

HEAT TRANSFER PROPERTIES OF ENGINE OILS

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ABSTRACT

The thermal properties of engine oil are important traits affecting the ability of the oil to transfer heat from the engine. The larger the thermal conductivity and specific heat, the more efficiently the oil will transfer heat. In this work, we measured the thermal conductivity and specific heat of a conventional mineral oil-based diesel engine lubricant and a Group V-based LHR diesel engine lubricant as a function of temperature. We also measured the specific heat of ethylene glycol. The measured values are compared with manufacturers' data for typical heat transfer fluids. The Group V-based engine oil had a higher thermal conductivity and slightly lower specific heat than the mineral oil-based engine oil. Both engine oils had values comparable to high-temperature heat transfer fluids.

INTRODUCTION

While engine oil lubricates and mitigates wear, it importantly serves as a heat-transfer fluid in engines. Oil thermal conductivity and specific heat are important parameters for engine cooling system design, and are a function of temperature. Oils with a larger thermal conductivity value will transfer heat energy more efficiently. Oils with a larger specific heat value will have a smaller temperature rise for a given amount of heat energy absorption. The heat transfer properties of lubricants for low heat rejection (LHR) diesel engines are particularly important. The external oil cooler and radiator will not be present in proposed uncooled LHR engines. The engine oil would be the sole heat transfer fluid. Current LHR engine oils are formulated with Group V base fluids, whose heat transfer properties have not previously been determined.

BACKGROUND

Surprisingly, little data on actual thermal properties of fully-formulated engine oils have previously been reported. Several engine oil manufacturers rely on a table in the National Bureau of Standards (NBS) Miscellaneous Publication No. 97 [1] from 1929 to report the thermal conductivity and specific

heat of their oils. In that publication, thermal conductivity and specific heat for petroleum products are listed as a function of specific gravity and temperature. Other technical literature contains only a few results on Group IV and Group V base fluids [2,3]. There is poor agreement among these results and reproducibility is rarely stated.

Manufacturers' measured data on high-temperature industrial heat transfer fluids, which include mineral oils, phenyl ethers, and silicones, is available [1,4,5,6]. Figures 1 and 2 show the typical ranges of reported data for water, glycols, engine oils, and heat transfer fluids. Water has thermal conductivity and specific heat values approximately twice those of typical glycols. High-temperature heat transfer fluids and petroleum engine oils have lower values for thermal properties than glycols. Many types of oils are used as heat transfer fluids, which leads to a fairly wide band of typical thermal conductivity and specific heat values. Hydrocarbon or mineral oils, similar to Group II engine oils, have thermal conductivity values and specific heat values within the upper half to third of all high-temperature heat transfer fluids.

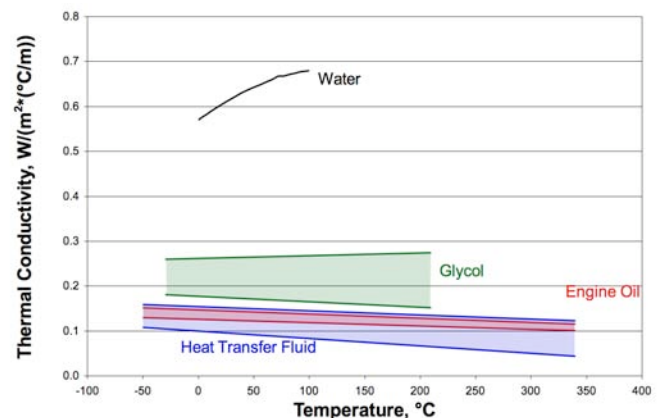


Figure 1. Typical ranges for thermal conductivity.

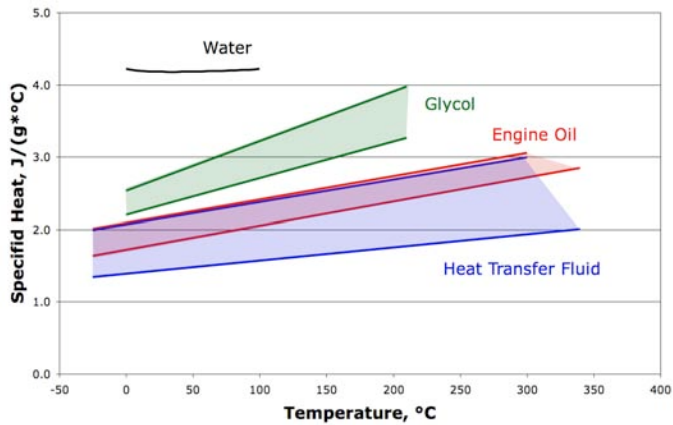


Figure 2. Typical ranges for specific heat.

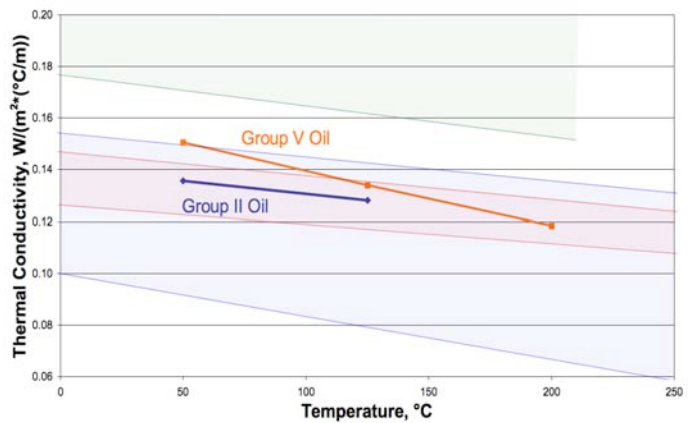


Figure 3. Measured thermal conductivity for Group II and Group V-based engine oils.

THERMAL PROPERTY MEASUREMENTS

Thermal conductivity and specific heat were measured for a Group II conventional mineral oil-based diesel engine lubricant and a Group V-based LHR diesel engine lubricant. Measurements were taken as a function of temperature using standard ASTM methods. Thermal conductivity was measured by the hot-wire technique outlined in ASTM D2717 *Standard Test Method for Thermal Conductivity of Liquids*. Specific heat was measured using ASTM D1269 *Standard Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry*. For the specific heat measurements, four separate samples were tested to determine repeatability. Using the average of the four samples, the reproducibility of all specific heat results was within $\pm 8.6\%$.

The Group V-based engine oil had a slightly higher thermal conductivity than the Group II-based engine oil, shown in Figure 3. For all measured temperatures, the Group V-based engine oil had thermal conductivity values in the upper portion of the heat transfer fluid range and exceeded the engine oil range at 50°C. The Group II-based engine oil had a thermal conductivity value within the typical range for engine oil, but was less dependent on temperature than the Group V-based oil.

The Group V-based engine oil had a slightly lower specific heat than the Group II-based engine oil, shown in Figure 4. The Group II-based engine oil had a specific heat within the typical range for engine oils. The Group V-based engine oil had a specific heat slightly lower than the typical range for engine oils. Specific heat of ethylene glycol was measured, as a reference to confirm the literature values for glycol and to verify all specific heat results. The ethylene glycol specific heat measurements were well within the reported values for glycols.

SUMMARY AND CONCLUSIONS

Requirements for LHR engine oils have much in common with high-temperature industrial heat transfer fluids. Both high-temperature heat transfer fluids and LHR engine oils require superior high-temperature stability and low deposit-forming tendency, as well as reasonably high specific heat and thermal conductivity. Both oils compared favorably to heat transfer fluids in thermal properties. In addition, the LHR oil

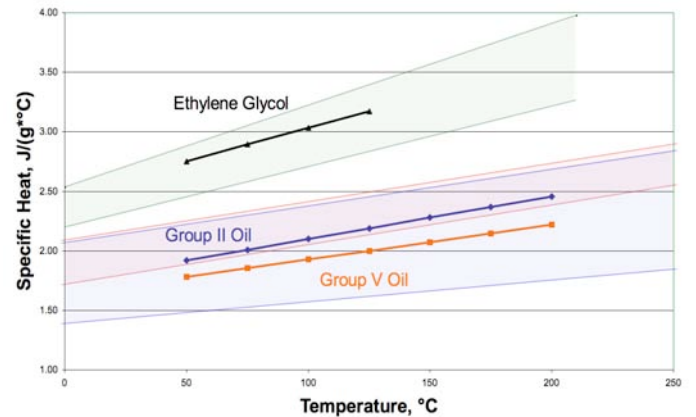


Figure 4. Measured specific heat for the Group II-based engine oil, Group V-based engine oil, and ethylene glycol.

has the outstanding high-temperature stability and lubricating properties necessary for LHR engine operation.

ACKNOWLEDGMENTS

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