THE INFLUENCE OF GASOLINE & PROPANE FUELS ON SPARK IGNITION ENGINE WEAR RATES DURING LOW TEMPERATURE OPERATION

by
B. T. Stephanson
Member C.S.A.E.
Agricultural Engineering Department, University of Edmonton, Edmonton, Alta.

INTRODUCTION

While engineers have long been interested in propane and butane fuels for internal combustion engines the commercial use of propane only began about 1928. It is only since about 1950 that the use of propane began attracting any widespread attention. At about that time engine manufacturers were announcing engines specifically designed to utilize LPG fuels to best advantage. The increase in use of these fuels, however, has been erratic and in 1953 only 3% of all tractors in the United States used propane, compared to 7% for diesel, 84% for gasoline and 6% for other fuels. The clean burning qualities of propane make this fuel attractive whenever the price is competitive.

The situation in Alberta is similar to that found in the United States. There is at present a surplus of LPG fuel and according to Wright (20) this surplus will continue and very likely increase tremendously in the years to come.

The major problem facing the LPG industry at the present time is to find markets and to develop distribution systems and methods which will serve the markets efficiently.

Because the surplus of LPG is seasonal and because the greatest surplus is during the summer, the automotive field and particularly farm tractors are promising outlets for this fuel. At the present time there are very few tractors using this fuel in Western Canada. One estimate indicates that there are perhaps 750 tractors now using propane. This is only about one quarter of 1% of the 307,450 tractors (Jan., 1960) on all Western Canadian farms. The propane consumption of all engines, including farm tractors, in Western Canada makes up less than half of one per cent of the total propane sales.

Until 1959 the high price of propane restricted its use. In October, 1959 a price drop in the Edmonton area from 16 cents per gallon to 12 changed this situation. At this price it is in a competitive position with diesel fuel at 17 cents and gasoline at 20.5 cents.

These factors would suggest a possibility of an increased use of propane as an engine fuel. The farmer is in a good position to take advantage of the properties of this fuel in his tractor if he can combine it with domestic use.

While the literature reveals a number of reports referring to the advantages of propane as an engine fuel, practically nothing is found on the effect of this fuel on the wear rate of an engine.

A number of reports can be easily found that suggest the engine maintenance costs are lower for propane than gasoline by amounts ranging from 25 to 66%. It should be pointed out here that these estimates are based almost entirely on practical experience and not on research findings. No information at all can be found in the literature which indicates the comparative wear rate between these two fuels under winter start-up conditions.

In view of the possible impending importance of propane as an engine fuel in Alberta and because of the cold winters and increasing amount of winter operation, it was decided that this problem of low temperature wear rate should be investigated.

ENGINE WEAR

While engine wear, its causes and prevention has been covered very thoroughly by various authorities (7, 9, 13, 15, 18, 19) some of this information is pertinent to this discussion. Engine wear is divided into 3 classes:

1. *Corrosion* — wear due to oxidation, or chemical action on metal surfaces by corrosive constituents and moisture originating from the combustion process.
2. *Erosion* — wear due to metal to contact, resulting from inadequate lubrication.
3. *Abrasion* — wear due to foreign particles in the oil film.

Corrosion:

Corrosion is now generally recognized as the main cause of the engine wear. Jackson (7) suggests 45% of wear in passenger car engines is due to low temperature corrosion. Some reports have indicated rates of wear up to 85 times normal. A number of measures have been developed that have resulted in increased engine life. These include such things as uniform temperatures in the cooling system; control of oil temperatures; adequate crankcase ventilation; superior oils and metals; and better fuels and engine design.

Erosive Wear:

This wear is caused by lack of or inadequate lubrication. In certain phases of engine operation the maintenance of adequate lubricating oil films is not possible and erosive wear results. This oil starvation is most often found in the piston ring zones during starting of cold engines. Engines subject to frequent stops and starts are accordingly subject to rapid wear from this source. Yeates (6) reported wear five times as great for an engine starting once each ten hours of operation over one running 200 hours per start. Thiery (16) reported start-up wear to be 9 to 10 times as great in the first 15 minutes, as the steady running rate.

Erosive wear can be minimized by the following preventative measures. Proper grade and viscosity of oil; rapid engine warm up and maintenance of higher crankcase temperatures and better ventilation.

Abrasion:

This wear is due to dust, dirt and other solids in the oil film. These foreign particles cause the wear of the metal surfaces. Cylinder wear up to 150 times normal were found when an air cleaner was removed and the intake pipe placed in a dusty location. It was also reported that a tractor engine was ruined after 15 hours of operation in a dusty atmosphere with no air cleaner. Abrasive wear can be very easily controlled by the use of efficient air cleaners for the carburetor and for the crankcase ventilation system and by employing effective seals on all parts subjected to dust.

Effect of Propane and Gasoline Fuel:

In considering the two fuels and their effect on cold start-up wear, only the corrosive and erosive types of wear are involved. While no evidence could be found in the literature to indicate the relationship between these fuels and the resulting wear-rates under cold start-up conditions there is enough information to indicate three possible relationships:

1. The gasoline engine may have more wear during cold weather starting. The oil film on the cylinder walls will be washed down by the gasoline which will also dilute the crankcase oil. Both of these possibilities can result in increased erosive wear. There is also the possibility that corrosive wear might increase because the metal surfaces are unprotected by an oil film and they can be attacked by acidic materials.

2. The propane engine will have more wear than the gasoline under cold start-up conditions for the following reasons:

The dry nature of the propane will not wash down the cylinder wall but neither will it give any liquid protection when the residual oil film has been burned or scraped off by the oil ring. It is possible that the liquid gasoline present in the gasoline engine will provide some protection from erosive wear while the dry propane will not. There is a possibility that there may be more blow-by in a propane engine under cold starting conditions because of the dry cylinder walls and rings during the interval between starting and effective oil circulation. The liquid gasoline will probably reduce blow-by to a greater extent than the dry rings and cylinder walls in the propane engine. If there is more blow-by in the propane engine, then there will be more corrosive material build-up in the oil which will attack the metal parts resulting in increased corrosive wear in the propane engine.

3. The different interrelated factors causing corrosive and erosive wear might balance each other and the wear rate in the two engines would be approximately the same.

If either of the latter two theories prove to be correct then propane as a tractor fuel for winter operation would not have the same advantage that it does during the summer when wear rates considerably less than gasoline, are to be expected. This factor would need to be considered by farmers when they contemplate purchasing a tractor. As it seemed impossible to reconcile these different points of conjecture it was decided that an attempt should be made to answer the problem by means of comparative tests.

METHOD AND EQUIPMENT

There are three methods that can be used to measure wear rates in engines. The advantages and disadvantages of each method have been well documented (2, 5, 8, 10, 11, 12, 14, 16) and no detailed discussion of these methods will be included. The three methods are, physical, chemical and radioactive tracer. For the testing carried out in this investigation the physical or ring weight loss method was used. While it is recognized that the radioactive technique would be most accurate there were several reasons for selecting the ring weight loss method.

1. The extensive equipment required for the radioactive tracer method was not readily available.

2. The type of testing proposed involved several hundred one half hour runs in outside winter temperature and this provided further obstacles to the use of the radioactive tracer technique.

3. It appeared that the ring weight loss method could be used with significant accuracy to give valid comparisons for the type of investigation to be carried out.

The engines used in the test were 2 new Lauson air-cooled engines with 2⅞ inch bore by 2¾ inch stroke. The maximum horse power rating was 6.3 at 3600 r.p.m. The loading was accomplished by two identical aluminum fan brakes, which loaded the engines at 1.8 horse power at 2000 r.p.m. The two engines were mounted on a heavy platform with an electric starting motor located between them. One engine was converted to propane fuel by installing an Ensign model F. fuel pressure regulator and spud-in propane assembly.

Sample oil warm up curves indicated that the temperatures increased rapidly during the first 30 minutes and then began to level off. This warm-up time agreed quite closely with Thiery (16) who found that the wear was most rapid for the first 35 minutes after start. Domier (4) found that the engine had a high rate of wear for the first 30 minutes. Accordingly 30 minutes was chosen as the length of time of operation after starting.

The procedure followed was to start and run the engines for these 30 minute periods recording the initial and final temperatures. After the engines had cooled down to near the air temperature they would be started again. It was found that 3 to 5 runs per day were possible. The total of 288 such runs were made between December 22nd, 1959, and March 10th, 1960. The coldest start was made at 26° below zero on March 2nd. There were only 5 other starts made at temperatures colder than 10° below zero.

After every 24 starts the engines were dismantled and the rings and bearing shells weighed. It was decided initially that the oil should be changed after 24 hours of operation as recommended in the operator's manual. However, after 3 such oil changes it was plainly evident that the wear rate was reduced considerably by the new oil following each change. Therefore, for a subsequent test oil was left in for three times the normal oil change period or 72 hours. Following this, there were four 12 hour continuous operation runs made at normal temperatures. This was done to determine normal wear rates.

The air fuel ratios were adjusted periodically for the same relative amounts of excess oxygen in the two engines.

RESULTS

Fig. 1 shows the results obtained when oil was changed at the 24 hour period. The curves shown are the averages of the tests. The most notable feature about this curve is the increase in wear rate after the 12 hour period. The rate increased from .27 milligrams per ring per hour dur-

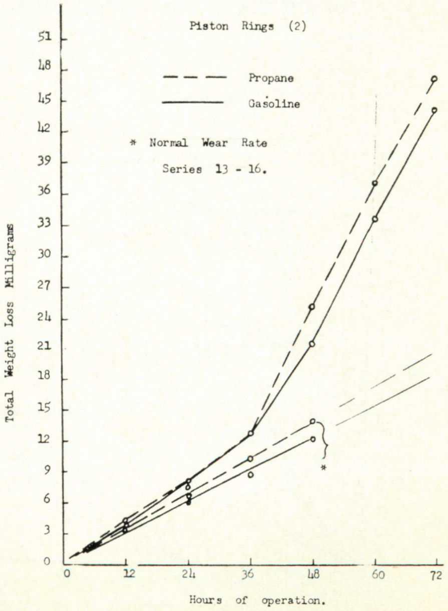

Figure 1. Effect of Cold Start-up Type of Operation on Wear Rate.

ing the first 12 hours, to .47 milligrams per ring per hour in the second 12 hours. The start up wear rate is also compared with the normal wear rate obtained from the normal temperature continuous run operation. It should be noted that the piston ring wear after the 24 hour period under cold start up conditions was about 3½ times the normal wear rate. The bearing shell wear rate under cold start up conditions did not increase as much as did the piston rings. It should also be noted that there is no significant difference displayed in the effects of the two fuels on the wear rates.

Fig. 2 shows the results obtained from the 72 hour period of start stop operation. Again the most notable feature is the rapid wear after the 24 hour period. The wear rate at the end of 72 hours was about 3 times that expected under normal operation.

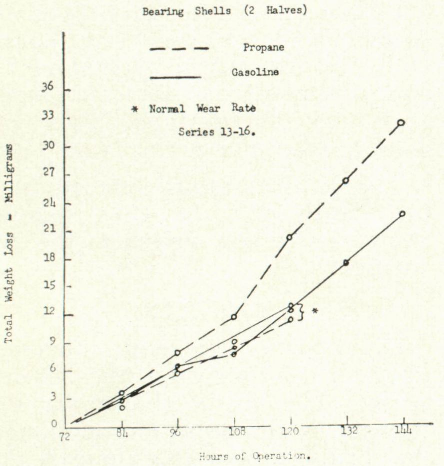

Figure 2. Effect of Cold Start-up Type of Operation on Wear Rate.

Fig. 3 shows the bearing shell wear rates under the same conditions as under Fig. 2. It should be noted that the bearing shell wear rates were considerably closer to the normal wear rate than were the piston rings. It should also be noted that there was no significant difference between the fuels and their effect on the wear rate under cold start up conditions.

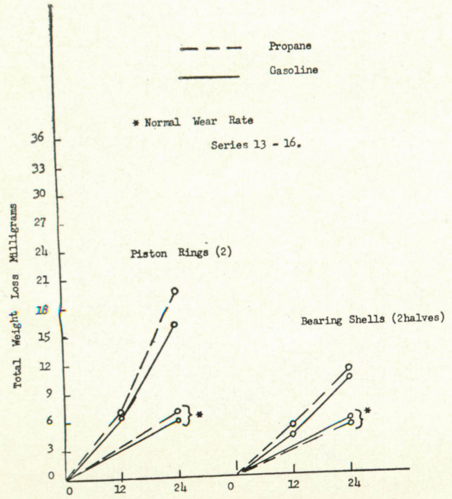

Figure 3. Effect of Cold Start-up Type of Operation on Wear Rate.

CONCLUSION

1. Rapid oil contamination appears to be a major cause of increased piston ring and bearing shell wear under cold start up conditions.

2. The wear rate during the last half of the regular oil change period was found to be double that recorded for the first half.

3. An engine operating under cold start up short run conditions can be expected to have a wear rate 3 to 4 times that expected from an engine operating under normal conditions.

4. There appears to be no significant difference in wear rate between engines using propane and gasoline under cold start up conditions.

5. The results give no support to the claim that propane engines have lower wear rates than gasoline engines under normal operating conditions.

REFERENCES

1. Alden, R.C., Selim, F. E., L. P. Gas for Motor Fuel. Paper presented at Amer. Gas Assoc. Meeting, April, 1951.
2. Boerloge, G. D. and Gravesteyn, B. J. J., Cylinder Wear in Diesel Engines, Soc. Auto. Eng. Jour., V38 N5. May, 1936, p. 197-199.
3. Brodell, A. P., Kendall, A. R., Liquid Petroleum Fuel — Consumption for Farm Purposes. Statistical Bulletin N.188, July, 1956.
4. Domier, K. W., Measuring Engine Wear with Radio Active Tracers. Can. Soc. Agr. Eng. Jour. V2 N1, Jan., 1960. p. 33-34.
5. Dyson, A., Williams, K. R., The Use of Radio Active Technique in the Wear Testing of Engine Lubricating Oils. Inst. Pet. Jour., V 39, 1953, p. 524-30.
6. Georgi, C. W., Motor Oils and Engine Lubrication — New York Reinhold Pub. Co., 1950.
7. Jackson, H. R. Why Does your Car Wear Out? Soc. Auto. Eng. Jour. V65 N6, June, 1957. p 64.
8. Jackson, H. R., Burk, F. C., Test, L. J., Cowell, A. T. Some Phenomena of Engine Wear as Revealed by Radio Active Tracer Technique. Soc. Auto. Eng. Jour., V60 N2, Feb., 1952. p. 24-27.
9. Kunc, J. F., McArthur, D. S., Moody, L. E. How Engines Wear. Soc. Auto. Eng. Trans. V 61, 1953. p. 259.
10. Moore, C. C., Kent. W. L., Wear Measurements by Physical, Chemical or Radioactivity Methods. Soc. Auto. Eng. Trans. 1953.
11. Pennington, J. W. Piston Ring and Cylinder Wear in Diesel Engines. Soc. Auto. Eng. V 57, N2, Feb. 1949. p. 39-44.
12 Pinotti, P. L., Hull, D. E., McLaughlin, E. J. Application of Radio Active Tracers to Improvement of Fuels, Lubricants and Engines. Soc. Auto. Eng. Trans. V.3 N.4, Oct., 1949.
13. Ricardo, H. R. Some Notes and Observations on Petrol and Diesel Engines. Inst. Auto. Eng. Proc. V27, 1933. p. 434.
14. Robbins, B. A., Pinotti, P.L., Jones, D. R., The Use of Radioactive Tracer Techniques to Determine the Effect of Operating Variables on Engine Wear. Soc. Auto. Eng. Jour. V.67, N10 Oct. 1959 p. 64-67.
15. Roensch, M. M., Observations on Cylinder Bore Wear. Soc. Auto. Eng. Jour. V.40 N3 Mar. 1937. p. 89-98.
16. Thiery, J., Radio Tracers in Piston Ring Wear. Soc. Auto. Eng. V.67 N10, Oct. 1959. p.68-69.
17. Thompson, F. L., Liquified Petroleum Gases, Western Can. Unpublished paper presented to L. P.G. Assoc. Convention, Chicago, May, 1959.
18. Williams, C. G. Cylinder Wear in Gasoline Engines. Soc. Auto. Eng. Jour. V.38 N5, May, 1936. p.191.
19. Williams, C. G. Interim Report of Research and Standardization Committee on Cylinder Wear. Inst. of Auto. Eng. June 1933. p.73-92.
20. Wright, R. W. An Analysis of the Liquified Petroleum Gas Industry in Alberta. Master's Thesis, Univ. of Alta., Pub. by Res. Council of Alberta as Mimeo. Circular N29, 1959.