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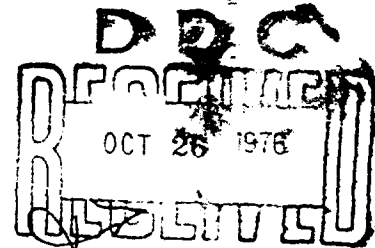
ENGINE EXPERIMENTS WITH FIRE SAFE FUELS

**FINAL REPORT
AFLRL NO. 31**

by

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A. A. Johnston**

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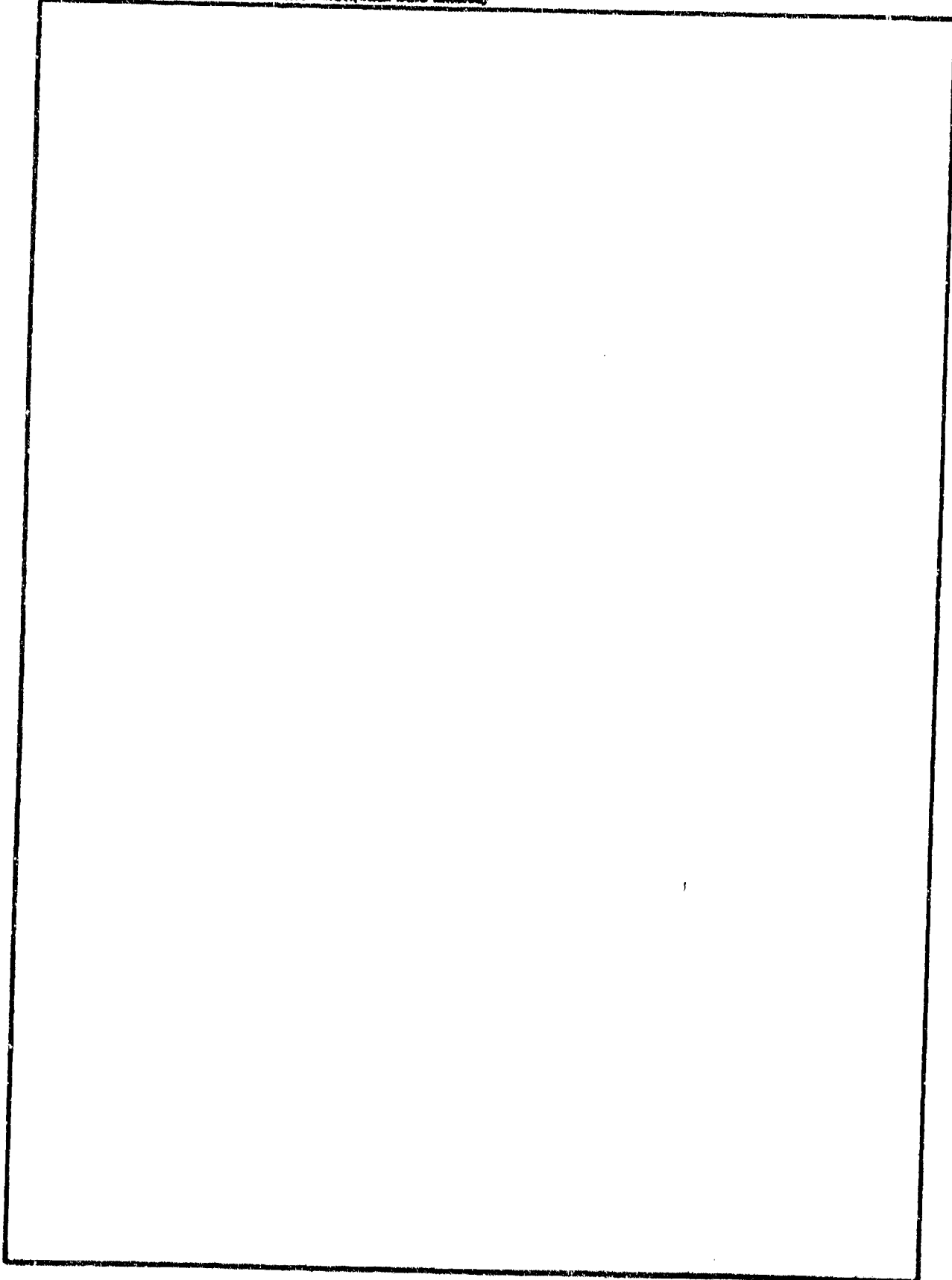
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I. INTRODUCTION

There is an acknowledged need for the development of fuels which will burn satisfactorily in engines but will not burn as a result of enemy attack on combat vehicles. The availability of such a fuel would not only reduce vehicle vulnerability resulting in a saving of lives, but would also provide for significant weight savings due to reduction in armor surrounding the vehicle fuel tank system. One approach currently being investigated involves using halogenated hydrocarbons and is principally a result of research done by the Terminal Ballistics Laboratory at the Ballistics Research Labs. Initial research was conducted on diesel fuel containing dibromomethane and vulnerability results indicated significant reductions in fires when dibromomethane up to 10 percent vol was added to the fuel. Following the initial vulnerability experiments, the treated fuel was evaluated in a single cylinder research engine (CFR) and a six cylinder production engine (Cummins) for performance and possible materials degradation. CFR engine results showed there to be no significant effects on fuel ignition quality. Work with the Cummins engine showed there to be a significant decrease in power output (predicted by the decrease in Btu) although the engine was responsive throughout the speed and load range. Additionally, some attack of combustion products on engine materials was noted.*

Continued research for the best type material to achieve maximum vulnerability reduction resulted in a change from dibromomethane to a mixture of materials containing approximately 85 wt percent bromochloromethane, 10 wt percent methylene chloride, and 5 wt percent methylene bromide (referred to as BCM). Gunfire tests indicated a good measure of fire safety when 5 percent of this mixture was added to diesel fuel. However, the following questions remained to be answered:

- How would diesel fuel + 5 percent bromochloromethane respond in diesel engines?
- What is the composition of the exhaust and what affect might this have on human, animal, and plant life?
- What are the flammability limits of bromochloromethane when blended into diesel fuel?

Since answers were not readily available from prior research or previously compiled data, these questions formed the basis for the research work described in this and companion reports.

*USAFRLR Letter Report to TBL, 6 November 1972, Subj: Evaluation of Diesel Fuel Containing Dibromomethane (Contract DAAD05-72-C-0410).

II. SUMMARY AND CONCLUSIONS

A series of experiments were performed in a single cylinder research engine using diesel fuel and diesel fuel plus 5 vol percent bromochloromethane in order to determine the response of the fuel blend to changes in injection system parameters. Initial baseline data showed a decrease in power for BCM-containing fuel run under the same conditions as diesel fuel. When run at diesel power, there was a significant decrease in efficiency. A series of experiments was then conducted to investigate injection system variables including camshaft profile, barrel and plunger diameter, injection nozzle configuration, and nozzle hole size. Part load performance was also evaluated. From these experiments, the following was concluded:

- Open chamber diesel engines can be modified to perform satisfactorily on diesel fuel plus 5 percent BCM (satisfactorily defined as diesel power) and no greater than 9.4 percent increase in fuel consumption on a mass basis.
- Diesel fuel plus 5 percent BCM responds basically the same as neat diesel fuel to changes in the fuel-air mixing parameters. However, diesel fuel plus 5 percent BCM is more sensitive to changes than neat diesel fuel.
- Presence of 5 percent BCM has no deleterious effect on the ignition delay period.
- The data indicate there to be no chemical inhibition of the combustion process due to the presence of 5 percent BCM. The treated fuel burns like a diesel fuel, although more Btu input is required to overcome the heat capacity of the BCM.
- Differences in the combustion events between diesel fuel and the treated fuel can be explained by the differences in viscosity, density, and volatility which affect the injected spray pattern.

III. PROGRAM PLAN AND OBJECTIVES

Following the engine runs with dibromomethane, questions arose concerning the type of changes which would have to be made to an engine in order to achieve diesel fuel power levels and still maintain reasonable fuel economy. As a result, the decision was made to conduct a combustion study of diesel fuel treated with 5 percent BCM in a single cylinder research engine. The principle objective would be to determine the response of the fuel blend to changes in injection system parameters in order to establish guidelines under which full scale engines could be modified to achieve satisfactory performance on diesel fuel + BCM. A secondary objective was to determine the mechanism of combustion inhibition of bromochloromethane in diesel fuel.

IV. PROGRAM DETAILS

A. Fuel Properties

The physical and chemical properties of the base diesel fuel and treated fuel are compared in Table 1. The base fuel was a reference diesel fuel (Cat 1-H) used for oil testing with properties typical of No. 2 diesel fuels. The specification under which the fuel is procured is quite narrow and closely controlled, and significantly reduces the batch to batch variations. Therefore, the property control of the test fuel was insured throughout the duration of the program. The bromochloromethane was added at 5 percent by volume to the base fuel. The particular properties whose

TABLE 1. NEAT AND TREATED FUEL PROPERTIES

Property	Neat Diesel Fuel (Cat 1-H)	Diesel Fuel +5% BCM
Density	0.86	0.90
Viscosity at 100°F	3.40	2.56
Flash Point, °F	185	+230
Cloud Point, °F	+23	
Pour Point, °F	+18	
Water & Sediment	0	
Carbon Residue, %	0.10	-
Lamp Sulfur, %	0.415	-
Acid No.	1.08	
Aniline No., °F	145	
Copper Corrosion	1A	
Distillation, °F		
IBP	410	140
10%	468	445
50%	519	520
90%	603	601
EP	689	675
Cetane No.	47	
Heat of Combustion, BTU/lb	19,550	17,673

TABLE 2. FUEL VARIABLES MOST SIGNIFICANT TO SPRAY AND COMBUSTION

	Density	BTU/lb	BTU/Gal	Vis, cs	Boiling Range, °F
Diesel Fuel (Cat 1-H)	0.86	19,500	139,483	3.40	410-689
W/5% BCM	0.90	17,672	133,145	2.56	140-675

TABLE 3. CLR OPEN CHAMBER ENGINE

Bore	3.80 in.
Stroke	3.75 in.
Displacement	42.5 in ³
Compression Ratio	16.5:1
Valve Timing (In)	18° BTDC-38° ABDC (Ex) 124° ATDC-20° ATDC 38° Overlap

differences may affect the spray and combustion process are compared in Table 2. Addition of bromochloromethane increased the density while significantly decreasing the viscosity. The heat content was decreased on a mass basis that is a total of 9.4 percent for the test fuel with 5 percent bromochloromethane and 4.5 percent on a volume basis. Additionally, the boiling range of bromochloromethane is approximately 105° to 200°F, whereas, the initial boiling point of the base diesel fuel is approximately 410°F. Therefore, there are significant heat content and physical property differences between the two fuels which would not only account for a difference in power output, but could also result in a significant spread in injection system and spray performance.

B. Engine Parameter Investigation

1. Description of Engine

The engine chosen for this phase of research was the cooperative lubricants research (CLR) open-chamber diesel engine manufactured by the Laboratory Equipment Corporation (LABECO). Engine characteristics are shown in Table 3. Of particular interest is the relatively non-typical valve overlap of 38° as compared to a more normal 4 or 5°. By way of explanation, LABECO has developed a widely used spark-ignition CLR

engine and has done very little development on the diesel version. Many parts of the two engines, including the camshaft, are interchangeable. Therefore, the overlap normally associated with spark ignition engines was also found on the diesel version. The overlap, combined with the relatively low (for an engine of this displacement) $16\frac{1}{2}$ to 1 compression ratio, results in relatively anemic performance under best diesel conditions, but still provides an adequate research tool for comparing the relative combustion performance of fuels. The combustion chamber utilizes a deep, small diameter cup in the piston into which the fuel spray is directed (Figure 1). Additionally, a shrouded intake valve is used to control air swirl in the chamber.

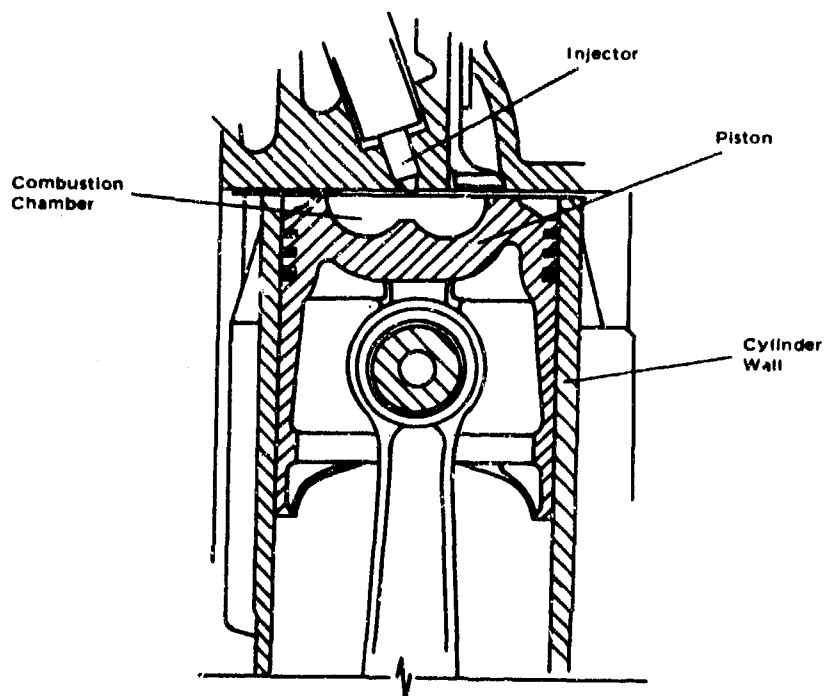


FIGURE 1. CLR OPEN CHAMBER ENGINE (HALF SIZE)

2. Baseline Data

Initial runs were conducted to obtain baseline data on the reference diesel fuel as well as preliminary data on diesel fuel containing 5 percent BCM. These results are shown in Figure 2 along with the engine conditions (Table 4) in which indicated horsepower and indicated specific fuel consumption are plotted versus engine speed. These data represent best power timing for diesel fuel at No. 5 to No. 7 smoke level (Robert Bosch). Then the treated fuel (diesel + 5 percent BCM) was run under conditions identical to the diesel fuel. A lower horsepower curve was the result. Additionally, there was a decrease in efficiency as

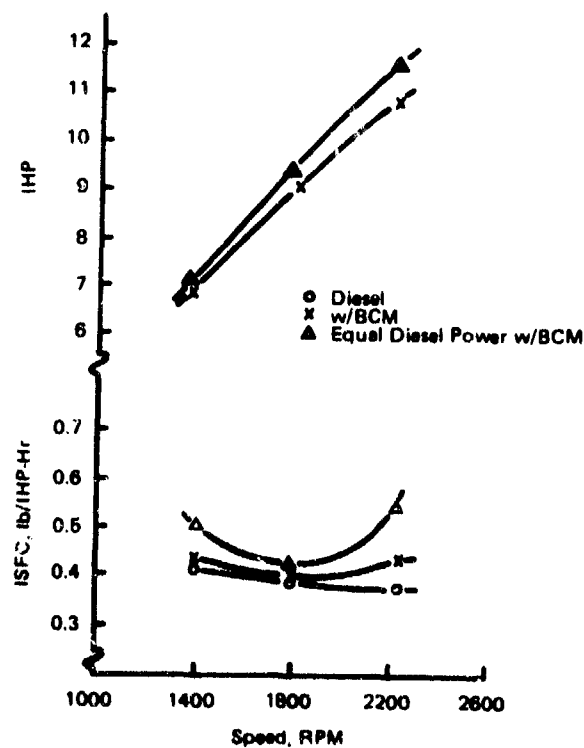


FIGURE 2. BASELINE RESULTS

TABLE 4. BASELINE COMPARISON

Nozzle: NL-141
 4 Hole
 0.0098-in. Dia.
 3.02×10^{-4} in² Area

Camshaft: Basic Metric
 Plunger Dia: 10 mm

Engine Speed, RPM	Nozzle Opening: 2500 psi		
	1400	1800	2200
Diesel Fuel } Indicated Horsepower	7.0	9.0	11.0
} ISFC, lb/IHp-hr	0.419	0.389	0.377
Diesel Fuel + 5% BCM, Diesel Conditions } Indicated Horsepower	6.8	8.6	10.6
} ISFC, lb/IHp-hr	0.464	0.394	0.447
Diesel Fuel + 5% BCM, Diesel Power } Indicated Horsepower	7.0	9.0	11.0
} ISFC, lb/IHp-hr	0.506	0.427	0.541

indicated by the higher ISFC for the treated fuel. Therefore, under identical engine conditions, both a decrease in power and efficiency were noted with the bromochloromethane containing fuel. The final set of baseline data was obtained by increasing the flow rate of fuel with BCM so that the same power, as indicated with diesel fuel, was obtained. Under these conditions, the indicated specific fuel consumption was the primary comparative criteria, and as illustrated in Figure 2, there was a decrease in efficiency ranging from 10 to 40 percent with the greatest difference shown at higher speeds.

3. Criteria and Test Procedures

As a result of the data obtained during the baseline evaluations, a procedure was established in which the primary criteria for comparing performance of fuels (with and without BCM) would be engine efficiency in terms of ISFC. This procedure involved operating at 1400, 1800, and 2600 rpm (the indicated horsepower level obtained during the baseline runs). Best power timing would be established for each fuel and each set of injection system variables and fuel rate determined. Therefore, power would be the independent variable and fuel rate or efficiency would be the dependent variable. Satisfactory performance for this series of experiments was defined as horsepower equal to diesel performance with the best specific fuel consumption possible over the range of variables investigated. Based on the difference in heat content between diesel fuel and diesel fuel + 5 percent BCM, a decrease in ISFC of 9.4 percent would represent equal Btu utilization.

4. Experimental Results

The experimental program involved an investigation of the injection system variables shown in Table 5. Time did not permit a full factorial matrix of experiments, therefore, runs were selected to provide the following comparisons:

a. *Camshaft Profile Effect*

4 Hole Nozzle (3.02×10^{-4} in²) Area; 10 mm barrel and plunger
 Slow Rate vs Fast Rate

b. *Barrel & Plunger*

4 Hole Nozzle - 10 mm vs 7 mm
 5 Hole Nozzle - 10 mm vs 7 mm

c. *Nozzles*

(1) *Effect of Number of Holes (Total Area Equal)*

10 mm B&P - 4 Hole (3.02×10^{-4} in²) vs
 6 Hole (2.94×10^{-4} in²)

7 mm B&P -- 5 Hole ($2.45 \times 10^{-4} \text{ in}^2$) vs

3 Hole ($2.26 \times 10^{-4} \text{ in}^2$)

(2) Effect of Total Area (Number of Holes Equal)

10 mm B&P -- 4 Hole $3.02 \times 10^{-4} \text{ in}^2$ vs $5.23 \times 10^{-4} \text{ in}^2$)

In all cases, runs with diesel fuel and diesel fuel with bromochloromethane were made back to back. Duplicate runs were made with several of the variables when data appeared questionable and a part load analysis was conducted to verify full load results. Additionally, combustion data were obtained on most of the runs. Heat release data were calculated from the pressure time diagrams for analysis of events during the combustion expansion parts of the cycle. The engine performance and combustion data are contained in Appendix I and heat release data in Appendix II. The results of each of the performance comparisons were as follows:

TABLE 5. DESCRIPTION OF INJECTION SYSTEM VARIABLES

Camshaft			
Slow Acceleration Rate			
Fast Acceleration Rate			
Nozzles			
3 Hole	0.0098 In. Diameter	$2.26 \times 10^{-4} \text{ in}^2$ Total Area	(123)
4 Hole	0.0098 In. Diameter	$3.02 \times 10^{-4} \text{ in}^2$ Total Area	(141)
4 Hole	0.0129 In. Diameter	$5.23 \times 10^{-4} \text{ in}^2$ Total Area	(537)
5 Hole	0.0079 In. Diameter	$2.45 \times 10^{-4} \text{ in}^2$ Total Area	(6961)
6 Hole	0.0079 In. Diameter	$2.94 \times 10^{-4} \text{ in}^2$ Total Area	(6969)
Barrel and Plunger			
7 mm			
10 mm			

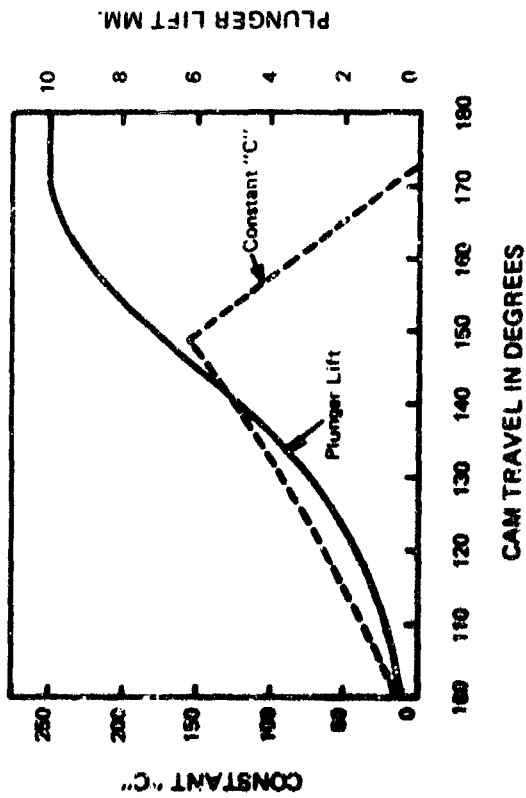
(3) Effect of Injection Pump Camshaft Profile

The two profiles investigated are characterized by the curves and data supplied by American Bosch in Figures 3 and 4.

The basic metric camshaft, which is standard with the CLR diesel engine, provides a relatively low acceleration rate, whereas the tangential cam is a fast acceleration cam resulting in higher instantaneous plunger velocity during the initial part of the delivery stroke. The relative effect of camshaft acceleration rate is illustrated by the comparisons with diesel fuel and diesel fuel + 5 percent BCM in Figure 5. As previously stated, all data were obtained at the same power setting, therefore, efficiency, in terms of indicated specific fuel consumption, is the primary comparative criterion. The effect of the injection system variable on diesel fuel performance is shown at the top of the figure and on diesel fuel + 5 percent BCM at the bottom of the figure. Therefore, diesel fuel performance can be compared as a function of the injection system variable as well as compared to the performance of diesel fuel + bromochloromethane. For this comparison, the 10 mm barrel and plunger and 4 hole nozzle were utilized. The basic metric cam data was obtained during the baseline part of the evaluation so that data were obtained at only 3 speeds. The tangential camshaft data were obtained at the 4 speeds which will be carried through for the remainder of the comparisons.

Data compiled in Figure 5 indicate that diesel fuel performance, especially through the low and mid-range, was significantly improved with the higher acceleration profile although the difference in efficiency decreased at the higher speed. The treated fuel, on the other hand, performed significantly better with the higher injection rate throughout the speed range. The dif-

PUMP TYPE APE-B, CAM PROFILE 6/1-BASIC METRIC



PUMP TYPE APE-B, CAM PROFILE 6/4-TANGENTIAL

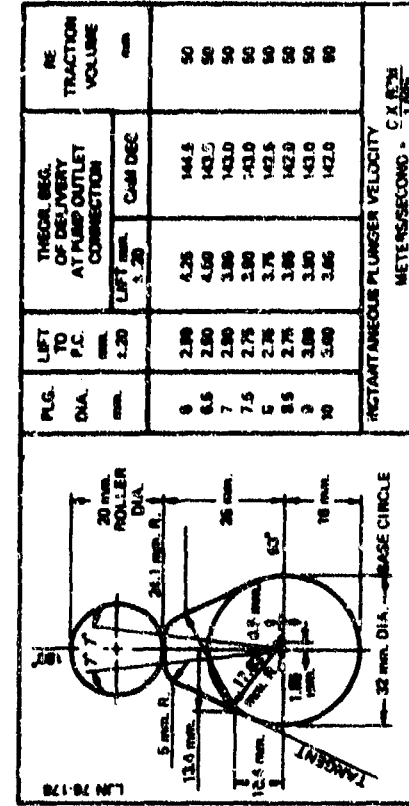
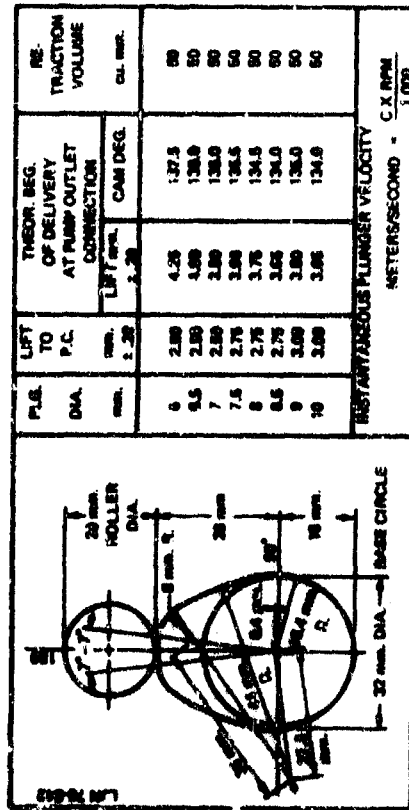
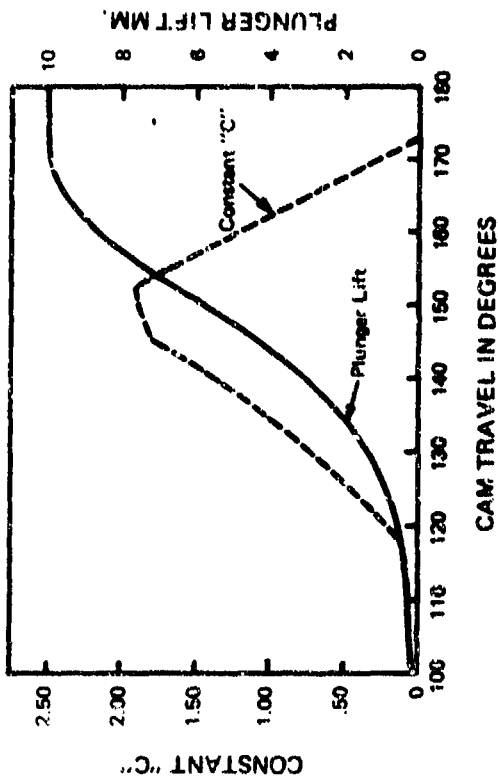


FIGURE 3. PLUNGER LIFT AND VELOCITY CHART

FIGURE 4. PLUNGER LIFT AND VELOCITY CHART

that the rate of injection, which controls rate of burning, is of greater significance with the BCM inhibitor in the fuel than for the reference diesel fuel itself. While this could be explained in terms of a chemical inhibition on rate of combustion, it could also be due to the effect on injected spray pattern and the need for injecting a greater quantity of fuel in order to achieve equal horsepower output. The analysis of the combustion event is discussed in more detail on page 15 of this report. As a result of these experiments, it was decided to conduct the remainder of the experimental program using the tangential camshaft.

(4) Effect of Plunger and Barrel Size

Two plunger and barrel diameters, 10 mm and 7 mm, were utilized to evaluate the effect of this variable. Data were obtained with two different nozzles, the 4 hole (3.02×10^{-4} sq in. total area) and 5 hole (2.45×10^{-4} sq in. total area). A comparison with the 4 hole tip is shown in Figure 6. The 4 hole tip and 10 mm barrel and plunger combination provided the best operating performance throughout all experiments for the diesel fuel + BCM. Changing to the 7 mm barrel and plunger, which would have the effect of decreasing the time rate of injection, resulted in a significant decrease in efficiency. A similar decrease in efficiency was noted at the lower speeds with diesel fuel. However, at the 2000 and 2400 rpm operating points, an improvement in efficiency with the 7 mm barrel and plunger was observed. This is believed to be a tradeoff between fuel-air mixing and rate of injection. At the lower speeds, the higher rate of diesel fuel injection with the 10 mm barrel and plunger provides better atomization and mixing, thus resulting in improved combustion. However, at the higher speeds, the injection rate with the 7 mm barrel and plunger is sufficient for adequate atomization and the slower rate of injection results in improved combustion control, therefore providing an improvement in efficiency. Analysis of the combustion data showed slightly advanced timing for the fuel with BCM compared with neat diesel, but approximately the same injection duration. There was no significant affect on ignition delay.

The performance comparison with the 5 hole tip is shown in Figure 7. Performance with the 5 hole tip for both diesel and BCM was poorer than with the 4 hole nozzle. However, again diesel fuel appeared less sensitive to injection rate than did diesel fuel + BCM. While there was a significant difference between the 7 and 10 mm performance with BCM, the difference in performance with diesel fuel was less pronounced. In fact, at all but the high speeds, the 7 mm barrel and plunger performed as well, if not better, than the 10 mm barrel and plunger. The high speed data were affected by the occurrence of multiple injections which were ultimately brought under control by increasing the nozzle opening pressure.

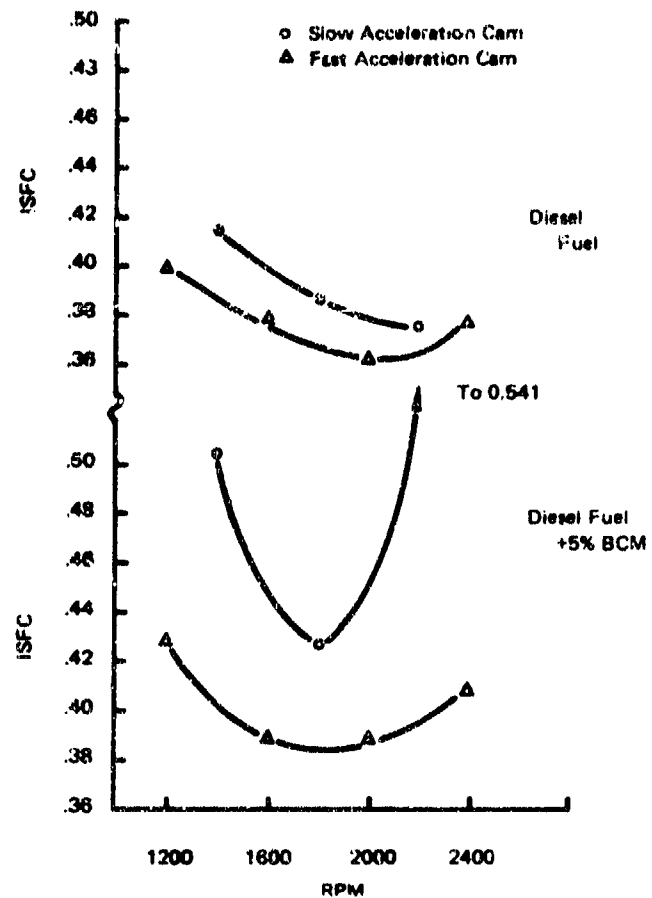


FIGURE 5. EFFECT OF CAMSHAFT
(10mm B&P 4-Hole Nozzle)

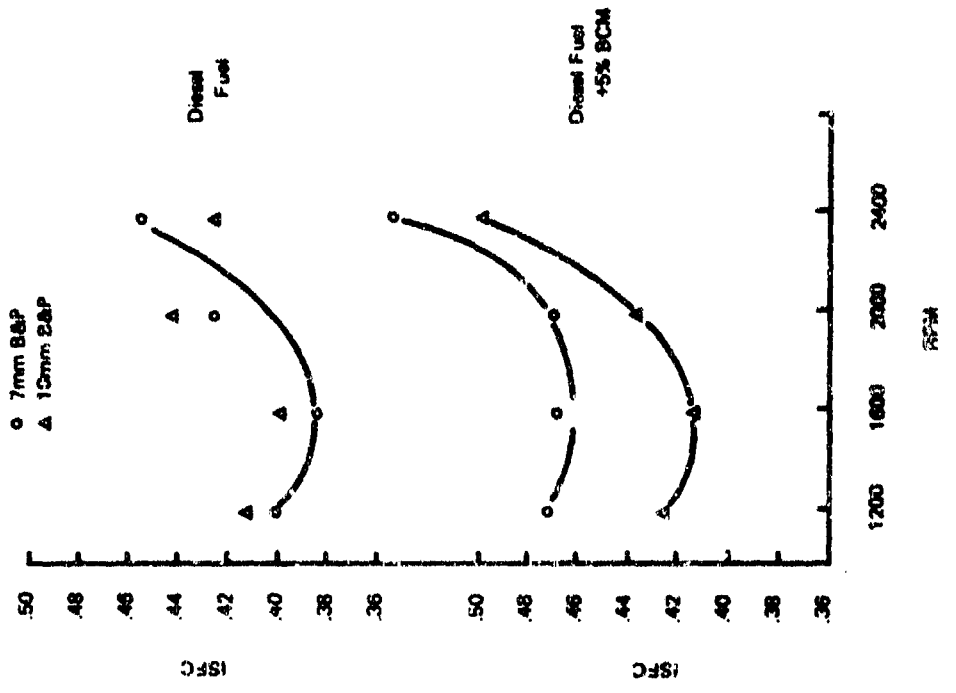


FIGURE 6. EFFECT OF BARREL & PLUNGER (4-Hole Tip)

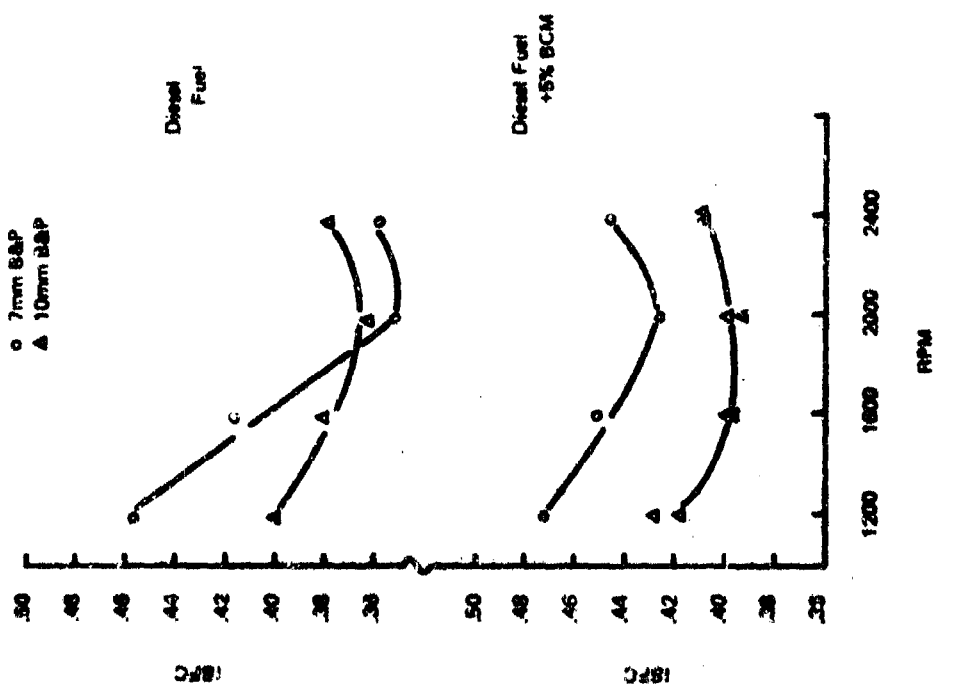


FIGURE 7. BARREL & PLUNGER EFFECT (5-Hole Tip)

(5) Effects of Nozzle Configuration

Three types of comparisons were made to observe the effect of nozzle configuration. Two sets of experiments were conducted with nozzles having approximately equal areas, but different number of holes. Then, a comparison was made with equal number of holes to determine the effect of total area. The results of these comparisons are as follows:

• Effect of Number of Holes (Areas Equal)

The first set of experiments was conducted with a 5 hole nozzle of 2.45×10^{-4} sq in. total area, and a 3 hole of 2.26×10^{-4} sq in. total area. The 7 mm barrel and plunger was used for these experiments and the results are shown in Figure 8. For both diesel fuel and diesel with BCM, 5 hole nozzle performance was better at the low speeds, whereas, 3 hole nozzle performance significantly improved at the higher speeds. In both cases, this can be explained by an improvement in spray distribution for the 3 hole nozzle as engine speed and air movement in the cylinder increased. The 5 hole nozzle performance was probably poorer as a result of under-penetration and failure to mix well with the air in the outer perimeter of the chamber. The difference at the 2400 rpm speed with BCM emphasizes again the importance of good atomization and mixing with air regardless of the presence of inhibitor.

The second experiment in this series compares the 4 hole nozzle performance (3.02×10^{-4} sq in.) to 6 hole nozzle (2.94×10^{-4} sq in.).

These data were obtained using the 10 mm barrel and plunger and are illustrated in Figure 9. As with the 3 and 5 hole nozzles, the directional effects of the 4 and 6 hole are the same with diesel fuel and the BCM-containing fuel. However, the relative differences are much greater with the BCM. The difference in number of holes with the diesel fuel would have the effect of under-penetration with the 6 hole nozzle as the speed increases, resulting in a relatively rich zone toward the center of the chamber and a lean zone toward the walls. As a result, combustion efficiency suffers. It was interesting to note the same general response of diesel + BCM to the change in injection system as observed with diesel fuel.

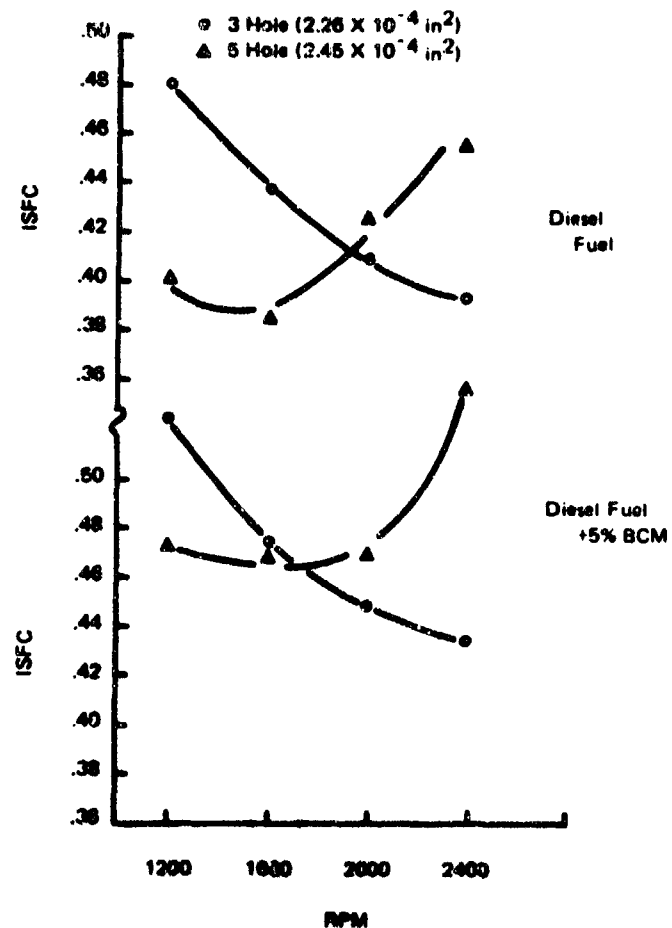


FIGURE 8. EFFECT OF NUMBER OF HOLES (7mm B&P)

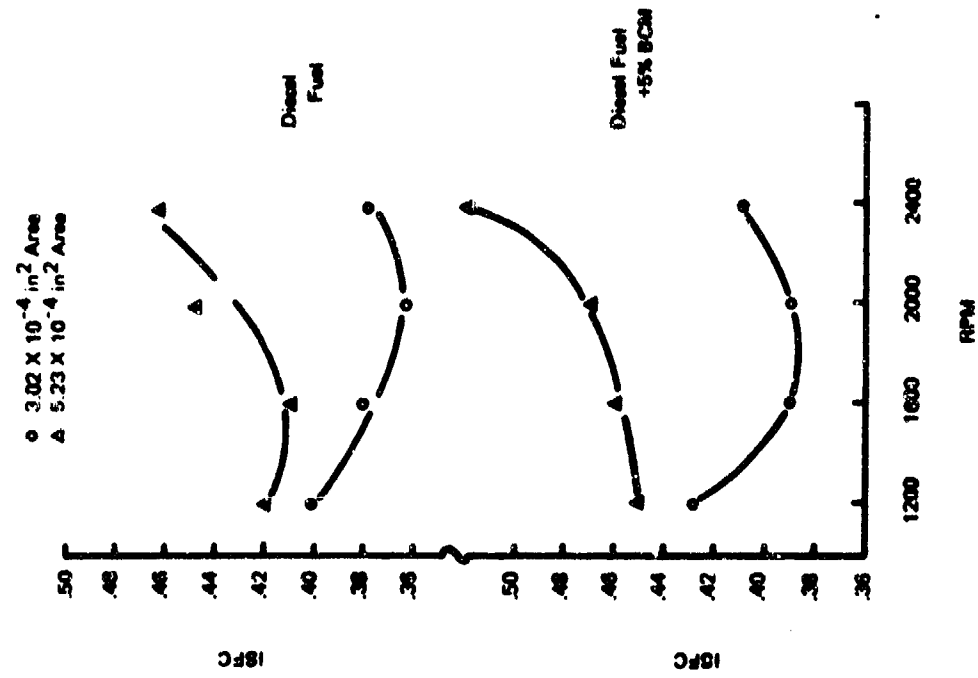


FIGURE 9. EFFECT OF NUMBER OF HOLES
(10mm B&P)

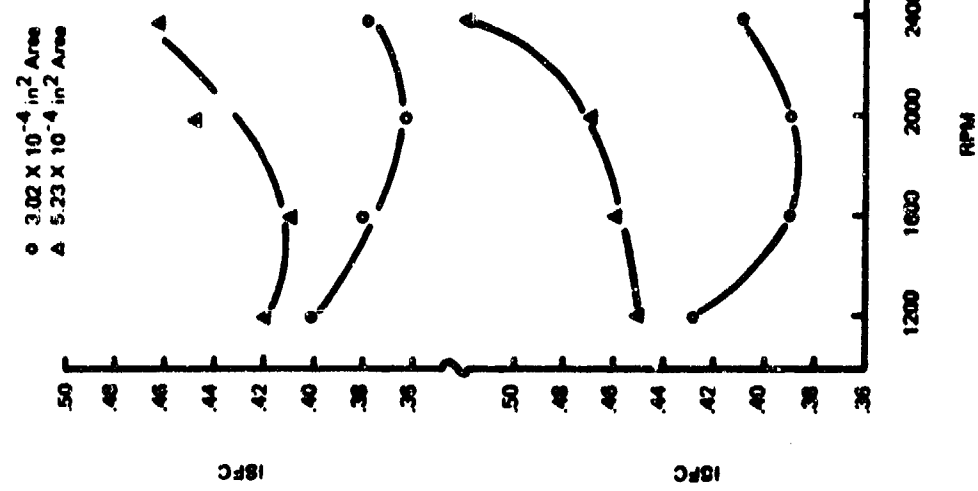


FIGURE 10. EFFECT OF TOTAL NOZZLE AREA
(4-Hole Nozzle 10mm B&P)

• *Effect of Nozzle Area (Number of Holes Equal)*

The final comparison of the effect of nozzle configuration was made with two nozzles having 4 holes, one with 3.02×10^{-4} sq in. total area and the other 5.23×10^{-4} sq in. total area. The 10 mm barrel and plunger were utilized for these comparisons as shown in Figure 10. Since the small 4 hole nozzle had the best performance for BCM and diesel fuel, the increase in total area resulted in the degradation of performance for both fuels. However, again the degradation was more marked for BCM than diesel fuel. In this case, the difference was expected since the poor performance was probably due to over-penetration and poor atomization.

(6) Part Load Analysis

To verify that the relative performance of diesel fuel containing bromochloromethane was basically the same throughout the engine load range, a series of experiments was run at 2000 rpm (best power timing) utilizing the 10 mm barrel and plunger and 4 hole nozzle. These data, illustrated in Figure 11, were obtained with diesel fuel, diesel fuel plus 5 percent BCM and diesel fuel plus 10 percent BCM. With each fuel, the engine was set up at the indicated horsepower level established during the baseline runs, then the fuel flow rate systematically decreased until the misfire limit was reached. Since the engine was run at constant speed, the airflow rate was essentially constant, thus resulting in a decreasing fuel-air ratio as the fuel flow rate dropped. However, as may be observed by the three curves, the relative effect of the BCM in the fuels remained essentially unchanged throughout the load range. Therefore, it was concluded that diesel fuel with BCM responds basically the same regardless of engine load.

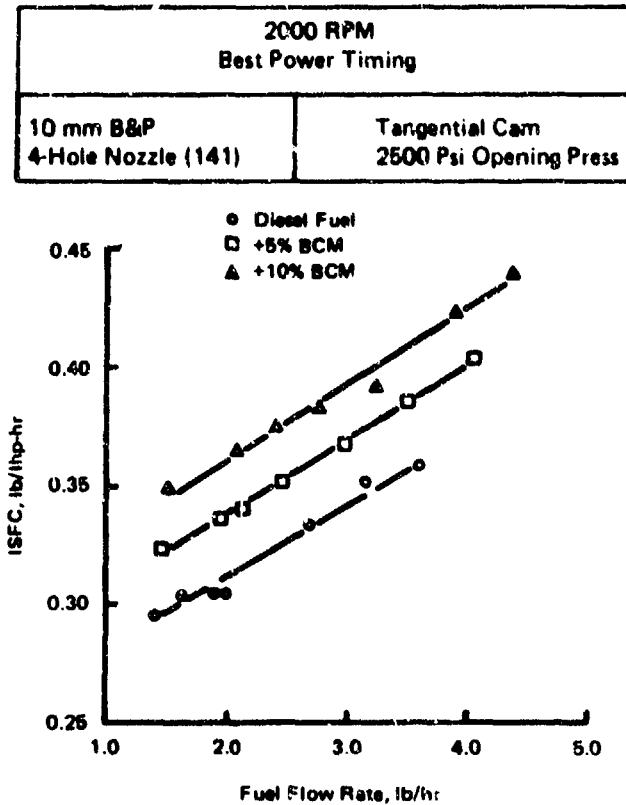


FIGURE 11. EFFECT OF FUEL FLOW RATE (ENGINE LOAD) ON PERFORMANCE

V. DISCUSSION

From the results of these tests, the following observations are apparent:

- The response of diesel fuel with 5 percent BCM is in almost all cases directionally the same as diesel fuel with regard to injection system parameters. The treated fuel very often showed a greater sensitivity as far as response was concerned, however, it was demonstrated that satisfactory performance (ISFC within 9.5 percent of diesel fuel performance) could be obtained with the BCM containing fuel. Therefore, the primary objective of the project was met.

- The data obtained provide no clear-cut evidence of the mechanism of BCM flame inhibition in diesel engine operation. If the inhibiting mechanism could have been described, greater flexibility would be provided to the person ultimately responsible for achieving satisfactory performance in real engines in the field. Additionally, some insight could also be provided in describing the manner in which BCM inhibits combustion under ambient pressure and temperature conditions and provide improved vulnerability. There are two mechanisms generally proposed for flame inhibition. The first is a chemical inhibition in which the added material, or some of its reacted species, interferes with the free radical formation process necessary for hydrocarbon fuel ignition and combustion. The second mechanism suggested is a function of the physical properties of the fuel additive. Those additives having a high specific heat produce a heat sink effect precluding the attainment of stable flame temperatures. A possible contributor to both mechanisms is the high volatility of the bromochloromethane relative to diesel fuel in a low temperature environment (under 400°F). The quantity of BCM in the vapor state over the liquid will be significantly greater (as much as several hundred to 1 ratios) than the 5 vol percent added into the base fuel. Therefore, under some conditions, an additional contributing mechanism would be the overpowering presence of an inert material resulting in air-fuel ratios too lean for combustion. This factor is probably not too important in open chamber diesel engine combustion, but could be of significant importance in pre-chamber and MAN systems.

Until recently, it was generally considered that the halogenated materials functioned by a chemical inhibiting process. However, a presentation* was made by Eric R. Larsen (at an ACS meeting) which very strongly supports the heat sink mechanism theory. Unfortunately, the conclusions related in this presentation were based on the results presented in other publications (they conducted no experiments themselves), so there is reason to question the validity of their conclusions. Also, most prior publications and many workers in the field generally subscribe to the chemical inhibition mechanism even though there is no supporting data.

This comparison is illustrated in Figure 12 with diesel fuel results shown at the top and BCM at the bottom. The injection system configuration for each data point is identified on the curve. As previously noted, the best performance for both BCM and diesel fuel was obtained with the 4 hole nozzle, although BCM performance was best across the board with the 10 mm barrel and plunger, whereas the diesel fuel responded best with the 10 mm system at low speeds and the 7 mm barrel and plunger at the higher speeds. The worst performance comparison is not so direct. First, it is interesting to note that the degradation of performance with the BCM was significantly greater than the worst cases for diesel fuel. Secondly, the low-speed results were approximately the same. That is, the performance with the 3 hole nozzle and 7 mm barrel and plunger was worse in

*Halogenated Fire Extinguishants: A Physical Mechanism of Flame Suppression, Eric R. Larsen, Dow Chemical Co. Presented at the 166th National ACS Meeting, Aug 26-31, 1973, Paper No. 1NOE054.

both cases. Although at 1600 rpm, the 6 hole and 5 hole nozzle performance was almost as bad with BCM. The degradation of performance at high speed, however, shows a different effect. With diesel fuel, worst performance was obtained with the large area 4 hole nozzle and 10 mm barrel and plunger which resulted in very poor mixing and over-penetration. However, the worst performance with the BCM was with the 5 and 6 hole nozzle which would tend to result in under-penetration of the spray, thus concentrating the fuel in the mid-part of the chamber.

Injection and combustion data for the conditions in Figure 12 were compared to investigate the combustion event during the first part of the burning cycle. Diesel fuel performance is illustrated in Figures 13 and 14, and diesel fuel plus BCM in Figures 15 and 16. Injection performance is described in terms of start of injection and injection duration, and the combustion parameters are ignition delay, maximum rate of pressure rise and the occurrence of max pressure. Combustion data with the 6 and 4 hole nozzles and photographs were not obtained; therefore,

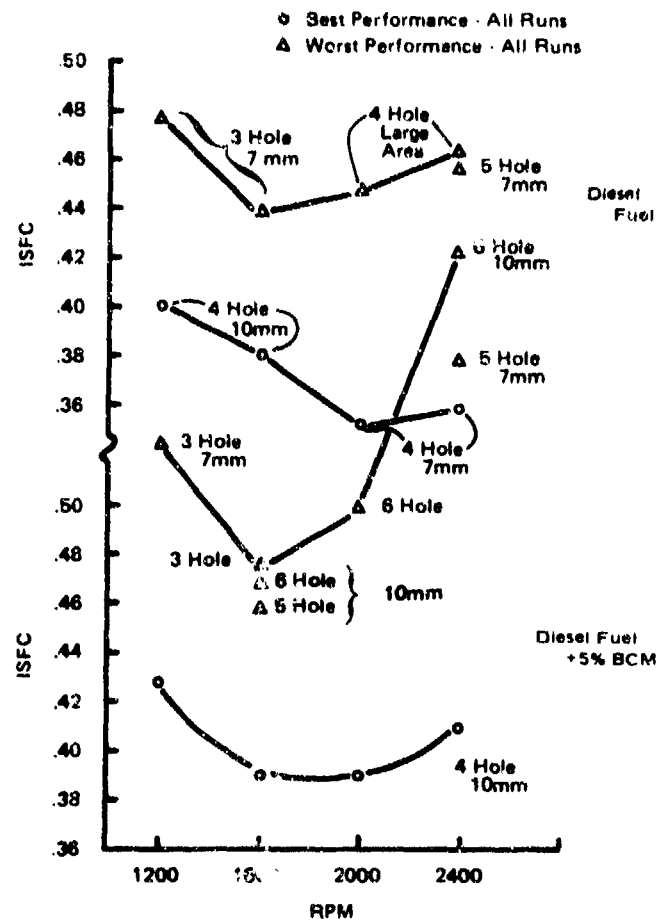


FIGURE 12. COMPARISON OF BEST AND WORST PERFORMANCE

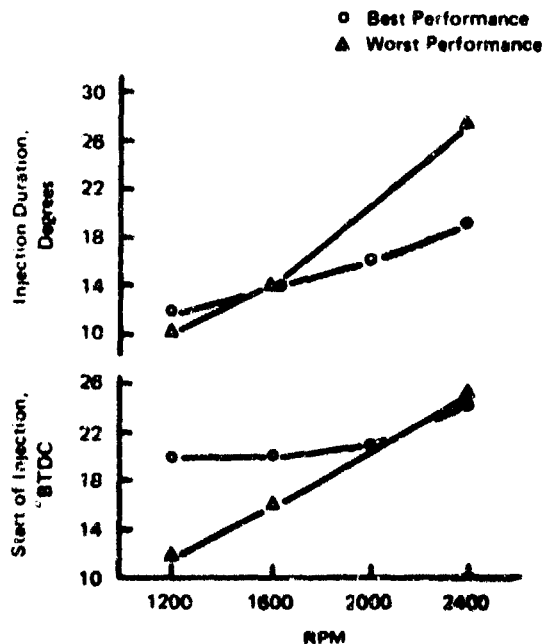


FIGURE 13. DIESEL FUEL

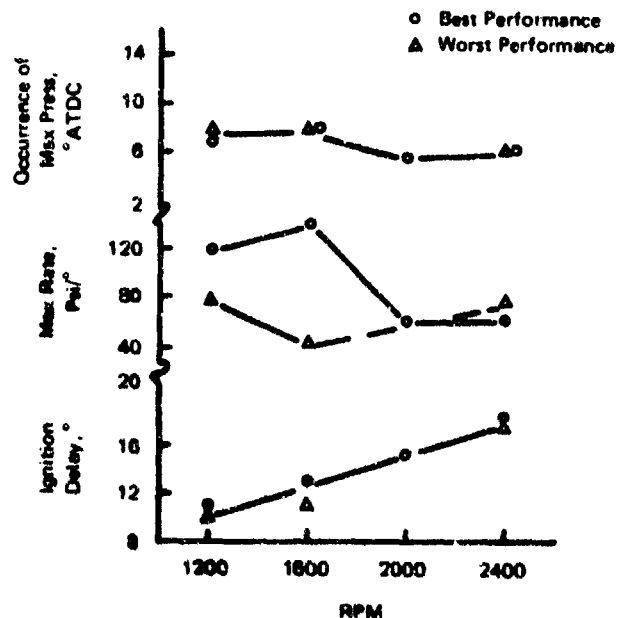


FIGURE 14. DIESEL FUEL

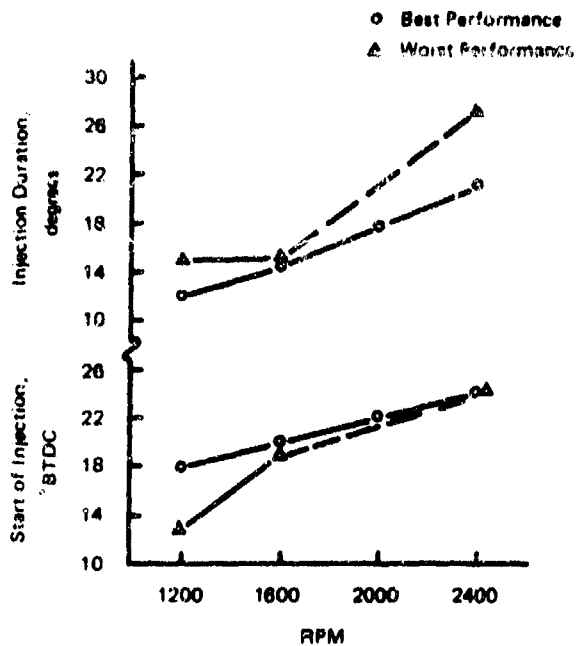


FIGURE 15. DIESEL FUEL WITH BCM

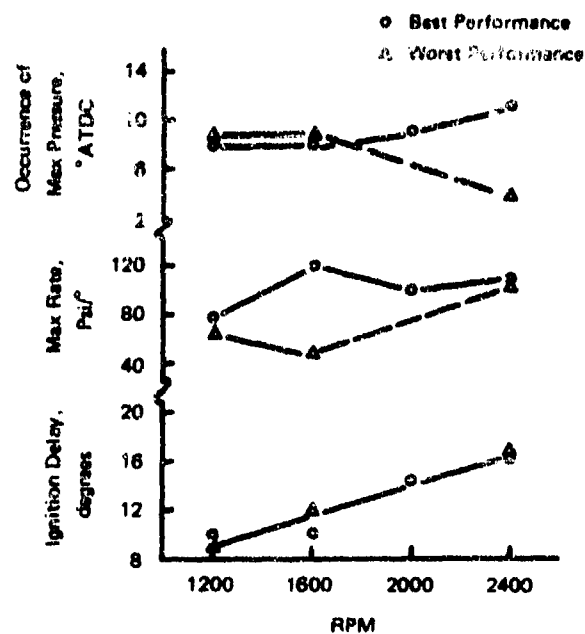


FIGURE 16. DIESEL FUEL WITH BCM

the comparison at 2400 is with the 5 hole 7 mm system which resulted in almost as poor a performance as the 4 and 6 hole nozzles for diesel fuel and diesel fuel with BCM, respectively.

When comparing the best and worst performances with BCM in terms of injection characteristics, results principally showed that at the higher speed, poorer performance was accompanied by longer duration; however, this was also the case with diesel fuel. The combustion data demonstrated no significant difference in ignition delay for the best and worst conditions, and when compared to diesel fuel, showed that there was no significant effect due to the presence of BCM. The best performance with BCM generally had a higher rate of pressure rise, and at the higher speeds, the occurrence of max pressure was later in the cycle. Again, these two trends were generally noted to be the same with diesel fuel.

The comparison of the injection and combustion results showed that the neat diesel fuel and diesel fuel plus BCM responded basically the same to changes in injection parameters. The part load analysis provided the same results. In addition to the same relative difference in ISFC throughout the load range, the lean flameout limit (the point where misfire occurred) was essentially the same in terms of diesel fuel flow rate, thus indicating no chemical interference in the lean region. Since the response was basically the same with and without BCM and there was no affect on ignition delay, it was concluded that there were no inhibiting effects during the combustion event from start of injection to occurrence of maximum combustion pressure. The absence of inhibition of the ignition delay process strongly suggested there was no chemical inhibition since free radical formation is essential to compression ignition. However, there remained the possibility that chemical inhibition might be a function of the presence of reacted halogenated species requiring temperatures above that found during the pre-flame period leading to the ignition and rapid combustion of the initial charge of fuel. Therefore, in order to evaluate combustion inhibition during the later part of the combustion event, a rate of heat release analysis was conducted. This analysis utilizes a computer program which calculates the heat release required to create the pressure

difference between the firing and motored trace. Input data for the analysis is derived from pressures and crank angles read from the pressure time diagrams. Tabulated data for the analysis and the results are in Appendix II.

For the purposes of the analysis, plots were made of several of the comparisons previously discussed. Figure 17 illustrates the rate of heat release for diesel fuel and treated fuel

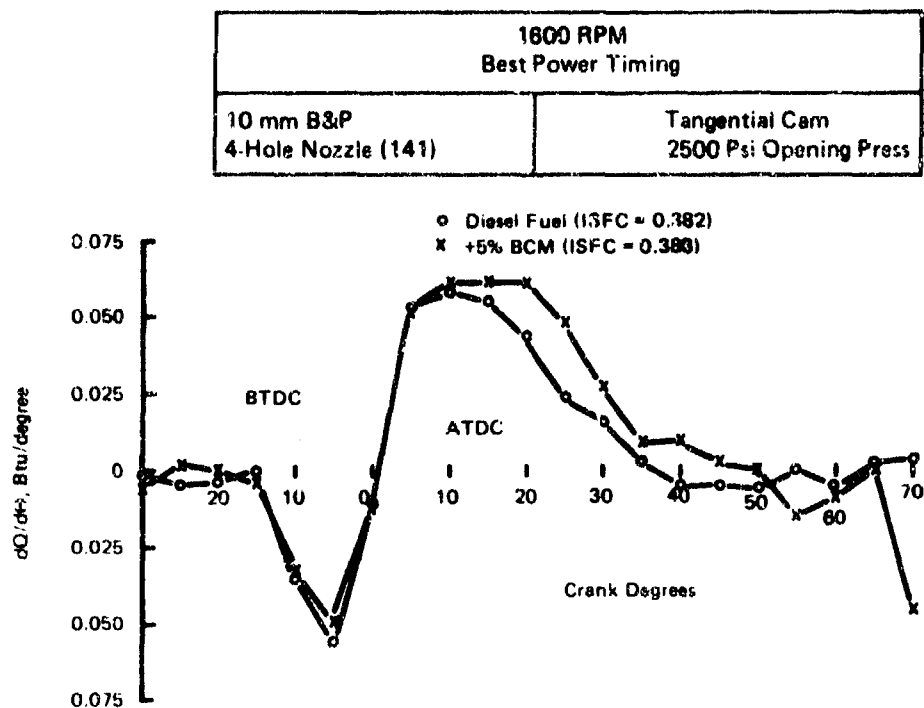


FIGURE 17. COMPARATIVE HEAT RELEASE VS CRANK ANGLE

when run under the best conditions and are compared at 1600 rpm. Absolute numbers of $dQ/d\theta$ data are not as important as the relative occurrence of heat release events. Of principal interest is the shape of the curves which illustrate that the heat release period is essentially the same for both diesel fuel and the fuel treated with BCM.

Another comparison between diesel fuel and the treated fuel is made in Figure 18. In this evaluation, the ISFC of diesel fuel was substantially better than that with BCM. However, again the heat release rate curves essentially follow each other in terms of the time in the cycle at which significant heat release took place. Other curves demonstrated the same type of performance thus leading to the conclusion that the presence of BCM does not inhibit the combustion process during the pressure build-up and expansion event as might have been anticipated had there been a chemical inhibiting mechanism involved. Therefore, as a result of these analyses, the conclusions of Larsen regarding the inhibiting mechanism of the halogen materials is strongly supported primarily because it is principally a physical effect rather than chemical, and the effects of blending BCM into diesel fuel causes performance variation in engines as a result of significant changes in heat content, density, and viscosity.

1200 RPM Best Power Timing	
7 mm B&P 3-Hole Nozzle	Tangential Cam 2500 Psi Opening Press

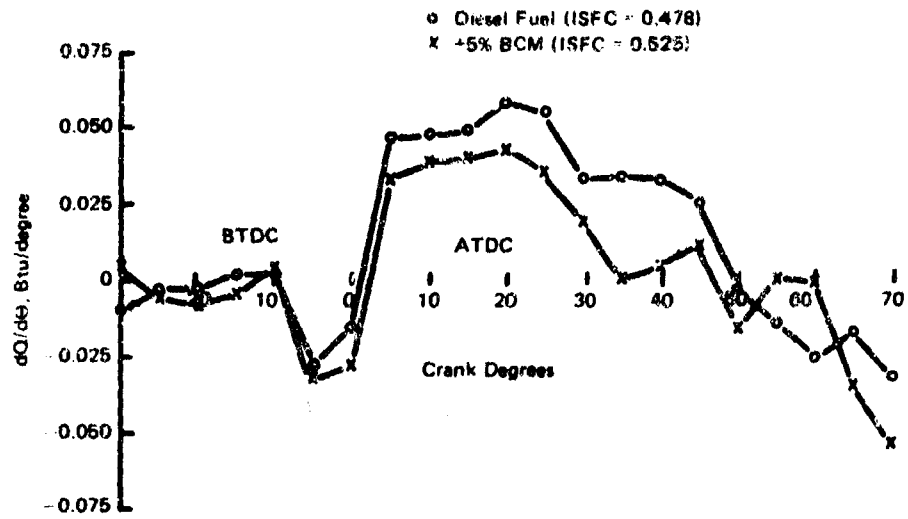


FIGURE 18. COMPARATIVE HEAT RELEASE VS CRANK ANGLE

**APPENDIX I. ENGINE PERFORMANCE
AND COMBUSTION DATA**

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 4 Hole
 0.0098" Dia
 3.02×10^{-4} in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

Engine Speed, rpm	1200	1600	2000	2400
Indicated Horsepower	5.8	8.0	10.2	12.5
iSFC, lb/lhp-hr	0.402	0.381	0.363	0.379
Start of injection, ° BTDC	20.0	20.0	22.5	24.5
End of injection, ° BTDC	8.0	6.0	6.0	4.0
Occur. of Rapid Rise, ° BTDC	8.5	6.5	7.0	6.5
Occur. of Max Press., ° ATDC	7.0	8.0	8.0	9.0
Max Comb. Press., psig	800	700	640	540
Ignition Delay, °	11.5	13.0	15.5	18.0
Avg Rate, psi/°	30.0	30.0	25.0	22.0
Max Rate, psi/°	120	140	173	167

Comments:

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 4 Hole
 0.0098" Dia
 3.02×10^{-4} in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

	1200	1600	2000	2400
Engine Speed, rpm	1200	1600	2000	2400
Indicated Horsepower	5.8	8.0	10.2	12.5
ISFC, lb/lhp-hr	0.402	0.386	0.370	0.384
Start of Injection, °BTDC	20	20	23	25
End of Injection, °BTDC				
Occur. of Rapid Rise, °BTDC				
Occur. of Max Press., °ATDC				
Max Comb. Press., psig				
Ignition Delay, °				
Avg Rate, psi/°				
Max Rate, psi/°				

Comments: Duplicate Performance Data

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 4 Holes
 0.0098" Dia
 3.02×10^{-4} in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

Engine Speed, rpm	1200	1600	2000	2400
Indicated Horsepower	5.8	8.1	10.2	12.5
ISFC, lb/lhp-hr	0.428	0.388	0.388	0.407
Start of Injection, ° BTDC	18.0	20.0	22.0	23.5
End of Injection, ° BTDC	5.5	5.5	4.5	2.5
Occur. of Rapid Rise, ° BTDC	8.0	8.0	7.5	7.5
Occur. of Max Press., ° ATDC	8.0	7.5	9.0	11.5
Max Comb. Press., psig	740	700	600	520
Ignition Delay, °	10.0	10.0	14.5	16.0
Avg Rate, psi/°	26	26	22	17
Max Rate, psi/°	76	124	106	115

Comments:

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 4 Hole
 0.0098" Dia
 3.02×10^{-4} in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

	1200	1600	2000	2400
Engine Speed, rpm				
Indicated Horsepower	5.8	8.1	10.2	12.5
ISFC, lb/lhp-hr	0.417	0.398	0.391	0.406
Start of Injection, ° BTDC	18	20	22	24
End of Injection, °				
Occur. of Rapid Rise, ° BTDC				
Occur. of Max Press., ° ATDC				
Max Comb. Press., psig				
Ignition Delay, °				
Avg Rate, psi/°				
Max Rate, psi/°				

Comments: Duplicate Performance Data

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 4 Hole
 0.0098" Dia
 3.02×10^{-6} in² Area

PLUNGER DIA: 7mm

Nozzle Opening Press: 2500 psi

	1200	1600	2000	2400
Engine Speed, rpm	1200	1600	2000	2400
Indicated Horsepower	5.9	8.2	10.6	12.6
ISFC, lb/lhp-hr	0.459	0.418	0.352	0.358
Start of Injection, ° BTDC	12.0	16.0	21.0	24.0
End of Injection, °	0.5° ATC	1.5° BTC	4.5° BTC	5.0° BTC
Occur. of Rapid Rise, ° BTDC	1.0	4.5	5.5	5.5
Occur. of Max Press., ° ATDC	11.0	8.0	5.0	6.0
Max Comb. Press., psig	460	400	340	320
Ignition Delay, °	11.0	11.5	15.5	18.5
Avg Rate, psi/°	15	14	17	14
Max Rate, psi/°	60	43	62	62

Comments:

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 4 Hole
 0.0098" Dia
 3.02×10^{-4} in² Area

PLUNGER DIA: 7mm

Nozzle Opening Press: 2500 psi

	1200	1800	2000	2400
Engine Speed, rpm	1200	1800	2000	2400
Indicated Horsepower	6.0	8.2	10.6	12.6
ISFC, lb/1hp-hr	0.473	0.450	0.424	0.444
Start of Injection, °BTDC	14.0	18.0	22.0	24.5
End of Injection, °BTDC	3.5	2.5	4.5	4.0
Occur. of Rapid Rise, °BTDC	5.5	6.5	7.5	7.5
Occur. of Max Press., °ATDC	8.0	7.5	5.0	5.0
Max Comb. Press., psig	480	400	380	320
Ignition Delay, °	8.5	11.5	14.5	17.0
Avg Rate, psi/°	16	14	16	14
Max Rate, psi/°	78	51	64	54

Comments:

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 3 Hole
0.0088" Dia
2.26 X 10⁻⁴ in² Area

PLUNGER DIA: 7mm

Nozzle Opening Press: 2500 psi

	1200	1800	2000	2400
Engine Speed, rpm	1200	1800	2000	2400
Indicated Horsepower	5.8	8.0	10.5	12.7
ISFC, lb/lhp-hr	0.483	0.439	0.410	0.394
Start of Injection, °BTDC	12.0	18.0	21.0	24.0
End of Injection, °BTDC	1.5	2.0	4.0	5.0
Occur. of Rapid Rise, °BTDC	2.0	4.5	5.5	6.0
Occur. of Max Press., °ATDC	8.0	7.5	5.5	5.5
Max Comb. Press., psig	480	420	410	380
Ignition Delay, °	10.0	11.5	15.5	18.0
Avg Rate, psi/°	20	17	19	19
Max Rate, psi/°	77	45	94	104

Comments:

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 3 Hole
0.0098" Dia
 2.26×10^{-4} in² Area

PLUNGER DIA: 7mm

Nozzle Opening Press: 2500 psi

	1200	1600	2000	2400
Engine Speed, rpm	1200	1600	2000	2400
Indicated Horsepower	5.7	8.0	10.3	12.7
ISFC, lb/lhp-hr	0.528	0.474	0.448	0.433
Start of Injection, °BTDC	13.0	19.0	23.0	25.0
End of Injection, °BTDC	2.0	3.5	5.0	4.5
Occur. of Rapid Rise, °BTDC	4.0	7.0	7.0	7.0
Occur. of Max Press., °ATDC	7.0	7.0	5.0	3.5
Max Comb. Press., psig	480	420	400	320
Ignition Delay, °	9.0	12.0	16.0	18.0
Avg Rate, psi/°	18	16	20	19
Max Rate, psi/°	68	47	88	85

Comments:

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 5 Hole
 0.0079" Dia
 2.45×10^{-4} in² Area

PLUNGER DIA: 7mm

Nozzle Opening Press: 2500 psi

	1200	1600	2000*	2400*
Engine Speed, rpm	1200	1600	2000*	2400*
Indicated Horsepower	5.9	8.1	10.4	12.5
ISFC, lb/ihp-hr	0.403	0.386	0.428	0.457
Start of Injection, ° BTDC	17.0	18.0	21.0	24.0
End of Injection, ° ATDC	2.5	4.5	3.0	2.5
Occur. of Rapid Rise, ° BTDC	6.5	5.5	6.5	6.5
Occur. of Max Press., ° ATDC	10.0	10.0	6.5	6.0
Max Comb. Press., psig	620	530	420	340
Ignition Delay, °	10.5	12.5	14.5	17.5
Avg Rate, psi/°	18	16	17	12
Max Rate, psi/°	41	42	80	71

Comments: *Run at ~ 4000 psi opening pressure to eliminate post injection.

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 5 Hole
0.0079" Dia
 2.45×10^{-4} in² Area

PLUNGER DIA: 7mm

Nozzle Opening Press: 2500 psi

Engine Speed, rpm	1200	1600	2000*	2400*
Indicated Horsepower	5.9	8.1	10.4	12.6
ISFC, lb/lhp-hr	0.473	0.469	0.469	0.536
Start of Injection, ° BTDC	16.0	18.0	21.0	25.0
End of Injection, ° ATDC	5.0	6.5	3.0	2.5
Occur. of Rapid Rise, ° BTDC	7.0	7.0	8.0	8.5
Occur. of Max Press., ° ATDC	10.0	10.0	9.0	8.0
Max Comb. Press., psig	600	500	440	340
Ignition Delay, °	9.0	11.0	13.0	16.5
Avg Rate, psi/°	18	14	14	14
Max Rate, psi/°	65	58	100	112

Comments: * Run at ~ 4000 psi opening pressure to eliminate post injection.

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 5 Hole
0.0079" Dia
 2.45×10^{-4} in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

	1200	1600	2000	2400
Engine Speed, rpm	1200	1600	2000	2400
Indicated Horsepower	5.8	8.1	10.5	12.9
ISFC, lb/lhp-hr	0.415	0.388	0.445	0.433
Start of Injection, ° BTDC	12.0	17.0	17.0	18.0
End of Injection, ° ATDC	3.5	0	3.0	7.0
Occur. of Rapid Rise, ° BTDC	3.0	5.5	4.5	3.5
Occur. of Max Press., ° ATDC	9.5	10.0	11.5	13.0
Max Comb. Press., psig	640	600	520	420
Ignition Delay, °	9.0	11.5	12.5	14.5
Avg Rate, psi/°	22	21	18	13
Max Rate, psi/°	83	100	75	75

Comments:

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 5 Hole
 0.0079" Dia
 2.45×10^{-4} in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

Engine Speed, rpm	1200	1600	2000	2400
Indicated Horsepower	5.8	8.1	10.5	12.9
ISFC, lb/lhp-hr	0.417	0.415	0.445	0.422
Start of Injection, °BTDC	12.0	17.0	17.0	18.0
End of Injection, °				
Occur. of Rapid Rise, °BTDC				
Occur. of Max Press., °ATDC				
Max Comb. Press., psig				
Ignition Delay, °				
Avg Rate, psi/°				
Max Rate, psi/°				

Comments: Duplicate Performance Data

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 5 Hole
0.0079" Dia
 2.45×10^{-4} in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

	1200	1600	2000	2400
Engine Speed, rpm	1200	1600	2000	2400
Indicated Horsepower	5.8	8.1	10.5	12.9
ISFC, lb/lhp-hr	0.436	0.419	0.419	0.495
Start of Injection, ° BTDC	13.0	14.0	15.5	21.0
End of Injection, ° ATDC	3.5	5.5	5.5	2.5
Occur. of Rapid Rise, ° BTDC	5.0	4.5	5.0	7.0
Occur. of Max Press., ° ATDC	9.0	11.0	10.5	12.0
Max Comb. Press., psig	640	520	460	440
Ignition Delay, °	8.0	9.5	10.5	14.0
Avg Rate, psi/°	21	17	14	15
Max Rate, psi/°	46	40	48	85

Comments:

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 5 Hole
0.0079" Dia
2.45 X 10⁻⁴ in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

Engine Speed, rpm	1200	1600	2000	2400
Indicated Horsepower	6.0	8.0	10.5	12.9
ISFC, lb/lhp-hr	0.418	0.408	0.452	0.592
Start of Injection, ° BTDC	13.0	14.0	16.0	21.0
End of Injection, °				
Occur. of Rapid Rise, ° BTDC				
Occur. of Max Press., ° ATDC				
Max Comb. Press., psig				
Ignition Delay, °				
Avg Rate, psi/°				
Max Rate, psi/°				

Comments: Duplicate Performance Data

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 6 Hole
 0.0079" Dia
 2.94×10^{-4} in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

	1200	1800	2000	2400
Engine Speed, rpm				
Indicated Horsepower	5.8	8.0	10.2	12.5
ISFC, lb/lhp-hr	0.407	0.416	0.410	0.442
Start of Injection, °BTDC	12.0	18.0	22.0	23.0
Enc. of Injection, °				
Occur. of Rapid Rise, °BTDC				
Occur. of Max Press., °ATDC				
Max Comb. Press., psig				
Ignition Delay, °				
Avg Rate, psi/°				
Max Rate, psi/°				

Comments:

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 6 Hole
 0.0079" Dia
 2.94×10^{-4} in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

Engine Speed, rpm
 Indicated Horsepower
 ISFC, lb/lhp-hr
 Start of Injection, ° BTDC
 End of Injection, °
 Occur. of Rapid Rise, ° BTDC
 Occur. of Max Press., ° ATDC
 Max Comb. Press., psig
 Ignition Delay, °
 Avg Rate, psi/°
 Max Rate, psi/°

	1200	1600	2000	2400
Indicated Horsepower	5.8	8.0	10.2	12.5
ISFC, lb/lhp-hr	0.455	0.468	0.499	0.592
Start of Injection, ° BTDC	12.0	20.0	19.0	21.0
End of Injection, °				
Occur. of Rapid Rise, ° BTDC				
Occur. of Max Press., ° ATDC				
Max Comb. Press., psig				
Ignition Delay, °				
Avg Rate, psi/°				
Max Rate, psi/°				

Commer

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel

CAMSHAFT: Tangential

NOZZLE: 4 Hole
 0.0123" Dia
 5.23×10^{-4} in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

Engine Speed, rpm
 Indicated Horsepower
 ISFC, lb/lhp-hr
 Start of Injection, ° BTDC
 End of Injection, °
 Occur. of Rapid Rise, ° BTDC
 Occur. of Max Press., ° ATDC
 Max Comb. Press., psi
 Ignition Delay, °
 Avg Rate, psi/°
 Max Rate, psi/°

	1200	1600	2000	2400
Engine Speed, rpm	1200	1600	2000	2400
Indicated Horsepower	6.0	8.1	10.7	12.6
ISFC, lb/lhp-hr	0.422	0.410	0.448	0.463
Start of Injection, ° BTDC	14.0	20.0	27.0	28.0
End of Injection, °				
Occur. of Rapid Rise, ° BTDC				
Occur. of Max Press., ° ATDC				
Max Comb. Press., psi				
Ignition Delay, °				
Avg Rate, psi/°				
Max Rate, psi/°				

Comments:

ENGINE PERFORMANCE AND COMBUSTION DATA

FUEL: Diesel + 5% BCM

CAMSHAFT: Tangential

NOZZLE: 4 Hole
 0.0123" Dia
 5.23 X 10⁻⁴ in² Area

PLUNGER DIA: 10mm

Nozzle Opening Press: 2500 psi

Engine Speed, rpm
 Indicated Horsepower
 ISFC, lb/lhp-hr
 Start of Injection, ° BTDC
 End of Injection, °
 Occur. of Rapid Rise, ° BTDC
 Occur. of Max Press., ° ATDC
 Max Comb. Press., psig
 Ignition Delay, °
 Avg Rate, psi/°
 Max Rate, psi/°

	1200	1600	2000	2400
Indicated Horsepower	5.8	8.0	10.5	12.9
ISFC, lb/lhp-hr	0.450	0.459	0.469	0.519
Start of Injection, ° BTDC	15.0	17.0	22.0	23.0
End of Injection, °				
Occur. of Rapid Rise, ° BTDC				
Occur. of Max Press., ° ATDC				
Max Comb. Press., psig				
Ignition Delay, °				
Avg Rate, psi/°				
Max Rate, psi/°				

Comments:

APPENDIX II. HEAT RELEASE ANALYSIS DATA

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM Ø+P, 1200 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .700
 INLET PRESSURE = 13.910 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 15.000
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
174.00	30.00	-.008782
236.20	25.00	-.001517
298.30	20.00	-.002704
397.70	15.00	.001664
459.90	10.00	.002435
534.50	5.00	.026777
820.40	0.00	-.015385
969.50	5.00	.046683
1006.80	10.00	.048470
957.10	15.00	.049000
870.10	20.00	.058544
808.00	25.00	.057290
683.60	30.00	.033576
596.60	35.00	.034674
509.60	40.00	.034442
459.90	45.00	.027243
385.30	50.00	-.001042
335.60	55.00	-.013119
273.50	60.00	-.024978
236.20	65.00	-.016454
198.90	70.00	-.031941

W = 3.6580E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 1200 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .700
 INLET PRESSURE = 13.910 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.000
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATH = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
157.40	30.00	.005467
181.60	25.00	-.005531
278.50	20.00	-.007194
363.30	15.00	-.002879
460.20	10.00	.002857
496.50	5.00	-.028593
835.60	0.00	-.027474
932.50	5.00	.033810
932.50	10.00	.037802
884.00	15.00	.042172
799.30	20.00	.043567
714.50	25.00	.037963
605.50	30.00	.021162
508.60	35.00	.001694
399.60	40.00	.005073
363.30	45.00	.012747
290.60	50.00	-.015774
242.20	55.00	.001594
218.00	60.00	.000880
181.60	65.00	-.032777
133.20	70.00	-.055547

W = 2.9919E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 1600 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .672
 INLET PRESSURE = 13.870 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 15.400
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
172.60	30.00	-.007124
230.10	25.00	-.000358
287.60	20.00	-.003005
388.30	15.00	-.000373
460.20	10.00	.001624
532.10	5.00	-.024491
848.40	0.00	-.020011
992.20	5.00	.045038
1006.60	10.00	.049287
977.80	15.00	.057114
891.60	20.00	.057738
805.30	25.00	.068807
733.40	30.00	.074315
661.50	35.00	.076168
589.60	40.00	.073418
532.10	45.00	.037865
445.80	50.00	.027456
417.00	55.00	.075908
373.90	60.00	-.011107
316.40	65.00	-.050124
273.20	70.00	-.051323

W = 4.2722E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 1600 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .672
 INLET PRESSURE = 13.870 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.200
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DO/DTHETA
153.30	30.00	-.017296
230.00	25.00	-.007540
306.60	20.00	-.003315
398.60	15.00	.002795
459.90	10.00	-.027787
797.20	5.00	-.048202
1011.80	0.00	-.015548
1103.80	5.00	.041416
1103.80	10.00	.044363
1011.80	15.00	.043714
904.50	20.00	.048687
797.20	25.00	.041947
674.50	30.00	.037844
597.90	35.00	.039258
505.90	40.00	.023489
444.60	45.00	-.000463
352.60	50.00	-.007639
321.90	55.00	.018027
275.90	60.00	-.018630
230.00	65.00	-.038188
184.00	70.00	-.053822

W = 3.6098E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 2000 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .653
 INLET PRESSURE = 13.830 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 15.200
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
147.20	30.00	-.008560
202.40	25.00	-.008703
294.40	20.00	-.006649
386.40	15.00	.000423
460.00	10.00	-.009484
625.60	5.00	-.058096
1104.00	0.00	-.062662
1122.40	5.00	.026863
1085.60	10.00	.040514
1012.00	15.00	.047907
901.60	20.00	.062410
846.40	25.00	.093667
772.80	30.00	.106674
717.60	35.00	.140740
662.40	40.00	.191394
625.60	45.00	.247347
570.40	50.00	.196388
496.80	55.00	.239236
478.40	60.00	-1.345501
432.20	65.00	-.003438
386.40	70.00	.498421

Pressure error

W = 5.0757E+02

410 174 5
 45 167 7
 55 162 7
 60 158 4
 70 152 6
 80 143 4
 90 132 6

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 2000 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .653
 INLET PRESSURE = 13.830 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.200
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATH = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
146.40	30.00	-.011896
209.10	25.00	-.008007
292.70	20.00	-.000843
355.50	15.00	-.001511
460.00	10.00	-.044753
941.00	5.00	-.070880
1171.00	0.00	-.020857
1254.60	5.00	.045940
1233.70	10.00	.054895
1150.00	15.00	.071402
1066.40	20.00	.084849
941.00	25.00	.090366
857.30	30.00	.128481
773.70	35.00	.089559
648.20	40.00	.022855
564.60	45.00	.042047
522.80	50.00	.072022
439.10	55.00	-.065269
376.40	60.00	-.023238
334.60	65.00	-.016195
292.90	70.00	-.054222

W = 4.8335E+02

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 2400 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .659
 INLET PRESSURE = 13.790 PSI
 INLET TEMPERATURE = 560.000 DEG, R
 AIR/FUEL RATIO = 15.800
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
138.00	30.00	-.015325
207.00	25.00	-.002381
253.00	20.00	-.002330
345.00	15.00	-.007268
460.00	10.00	-.040385
851.00	5.00	-.071818
1196.00	0.00	-.033005
1311.00	5.00	.053740
1288.00	10.00	.062487
1219.00	15.00	.084113
1127.00	20.00	.118405
1050.00	25.00	.171254
966.00	30.00	.206788
874.00	35.00	.321638
805.00	40.00	1.373376
759.00	45.00	-.583652
713.00	50.00	-.160553
644.00	55.00	-.078887
598.00	60.00	-.022469
529.00	65.00	.023640
483.00	70.00	.012634

W = 6.3817E+02

JEL

CLR DIESEL HEAT RELEASE DATA -- NL 123 TIP, 7 MM B+P, 2400 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .659
 INLET PRESSURE = 13.790 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.400
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DO/DTHETA
81.20	30.00	-.034159
189.40	25.00	-.017398
270.60	20.00	-.004067
378.80	15.00	-.003184
460.00	10.00	-.069646
1136.50	5.00	-.078074
1190.60	0.00	.015542
1353.00	5.00	.064303
1325.90	10.00	.057415
1217.70	15.00	.076625
1136.50	20.00	.111377
1028.30	25.00	.122076
920.00	30.00	.155273
838.90	35.00	.232207
757.70	40.00	.243716
659.40	45.00	.198330
595.30	50.00	.723374
541.20	55.00	-.080752
460.00	60.00	-.470356
405.90	65.00	-.268417
351.80	70.00	-.283175

W = 5.5561E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6461 TIP, 10 MM B+P, 1200 RPM, DF-2 FUE

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .700
 INLET PRESSURE = 13.910 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 17.400
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATH = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
174.80	30.00	.002334
211.50	25.00	.000605
276.00	20.00	-.000635
349.50	15.00	-.003891
460.00	10.00	-.002950
533.60	5.00	-.025606
809.60	0.00	-.014372
956.80	5.00	.046807
1002.80	10.00	.049890
956.80	15.00	.050289
874.00	20.00	.045623
754.40	25.00	.030310
634.80	30.00	.024040
542.80	35.00	.017729
450.80	40.00	-.001072
368.00	45.00	-.009412
303.60	50.00	-.006399
257.60	55.00	-.009782
211.50	60.00	-.003415
193.20	65.00	.003427
165.60	70.00	-.015147

W = 3.2070E+02

CLR DIESEL HEAT RELEASE DATA -- ADR 6961 TIP, 10 MM B+P, 1200 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .700
 INLET PRESSURE = 13.910 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 16.600
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
201.20	30.00	.000074
249.10	25.00	.001387
316.10	20.00	.002878
383.20	15.00	.003220
459.80	10.00	-.002721
555.20	5.00	-.028903
843.00	0.00	-.014123
996.30	5.00	.050981
1053.80	10.00	.056444
1015.50	15.00	.054831
938.80	20.00	.058296
823.80	25.00	.042134
699.30	30.00	.020774
574.80	35.00	.011041
488.60	40.00	.013044
411.90	45.00	.006493
353.30	50.00	-.000148
297.00	55.00	-.029250
229.40	60.00	-.026626
201.20	65.00	.012893
141.60	70.00	.028150

W = 3.4893E+02

CLR DIESEL HEAT RELEASE DATA -- AOB 6961 TIP, 10 MM B+P, 1600 RPM, DF-2 FUE

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .672
 INLET PRESSURE = 13.870 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 17.200
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
149.20	30.00	-.016661
223.70	25.00	-.004945
285.90	20.00	-.001714
372.90	15.00	-.001397
459.90	10.00	-.016171
671.20	5.00	-.048328
1019.30	0.00	-.026778
1156.00	5.00	.066636
1267.80	10.00	.093407
1243.00	15.00	.095419
1143.60	20.00	.099530
1031.70	25.00	.104626
907.40	30.00	.068046
758.20	35.00	.024281
646.40	40.00	.033171
559.40	45.00	.011978
472.30	50.00	-.026247
397.80	55.00	.000412
360.50	60.00	.010171
310.80	65.00	-.001347
285.90	70.00	.025743

W = 4.8221E+02

FUE

CLR DIESEL HEAT RELEASE DATA -- AOS 6961 TIP, 10 MM B+P, 1600 RPM, BCM FUEL

BORE DIAMETER * 3.800 INCHES
CRANK RADIUS * 1.875 INCHES
CONNECTING ROD LENGTH * 6.375 INCHES
COMPRESSION RATIO * 16.700
VOLUMETRIC EFFICIENCY * .572
INLET PRESSURE * 13.870 PSI
INLET TEMPERATURE * 560.000 DEG. R
AIR/FUEL RATIO * 15.900
FUEL MOLECULAR WT * 181.200 LB/LB-MOLE
SF1 * 0.000
SF2 * 1.000
PATH * 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
181.70	30.00	-.007589
242.20	25.00	-.000441
302.80	20.00	.003915
363.30	15.00	.000266
460.20	10.00	-.004137
557.10	5.00	.008354
487.70	0.00	.052758
456.70	5.00	.096326
1053.60	10.00	.064385
1041.50	15.00	.074383
980.90	20.00	.084129
920.40	25.00	.101327
823.50	30.00	.071141
702.40	35.00	.039873
605.50	40.00	.022112
508.60	45.00	.025080
460.20	50.00	.042696
399.70	55.00	-.013196
339.10	60.00	-.032059
290.60	65.00	-.023337
254.30	70.00	-.026668

W = 4.3495E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 10 MM B+P, 2000 RPM, DF-2 FUEL

BORE DIAMETER * 3.800 INCHES
 CRANK RADIUS * 1.875 INCHES
 CONNECTING ROD LENGTH * 6.375 INCHES
 COMPRESSION RATIO * 16.700
 VOLUMETRIC EFFICIENCY * .653
 INLET PRESSURE * 13.830 PSI
 INLET TEMPERATURE * 560.000 DEG. R
 AIR/FUEL RATIO * 14.000
 FUEL MOLECULAR WT * 184.000 LB/LB-MOLE
 SF1 * 0.000
 SF2 * 1.000
 PATM * 0.000

P (P S I)	THETA (D E G)	DO/DTHETA
158.20	30.00	-.008551
215.70	25.00	-.007009
302.00	20.00	-.004334
388.30	15.00	.001523
450.20	10.00	-.006759
604.00	5.00	-.044134
977.80	0.00	-.023667
1164.80	5.00	.068658
1222.30	10.00	.088186
1236.70	15.00	.130180
1207.40	20.00	.167722
1107.30	25.00	.187935
1006.60	30.00	.246631
891.60	35.00	.171786
747.80	40.00	-.068326
618.40	45.00	-.018635
546.40	50.00	.104102
488.90	55.00	-.004014
417.00	60.00	.005416
388.30	65.00	-.063456
330.70	70.00	-.220248

W = 5.4848E+02

FUEL

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 10 MM B+P, 2000 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
CRANK RADIUS = 1.875 INCHES
CONNECTING ROD LENGTH = 6.375 INCHES
COMPRESSION RATIO = 16.700
VOLUMETRIC EFFICIENCY = .653
INLET PRESSURE = 13.830 PSI
INLET TEMPERATURE = 560.000 DEG. R
AIR/FUEL RATIO = 14.900
FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
SF1 = 0.000
SF2 = 1.000
PATH = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
186.50	30.00	-.002329
236.20	25.00	.003098
285.90	20.00	.000145
372.90	15.00	-.001451
459.90	10.00	-.001916
546.90	5.00	-.029884
845.20	0.00	-.017522
994.40	5.00	.049791
1031.70	10.00	.058409
1019.30	15.00	.072836
957.10	20.00	.082314
882.50	25.00	.081135
770.70	30.00	.054528
671.20	35.00	.062692
596.60	40.00	.062461
522.10	45.00	.028152
447.50	50.00	-.000592
385.30	55.00	-.005294
335.60	60.00	-.000063
298.30	65.00	-.006640
261.00	70.00	-.032509

W = 4.2735E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 10 MM 8+P, 2400 RPM, DF-2 FUE

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .659
 INLET PRESSURE = 13.790 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.200
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATH = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
123.80	30.00	-.017308
194.60	25.00	-.008295
265.40	20.00	-.004743
353.80	15.00	-.005184
459.90	10.00	-.006356
566.10	5.00	-.037774
919.40	0.00	-.025936
1061.40	5.00	.064449
1185.20	10.00	.102682
1238.30	15.00	.133348
1185.20	20.00	.172401
1149.80	25.00	.260972
1026.00	30.00	.282956
937.60	35.00	.784994
831.40	40.00	-1.406309
725.30	45.00	.143599
601.50	50.00	.244299
566.10	55.00	-.362168
513.00	60.00	.038196
442.20	65.00	.325705
389.20	70.00	.748122

W = 6.0332E+02

FUE

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 10 MM B+P, 2400 RPM, BCM FUE

BORE DIAMETER = 3.800 INCHES
CRANK RADIUS = 1.875 INCHES
CONNECTING ROD LENGTH = 6.375 INCHES
COMPRESSION RATIO = 16.700
VOLUMETRIC EFFICIENCY = .659
INLET PRESSURE = 13.790 PSI
INLET TEMPERATURE = 560.000 DEG. R
AIR/FUEL RATIO = 12.400
FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
SF1 = 0.000
SF2 = 1.000
PATH = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
164.30	30.00	-.004358
213.60	25.00	-.001831
279.30	20.00	-.002034
361.50	15.00	-.002966
460.00	10.00	-.031353
788.60	5.00	-.045742
985.80	0.00	-.002101
1166.50	5.00	.064112
1199.40	10.00	.077885
1199.40	15.00	.111823
1150.10	20.00	.161658
1117.20	25.00	.278149
1051.50	30.00	.481190
952.90	35.00	1.450249
821.50	40.00	-3.755054
739.40	45.00	-.204251
640.80	50.00	-.063780
575.10	55.00	.024916
492.40	60.00	.154124
443.60	65.00	.187643
377.90	70.00	26.639926

W = 6.0089E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 1200 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .700
 INLET PRESSURE = 19.910 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 15.500
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DO/DTHETA
195.50	30.00	.000339
241.50	25.00	.000686
310.50	20.00	-.001762
402.50	15.00	.003552
460.00	10.00	.003615
529.00	5.00	-.007346
632.50	0.00	.017809
908.50	5.00	.059287
943.00	10.00	.050735
943.00	15.00	.060411
874.00	20.00	.061856
805.00	25.00	.061301
701.50	30.00	.049103
621.00	35.00	.054639
552.00	40.00	.038773
471.50	45.00	.029155
425.50	50.00	.042759
379.50	55.00	.020783
333.50	60.00	.010276
299.00	65.00	-.012653
253.00	70.00	-.053763

W = 3.9715E+02

CLP DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 1200 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .700
 INLET PRESSURE = 13.910 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.800
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
174.00	30.00	-.008983
236.20	25.00	.000794
285.90	20.00	.002181
360.50	15.00	-.002018
459.90	10.00	-.003228
546.90	5.00	-.033173
882.50	0.00	-.024487
1006.80	5.00	.045212
1044.10	10.00	.053340
1006.80	15.00	.064670
957.10	20.00	.076703
870.10	25.00	.071255
770.70	30.00	.060630
671.20	35.00	.048823
584.20	40.00	.050751
522.10	45.00	.076648
484.80	50.00	.067197
422.60	55.00	-.009351
360.50	60.00	-.009613
323.20	65.00	.003963
285.90	70.00	-.023579

W = 4.4119E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 1600 RPM, DF-2 FUEL

BORE DIAMETER = 3.900 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .672
 INLET PRESSURE = 13.870 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 15.700
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
178.10	30.00	-.000809
222.60	25.00	-.001699
296.80	20.00	-.000819
371.00	15.00	-.000076
460.00	10.00	-.002336
549.10	5.00	-.034349
890.40	0.00	-.026375
1009.10	5.00	.040536
1009.10	10.00	.051753
1009.10	15.00	.072703
949.80	20.00	.079037
875.60	25.00	.085057
786.50	30.00	.104547
742.00	35.00	.128900
653.00	40.00	.077681
578.80	45.00	.060278
504.60	50.00	.058227
460.00	55.00	.090248
415.50	60.00	.139674
400.70	65.00	.097483
341.30	70.00	-.217102

W = 4.8294E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 1600 RPM, 8CM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 15.700
 VOLUMETRIC EFFICIENCY = .672
 INLET PRESSURE = 13.870 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.600
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DG/DTHETA
138.00	30.00	-.025131
230.00	25.00	-.004674
276.00	20.00	-.000687
368.00	15.00	-.002997
460.00	10.00	-.015398
659.30	5.00	-.023637
797.30	0.00	.005207
981.30	5.00	.052046
1012.00	10.00	.057016
1012.00	15.00	.069628
935.30	20.00	.075151
874.00	25.00	.095026
797.30	30.00	.116099
751.30	35.00	.105476
628.70	40.00	.073237
598.00	45.00	.235035
567.30	50.00	.274360
506.00	55.00	.139622
460.00	60.00	.165962
414.00	65.00	.164710
383.30	70.00	.448744

W = 5.0140E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 2000 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .653
 INLET PRESSURE = 13.830 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 17.500
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
141.50	30.00	-.015804
212.30	25.00	-.006855
283.10	20.00	-.003516
371.50	15.00	-.001403
450.00	10.00	-.004301
566.20	5.00	-.050991
1043.80	0.00	-.053207
1114.60	5.00	.034272
1079.20	10.00	.040574
1008.50	15.00	.064045
973.10	20.00	.083715
866.40	25.00	.079716
796.20	30.00	.129962
760.80	35.00	.182498
690.00	40.00	.212384
654.60	45.00	.551507
619.20	50.00	-2.686332
566.20	55.00	-.262349
513.10	60.00	.038999
442.30	65.00	.146557
406.40	70.00	-.067482

W = 5.3628E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 2000 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .653
 INLET PRESSURE = 13.830 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.600
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
146.40	30.00	-.011893
209.10	25.00	-.008003
292.70	20.00	-.004136
376.40	15.00	-.000364
460.00	10.00	-.044864
920.00	5.00	-.067677
1150.10	0.00	-.020570
1233.70	5.00	.044689
1212.80	10.00	.060838
1171.00	15.00	.091021
1108.20	20.00	.119699
1024.60	25.00	.150546
941.00	30.00	.242708
899.10	35.00	.595518
815.50	40.00	4.019160
731.90	45.00	-.825198
710.90	50.00	-.216630
648.20	55.00	-.051727
585.50	60.00	-.039744
543.60	65.00	-.037430
501.80	70.00	-.006873

W = 6.3135E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM B+P, 2400 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .659
 INLET PRESSURE = 13.790 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 17.600
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
115.00	30.00	-.036589
230.00	25.00	-.009021
276.00	20.00	-.000704
368.00	15.00	-.003025
460.00	10.00	-.003049
552.00	5.00	-.049890
1035.00	0.00	-.041735
1196.00	5.00	.050147
1150.00	10.00	.048720
1104.00	15.00	.070157
1012.00	20.00	.085908
943.00	25.00	.121915
874.00	30.00	.172394
828.00	35.00	.300632
782.00	40.00	.730878
736.00	45.00	-1.215490
690.00	50.00	-.279157
644.00	55.00	-.131274
598.00	60.00	-.066165
552.00	65.00	-.025520
506.00	70.00	.006447

W = 6.1472E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 7 MM 8+P, 2400 RPM, 8CM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .659
 INLET PRESSURE = 13.790 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.100
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
153.40	30.00	-.006188
204.50	25.00	-.000244
255.60	20.00	-.004503
357.80	15.00	-.006299
460.10	10.00	-.046993
920.20	5.00	-.067512
1150.20	0.00	-.025041
1201.30	5.00	.044931
1226.90	10.00	.069300
1175.80	15.00	.078850
1073.50	20.00	.105690
1022.40	25.00	.170463
945.70	30.00	.191796
843.50	35.00	.258819
792.40	40.00	1.274925
756.80	45.00	-.526701
715.70	50.00	-.176766
664.60	55.00	-.132474
639.00	60.00	-.105843
613.40	65.00	-.068692
587.90	70.00	-.045092

W = 6.5658E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 1200 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .700
 INLET PRESSURE = 13.910 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 18.000
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
196.00	30.00	-.001893
247.10	25.00	.001996
306.70	20.00	.000512
391.90	15.00	.002432
460.10	10.00	-.041187
911.60	5.00	-.055039
1079.50	0.00	-.008668
1167.20	5.00	.038457
1133.20	10.00	.034867
1013.90	15.00	.036254
903.10	20.00	.031816
741.20	25.00	.004983
587.90	30.00	.006664
502.70	35.00	.008870
400.40	40.00	-.002787
340.80	45.00	.002321
281.20	50.00	.000450
247.10	55.00	-.000325
204.50	60.00	.005701
196.00	65.00	-.000224
153.40	70.00	-.044640

W = 3.0527E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 1200 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .700
 INLET PRESSURE = 13.910 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 16.900
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
194.70	30.00	.001022
239.00	25.00	.002111
300.90	20.00	-.000782
389.40	15.00	.001508
460.20	10.00	-.020300
725.70	5.00	-.037569
929.30	0.00	-.005190
1089.00	5.00	.051100
1106.30	10.00	.048016
1026.60	15.00	.039404
885.00	20.00	.029141
752.30	25.00	.019071
610.70	30.00	.009826
513.30	35.00	.007502
416.00	40.00	.001030
354.00	45.00	.007192
300.90	50.00	.001868
256.70	55.00	-.013842
203.60	60.00	-.009882
185.90	65.00	.003757
159.30	70.00	-.014154

W = 3.1166E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 1600 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .672
 INLET PRESSURE = 13.870 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 17.700
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
177.60	30.00	.000345
219.40	25.00	-.003209
303.00	20.00	-.001689
376.20	15.00	.001067
459.80	10.00	-.035950
846.40	5.00	-.054820
1065.90	0.00	-.010861
1201.80	5.00	.055853
1222.70	10.00	.059748
1139.00	15.00	.056932
1013.60	20.00	.046694
856.90	25.00	.026104
710.60	30.00	.017576
595.60	35.00	.004490
480.70	40.00	-.004240
407.60	45.00	-.002669
334.40	50.00	-.004761
292.60	55.00	.003493
250.80	60.00	-.003820
219.40	65.00	.003682
198.60	70.00	.005313

X.06 75 - 1.06

W = 3.6641E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 1600 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .672
 INLET PRESSURE = 13.870 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 17.200
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
180.00	30.00	-.003063
230.00	25.00	.002441
280.00	20.00	.000847
360.00	15.00	-.002884
460.00	10.00	-.033631
810.00	5.00	-.049025
1020.00	0.00	-.010137
1150.00	5.00	.054807
1190.00	10.00	.062626
1120.00	15.00	.063539
1020.00	20.00	.063998
890.00	25.00	.049709
760.00	30.00	.028716
630.00	35.00	.011479
530.00	40.00	.011358
450.00	45.00	.003696
380.00	50.00	.000826
330.00	55.00	-.013716
270.00	60.00	-.006683
250.00	65.00	.002577
210.00	70.00	-.039480

W = 3.9398E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM 8+P, 2000 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .653
 INLET PRESSURE = 13.830 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 17.700
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
175.40	30.00	.000684
216.50	25.00	-.002831
297.70	20.00	-.002981
378.80	15.00	.000449
460.00	10.00	-.052326
487.70	5.00	-.074042
1140.70	0.00	-.003893
1366.50	5.00	.083952
1434.20	10.00	.108951
1393.60	15.00	.115411
1244.80	20.00	.114136
1122.90	25.00	.141245
974.20	30.00	.076527
811.80	35.00	.003326
676.50	40.00	-.032650
554.70	45.00	-.258136
317.90	50.00	-.054455
378.80	55.00	.180575
338.30	60.00	.010591
297.60	65.00	-.018118
257.10	70.00	-.043337

W = 4.8459E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM 8+P, 2000 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .653
 INLET PRESSURE = 13.830 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 16.500
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATH = 0.000

P (P . S I)	THETA (D E G)	DQ/DTHETA
172.50	30.00	.003046
207.00	25.00	-.004507
249.00	20.00	-.002689
369.00	15.00	.000019
460.00	10.00	-.043097
897.00	5.00	-.056746
1069.50	0.00	-.010708
1161.50	5.00	.050232
1196.00	10.00	.064132
1127.00	15.00	.071573
1046.50	20.00	.083724
931.50	25.00	.119023
908.50	30.00	.188946
793.50	35.00	-.032448
586.50	40.00	-.092309
483.00	45.00	-.010135
414.00	50.00	.002345
356.50	55.00	-.016002
299.00	60.00	-.015946
264.50	65.00	-.022344
218.50	70.00	-.057792

W = 4.3203E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 2400 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .659
 INLET PRESSURE = 13.790 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 16.700
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
138.00	30.00	-.005435
184.00	25.00	-.005686
260.60	20.00	-.004148
337.30	15.00	-.006646
459.90	10.00	-.042119
858.50	5.00	-.068033
1165.10	0.00	-.023689
1303.00	5.00	.070850
1364.40	10.00	.104720
1364.40	15.00	.133737
1257.10	20.00	.130620
1119.10	25.00	.133012
981.10	30.00	.103020
827.80	35.00	-.002612
674.50	40.00	-.015342
582.50	45.00	-.021030
475.20	50.00	-.040809
413.90	55.00	.013393
367.90	60.00	.003079
321.90	65.00	-.002654
291.30	70.00	.002898

W = 5.1617E+02

CLR DIESEL HEAT RELEASE DATA -- NL 141 TIP, 10 MM B+P, 2400 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .659
 INLET PRESSURE = 13.790 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 15.600
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
209.10	30.00	-.015649
292.70	25.00	-.009178
397.30	20.00	.010672
418.20	15.00	.016338
460.00	10.00	-.081119
1275.50	5.00	-.143652
1568.20	0.00	-.015772
1777.40	5.00	.145599
1840.10	10.00	.235334
1819.20	15.00	.534068
1735.50	20.00	-3.451748
1610.10	25.00	-.301028
1421.90	30.00	-.132751
1275.50	35.00	-.078483
1129.10	40.00	-.020268
982.80	45.00	.013157
857.30	50.00	.042214
731.80	55.00	.028762
669.10	60.00	-.033867
627.30	65.00	-.008101
564.60	70.00	.040362

W = 8.4280E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 1200 RPM, DF-2 FUE

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .700
 INLET PRESSURE = 13.910 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 17.600
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
197.20	30.00	.000115
244.10	25.00	.003113
300.50	20.00	.002136
375.60	15.00	.000701
460.10	10.00	-.008724
610.40	5.00	-.025767
816.40	0.00	-.006291
967.20	5.00	.047784
1014.10	10.00	.053649
986.00	15.00	.054860
892.10	20.00	.049523
788.80	25.00	.040440
666.70	30.00	.024433
563.40	35.00	.015483
469.50	40.00	.005583
394.40	45.00	-.006842
319.30	50.00	-.011776
272.30	55.00	.006067
244.10	60.00	.002156
206.60	65.00	-.020977
169.00	70.00	-.034391

W = 3.3447E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 1200 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .700
 INLET PRESSURE = 13.910 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 15.100
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
204.40	30.00	.008194
235.10	25.00	.002505
306.60	20.00	-.000834
388.40	15.00	.002230
460.00	10.00	-.009935
633.60	5.00	-.025734
817.60	0.00	-.005738
950.50	5.00	.050668
1042.40	10.00	.065288
1027.00	15.00	.066185
950.50	20.00	.061186
838.00	25.00	.050140
725.60	30.00	.050630
643.90	35.00	.035888
531.40	40.00	.002534
449.80	45.00	.009703
388.40	50.00	-.008077
316.80	55.00	-.016942
276.00	60.00	-.006424
235.10	65.00	-.013339
204.40	70.00	-.016145

W = 3.7701E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 1600 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .672
 INLET PRESSURE = 13.870 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 17.200
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
200.40	30.00	.005634
235.80	25.00	.004015
294.80	20.00	.001956
365.60	15.00	-.000632
460.00	10.00	-.011678
624.90	5.00	-.026955
825.30	0.00	-.002689
1002.20	5.00	.055724
1061.10	10.00	.065670
1061.10	15.00	.077550
990.80	20.00	.081388
907.80	25.00	.078556
789.90	30.00	.055859
683.80	35.00	.045853
589.50	40.00	.031615
507.00	45.00	.004835
424.40	50.00	.002608
377.30	55.00	.001945
318.30	60.00	-.013665
283.00	65.00	-.003069
247.60	70.00	-.024261

W = 4.2309E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 1600 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .672
 INLET PRESSURE = 13.870 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.200
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P. (P S I)	THETA (D E G)	DQ/DTHETA
184.00	30.00	.002074
223.40	25.00	.003334
276.00	20.00	-.003740
381.10	15.00	-.002296
460.00	10.00	-.012128
644.00	5.00	-.028652
841.00	0.00	-.006078
985.50	5.00	.048221
1024.90	10.00	.059586
1024.90	15.00	.082306
998.60	20.00	.102630
933.00	25.00	.106501
841.00	30.00	.100484
749.00	35.00	.078640
643.90	40.00	.078609
591.30	45.00	.055937
486.20	50.00	-.018779
433.60	55.00	.002182
368.00	60.00	-.021692
328.60	65.00	.024427
302.30	70.00	.030580

W = 4.6714E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 2000 RPM, DF-2 FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .653
 INLET PRESSURE = 13.830 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 14.800
 FUEL MOLECULAR WT = 184.000 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
147.90	30.00	-.005934
197.20	25.00	-.003224
262.90	20.00	-.003161
345.00	15.00	-.005990
460.00	10.00	-.021793
690.10	5.00	-.047142
1002.20	0.00	-.023167
1133.70	5.00	.052024
1150.10	10.00	.060052
1100.80	15.00	.083991
1068.00	20.00	.135668
1035.10	25.00	.197913
969.40	30.00	.261350
887.20	35.00	.443169
821.50	40.00	-203.549418
722.90	45.00	-.721925
673.60	50.00	-.217097
607.90	55.00	-.046813
542.20	60.00	.033528
476.50	65.00	.003508
443.60	70.00	-.055622

W = 6.0422E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 2000 RPM, 5CM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .653
 INLET PRESSURE = 13.830 PSI
 INLET TEMPERATURE = 556.000 DEG. R
 AIR/FUEL RATIO = 12.300
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
162.40	30.00	-.006672
216.50	25.00	-.000321
270.60	20.00	-.000696
351.80	15.00	-.004644
460.00	10.00	-.032087
784.70	5.00	-.046097
987.70	0.00	-.010391
1109.50	5.00	.053112
1150.00	10.00	.066611
1109.50	15.00	.076715
1028.30	20.00	.082993
920.00	25.00	.074469
798.30	30.00	.050673
676.50	35.00	.044098
595.30	40.00	.050211
514.10	45.00	.025192
446.50	50.00	.000676
378.80	55.00	-.002356
338.20	60.00	-.012809
284.10	65.00	-.021523
257.10	70.00	.004467

W = 4.3553E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 2400 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .659
 INLET PRESSURE = 13.790 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 13.000
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/OTHEA
131.40	30.00	-.023869
219.00	25.00	-.004421
262.80	20.00	-.000638
350.40	15.00	-.005727
460.00	10.00	-.035140
810.30	5.00	-.048415
1007.40	0.00	-.011277
1116.90	5.00	.048664
1138.80	10.00	.064940
1116.90	15.00	.101492
1116.90	20.00	.153665
1051.20	25.00	.189940
985.50	30.00	.312457
919.80	35.00	.833055
854.10	40.00	-1.086248
810.30	45.00	-.290657
766.50	50.00	-.115697
700.80	55.00	-.035681
635.10	60.00	.001283
569.40	65.00	.068148
481.80	70.00	.190884

W = 6.5939E+02

CLR DIESEL HEAT RELEASE DATA -- ADB 6961 TIP, 7 MM B+P, 2400 RPM, BCM FUEL

BORE DIAMETER = 3.800 INCHES
 CRANK RADIUS = 1.875 INCHES
 CONNECTING ROD LENGTH = 6.375 INCHES
 COMPRESSION RATIO = 16.700
 VOLUMETRIC EFFICIENCY = .659
 INLET PRESSURE = 13.790 PSI
 INLET TEMPERATURE = 560.000 DEG. R
 AIR/FUEL RATIO = 11.300
 FUEL MOLECULAR WT = 181.200 LB/LB-MOLE
 SF1 = 0.000
 SF2 = 1.000
 PATM = 0.000

P (P S I)	THETA (D E G)	DQ/DTHETA
57.50	30.00	-.011651
103.50	25.00	-.002674
126.50	20.00	-.002335
184.00	15.00	-.003802
241.50	10.00	-.022343
483.00	5.00	-.024402
575.00	0.00	-.003554
632.50	5.00	.018418
621.00	10.00	.023632
609.50	15.00	.034969
586.50	20.00	.042382
552.00	25.00	.042176
444.50	30.00	.045939
471.50	35.00	.055685
425.50	40.00	.039543
379.50	45.00	.036449
345.00	50.00	.035551
310.50	55.00	.022460
276.00	60.00	.006135
241.50	65.00	-.025882
195.50	70.00	-.056077

W * 3.1148E+02

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