# A Study of the Low-Temperature Flow Properties of Highly Sooted, Heavy-Duty Engine Oils

## Results from a New Temperature-Scanning Viscometric Technique

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# Background:

- The negative impact of highly sooted, heavy duty engine oils regarding low-temperature starting and, particularly, pumpability has generated considerable interest, concern, and work.
- Older pumpability methods originally developed for fresh passenger car engine oils have been applied to sooted oil pumpability with limited success regarding analysis time, precision, and sensitivity to soot effects.
- What is obviously needed is a fast, precise test -- capable of providing all critical information regarding viscosity and soot structure.

# Recent Background:

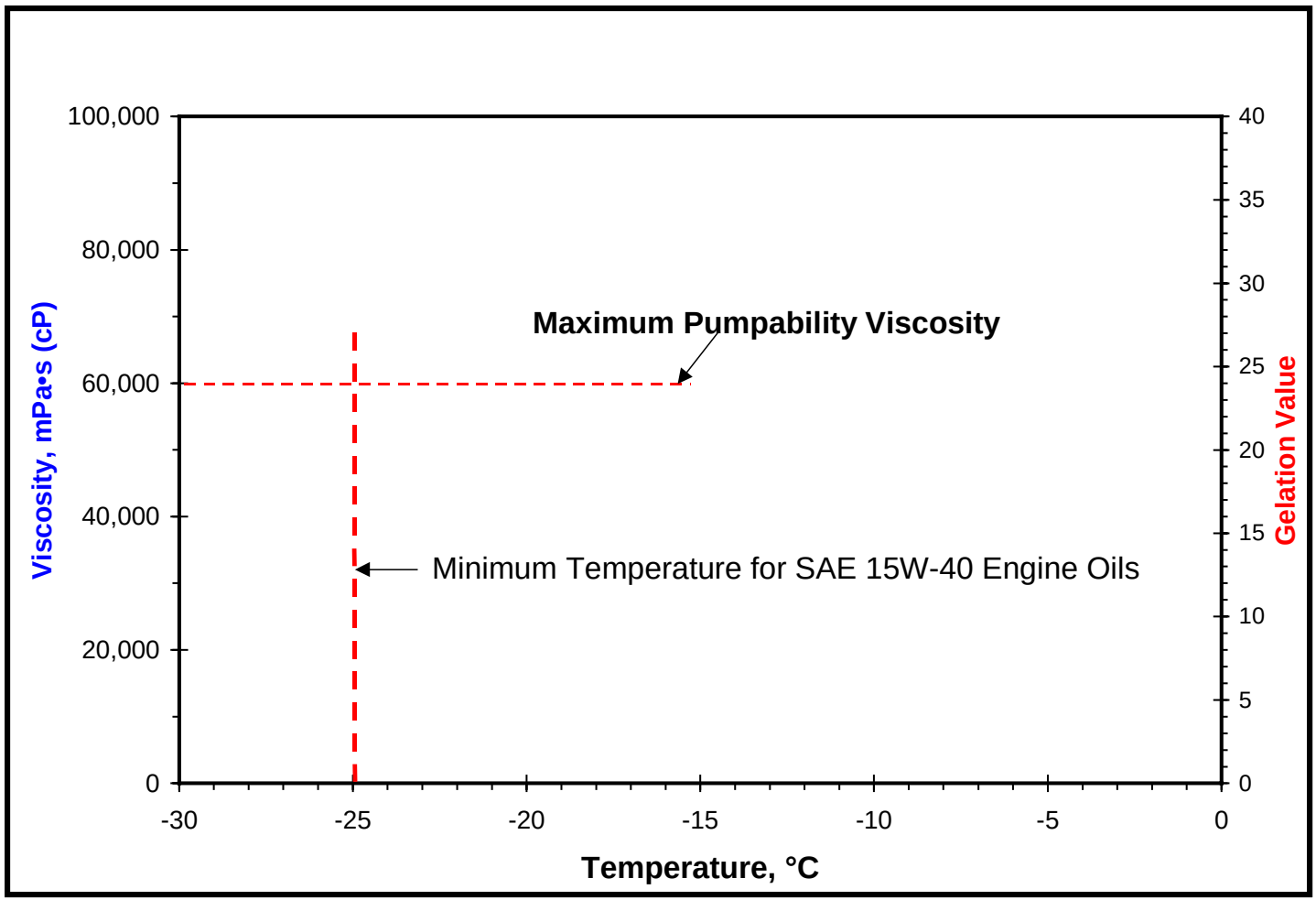
- The higher-torque temperature-scanning approach reported earlier has now been matched with a new program.
- Very recently, Chris May kindly supplied Savant with seven sooted oils from his collection.
- Savant used the oils and the new viscometers and program to apply a new method for characterizing the low temperature flow of sooted oils.
- Extensive work was completed and analyzed last week and the results are promising.

# The method developed and used in the study:

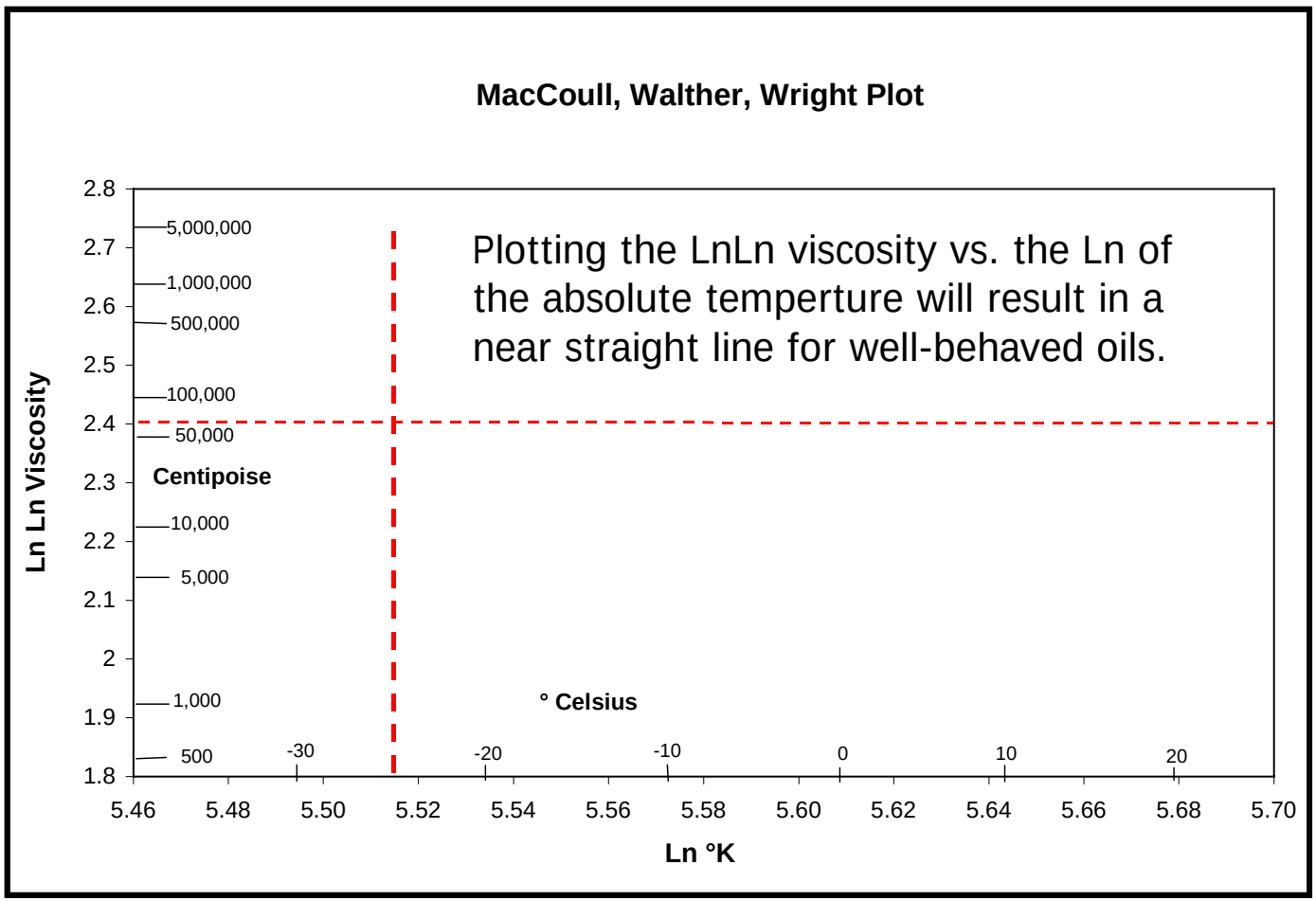
- The oil is heated to 90°C for one hour in a viscometer cell.
- The cell is brought to +20°C in the bath to be used while stirring the oil with the rotor at 12 RPM continuously.
- Alternatively, the oil is brought to -5°C while stirring.
- Starting at either +20°C or -5°C, the oil is cooled at 3°C/hr. Until the bath reaches -26°C.
- The temperature scan of viscosity is completed in either 16 hours or in 7 hours, respective to the starting temperature. (All oils in this study were cooled 16 hours.)

# A couple of examples to show how the data will be presented:

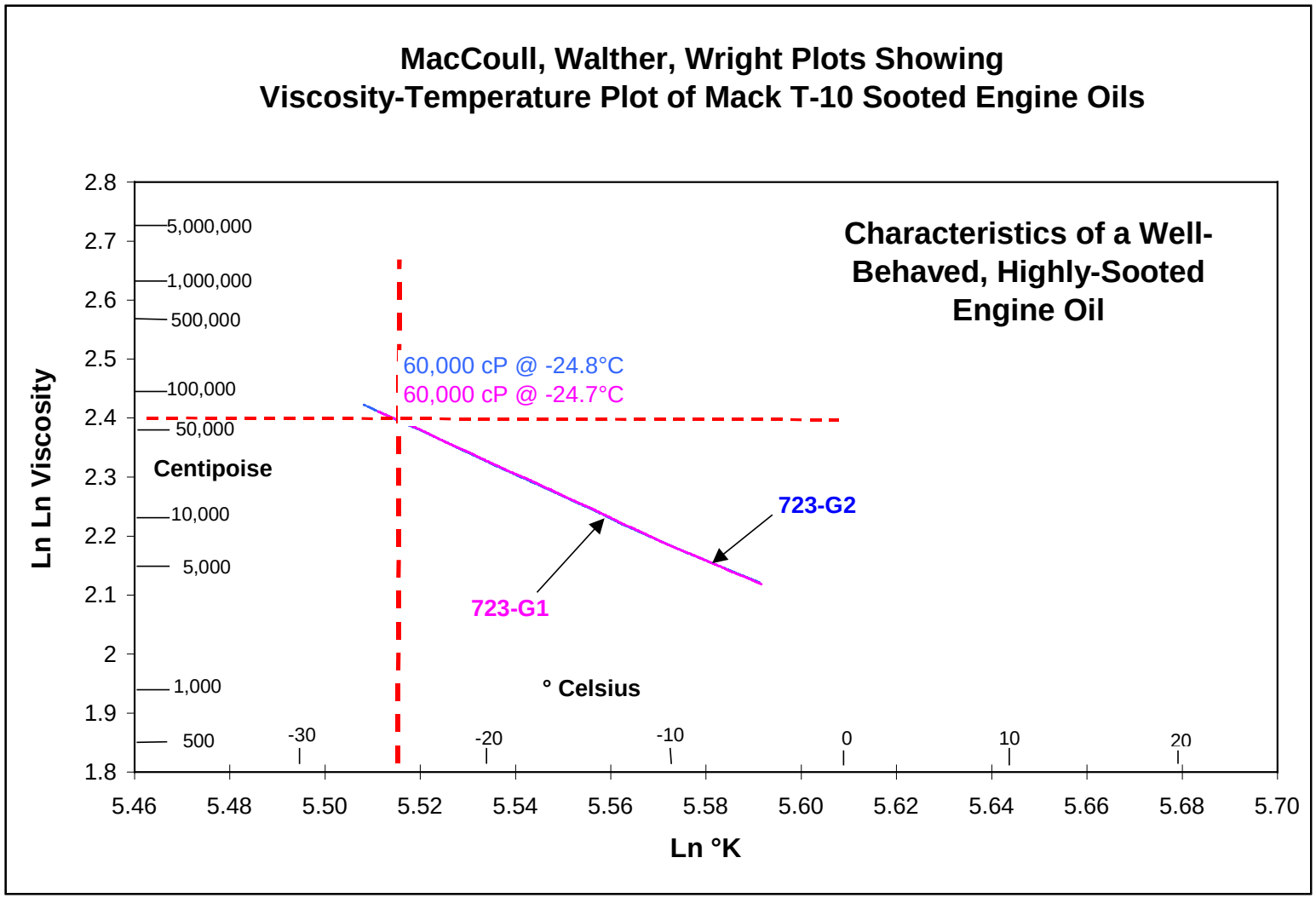
- A viscosity-temperature/Gelation Index graph:



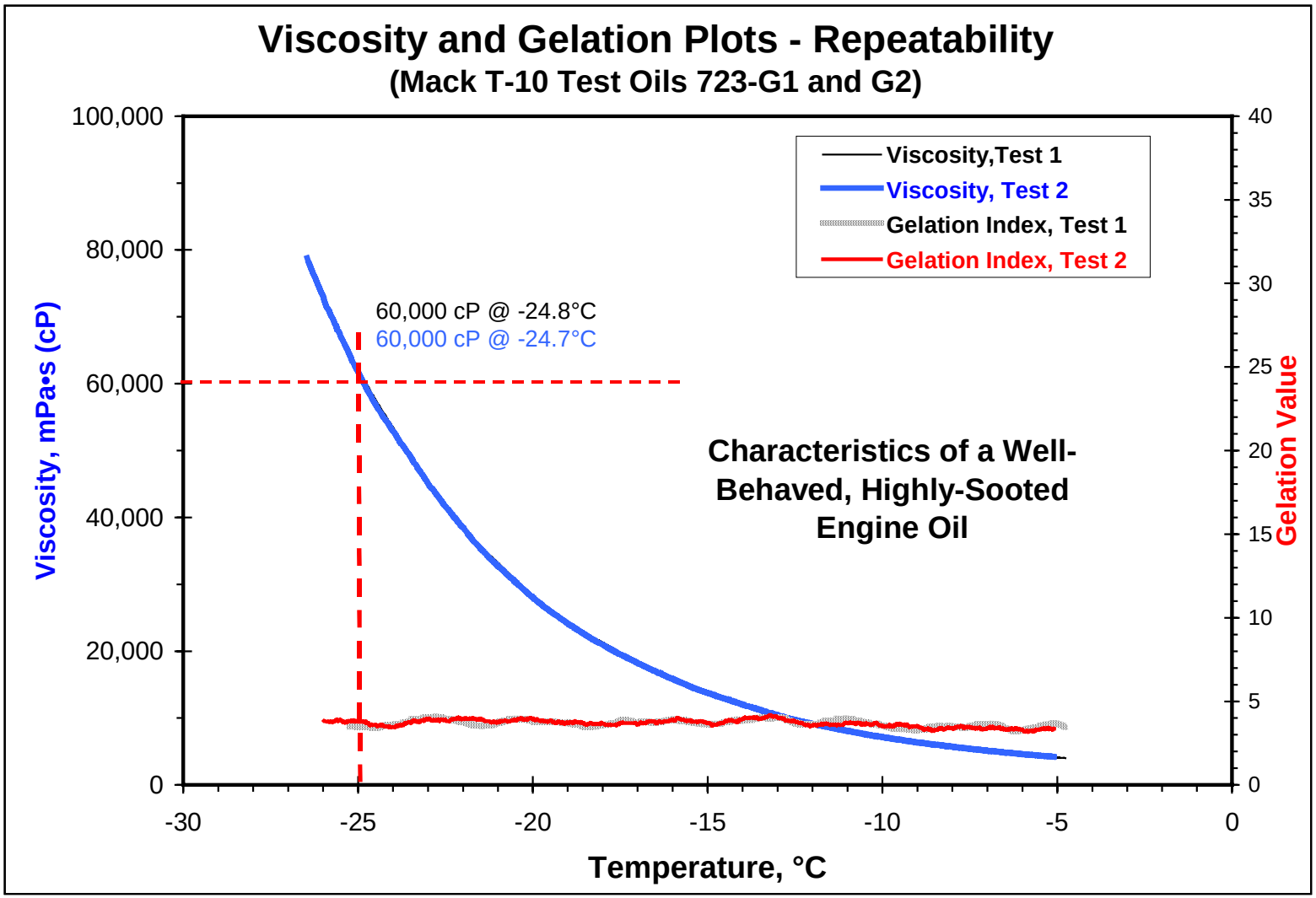
- A MacCoull, Walther, Wright graph:



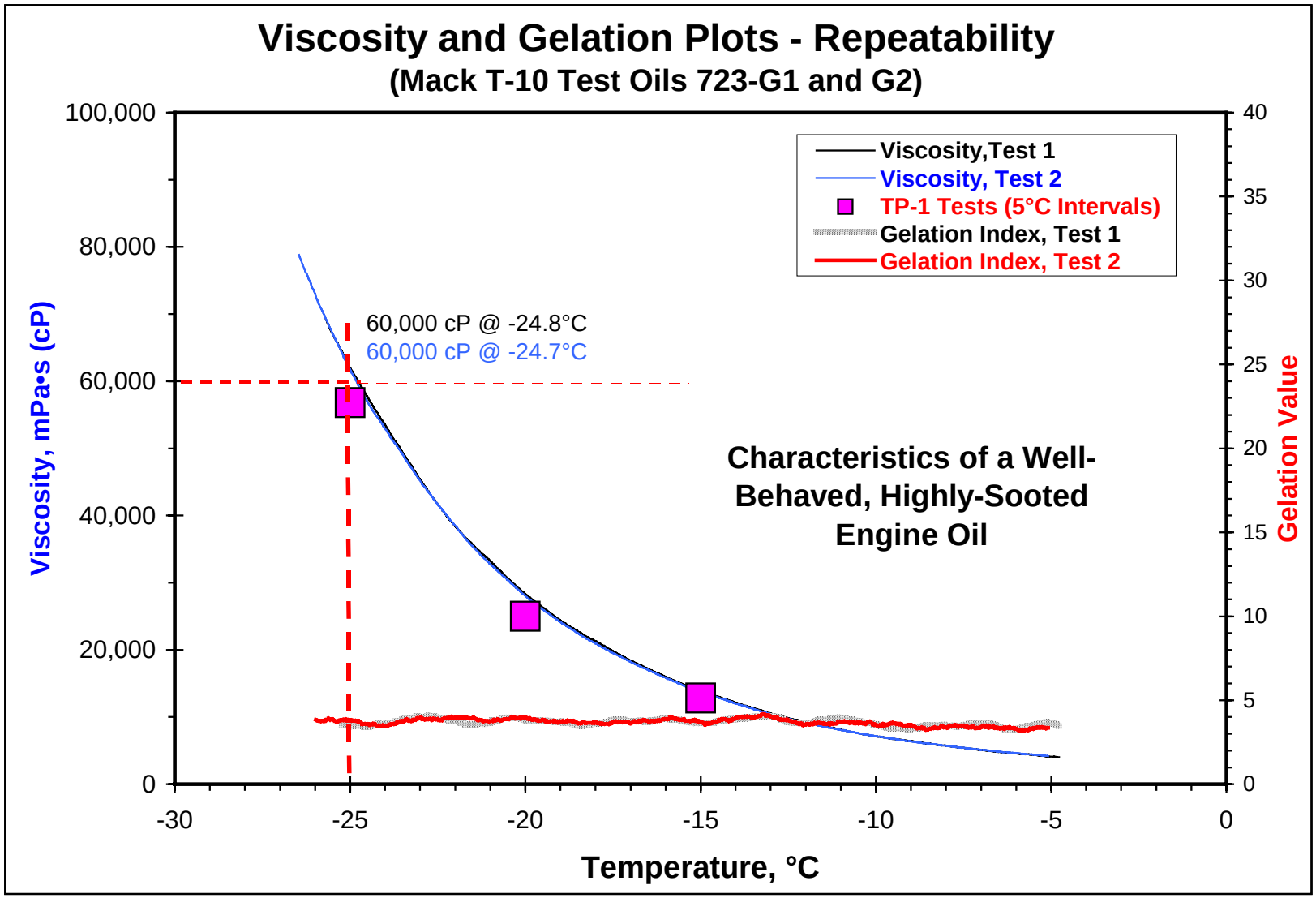
Well-behaved highly sooted Oil 723-G run in duplicate using temperature-scanning viscometry. Note the straight line of superimposed data.



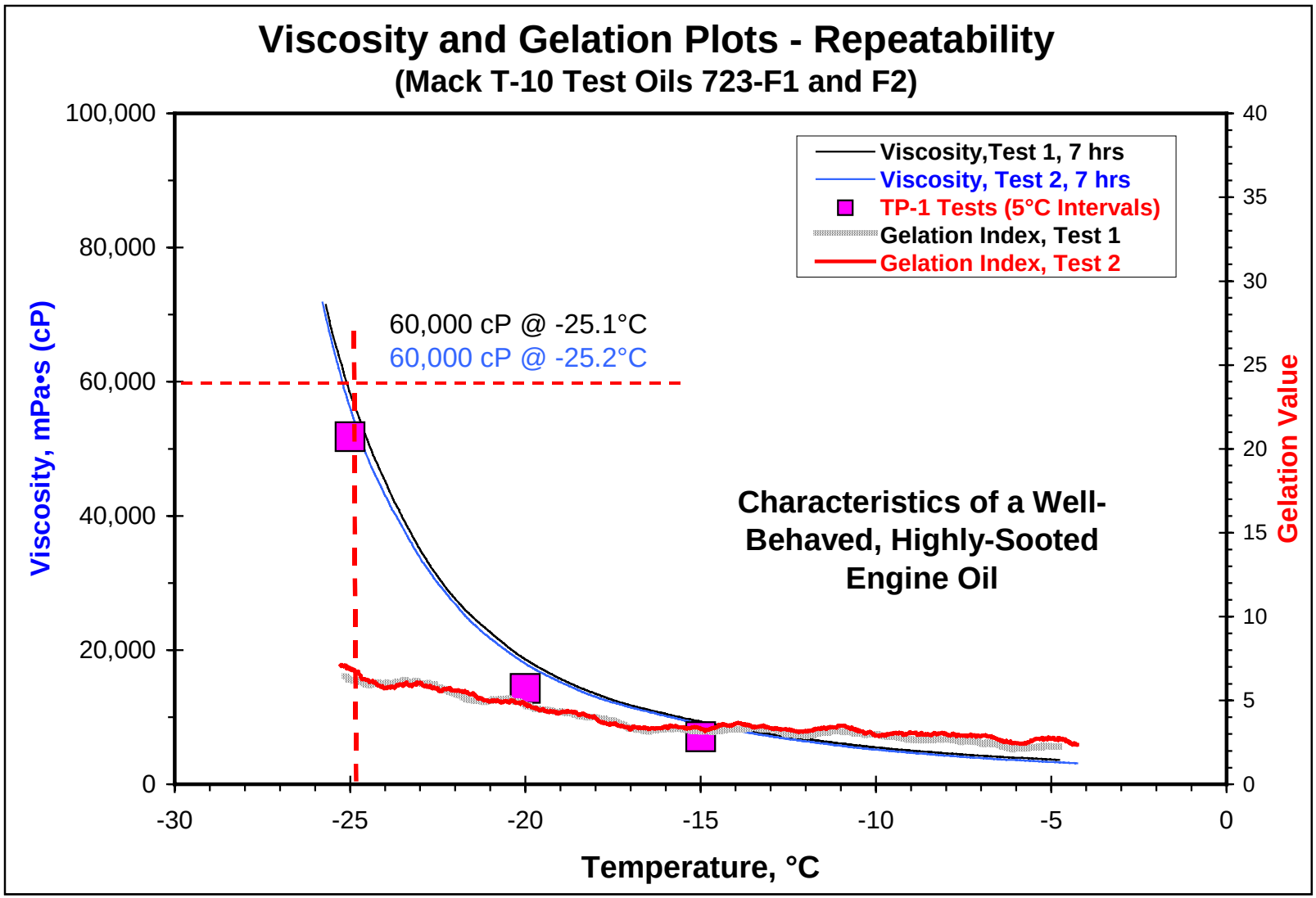
Another view of Oil 723-G run in duplicate showing the simple viscosity-temperature curve and Gelation Index. Repeatability is very good.



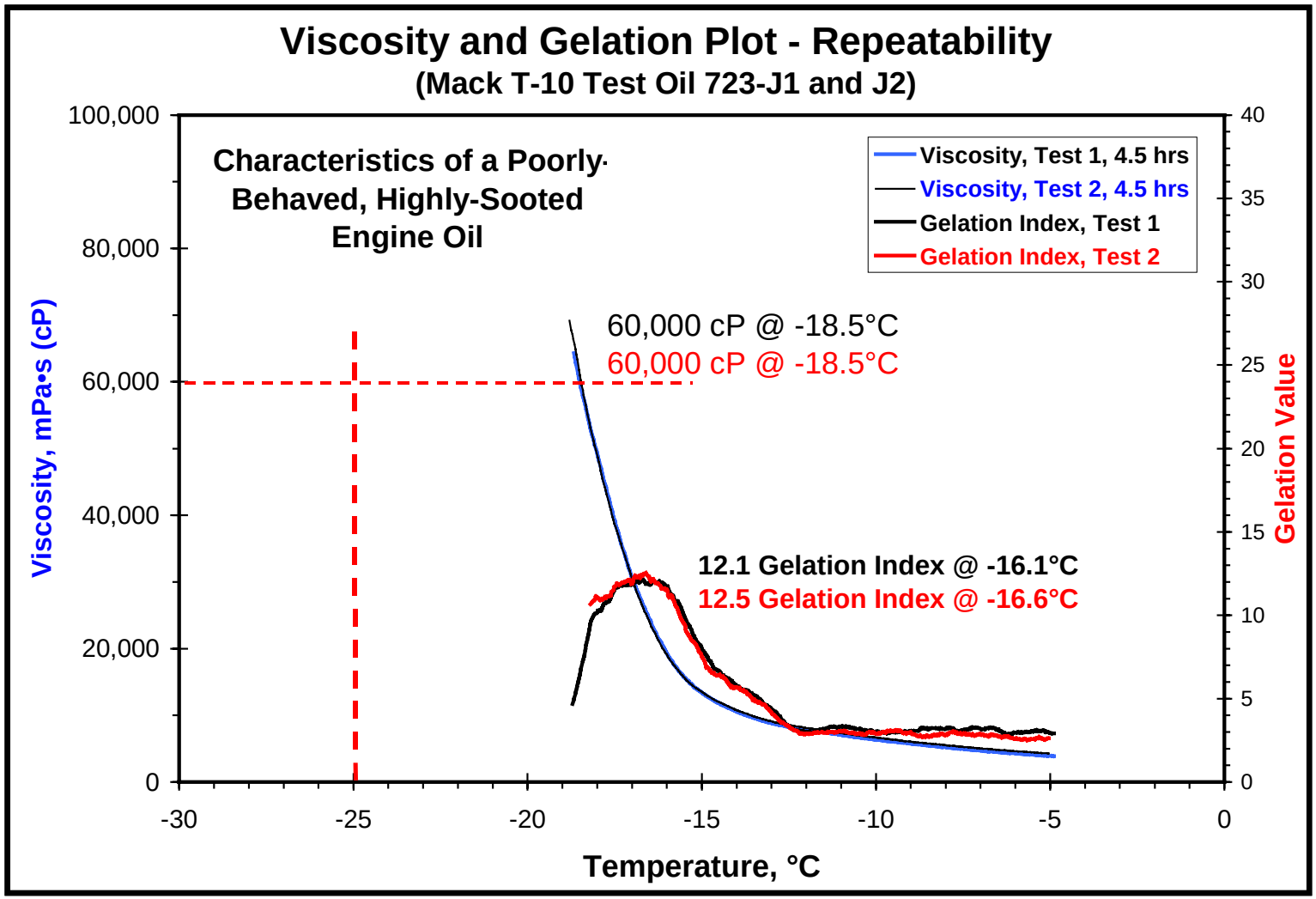
Three TP-1 values obtained at 5°C intervals are added to the information. Agreement of the two instruments is good with well-behaved oil.



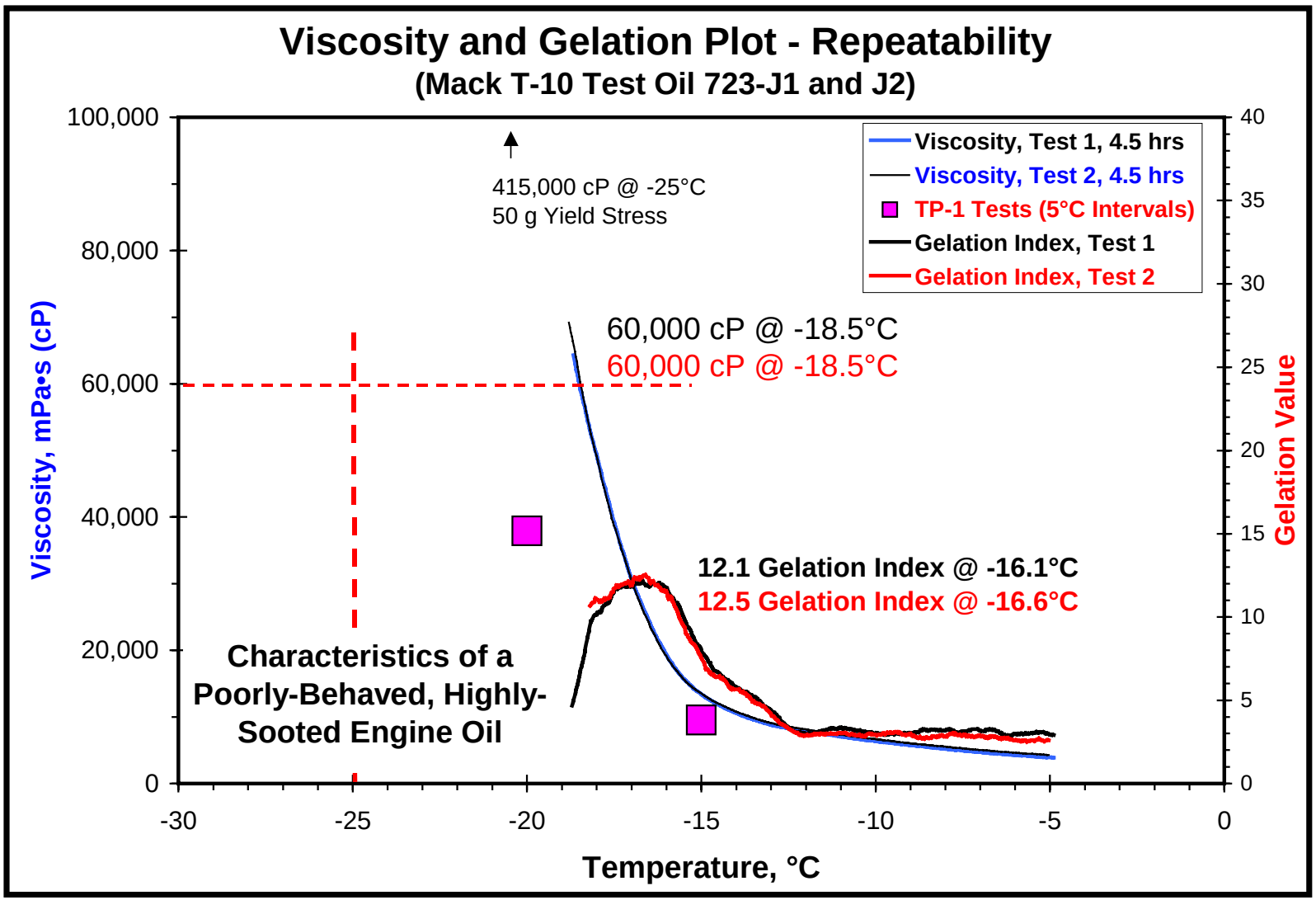
Another well-behaved oil is shown here. Again, repeatability of the temperature-scanning technique is good as is agreement between the two viscometric approaches.



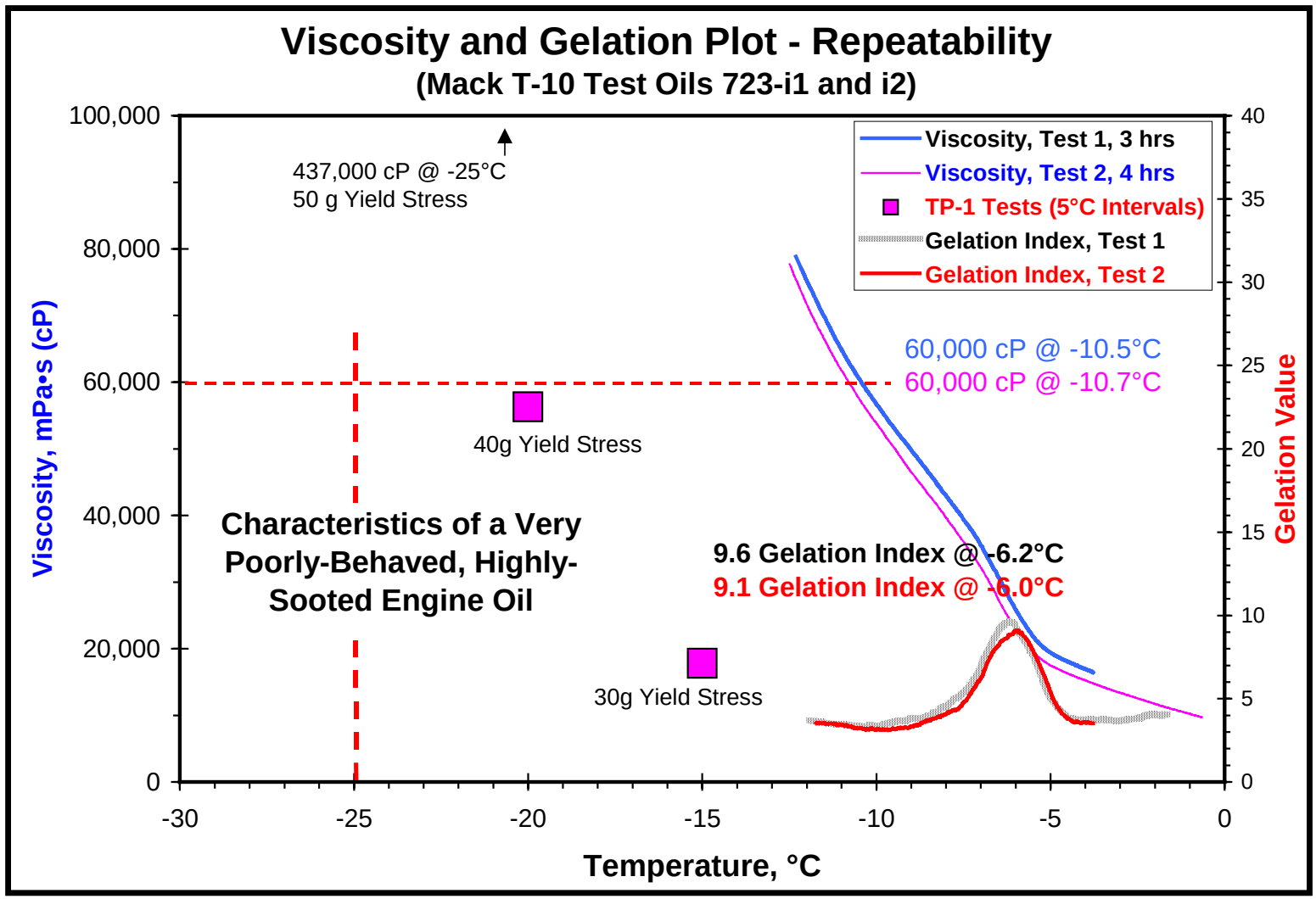
With poorly behaved oils a different viscometric character is shown. Gelation Indices are shown for Oil 723-J and are closely repeatable. The duplicate samples pass 60,000 cP at -18.5°C -- well below -25°C.



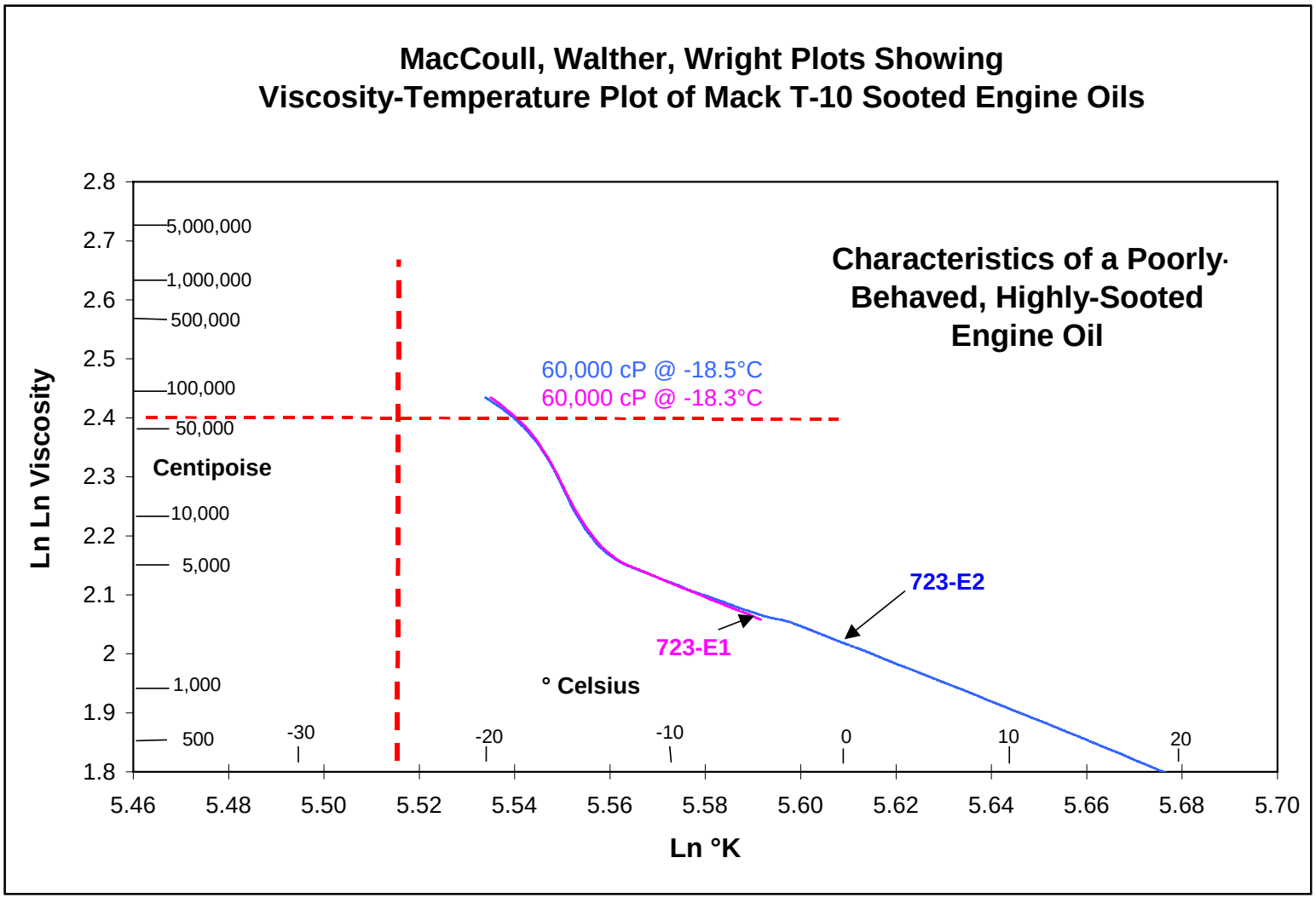
Including results from the TP-1 shows that agreement between the two methods is only reasonably close at -15°C -- before gelation begins.



A very poorly behaved Oil 723-i passes 60,000 cP at -10.5° to -10.7°C and has a clear Gelation Index of 9.1 to 9.6 at ~-6°C. No correlation with the TP-1 data is shown with this oil. The latter method shows Yield Stresses at all temperatures.



Recording the data continuously from +20°C to -25°C shows that further data can be collected if desired. In the case of Oil 723-E, the oil has a well behaved appearance from +20° to -12°C at which point the oil deteriorates into poor flow behavior.



Summarizing the data from the seven Mack T-10 highly sooted oils, the information in Table 1 is helpful. The Average Differences shows that the repeatability of the broader range scanning viscometry is good.

**Table 1 - Analysis of Seven Mack T-10 Highly-Sooted Engine Oils at Low Temperatures**

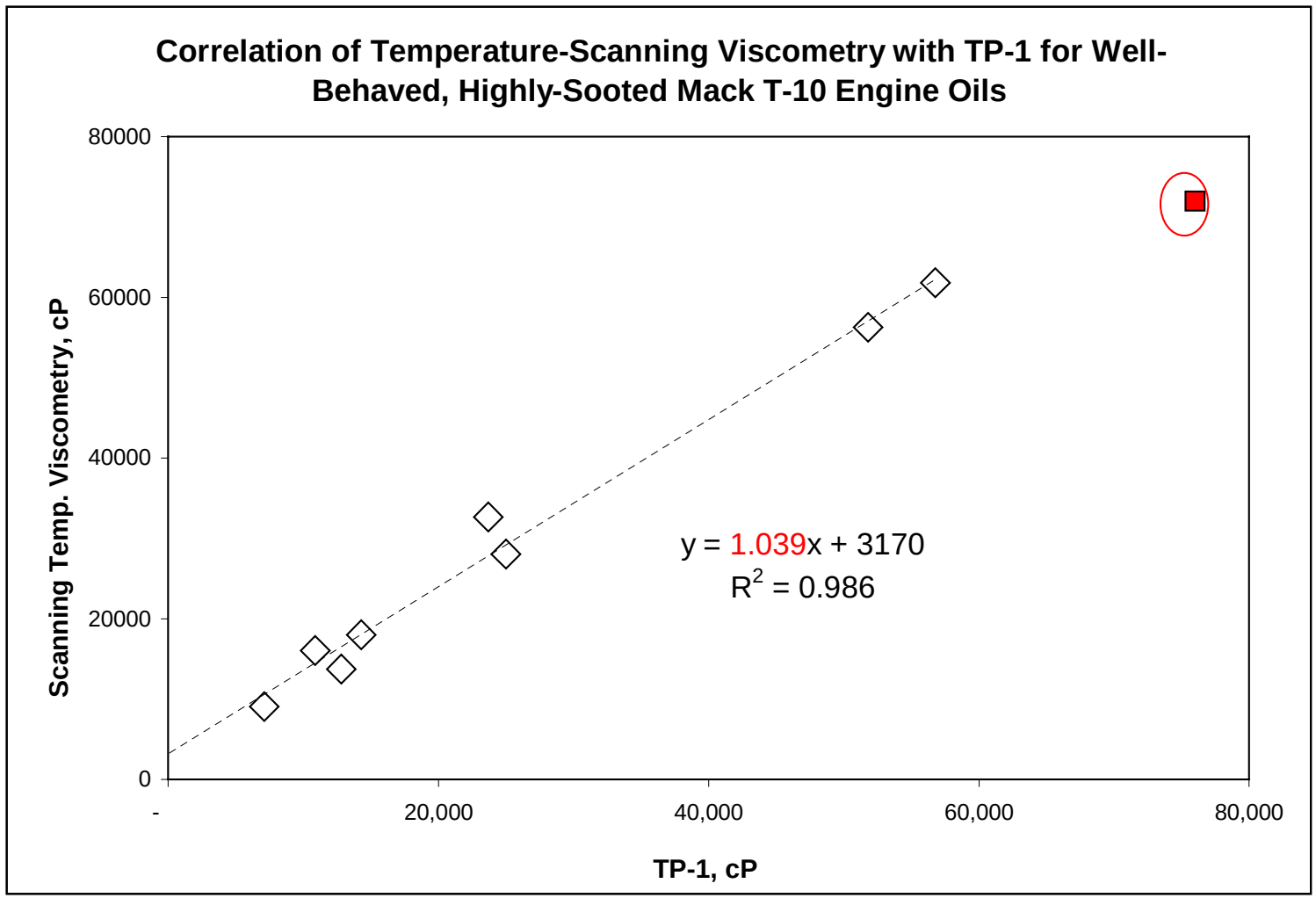
| Oil ID | Temperature at 60,000 cP | | Well-Behaved? | Gelation Index | | Gelation Index Temperature | | TP-1 Viscosity, cP | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Test 1 | Test 2 | | | | | | -15°C | -20°C | -25°C |
| 723-D | -17.9°C | -18.1°C | No | 15.1 | 15.7 | -16.6°C | -16.6°C | 8,040 | 26,500 | 165,000 |
| 723-E | -18.3°C | -18.5°C | No | 16.2 | 17.1 | -16.2°C | -17.1°C | 6,940 | 25,200 | 562,000 |
| 723-F | -25.2°C | -25.1°C | Yes | | | | | 7,100 | 14,300 | 51,800 |
| 723-G | -24.7°C | -24.8°C | Yes | | | | | 12,800 | 25,000 | 56,800 |
| 723-H | | -23.2°C | Yes | | | | | 10,900 | 23,700 | 76,000 |
| 723-I | -10.5°C | -10.7°C | No | 9.6 | 9.1 | -6.2°C | -6.0°C | 17,800 | 56,300 | 437,000 |
| 723-J | -18.5°C | -18.5°C | No | 12.1 | 12.5 | -16.4°C | -16.6°C | 9,520 | 37,900 | 415,000 |
| Average Difference | 1.3°C | | | 0.6 | | 0.3°C | | | | |

Repeatability of the temperature-scanning viscosities taken at -15°, -20°, and -25°C is shown in Table 2. In general, the repeatability is good.

**Table 2 - Repeatability of Viscosities at Three Temperatures**

| Oil ID | -15°C | | -20°C | | -25°C | |
|---|---|---|---|---|---|---|
| | Test 1 | Test 2 | Test 1 | Test 2 | Test 1 | Test 2 |
| 723-D | 12700 | 12700 | | | | |
| 723-E | 10700 | 10700 | | | | |
| 723-F | 9400 | 9100 | 18600 | 18000 | 58100 | 56300 |
| 723-G | 13900 | 13700 | 28200 | 28100 | 62000 | 61800 |
| 723-J | 13400 | 13500 | | | | |

Agreement between the Temperature Scanning Technique and the TP-1 method has been indicated to be fairly good. The following plot of the data collected in this study shows good correlation for viscosities lower than 70,000 cP with a slope of 1.039 and an $R^2$ value of 0.986.



# Conclusions:

The new method is

- Fast
  - 7 hours or 16 hours depending on the temperature range desired.
- Precise
  - Closely replicates viscosities, 60,000 cP intercepts, Gelation Indexes, and total flow curves.
- Informative
  - Shows entire flow curve and reasons for poor oil behavior.
- Correlates with TP-1
  - Correlates quantitatively with TP-1 values on well-behaved sooted oils.
  - Correlates qualitatively on failure of poorly behaved oils.

Thanks for your time and attention

Ted Selby