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Manifa Oil: Malodorous, But Really Not That Bad

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The development of the Manifa oil field in Saudi Arabia has been accelerated recently. This is the last neo-virgin field that Saudi Aramco has in its coffers with which it can increase production capacity (by 900,000 bpd in this case) - or just remain even in the fight vs. depletion of its existing fields. Although it was produced in a limited way 30 years ago and has been shut in since, there has been noise about its resurrection sporadically over the past decade. Much of the chatter has been about the supposed low quality of its oil. Phrases such as "virtually unusable" have been used or, more charitably, it has been described as being so heavy, so high in sulfur, and so vanadium contaminated that there are no refineries which can process it. If true, this would make the Saudi decision to spend the most money ever on this single project even more mysterious, given that there are other strikes against it as well.

In reality, the myth of unusable Manifa oil is just that. There is no evidence that it is as bad as has often been reported. In this post, I will briefly discuss what makes for low quality oil and show how Manifa actually compares to other crudes being sold by Saudi Arabia and elsewhere.

Birth of the Myth

If you do a web search for "Manifa vanadium", you will find a wealth of links which all say about the same thing: Manifa oil is really bad. Yet none of them provide any numbers which support this grim diagnosis. The semantic similarity of the reports suggests that they all have the same genealogy, with descendant articles repeating the received wisdom without question. I'm certainly guilty of having done this with this topic. But I believe the genesis of this myth lies with an article written by David Fleming and published in the year 2000 entitled After Oil. The story opens with:

> Beneath the seabed off the coast of Saudi Arabia, there is an oil field called Manifa. It is a giant, and its riches are almost untapped. There is, however, a snag. Its oil is heavy with vanadium and hydrogen sulphide, making it virtually unusable. One day, the technology may be in place to extract and dispose of these contaminants, but it will not be for some time and when, or if, it does happen, it will do no more than slightly reduce the rate at which world oil supplies slip away towards depletion. However, even this field has advantages relative to the massive reserves of oil which Middle East suppliers are said to hold ready to keep oil prices low and secure the future of civilisation. Unlike those fantasy fields, Manifa actually exists.

It is not my intention to vilify David Fleming based on this excerpt from a paper in which he otherwise makes some valid points. But that Manifa characterization seems to have stuck like superglue. Before 2000, the web search above yielded no hits. The count rose slowly at first and ramped up in the last few years to about 100 (admittedly not a common topic). But is there something to the claim? Seems not. I will first review some qualities of oil which decrease its value, and then show how Manifa oil fares in comparison to other crudes.

The Good and Bad of Oil

What emanates from an oil well can be quite a mess. There is the complex brew that one normally thinks of as crude oil, that being a mixture of hydrocarbons of various size and shape. But there is also variable amount of dissolved gases plus perhaps some (or considerable) water and salt and even sand. To create value from this mixture, one needs to separate the more valuable parts from the less valuable parts. Of course, value is in the eye of the buyer, and the highest demand is for transport fuels. Crude oil (except perhaps for something such as Arab Super Light) doesn't really work in this capacity, though; you probably wouldn't want to pour it in the gas (or diesel) tank of your car. Much value is added to the oil by refining, and most of this is realized by extracting the light and middle distillates because that is what goes into gasoline, diesel, and jet and heating fuels. Thus, the goal of most refiners is to maximize the amounts of these produced. Different crudes will naturally contain different amounts of the fuel-friendly extracts, and other refining process can convert some of the lesser-valued crude fractions into the more valuable ones. Complex refining costs more money, however, so oil which can produce more valued products with less effort are usually sold at a premium. Also, oil usually has contaminants which can hinder some refining processes, and these will affect the crude market price.

Heavy and Sour

Heavy oil is defined by the USGS as:

> Asphaltic, dense (low API gravity), and viscous oil that is chemically characterized by its content of asphaltenes (very large molecules incorporating most of the sulfur and perhaps 90% of the metals in the oil). Although variously defined, the upper limit for heavy oils has been set at 22°API gravity and a viscosity of less than 100 cP.

Heavy oil has a higher proportion of large molecules which vaporize at higher temperatures, under vacuum conditions, or not at all. However, it is possible to break (crack) the large molecules into smaller ones, and these can then be blended into the popular transportation fuels. This adds cost to the refining, however, so oil with a "heavy bottom" will generally sell for less. However, what counts as heavy oil is somewhat fluid. Saudi Aramco has been peddling something called "Arabian Heavy" for half a century, but its 28°API gravity would seem to disqualify it. When the Safaniya field from which this flows was discovered, however, the oil was thought to be unsellable:

> Yet an Aramco refining man ruefully recalls that he was disappointed with the type of oil that flowed to the surface when the discovery well was drilled in the Safaniya Field in 1951. The first tests showed that Safaniya crude had an API gravity rating of 27, an arbitrary index that indicated its high fuel oil content.
>
> 'When they poked that first hole down," the refining man said recently, "we were aghast

> at the gravity. As far as we were concerned, we wished that the company would just let it lie there. At that time fuel oil was a headache. We were up against a surplus in world markets."

Arabian Heavy does leave quite a fraction of its volume left in the pot after vacuum distillation, hence the concern about fuel oil yield. When the Manifa field laden with similarly "heavy" oil was discovered six years later, it was put on hold until the market for such stuff improved. However, it had another problem:

> Manifa produces a sour crude, so called because it contains hydrogen sulfide, a poisonous, highly corrosive gas which must be removed in a stabilizer before the oil can be pumped into the hold of a tanker

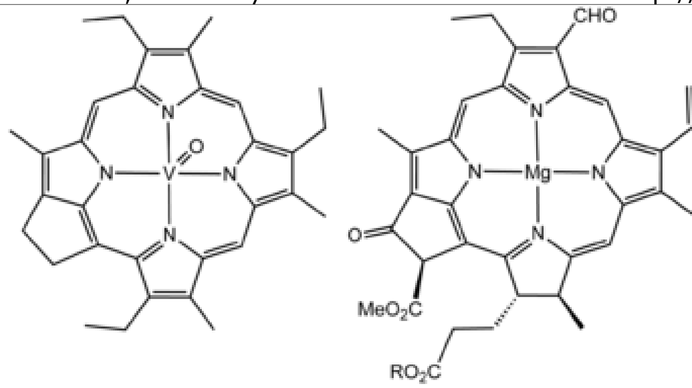
Way back then, the adjective "sour" was not applied to crude which would certainly be given such a moniker today.

> Aramco was already exporting three types of crude oil: Safaniya Grade, a sweet crude (one that contains no hydrogen sulfide), produced in the Safaniya field; Khursaniyah Grade, a sour crude produced from the Khursaniyah field; and Arabian Crude, another sour crude with properties different from the Khursaniyah Grade, and coming from the rest of Aramco's fields.
> ...
> Manifa zone crude proved to be similar to one of the export grades, the crude from Khursaniyah. Both are sour and both yield a high proportion of fuel oil when refined.

Under pressure in a reservoir, oil will generally have dissolved within it a number of volatile gases, including methane, ethane, carbon dioxide, and hydrogen sulfide. Historically, the "sour" label was tagged on an oil that had a high H_2S content, irrespective of other, less volatile occurrences of sulfur in the oil. But a high H_2S concentration in the "wet" crude is more an upstream problem, as it is mostly removed prior to loading on tankers. In current use, the term "sour" refers to the presence of sulfur in the oil to be refined. The problem with sulfur in oil is twofold. First, its presence hinders some of the processes used to crack larger hydrocarbons into smaller ones. Second, sulfur in refined products leads to environmental problems when the latter are combusted (formation of acid rain, for example) as well as fouling platinum and palladium in automotive catalytic converters. The allowable amount of sulfur has been reduced in the last few years, notably even for bunker oils used to power cargo ships.

Vanadium

Trace amounts of vanadium, nickel, and other metals are often found in crude oil, especially those which are heavy and sour. The metals are typically found as complexes with certain porphyrins. These are large, cyclic molecules markedly similar to biologically important molecules:



Similarity of vanadyl porphyrin to chlorophyl-a (from Wikipedia)

The amount found in crude is believed to be related to the depositional environment as well as the amount of requisite biological precursors in the forming oil.

Although the amounts found in oil are typically small (1-200 ppm/wt. range), they cause problems in both refining and use similar to sulfur. The metals form deposits on catalyst surfaces, decreasing activity. When combusted, V-laden fuels foul the insides of boilers etc. and release vanadium into the environment.

For more on oil refining and the factors which determine crude oil value, I refer the reader to these two earlier articles from The Oil Drum:

Refining 101: The Assay Essay by Robert Rapier

Global Refining Capacity by Stephen Bowers

Both discuss in detail how oil assays are used by refineries to compare the various feedstock options.

Manifa Crude Assay

The simple statement that a particular crude is low value because it is "heavy with vanadium and hydrogen sulfide" has limited value in that, as it is merely a qualitative judgement; the reader must trust the author's judgement on that assessment. A more objective comparison is obtained by comparing crude assays. Unfortunately, while these are readily available for most crudes sold today, Manifa has not been sold for many decades. However, I was able to obtain data from assays performed by a major oil company in the early 1980's. This includes data for the two Manifa reservoirs which will be tapped in the current development project, as shown in Table 1.

	Manifa (Manifa)	Manifa (L. Ratawi)	Zuluf Hvy (Safaniya)	Arabian Hvy	
API	30.2	26	27.7	28.2	
%S	2.8	3.7	2.9	2.84	
V (ppm)	6.9	14.5	37.6	45.8	
Ni (ppm)	2.24	4.85	11.14	14.20	
TBP Yields					
C4	1.7	1.6	0.7		
Lt Gasoline 55-175	5.5	4.8	4.2		
lt Naph 175-300	9.3	7.7	10	7.9	lt Naph 68-212
Hvy Naph 300 400	9.2	7.5	9.2	6.8	Hvy Naph 212-302
Kero 400 500	9.5	8.2	10	12.5	Kero 302-455
AGO 500 650	14.6	13	13.3	16.4	Lt Gas Oil 455-650
Lt VGO 650 800	14.3	12.7	12.5	26.3	Hvy Gas Oil 650-1049
Hvy VGO 800 1000	13.5	16	14.2		
Resid 1000+	22.4	28.5	25.9	26.8	Residual 1049+
Vac Resid Quals					
API	6.4	5.4	5	4	
Sulfur (%wt.)	5.6	6.6	5.8	5.6	
Nitrogen (ppm)	2550	2430	4300		
Nickel (ppm)	10	17	43	53	
Vanadium (ppm)	31	51	145	171	
Iron (ppm)	1	23	8	28	
Asphaltenes	7	4.8	11.3		
Rams Carbon	22.8	24.8	20.9	24.4	

Table 1: *Oil assays from samples from reservoirs in Manifa, Zuluf, and Safaniyah fields, Saudi Arabia*

The assays in the first three (non-label) columns are those obtained from samples in the 1980s. Note that the Safaniyah reservoir is not the primary source of oil from the Zuluf field. I have thus added data (second to last column) for Arabian Heavy, which is oil from the Safaniyah reservoir in the Safaniyah field. Somewhat different distillation temperature ranges were used in the latter (far right column), but a reasonable comparison can still be made.

The first four rows show all-crude values, although the metal concentrations are derived values (explained below). The TPB Yields section gives the fractions obtained (in % of total by volume) for each temperature range (in °F). The section with the subheading Vac Resid Quals lists the parameters for the oil remaining after vacuum distillation to 1000°F (or 1049°F), corresponding to the last fraction in the above section. This is often referred to as the "vacuum bottoms" or resids, and is usually processed further to obtain more valuable products. Although some sulfur and even some metal contamination makes its way into lower-temperature cuts, most of the bad stuff gets concentrated into the dregs of the distillation. Some assays will report concentrations of vanadium and nickel only for the vacuum resids, while others will have whole crude values. I have thus computed whole crude values for the assays above (top section of the table) to better compare with other values presented below.

Overall, the values from the two Manifa reservoirs don't look bad in comparison. The Lower Ratawi reservoir has markedly higher sulfur and a somewhat higher residual fraction, but the metal concentrations are lower. Certainly in comparison to Arabian Heavy (of which Saudi Aramco sells quite a bit), Manifa doesn't stand out as an inferior product.

Other World Crudes

Here is one resource which lists sulfur and metals contamination for various crudes which might make their way into a refinery near you:

Modern instrumental methods of elemental analysis of petroleum products and lubricants, R. A. Nadkarni, ASTM International 1991.

TABLE 2—*Elemental analysis of crude oils from giant oil fields* [1].

Country	S, wt%	N, wt%	V, ppm	Ni, ppm	Fe, ppm
Abudhabi	0.62–0.77	0.03	1	0.43	...
Algeria	0.02–0.31	0.01–0.09	0.2–1.5	...	...
Canada	0.2–3.67	0.02–0.12	<1–220	1–60	<1–629
Colombia	0.25–1.11	0.15	59–135	9–14	2–18
Egypt	0.84–2.06	0.08–0.18	15–120	7–72	58
Indonesia	0.07–0.18	0.12–0.34	...	7–33	...
Iran	0.76–3.68	0.02–0.3	11–151	3–39	...
Iraq	1.36–2.1	0.28	6–95	4–15	...
Kuwait	1.82–2.58	0.10–0.13	23–43	6–9	0.3–0.7
Libya	0.13–1.04	0.08–0.27	1–28	1–35	...
Nigeria	0.10–0.26	0.03–0.18	1-4	1-13	...
Saudi Arabia	1.25–3.91	0.03–0.34	6-80	1-20	...
United States					
Alaska (N. Slope)	1.07	0.23	16–30	4–13	...
Arkansas	0.9–2.1	0.02–0.11	12–19	4–23	1–6
California	0.2–1.2	0.1–0.77	1–403	2–174	2–125
Louisiana	0.1–0.8	0.2–0.08	0–4	0–6	...
Oklahoma	0.2–1.18	0.05–0.27	0–148	0–71	1–51
Texas	0.1–2.4	0.01–0.11	0–23	0–5	...
Wyoming	0.1–3.44	0.06–0.36	1–144	1–102	1–23

There is quite a range of values, even within countries. Note, for example, the range of 1-403 ppm vanadium for California. It is interesting, however, to identify some of the sources of the lesser-quality oils in order to see how much gets sold. Here are some values I obtained from the Oil and Gas Journal for oil from the Americas:

Assorted Heavy Metal Crudes

Crude Type	Location	API	%S	V (ppm)
Maya	Mexico	22.1	3.31	291
Merey	Venezuela	18	2.28	295
Zuata	Venezuela	15.7	2.69	260
Cold Lake	Alberta (bitumen)	13.2	4.11	124
Lloydminster (LLB)	Canada	22	3.15	100
Hondo Monterrey	California	19.4	4.7	280

Sources: Oil and Gas Journal 10/18/2002 and 3/30/1992

Table 3: *Selected heavy sour grades refined in the US*

Maya, a blend of oil from the Cantarell and Ku Maloob Zaap fields, makes up two thirds of Mexico's production. For awhile, there was Maya crude in the US Strategic Petroleum Reserve:

> The Maya crude oil was acquired from Mexico in the early 1980s, as part of a purchase agreement between the Department and Petroleos Mexicanos, Mexico's national oil company. Since that time, the Maya has been segregated in a single cavern at Bryan

> Mound because its lower API gravity and greater sulfur content made it significantly different from the other inventory. This had the effect of reducing the site's operational flexibility, efficiency, and drawdown capability during an energy emergency.

One of the reasons that the US is exporting gasoline is that Mexico and other countries lack the heavy oil refining capacity needed to handle something like Maya.

> Many producing countries export their best grades of crude oil, and consume the poorest grades at home. In Mexico, the lack of refining modernization over the years meant that large amounts of residual fuel oil or "resid" are produced. With the heavier Mayan crude as feedstock, the resid that was produced is particularly high in sulfur and other components. Without an export market for this commodity, Pemex provided resid to Comisión Federal de Electricidad (CFE) – Mexico's national electricity organization – at very low prices. Electric power generated from this resid has contributed greatly to the extremely poor urban air quality in Mexico's cities.

Pemex has thus invested in Shell's Deer Park Refinery in Texas, which now processes about a quarter million barrels of Maya per day. Refineries operated by Valero, Exxon Mobile, and Chevron also process Maya. Similarly, the Merey Sweeny Refinery in Texas has a 70k bpd delayed coker for processing the dregs from (of course) Merey.

Can it get any worse?

While these crudes are by far more heavy and metal-laden (and similarly sulfurous) than Manifa, the answer is yes. Here are some assays for various Venezuela crudes, and the winner so far seems to be oil from the Boscán field:

Boscan	Characteristics	Units	Typical Value
	Gravity	°API	10.1
	Sulphur	WT %	5.4
	Kinematic Viscosity at 100 °F	CST	11233
	Vanadium	ppm	11222
	Neutralization Number	Mg KOH/gr	.91
	Pour Point	°C	7

11.2 parts per thousand of vanadium! Of course, this has an upside:

> An interesting suggestion regarding the presence of up to 0.1% vanadium in some crude oils, particularly Venezuelan Boscán crude, has been to use the resid bottoms as a source of vanadium ore as a byproduct of petroleum refining.

(quoted from the book referenced earlier)

Even without that business twist, Chevron must be selling some of it to somebody.

Hydrogen Sulfide?

Without question, Manifa oil in the reservoir has a high H_2S content. Shown in Table 5 below is a comparison of the contaminant levels found in associated gas from oil production elsewhere in Saudi Arabia.

Selected Contaminants in Associated Gas From Saudi Arabian Oil Fields

Field	Gas Oil Ratio	mole% N_2	mole% CO_2	mole% H_2S
Ain Dar	544	0.3	11.85	3.72
Haradh	400	0.39	9.43	1.17
Uthmaniyah	461	0.28	10.28	1.78
Fazran	448	0.11	7.45	1.8
Shedgum	543	1.23	9.88	2.45
Hawiyah	400		10.9	1.3
Abqaiq	846	0.6	9.36	3.23
Abu Hadriyah	267	0.6	4.07	5.12
Abu Safah	64	3.52	6.82	2.9
Berri	758	0.24	7.97	7.74
Dammam	485	11.99	10.06	1.66
Harmaliyah	739	0.08	9.38	6.23
Khurais	274	0.5	5.25	0.23
Khursaniyah	375	0.27	6.39	3.77
Manifa	145		11.43	16.05
Marjan	840	0.32	1.47	
Qatif	679	0.39	17.5	14.1
Safaniyah	177	1.49	1.87	
Zuluf	555	0.48	1.07	
Source: Energy Vol. 16, No. 8, pp. 1089-1099, 1991				

Table 5: *Selected contaminants in associated gas from Saudi Arabia oil fields (gas oil ratio (GOR) in CCF/barrel)*

Yes, Manifa seems to lead the pack with 16 mole% H_2S. But hydrogen sulfide is mostly an upstream problem, adding health risks during drilling and production, and the risk is proportional to the total amount of gas dissolved in the oil as well as the fraction of the gas which is H_2S. Note the much higher gas oil ratio (GOR) for the Qatif field. Even the Berri field, with an H_2S mole% which is half that of Manifa, has more H_2S per barrel of oil. Of course, problems in processing the sour gas from Manifa will be slightly more than for Qatif and Berri fields. But these are not insurmountable, and the crude oil shipped to refineries can be processed similarly to that from Safaniya.

To find a worse case scenario, we must travel about 1300 miles north to the Caspian Sea, where the much delayed Kashagan project is still running up the tab - now at $46 billion. Kashagan crude, while much lighter, bears associated gas with an H_2S content of 16-20 mole%. Not much worse, except that the GOR is a whopping 1,900 - 2,200 cubic feet per barrel. Thus, if we take the crude from Boscán and dissolve within it the gas of Kashagan, perhaps then we would have something as bad as Manifa was portended to be.

Conclusion

That Saudi Aramco chose Manifa field as its next big increment still raises questions due to its cost (now at $17 billion) as well as the quality of the oil, even though it is nowhere near as bad as has been reported. Saudi Aramco has made the latter issue somewhat moot by, along with multinational partners, building new refineries (together costing more than the field re-development) to process Manifa oil into more valuable products. In a future article, I will take a closer look at the project itself and possibly speculate further on the why of Manifa.