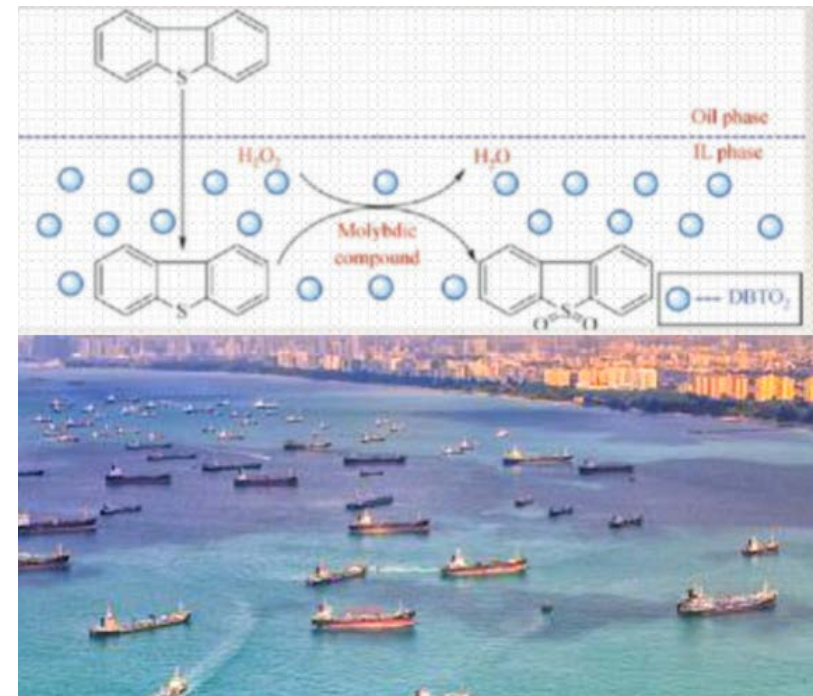


# Curve Marine

## Reactor Demo and Chemistry Report



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Report Ref: D-R.01

## EXECUTIVE SUMMARY

On 22<sup>nd</sup> January 2020, Curve Marine Pte Ltd demonstrated its *MARPOL-Ready* desulphurization reactor system for PETRONAS, in Port Klang. Potential partners and investors Curve has been developing with throughout 2019 from various oil service companies of several international jurisdictions including Pemex/ Mexico, Colombia/Ecopetrol were present to discuss technical details and investment structure. Also attending the showcase were independent energy companies from Singapore. An accompanying lecture on Curve's proprietary desulphurization chemistry which utilizes a low Capex and low energy reactor system for post-MARPOL Residuum and HFO treatment was given by the Curve Marine Technical Director, Mat Wyatt.

During the same week, Curve conducted pressure testing, pressure balance testing and energy efficiency assessments on the reactor system at various operational settings. Live runs of HFO were conducted. The independent lab Intertek collected samples before and after on a treatment run of the Curve Marine M10-Cat-ODS chemistry, applied to IFO 180 HFO. The findings are summarized in this report; pg4. The original Intertek report can be made available.

At the same time as fine-tuning the commercial readiness of Generation 1, Curve Marine has been developing Generation 2 - Curve's *M-Nano* Desulphurization Chemistry. Whilst Curve Generation 1 requires a two-phase treatment, Curve Generation 2 achieves a single phase hybrid desulphurization treatment.

During this same week that Intertek verified Generation 1, SGS conducted tests on the Generation 2 chemistry in single phase tests on the same IFO 180 HFO. The results were very compelling and improved on the already better than expected results from the Generation 1 tests. The Gen 2 chemistry results are also given in this report. The original SGS reports can be made available.

TARGET RESULTS:

In 2018 and 2019, the main option making HFO MARPOL compliant (bringing 3.5% Sulfur content to less than 0.5%) was blending with distillates/diesel.

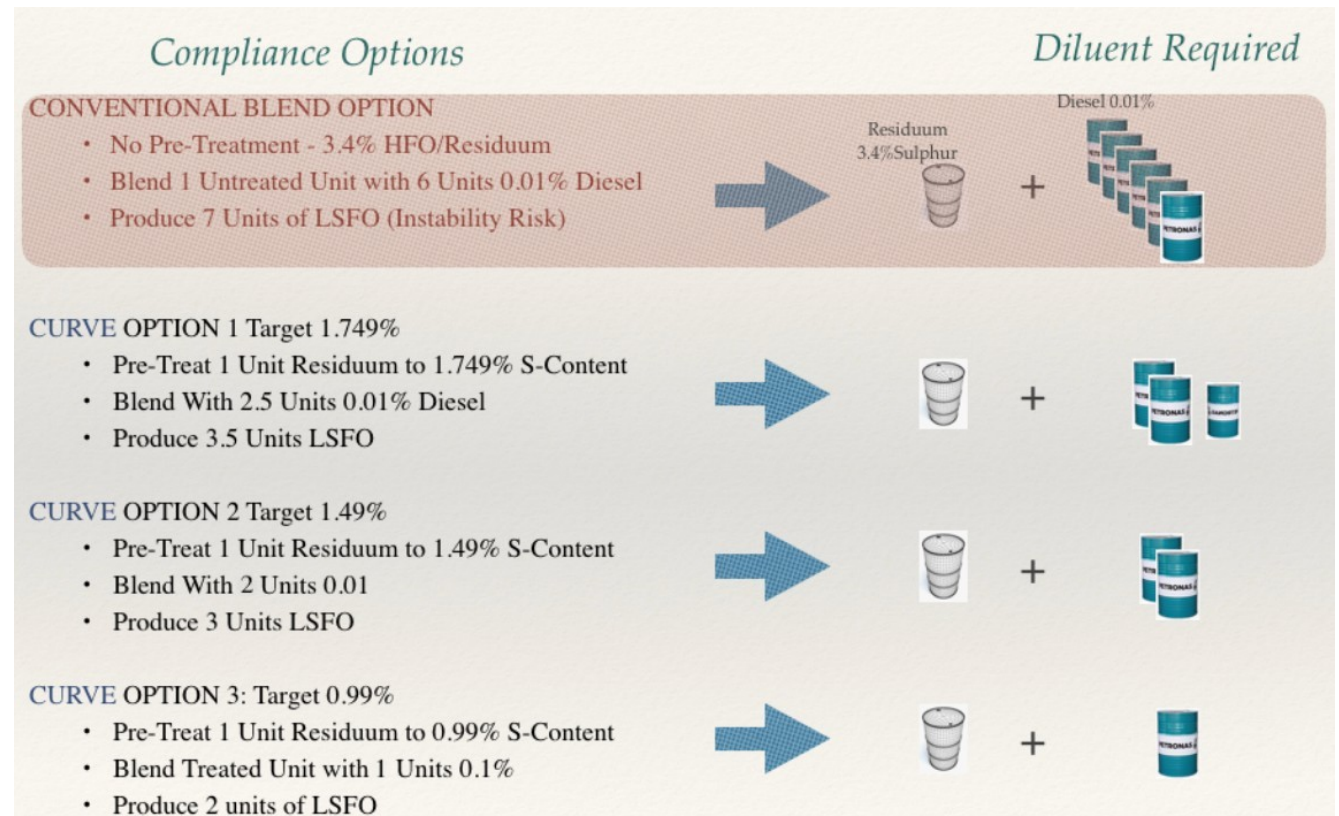
However blending at high ratios >1:2.5, can produce unstable Fuel products mainly due to asphaltene deposition and phase separation.

In order to produce a stable fuel, the blend ratio of HFO to diesel has to be low. This required Sulfur removal.

The ideal ratio is less than 1:1.

The Curve target therefore was to get below 1% - this is indicated in the chart as Option3, "Curve 3".

Both Gen 1 and Gen 2 chemistries achieved "Curve 3".



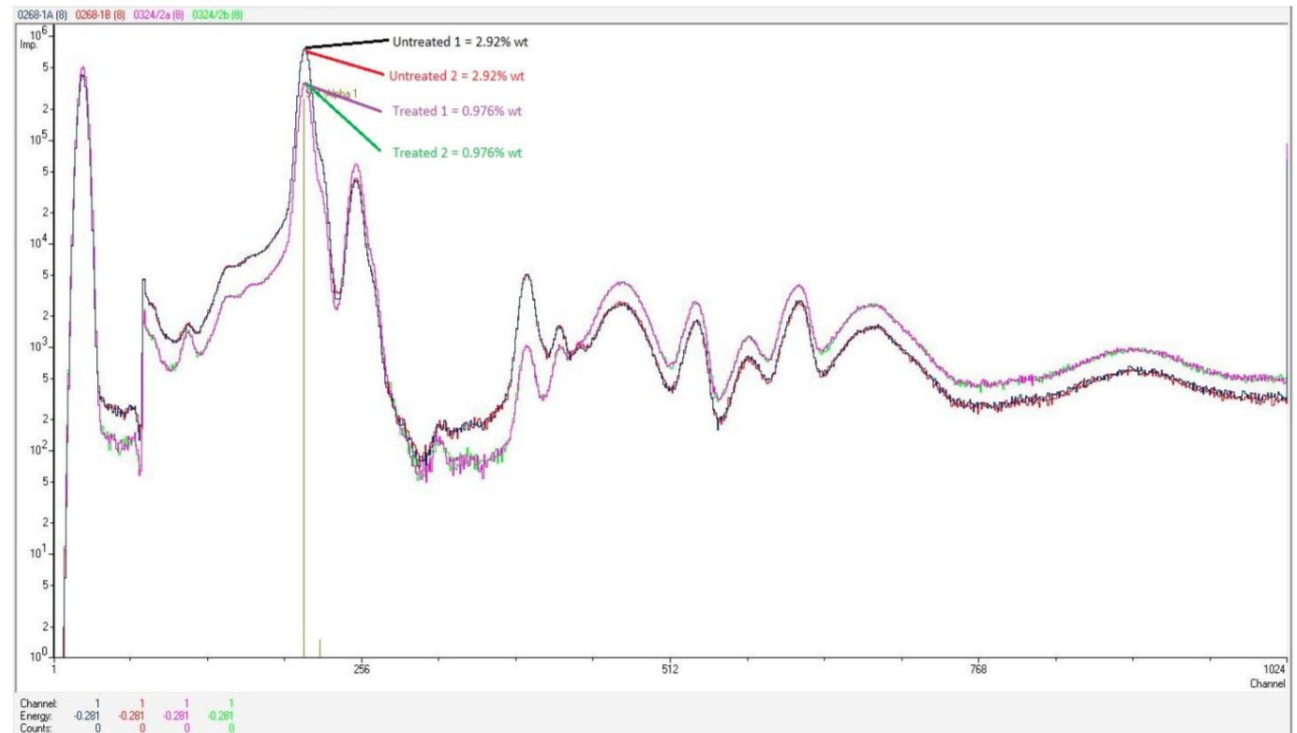
GEN 1 CHEMISTRY RESULTS - CURVE M10 Cat-ODS (Dual Phase)  
(INTERTEK VERIFIED)



Table 1 : Sulphur content results

Sample	Test	Unit	Method	Results
Untreated 01	Sulphur content	% weight	ASTM D 4294	2.920
Untreated 02				2.920
Treated 01				0.976
Treated 02				0.977

Figure 1 : Sulphur content results



Official Report can be made available.

**GEN 2 CHEMISTRY - SINGLE PHASE CURVE M-NANO (Integrated ODS & Extractive Desulphurization; EDS )  
(SGS VERIFIED)**

Test	Method	Result	Unit
Sulfur IFO180	ASTM D4294-16e1		mass %
1.OGCPK 33743		0.900	
2		0.912	



*Official Report can be made available.*

## THE REACTOR

### PRESSURE TEST

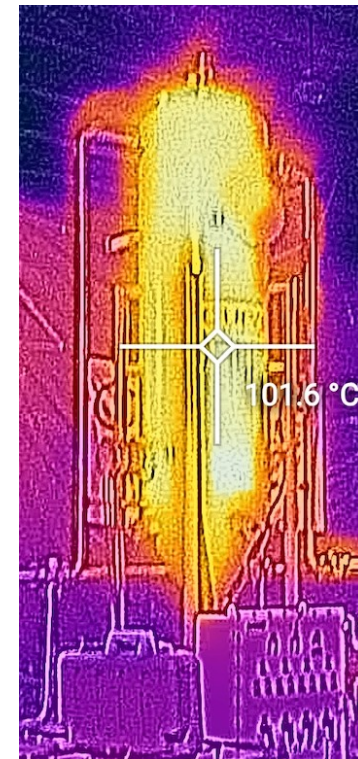
10 bar Test successfully conducted.

4 bar relief Valve test completed and calibration reconfirmed.

### PRESSURE DISTRIBUTION

An eight-hour Water Run, up to 101° C, demonstrated continuous balance and no leakage.

A four-hour oil run, up to 101° C, demonstrated full balance of pressure across the system factoring in the high sheer pump draw effect.



## REACTOR - HEAT CONSERVATION

(Energy Consumption calculated on 40m<sup>3</sup> reactor volume)

From Gen 1 (dual phase 75° C.) to Gen 2 (Single Phase 45° C), energy consumption Chemistry improves an already good environmental performance in terms of Carbon Footprint

Pumping and Heating Costs (Full Reactor 1 Vessel 40m <sup>3</sup> )	KWh/Day	Unit Price (\$0.08)	Cost
Energy consumption Gen 1 (75° C)	7475	\$ 0.08	\$ 598
Energy Consumption Gen 2 (45° C)	1485	\$ 0.08	\$ 119

- (Not including Separation or Recovery - Reactor Operation only)
- Based on ambient being 27° C

Lower Carbon Footprint of Gen 2 is five times lower than Gen 1.

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## KEY FINDINGS - THE TWO CHEMISTRIES ACHIEVED “CURVE 3”:

Generation 1 - Dual Pass Curve M10 Cat ODS - 0.97% S-Content - Achieved “Curve 3”

Generation 2 - Single Pass Curve M-Nano Hybrid ODS - 0.91 % S-Content - Achieved “Curve 3”

