

PPD Effect on Low Temperature Viscometrics of Gr. III Oils

Functional Products Inc.
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- Pour Point (ASTM D97)
 - Determines temperature at which lubricant no longer flows
 - Used as metric for low temperature performance
- Brookfield Viscosity (ASTM 2983)
 - Determines viscosity at a given temperature
 - Measures dynamic viscosity
 - Gives more accurate picture of low temperature performance than Pour Point alone



- Measurements run according to ASTM 2983
 - Lubricant sample placed in temperature controlled bath
 - Sample chilled to desired temperature at a set rate
 - Sample allowed to equilibrate to set temperature for 16h
 - Calibrated spindle is rotated in the sample and viscosity is determined by the resulting torque
- Viscosity measured at -40C
- Spindle type LV4 was used



Brookfield Viscometer and Spindle

- Comparing PPD performance in 4 cSt Gr. III base oils
 - Performance compared in terms of both Pour Point and Brookfield Viscosity at -40C
 - PPD used at 1% treat unless otherwise stated

Pour Point Depressants	Gr. III Oil
Functional PD-630	Yubase 4
Functional PD-620	Yubase 4+
Functional PD-610	Nexbase 3043
Viscoplex 1-3003	Motiva Star HVI 4
Infinium V385	Adbase Adnoc 4
Cristol LX250	Ultra S-4
Lubrizol 6662A	
Viscoplex 1-810	
Keilflo 195*	

*used at 0.5% treat

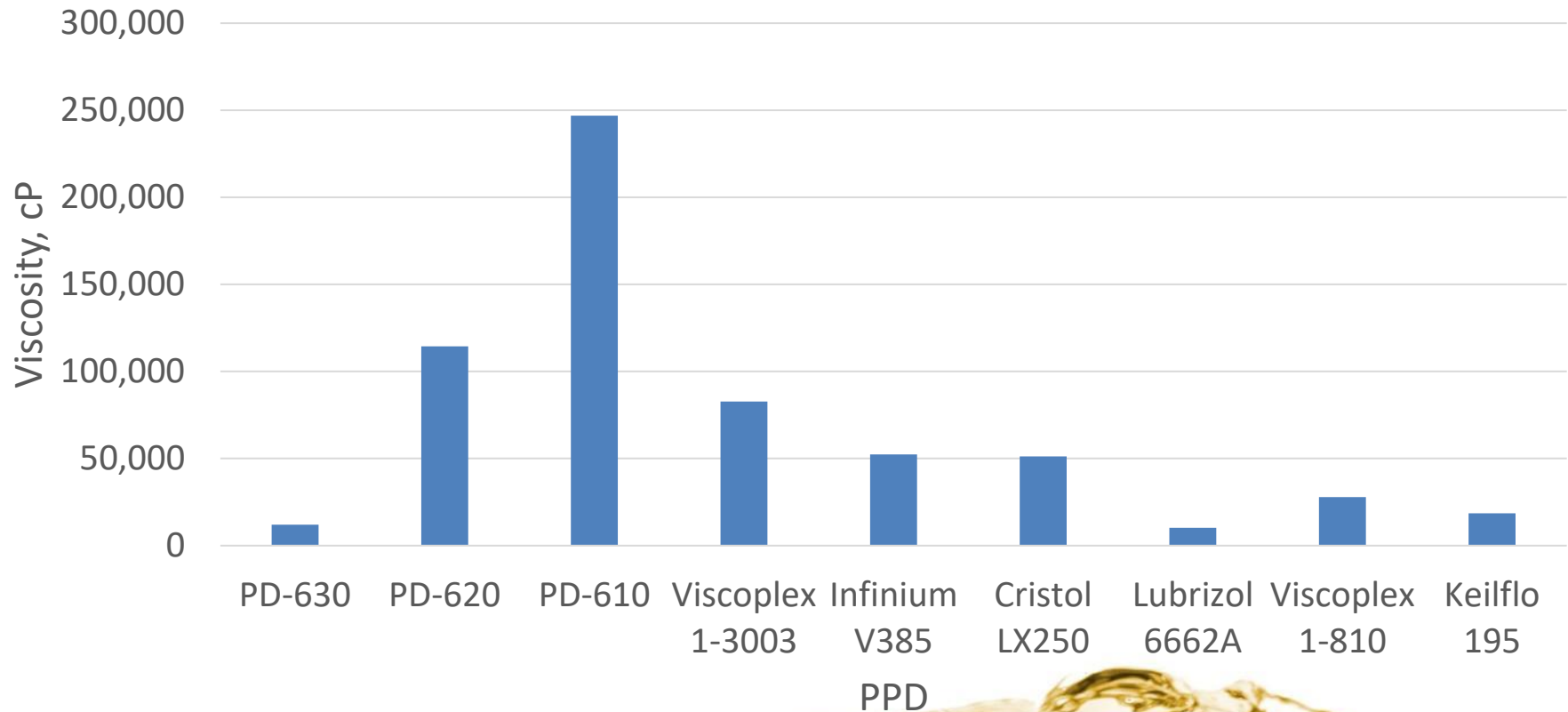
- The full unprocessed data set is included in the next slide
- PPD's are most effective when tailored to a specific application at an optimized treat
 - The unprocessed data is helpful in picking out optimal PPD's for a base oil
- General trends can also be pulled from the data
 - Trends are useful when selecting a limited inventory
 - Oils that more consistently give low temperature performance
 - PPD's that work across a broad range of base oils
 - Is pour point a good metric for gauging low temperature performance?

	Yubase 4	Yubase 4+	Nexbase 3043	Motiva Star HVI 4	Adnoc 4	Ultra S-4
PD-630	-45C PP	-48C PP	-45C PP	-51C PP	-48C PP	-48C PP
--> -40C BF	17,915	10,140	13,130	10,113	11,328	9,513
PD-620	-42C PP	-48C PP	-39C PP	-51C PP	-42C PP	-42C PP
--> -40C BF	432,000	36,400	72,800	16,900	83,600	44,800
PD-610	-39C PP	-45C PP	--	--	--	--
--> -40C BF	455,000	38,900	--	--	--	--
Viscoplex 1-3003	-39C PP	-42C PP	-42C PP	-48C PP	-45C PP	-48C PP
--> -40C BF	216,400	82,000	47,100	32,400	77,800	41,100
Infinium V385	-39C PP	-42C PP	-45C PP	-48C PP	-48C PP	-45C PP
--> -40C BF	164,400	25,400	37,000	12,380	53,200	21,850
Cristol LX250	-42C PP	-45C PP	-45C PP	-48C PP	-48C PP	-45C PP
--> -40C BF	136,800	43,500	38,000	21,000	39,400	28,450
Lubrizol 6662A	-45C PP	-45C PP	-45C PP	-48C PP	-48C PP	-48C PP
--> -40C BF	13,000	7,917	10,930	7,800	12,800	8,425
Viscoplex 1-810	-45C PP	-45C PP	-45C PP	-48C PP	-48C PP	-45C PP
--> -40C BF	47,300	21,250	27,800	12,530	38,800	19,600
Keilflo 195*	-42C PP	-45C PP	-45C PP	-48C PP	-48C PP	-48C PP
--> -40C BF	34,300	18,500	14,850	8,367	21,900	13,400

*used at 0.5% treat

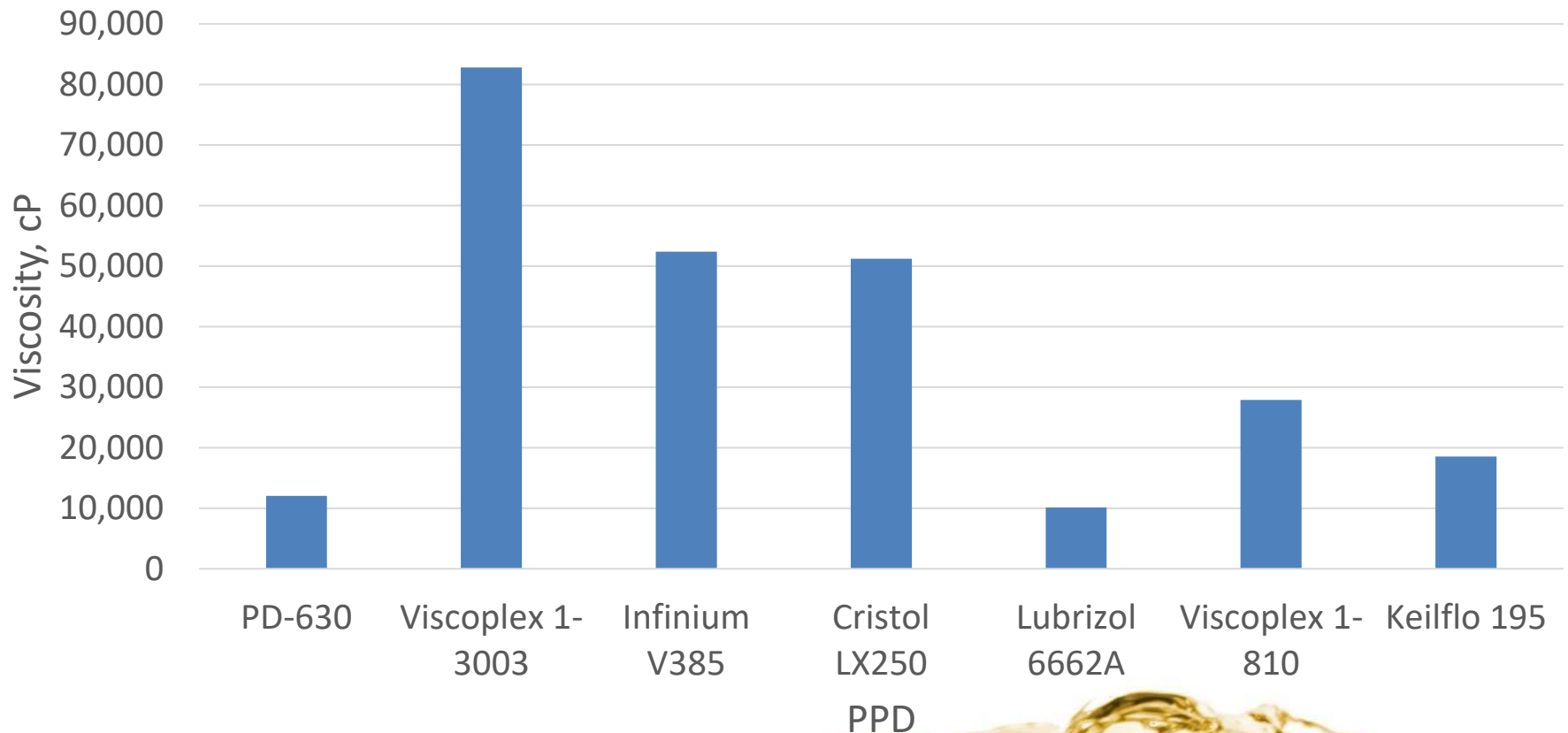
- Average Brookfield Viscosity across all tested oils

Average -40C Viscosity by PPD (in Gr. III Oil)



- Average Brookfield viscosity across all tested oils

Average -40C Viscosity by PPD (in Gr. III Oil)

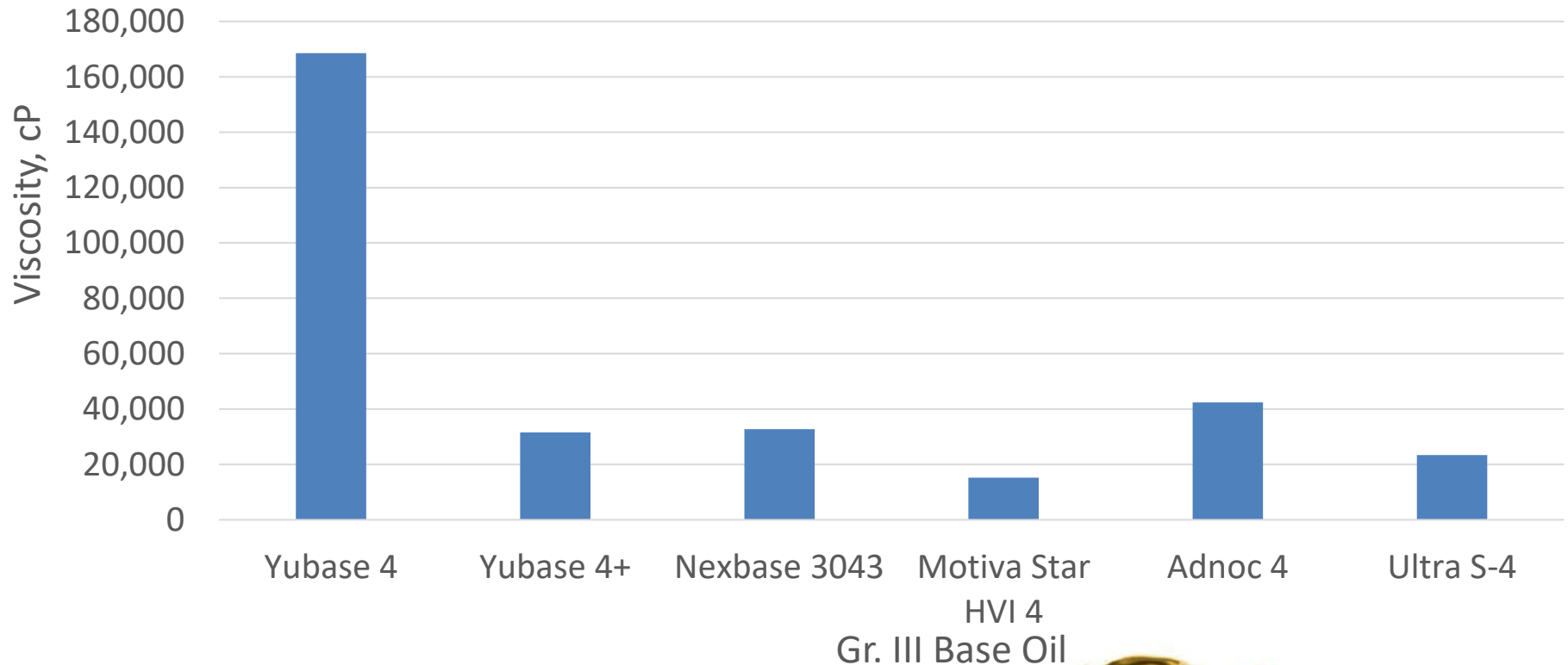


- Several types of PPD chemistry were included
 - PMA, fumerate/vinyl acetate, styrene ester, and active hydrocarbon
- Compatibility with wax profile more important than type of chemistry used
 - PMA based PPD's were best and worst of those tested
- PD-630 and Lubrizol 6662A showed best average results
 - Same average within error
 - Keilflo 195 worse on average, but equivalent or better in specific oils
- PD-610 performed the worst
 - Expected as an example of PMA not tuned to Gr. III wax profile
- This kind of analysis is useful for stocking limited PPD's to treat multiple kinds of base oils or when base oil stocked may vary based on oil prices or availability.

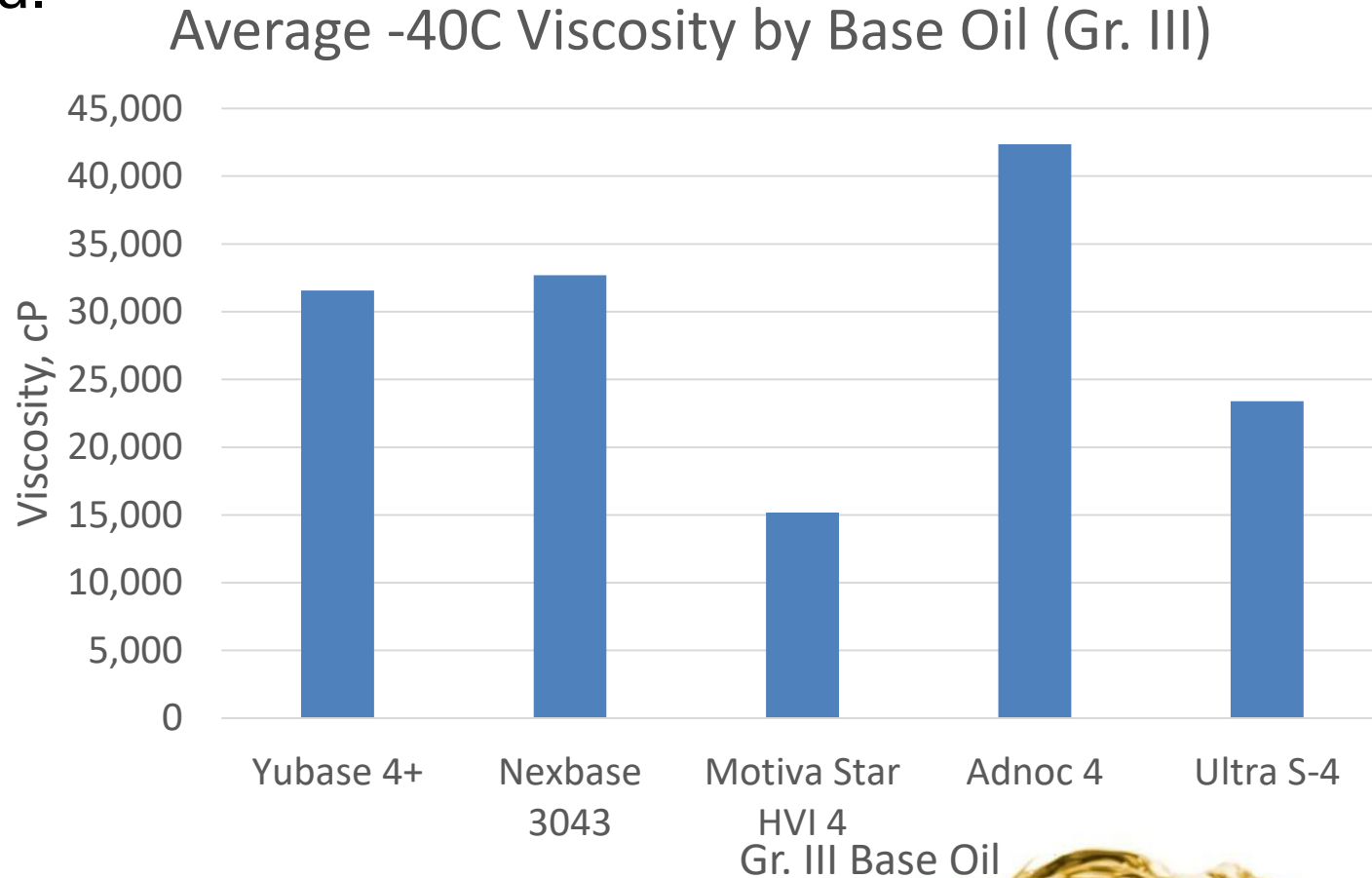


- Average Brookfield Viscosity for Gr. III oils across all PPD's tested.

Average -40C Viscosity by Base Oil (Gr. III)



- Average Brookfield Viscosity for Gr. III oils across all PPD's tested.



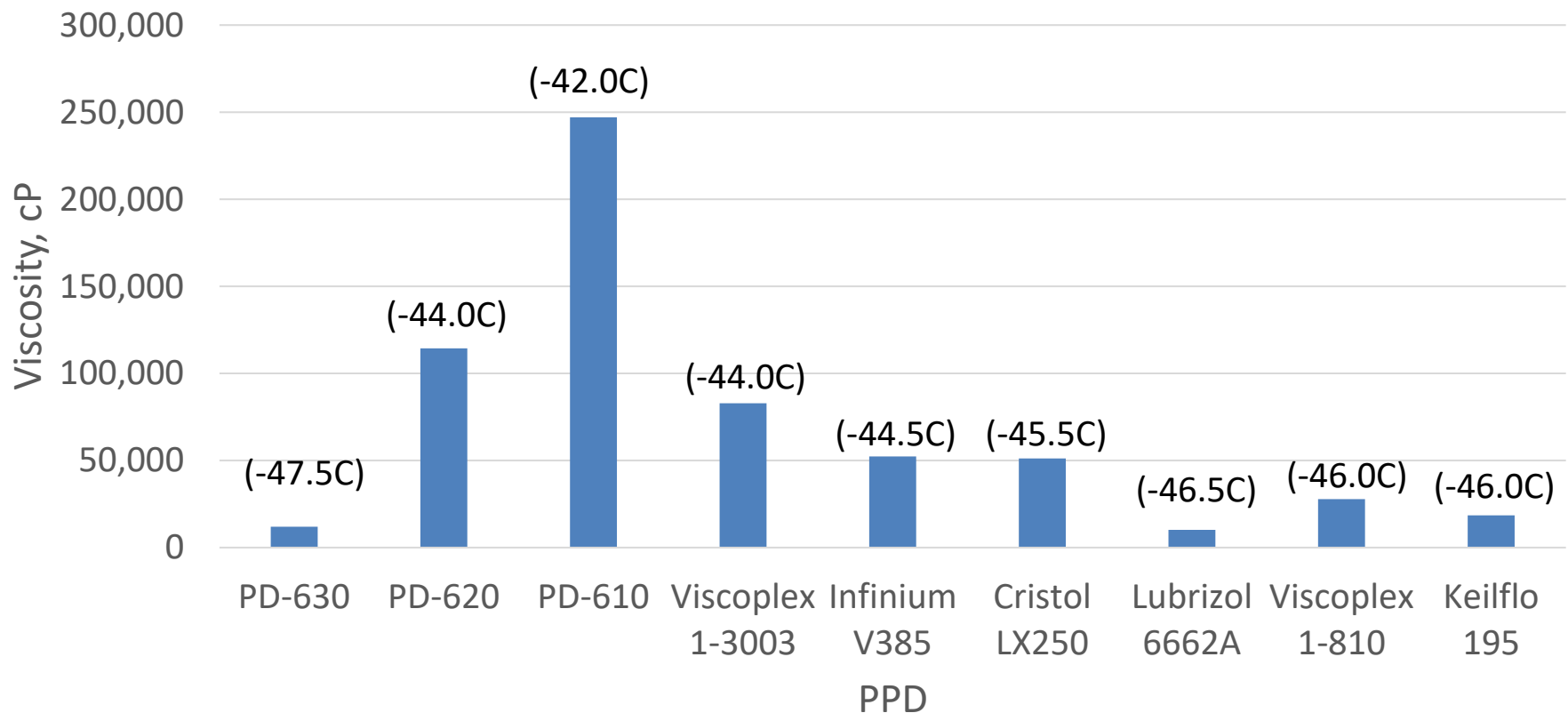
- On average group III oils behave similarly at low temperature across tested PPD's with two notable exceptions.
 - Yubase 4 is notably worse on average, but comes in line with the others when using more specific PPD's.
 - Has a different wax profile requiring different treatment
 - Motiva Star HVI 4 outperforms other group III oils with all tested PPD's
- This kind of analysis is useful when looking to stock a base oil for multiple products that may require different PPD's and additive systems.



Pour Point Results

- How closely does Pour Point track with viscometric results?
 - Is Pour Point a good metric for low temperature viscosity?
- The average Pour Point result is shown above each bar on the graph
 - Follows general trends, but can be misleading
 - Lower Pour Point correctly predicts lower BF in 79.4% of cases

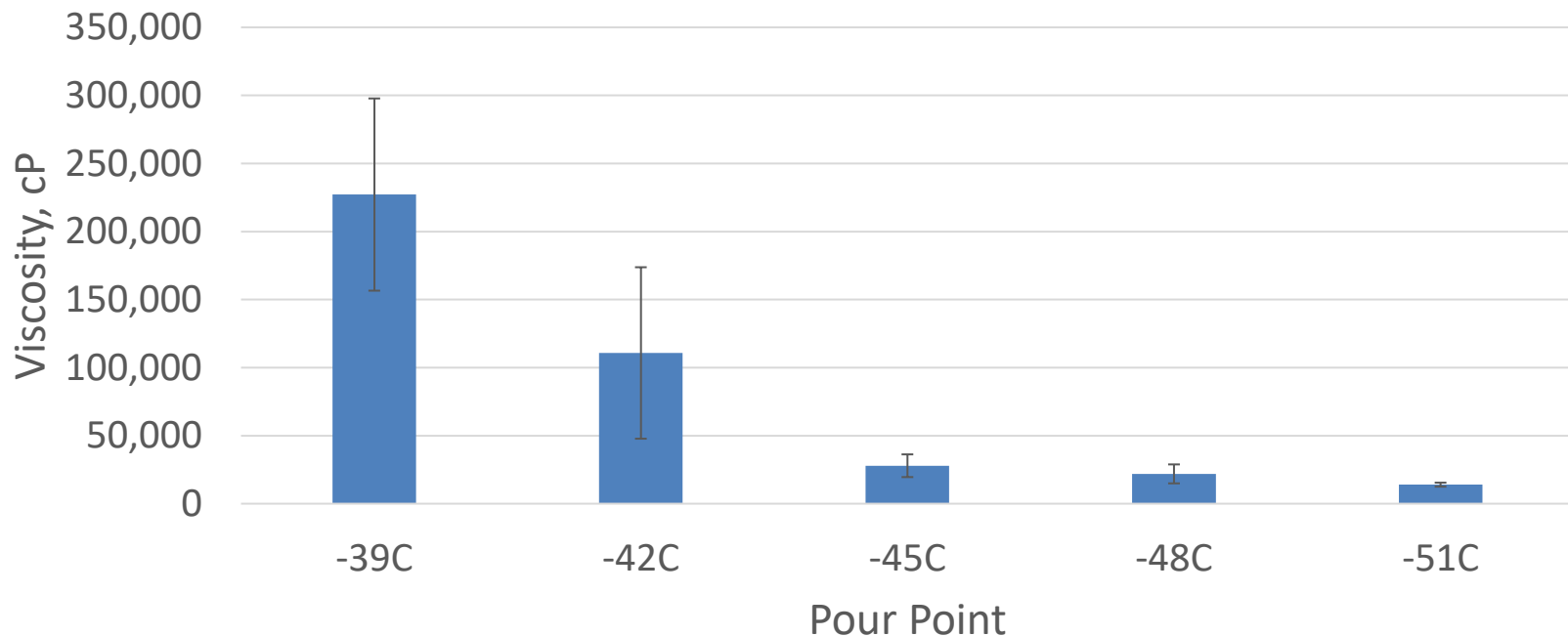
Average -40C Viscosity by PPD (in Gr. III Oil)



Pour Point Results

- How closely does Pour Point track with viscometric results?
 - Is Pour Point a good metric for low temperature viscosity?
- Wide range of viscometric behavior within the same Pour Point Result
 - More consistent behavior the farther Pour Point is from BF temperature

Average -40C Viscosity by Pour Point



- Functional PD-630 and Lubrizol 6662A performed best across a wide range of Gr. III oils
 - Tested using a Brookfield Viscometer at -40C
- Yubase 4 requires more specific PPD than other oils, Motiva HVI 4 performed best on average
 - Most Gr. III oils behave similarly across available PPD's
- Pour point testing is a good first screen for low temperature viscosity, but can sometimes be misleading
 - Pour point correctly predicts relative viscosity in 79.4% of cases
- A wide range of performance exists within a given pour point result
 - Range narrows the farther from the BF test temperature the pour point is found

Questions?



- Similar pour points have differing Brookfield results
- Functional PD-630 provides enhanced Brookfield in Gr. III oils.

	Test	Yubase 4	Yubase 4+	Nexbase 3043	Motiva Star HVI 4	Adnoc 4	Ultra S-4
PD-630	Pour Point	-45C	-48C	-45C	-51C	-48C	-48C
	Brookfield*	17,915cP	10,140cP	13,130cP	10,113cP	11,328cP	9,513cP
PD-620	Pour Point	-42C	-48C	-39C	-51C	-42C	-42C
	Brookfield*	432,000cP	36,400cP	72,800cP	16,900cP	83,600cP	44,800cP
Comp. 1	Pour Point	-39C	-42C	-42C	-48C	-45C	-48C
	Brookfield*	216,400cP	82,000cP	47,100cP	32,400cP	77,800cP	41,100cP
Comp. 2	Pour Point	-45C	-45C	-45C	-48C	-48C	-45C
	Brookfield*	47,300cP	21,250cP	27,800cP	12,530cP	38,800cP	19,600cP
Comp. 3	Pour Point	-42C	-45C	-45C	-48C	-48C	-45C
	Brookfield*	136,800cP	43,500cP	38,000cP	21,000cP	39,400cP	28,450cP

*Brookfield measurements taken at -40C after 16 hour equilibration.

All PPD treat rates at 1%.

- Similar pour points have differing Brookfield results
- Functional PD-630 provides competitive Brookfield results in Gr. III oils

	Test	Yubase 4	Yubase 4+	Nexbase 3043	Motiva Star HVI 4	Adnoc 4	Ultra S-4
PD-630	Pour Point	-45C	-48C	-45C	-51C	-48C	-48C
	Brookfield*	17,915cP	10,140cP	13,130cP	10,113cP	11,328cP	9,513cP
Dialkyl Fumerate	Pour Point	-39C	-42C	-45C	-48C	-48C	-45C
	Brookfield*	164,400cP	25,400cP	37,000cP	12,380cP	53,200cP	21,850cP
Active Hydrocarbon	Pour Point	-42C	-45C	-45C	-48C	-48C	-48C
	Brookfield*	34,300cP	18,500cP	14,850cP	8,367cP	21,900cP	13,400cP
Styrene Ester	Pour Point	-45C	-45C	-45C	-48C	-48C	-48C
	Brookfield*	13,000cP	7,917cP	10,930cP	7,800cP	12,800cP	8,425cP

*Brookfield measurements taken at -40C after 16 hour equilibration.

All PPD treat rates at 1%.