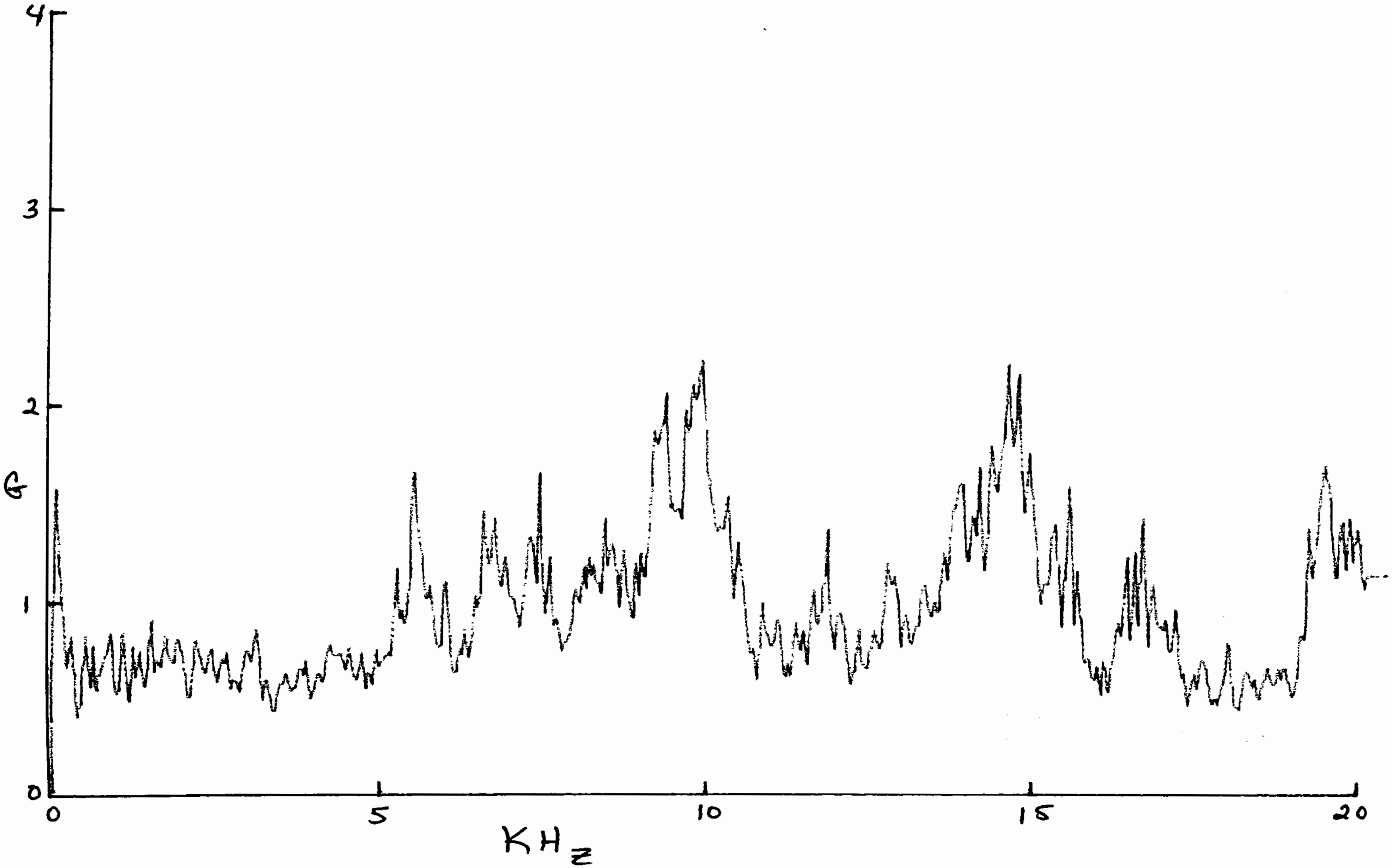
FV3-6

FV3 - 6 2.8 L, Ford V-6
Passenger side rear head (axial)
C-85, 1600 RPM, T+
(TI 412/429)

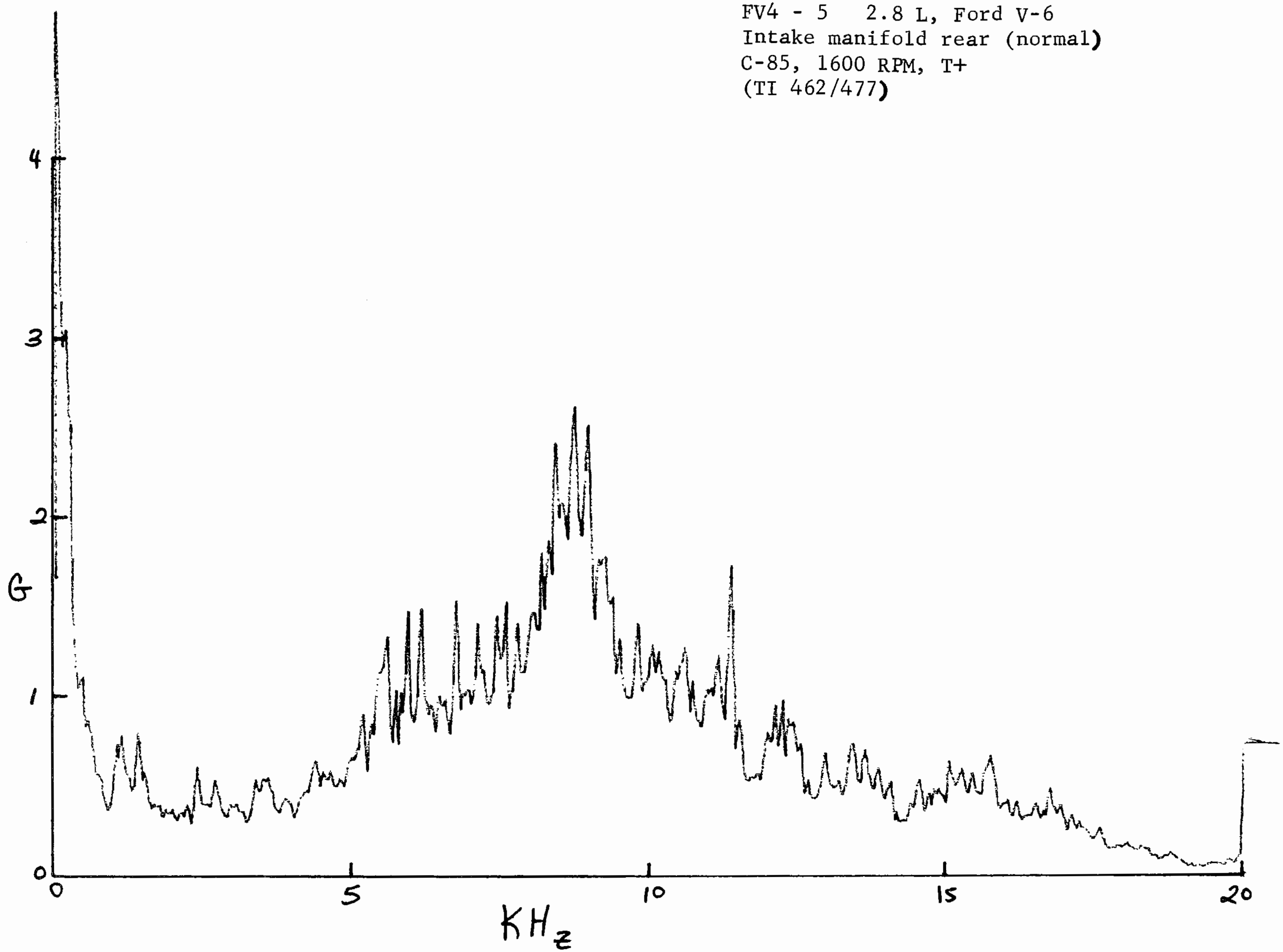


FV3-7

FV3 - 7   2.8 L, Ford V-6
Head front bolt passenger side(normal)
C-85, 1600 RPM, T+
(TI 412/429)

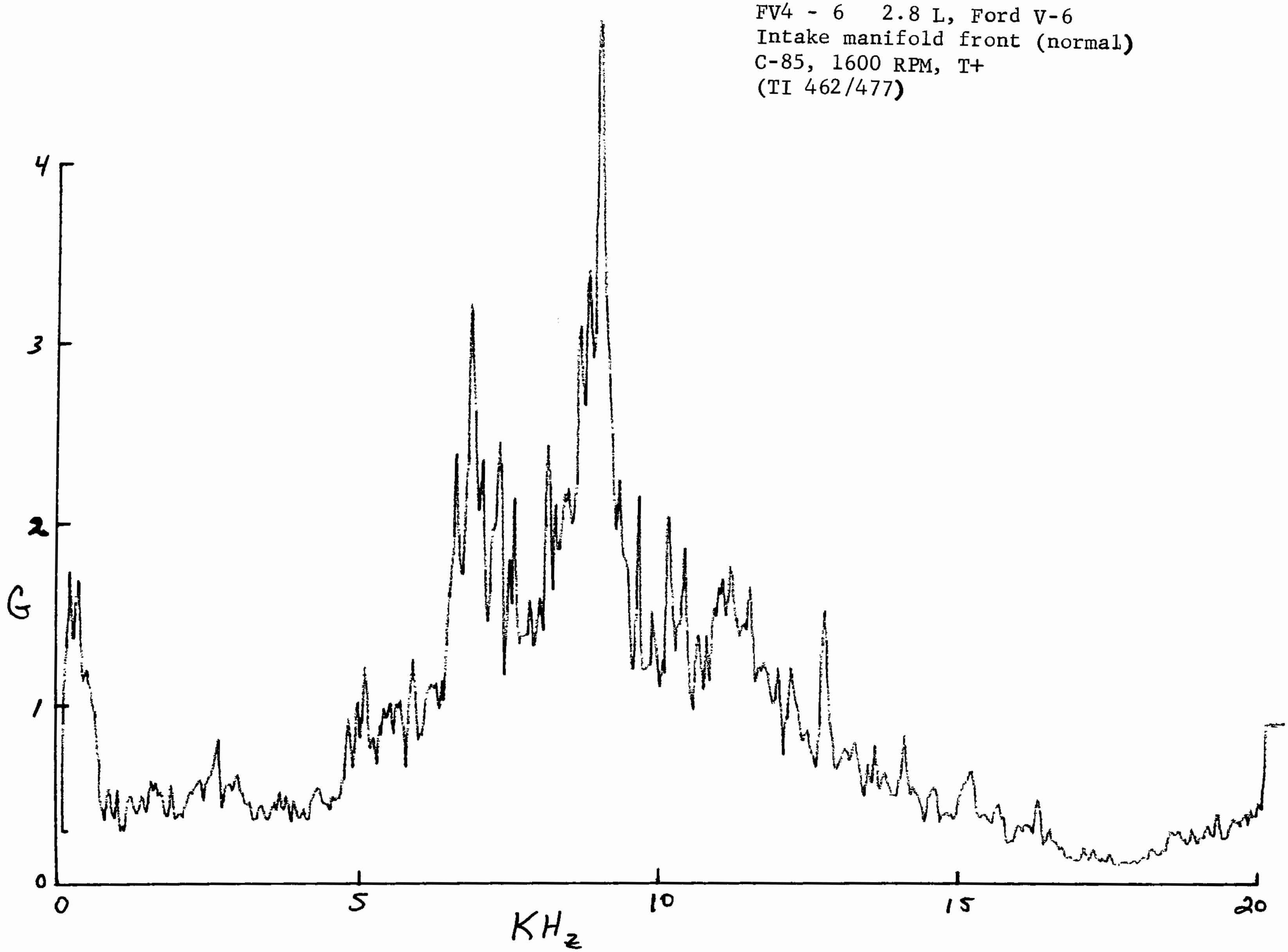


FV4-5


FV4 - 5 2.8 L, Ford V-6
Intake manifold rear (normal)
C-85, 1600 RPM, T+
(TI 462/477)
G
0
1
2
3
4
0
5
10
15
20
KHz

FV4-6

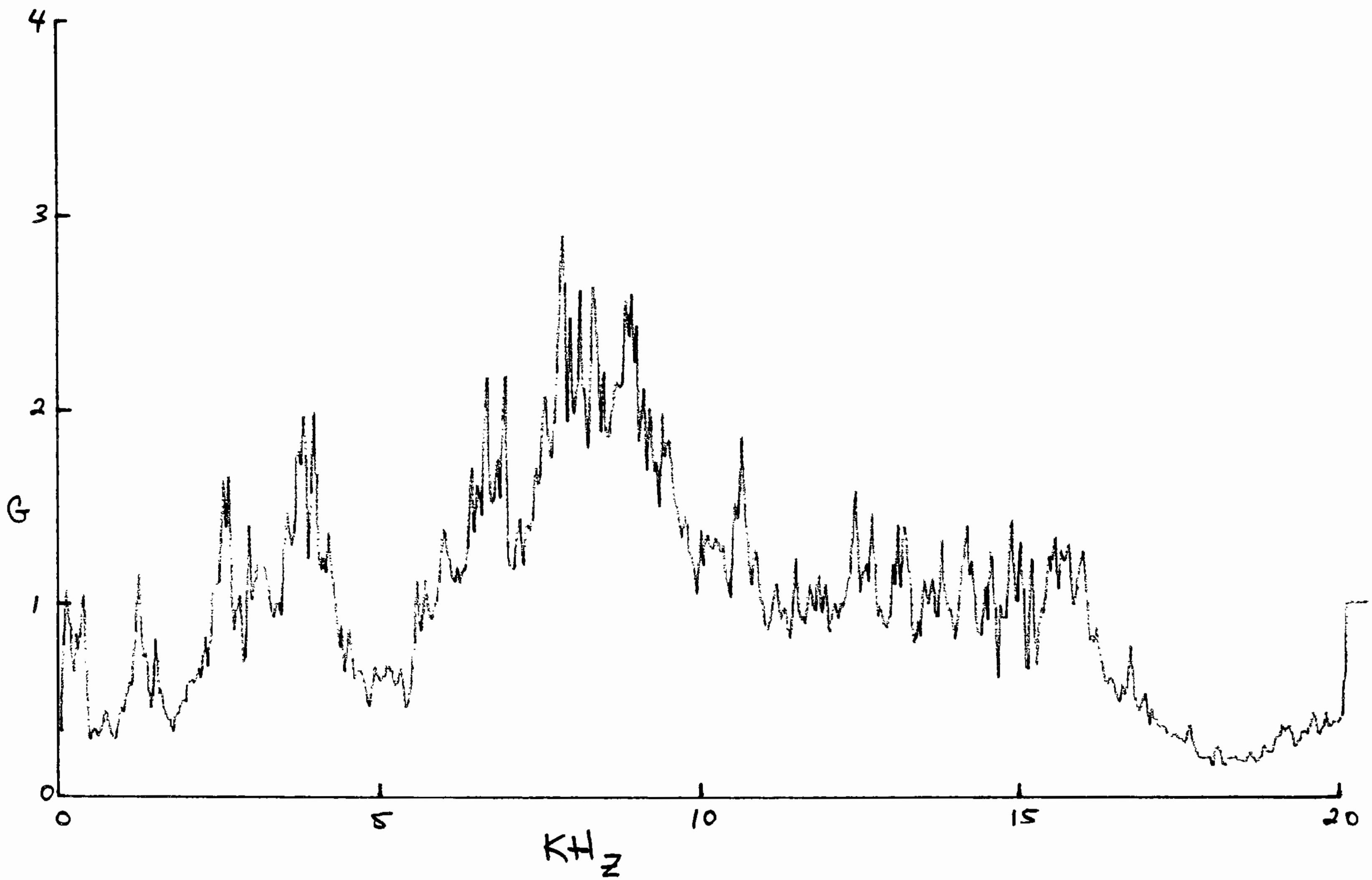
FV4 - 6   2.8 L, Ford V-6
Intake manifold front (normal)
C-85, 1600 RPM, T+
(TI 462/477)




- 584 -

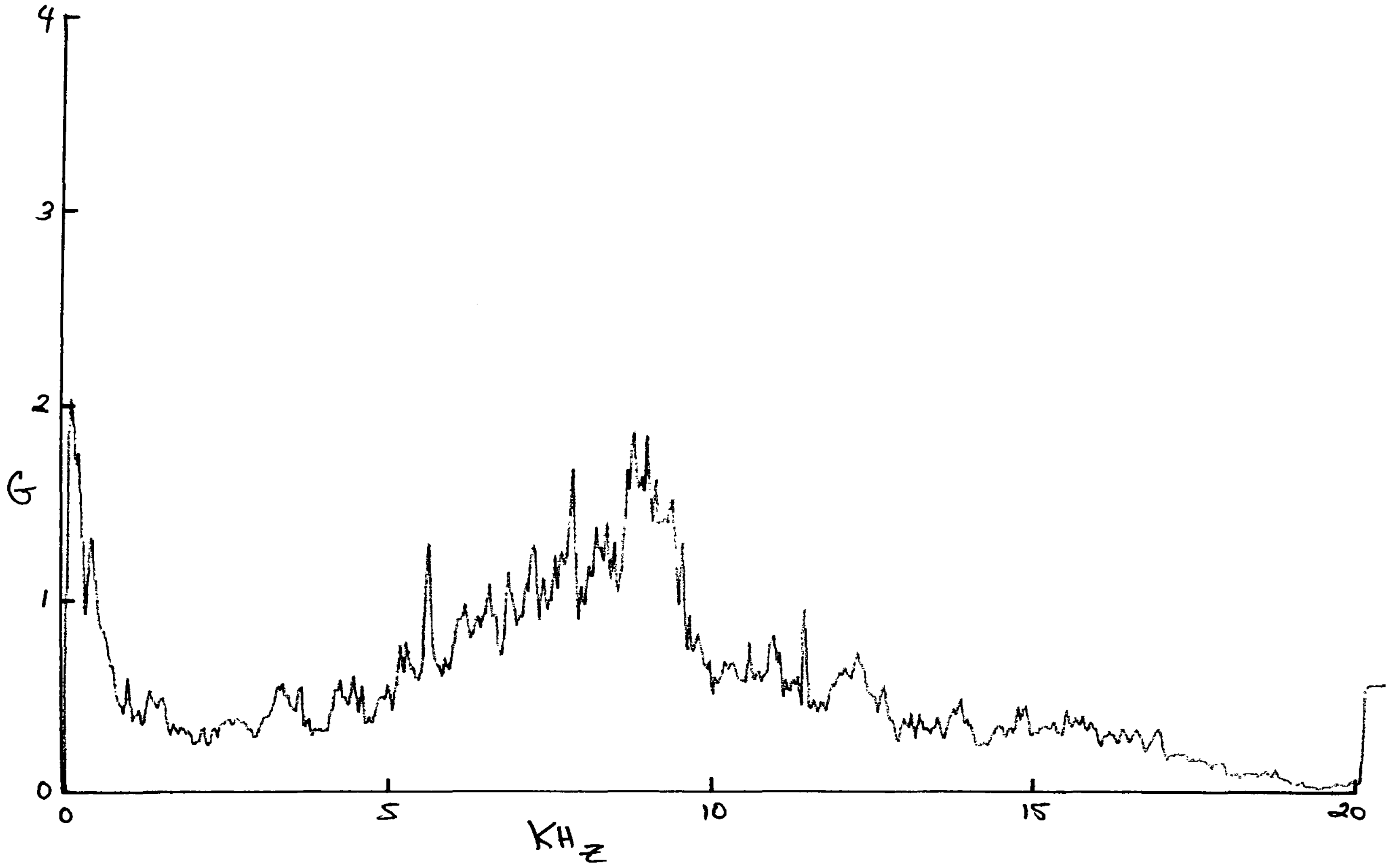
FV4-7

FV4 - 7 2.8 L, Ford V-6
Driver side rear head (axial)
C-85, 1600 RPM, T+
(TI 462/477)



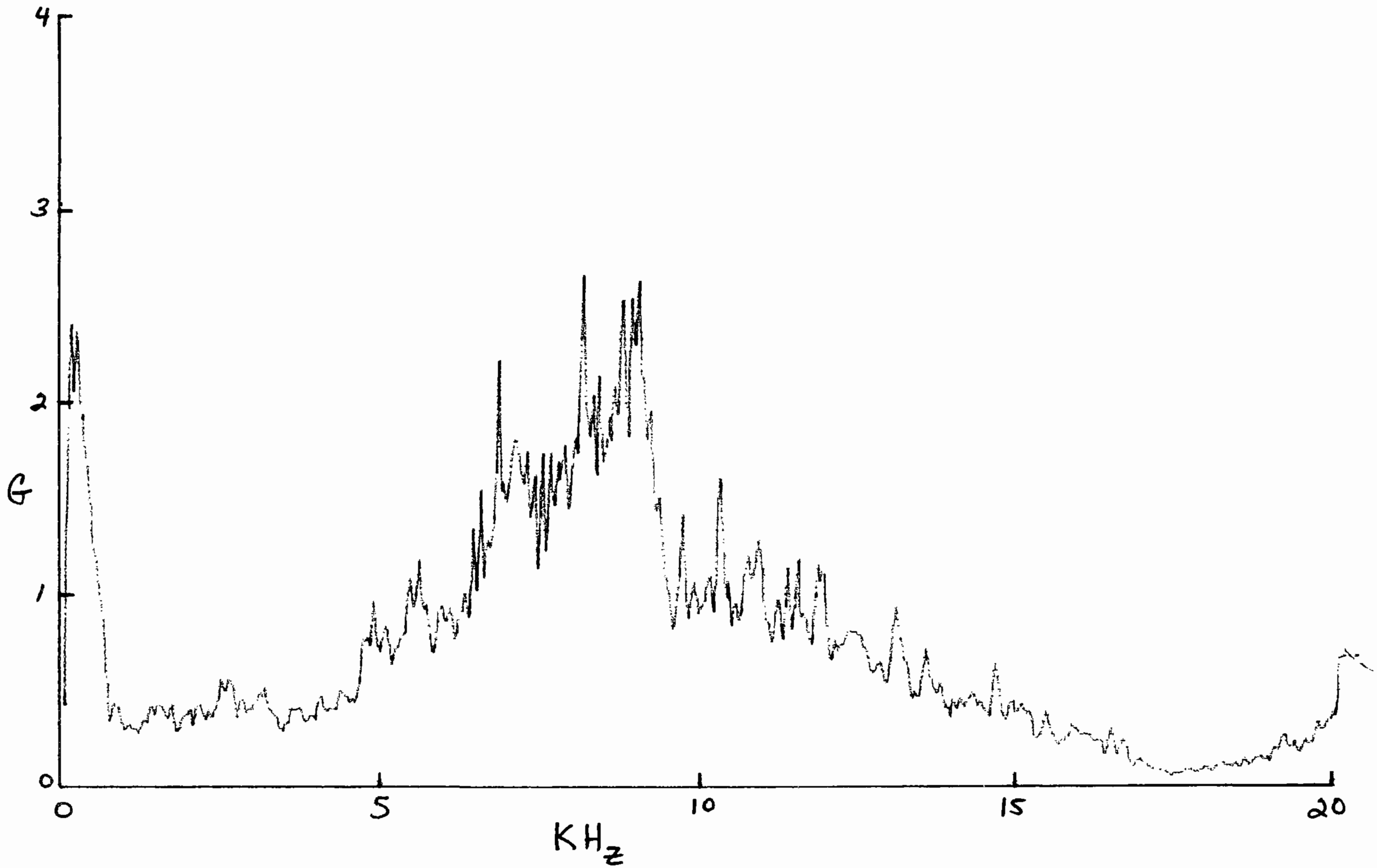
FV5-5

FV5 - 5   2.8 L, Ford V-6
Intake manifold rear (normal)
C-85, 1600 RPM, T-
(TI 502/518)



FV5-6

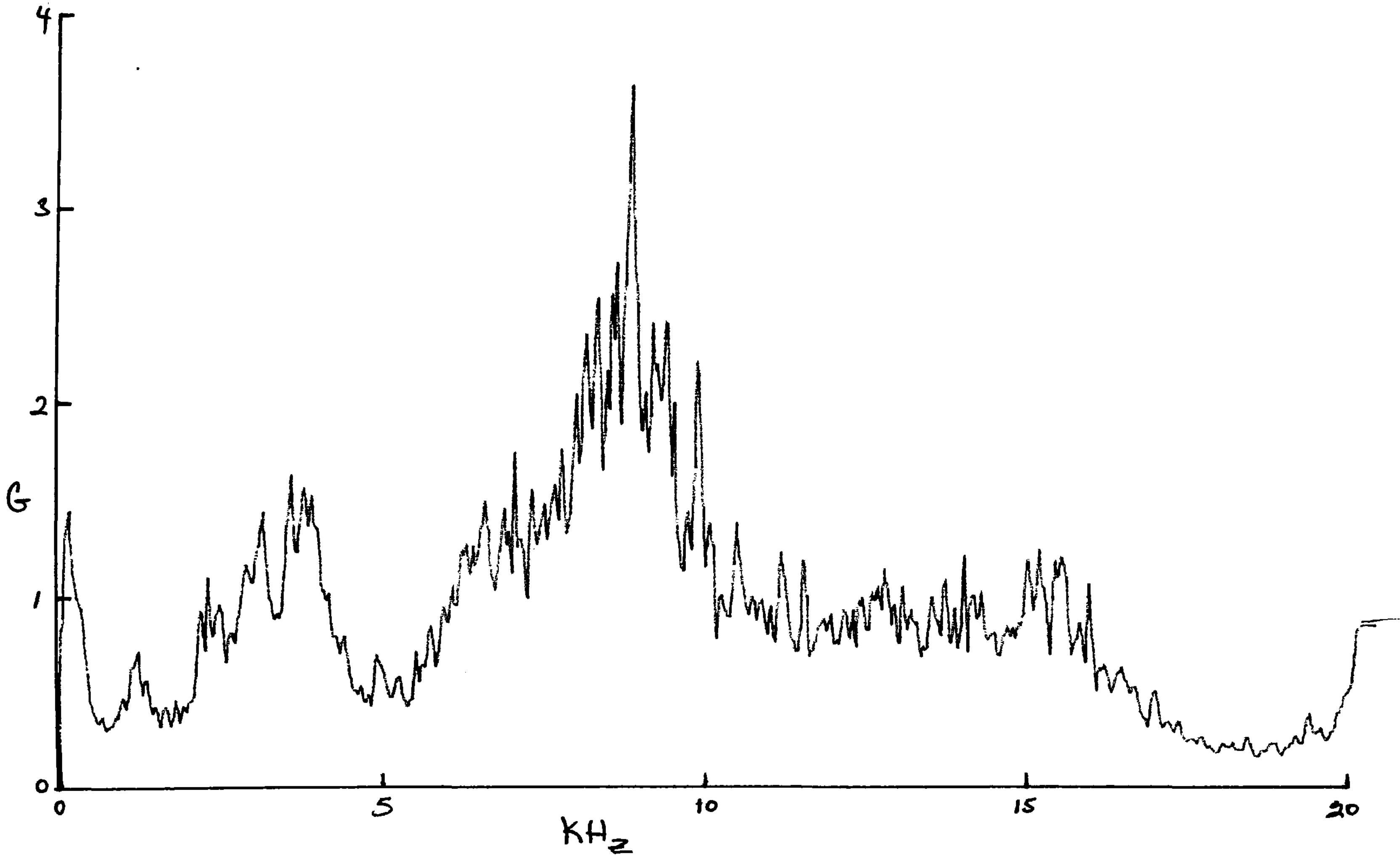
FV5 - 6   2.8 L, Ford V-6
Intake manifold front (normal)
C-85, 1600 RPM, T-
(TI 502/518)




- 587 -

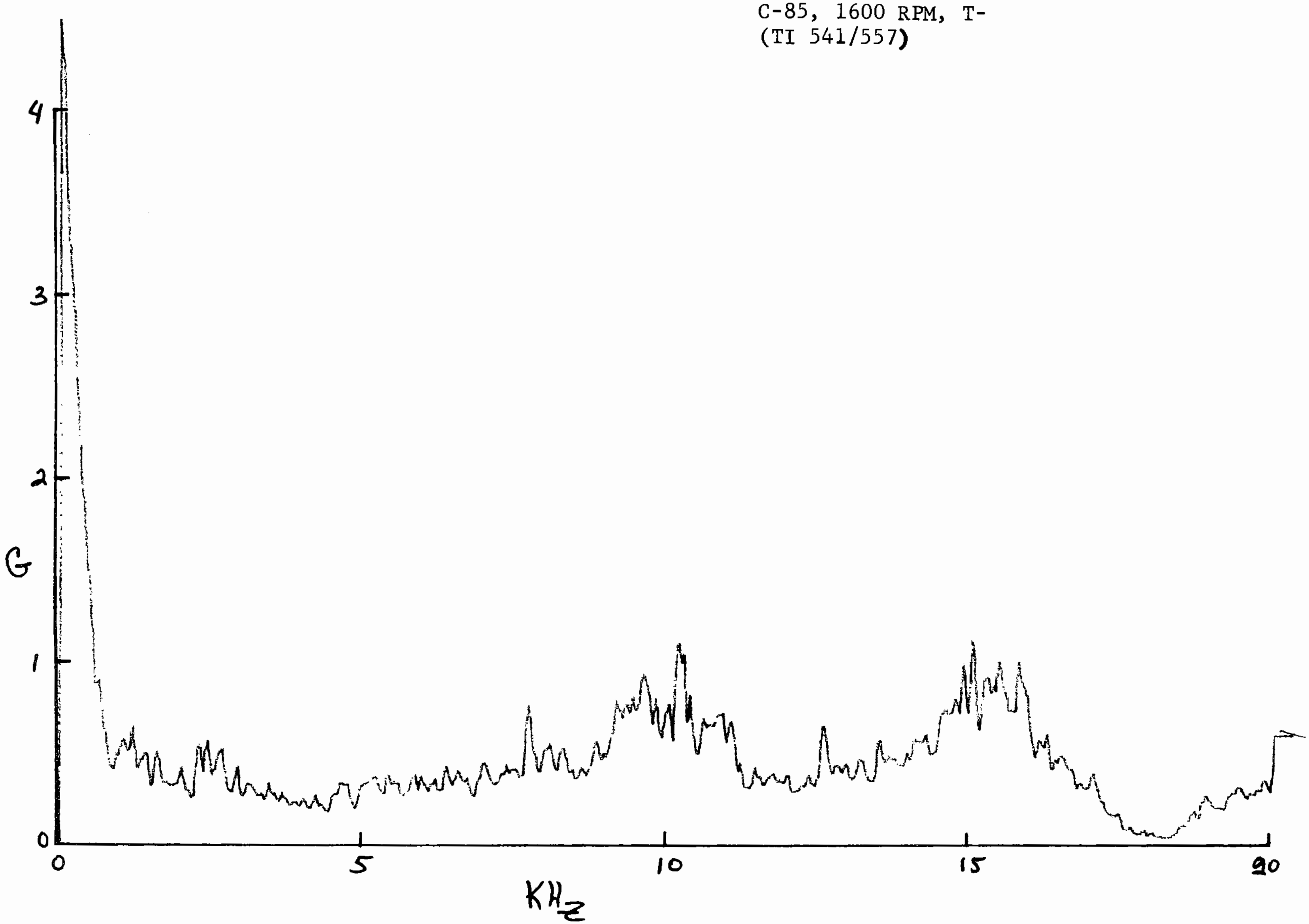
FV5-7

FV5 - 7 2.8 L, Ford V-6
Driver side rear head (axial)
C-85, 1600 RPM, T-
(TI 502/518)

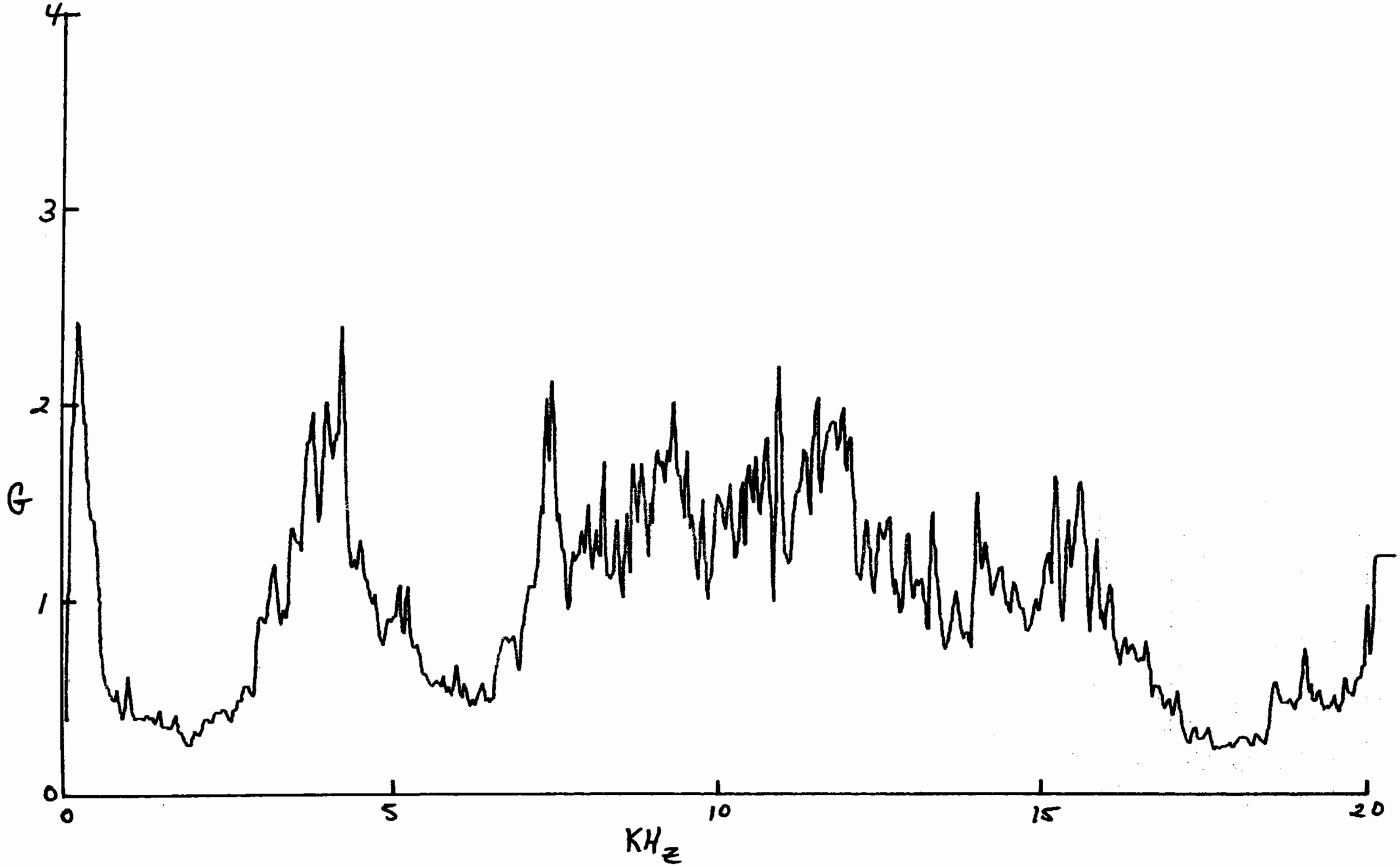


FV6 -5

FV6 - 5 2.8 L, Ford V-6
Head front bolt driver side(normal)
C-85, 1600 RPM, T-
(TI 541/557)

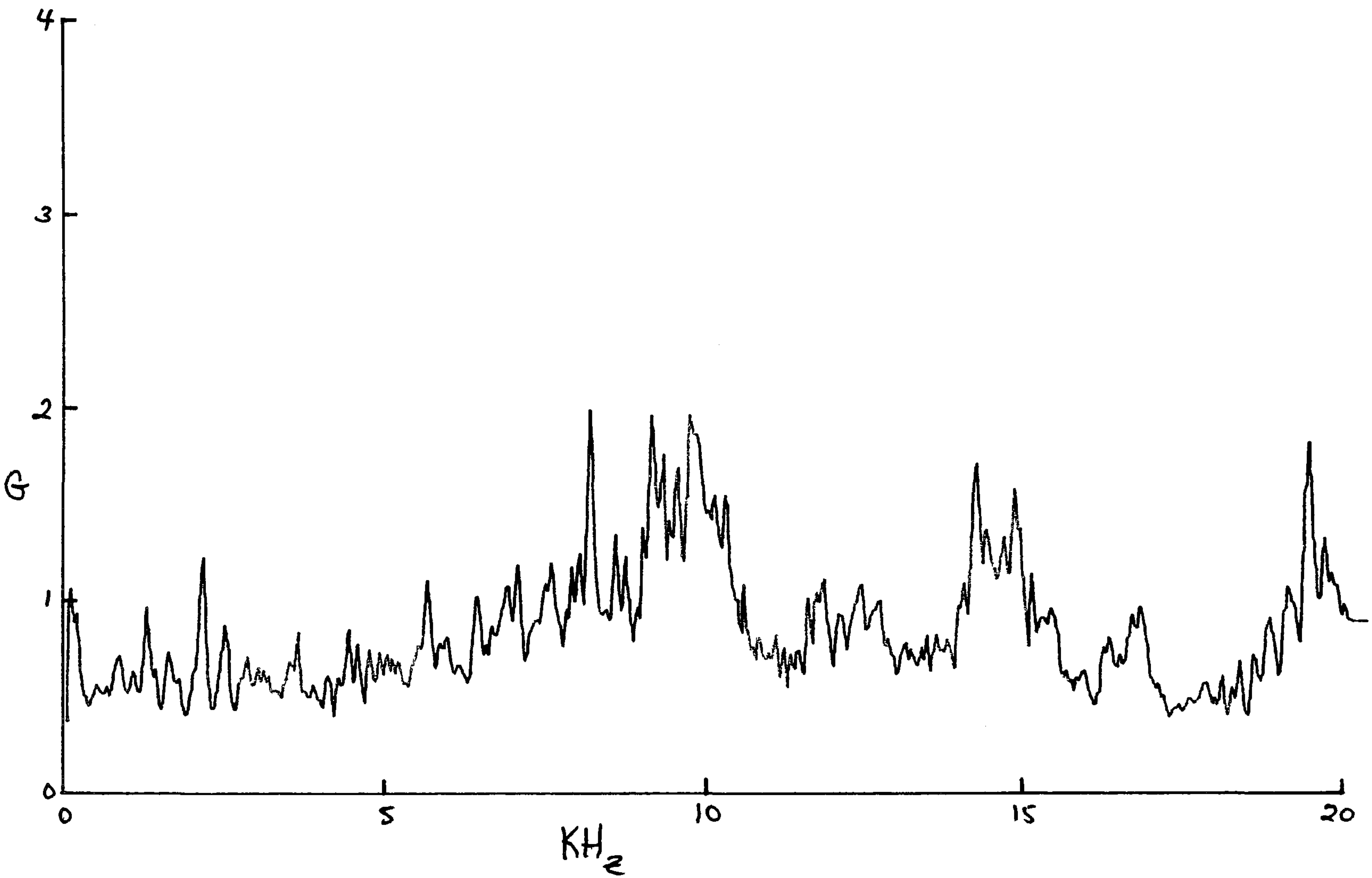


FV 6 - 6   2.8 L, Ford V-6
Passenger side rear head (axial)
C-85, 1600 RPM, T-
(TI 541/557)

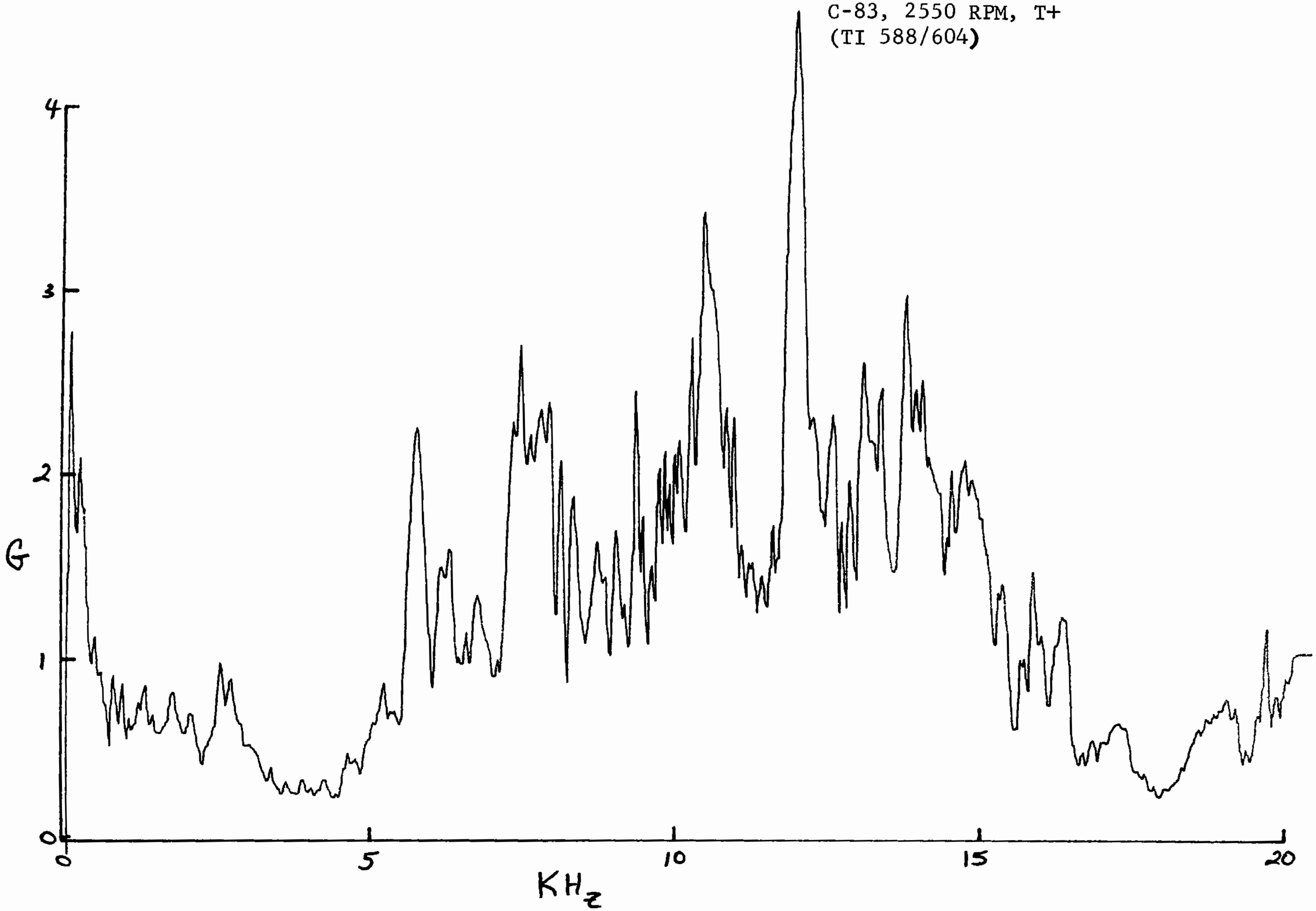


FVG-7

FV6 - 7 2.8 L, Ford V-6
Head front bolt passenger side(normal)
C-85, 1600 RPM, T-
(TI 541/557)

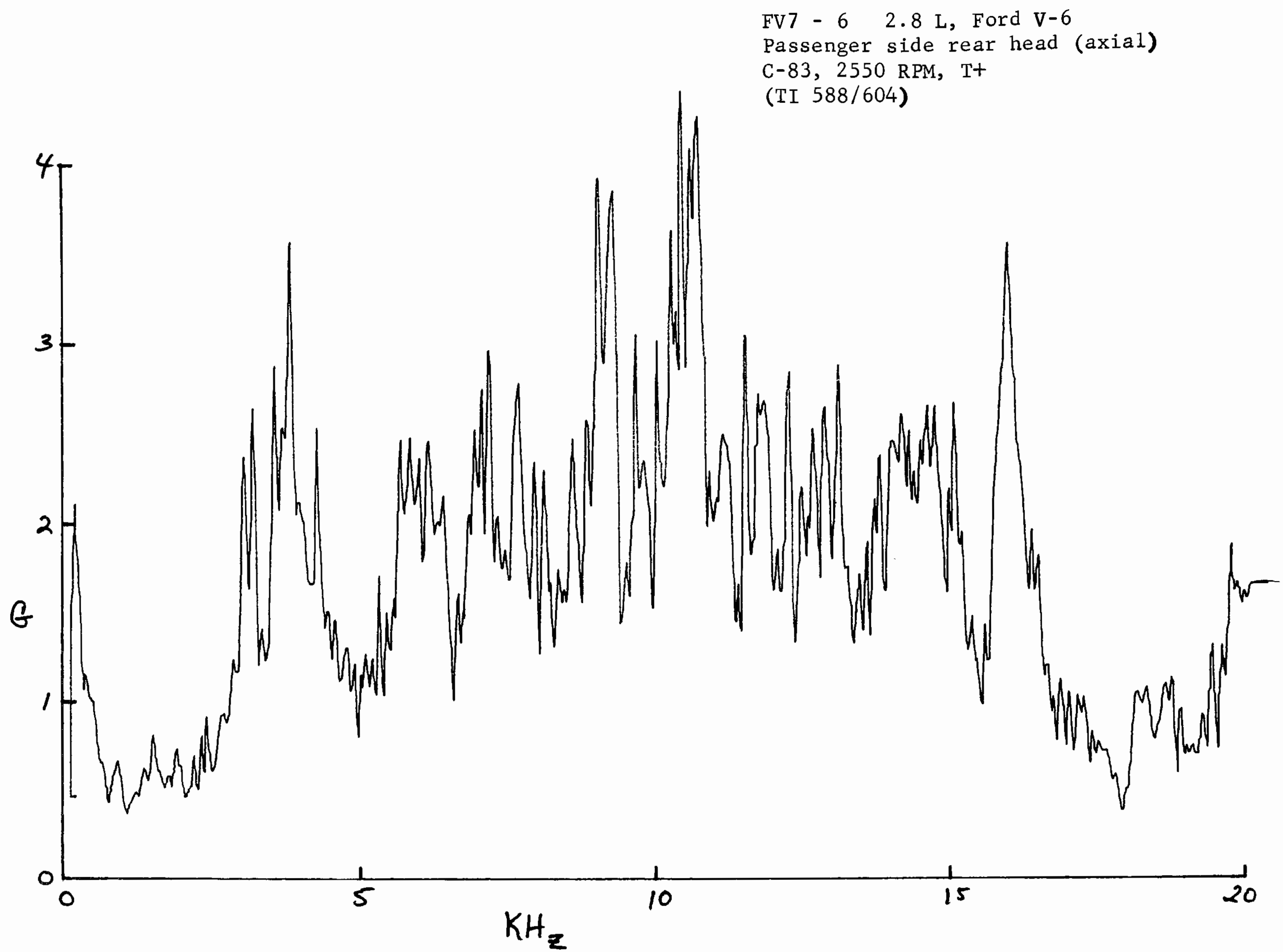


FV7-5


FV7 - 5   2.8 L, Ford V-6
Head front bolt driver side(normal)
C-83, 2550 RPM, T+
(TI 588/604)
G
0
1
2
3
4
0
5
10
15
20
KHz

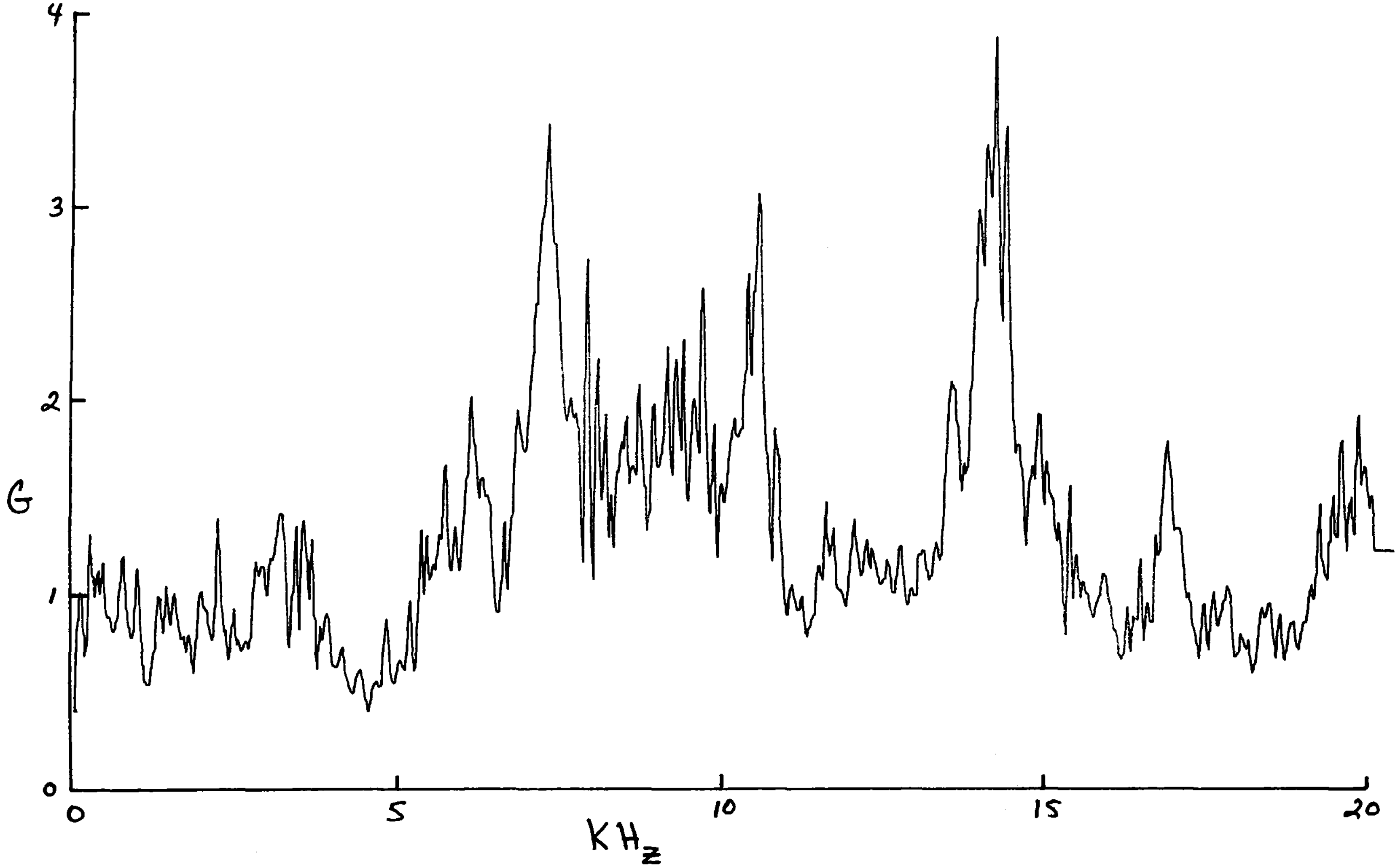
- 592 -

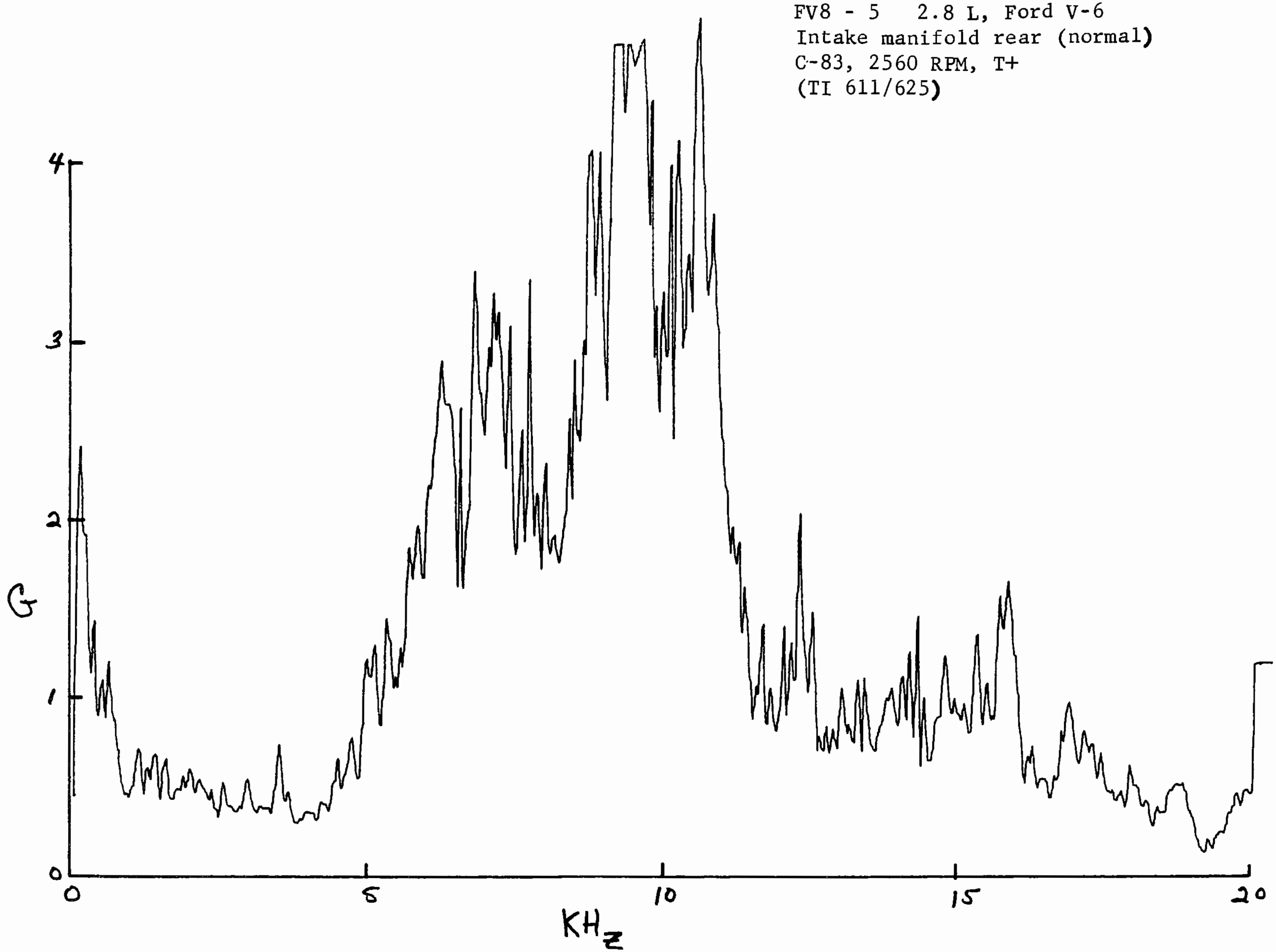
FV7-6


FV7 - 6 2.8 L, Ford V-6
Passenger side rear head (axial)
C-83, 2550 RPM, T+
(TI 588/604)
G
0
1
2
3
4
0
5
10
15
20
KHz

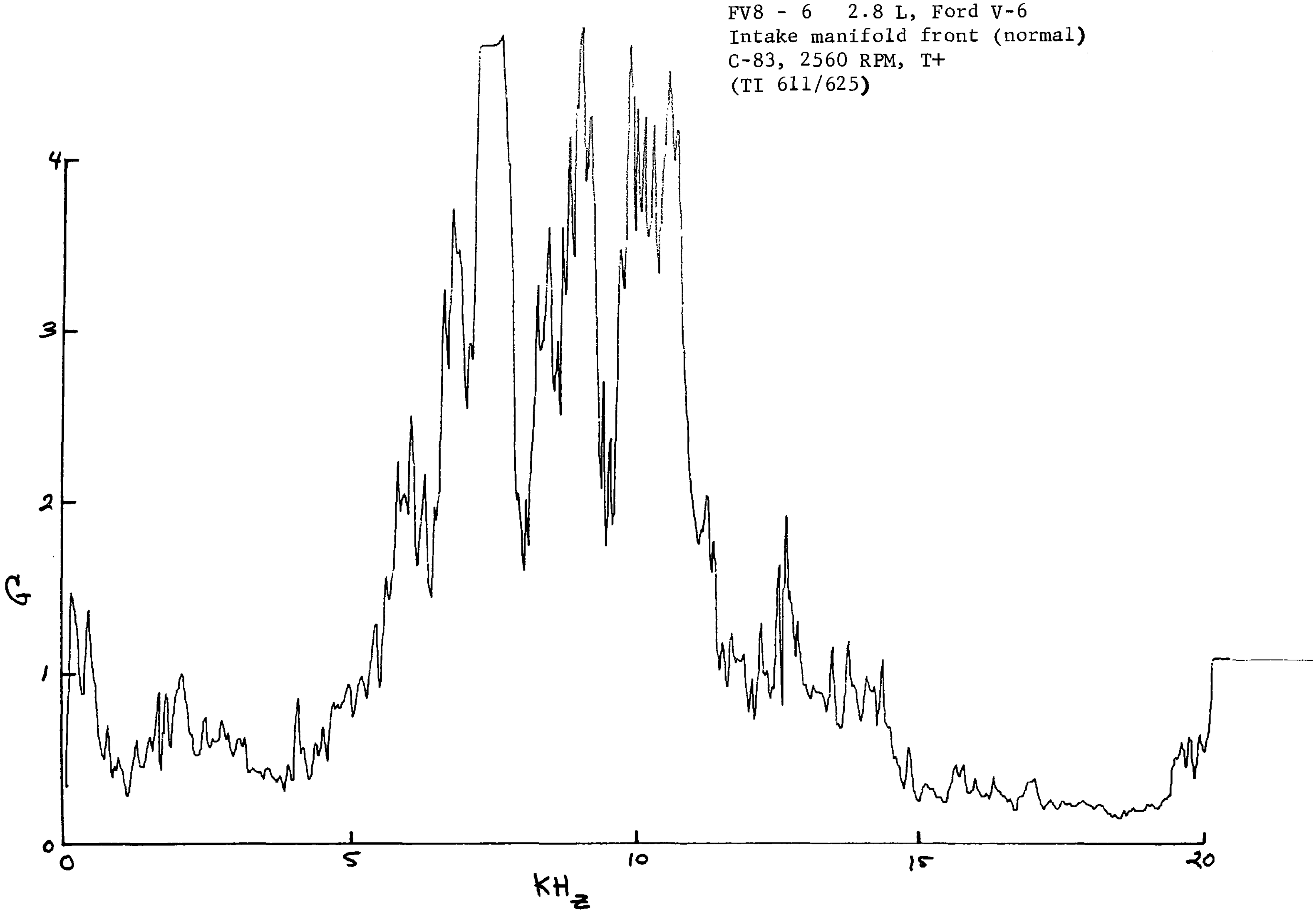
FV7-7

FV7 - 7 2.8 L, Ford V-6
Head front bolt passenger side (normal)
C-83, 2550 RPM, T+
(TI 588/604)

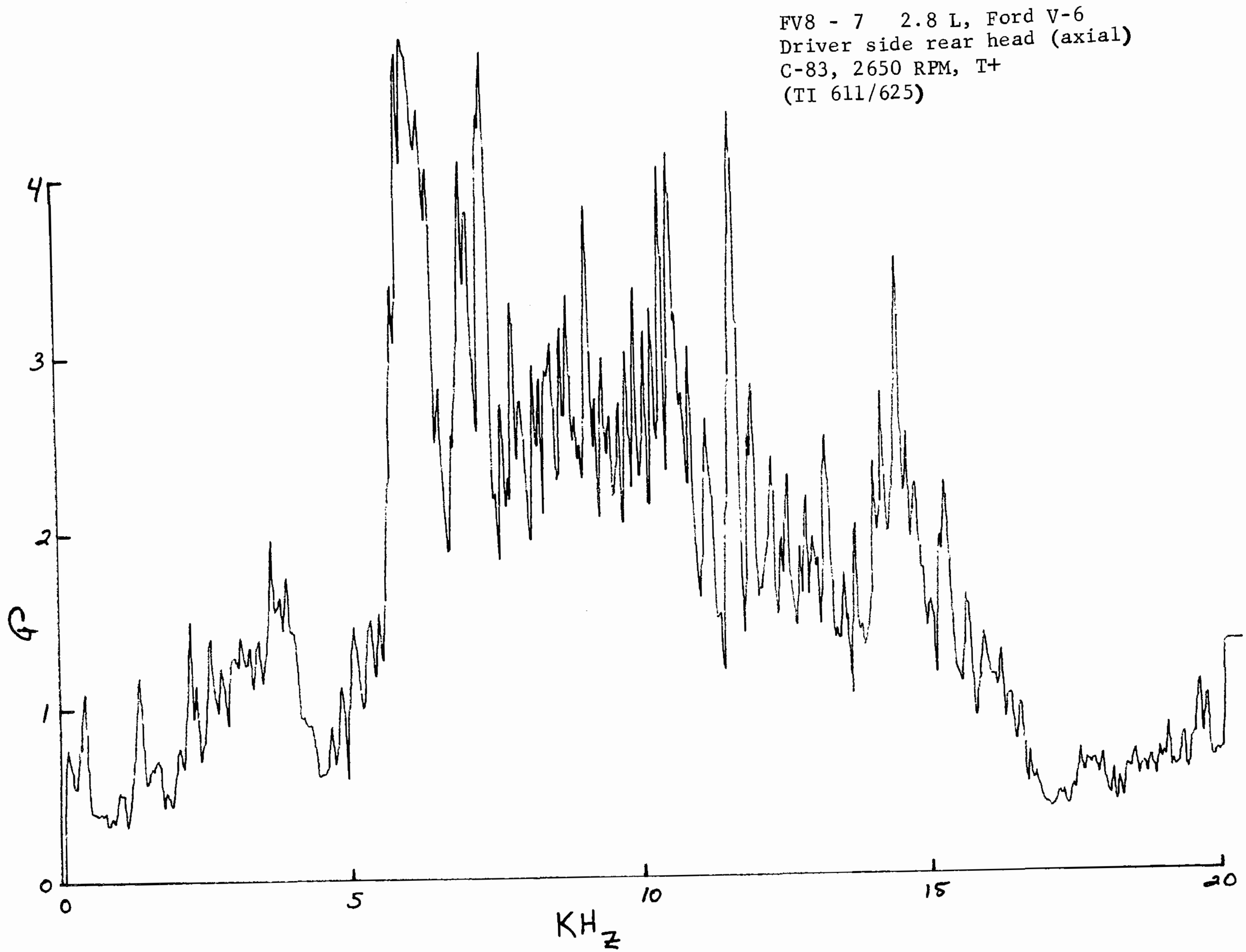



FV8 - 5 2.8 L, Ford V-6
Intake manifold rear (normal)
C-83, 2560 RPM, T+
(TI 611/625)
G
0
1
2
3
4
0
5
10
15
20
KHz

FV8-6

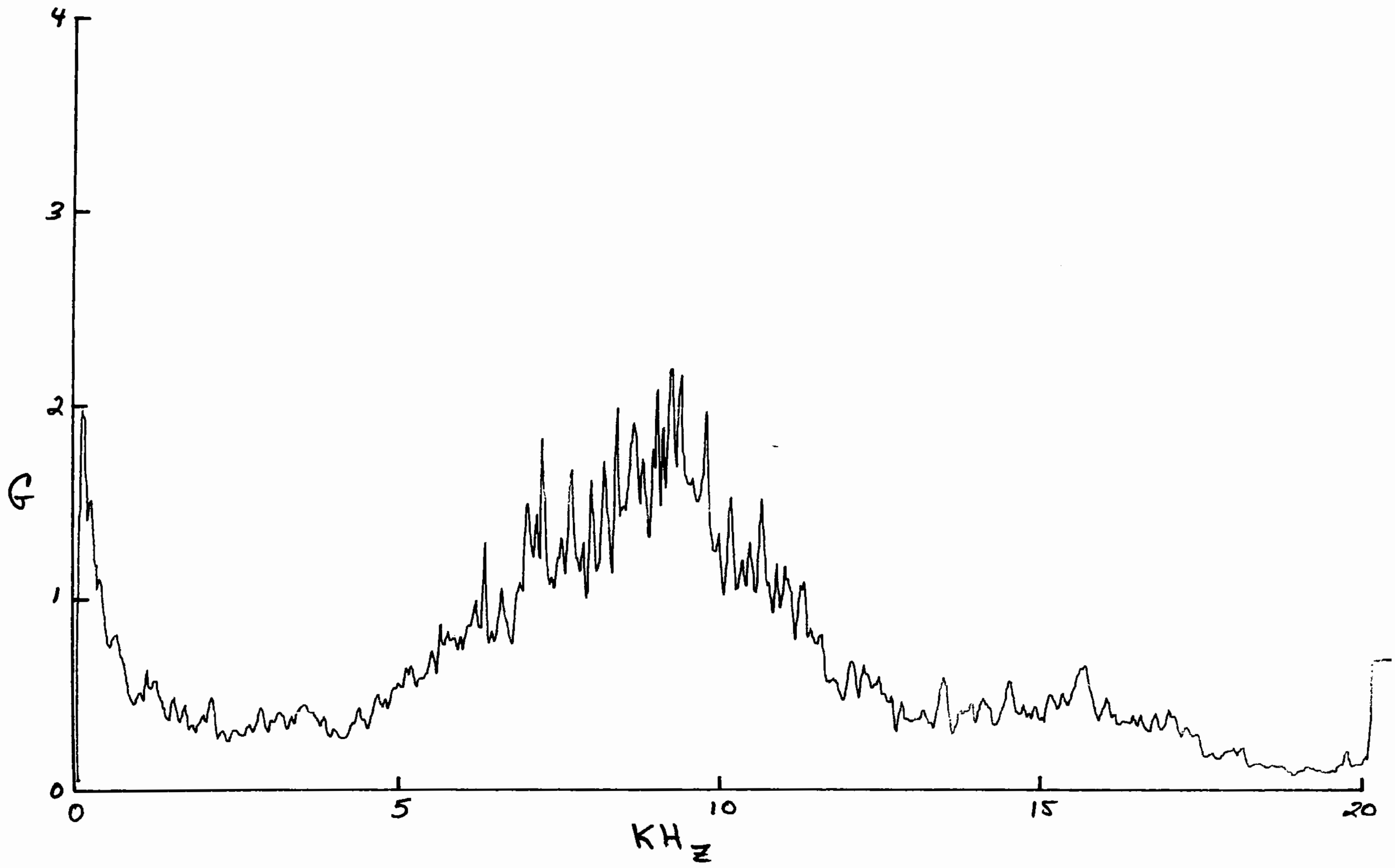

FV8 - 6 2.8 L, Ford V-6
Intake manifold front (normal)
C-83, 2560 RPM, T+
(TI 611/625)
G
4
3
2
1
0
0
5
10
15
20
KHz

FV8-7

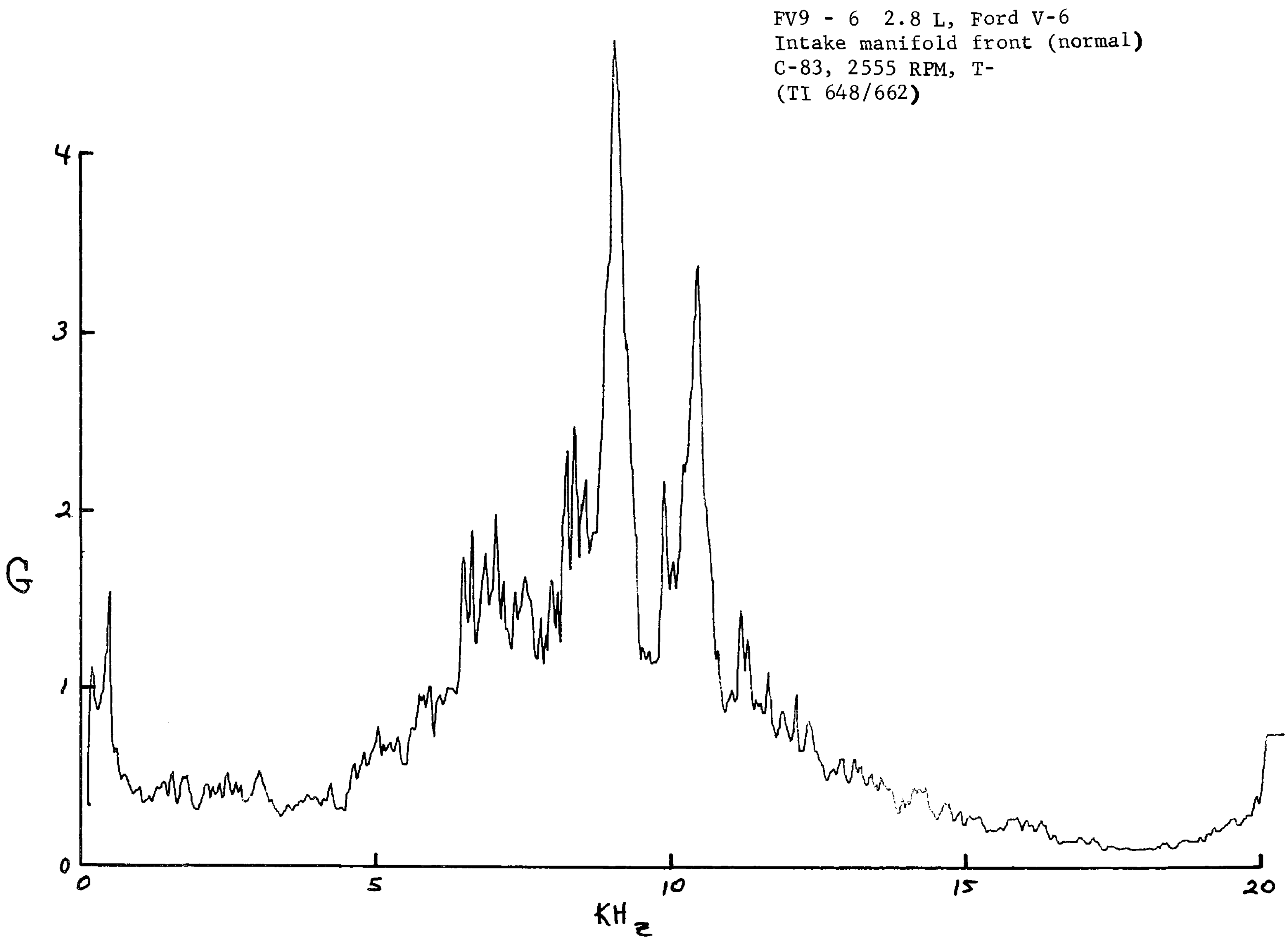

FV8 - 7 2.8 L, Ford V-6
Driver side rear head (axial)
C-83, 2650 RPM, T+
(TI 611/625)
G
4
3
2
1
0
0
5
10
15
20
KHz

FV9-5

FV9 - 5   2.8 L, Ford V-6
Intake manifold rear (normal)
C-83, 2555 RPM, T-
(TI 648/662)

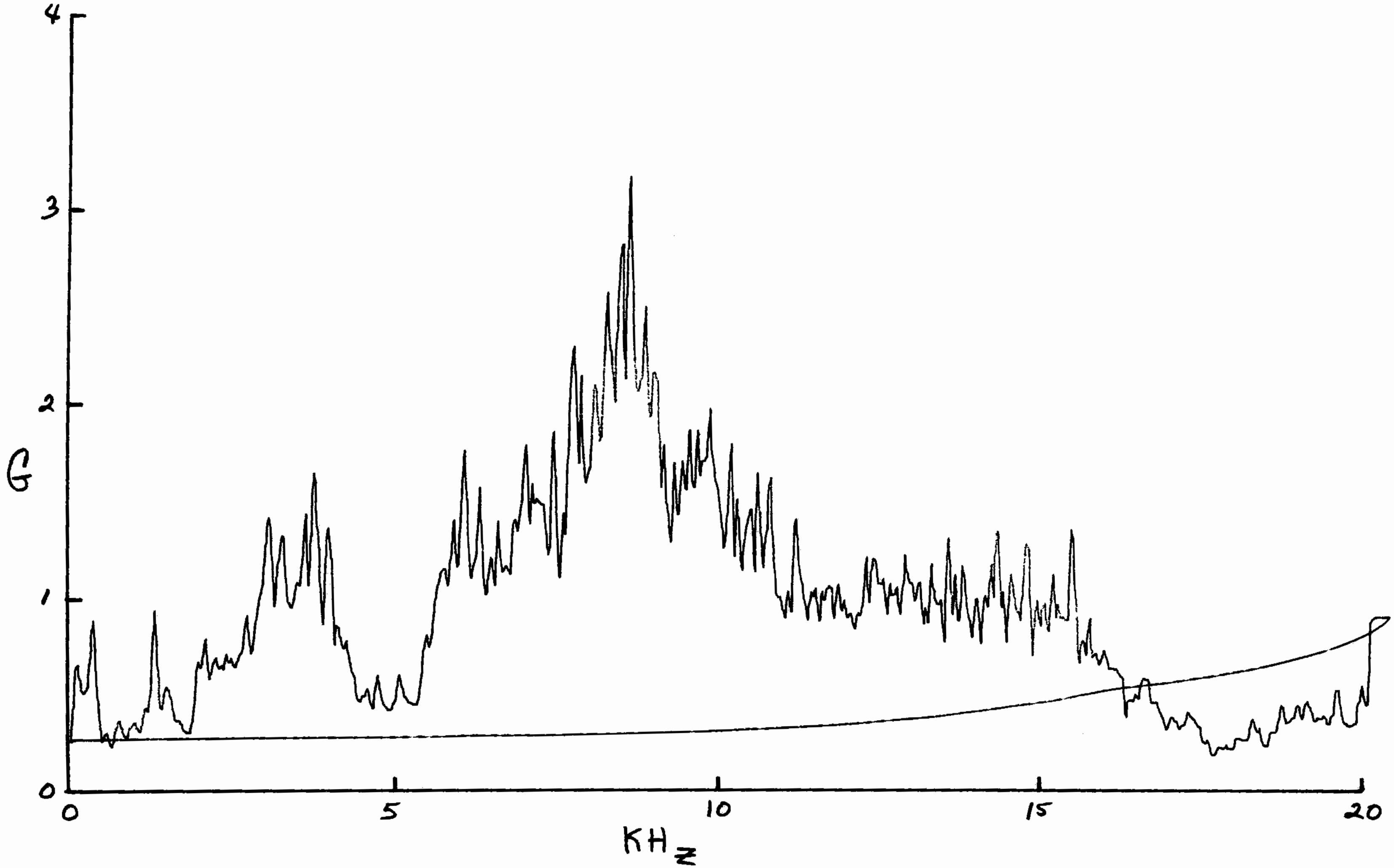


FV9-6


FV9 - 6 2.8 L, Ford V-6
Intake manifold front (normal)
C-83, 2555 RPM, T-
(TI 648/662)
G
4
3
2
1
0
0
5
10
15
20
KHz

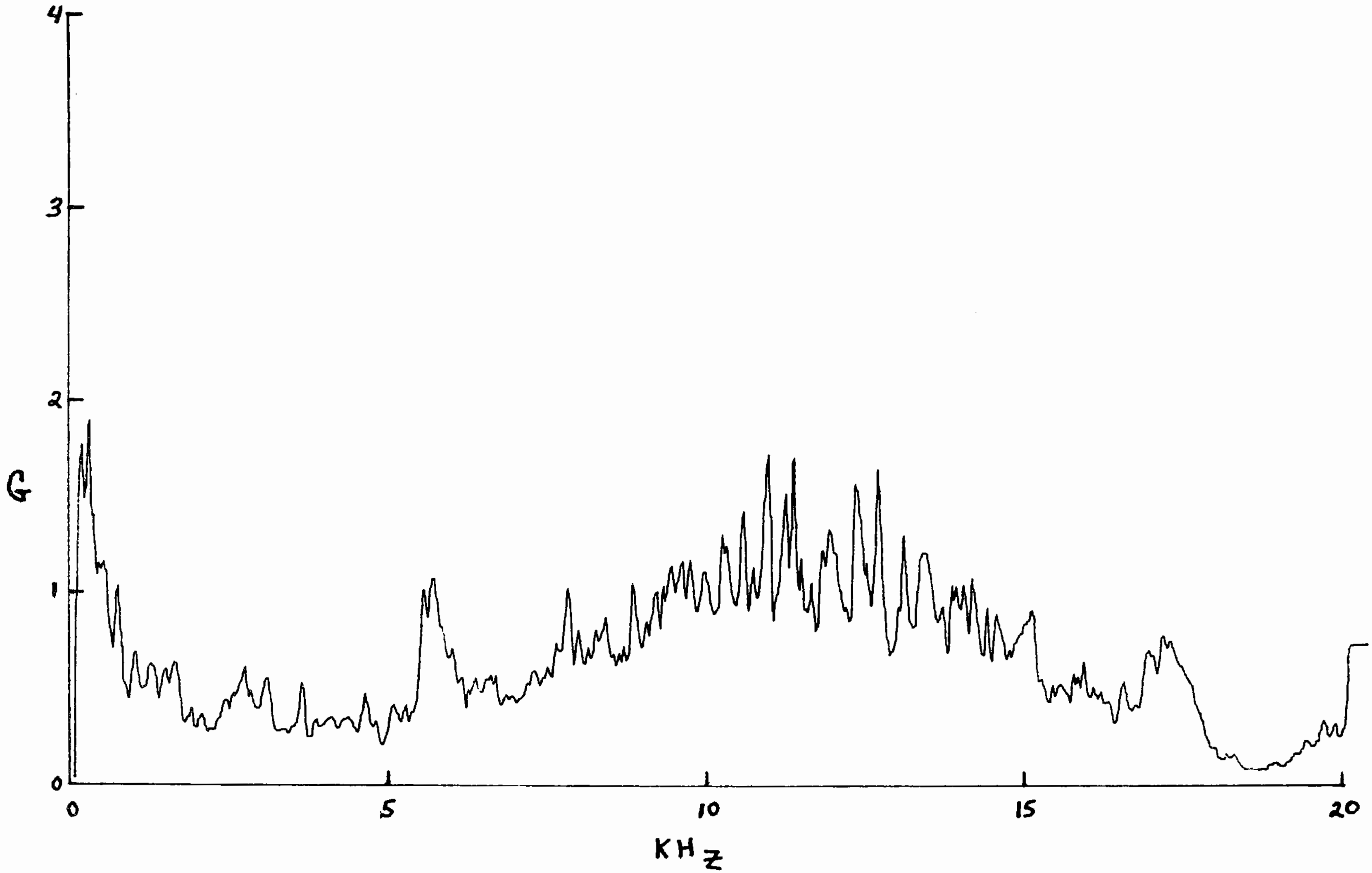
FV9-7

FV9 - 7   2.8 L, Ford V-6
Driver side rear head (axial)
C-83, 2555 RPM, T-
(TI 648/662)



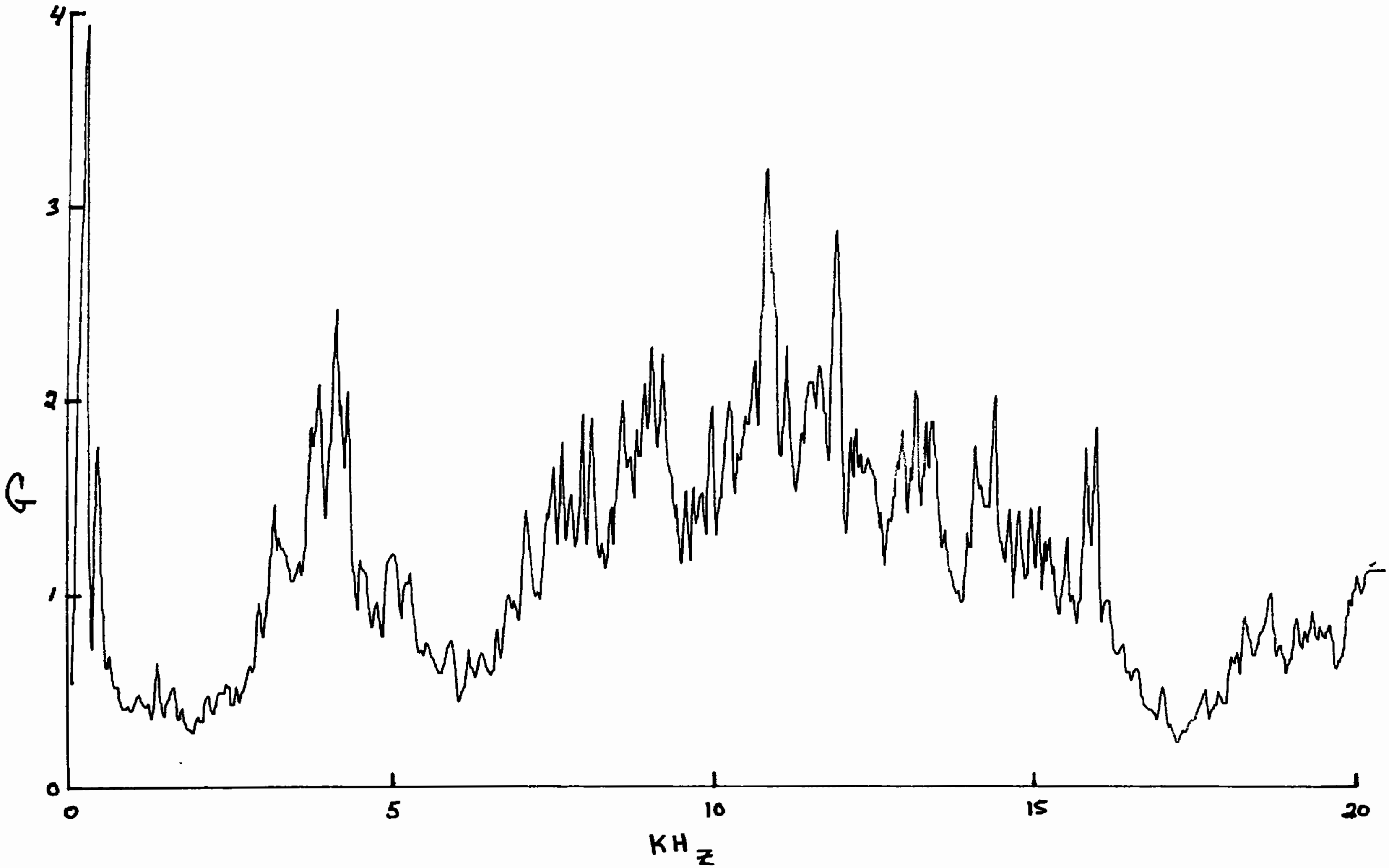
FV10-5

FV10 - 5   2.8 L, Ford V-6
Head front bolt driver side (normal)
C-83, 2555 RPM, T-
(TI 677/690)



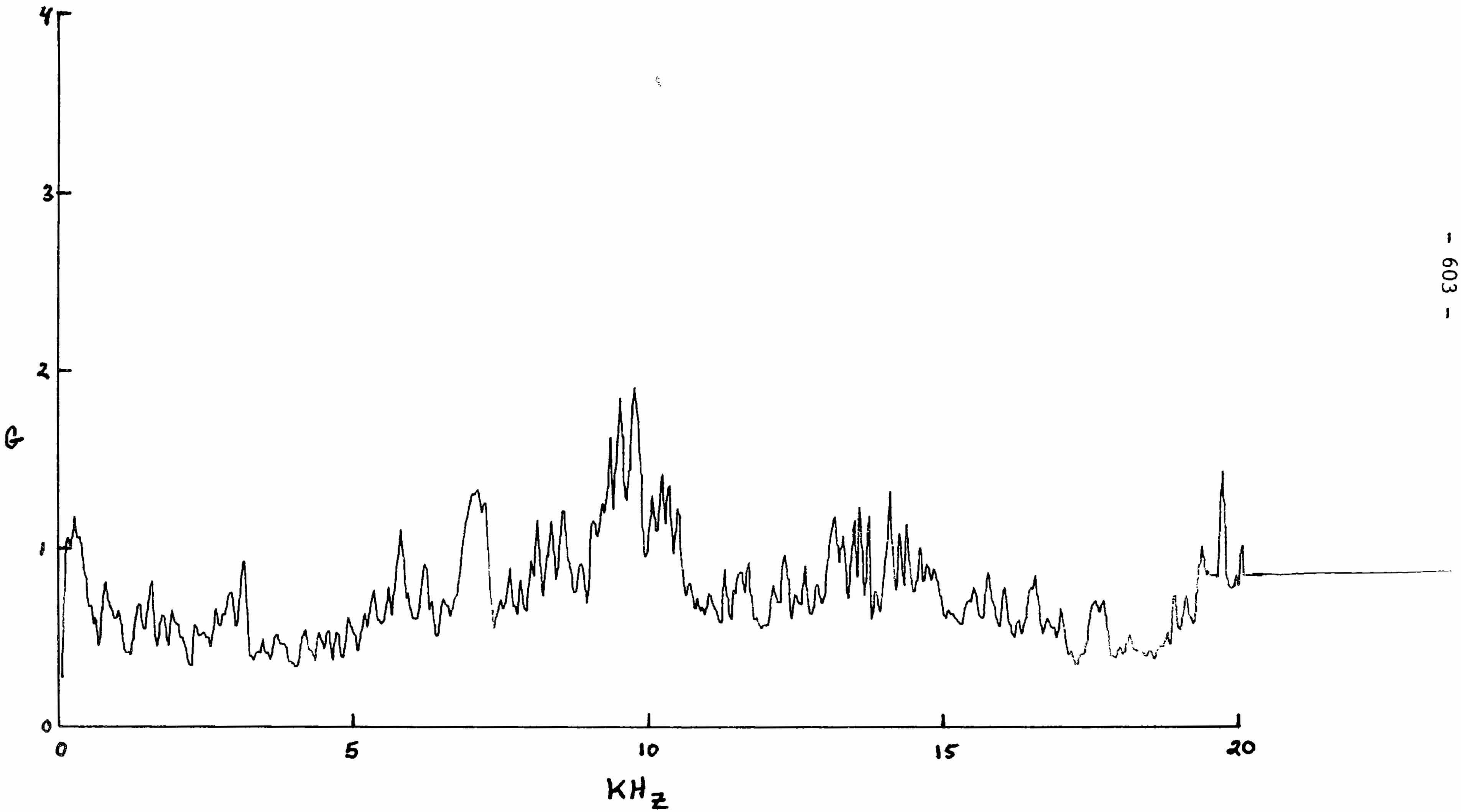
FV10-6

FV10 - 6   2.8 L, Ford V-6
Passenger side rear head (axial)
C-83, 2555 RPM, T-
(TI 677/690)



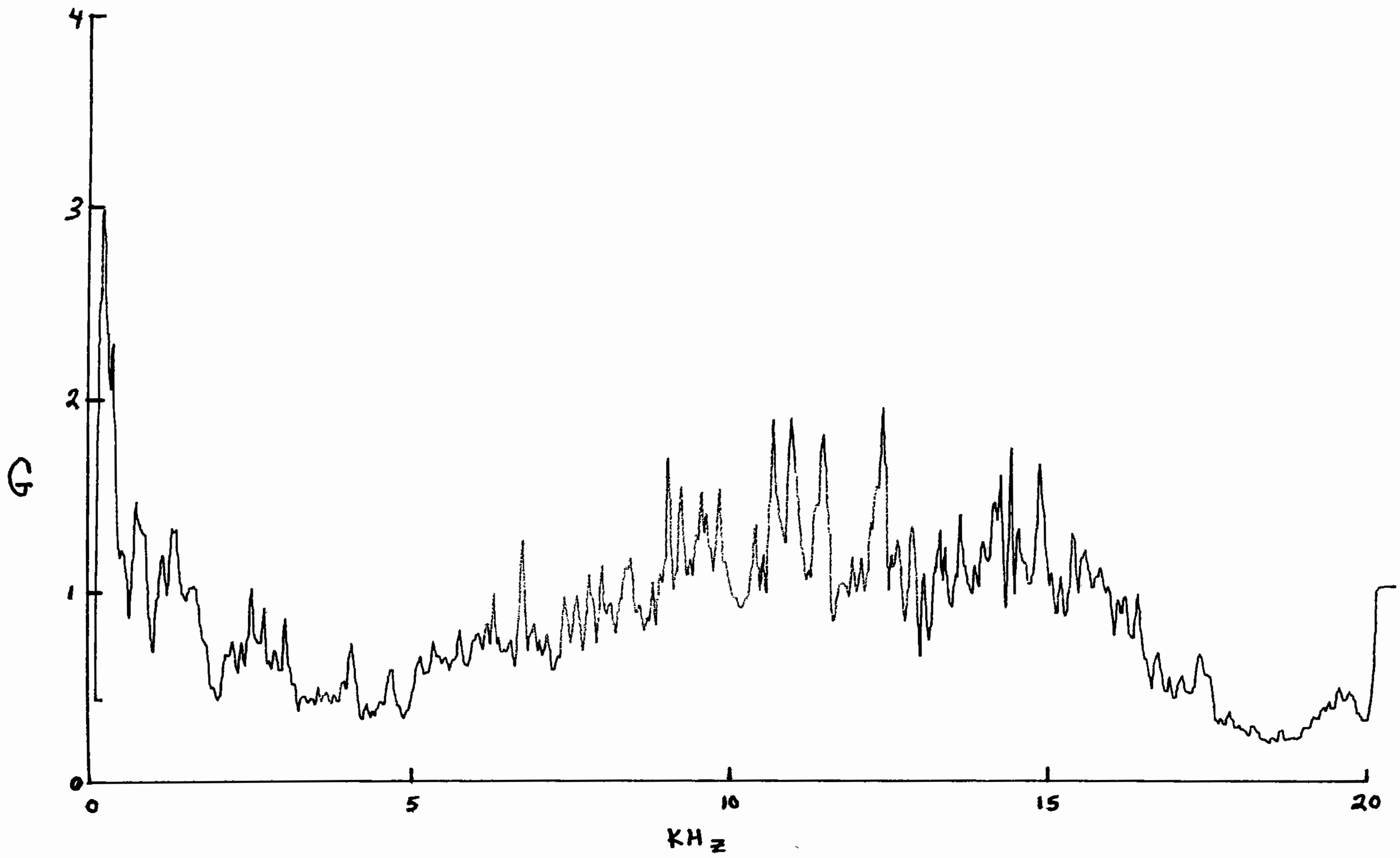
FV10-7

FV10 - 7   2.8 L, Ford V-6
Head front bolt passenger side(normal)
C-83, 2555 RPM, T-
(TI 677/690)



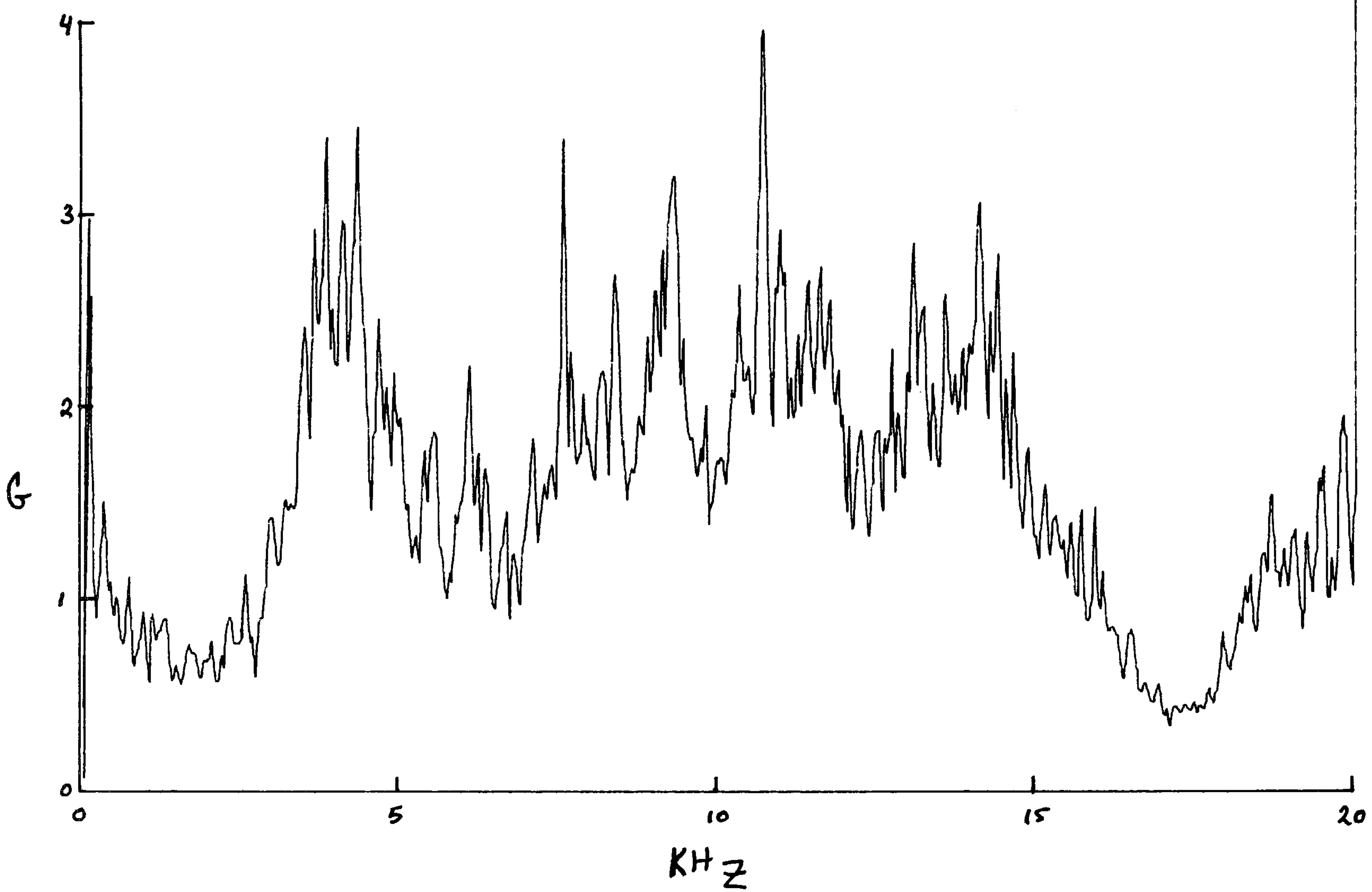
FV11-5

FV11 - 5   2.8 L, Ford V-6
Head front bolt driver side (normal)
Iso-octane, 40-70 MPH Accel., NK
(TI 758/772)



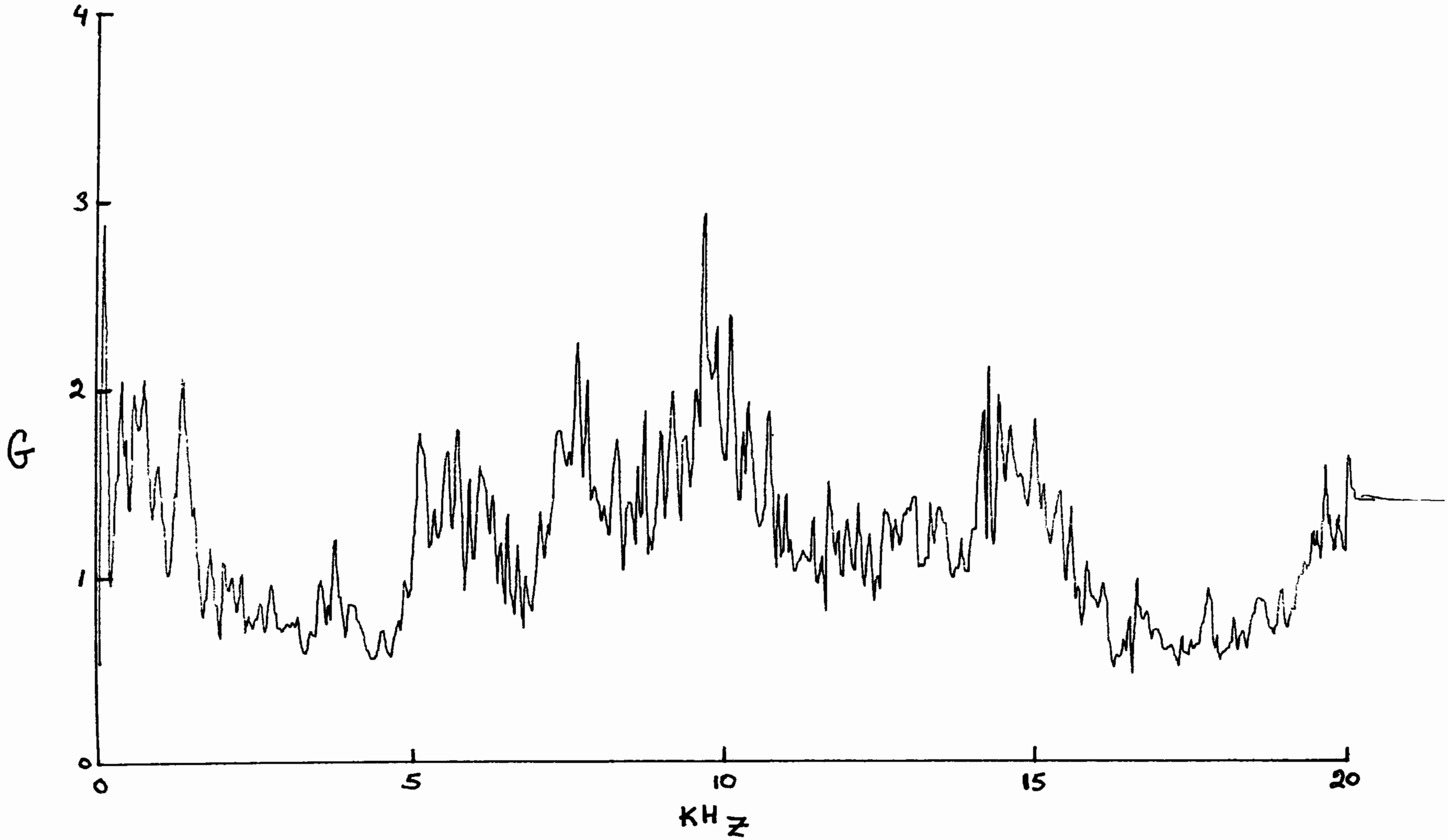
FVll-6

FV11 - 6   2.8 L, Ford V-6
Passenger side rear head (axial)
Iso-octane, 40-70 MPH Accel, NK
(TI 758/772)

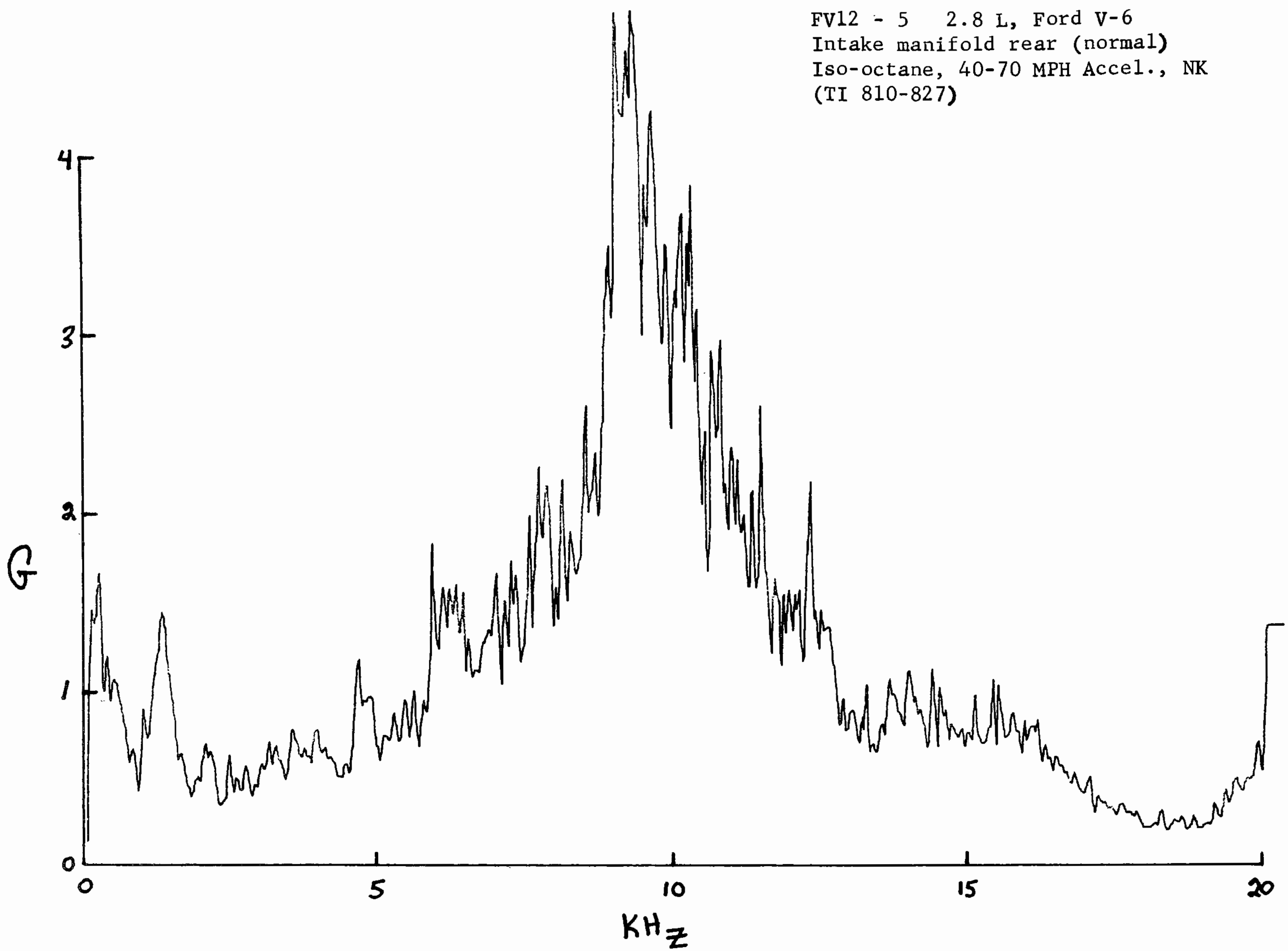


FVll-7

FVll - 7 2.8 L, Ford V-6
Head front bolt passenger side(normal)
Iso-octane, 40-70 MPH Accel. NK
(TI 758/772)

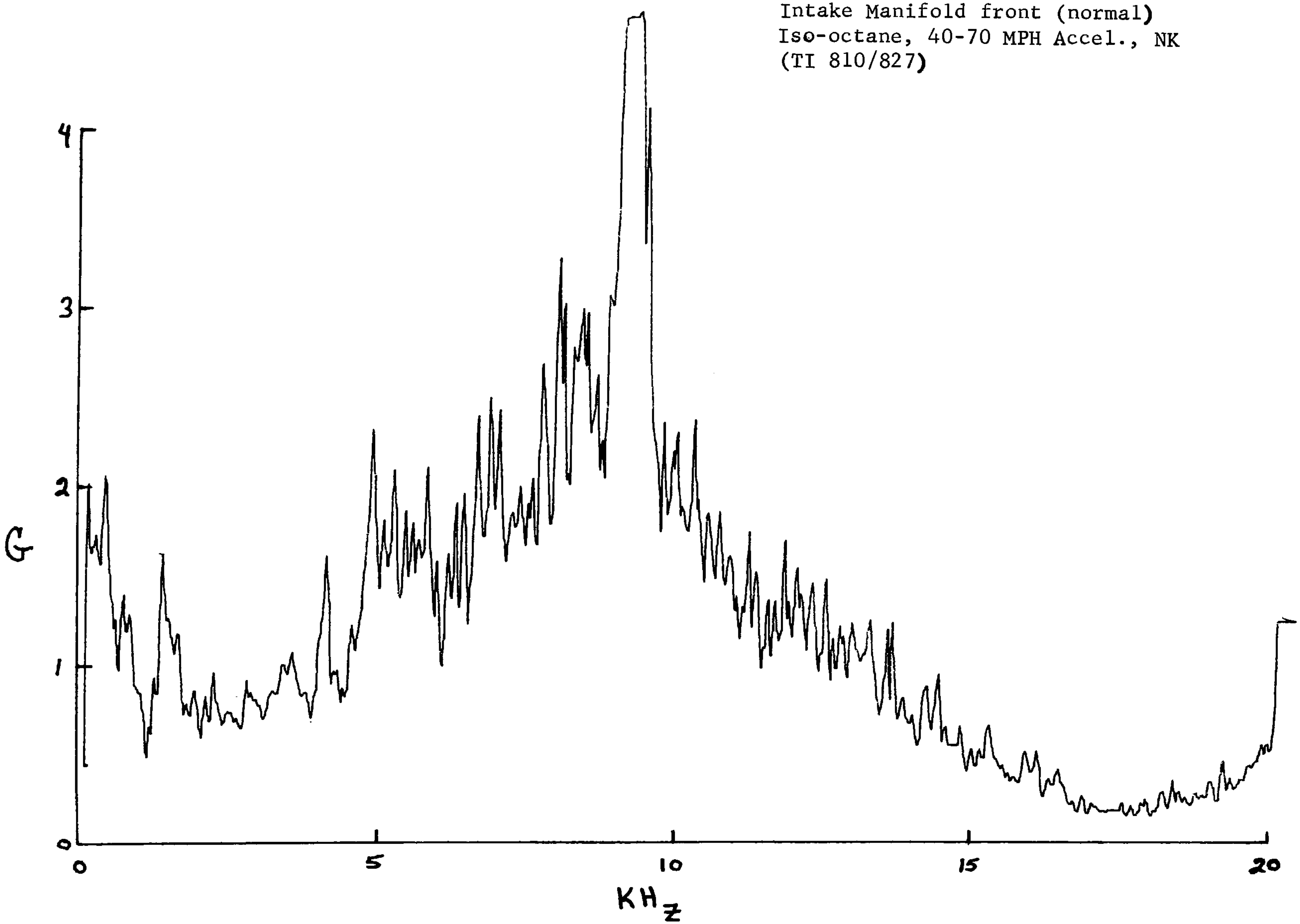


FV12-5


FV12 - 5 2.8 L, Ford V-6
Intake manifold rear (normal)
Iso-octane, 40-70 MPH Accel., NK
(TI 810-827)
G
0
1
2
3
4
0
5
10
15
20
KHz

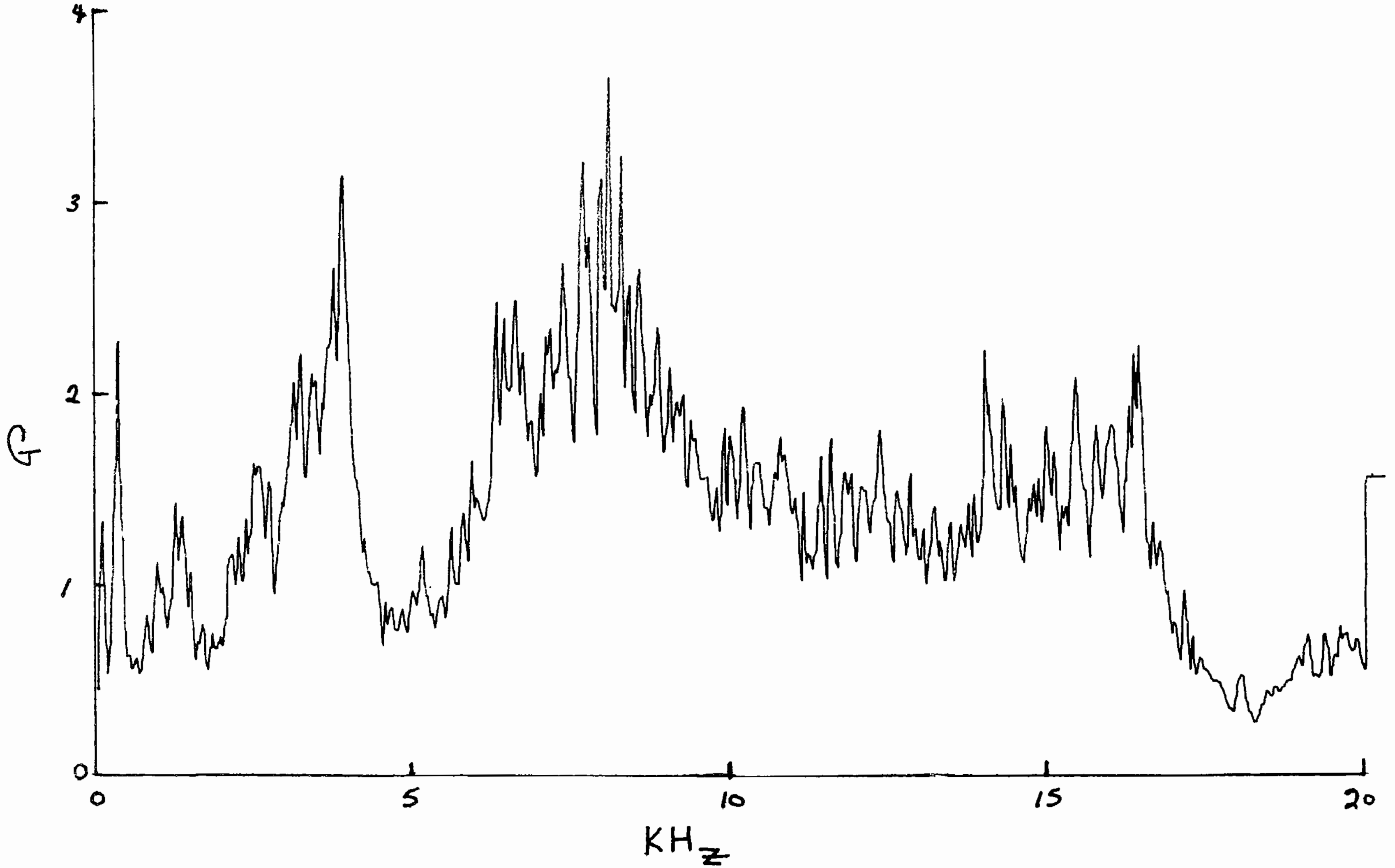
FV12-6

FV12 - 6 2.8 L, Ford V-6
Intake Manifold front (normal)
Iso-octane, 40-70 MPH Accel., NK
(TI 810/827)



FV12 -7 [2]

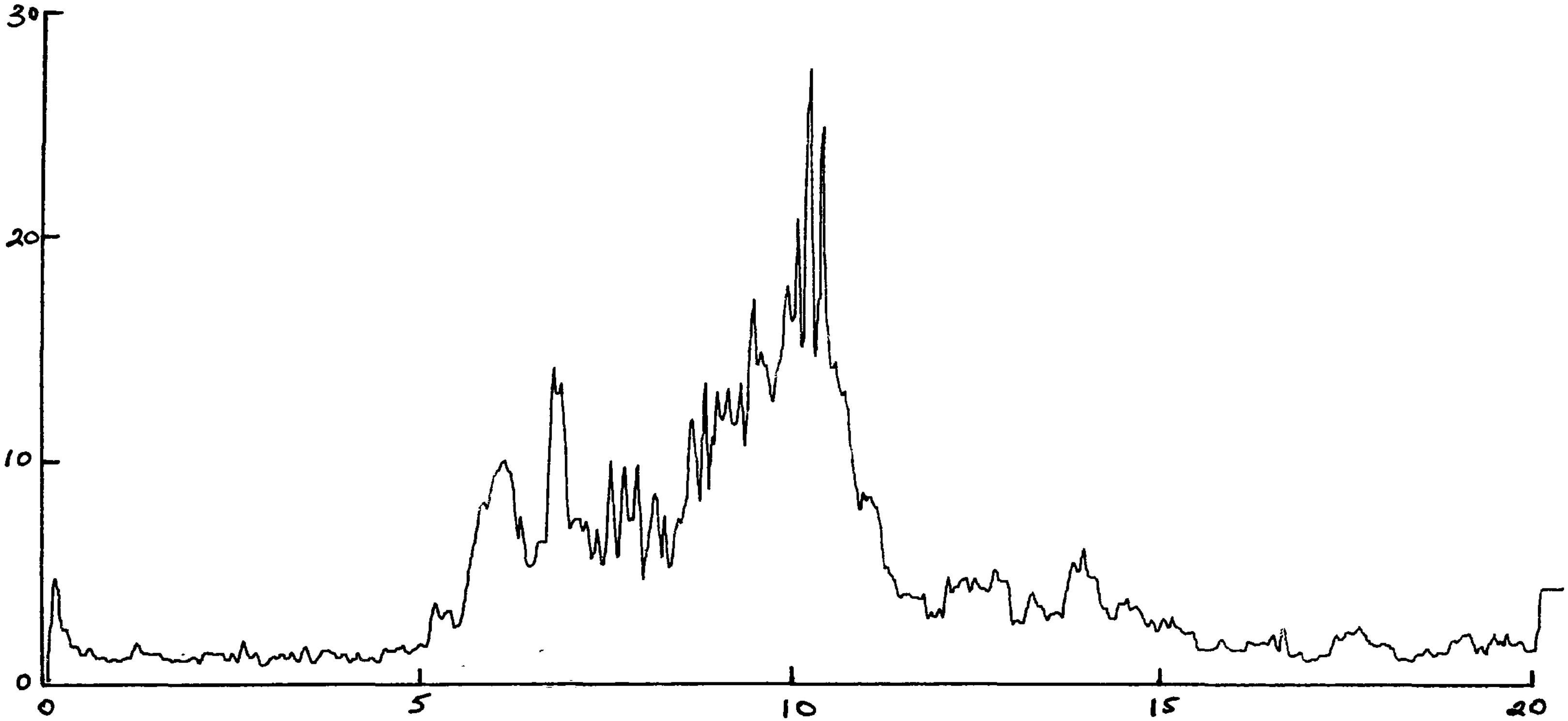
FV12 - 7   2.8 L, Ford V-6
Driver side rear head (axial)
Iso-octane, 40-70 MPH Accel, NK
(TI 810/827)




- 609 -

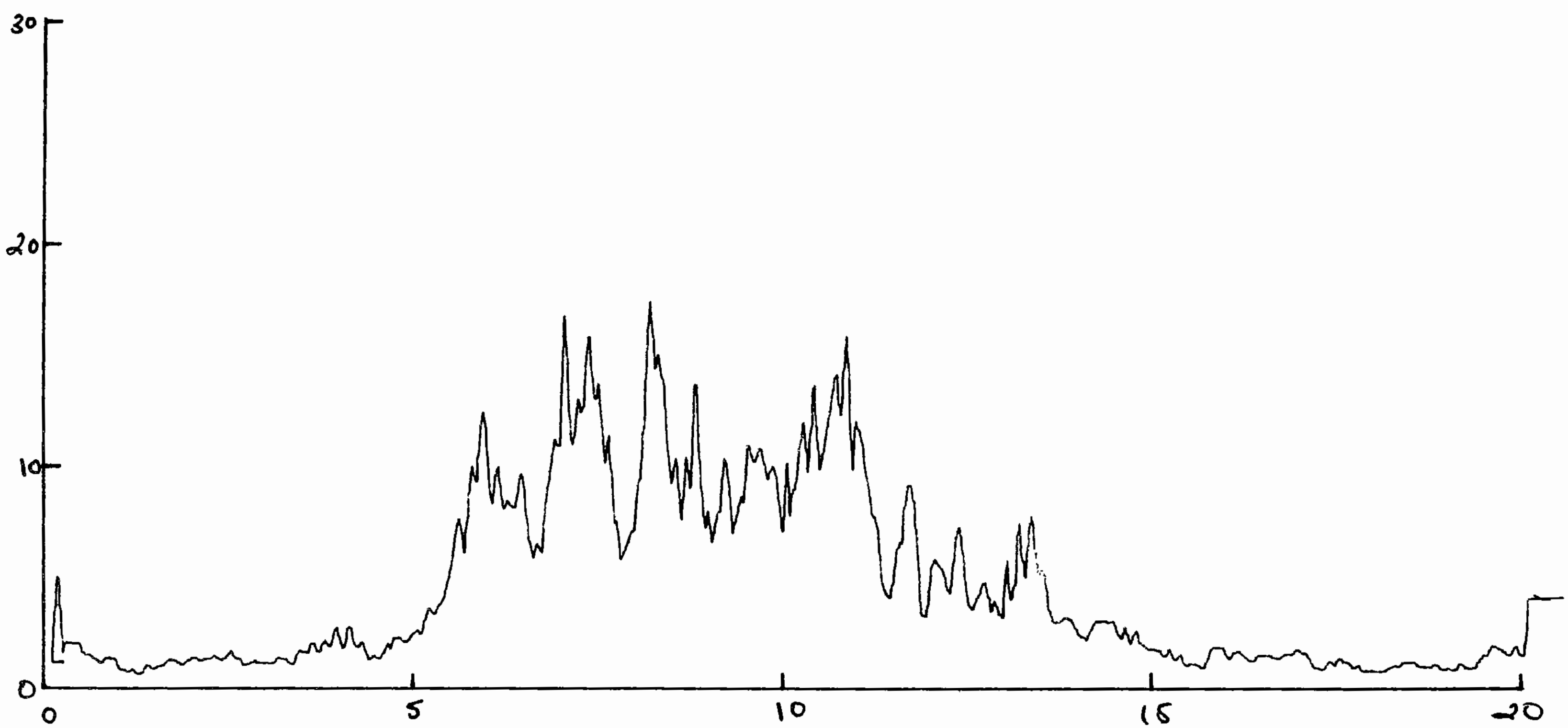
FV13-5
10V scale
(x10)

FV13 - 5   2.8 L, Ford V-6
Intake manifold rear (normal)
C-82, 40-70 MPH Accel., Too heavy
to rate, (TI 857/868)



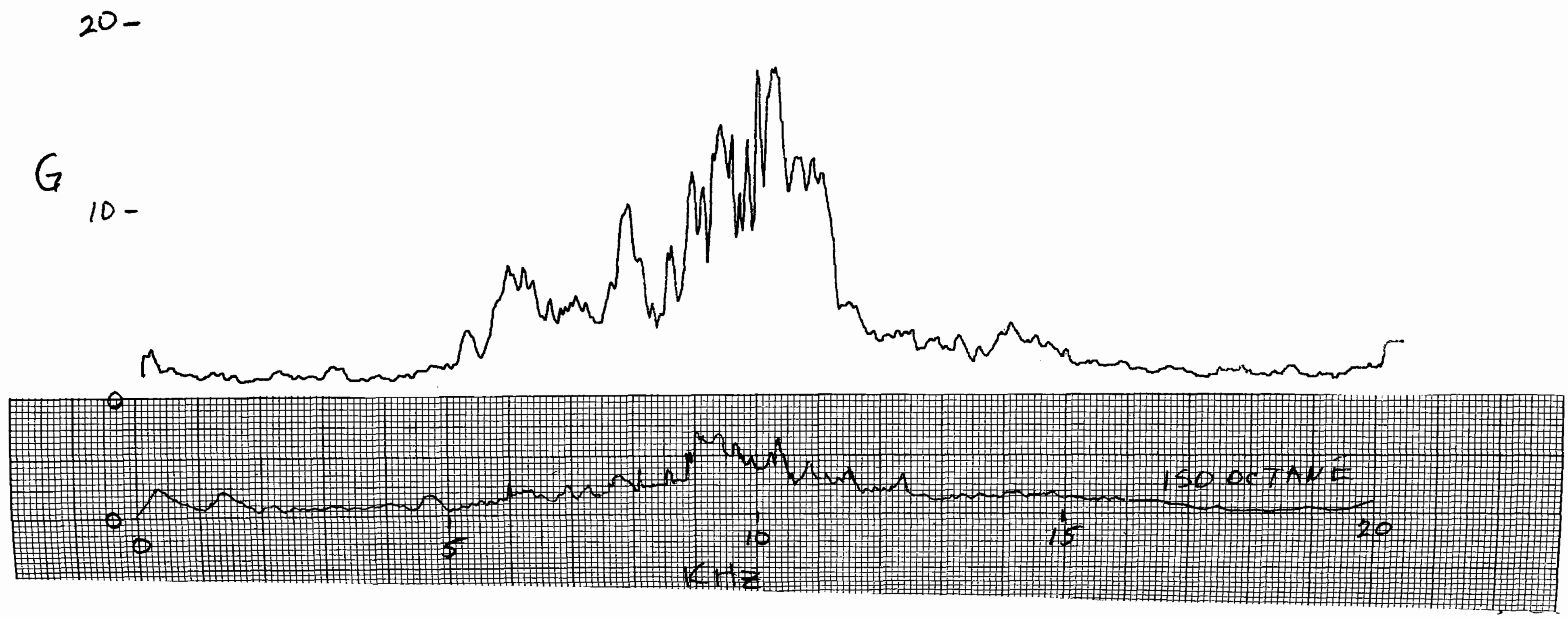
FV13-6
10volt
Range.

FV13 - 6   2.8 L, Ford V-6
Intake manifold front (normal)
C-82, 40-70 MPH Accel., Too heavy
to rate, (TI 857/868)



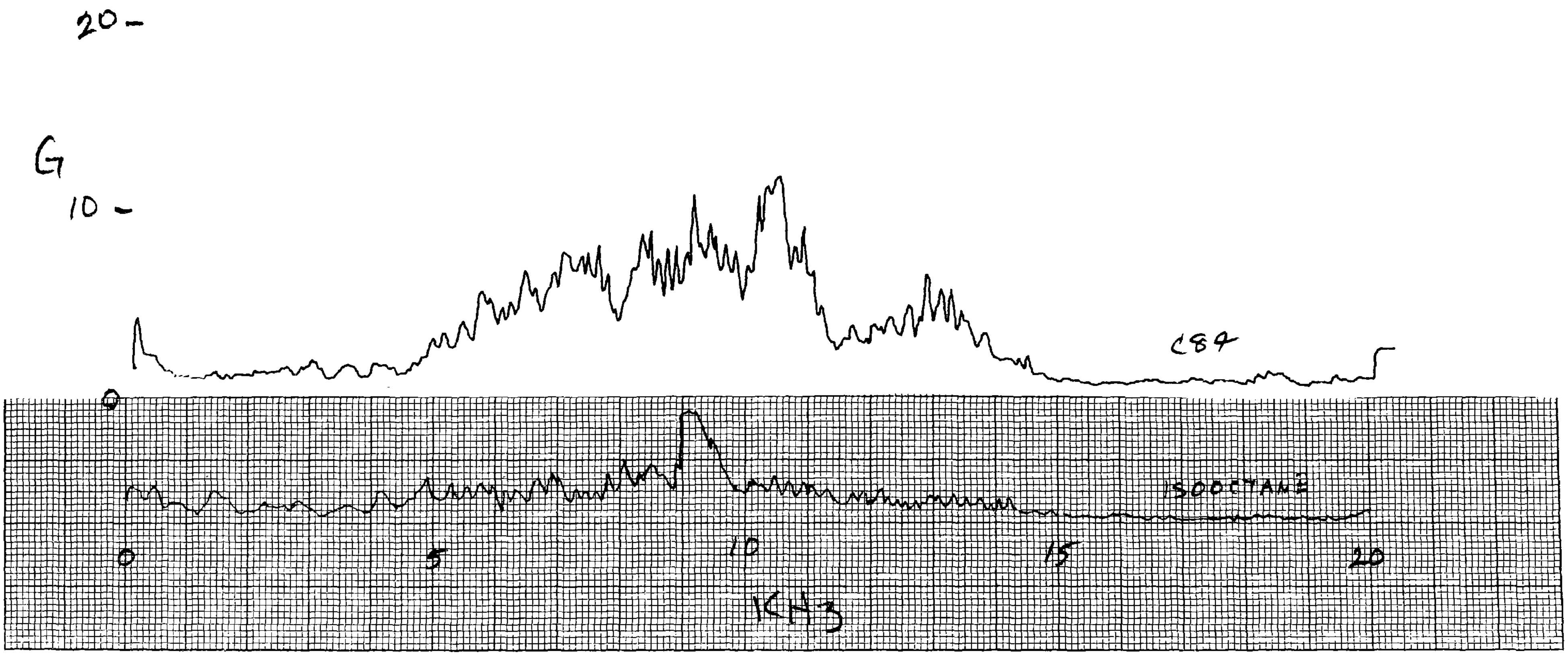
FV14-5
10 VOLT
Scale

FV14 - 5    2.8 L, Ford V-6    TOP
Intake manifold rear (normal)
C-84, 40-70 MPH Accel., VL+
(TI 889/904)



FV14-6
10VOLT
Scale

FV14 - 6   2.8 L, Ford V-6
Intake manifold front (normal)
C-84, 40-70 MPH Accel., VL+
(TI 889/904)

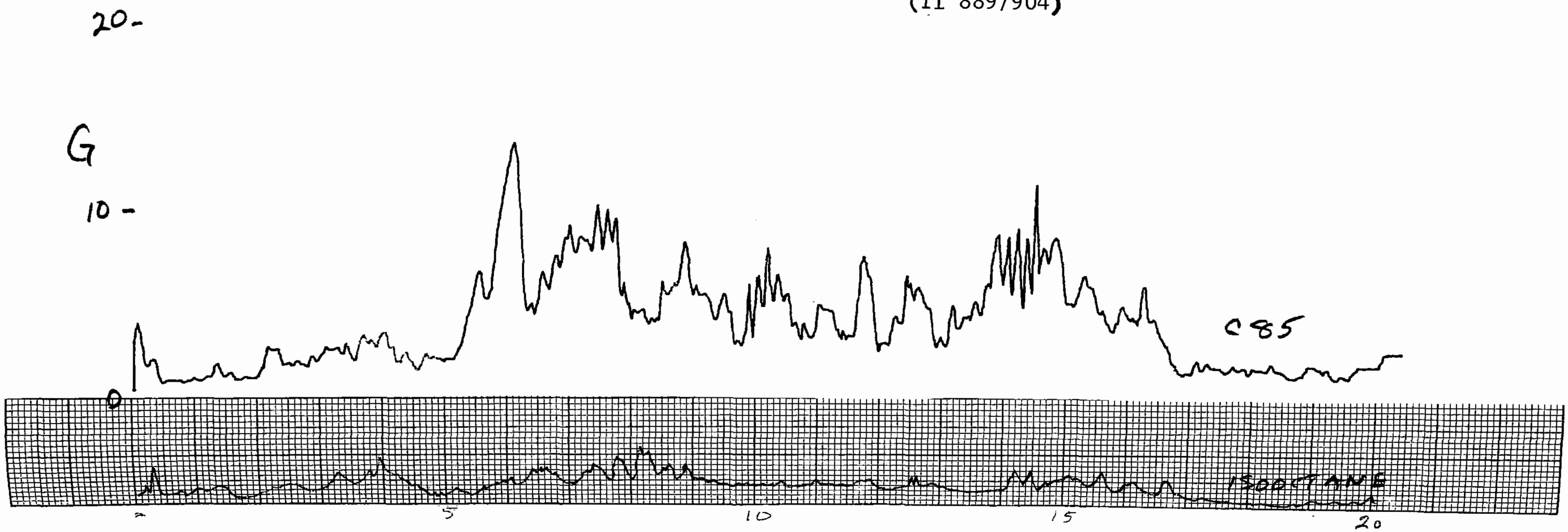


FV14-7
10V scale

DRIVERS SIDE
REAR HEAD
AXIAL
40-70 MPH

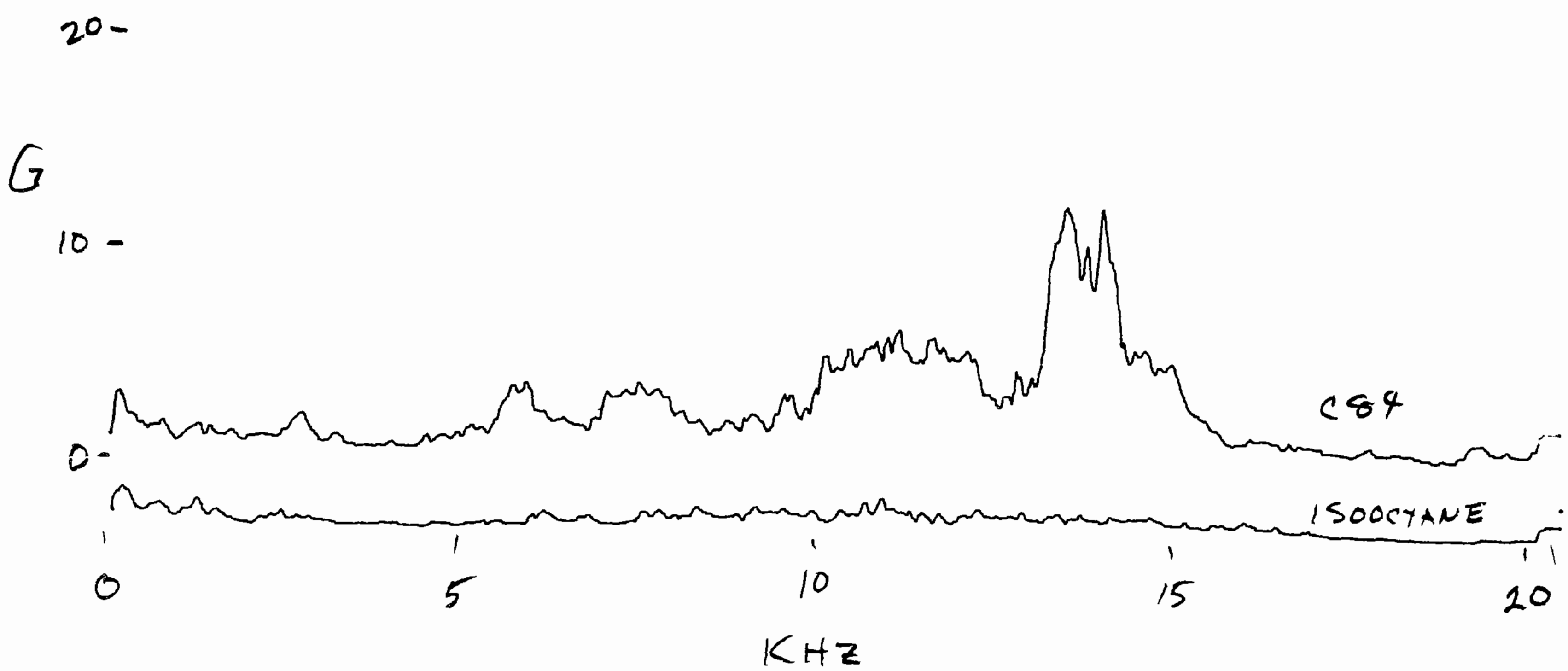
TOP C85
BOTTOM ISOOCTANE

FV14 - 7 2.8 L, Ford V-6
Driver side rear head (axial)
C-84 40-70 MPH Accel., VL+
(TI 889/904)



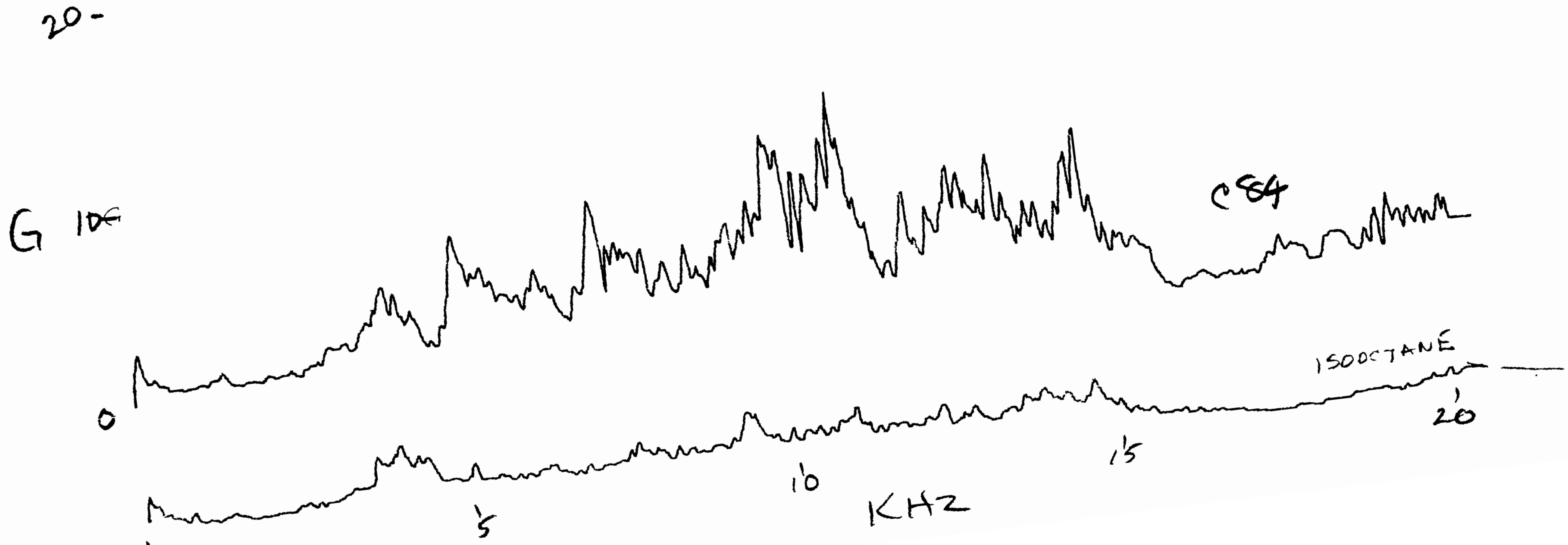
FV15-5
10V
Scale

FV15 - 5   2.8 L, Ford V-6
Head front bolt driver side (normal)
C-84, 40-70 MPH Accel., VL+
(TI 926/942)



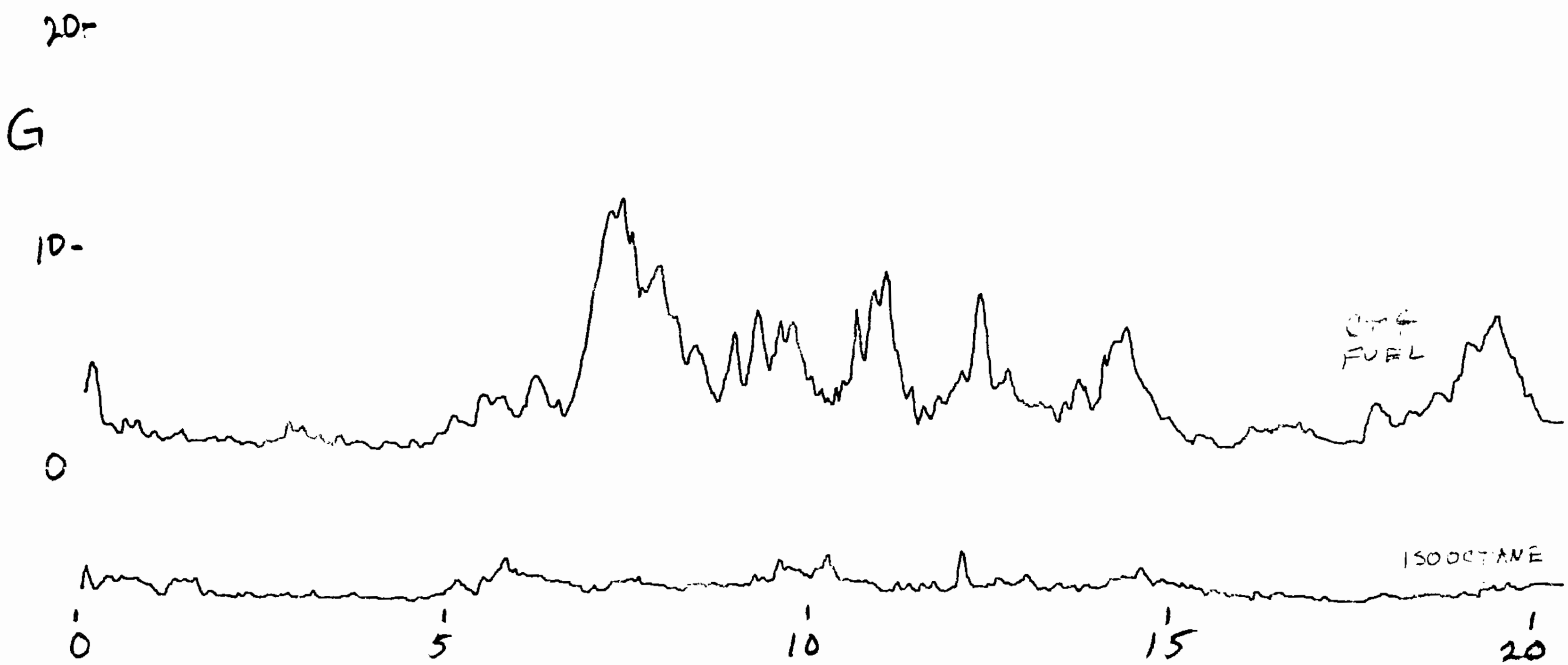
10V Scale

FV15 - 6   2.8 L, Ford V-6
Passenger side rear head (axial)
C-84 40-70 MPH Accel., VL+
(TI 926/942)



FV15-7
10V scale

FV15 - 7   2.8 L, Ford V-6
Head front bolt passenger side(normal)
C-84, 40-70 MPH Accel., VL+
(TI 926/942)



## TECHNICAL REPORT DATA
*(Please read Instructions on the reverse before completing)*

| | | |
|---|---|---|
| 1. REPORT NO. EPA 460/3-78-009 | 2. | 3. RECIPIENT'S ACCESSION NO. |
| 4. TITLE AND SUBTITLE 91 RON-Increased Compression Ratio Engine Demonstration | | 5. REPORT DATE October 1978 |
| | | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) Dr. Patrick E. Godici<br>Dr. Bernhard J. Kraus | | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS Exxon Research and Engineering Company<br>Products Research Division<br>Linden, NJ 07036 | | 10. PROGRAM ELEMENT NO. |
| | | 11. CONTRACT/GRANT NO. 68-03-2162 |
| 12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency<br>Office of Mobile Source Air Pollution Control<br>Office of Air, Noise and Radiation<br>Emission Control Technology Division<br>2565 Plymouth Rd., Ann Arbor, MI 48105 | | 13. TYPE OF REPORT AND PERIOD COVERED |
| | | 14. SPONSORING AGENCY CODE EPA/200/05 |
| 15. SUPPLEMENTARY NOTES | | |

16. ABSTRACT


This program was an experimental effort to evaluate several methods of reducing the octane requirement of a 350 CID Chevrolet engine (1975 California model). Increased squish and two spark plugs per cylinder did not provide the expected gains in this particular application. Aluminum heads and a knock-actuated spark control system were identified as potential methods of reducing octane requirement.

The spark control system was incorporated into a vehicle emission control system to enable the use of higher compression ratio heads without substantial losses in emission control and with a gain in fuel economy.


17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Driveability<br>Exhaust Emissions<br>Fuel Economy<br>Octane Requirement Increase | Light-Duty Vehicles<br>1975 FTP Emission Tests<br>Octane Rating | |

| | | |
|---|---|---|
| 18. DISTRIBUTION STATEMENT Unlimited | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES |
| | 20. SECURITY CLASS *(This page)* | 22. PRICE |

## INSTRUCTIONS

1. **REPORT NUMBER**
Insert the EPA report number as it appears on the cover of the publication.

2. **LEAVE BLANK**

3. **RECIPIENTS ACCESSION NUMBER**
Reserved for use by each report recipient.

4. **TITLE AND SUBTITLE**
Title should indicate clearly and briefly the subject coverage of the report, and be displayed prominently. Set subtitle, if used, in smaller type or otherwise subordinate it to main title. When a report is prepared in more than one volume, repeat the primary title, add volume number and include subtitle for the specific title.

5. **REPORT DATE**
Each report shall carry a date indicating at least month and year. Indicate the basis on which it was selected *(e.g., date of issue, date of approval, date of preparation, etc.).*

6. **PERFORMING ORGANIZATION CODE**
Leave blank.

7. **AUTHOR(S)**
Give name(s) in conventional order *(John R. Doe, J. Robert Doe, etc.).* List author's affiliation if it differs from the performing organization.

8. **PERFORMING ORGANIZATION REPORT NUMBER**
Insert if performing organization wishes to assign this number.

9. **PERFORMING ORGANIZATION NAME AND ADDRESS**
Give name, street, city, state, and ZIP code. List no more than two levels of an organizational hirearchy.

10. **PROGRAM ELEMENT NUMBER**
Use the program element number under which the report was prepared. Subordinate numbers may be included in parentheses.

11. **CONTRACT/GRANT NUMBER**
Insert contract or grant number under which report was prepared.

12. **SPONSORING AGENCY NAME AND ADDRESS**
Include ZIP code.

13. **TYPE OF REPORT AND PERIOD COVERED**
Indicate interim final, etc., and if applicable, dates covered.

14. **SPONSORING AGENCY CODE**
Insert appropriate code.

15. **SUPPLEMENTARY NOTES**
Enter information not included elsewhere but useful, such as: Prepared in cooperation with, Translation of, Presented at conference of, To be published in, Supersedes, Supplements, etc.

16. **ABSTRACT**
Include a brief *(200 words or less)* factual summary of the most significant information contained in the report. If the report contains a significant bibliography or literature survey, mention it here.

17. **KEY WORDS AND DOCUMENT ANALYSIS**
(a) DESCRIPTORS - Select from the Thesaurus of Engineering and Scientific Terms the proper authorized terms that identify the major concept of the research and are sufficiently specific and precise to be used as index entries for cataloging.

(b) IDENTIFIERS AND OPEN-ENDED TERMS - Use identifiers for project names, code names, equipment designators, etc. Use open-ended terms written in descriptor form for those subjects for which no descriptor exists.

(c) COSATI FIELD GROUP - Field and group assignments are to be taken from the 1965 COSATI Subject Category List. Since the majority of documents are multidisciplinary in nature, the Primary Field/Group assignment(s) will be specific discipline, area of human endeavor, or type of physical object. The application(s) will be cross-referenced with secondary Field/Group assignments that will follow the primary posting(s).

18. **DISTRIBUTION STATEMENT**
Denote releasability to the public or limitation for reasons other than security for example "Release Unlimited." Cite any availability to the public, with address and price.

19. & 20. **SECURITY CLASSIFICATION**
DO NOT submit classified reports to the National Technical Information service.

21. **NUMBER OF PAGES**
Insert the total number of pages, including this one and unnumbered pages, but exclude distribution list, if any.

22. **PRICE**
Insert the price set by the National Technical Information Service or the Government Printing Office, if known.