THE EFFECT OF OIL VISCOSITY
ON PISTON RING WEAR
AS DETERMINED BY RADIOACTIVE TRACER

by

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INTRODUCTION

Proper lubrication of the modern high speed internal combustion engine is one of the great problems facing the engine designer, the oil companies producing lubricants, and the owner who must operate and see to the servicing of the engine. Its importance is brought out by research which has indicated that frictional, abrasive and corrosive wear of piston rings and cylinder walls is the major factor limiting engine life. This wear of rings and cylinder walls increases engine clearances to the point where power loss and oil consumption finally become excessive and the engine must be overhauled. To prolong the economic service life of the engine then, lubricants which reduce or eliminate these various types of wear must be utilized. This problem is becoming more complicated as a result of the current horsepower race among automobile manufacturers. With the resulting higher loads, stresses, and temperatures on pistons, rings, bearings and valves, the demands upon the motor oil will become correspondingly more severe, so that the problems of engine lubrication and of oil quality and performance will undoubtedly continue to be of paramount importance.

In the solution of this problem, one of the properties of lubricating oils which is generally considered of prime importance is viscosity (7, pp.39-44). The oil must be fluid enough at low temperatures to provide proper lubrication when starting, yet not fail at the higher temperatures which exist after warm-up. To provide this type of lubrication, multi-grade oils which employ viscosity index improvers have recently been developed by several oil companies. The lubricant must also provide an oil film of sufficient viscosity to support the load imposed upon it and to prevent metal-to-metal contact of the moving surfaces. The oil film must also protect the metal surfaces from the corrosive products of combustion. Consequently, the determination of the optimum oil viscosity in regard to engine wear and the evaluation of the new multi-grade oils in the role of wear reducers would add to the knowledge of factors influencing engine wear and make easier the task of improving engine life.

THEORY OF RING AND CYLINDER WEAR

The processes by which wear of rings and cylinders occurs in internal combustion engines are complex. However, authorities on this subject generally agree that wear occurs by the following processes: (1) Friction (2) Abrasion (3) Scuffing (4) Corrosion (15, pp.1-9 and 3, p.3).

Friction. Wear by friction is the cutting or deforming action of the ring passing over the cylinder wall surface. Irregularities on each surface will cut or deform the other surface at the points of contact where the oil film is penetrated. This action will actually remove the irregularities and increase the contact area thus improving the load-carrying ability of the surfaces. During the break-in period this type of wear is desirable, but after the surfaces fit properly it should be brought to a minimum. It is probable that surface finish, material properties, and oil viscosity are the major factors in friction wear. The surface finish governs the number of irregularities in the surface. Hardness of the materials affects the depth of surface penetration by irregularities and hence, the amount of cutting. Oil viscosity determines how close the two surfaces approach each other or how small an irregularity will penetrate the oil film and cut the other surface. This form of wear is greatest where the pressure and temperature are high and the rubbing velocity is relatively low, that is, in the top end of the cylinder. This indicates that volatility may have an appreciable effect in that it determines how well the oil resists being burned from the surface.

Abrasion. By abrasive wear is meant the friction wear caused by foreign particles between the rubbing surfaces. These particles may be brought in with the intake air or carried in the lubricating oil.

Well-designed oil and air filters reduce this type of wear, but under adverse atmospheric conditions some particles may still find their way into the engine. It is reasonable that, in addition to the factors affecting friction wear, the quantity, size, shape and hardness of the particles affect abrasive wear. Unlike friction wear, the harder surface will wear more because the abrasive particles embed themselves in the softer material.

Scuffing. Scuffing is wear caused by the welding of points on the two surfaces and subsequent tearing away of the welded junctions. High surface temperatures and clean metallic contact are the main factors that initiate scuffing. Any oil film, of course, will aid in preventing scuffing by separating the surfaces. Once the surface is roughened by scuffing, wear rates will be high because of friction wear. Scuffing is critical during break-in since there are high temperatures and thin oil films between the surfaces. Temperature, pressure, and rubbing velocity are important factors. The possibility of scuffing is increased as these conditions are made more severe. Cylinder distortion, which will cause localized high pressures will tend to produce scuffing. Higher viscosity lubricants provide a film which is more difficult to penetrate thus hindering scuffing. Dust or any other abrasive particles present greatly aggravate scuffing. Considerable work has been done on metal coatings and finishes to prevent scuffing. If a continuous oil film for the compression rings were maintained for all conditions of operation, this type of wear would be eliminated.

Corrosion. Corrosive wear is, as the name implies, a chemical process. It is a result of acid attack of metal surfaces by certain products of combustion of fuel or of contamination or oxidation of the lubricating oil. Any acid-forming substance can cause this type of wear, but it appears that sulfur and its acids are the major offenders. The corrosive wear tests that have been conducted indicate that the cylinder wall temperature is the critical factor (16, p.34). Other factors that could affect corrosive wear are oil film thickness, oil alkalinity, cylinder pressures and temperatures, and material composition. Oil film thickness could affect corrosion by acting as a protective covering which hinders the acid particles from contacting the metal surface. Oil alkalinity could retard corrosion by neutralizing the acids before they reach the metal. Cylinder wall temperatures could influence the chemical reaction rate, increasing it as the temperature rises. But more important, they affect the amount of condensation on the walls, and hence the quantity of acid causing the corrosion. Corrosive wear has been observed to occur mainly when cylinder wall temperatures are low as in the case of short drives where the engine doesn't have ample time to warm up. Upon reaching normal operating temperatures, this form of wear virtually disappears in relation to the other types of wear.

WEAR TEST METHODS

Wear rates in engine wear research are determined by measuring the iron worn from the parts in question. This creates quite a problem because the amount of wear is usually very small and sometimes makes it very difficult to determine the effect of any set of operation conditions. There are at present three methods used in the measurement of these minute amounts of wear (14, pp.1-3).

The first method is the physical measurement of rings and cylinder bore. In this method, the engine is run under the desired conditions for a period of time and then disassembled and the change in dimensions determined by the use of micrometers, dial indicators and feeler gages. To obtain sufficient amounts of wear so that the amount of wear can be accurately determined, the engine must be operated for very long and, consequently, expensive periods (above 500 hours). The isolation of variables and reproducibility of results are difficult because of the difficulty of maintaining constant conditions over such long periods of time. Also, differences in material composition, surface condition, break-in processes, or even in torquing of nuts can add to the uncertainties of wear measurements by the direct method.

A quicker and more precise method of wear measurement is the chemical analysis of the lubricating oil for iron content. By obtaining wear measurements in shorter periods of time (about 100 hours) many of the problems of the direct method are eliminated. With this method, the iron content of the lubricating oil in the range of 5 to 10 parts per million can be determined with an accuracy of 5 to 10 per cent. This is a great deal more accurate than the first method, corresponding to measuring the change in cylinder diameter to within 3 to 5 ten millionths of an inch. Laboratory analysis of oil samples is necessary and sampling procedure is critical. Oil changing, and accounting for iron lost due to oil consumption are also problems, but can be solved without difficulty. It is also necessary and entirely reasonable to assume that the iron from other engine parts is of negligible quantity.

The final and most recently developed method of wear measurement is the use of radioactive piston rings. This method utilizing radioisotopes as tracers to determine the wear of piston rings was originated by Atlantic Refining Company in 1940. This method wasn't used to any appreciable extent as a research tool until after the war when irradiation service from the reactor at Oak Ridge was made commercially available. Since that time, this method has become widely used as a means of measuring engine wear.

The method (8, pp.22;9, pp.1-9;12, pp.5-6;14, pp.1-6; and 17, pp.1-6) consists of irradiating a standard piston ring in a nuclear reactor for one month to bring it to a relatively high level of activity. Actually only one atom in a billion becomes radioactive iron, Fe^{59}. The isotope has the same chemical properties as the stable iron except it is radioactive. By the use of special tools the rings are mounted on the piston and placed in the engine. Then as the ring wears under set condition, the radioactive particles are carried into the lubricating oil. By periodically sampling and measuring the activity of the lubricating oil, the amount of wear can be determined. Since special geiger counters can accurately detect radioactive iron in lubricating oil in concentrations as low as one part per ten million, wear rates under set operating conditions can be established in as little as five hours. Consequently variables can be isolated and the same engine used to obtain all the data necessary for the determination of the effect of one variable on wear. The disadvantage of this method using only radioactive rings is that the ring wear is assumed to be the same as the cylinder wear although this may not be necessarily so. Using radioactive cylinder liners eliminates this objection, but also increases the health hazard because of the increased radioactivity level in the laboratory. Other disadvantages are the expensive radiation measuring instruments required and the precautions necessary to protect personnel from radiation hazards, but they are more than offset by the time and money saved in operation.

OBJECTIVES OF THIS TEST

Oil viscosity has been claimed to be one of the more important characteristics of lubricating oils, yet from all indications it is not known exactly what oil viscosity to use in internal combustion engines to attain the best lubrication:i.e., the least wear (18, pp.1-9). Added confusion is introduced by the new multi-grade 10-30 oils which are made by adding high molecular weight polymers to very light base stocks as viscosity index improvers. Many claims are made for these oils and although some are undoubtedly true, it is considered by some experts that these oils behave as multi-grade oils in a laboratory viscosimeter, but not in actual service (7, pp.196-207). It was decided, therefore, to investigate the effect of oil viscosity on engine wear by placing SAE 5, 10, 20, 30, 40, 50, and 10-30 oils in the engine holding other conditions constant and plotting wear rates against oil viscosity. To compare oil grade, and wear rate against sump temperature as a means of investigating the effect of the higher viscosity of the 10-30 oil, a 10, 30, and 10-30 oil were run in the engine under constant conditions with sump temperatures of 140, 160, and 200 F.

The radioactive ring method was selected as the means of measuring the wear rates in this test. In addition to being a convenient and rapid method of determining wear, it was desired to apply more recent techniques and instrumentation to the radioactive tracer method which was adopted at Oregon State College in 1952 as a tool for engine research. The improved instrumentation vastly improved the ease of carrying out research with radioactive tracers and suggested unlimited horizons in the investigation of factors influencing engine wear.

APPARATUS

The engine used for this test was a Lauson 2-5/8 in. by 2-3/4 in., 4 cycle, H-2 Oil Test Engine. The engine was loaded by overspeeding a 3 horsepower, 3 phase, 60 cycle, 220 volt electric motor, thus causing it to act as an induction generator. The generator output was fed back

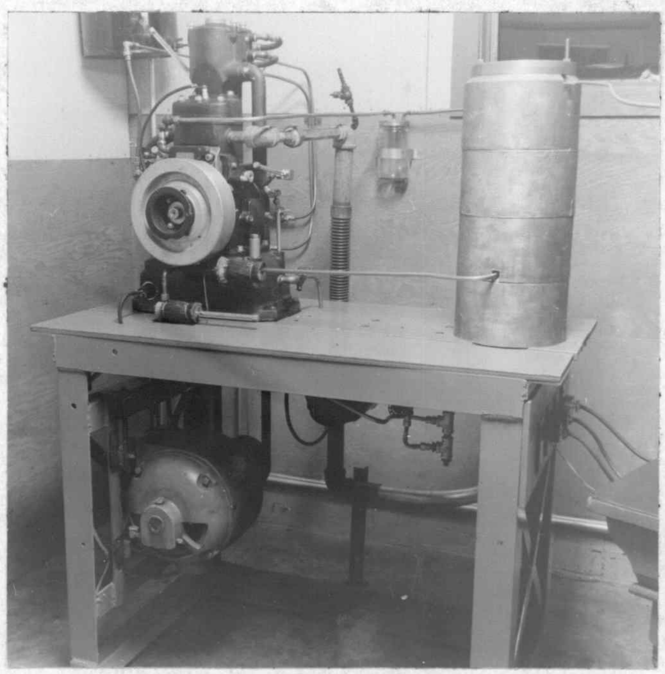

Fig. 1. Engine Test Stand

into the 220 volt commercial power source through a watt hour meter. With a stopwatch, the instantaneous power output of the generator could be determined. A V-belt drive was used for connecting the test engine to the induction generator for ease of disassembly and assembly when working on the engine. The efficiency of the belt drive and the induction generator was not determined, but was estimated to be 85 per cent. Since all the test runs were at the same speed, load, and belt tension the only effect of incorrectly estimating the efficiency would be in the reporting of the percentage load at which the tests were conducted. The load was controlled by throttle

Fig. 2. Arrangement of Control Panel and Engine Test Stand.

setting or amount of overspeeding. This method of loading worked satisfactorily in this instance, but if the load were to be varied rather than held constant some other method of loading would have to be employed. A gravity fuel system was used for dependability.

The engine was equipped with a reflux condenser that

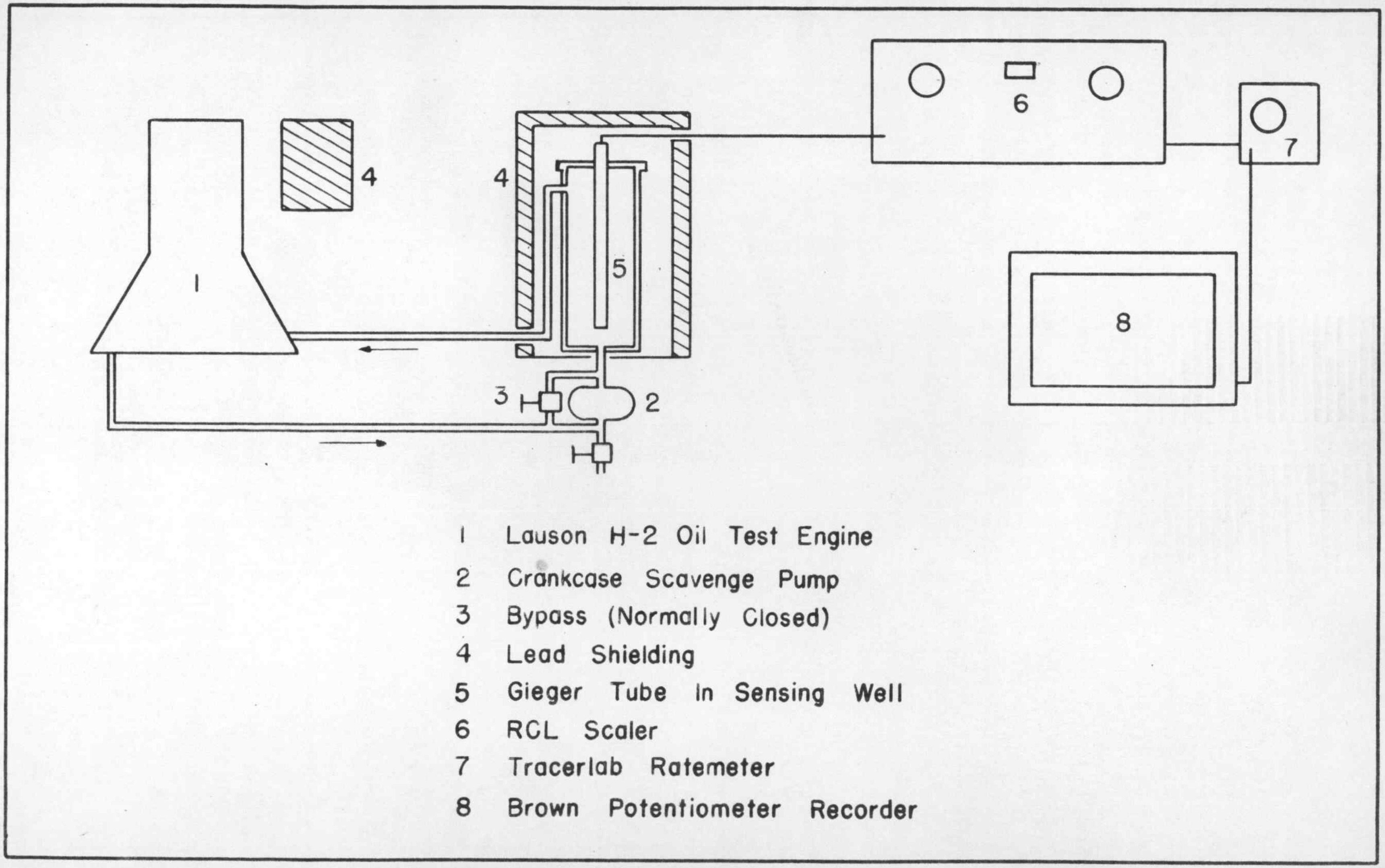

Fig. 3. Schematic Diagram of Oil and Recording Circuits

kept the jacket temperature at the boiling point of the liquid placed in the engine. In this test water was employed as the jacket coolant. City water was used to remove the heat from the condenser. The oil temperature was controlled by an electrically heated oil sump. The current to the heater in the engine crankcase was controlled by a "Power Stat" mounted on the control panel. An ammeter indicated the current being supplied to the oil heater. About six amperes were the average current required to maintain test conditions.

The lubricating oil was circulated through an external sensing well by a gear pump driven by a small, single phase motor. The sensing well and piping held three quarts of oil and the engine two and one-half quarts giving a total oil capacity of the system of five and one-half quarts. The capacity of the circulating pump was about two gpm in this installation so the oil in the system was circulated through the sensing well approximately twice a minute. A mercury-in-glass thermometer was placed in the pump suction line next to the engine to measure sump temperature. Iron-constantan thermocouples measured the oil temperature leaving and re-entering the engine and were recorded on a Brown "Electronic" Potentiometer recorder. The mercury-in-glass thermometer was used as the control check on the oil temperature because of its accuracy.

The activity of the lubricating oil was measured by an immersion type geiger counter. The counting operation was performed by a RCL Mk 13 Mod 1 scalar shown in the upper left of Fig. 4. Since this instrument only counts total counts, it was modified so that a Tracerlab Ratemeter could be connected to it to convert total counts to

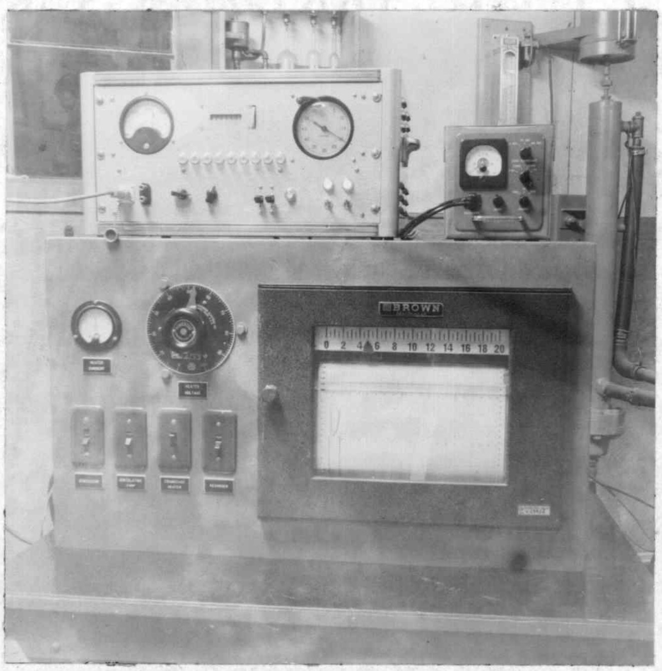

Fig. 4. Control Panel and Radiation Counting Instruments

instantaneous values of counts per minute (cpm) and indicate these values as a millivolt output signal. This millivolt output was fed to a Brown Continuous Balance Potentiometer recorder which then recorded cpm against time. The recorder chart was lined for temperatures and had to be calibrated in terms of cpm for the different scales of the ratemeter. With this done, the recorder maintained a continuous record to oil activity in cpm.

The oil sensing well was surrounded by one inch of lead to reduce the background count so that the geiger counter would be measuring only the oil activity. Six inches of lead was also interposed between the rings and the sensing well to reduce the count from the engine. Before placing the lead shielding around the sensing well and installing the radioactive rings, the background count was 84 cpm. After placing the rings in the engine and placing the lead shielding in place, the background was 96 cpm; a negligible increase.

The irradiated rings were shipped in a special container constructed and used in previous radioactive wear tests for that purpose. It surrounded the rings with two inches of lead and made shipping the rings safe. The lead container was enclosed in a plywood box with a total shipping weight of about 85 pounds.

Special tools were used to place the radioactive rings on the piston. A commercial ring expander and ordinary ring compressor were equipped with long handles so that the manipulator was over one foot from the rings when working with them. The operation of placing the rings on the piston was shielded by two-inch thick lead bricks and observed by peering over the top of the shield. This protected the body but not the hand and forearm. The piston was carried and placed in the engine with the ring compressor.

The instrument on the left in Fig. 5 is a Tracerlab SU-1F Portable Radiation Survey Meter used to measure the radiation level in the vicinity of the engine. This instrument gives readings of milliroentgens per hour and

Fig. 5. Radiation Safety Instruments.

permits quick and convenient measurements of radiation dosage rates. The instrument in the center is a minometer sold by the Victoreen Instrument Company. Inserted in the minometer is a pocket ionization chamber. Two ionization chambers ready for use are shown at lower center. The minometer and pocket chamber measure the dosage from gamma and x-rays. A charge is placed on the chamber and as the radiation ionizes the gas in the chamber, the charge leaks off. After a period of time, the amount of discharge is measured by the minometer on a scale calibrated in roentgens. The instrument at right is a RCL Mark 11 Model 10 portable geiger counter. It is used for detecting small amounts of radioactive contamination. It does not measure dosage, but is useful in examining clothes, tools, hands, etc. for contamination.

A Tag-Saybolt Thermostatic Viscosimeter was used to determine the viscosity characteristics of the oils used in the test.

RADIATION SAFETY

In previous work with radioactive piston rings at Oregon State College, it was found that the health hazard from the radioactive rings was not too great if the proper precautions were taken (16, pp.19-22). The wealth of information covering the physiological effects of various types of radiation is growing by leaps and bounds so that only the material pertaining to this type of application is discussed herein.

The unit used to define radiation dosage is the roentgen and is based on the ionizing effect of the radiation on a gas. The types of radiation from the rings are beta and gamma rays. In determining physical dosage both radiations are considered to be the same and are measured in the same units. The safe dosage rates in current acceptance are a maximum permissible dose for whole body radiation of 300 milliroentgens per week, i.e., 60 milliroentgens per day for a five-day week and 7.5 milliroentgens per hour (1, pp.56-57). For partial body exposures such as to hands, forearms, and feet, the maximum permissible dose is set at five times the whole body dose. The dosage is generally measured by personnel meters such as film badges, film rings, and pocket ionization chambers and beta-gamma survey meters, such as geiger counters, for qualitative estimation of the radiation hazard and ionization survey meters for quantitative evaluation.

The hazard to personnel is usually eliminated or reduced by shielding of various types. Beta rays are easily stopped by most materials and constitute a hazard only if ingested into the body or absorbed through the skin because their penetrating power is low and their path in air is short. Gamma rays are very penetrating and several inches of lead are required to effectively stop them. For this reason, personnel should be shielded to minimize the dosage when handling the rings or working around the engine. Even though the oil activity is low, skin contact should be avoided. Any time the oil must be handled, rubber gloves should be worn to eliminate the possibility of absorption into the body. In general, the best protection from any type of radiation is distance since intensity decreases as the square of the distance.

In this test, the rings were shipped from the Oak Ridge National Laboratory with an activity of 3000 milliroentgens per hour at a distance of four inches. Using this figure, the allowable exposure time was ten minutes at one foot while installing the rings. Two and one-half minutes were required to place both compression rings on the piston and to place the piston assembly in the engine. In this operation then, only a fraction of the daily dose was acquired. The following day the connecting rod was connected to the crankshaft and the engine made ready for operation. Pocket dosimeters indicated a dosage of 70 milliroentgens acquired during this operation. This was greater than the allowable daily dose, but still considered safe since the allowable weekly dose had not been accumulated.

After the engine was in operating condition, measurements were taken around the engine to determine the safe time in the vicinity. At an average radius of two feet the dosage rate around the engine cylinder and head was 7.5 milliroentgens per hour. It was, then, safe to stay at least eight hours in the vicinity of the engine if staying more than two feet from the engine. With the recorders recording most of the data, about two hours a day were spent attending to the engine and making readings. Consequently, as can be seen, the radioactive rings presented no health hazard if the proper precautions were observed.

Paper towels were used to wipe up any oil drops around the engine when draining the oil from the engine upon the completion of a test run. A reverse flow muffler was used for this test setup. This muffler was found in previous work to stop contaminated solids, if any, in the exhaust. The blow-by from the engine was sent through a trap to remove any liquids which might be contaminated before discharging the gas to the atmosphere.

The entire operation was safe from a radiological health standpoint so long as the rings were handled with due regard to their lethal possibilities.

PROCEDURE

After obtaining proper authorization from the Atomic Energy Commission, two standard compression rings for the Lauson engine were sent to the Oak Ridge National Laboratory for irradiation. Approximately six weeks elapsed from shipment to receipt of the rings. The rings were installed in the engine with special tools described in the previous chapter. The fuel used was ethyl gasoline. The oil was all obtained from the same manufacturer to eliminate differences from methods of production and was of the same type to eliminate the effects of additives. The constant conditions held were as follows:

Load	2/3
Speed	1845 rpm
Jacket Temperature	212 F
Fuel	Ethyl
Ignition Timing	23^{o}BTC
A/F Ratio	13 to 1
Intake Temperature	75 F

After the active rings had been installed, the engine was operated on SAE 20 oil for about twenty hours as a break-in run. Previous investigations at Oregon State College indicated that about ten hours were necessary for break-in for this type of engine. Upon completion of the break-in run, the oil was drained from the engine and the test runs commenced. The effect of oil viscosity was investigated at an oil sump temperature of 160 F, using the following procedure: a weighed amount of the oil to be investigated was placed in the oil system and the oil heater and circulating pump started. When the oil had been warmed to about 120 F, the engine was started and operated for about two hours to attain equilibrium conditions. Upon reaching equilibrium, the engine was operated for about ten hours on the test conditions. By starting in the morning, a test run could be completed late in the evening and the oil allowed to drain from the system over night. The oil recovered was weighed to determine the oil loss. Following this procedure runs were obtained with SAE 5, 10, 10-30, 20, 30, 40 and 50 oils.

The oil sump temperature was varied on SAE 10, 10-30, and 30 oils to investigate the effect of sump temperature upon wear. The oil sump temperatures were 140, 160, and 200 F. The higher temperature was limited by the temperature to which the geiger counter tube could be subjected. The lower temperature was limited by the natural temperature that could be obtained with no crankcase heat supplied. A fan was used to blow air across the engine crankcase to maintain the lower temperature. It required about one-half hour to reach equilibrium after changing the sump temperature. After a run of five or six hours under test conditions, the sump temperature was again changed. The method of starting the tests was the same for the varied sump temperature and the varied oil viscosity runs.

The recorder records of the test runs were used to determine the wear rates. The decay of the radioactive iron occurs in a random manner so that the recorder trace was not a straight line, but was a saw-toothed curve. Errors in the instrumentation counting and recording the oil activity also contributed to the saw-toothed effect of the record. To average out the errors and to establish a slope for the curve, a straight line was drawn through the recorder trace in such a manner as to represent the slope of the trace. In order to compare them on a common basis, the slopes obtained from the various test runs, representing the wear rate in cpm/hr, had to be corrected for the decrease in the activity of the radioactive iron. Radioactive decay is a probability process in which the rate of decay is proportional to the number of unstable nuclei present at any time. From this fact the following equation (1, p.33) can be derived:

(1) $N = N_o e^{-\lambda t}$

Where: N = number of unstable nuclei at the time t

λ = the decay constant

N_o = the number of atoms at zero time

From (1), the time $t_{\frac{1}{2}}$ for the number of atoms to fall to one-half of any given value (the half-life) is:

(2) $t_{\frac{1}{2}} = 0.693/\lambda$

For the radioisotope of iron which has a half-life of 46.3 days, λ from (2) is 0.01495 and equation (1) becomes

(3) $K = N/N_o = e^{-0.01495\ t}$

Where: K = decay correction factor

N = number of unstable nuclei at time t

t = time in days from determination of N_o

N_o = number of atoms at zero time

In this test the first test run was taken as N_o equal to 1.0 and t of 0. Succeeding test days were corrected to compare with the first days run using the following relationship:

(4) $R_1 = R_o/K$

Where: R_1 = corrected wear rate in cpm/hr

R_o = uncorrected wear rate in cpm/hr as determined from the recorder chart

K = decay correction factor

An additional correction that was considered was the loss of radioactive iron in the oil consumed in the engine. The oil consumption in these tests, however, was so slight as to be negligible and no correction was necessary.

The corrected ring wear rates were plotted against oil viscosity or oil sump temperature to present the effects of viscosity and oil sump temperature upon piston ring wear.

RESULTS

The results of this test are shown in graphical and tabular form on the following pages.

The viscosity characteristics of the oils used in this test are presented in Figure 6. The higher viscosity index of the 10-30 oil is readily evident. These viscosities were used in plotting ring wear rates against viscosity.

The effect of variable SAE oil grades on ring wear is shown in Figure 7. The wear rate from the two compression rings as expressed in CPM/hr is shown against SAE grades from 5 to 50. The viscosities of these oils were taken at 210 F and used as the abscissa to plot ring wear rates against oil viscosities. In Figure 8 the effect of oil viscosity upon piston ring wear is shown.

In Figure 8 the range of optimum oil viscosity for the least ring wear is from 48 to 58 SSU at 210 F, a range that encompasses the SAE 10 and 20 oils. About the same wear occurs with the 10 and 20 oil with the wear rate of the SAE 5 (43.7 SSU at 210 F) nearly nine times the wear rate of the optimum range. As the oil viscosities increased above the optimum viscosity, the wear rate increased becoming a little over four times as great with an SAE 50.

The tests were conducted at a jacket temperature high enough to eliminate corrosive wear leaving only friction, abrasion and scuffing to cause wear. The increased wear rate of the SAE 5 oil results from the high volatility of the light stocks in the oil which permits the oil film to burn off the cylinder walls, allowing intermittent metal-to-metal contact. Also the oil film is so thin as to fail under load, giving boundary lubrication and high wear rates.

As the oil viscosity is increased it would be expected that thick film lubrication would exist and increasing the viscosity would only increase the film thickness and reduce the wear rate. However, as the oil becomes more viscous, after passing the optimum viscosity, the wear rate increases. A reasonable explanation is that as the oil becomes more viscous the flow of oil to the lubricated surfaces is reduced and adequate lubrication does not exist. In the Lauson engine, the cylinder walls and piston assembly are lubricated by a splash system and the oil furnished to lubricate the rings and cylinder walls is thrown on those surfaces by the rotating crankshaft. The oil thrown on the cylinder walls and inside the piston finds its way to the oil ring and is distributed by the oil ring to lubricate the cylinder walls and piston rings. The viscosity of the oil at the temperatures of the cylinder walls and piston then would govern how effective the oil rings would be in providing proper lubrication. These temperatures are controlled by the jacket temperature, consequently it would seem that the jacket temperature would be a factor in selecting the proper oil viscosity.

The effect of oil sump temperature upon ring wear is presented in Figure 9. In this curve the wear rate changes very little with oil sump temperature and indicates that oil sump temperature doesn't affect the wear rate. These curves were obtained at relatively high sump temperatures, and at cold starting conditions such as sub-zero operation, the oil sump temperature would affect the wear rate. For warmed up operation, then, the jacket temperature controls the ring wear rate rather than oil sump temperature.

From Figures 7, 8, and 9, it is evident that the SAE 10-30 oil is not better than regular oils in reducing wear, but lies above an SAE 20 and below an SAE 30 in ring wear rate. These multi-grade oils are desired to provide optimum fluidity at low temperatures for easy starting and rapid circulation in a cold engine and to maintain maximum viscosity at high temperatures to assure good lubrication and low oil consumption in running engines (13, p.5). Using the viscosity characteristics curve, the SAE 10 oil extended to -20 F has a lower viscosity at that temperature than the 10-30. The 10 also has a lower wear rate at the running conditions used in this test. The oil consumption characteristics were not determined, but unless consumption was a great deal greater with the 10 oil, the SAE 10 seems to be a more economical oil both from cost and from wear rate considerations.

The results of these tests are presented in tabulated form in Figure 10. The curves were plotted using the information given in this data sheet.

Typical recorder charts for each of the oils used in this test are enclosed to present the change in slope with change of oil viscosity and to indicate the method of determining the slope of the wear rate curves. From Figure 11, the large increase in oil activity immediately after starting shows the large wear that occurs when starting. The wear when starting is equivalent to over an hour of running under warmed up conditions, even at the high wear rate of the SAE 5 oil.

The results of this test are, in general, quite satisfactory with the points falling on a smooth curve. The results were reproducible as is shown by the 48.6 (SAE 10) and 67 SSU (SAE 30) points in Figure 8. The check runs were run a considerable period after the initial runs and show that test conditions had not changed by scuffing, engine deposits or normal wear during the interum.

Many more theories of ring and cylinder wear too numerous to discuss here are listed in the Bibliography as SAE papers.

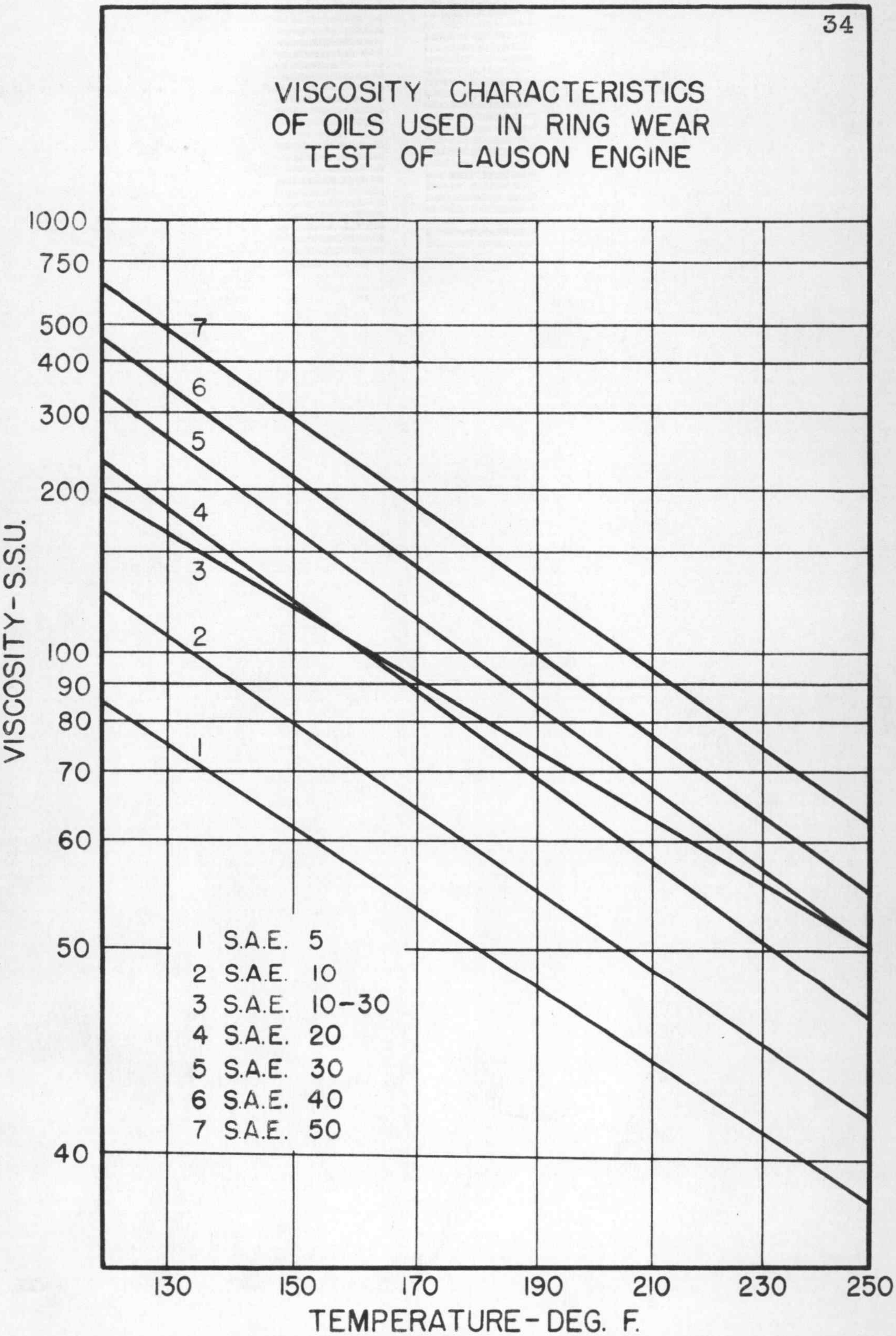

Fig. 6. Viscosity Characteristics of Oils Used in Ring Wear Test

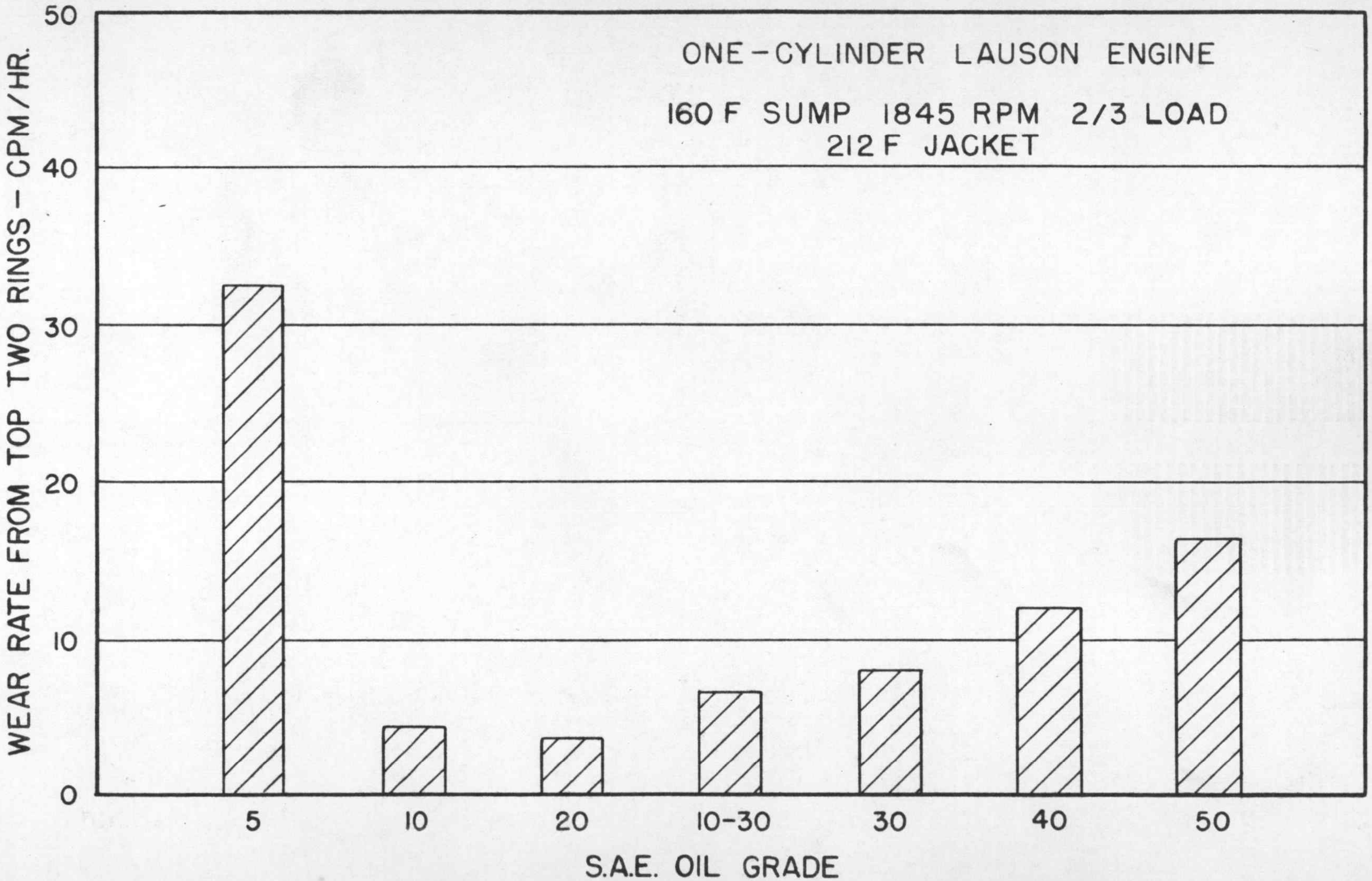

Fig. 7. Effect of S.A.E. Oil Grade on Ring Wear

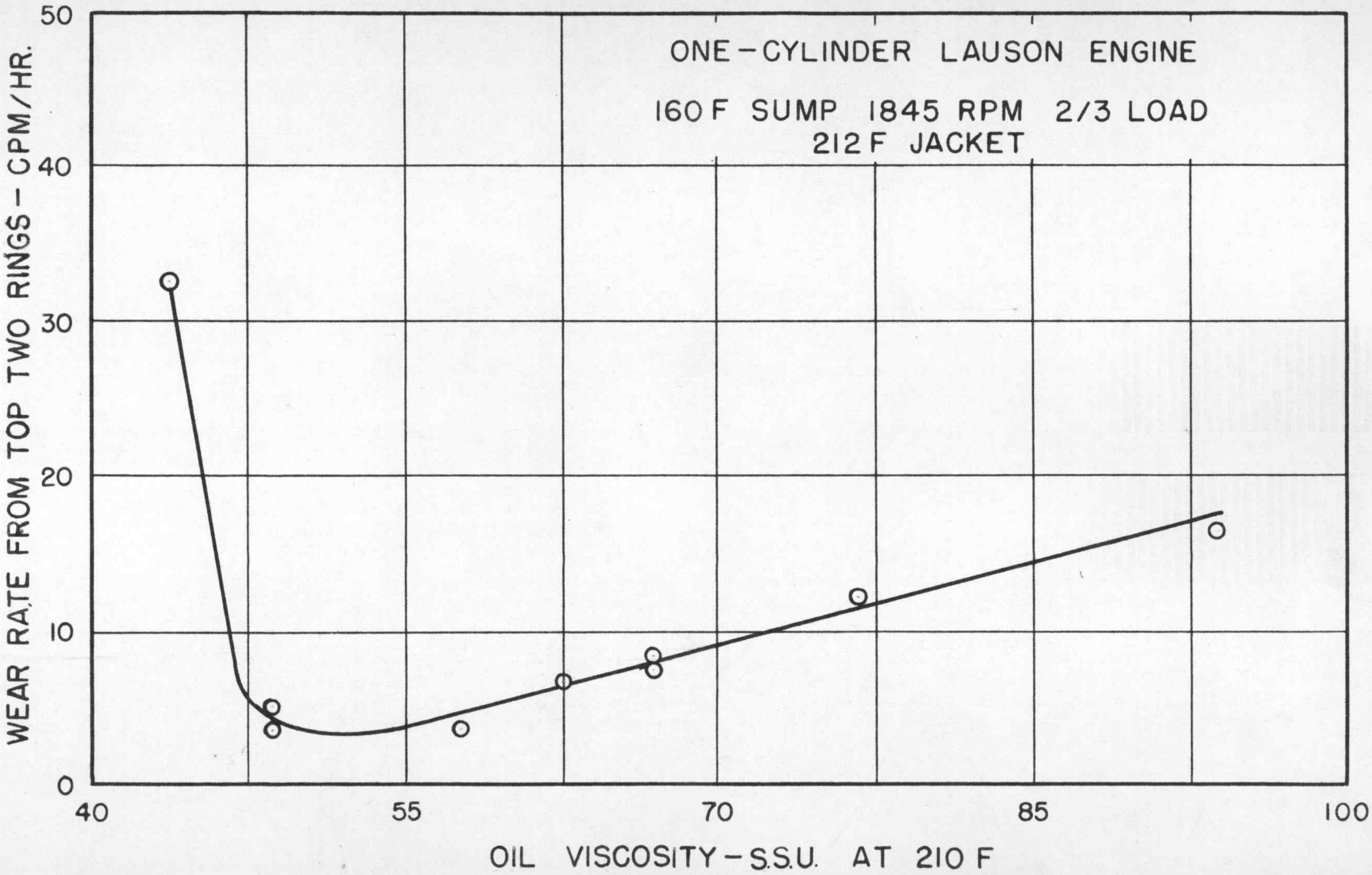

Fig. 8. Effect of Oil Viscosity on Ring Wear

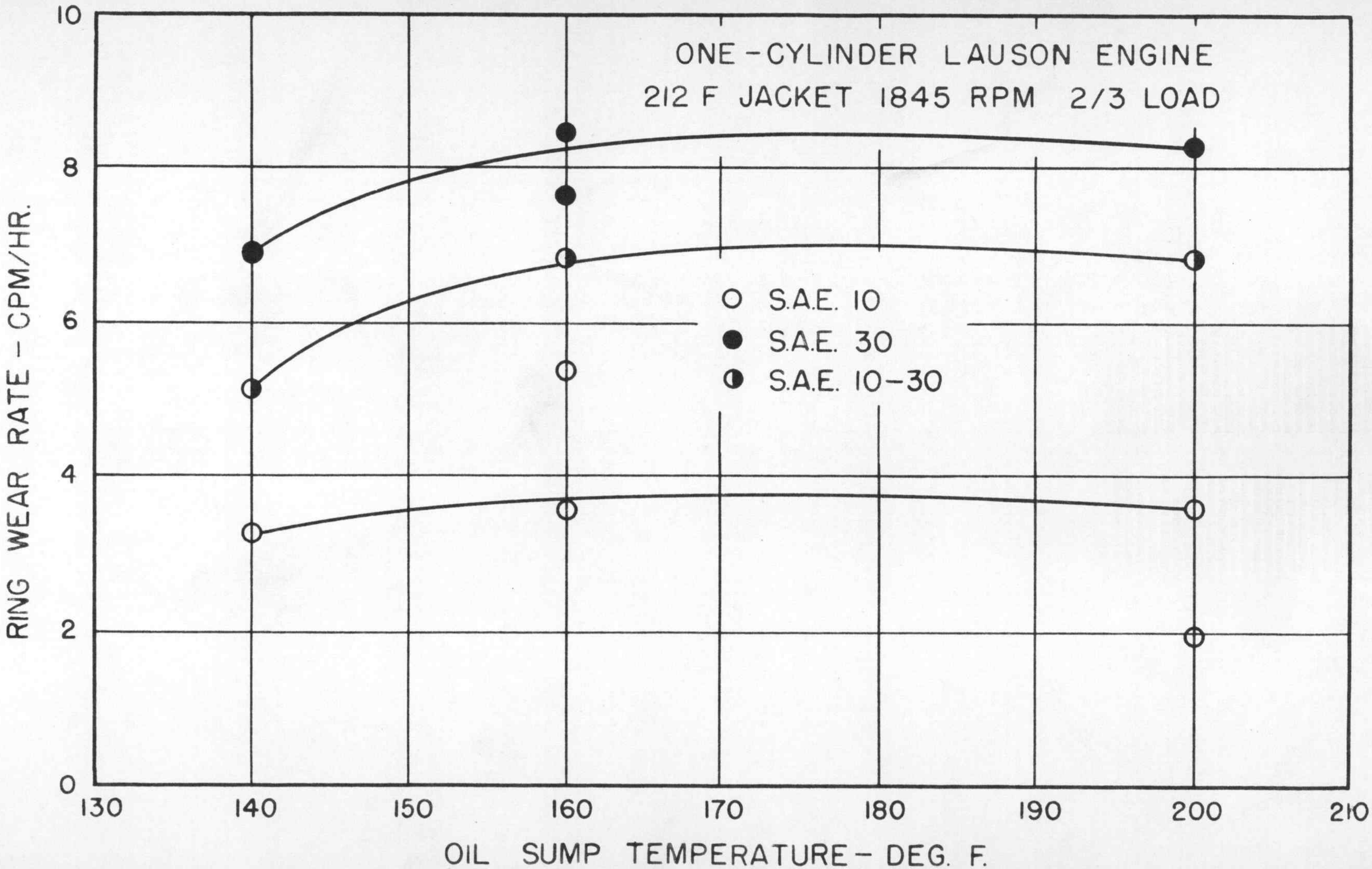

Fig. 9. Effect of Oil Sump Temperature on Ring Wear

RESULTS

One cylinder Lauson engine, Jacket 212F, A/F 13.0, Spark 22°BTC, Air 75F, Load 2/3

Oil grade	Viscosity @ 130F SSU	Viscosity @ 160F SSU	Viscosity @ 210F SSU	Date	Oil Sump Deg F	Uncorrected slope Deg F/hr.	Conversion factor Cpm/deg F	Uncorrected wear rate Cpm/hr.	Decay Correction K	Corrected wear rate Cpm/hr.
5	74.3	56.5	43.7	2-12-55	160	142	0.215	30.5	0.928	32.7
10	105.8	71.0	48.6	2-19-55	160	4	1.12	4.48	0.835	5.37
				2-19-55	200	3	1.12	3.36	0.835	3.60
				2-26-55	140	11.5	0.215	2.47	0.752	3.29
				2-27-55	200	6.75	0.215	1.45	0.741	1.96
				2-28-55	160	2.32	1.12	2.6	0.730	3.56
20	188.1	103	57.7	2- 7-55	160	17.5	0.215	3.76	1.00	3.76
30	260.5	135	67.0	2- 8-55	160	35	0.215	7.52	0.985	7.63
				2-21-55	200	6	1.12	6.72	0.811	8.23
				2-21-55	140	5	1.12	5.6	0.811	6.91
				2-21-55	160	32	0.215	6.88	0.811	8.48
10-30	163.3	103	62.5	2-23-55	160	25	0.215	5.38	0.787	6.83
				2-22-55	140	19	0.215	4.08	0.799	5.12
				2-23-55	200	25	0.215	5.38	0.787	6.83
40	347.2	170	76.6	2- 9-55	160	55	0.215	11.85	0.970	12.2
50	492.4	215	93.8	2-11-55	160	73	0.215	15.7	0.942	16.65

Fig. 10. Tabulated Test Results

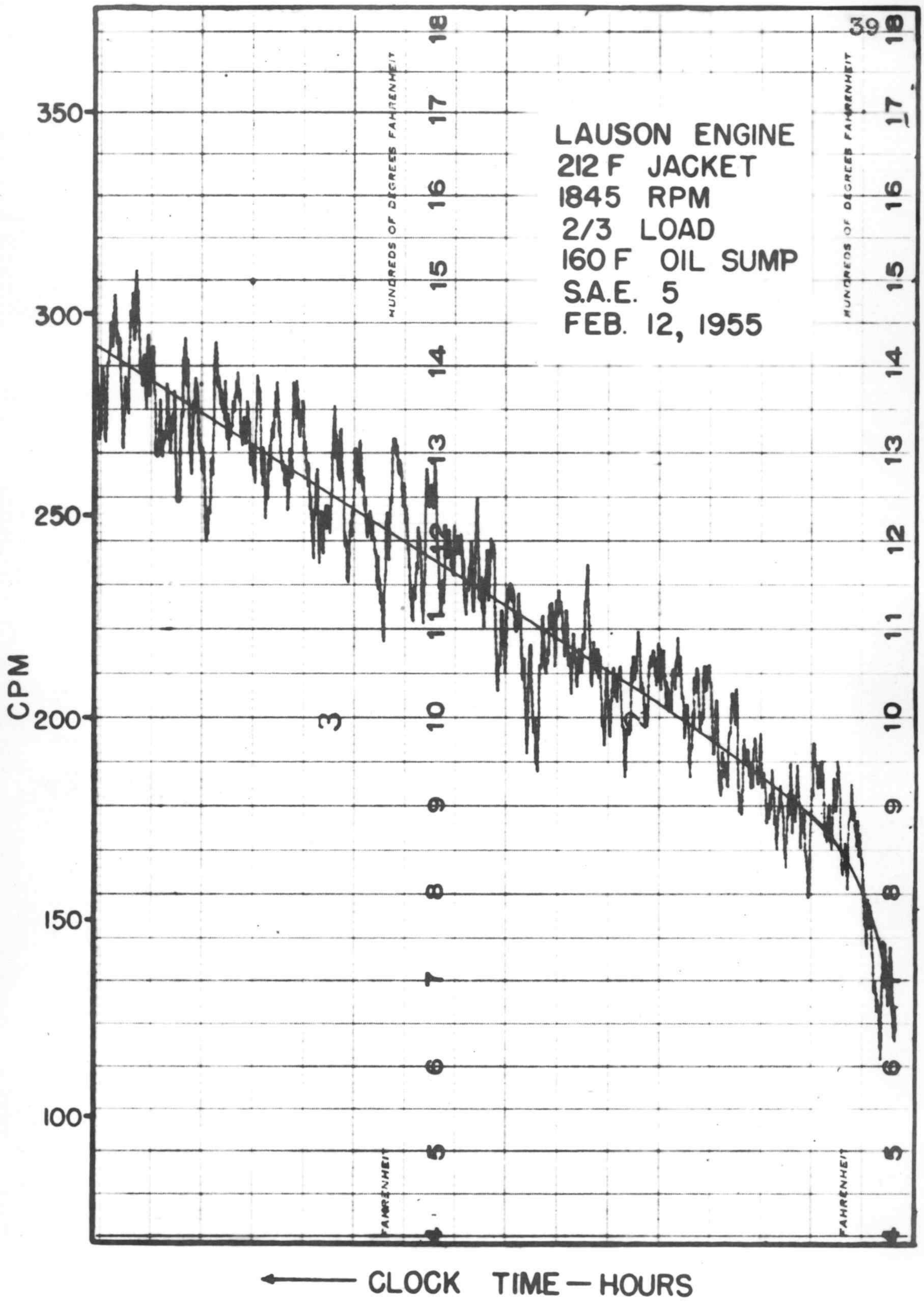

Fig. 11. Wear Rate Record for an S.A.E. 5 Oil

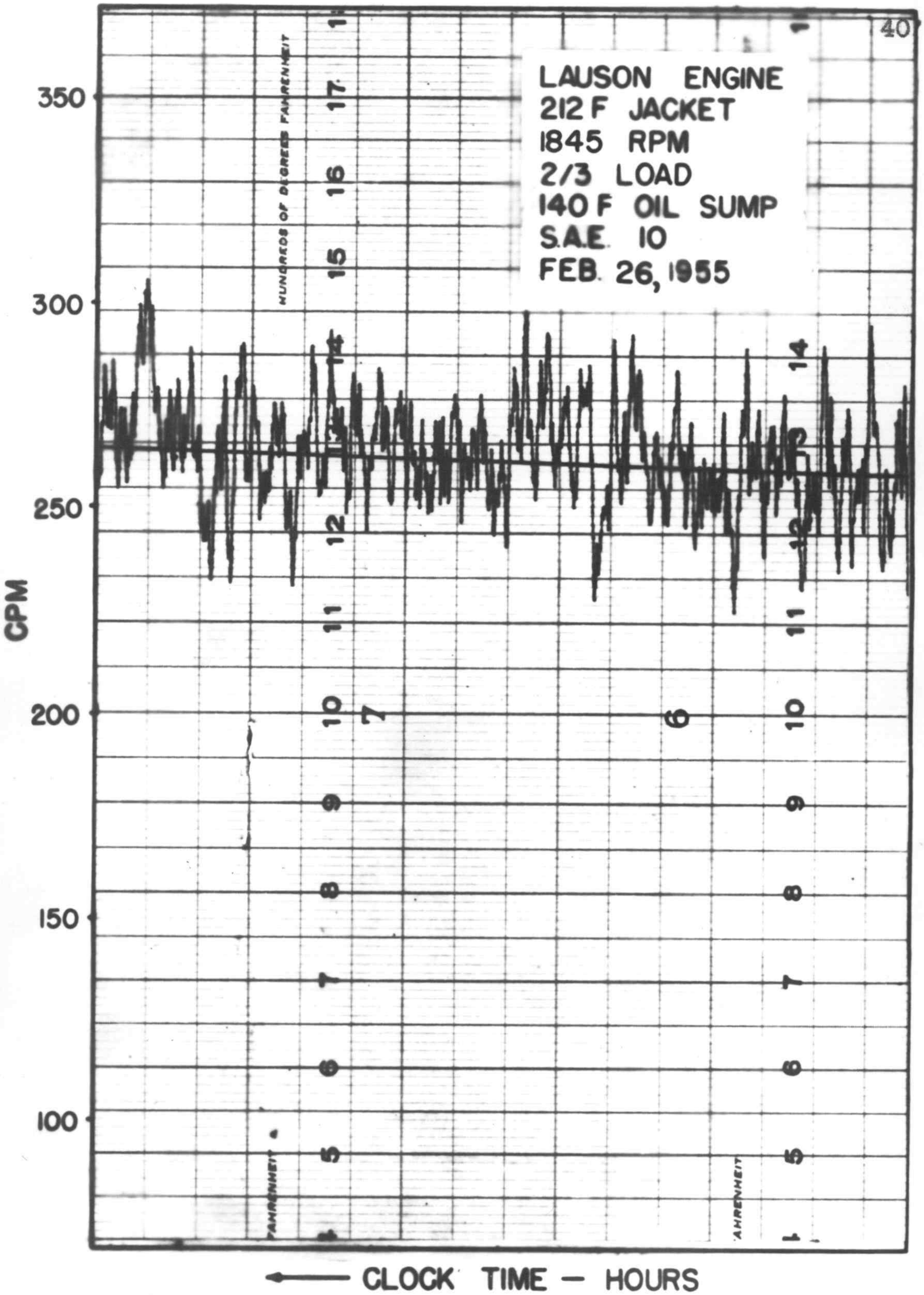

Fig. 12. Wear Rate Record for an S.A.E. 10 Oil

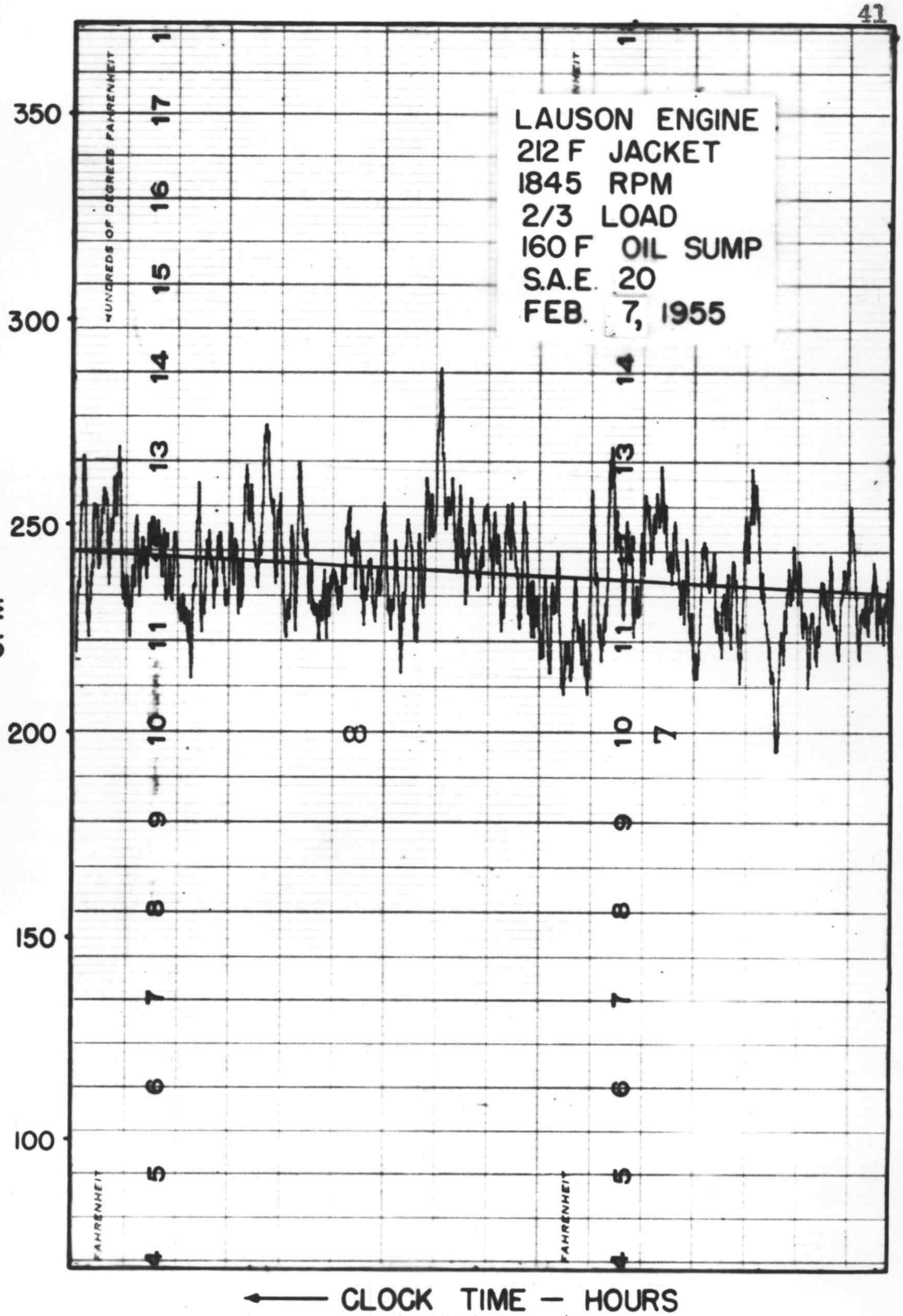

Fig. 13. Wear Rate Record for an S.A.E. 20 Oil

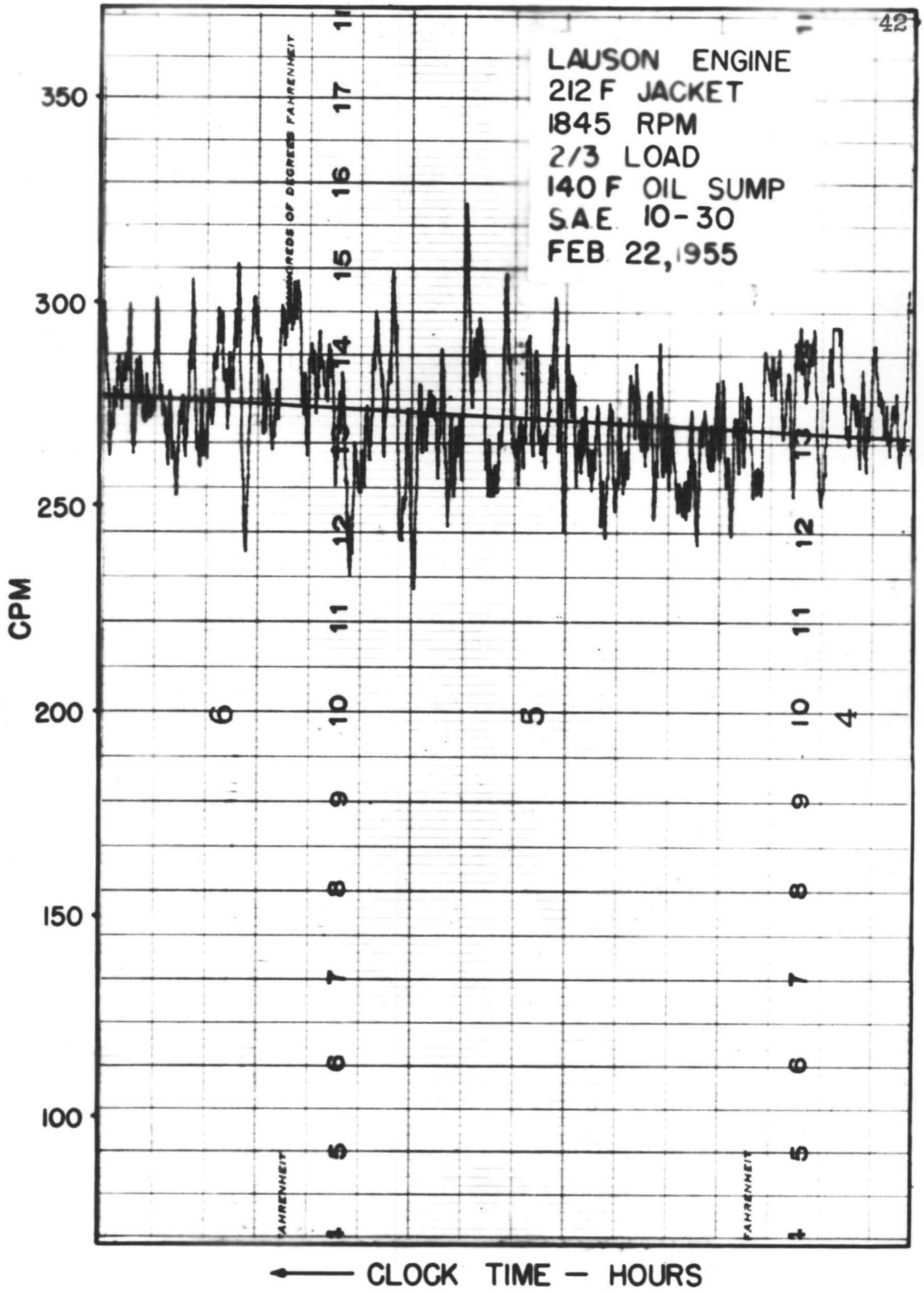

Fig. 14. Wear Rate Record for an S.A.E. 10-30 Oil

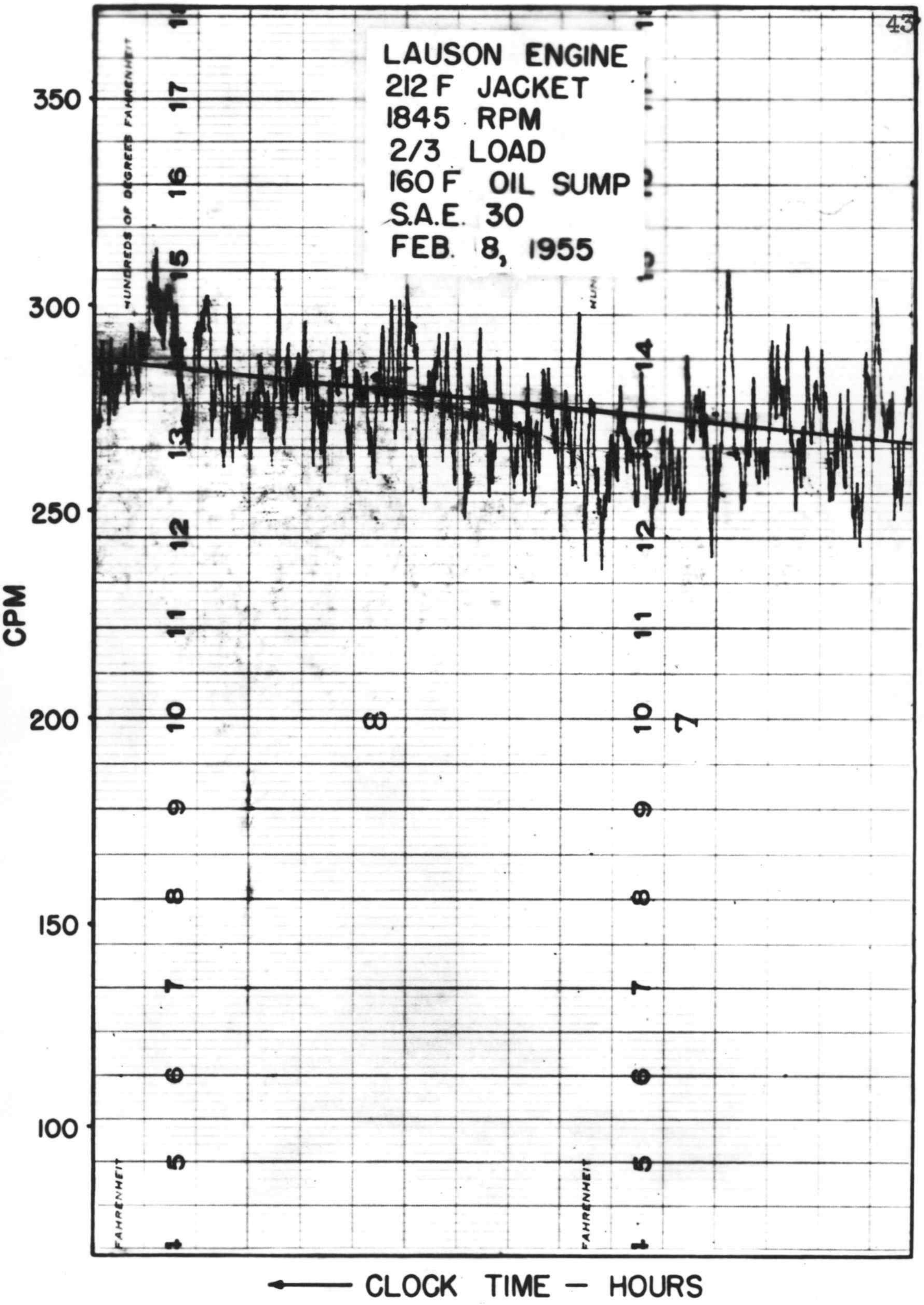

Fig. 15. Wear Rate Record for an S.A.E. 30 Oil

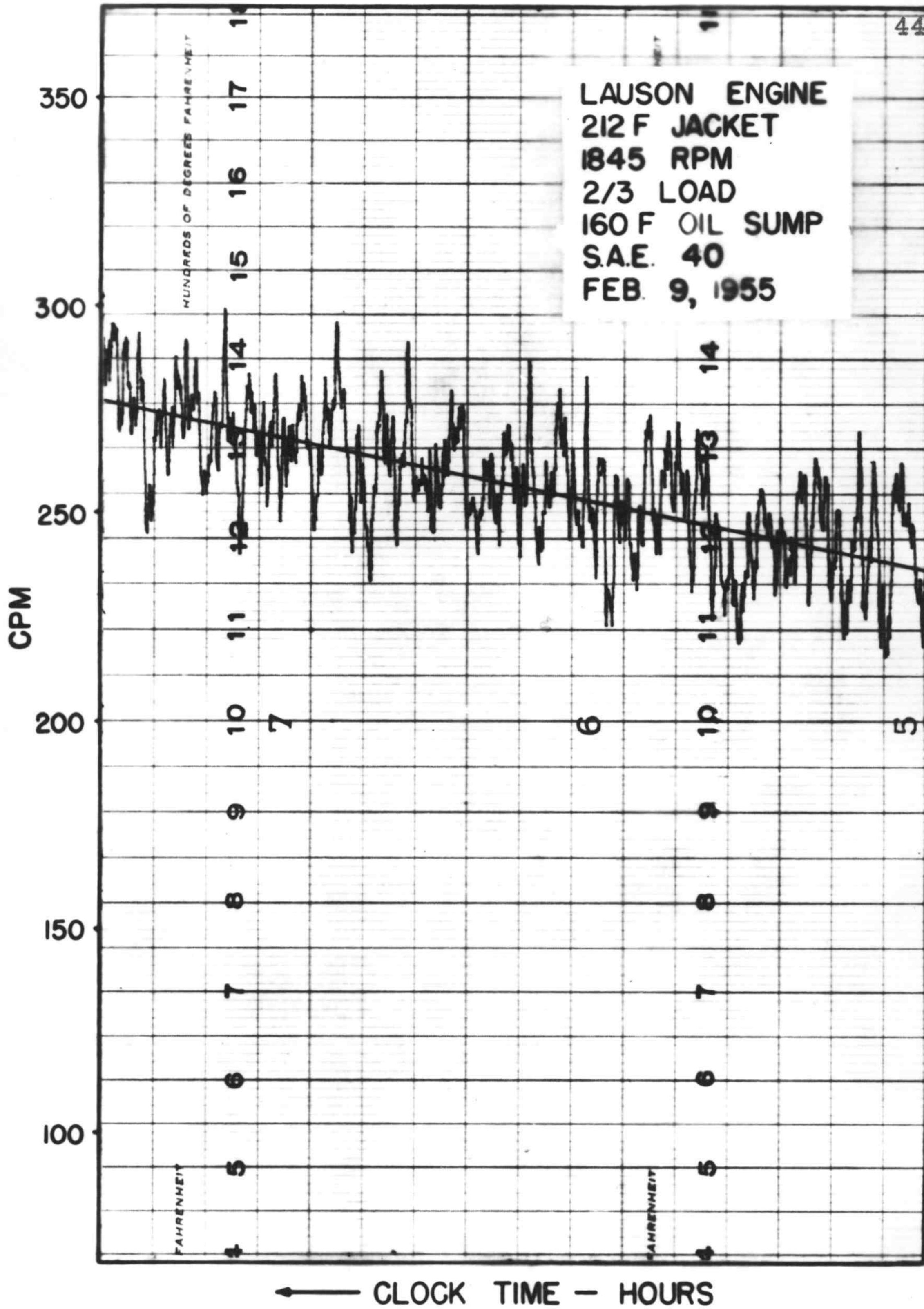

Fig. 16. Wear Rate Record for an S.A.E. 40 Oil

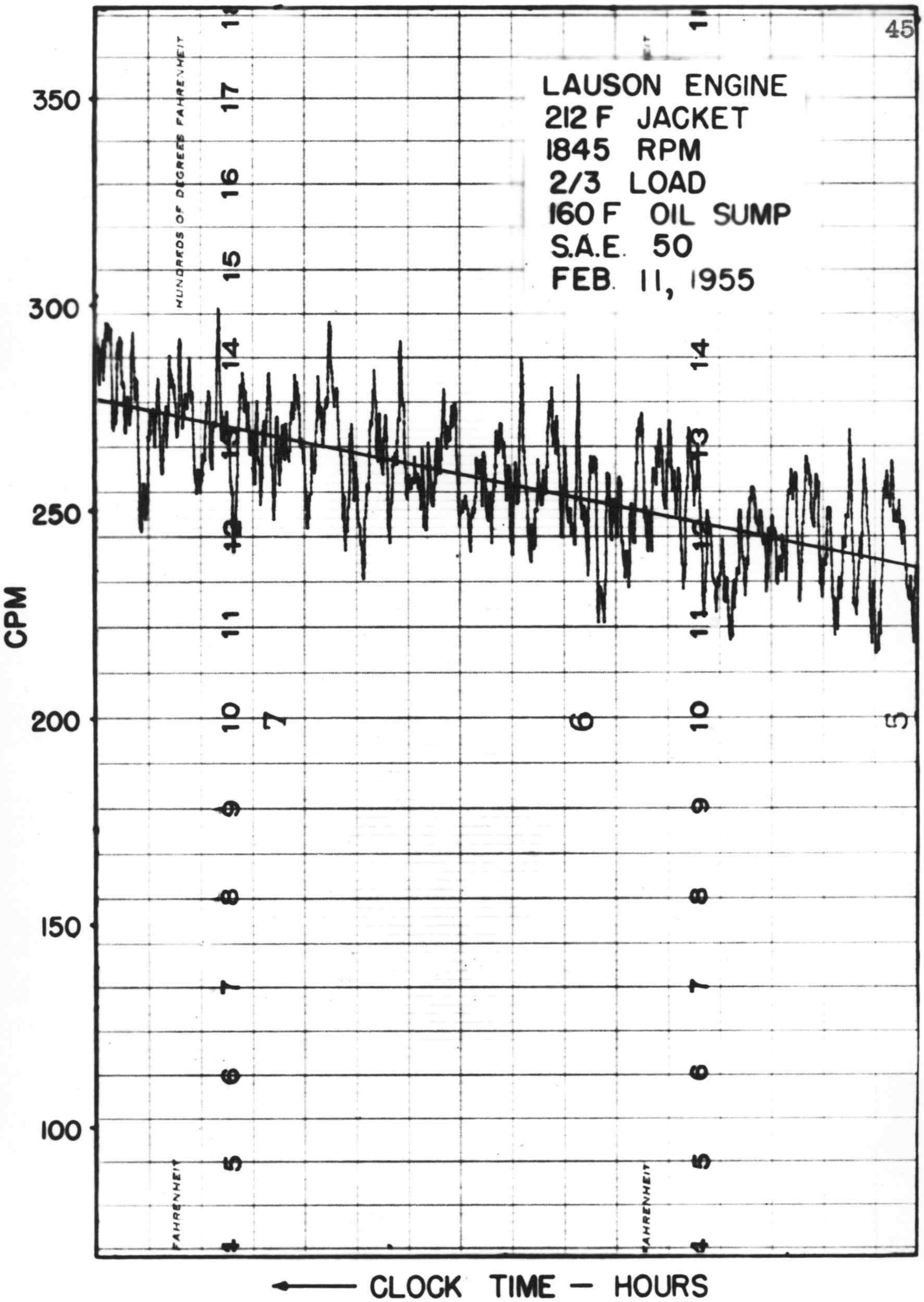

Fig. 17. Wear Rate Record for an S.A.E. 50 Oil

CONCLUSIONS

It can be concluded from this test that under warmed-up conditions where corrosive wear is eliminated, that lubricating oils having viscosities between 48.6 and 57.7 SSU at 210 F are the most effective in reducing ring wear. This viscosity range encompasses the SAE 10 and 20 oil grades.

The oil sump temperature within reasonable limitations has no appreciable effect on the wear rates of different grades of oil. This indicates that the oil viscosity at the temperatures of the cylinder walls, as controlled by jacket water temperature, governs the ring wear rates.

The SAE 10-30 oil was found to have a wear rate higher than an SAE 20 oil. With the exception of the possibility of higher oil consumption, an SAE 10 is better than an SAE 10-30 oil. It has a greater fluidity at low temperatures for ease of starting, yet has a lower wear rate when operating at higher temperatures when the engine is warm. At present prices, two quarts of premium SAE 10 could be consumed in an engine having a six quart oil capacity against none of the SAE 10-30 and still have equal oil costs. The SAE 10 oil would still be more economical because of the reduced engine wear. The saving in oil consumption with the 10-30 oil would have to be substantial and the cost of this oil would have to be much less in order to make it more economical than the SAE 10 oil.

The test definitely indicates there is an optimum oil viscosity for wear reduction. It appears that the range of SAE 10 and SAE 20 oils are ideal for the Lauson engine. This quantitative result from the Lauson engine can be applied to other engines with reasonable accuracy because the conditions affecting the lubrication of the piston rings are comparable.

RECOMMENDATIONS

In addition to the effects of oil viscosity upon ring wear determined in this test, other factors involving the oil viscosity need further research. Information on the effect of jacket temperature and oil viscosity upon wear rates would indicate if optimum oil viscosity changes with jacket temperature. The load and speed should both be varied with oil viscosity to study their effects upon proper lubrication of the piston rings and cylinder walls. This is of importance because the automotive engine very rarely operates under conditions of constant load and speed.

A schedule of starts and stops could be set up with varied oil viscosity to investigate the effectiveness of the various oils in reducing the large amount of wear that occurs when the engine is started, run only a short distance, and stopped. A large amount of city driving is done under this type of service, recognized to be the severest conditions to which a lubricating oil may be subjected.

Considerable discussion is also in process as to whether sulfur should be added to the oil to reduce wear, and if so, under what conditions does it reduce wear; or whether the oil should be highly alkaline to neutralize any acids formed and thus reduce corrosive wear. These factors coupled with oil viscosity and jacket temperature possibly would give some very interesting information as to the role of additives and oil viscosity in reducing all forms of piston ring wear.

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