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NEXT GENERATION ISODEWAXING® AND HYDROFINISHING TECHNOLOGY FOR PRODUCTION OF HIGH QUALITY BASE OILS

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Introduction

In the past decade, Chevron and its ISODEWAXING® licensees have been playing a key role in effecting a shift to base oil production via hydroprocessing. This has resulted in the production at lower operating cost of Group II (and some Group III) base oils with excellent lubricant properties. Higher quality base oils are favored by Original Equipment Manufacturers (OEMs), who continue to raise the bar on quality; in addition, increased environmental regulations are also accelerating the change. The Group II base oil market share is rising in North America as well as in the rest of the world.

Chevron has long been active in hydroprocessing, and in late 1984 commercially produced the first all hydroprocessed base oil [1]. The first ISODEWAXING® base oil catalyst, ICR 404, was installed in 1993 [2, 3]. In 1996, the next generation improved ISODEWAXING® catalyst ICR 408 was commercialized [4]. Chevron has always used noble metal hydrofinishing (HDF) catalysts to complement the ISODEWAXING® catalysts. Our HDF catalysts provide excellent stability and improved product color to the base oil product.

Currently, ISOCRACKING, ISODEWAXING®, and HDF technologies are licensed by Chevron Lummus Global LLC (CLG). There are now ten ISODEWAXING® units in commercial operation with a total capacity exceeding 100 MBPD. Eight additional ISODEWAXING® units with an additional capacity in excess of 60 MBPD are in various stages of engineering and construction. This total capacity is more than 20% of the total worldwide paraffinic base oil production. The high quality of these hydroprocessed oils has helped to transform a traditionally Group I dominated base oil market into a high quality Group II and Group III market in less than a decade.

Figure 1 shows a typical base oil hydroprocessing plant configuration. The feed types treated include hydrocrackate, slack wax, raffinates, wax, and foots oil. Product slates range from 40N to Bright Stock (BS). This has enabled us to gain experience on a variety of operating conditions and feeds. Furthermore, the wealth of commercial data has allowed us to update our process guidelines to reflect collective learning in order to benefit the licensees.

The focus of this paper will be to present information on the next generation of ISODEWAXING® and HDF catalysts which offer exciting catalyst performance improvements to enhance the profitability of new and existing plants. These catalysts give higher yield and enhanced base oil product quality, and further widen the gap with solvent dewaxing operations. Data on expected improvements will be presented on a variety of feeds.

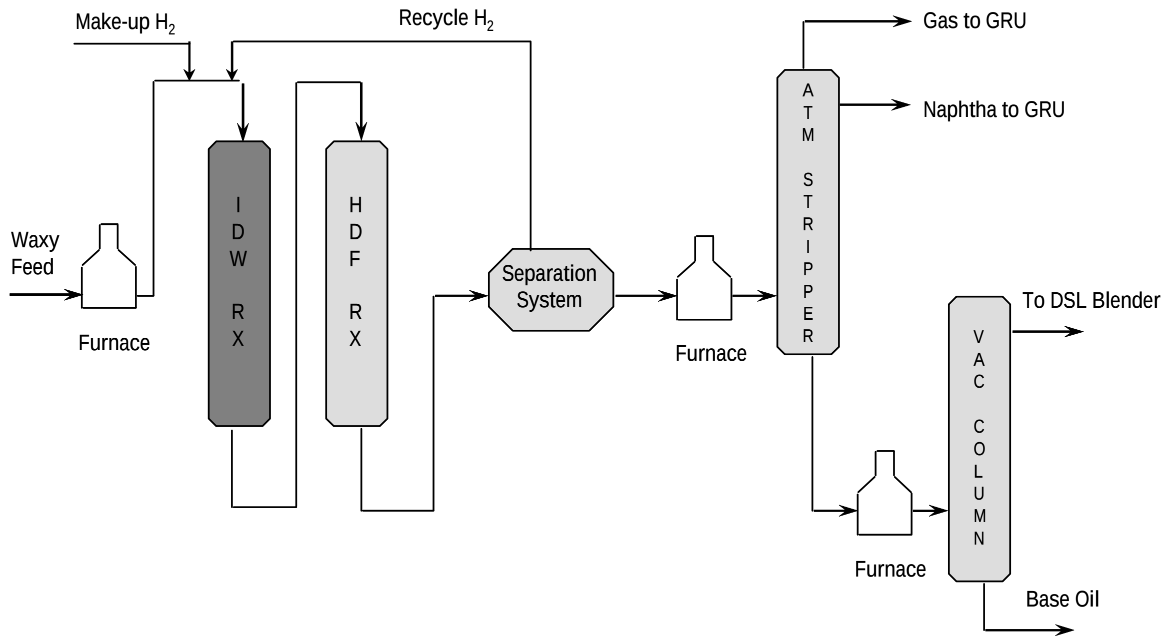

Figure 1. Isodewaxer/Hydrofinisher Schematic Flow Diagram

ISODEWAXING®

Since the commercialization of the first ISODEWAXING® catalyst in 1993, there have been improvements and subsequent generations of catalysts that Chevron/CLG has offered. Due to the high value of base oils, there is a significant incentive to improve yields. A focused effort was undertaken to specifically increase the Light Neutral (LN) product yield and viscosity index (V.I.), which were felt to offer the biggest opportunity as this is a key product for all lubricant base oil producers. The goal was to accomplish this while maintaining (or further improving) the high yields on HN and BS feeds. As has been noted before [2], ISODEWAXING® offers a significant yield advantage over solvent dewaxing (SDW). The yield advantage increases with feed wax content. In this effort, the goal was to further widen the gap with SDW.

In order to evaluate a large number of changes in catalyst formulation, an intense testing effort was carried out by a dedicated group of researchers. This included pure compound testing to screen various candidates, followed by real feed testing using a high wax LN, and ultimately testing with multiple feeds to quantify improvements. We are pleased to announce that this has lead to the identification of a superior ISODEWAXING® catalyst, ICR 418. Data will now be presented on some of the feeds that were tested.

<u>Data on LN Feeds</u>

Table 1 and Figure 2 show the relative performance of ICR 408 and ICR 418 on a waxy 150N feed. The new catalyst gives a higher yield and V.I. than ICR 408; it has a lower gas, naphtha, and jet make. The diesel by-product yield is unchanged. The high quality distillate products from this process are also valuable.

Table 1. Comparison of SDW Vs. ISODEWAXING® on Group II - 150N

	Solvent Dewax	ICR 408	ICR 418
Products, Wt %			
Gas		1.8	1.0
Naphtha		2.7	1.5
Distillate		4.5	3.9
Base Oil Yield	90	91	93.5
Base Oil Product Properties			
Pour, °C	-11	-12	-15
Viscosity at 100°C, cSt	5.3	5.4	5.3
V.I.	104	105	107

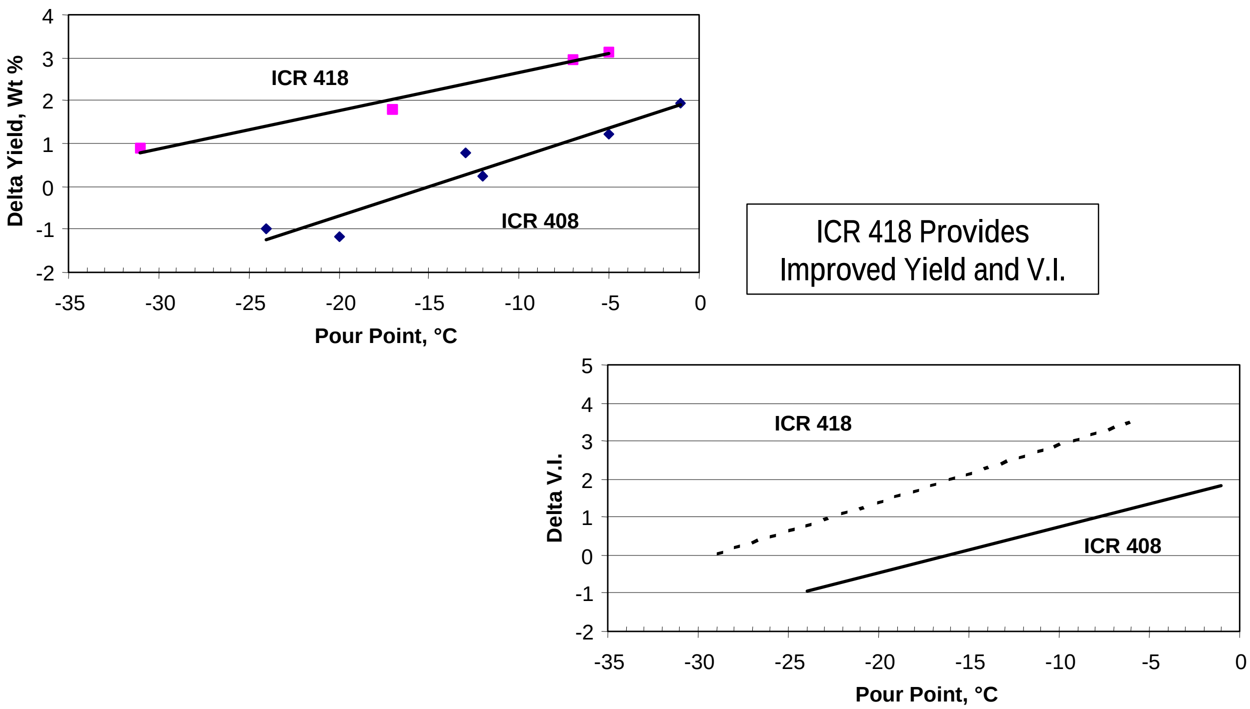

Figure 2. Yield and V.I. Improvements on LN Feed (Group II, 150N)

ICR 418 also shows enhanced performance when producing Group III base oils, as seen from Table 2 and Figure 3. On this feed, we see an improvement in V.I. and a substantial increase in product yield, in excess of 5 wt %.

Table 2. Comparison of SDW Vs. ISODEWAXING® on Group III - 100N

	Solvent Dewax	ICR 408	ICR 418
Base Oil Yield	Base	Base + 5.5%	Base + 11%
Base Oil Product Properties			
Pour, °C	-15	-16	-15
Viscosity at 100°C, cSt	4.2	4.1	4.1
V.I.	129	130	131

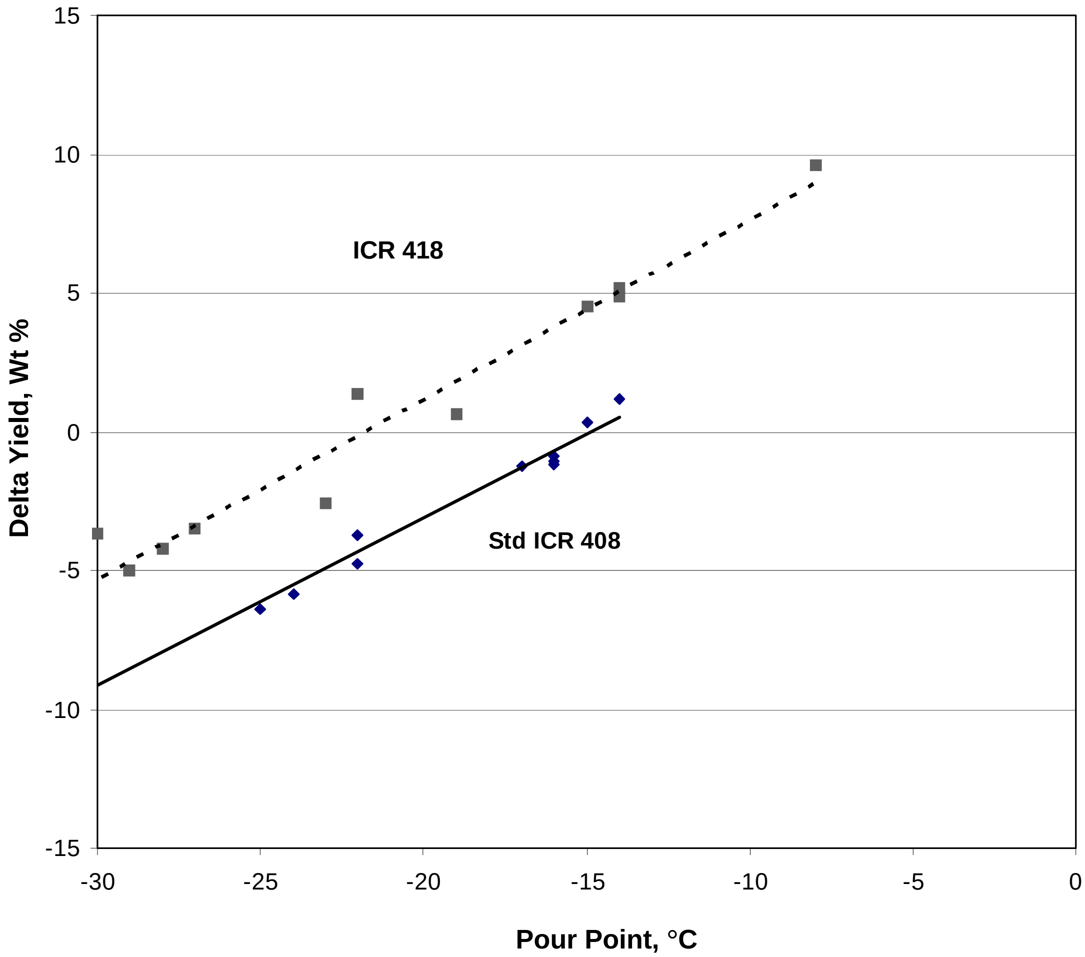

Figure 3. Yield Improvement on LN Feed (Group III, 100N)

Significant improvements in yield and V.I. were seen on all the five LN feeds tested. Independent testing has confirmed our pilot plant results and established ICR 418 to be the best catalyst available in the marketplace today for this service.

Heavy Neutral (HN) Feeds

ICR 408 has very attractive yields on heavy feeds; product V.I. is also higher than that obtained by SDW. ICR 418 provides further improvement. Table 3 and Figures 4a and 4b show yields and V.I. on a waxy 500N feed. Similar improvements were also obtained on a waxy 600N feed.

Table 3. Comparison of SDW Vs. ISODEWAXING® on Waxy 500N

	Solvent Dewax	ICR 408	ICR 418
Base Oil Yield	80	92	94
Base Oil Product Properties			
Pour, °C	-18	-18	-20
Viscosity at 100°C, cSt	11.1	10.6	10.5
V.I.	106	111	113

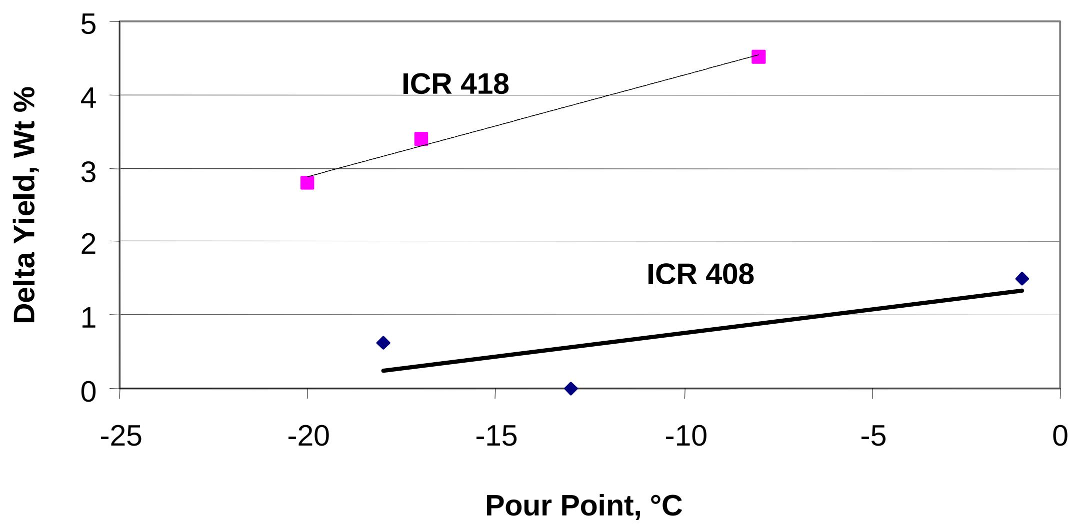

Figure 4a. Yield Improvement on HN Feed (500N)

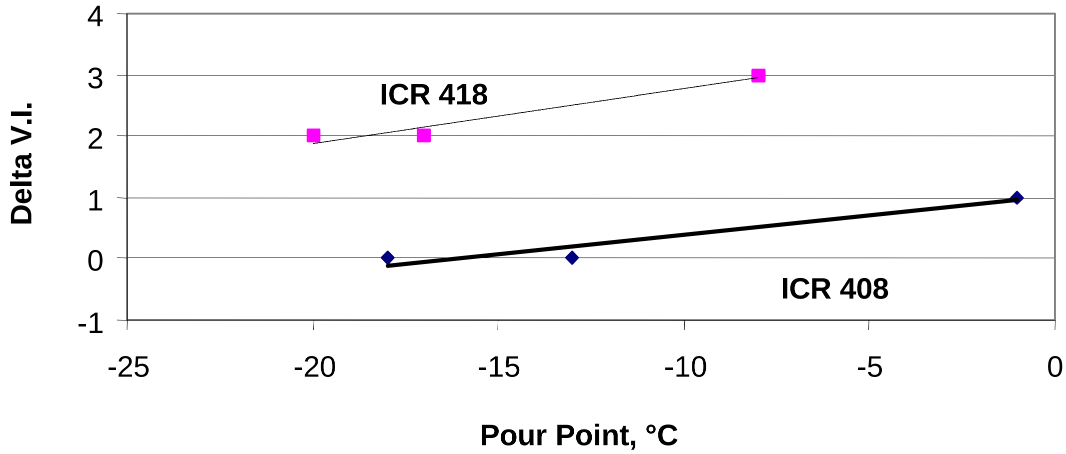

Figure 4b. V.I. Improvement on HN Feed (500N)

Bright Stock

Chevron ISODEWAXING® catalysts produce very high yields on waxy bright stock. Tables 4a and 4b show yields and product properties from two different waxy BS feeds. (Both our ISODEWAXING® catalysts give similar yields on Bright Stock A; Bright Stock B has only been tested on ICR 408 at this time.)

In both cases, yields by ISODEWAXING® far exceed SDW yield and product V.I. As can be seen from the data, it is hard to predict BS yield from feed properties, as the two feeds with very different wax contents both give 90+ wt % BS yield. Pilot plant studies are useful to determine the BS yield on a specific feed.

Table 4a. Bright Stock A

	SDW	ICR 408/ICR 418
Yield, Wt %	48	91
Pour, °C	-20	-19
Viscosity at 100°C, cSt	30.4	27.8
V.I.	106	114

Table 4b. Bright Stock B

	SDW	ICR 408	ICR 408
Yield, Wt %	33.5	95.5	93.4
Pour, °C	-15	-13	-22
Viscosity at 100°C, cSt	30.9	29.4	29.1
V.I.	104	116	114

Hydrofinishing

Chevron's hydrofinishing catalysts are very effective for finishing hydrocrackates in order to improve color and stabilize the base oil product. Due to their high activity, they operate at low temperatures and hence can saturate large multi ring aromatics. Chevron's first catalyst in this service, ICR 402, was commercialized in 1983, followed by ICR 403 in 1993 and ICR 407 in 1996. ICR 403 has a high activity for clean feeds while ICR 407 is more active and has a lower deactivation rate with high sulfur feeds.

Due to specific customer requirements, we have worked to improve both types of catalyst. Our testing was carried out with clean feeds as well as feed spiked with sulfur and nitrogen to measure the tolerance of the catalysts to higher levels of feed sulfur and nitrogen. We also varied the hydrogen partial pressure to see how this affects aromatics saturation.

Figure 5 shows a schematic of the pilot plant used in testing. Base cases were established with the current commercial catalysts (ICR 403 and ICR 407) and new formulations were compared to the two base cases.

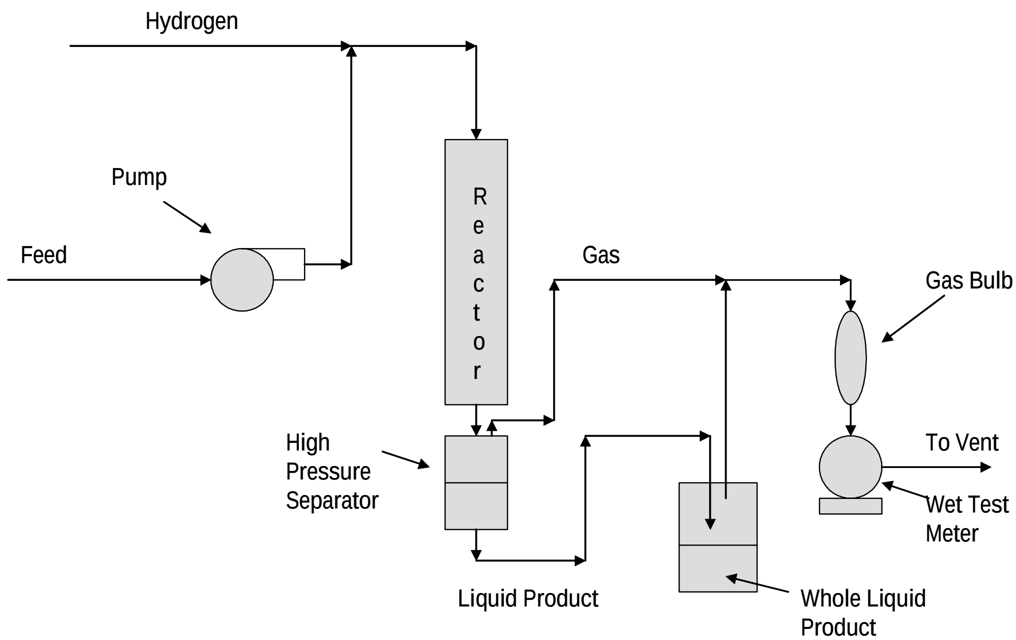

Figure 5. HDF Pilot Plant

Figure 6 shows the performance of our new improved clean feed catalyst. This catalyst shows a substantially improved deactivation rate and improved activity. This test was conducted at high pressure, targeting low product aromatics.

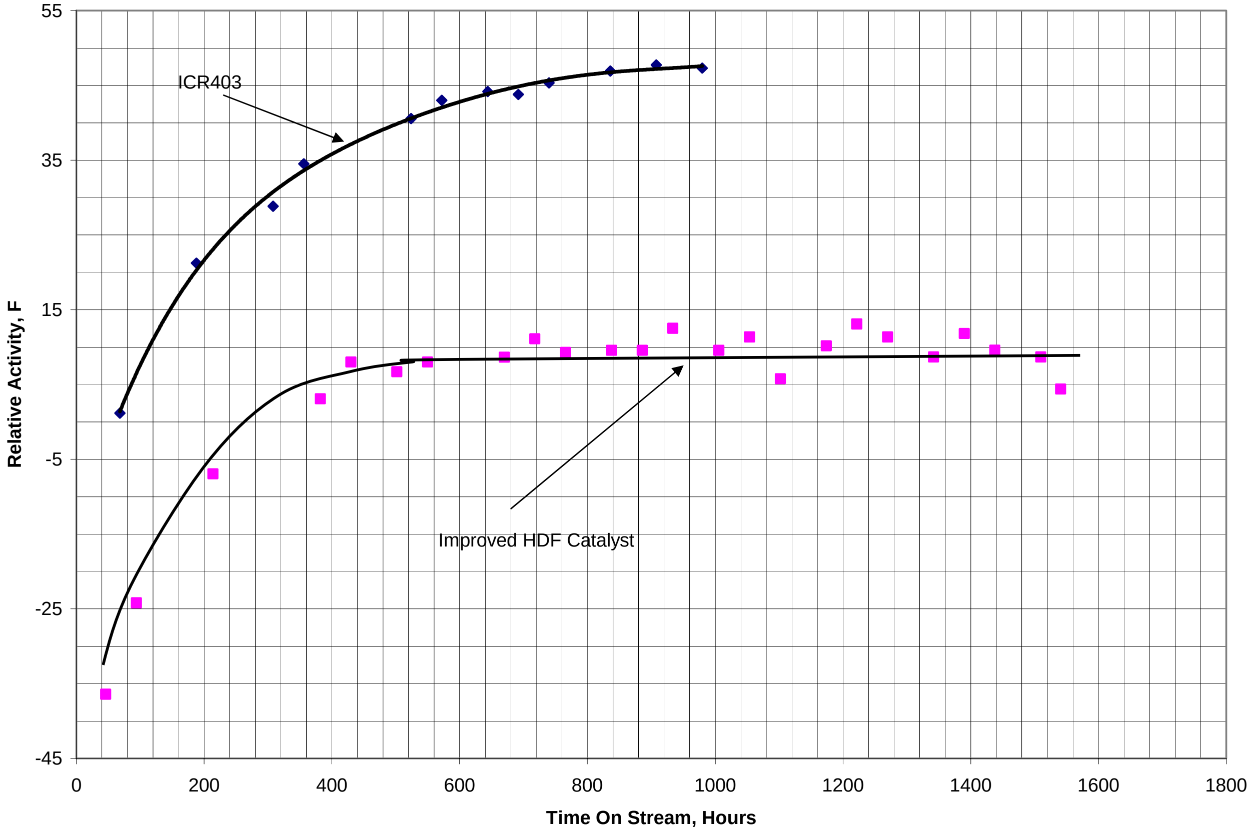

Figure 6. Relative Activity for HDF of Heavy Neutral With Experimental and Standard HDF Catalyst

Figure 7 shows the performance of a new sulfur tolerant catalyst for relatively high sulfur feeds. The catalyst is ~70°F more active than the base case ICR 407 at a similar deactivation rate. This formulation will be available as ICR 417 later this year.

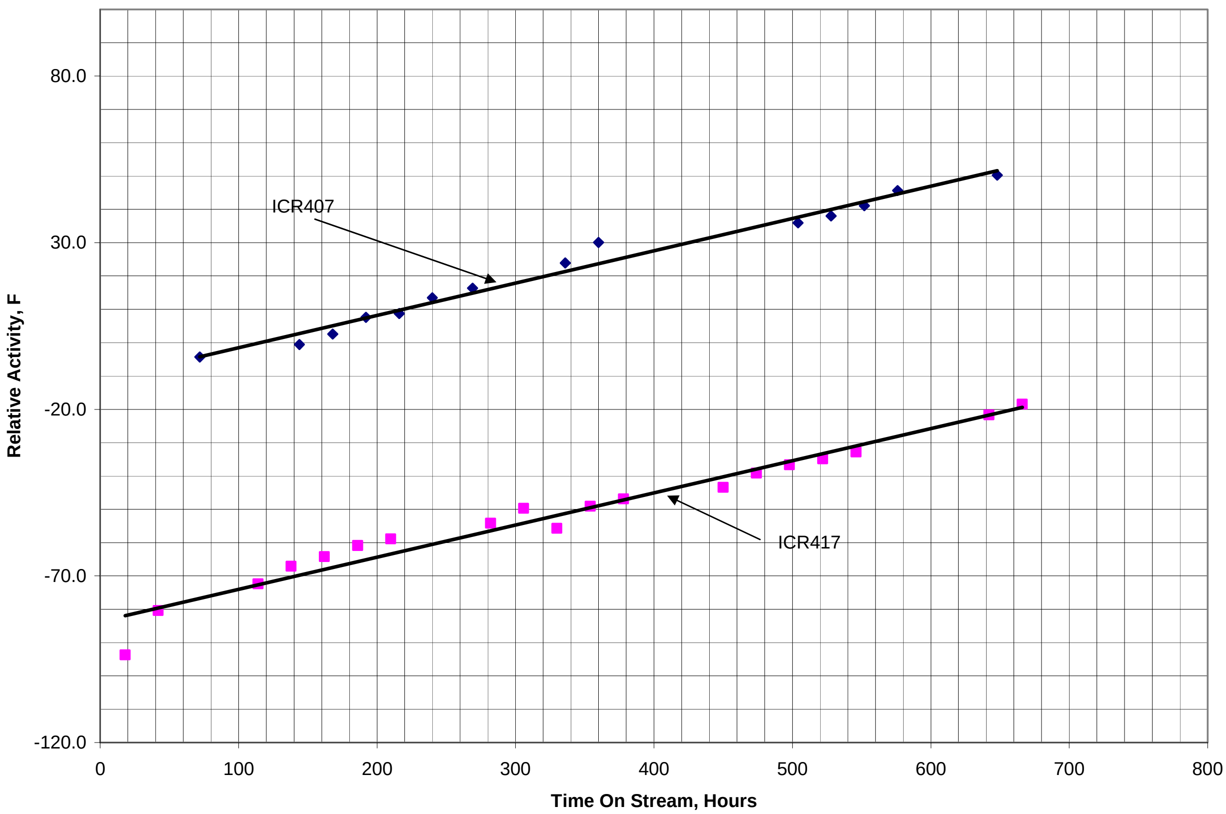

Figure 7. Relative Activity Under Accelerated Deactivation Conditions (300N Spiked With S and N)

Summary

Chevron invented the ISODEWAXING® process and pioneered the all hydroprocessing route to high quality base oil production. Since this process was first commercialized in 1993, several process and catalyst improvements have been achieved. Now the latest generation of ISODEWAXING® and HDF catalysts are in the process of commercialization. These new catalysts will raise the bar on performance (yield and product quality). Recent independent testing has confirmed the excellent performance of our new ISODEWAXING® catalyst. We are equally confident that the new HDF catalyst will also prove to be superior. We anticipate commercial applications of these exciting new catalysts in the very near future.

Acknowledgment

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