MSAR® Technology - Emulsion Fuel for Power Generation, Marine Bunkers & Refinery Uses
Introduction to Quadrise

- Quadrise is the supplier of proprietary MSAR® technology that produces a low cost, low viscosity, synthetic HFO from refinery residue streams.

- MSAR® emulsion fuel is used as a direct substitute for HFO in marine and power applications as well as refinery refuelling, with economic and environmental benefits for producer and consumer.

- Low capex method of improving refinery margins that is proven and verified at commercial scale.

- IP is protected jointly with Akzo Nobel and projects are being developed with major global companies.

- QFI plc is listed on the London Stock Exchange under AIM companies.

Industry participants:

[List of logos]

MSAR® = Multiphase Superfine Atomised Residue
Quadrise license and supply MSAR® technology and additives to produce a stable ‘Oil-in-Water’ emulsion fuel

**How it works:**
Tiny droplets of extra-heavy residue are dispersed in water using proprietary processes and additives

**Key benefits:**
- Water & chemicals replace premium fuels
- Significant value is added
- MSAR® viscosity is lower
- Can blend ‘incompatible’ fuel

MSAR® provides refiners with low-cost, rapidly deployed upgrading solutions for HFO

**Key benefits:**
- Stable, lower cost synthetic HFO
- Enhanced combustion & lower emissions (NOx, PM)

Delivers HFO consumers with tangible cost savings and environmental benefits

**Quadrise provides unique expertise from production to consumption**
**MSAR® Technology**

- **Additives**: <1%
- **Water**: ~29%
  - Can be derived from several utility or wastewater sources

**Solid, viscous residues** ~70%

- Vacuum column
- Visbreaker
- Hydrocracker
- SDA
- Thermally cracked
- Unstable/incompatible residues

Oil residues are taken direct from refinery rundown lines and cooled to achieve the required viscosity (~200-1000cSt @ 100-200°C typically) for the colloid mill.

Water, together with proprietary additives, is added to the residue in a high-speed colloid mill under pressure.

The mixture is processed in the mill and cooled to provide a **highly stable** oil-in-water fuel oil equivalent (~200cSt at 50°C) that can be run down to existing fuel oil tanks.

**“Plug & Play” Refinery Technology**

“Semi-complex” Refinery

1. Crude
2. Water & Additives
3. MSAR® Unit
4. Fuel Oil
5. Fuel Oil Market

Premium fuels
# Project Timeline

<table>
<thead>
<tr>
<th>1-2 months</th>
<th>3-4 months</th>
<th>6-12 months</th>
<th>Operations</th>
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</thead>
<tbody>
<tr>
<td><strong>Scoping</strong></td>
<td><strong>Pilot Testing</strong></td>
<td><strong>FEED</strong></td>
<td><strong>EPC</strong></td>
</tr>
<tr>
<td>Refinery residue stream identified.</td>
<td>Pilot testing at QRF*, additive formulation optimized based on end-use application and product specs.</td>
<td>Scope developed and a design prepared for implementation. Quadrise provide client training and experience.</td>
<td>Implementation/integration of MSAR® project in modular, scalable units.</td>
</tr>
</tbody>
</table>

A typical MSAR® project costs around $10m and is implemented within 12 months.

*QRF = Quadrise Research Facility

MSAR® installation at Cepsa San Roque Refinery
To note:

**Water**
- MSAR® contains ~30% water, resulting in a reduced calorific value when compared to HFO.
- Typically 50% more fuel required (factored into economics).

**Density**
- MSAR® density is higher as residue based.

**Viscosity**
- MSAR® Viscosity is lower as a function of the water in the bulk phase.

**Sulphur**
- Like HFO, MSAR® contains sulphur as a feature of the residue.

### Comparison of ISO8217:2010 marine residual fuel (RMG) versus MSAR®

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Limit</th>
<th>Category ISO-F-</th>
<th>ISO Test Method</th>
<th>RMG 380</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>Density at 15°C, kg/m³</td>
<td>max.</td>
<td>991,0</td>
<td>ISO 3675 / ISO 12185</td>
<td>1050,0</td>
<td>180,0*</td>
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<tr>
<td>Kinematic Viscosity at 50°C, mm²</td>
<td>max.</td>
<td>380,0</td>
<td>ISO 3104</td>
<td>1050,0</td>
<td>60</td>
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<tr>
<td>Flash Point °C</td>
<td>min.</td>
<td>60</td>
<td>ISO 2719</td>
<td>60</td>
<td>N/A</td>
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<tr>
<td>Pour Point (upper)</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>Winter Quality °C</td>
<td>max.</td>
<td>30</td>
<td>ISO 3016</td>
<td>N/A</td>
<td>20</td>
</tr>
<tr>
<td>Summer Quality °C</td>
<td>max.</td>
<td>30</td>
<td>ISO 3016</td>
<td>N/A</td>
<td>20</td>
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<td>Carbon Residue, % (m/m)</td>
<td>max.</td>
<td>18</td>
<td>ISO 10370</td>
<td>20</td>
<td>0,3</td>
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<td>Ash, % (m/m)</td>
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<td>0,15</td>
<td>ISO 6245</td>
<td>33,0</td>
<td>0,3</td>
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<td>Water, % (v/v)</td>
<td>max.</td>
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<td>ISO 3733</td>
<td>33,0</td>
<td>0,3</td>
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<tr>
<td>Sulfur, % (m/m)</td>
<td>max.</td>
<td>3,5</td>
<td>ISO 14597 / 8754</td>
<td>3,5</td>
<td>2,5</td>
</tr>
<tr>
<td>Acid number, mg KOH/g</td>
<td>max.</td>
<td>2,5</td>
<td>ISO 14597 / 8754</td>
<td>3,5</td>
<td>2,5</td>
</tr>
<tr>
<td>Hydrogen Sulfide, mg/kg</td>
<td>max.</td>
<td>2,0</td>
<td>IP 570 Part A</td>
<td>2,0</td>
<td>N/A</td>
</tr>
<tr>
<td>Vanadium, mg/kg</td>
<td>max.</td>
<td>350</td>
<td>ISO 14597 / IP 501</td>
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<td>N/A</td>
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<td>Sodium, mg/kg</td>
<td>max.</td>
<td>100</td>
<td>ISO 14597 / IP 501</td>
<td>100</td>
<td>N/A</td>
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<tr>
<td>Total Sediment Potential, % (m/m)</td>
<td>max.</td>
<td>0,10</td>
<td>ISO 10307-2</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Aluminium plus Silicon, mg/kg</td>
<td>max.</td>
<td>80</td>
<td>ISO 10478</td>
<td>15</td>
<td>N/A</td>
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<tr>
<td>Used lubricating oil (ULO)</td>
<td>max*</td>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Zinc, mg/kg**

**Phosphorus, mg/kg**

**Calcium, mg/kg**

* The fuel shall be considered free of ULO if one or more elements Zn, P and Ca are below or at the specified limits. All three elements shall exceed the same limits before a fuel shall be deemed to contain ULO.

* = at 100s^{-1}
N/A = Not relevant for emulsion fuel
Economic drivers for MSAR®

Value is created at the refinery by saving distillate fuels – to be shared with consumer*

Traditional refinery process

- 50% Refinery output
- 30% HFO
- 20% Residual fuels

Every barrel of high value premium fuel used to create HFO is lost margin to the refinery

High value transport fuels | High value fuels used to dilute HFO | Residual fuels

HFO example: 60% residue, 40% diluent

An MSAR® refinery

- 70% Refinery output
- 30% MSAR®

An additional 20% of higher value fuel can be sold by the refinery at the market rate vs HFO value

Water & <1% chemicals

High value fuels used to dilute HFO | Residual fuels | MSAR®

* Price of MSAR® < HFO on a per unit of energy basis

In simple terms, MSAR® works where: HFO Distillates Uplift Value > Water + Additives...

Low Capital Cost & Rapid Implementation → Rapid Payback

~$10m < 12 months
Positive for QFI and the MSAR® fuel solution:
- Higher distillate spreads = even better economics
- Low capex and quick implementation = <2 year payback by stakeholders
- Good fit with EGCS solutions, + lower NOx & PM
- Also positive for End Users with EGCS ("scrubber")

< 12 months to implement at refineries
MSAR® can be used as a permanent solution to residue streams as a result of new upgrading projects or as an interim solution to take advantage of high distillate spreads in 2020 and beyond.
Economic & Environmental Benefits

1. Energy Savings
   - MSAR® is stored & transported at ambient temperatures (>25°C)

2. Efficient Combustion
   - Complete Carbon burnout = lower PM* emissions
   - = less Black Carbon (BC)

3. Lower NOx Emissions
   - Water reduces the combustion temperature = >20% lower NOx emitted

MSAR® is compatible with EGCS which enables affordable compliance with environmental standards

4. CO2 Impact
   - To provide 0.5%S by 2020 results in 17 Mt/y (11.6%) increase in EU refinery CO2 emissions and $19bn CAPEX.
   - Partially offset by 8 Mt/y (5.5%) increase CO2 emissions from scrubber energy requirements on vessel.

   ✓ Considerable CO2 emission savings of 9 Mt/y (6.1%) CO2 using EGCS vs. use of refined distillates.

Source: Concawe Report 1/13R (EU Refineries)
CEPSA MSAR® Project (2016)

- 6 KBD MSAR® system installed at the CEPSA 240 KBPD* Gibraltar San Roque Refinery, initially to supply Maersk
- Quadrise responsible for MSAR® system installation, commissioning, operations, quality control
- MSAR® system designed to supply Marine or Power end users, installed in 9 months for <$5m
- Processing visbreaker residue from LS or HS opportunity crudes
- Proven, reliable, 24/7, continuous operation

* BPD - Barrels per day
• MSAR® is proven in Wärtsilä 4-stroke diesel engines
• JDA with Maersk commenced in 2008 to demonstrate MSAR® use in large 2-stoke diesel propulsion engines
  • Laboratory and land-based tests completed 2009-2013
  • Two sea-borne “proof of concept” vessel tests completed in 2014
  • Joint refinery scoping studies carried out during 2014-15
• “Operational LONO Trial” contracts with Cepsa and Maersk signed Q4 2015
  • Fast-track commercial-scale MSAR® facility installed & commissioned within 9 months
  • 1,500 MSAR® running hours on Seago Istanbul completed in 2017 and interim LONO received from Wärtsilä.
• Significant worldwide emulsion fuel experience
• Experience applied to MSAR® improvements
• >60 million tons emulsion fuel fired: 50MWth to 770MW
Quadrise and major stakeholders are in the final stages of defining a commercial scale MSAR® combustion project on a 400MWe boiler in the Kingdom of Saudi Arabia.

Scope of demonstration:
• Production of Power MSAR® for seaborne oil tanker supply to a modern 400MWe boiler
• ~2 month combustion trial, plus potential follow-on opportunities at the power station as well as other power stations in Kingdom.
• HFO use in KSA today is circa 500,000bpd with around half of this volume sourced domestically and the remainder imported.
• Following trial success, potential MSAR® supply opportunities for domestic and international refineries.

Power Plant Applications
• KSA hosts the largest oil-fired power stations in the world, all located in the Western Province.
• Boilers range from 400MWe to over 600MWe, most with supercritical steam efficiencies.
• Each 400MWe boiler requires around 1 million tonnes of MSAR® from 3 MMUs* producing MSAR® 24/7.
• On trial success there are potential MSAR® supply opportunities for domestic and international refineries (a “residue sink”) with KSA benefitting from lower cost power generation.

*MMU = MSAR® Manufacturing Unit
Global Opportunities

Complementary Global Opportunities

- Refinery power & steam opportunities.
- Synergies of working collaboratively with national oil companies and refiners at global fuel hubs to provide MSAR® for Marine & Power.
- Selected upstream opportunities.

MSAR® production is an opportunity for refineries seeking an affordable, quickly implemented solution to improve distillate yields. Either as a destination for residue streams as a result of 2020 upgrading projects, an interim solution or a standalone project.

Power

- Initial focus commercial roll-out in KSA for Power generation (40% of global power market).
- Expand selectively into other markets in Middle East and Asia.

Marine

- Initial focus on using positive outcomes of marine trial to secure OEM (MAN & Wärtsilä) approvals for MSAR® use alongside scrubbers.
- Expand to commercial shipping operators deploying scrubbers supplied by fuel hubs.
15th November 2017
Athens

MSAR® - Emulsion Fuel for Power Generation, Marine Bunkers & Refinery Uses

Thank you / Ευχαριστώ - questions welcome!

Further info available:

www.quadrisefuels.com or info@quadrisefuels.com
Refinery economics (2018 example)

Refinery economics:

MSAR vs HFO = [ HFO value – distillate savings + additive costs ] x Net Calorific Value Adjustment

Step 1...
Derive the value of the residue per ton, based on value of HFO less the cost of distillates (LCO)

Step 2...
Calculate the cost of MSAR® (residue + water + additives)

Step 3...
Adjust for lower calorific value and compare savings “like for like” vs HFO. MSAR® value to be shared...
## MSAR®/QuadriRE References – Global oil-in-water emulsion fuel use

**Major ORIMULSION® Users (up to y/e 2006)**

Plants in **Bold Blue** indicate facilities where the **QuadriRE team** were actively involved in engineering, commercial development (including evaluations) and operations.

<table>
<thead>
<tr>
<th>Country</th>
<th>Plant Name</th>
<th>Dates Start-End</th>
<th>Boiler Design Fuel</th>
<th>Boiler Rating MWe</th>
<th>Orimulsion® Consumption [million tonnes Per year Total]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singapore</td>
<td>Power Seraya Stage I</td>
<td>04-06</td>
<td>HFO</td>
<td>3x250</td>
<td>1.5 2.5</td>
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<tr>
<td>Guatemala</td>
<td>Constellation Energy Planta Arizona</td>
<td>04-06</td>
<td>HFO</td>
<td>150 Diesel</td>
<td>0.3 1.0</td>
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<tr>
<td>South Korea</td>
<td>KOSPO Youngnam</td>
<td>03-06</td>
<td>HFO</td>
<td>2x200</td>
<td>1.0 2.0</td>
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<tr>
<td>China</td>
<td>GEPB Nanhai A/B (1)</td>
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<td>HFO</td>
<td>400 + 100</td>
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<tr>
<td></td>
<td>GEPB Heng Yun (2)</td>
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<td>HFO</td>
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<td></td>
<td>GEPB Huang Pu (2)</td>
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<td>500</td>
<td>0.1 0.6</td>
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<td>Italy</td>
<td>ENEL Fiume Santo 3, 4</td>
<td>99-04</td>
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<td>1.1 4.0</td>
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<td>Cement Klin</td>
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<td>1.4 6.1</td>
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<td>LE Lietuvos Elektrine</td>
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<td>150+Steam</td>
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</table>

**Notes:**

(1) ORIMULSION® was used as a start-up and combustion support fuel for coal.
(2) ORIMULSION® co-fired with LISO.