Final Report
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Technical Due Diligence
MSAR® Project
Lithuania

Phase 1

Prepared for:
European Bank
for
Reconstruction and Development

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Executive Summary

A demonstration project is being undertaken by Quadrise Fuels International (QFI) to produce MSAR® (Multiphase Superfine Atomized Residue) fuel in Lithuania at the Mazeikiu Nafta refinery; transport the fuel 300 km by rail and use the fuel at the Lietuvos Elektrine power station. At the time of writing, QFI has just completed the manufacture of 20 thousand tonnes of MSAR®, successfully transported it by rail and has successfully combusted the product to generate electricity at the Lietuvos Elektrine power station.

As part of the project evaluation the European Bank of Research and Reconstruction and Development commissioned a technical due diligence of the project.

The writer, John Sturgeon is the principal of JRS Consulting from Canada. He is experienced in the use of Orimulsion® fuel at power stations and was retained by QFI to perform Phase 1 of the Technical Due Diligence of the MSAR® Project in Lithuania. The Phase 1 Terms of Reference (TOR) specified a requirement to review the demonstration test procedures and results and other information available on the MSAR® process and pertinent data on Orimulsion® which was used at the Lietuvos Elektrine power station for ten years. The specified purpose is to discover any potential problems with using MSAR® as a fuel in the power station. The TOR listed specific questions relative to the Project.

The writer has completed the assessment and has presented a response to each of the questions in scope based on the state of knowledge available. The assessment evaluated the operation of the Lietuvos Elektrine power station using MSAR® fuel based on operating data available from the power station and data on the fuel provided by QFI. An important factor in the assessment was the parallel drawn between the expected behavioural similarities of MSAR® and Orimulsion® and to consider the Orimulsion® operating experience at the Lithuanian Power Plant.

The available data on Orimulsion® consistently states the combustion of Orimulsion® can be adequately controlled using commercially available best control technologies. The technologies being installed as part of the modernization will be utilized for MSAR®.

The writer has observed the project EIA included Orimulsion® as a fuel and the EIA was approved by the regulator. The approval indicates the modernization project will meet or exceed EU Directives.

On the basis of the risk assessment of the MSAR® technology and one accepts that MSAR® characteristics will be similar to Orimulsion® behaviour and there is every reason to draw this conclusion, then there should be no greater risk with the MSAR® technology if the equipment being installed is appropriately designed and operated.

Legal Notice:

Background

John Sturgeon is the principal of JRS Consulting Inc, a leading independent consultant in the combustion of emulsion fuels and based in New Brunswick, Canada. He performed the assigned portion of Phase 1 *Technical Due Diligence MSAR® Project, Lithuania* for the European Bank for Reconstruction and Development (EBRD) as defined in the Terms of Reference (TOR) for a project to produce and use MSAR® (Multiphase Superfine Atomized Residue) fuel in Lithuania. The project as defined in the demonstration phase and at the time of writing is underway with manufacturer of the MSAR® fuel at the Mazeikiu Nafta refinery, transported 300 km by rail, unloaded to tank storage at the power station and used as fuel in the Leituvos Elektrine power station. The assignment included specific questions relative to Phase 1 of Terms of Reference (TOR) that are addressed in this report.

Methodology

The approach adopted in this Technical Due Diligence has been not to address each question listed in the Terms of Reference based on the present state of knowledge of MSAR® but to draw from available data about MSAR®'s predecessor emulsion fuel, Orimulsion®. Considering that there is a paucity of technical information about MSAR® manufacture, handling and combustion at the scale of the Lithuanian Power Plant, this report has legitimately drawn upon the similarities between MSAR® and Orimulsion®. Bearing in mind that the Lithuanian Power Plant has ten years' experience of handling and burning Orimulsion®, this is considered to be a valid approach in the absence of specific data on MSAR®. There is considerable reference information and experience on the manufacture, handling, transport and combustion of Orimulsion® fuel, on the use of emission control technology with Orimulsion® that did meet regulated standards for air pollutants and for the management of by-products generated and this information is drawn upon at length in this report.

This assessment has evaluated the likely impact of MSAR® use on the operation of the Lietuvos Elektrine power station based on operating data available from the power station and the small amount of data on the fuel provided by QFI. There is publicly available information available on the power station, the regulatory requirements for the station and technical papers on experience with Orimulsion® that will be used for comparative purposes. Sources of information available for reference include those from Lietuvos Elektrine (LE) power station Environmental Assessment, Golder Associates technical papers, US Environmental Protection Agency (EPA), UK Electricity Association Services Limited (EA), various technical papers and presentations including PDVSA-Bitor with actual emission data for plants firing Orimulsion® and other liquid fuels.

The structure of this report is such that the Terms of Reference are listed first, and then there is a short introduction about Lietuvos Elektrine (LE) power station, before the main section which covers the answers to the main questions of interest.

Terms of Reference

Introduction

Quadrise Fuels international plc (the Sponsor) has approached European Bank for Reconstruction and Development (EBRD) requesting finance for a project to produce and use MSAR® (Multiphase Superfine Atomised Residue) fuel in Lithuania (the Project). A demonstration of the fuel preparation, transportation and ultimate combustion is currently being undertaken in Lithuania, with manufacture at the Mazeikiu Nafta refinery, transport some 300 km by rail and used as fuel in the Lietuvos Elektrine power station.

As part of the project evaluation EBRD wishes to commission technical due diligence in two phases. The due diligence for the first phase shall also cover some commercial and environmental and social issues.

Phase 1 will review the demonstration test procedure and results and other information that is available on the MSAR process and pertinent data on the Orimulsion® process which was used at the Lietuvos Elektrine power station for ten years. The purpose of this phase is to discover any actual or potential problems with the use of MSAR technology in this project.

Phase 2 will be contingent upon the Bank deciding to proceed with due diligence after considering the results of the phase 1 study and other considerations. It will focus upon the financial viability of the project and the steps needed to implement it.

Phase 1 Report on viability of MSAR process

Objective

The objective of Phase 1 is to determine whether there are fundamental risks associated with the project which would make it unsuitable for loan finance, e.g. technology development risk.

Thus the Consultant is required to review and make a critical assessment of the technology involved and opine on whether it is proven technology or the extent to which there are technology development risk involved. The tasks are the following:

1. Review the prior experience of the Sponsor and opine on his competence to successfully complete the project
2. Review Demonstration plant report on the results so far
3. Describe crude sources and cuts used, potential limitations relative to Mazeikiai refinery current and planned future configuration and potential sourcing of crude, opine on the risks related to the change of residue quality/characteristics and what consequences it may have on the equipment and quality of final product.
4. Describe the equipment used for MSAR fuel preparation and potential scale up problems
5. Report any known or potential problems such as corrosion, emulsion stability, fuel characteristics – summer and winter extremes
6. Assess the current state of modernisation of the power station, opine on any need for an upgrading of the existing facility to be used for MSAR® combustion on the power station, describe the pollution abatement measures and opine on their suitability for use with MSAR® fuel and what additional investments are need to meet EU environmental standards.
7. Comment upon the results to date of the power station tests, satisfaction of management
8. Identify any environmental changes, for better or for worse, as a result of using MSAR® fuel in place of HFO. In particular examine the fate of heavy metals: efficiency of particulate traps, dispersion of microscopic particles. This will include a review whether the combustion of this type of fuel will allow the plant to attain EU Large Combustion Plant (LCP) Directive requirements and requirements of the EU IPPC Directive (Best Available Techniques – BAT

requirements). The review will also include a summary of carbon and sulphur emissions and compliance with National and EU emissions limits and emission trading schemes (EU ETS).

9. Compare the MSAR process to Orimulsion in the specific application inclusive of carbon intensity.
10. Provide a summary risk assessment

Method and Deliverables

For phase 1 the consultant should visit the sites for both the refinery and the power station while the demonstration is in operation, and also the relevant department of Akzo Nobel, the process licensor. Further information should be gathered by desk research. An inception meeting with the Bank and the Sponsor may be held in London before the site visits. The results of the study should be presented to the Bank in a draft report in English (3 copies) within 1 month of the inception meeting. The final report should be issued within a week of receiving comments from the Bank.

Lietuvos Elektrine (LE) Power Station

The 1,800 MW Lithuanian Power Plant is situated in the town of Elektrenai, 50 km west of the capital city Vilnius.

Elektrenai was built between 1960 and 1972 producing steam, heat and power. The station consists of eight units: 4 x 150 MW with 500 t/h boiler steam supply and 4 x 300 MW each with a 950 t/h steam supply from two separate boilers. The station was originally designed to burn heavy fuel oil and natural gas before a third fuel source Orimulsion®, imported from Venezuela, was added to diversify fuel sources. A modernization project to be completed in two phases began in 2006 and is scheduled to be complete in 2009.

The existing station did not comply with EU directives for new plant standards on large combustion plants.

EU Emission Limits[1]

Fuel	mg/Nm^3		
	NO_x	SO_2	Dust
Liquid fuels	400	200	30

To meet these directives environmental approval was obtained for the modernization project that includes the addition of emission control technologies to ensure compliance with these 2008 directives.

This modernization project is installing environmental control equipment that includes:[2]

- NOx burners (LNB) with over fire air[3] to control nitrogen oxide emissions on Units 5, 6, 7 and 8 complete with new burner management controls.
- Electrostatic precipitator (ESP) for the removal of particulate that specifically states includes ash handling plants and emulsion fuel ash densification system on Units 7 and 8.
- Flue gas desulphurization (FGD) equipment for the removal of SO_2 on Units 7 and 8.
- Complete new control management system for Units 5, 6, 7 and 8.

1 Directive 2001/80/EC of the European Parliament and of Council of 23 October 2001 on limitation of emissions of certain pollutants into the air from large combustion plants

2 Executive Summary of EIA of Environmental and Related Technical Upgrading of Lithuanian Power Plant

3 An "over-fire air" system is the second part of a staged-NOx combustion system. In the first stage (the burners), fuel is combusted in an oxygen- depleted zone to minimize the formation of thermal NOx. In the second stage a small amount over-fire air is added to complete combustion outside of the burner zone. The power plant facility also can also use gas recirculation (exit gases returned to the furnace) to achieve further NOx benefits. In all cases the objective is to minimize NOx, excess oxygen (measured after the over-fire air zone) and hence production of sulphur trioxide.

Question 1:

Review the prior experience of the Sponsor and opine on his competence to successfully complete the project.

The writer has known many of the Quadrise Fuels International (QFI) Executive and Technical Management, as well as some of QFI's contract consultants, during his career and when they worked in senior positions in British Petroleum (BP) and Bitor[4] during the development of Orimulsion®. Orimulsion® was a bitumen-in-water emulsion manufactured from Orinoco bitumen and was developed into a successful power station fuel. It is therefore clear, in the writer's opinion, because of the association with Orimulsion® and the development of the Bitor business, that key members of the QFI team have considerable emulsion fuel expertise and experience. The writer therefore believes that this is being applied successfully by QFI in the development of MSAR® (Multiphase Superfine Atomised Residue) – a new emulsion fuel, similar to Orimulsion®, for use in power generation boilers.

QFI's ability to develop the MSAR® business is related almost entirely to their expertise and experience with Orimulsion® which includes experience in emulsion fuel production and formulation and considerable in-field operating experience with emulsion fuel handling, combustion and emission control. Some of QFI's staff were key players in the early development and testing of Orimulsion®. Their success in turn ensured that when power station operations staff and third party consultants tested Orimulsion® their reports demonstrated that the fuel could be burned successfully and that conventional emission control technology can be effective. Orimulsion® became a very successful fuel with over six million tonnes per annum being sold worldwide, until it was withdrawn from the market in 2006, because of changes in Venezuelan government ideology. With the same key individuals now employed by QFI, it is not unreasonable to assume that MSAR® over time will have similar commercial success to Orimulsion®.

[4] Bitor – **Bit**umenes **Or**inoco a subsidiary of Petroleos de Venezuela SA (PDVSA)

Question 2:

Review Demonstration plant report on the results so far.

There was not a demonstration plant report of results available for the writer to review at the time of his visit. The writer did witness MSAR® delivery and the ignition of MSAR® in two burners.

The writer has learned from a Press Release that the Lietuvos Elektrine power station has reported they have successfully completed the demonstration test burn of the shipment of 20,000 tonnes of MSAR® with excellent results. It reports that with the excellent results of the Mazeikiu Nafta refinery to produce the product and the Lietuvos Elektrine power station is ready to use it for energy production.[5]

In subsequent information made available the writer has learned more of the 20,000 T test burn of MSAR® as presented in brief summary.[6] The Lietuvos Elektrine power station was able to demonstrate on Unit 7 that the fuel could be fired and could achieve compliance with the required environmental emissions. It was noted that:

- The fuel handling system utilized for Orimulsion could be used for MSAR®.
- Atomizer/burner design was adequate to fire MSAR®.
- Boiler fouling levels were not problematic; that build-up was not any greater than normal; and, the on-line soot cleaning equipment was effective.
- Established that emissions could meet compliant conditions firing MSAR® utilizing the emission technology installed on Unit 7 as part of modernization. The results of more detailed analysis of gaseous and dust emissions are targeted to be complete in the final quarter of 2008.
- Lietuvos Elektrine power station staff deemed MSAR® fuel to be similar to and in many cases better than Orimulsion®.
- It was noted that time constraints impacted the opportunity to fully evaluate and optimize the use of MSAR® because of the commissioning program of the new equipment installed as part of the modernization project.

[5] See www.nafta.lt/en/news_item.php?pid=1&id=177

[6] Personal communication

Question 4:

Describe MSAR® fuel delivery.

From September 4th to 6th the writer visited Lietuvos Elektrine power station with the objective of:

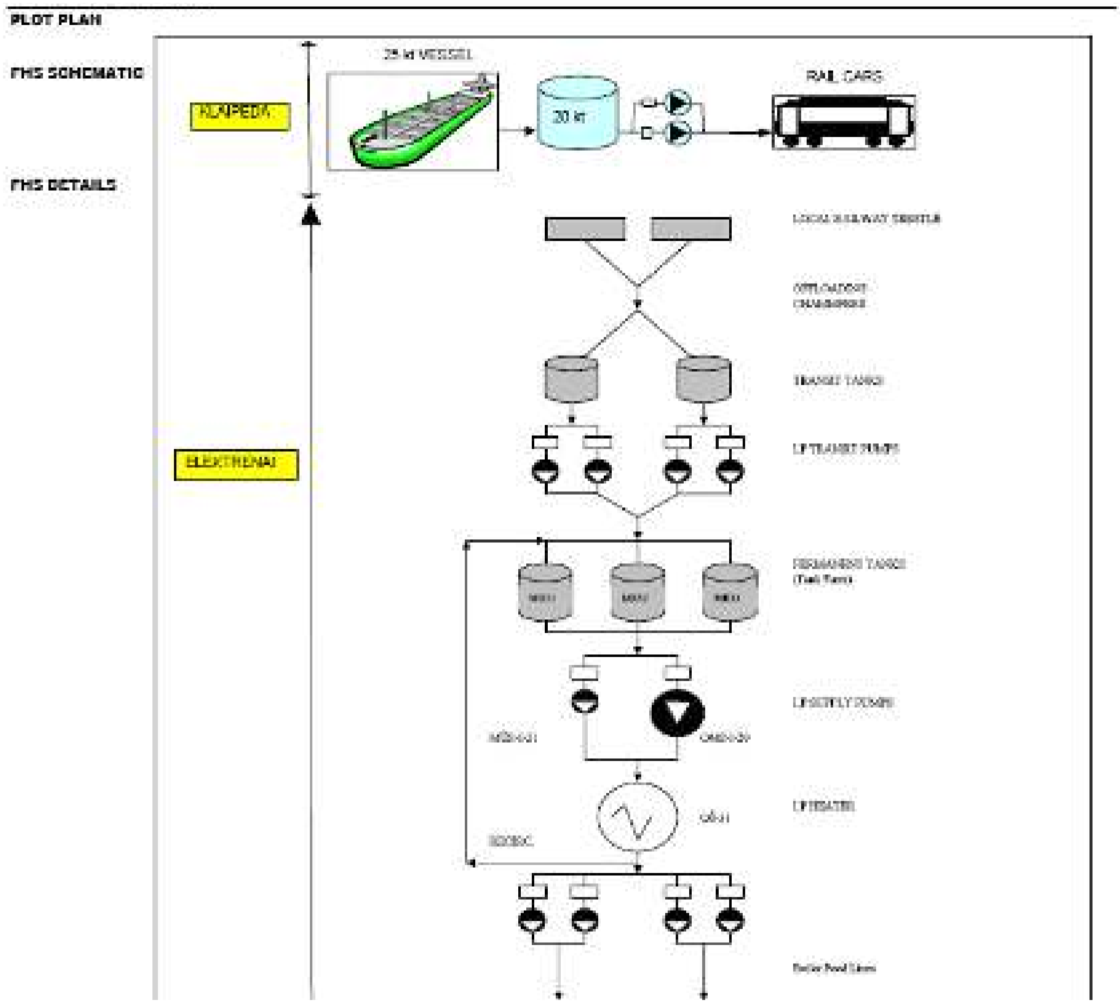
- Conducting a detailed tour of the facility including the fuel delivery, unloading and storage.
- Obtaining reference material from the project EIA reference LE EIA Addendum – *Section 5 – The Transport, Storage and Handling of Orimulsion®*.
- Obtaining a reference sketch included – Plant Details that depicts the plant fuel loading, fuel storage and fuel delivery system.

The writer observed the facility to be very clean which is typically an indicator of a well maintained operation. It was reported that the station has had 10 years' operating experience with Orimulsion®.

The writer toured the complete fuel delivery system among other areas and observed:

- Twenty five rail cars (55 – 60 tonnes each) operated by Lietuvos Gelezinkeliai that had delivered MSAR® fuel 300 km by rail car from the MSAR® production facility at the Mazeikiu Nafta refinery. The station has the capacity to unload up to 58 rail cars simultaneously. A total of 20,300 Tonnes of MSAR® was reported to have been delivered, using over 370 rail cars, which was unloaded and pumped to tank storage on site. The MSAR® was observed in one rail car at the unloading area. From visual examination the MSAR® looked to have withstood the transport well and looked homogeneous with no visible sign of instability. The fuel temperature was observed to be at or about 40 ^{o}C.
- MSAR® rail car unloading from 25 rail cars that went without any unusual event. Lietuvos Gelezinkeliai is reported to have much experience in fuel delivery and the station operating staff appeared experienced with the operation; no doubt from their 10 years' experience unloading Orimulsion®. The fuel is discharged by gravity through a drain opened to atmosphere at the bottom of the rail car, draining to a sump also opened to atmosphere. The question was asked and answered as to potential risk of exposure of MSAR® to cold winter temperature during unloading that may impact fuel quality. In reply it was noted there is the capability to pre-heat the delivery system (including trenches) with steam prior to deliveries in cold temperatures. The steam heating is stopped just prior to fuel unloading to avoid potential fuel temperature extremes as was successfully done during winter delivery for Orimulsion®. As well, there is excessive fuel storage capacity at the production facility to stock pile fuel and to avoid delivery in cold temperature or any adverse weather conditions. The operation practice in the event of cold temperature delivery would ensure higher fuel delivery temperature and the operation of the installed heating system as well as minimum time to unload and pump to tank storage. The turn around to unload on this day was in fact short. It was reported that Orimulsion® delivery for 10 years was handled in the same system with no events reported even in extremes of winter temperatures.
- All MSAR® storage tanks at the facility were insulated as were the supply, discharge and recirculation pipelines. The pipelines were also heat traced for added temperature protection. The tanks were unheated but design included a recirculation pipeline that allowed circulation of MSAR® pumped from the storage tank through a shell and tube heat exchanger, supplied with a hot condensate heating medium, back to storage. This system was designed to maintain adequate MSAR® temperature for low viscosity and freeze protection. All within good standard for emulsion fuel.
- The fuel delivery system to the burner included double screw pumps complete with variable frequency drive motors for flow control and low turn down with suitable heat exchangers and valves that satisfy typical minimum requirements for emulsion fuels. The system was designed with adequate system redundancy. It is important to note the system was used for handling Orimulsion®.

PLANT SCHEMATIC[7]



Summary

Equipment assessment for MSAR® compared with what is recommended for Orimulsion®:

- LP Transfer pumps – redundancy - centrifugal – low speed – acceptable
- Storage Tanks – insulated, bottom entry filling and suction lines, heating via external circulation loop through shell and tube heat exchangers - acceptable
- Storage tank containment – exists.
- Storage tank level measurement – exists – as recommended
- Storage tank temperature measurement – exists – as recommended
- LP Supply pumps – redundancy – double screw – twin screw – as recommended

[7] Supplied by Jason Miles, QFI

- LP Heater – shell and tube with hot condensate heating medium – as recommended

- High pressure pumps – redundancy – double screw – VFD speed control – as recommended

- Pipeline – insulated and heat traced – as recommended

- Recirculation pipeline – low pressure - acceptable

- Filters – exist – suitable type – as recommended

- Valves – exist – suitable type - as recommended [8]

In respect to preparedness for a MSAR® fuel spill, the writer has assumed that the fate and behaviour of MSAR® is similar to Orimulsion® as both are bitumen in water emulsion fuels. The writer understands that work is underway to validate this assumption. The writer has referenced the Lietuvos Elektrine power station EIA Addendum – *Section 5 – The Transport, Storage and Handling of Orimulsion®* which indicates that emergency plans have been established.[9] The reference indicates "*Contingency Plans for spillage of Orimulsion® to water and to land are developed to minimize risks*." Because the EIA for the project has been approved it would then appear that the regulator has accepted the emergency plans. In summary, the references include the following:

- Rail Operational Plan provided to assist personnel and that covers the rail operation for fuel delivery. It states the plan explains the loading and unloading operations, highlights the sensitive areas and river crossings along the route.[8]
- Emergency Plan for Orimulsion® Handling in Lietuvos Elektrine power station that states it covers the operation of personnel in fuel receiving, storage and waste water treatment.
- Safety Data Sheet for the fuel provides physical and chemical properties, first aid, fire-fighting, exposure control/personal protection and accidental release measures.[10]

Without specifics, these appear to be consistent with typical general standards used internationally to prevent and manage spill risk.

Because of time constraints the writer can not identify and comment on all potential operational risks including spill risk detail but from experience has attempted to identify the most likely potential risks based on his short visit.

[8] Bitor Design & Operational Manual
[9] LE EIA Addendum – *Section 5 – The Transport, Storage and Handling of Orimulsion*
[10] PDVSA Bitor - Orimulsion® 400 General Information

Question 5:

Report any known or potential problems such as corrosion, emulsion stability, fuel characteristics – summer and winter extremes.

The writer will address the question in respect to known experience with Orimulsion®. In this regard the following table is a useful starting point and presents the comparative fuel analysis of MSAR® and other liquid fossil fuels.

Characteristics	MSAR® [11] QFI Expected	MSAR® [8] Delivered	Orimulsion® 400[12]	Heavy Fuel Oil[8]	Test Method [8]
Water content, % w/w	31	30*	28.6	0.3	ASTM D-4006 / D95
Density, g/cm^3	1.02	1.03	1.01	1.03	ASTM D-4052
Mean droplet size, Microns	7.0	9.2	25	NA	Malvern Particle Sizer
Droplets 150 Microns, % w/w	2.0	1.3*	0.2	NA	Sieve Test
Apparent Viscosity, 50 $^oC/20s^{-1}$,cP	300	191*	77		Coaxial Cylinder Viscometer
Gross Heating Value, MJ/kg	29.0	30.2*	30.1	43	ASTM D-240 / D-4809
Net heating Value, MJ/kg	27.0	28.0*	27.8	40	ASTM D-240 / D-4809 Calculated
Sulfur, % w/w	2.0	1.9*	2.8	1 - 4	ASTM D-1552
Carbon %, w/w	60.3	63.0*	62.5	86	ASTM D- 5291
Hydrogen, % w/w	6.6	6.8*	7.6	11	ASTM D- 5291
Nitrogen, % w/w	0.6	0.63	0.50	0.4	Chemiluminiscene or ASTM D - 5291
Sodium, % w/w	70	30*	10	0 - 30	Atomic absorption / ASTM D - 5863
Vanadium, % w/w	240	176*	320	32 - 300	Atomic absorption / ASTM D - 5863
Nickel, % w/w	70	53*	70	20 - 50	Atomic absorption / ASTM D - 5863
Ash, % w/w	0.1	0.1	0.1	0.1	ASTM D - 482
Flash Point, ^oC	>65	>65	>65	>60	ASTM D – 92 /IP303 (or similar)
Pour Point, ^oC	<30	- 1*	<0	30	ASTM D-97 (or similar)
Asphaltenes, % w/w	11	11	11		ASTM D – 3279 (or similar)
Magnesium, PPM	125	111*	5	2.5	ICP-AES
* Better than might be expected					

[11] QFI
[12] Data ex Bitor Orimulsion 400

There is worldwide experience in the electrical power industry using heavy fuel oil and Orimulsion®. The engineer would consider the fuel specifications in the design when building and operating a power plant and would typically consider a range for each of these characteristic to ensure the plant has operating flexibility and design margins. This ensures the plant's capability to meet environmental regulations, fuel flexibility and to operate reliably. The Leituvos Elektrine power station has experience burning both heavy fuel oil for many years and Orimulsion® for 10 years.

From a technical and operational standpoint MSAR® from the Lithuanian refinery is a better fuel than Orimulsion® for the following reasons:

- Lower hydrocarbon droplet size (9µm vs 25µm), equating to higher surface area for complete fuel combustion at low levels of excess air.
- Lower sulphur content (1.9% vs 2.8% by weight), reducing potential for SO3 formation, SO2 emissions and hence gypsum production.
- Lower vanadium (176 vs 320 ppmw) and nickel (53 vs 70 ppmw) content, reducing boiler fouling, corrosion potential and ash content upstream of the ESP.
- No dependence on Venezuelan politics and a complex oceanic supply chain – the Lithuanian MSAR option couples a western refiner to a nearby (300km by rail) power plant using existing proven supply infrastructure.

Corrosion

The areas of concern with respect to corrosion are primarily related to:

- pH of the MSAR®
- Impact of water in the MSAR®
- Effect on the boiler internal parts after combustion.

QFI has reported that the Lithuanian MSAR® has a pH of 5[13]. This pH level is approaching the identified reference neutral pH and it would be the writer's opinion that the pH in itself would not be expected to present any concern, either with regard to potential acid attack on fuel handling equipment or post - combustion attack, on internal furnace metals.

When emulsion fuels were first introduced to the market place, a concern existed of the potential impact of the corrosive effects of the external water phase of the emulsion on any pipeline system and/or boiler internal metals with which the emulsion came into contact. Considering the comparison of MSAR® to Orimulsion® and the experience with Orimulsion® the water has proven not to be a concern when proper pipeline operation and maintenance is implemented. It is reported that pipelines transmitting normal crude oils and their products that the oil develops a thin protective layer over the pipe surface and inhibits corrosion. In a similar way, Bitor reported that with Orimulsion® the bitumen concentration is high enough to develop a thin oil film on the internal surface of the pipe that protects the pipe metal. Bitor operated their 300 km pipeline to transport Orimulsion® internally in Venezuela and during regular maintenance corrosion did not exceed acceptable code standards for pipeline operation.[14] There is also the suggestion that the surfactant used to stabilise Orimulsion® acted as a corrosion inhibitor.[15] Whatever the mechanism, it is clear that excessive corrosion does not occur with Orimulsion® and therefore by implication it is not expected to occur to any greater extent with MSAR®.

With respect to the corrosion of boiler internal parts after MSAR® combustion[16], one must consider the concentrations of sulphur, vanadium and sodium listed in the reference table of fuel characteristics. The three potential areas of corrosive concern all relate to the potential reactive behaviour of these elements.

[13] QFI – MSAR® Specification versus Orimulsion®
[14] Bitor - Orimulsion 400 – General Information
[15] Florida Power & Light – Corrosion Behaviour Orimulsion in pipeline
[16] ENEL Experience Firing Orimulsion in a 660 MW_e Power Plant

- High temperature oxidizing corrosion has potential to occur at the outlet of the furnace in the convective heat transfer surfaces of the boiler. The presence of vanadium (V) and sodium (Na) concentrations in MSAR® give rise to formation in the boiler of corrosive molten ash that could deposit on convective tube banks. Corrosion potential exists because of the fluxing action of the molten Na – V complexes on protective oxide scale build-up on the tubes. There is a similar risk operating with HFO and Orimulsion®, the latter having considerably higher concentrations of vanadium and sodium.
  Many years of operational experience with both HFO and Orimulsion® and extensive testing has identified that this risk is controllable with the use of magnesium. Magnesium is contained as an additive in MSAR® fuel and Orimulsion® and used as an additive in-situ at the burner with HFO to prevent vanadium corrosion. This mediation technique has been proven with experience to be an effective control of high temperature corrosion.
- High temperature reducing corrosion has potential to occur when staged combustion arrangements are applied to reduce nitrogen oxides (NOx) emissions regardless of the fuel burned. The presence of sulphur concentrations in fuel combined with a reducing atmosphere may result in H_2S attack on the furnace walls. With experience and the risk on all fuel types, the tube alloys selected for the furnace design is the effective means to counter this potential corrosion mechanism combined with effective maintenance techniques.
- Low temperature corrosion has potential to occur at lower flue gas temperatures and SO_3 in the flue gas is responsible. Three parameters in fuel contribute to the formation of SO_3 and include sulphur, oxygen and the catalyst vanadium. Control of the oxygen content in the flue gas at the burner is most important to control conversion of SO_2 to SO_3 during and after combustion. When SO_3 is formed the condensation of the gas phase of SO_3 , where temperature becomes lower and falls below the dew point, can lead to corrosion. The main measures to control SO_3 low temperature corrosion has been demonstrated by experience. The first measure is to operate at low excess oxygen levels to reduce the production of SO_3. It is much easier to operate at these low excess oxygen levels with emulsion fuels because of their pre-atomized nature and propensity to burn out completely. Therefore, as with Orimulsion® it is expected that with MSAR® extremely low excess oxygen levels will be achieved during combustion and the formation of SO3 will be mitigated. Under circumstances which require higher levels of excess oxygen for combustion and result in higher SO_3, effective corrosion control has been demonstrated by the use of additives. Magnesium has proven to be effective and the magnesium concentration contain in MSAR® would be such a control mechanism. Finally, managing flue gas exit temperatures above the identified acid dew point temperature is the corrosion preventive measure. These control mechanisms have been applied effectively to heavy fuel oil fired and Orimulsion® fired boilers for many years. It should therefore be considered that similar control mechanisms will be equally effective when applied firing MSAR®. MSAR®, as noted, contains a concentration of magnesium and with operator control of the other noted parameters this should minimize risk of low temperature corrosion.

Emulsion Stability

Emulsion stability will be addressed from the stand point of operating parameters to control MSAR® stability and not fuel production. If one accepts that MSAR® characteristics will be similar to Orimulsion® behaviour, and there is every reason to draw this conclusion, the operating parameters that may impact MSAR® stability are identified as:

- Static stability – defined as MSAR® tolerance to storage conditions with associated risk if the MSAR® were subjected to extreme factors such as contamination, temperature change or sedimentation of the emulsified oil phase.

- Dynamic stability – emulsion fuels typically have a limit of tolerance to shear. Excessive shear can result in conditions of instability. Pumps, valves and other restrictions in the fuel handling are sites that promote a potential for excess shear to be applied.

The production control of MSAR® with the correct selection of surfactant formula and concentration, droplet size and droplet size distribution are the first important factors of good stability. QFI have control of this parameter.

Experience has shown that heavy fuel oil facilities with only minor modifications are suitable for operation with Orimulsion®. Applying this same parameter for the use of MSAR® then one would conclude that the operator has adapted its facility to accommodate these recognized control parameters for both static and dynamic instability. This has been addressed specifically – see response to Question 4.

Fuel Characteristics and Summer and Winter Extremes

The writer has already stated his witnessing of MSAR® delivery via rail car and its ensuing release into a drain open to the atmosphere. It could be considered that at extreme winter temperatures this might be considered to be a risk. However, the writer observed and has noted in response to Q4, Page 7 that system design features at the station combined with ten years of successful and uneventful Orimulsion® delivery through these drains suggest that appropriate mediation to minimize temperature risk are in place. Apart from that, the rest of the system is well insulated with heat tracing in all the appropriate places therefore winter and summer extremes of temperature should not impact on the operation.

While discussing the impact of extremes in temperature it is worthwhile recording that MSAR® will be expected to have similar temperature limitations to Orimulsion®. The properties of water and its temperature behaviour were the prime considerations for setting temperature limits for handling Orimulsion®. These properties will be similar controlling factors with MSAR®.

Identified temperature limits for Orimulsion® (and therefore MSAR®) are:

- 10^{o}C - minimum low temperature limit as a margin above water freezing temperature to avoid fuel inversion.
- 80^{o}C – maximum temperature as the margin below water evaporating to avoid fuel inversion.
- 40 to 60^{o}C – typical combustion temperature limit – well within high and low temperature margin.
- 20 to 30^{o}C – typical tank storage temperature, well within temperature margin.

At the Leituvos Elektrine power station, the writer observed that these temperature limitations were respected and adhered to when handling MSAR®. In fact 40^{o}C was the noted temperature throughout the system for all operation including unloading, storage, pipeline flow and combustion temperature at the burner. As noted in response to question 4, the Lietuvos Elektrine power station has heating capabilities and mediation techniques as part of the operating procedures to minimize fuel exposure to temperature extremes.

Considering the Leituvos Elektrine power station's 10 years of successful operating experience with Orimulsion® and the accepted similarities between Orimulsion® and MSAR® temperature limits, under normal operation there is limited temperature risk for MSAR®.

Question 6

Assess the current state of modernisation of the power station, opine on any need for an upgrading of the existing facility to be used for MSAR® combustion on the power station, describe the pollution abatement measures and opine on their suitability for use with MSAR fuel and what additional investments are need to meet EU environmental standards.

The writer has reviewed pertinent environmental data, specific to the environmental approval of the project, to upgrade the Elektrenai power station to obtain the current status of modernization. To paraphrase the referenced Elektrenai power station project EIA documents, it states that the modernization project requires the installation of environmental control equipment that includes:

- *Low NOx Burners (LNB) with over fire air to control nitrogen oxide emissions on Units, 5, 6, 7, and 8 complete with new burner management controls.*
- *Electrostatic Precipitator (ESP) for the removal of particulate that specifically includes ash handling plants and emulsion fuel ash densification system on Units 7 and 8.*
- *Flue Gas Desulphurization (FGD) equipment for the removal of SO_2 on Units 7 and 8.*
- Complete new control management system for Units 5, 6, 7 and 8.

The project EIA was approved by the regulating authorities and in summary concludes:

i. *The renovated power station will comply with EU requirements for emission from large combustion plants (using both gaseous and high sulphur liquid fuels).*

The EIA for the Lietuvos Elektrine power station has referenced emission levels that will be achieved for heavy fuel oil and Orimulsion® after the approved modernization and installation of BACT emission controls.

Fuel	mg/Nm^3		
	NOx [17]	SO_2 [18]	Dust [19]
Heavy Fuel Oil	400	200	30
Orimulsion®	400	200	30

The writer has reviewed the existing equipment at the power station which has operated successfully with Orimulsion® for 10 years including the emission control equipment that is being added as part of the modernization. On the basis that one assumes, as expected, operating similarities of MSAR® with Orimulsion® one would not expect there to be a need for any additional upgrades or investment to meet the EU environmental standards as identified and declared achievable as part of the EIA approval. An important factor to consider is the concentration of each of the elements of nitrogen, sulphur and ash, including the heavy metals, and to consider how they compare between MSAR® and Orimulsion®. In the independent summary results analysis of the fuels provided, they are directly comparable.

Publically available documentation from reliable sources clearly state the emissions from the combustion of Orimulsion® can be adequately controlled using commercially available best control technologies. The writer presents highlights from some sources with statements that include:

ii. EA Environmental Briefing, March 2000, Electricity Association Services, London, England.[20]

[17] Table 2.9 Limited values of NOx that are reached by Lithuanian PP proposed techniques and the Best Available Control Techniques – EIA of Proposed Economic Activity, Sept 2003

[18] Table 2.6 SO_2 treatment limit values achieved by applying the best available control techniques - EIA of Proposed Economic Activity, Sept 2003.

[19] Table 2.3 Limited values of particulate matter that are reached by Lithuanian PP proposed techniques and the Best Available Control Technique (BAT) - EIA of Proposed Economic Activity, Sept 2003.

1. *…from Orimulsion® results in emissions of carbon dioxide, NOx and particulate matter which are comparable to or better than those from coal or heavy fuel oil, although greater then those from gas.*
2. *Conventional flue gas desulphurization process can remove most of the sulphur dioxide emissions associated with power stations using Orimulsion®.*

iii. Generation and Control of Air Pollutants from Orimulsion® Combustion, 1997, US Environmental Protection Agency.[21]

1. *Commercially available control technologies that are appropriate designed and operated can adequately control air emissions from the combustion of Orimulsion®.*

iv. Life Cycle Analysis of Power Plant Greenhouse Gas Emissions, August 2001, US Environmental Protection Agency.[22]

1. *Orimulsion® has lower greenhouse gas emissions than coal and residual oil.*

There has been considerable commercial experience using these best available control technologies with Orimulsion®. The following group of tables have been extracted from PDVSA Bitor Orimulsion® Environmental Manual[23]. The data indicate that with Orimulsion® the equipment is able to comply with the EU Directives noted in the Lietuvos Elektrine power station project EIA.

NOx control technology - The Lietuvos Elektrine power station modernization includes low NOx burners and over fire air – staged combustion. Staged combustion can be noted from the following reference table to have made an improvement when burning Orimulsion®.

Comparable EU Directive for NOx – 400 mg/N^3

Table 10.4 – NOx Technology & Performance at ORIMULSION® Facilities

Country - Station Name	Unit Size / Operation Start	Low-NOx Burners	Staged Combustion	SCR	NOx Emissions	
					mg/Nm^3 (3%O_2,dry)	lb/mmBtu
Canada - Dalhousie	320MW / 1994	×	×	×	390	0.27
Denmark - Asnaes	640MW / 1995	✓	×	×	408	0.28
Italy - Brindisi Sud	2x660MW / 1990	✓	×	✓	143	0.10
Italy - Fiume Santo	2x320MW / 1999	✓	✓	✓*	176	0.12
Japan - Kansai Electric	160MW / 1994	✓	✓	✓	82	0.06

[20] EA Environmental Briefing, March 2000, Electricity Association Services, London, England

[21] Generation and Control of Air Pollutants from Orimulsion Combustion, 1997, US Environmental Protection Agency

[22] Life Cycle Analysis of Power Plant Greenhouse Gas Emissions, August 2001, US Environmental Protection Agency.

[23] PDVSA Bitor – Orimulsion Environmental Manual 10. Nitrogen Oxides CYT-MA-03-001
Note: Arsines reported value exceeds 400 mg/Nm^3 because EU standard at the time was 450 mg/Nm^3 @ 3% O_2 hence report value well below standard.

SO2 control technology – the Lietuvos Elektrine power station modernization includes a FGD system.

Comparable EU Directive for SO_2 – 200 mg/N^3

The concentration of SO_2 after combustion of Orimulsion® is typically 6800 mg/Nm^3 (3% O_2 basis) and would require 94% FGD removal efficiency to comply with a limit of 400 mg/Nm^3.[24] The Orimulsion® experience listed in Table 8.7 with high efficiency FGD systems demonstrates the capability to meet a 400 mg/Nm^3 emission limit. A calculated value for the MSAR® concentration of SO_2 would be 4,600 mg/Nm^3 requiring 96% FGD removal efficiency to meet 200 mg/Nm^3.

Country	Customer	Plant	Output (Gross MWe)	Start Date	FGD		
					Type	Eff.	Product
Denmark	Energi E2	Asnæs Unit 5	640	1995	WLGP	99%	Wallboard Gypsum
Canada	NB Power	Dalhousie Units 1+2	100 215	1994	WLGP	93%	Wallboard Gypsum
Italy	ENEL	Brindisi Units 1,2,3,4	4 x 660(1)	1997	WLGP	96%	Wallboard Gypsum
	ENEL	Fiume Santo Units 3+4	2 x 320	1999	WLGP	95%	Wallboard Gypsum
Germany	RWE	Ibbenbueren Unit 1	700 (2)	1998	WLGP	94%	Wallboard Gypsum
Japan	Kansai Electric	Osaka Unit 4	160	1994	WLGP	95%	Wallboard Gypsum
	Hokkaido Electric	Shiriuchi Un. 2	350	1997	WLGP	94%	Wallboard Gypsum
	Kashima Kita	Units 1+2	95CHP 125CHP	1995 1991	WLGP	93%	Wallboard Gypsum
China	Guangdong Electric Power Bureau (3) (GEPB)	Nanhai "A"	400	2001	Dry	80%	To landfill
		Nanhai "B"	100	2001	Dry	80%	To landfill
		Heng Yun	200	2001	Dry	80%	To landfill
		Huangpu	500	2001	Dry	80%	To landfill

Notes: (1) Cofired; Units 1 and 2: 60% Coal, 40% ORIMULSION®. Units 3 and 4: 70% Coal, 30% ORIMULSION®
(2) ORIMULSION® used to support Coal firing.
(3) All units cofired with 70% Low Sulfur HFO
WLGP = Wet limestone gypsum process, Dry = Dry sorbent injection

Table 8.7 – Summary of selected FGD systems used for ORIMULSION® service

24 PDVSA Bitor -Orimulsion Environmental Manual 8. Sulfur Oxides CYT-MA-03-001

Particulate matter control technology for the Lietuvos Elektrine power station modernization includes electrostatic precipitator (ESP).

Comparable EU Directive for PM –30 mg/N^3

Location	Manufacturer	Design Fuel	No. of Fields	Outlet Conc. (mg/Nm^3)
Asnæs, Denmark	ABB Flakt	Coal/ HFO	5	<10
Brindisi, Italy	ABB Flakt	Coal/ HFO	7	<25
Dalhousie, Canada	ABB Flakt	ORI®/ Coal	3	15
Fiume Santo, Italy	ABB Flakt	HFO	7	10
Ince, UK	Lodge Sturtevant	ORI®	3	35
Richborough, UK	Musgrave	Coal	3	45
Setubal, Portugal	Research Cottrell	HFO/ ORI®	4	10

Table 11.11 – Summary of selected ESP systems used for ORIMULSION® service [25]

The following tables demonstrate from Orimulsion® experience the effectiveness of the ESP in control of emissions of heavy metals.[23]

	Station	**Asnæs**	**Dalhousie**	**Fiume Santo**
	Country	Denmark	Canada	Italy
	Fuel	*ORI-400*	*ORI-100*	*ORI-400*
	Date	1999	1995	1999
PM Stack Emission (mg/Nm^3)		2.5	15.0	10.0
PM Comp. (%wt.)	$CaSO_4$	92.8%	90.0%	N/D
	V	0.3%	1.2%	0.1%
	Ni	0.1%	0.4%	0.1%
	Mg	1.6%	2.8%	N/D
	Na	2.7%	2.4%	N/D
	Others	2.6%	3.2%	N/D
N/D – Not determined				

Table 8.8 – Measured WLGP ORIMULSION® plant stack PM emissions and compositions

[25] PDVSA Bitor -Orimulsion Environmental Manual 11. Particulate Matter CYT-MA-03-001

Asnæs (ORIMULSION®-400*, 1999)			
PM dia. µm	ESP inlet mg/m³	ESP outlet mg/m³	Removal Efficiency
<0.44	34.2	0.2	99.3%
0.44-0.65	21.1	0.2	99.0%
0.65-1.0	21.1	0.2	99.0%
1.0-2.1	12.6	0.3	97.4%
2.1-3.3	8.5	0.4	95.8%
3.3-4.8	5.4	0.3	95.0%
4.8-7.2	5.8	0.3	94.9%
7.2-11.4	2.2	0.3	86.8%
>11.4	2.7	0.3	89.0%
Total PM	113.8	2.5	97.8%
** - No FGA injection*			

Dalhousie (ORIMULSION®-100**, 1995)			
PM dia. µm	ESP inlet mg/m³	ESP outlet mg/m³	Removal Efficiency
<0.27	59.5	2.4	96.0%
0.27-0.55	60.8	1.7	97.1%
0.55-1.1	80.3	2.6	96.8%
1.1-2.1	42.9	1.5	96.5%
2.1-4.1	20.2	1.3	93.5%
4.1-10.1	11.2	1.7	84.5%
>10.1	45.1	3.8	91.6%
Total PM	320	15.0	95.3%
*** - Equivalent to >350ppm Mg additive injection*			

Table 13 – Measured removal efficiencies by PM size range at Asnæs and Dalhousie[24]

If one accepts that MSAR® characteristics will be similar to Orimulsion® behaviour, and there is every reason to draw this conclusion, and references Orimulsion® data then would one anticipates the emission abatement equipment being installed as part of the modernization of the Elektrenai power station will be equally effective. One must then consider the MSAR® fuel specification and if the equipment being installed is appropriately designed and operated then further investments should not be necessary to meet the noted project approved EU standards.

Question 7:

Comment upon the results to date of the power station tests, satisfaction of management

The writer met Mr. Algimantas Jasinskas, Deputy Chief Economist responsible for the modernization project. Mr. Jasinskas has been an employee at this power station since 1966 and from the writer's perspective has a comprehensive knowledge of the project and of the overall operation of the Lietuvos Elektrine power station. Mr. Jasinskas had also been responsible for co-ordinating the Orimulsion implementation project more than 10 years earlier.

Mr. Jasinskas frequently referenced the Lietuvos Elektrine power station ten year operating experience with Orimulsion® and noted that this experience was a particularly successful period in the power station's history. His technical conversations frequently drew parallels with his expectation that MSAR® operation would be similar and the performance would compare well with Orimulsion®.

Mr. Jasinskas noted his familiarity with and confidence in the QFI staff from their previous experience in Bitor and in particular their input into the successful 10 year Orimulsion® operation – "they are the same people, we trust them". He spoke of the importance of the three corporate participants; referencing the Lietuvos Elektrine power station, the Mazeikiu Nafta refinery and QFI and he noted the potential value to each participant of MSAR®. Mr. Jasinskas stated that he believed QFI had done an exceptional MSAR® production demonstration at the Mazeikiu Nafta Refinery and was looking forward to an equally successful demonstration of MSAR® combustion on his site. (This has now been completed successfully)

Mr. Jasinskas mentioned that the environmental modernization project with the addition of the emission control technology would not only be necessary but also help in fostering good relationship with the local community.

We discussed the expectation of the environmental impacts. Mr. Jasinskas noted that although there was no detailed operating data for MSAR® they did expect it to be similar with Orimulsion®. He compared the concentrations of sulphur, nitrogen and ash. It was his expectation that emission control equipment would be suitable for MSAR®. To support this it is important to note that he referenced the design specifications for the FGD included capability for 3.5% sulphur fuel also noting the comparison with MSAR®. He noted that it is lower in sulphur and his expectation that the FGD would meet sulphur emission requirements for MSAR®. Mr. Jasinskas noted their plan was to purchase heavy fuel oil with 3.5% sulphur for test purposes to certify the FGD guarantees.

The writer observed ignition and operation of two burners on MSAR®. The ignition of MSAR® and operation of the two burners was successful.

Question 8

Identify any environmental changes, for better or for worse, as a result of using MSAR® fuel in place of HFO. In particular examine the fate of heavy metals: efficiency of particulate traps, dispersion of microscopic particles. This will include a review of whether the combustion of this type of fuel will allow the plant to attain EU Large Combustion Plant (LCP) Directive requirements and requirements of the EU IPPC Directive (Best Available Techniques – BAT requirements). The review will also include a summary of carbon and sulphur emissions and compliance with National and EU emissions limits and emission trading schemes (EU ETS).

If one accepts that MSAR® characteristics will be similar to Orimulsion® behaviour, and there is every reason to draw this conclusion, then again reference to Orimulsion® data will help address the question with regard to the fate of heavy metals; and dispersion of microscopic particles.

Heavy Metals and Particulate Matter

The term trace element includes those elements otherwise termed trace metals, heavy metals, microelements, and trace inorganics. The reference material has stated that the emissions from Orimulsion® are not fundamentally different in character to those that would result from the use of heavy fuel oil and these concentrations are very small. The majority of the heavy metals in Orimulsion® were associated with the particulate matter (PM) in the gas stream and predominately contained oxides and sulphates of vanadium and nickel. This occurrence is similar with heavy fuel oil.

The technology most commonly selected in the power generation industry for the control of particulate matter (PM) emissions is the electrostatic precipitator (ESP). This report will not delve into technical detail of the technology but has presented important factors that impact on the efficiency to capture particles and trace elements. The ESP particle collection efficiency depends on a combination of the inlet ash load and trace element composition, the particle size distribution, ash resistivity as well as local operational issues. The ash resistivity of Orimulsion® flyash is referenced at around 10^9 ohm-cm and considered optimal to achieve high ESP collection efficiency.

From the fuel specifications provided it is anticipated that MSAR ash will be similar to Orimulsion ash and not finer – the ash particle size from optimal liquid fuel firing (complete carbon burnout) is a function of the metals volatizing, then re-condensing in the flue gas and subsequently associating with the PM. The US EPA study[21] undertook such a comparison between HFO and Orimulsion® ash which demonstrates the distinct similarities between the fuels.

In regard to operational issues re-entrainment of dust during rapping cycles is often a recognized concern. ESP operation with Orimulsion® has identified techniques to minimize dust re-entrainment. These techniques include the control of rapping frequency and the electrical amplitude that can allow a thicker ash layer to build on the collection plates; control of the impact of the rapping and the gas velocity all collectively helps minimize dust re-entrainment and the release of fine PM emissions.

It has been noted that the majority of trace elements associate with the particulate matter in the gas stream and increase the probability of capture of these particles by the ESP. The effectiveness of the ESP has been demonstrated for Orimulsion® at numerous power stations around the world and it is not unreasonable to expect similar performance with MSAR®.

Particulate emissions from Orimulsion® measured upstream and downstream of an ESP have demonstrated a high removal efficiency of both PM, nickel and vanadium. Furthermore additional nickel and vanadium are removed in the FGD system resulting in an overall removal efficiency of vanadium and nickel in excess of 99.9% (see table 11.14). The chemical composition of PM measured at the stack show that emitted particulates consist mostly of harmless gypsum carried over in low concentrations from the FGD.

Mass balance	ESP removal efficiency	Overall efficiency (ESP & FGD)
Nickel	98.5%	99.97%
Vanadium	98.3%	99.97%
PM	97.8%	
PM Stack Emission (mg/Nm^3)		**2.5**
Stack PM Composition (%wt.)	$CaSO_4$	92.8%
	V	0.3%
	Ni	0.1%
	Mg	1.6%
	Na	2.7%
	Others	2.6%

Table 11.14 – Measured removal efficiencies of vanadium and nickel at Asnæs (1999) [24]

Particulate emissions from power stations are typically controlled by limiting the emitted concentration at source so as to minimize the ground level ambient concentration of PM. The measured removal efficiency of fine particles from Orimulsion® combustion has been comparable to the overall removal efficiency of the ESP demonstrated in Table 13 discussed earlier.

Organic Trace Elements

Emissions of organic trace elements from burning Orimulsion® have been measured[26] and proven to give:

- Low concentrations of formaldehyde and toluene similar to heavy fuel oil, coal and natural gas.
- Lower concentrations of volatile organic compounds (VOC's) than coal and heavy fuel oil.
- Very low concentrations of dioxins similar to heavy fuel oil and coal.
- Very low concentrations of polycyclic aromatic hydrocarbons below the test detection limit.
- Very low levels of radionuclides similar to heavy fuel oil and an order of magnitude lower than coal.

Ash captured in the ESP from Orimulsion® combustion is typically processed then transported to a facility for the commercial recovery of metals and in particular the vanadium and nickel. This practise is similar to what has been the writer's experience in handling ash collected from burning Orimulsion® and heavy fuel oil.

Orimulsion® reference data shows the ESP control technology *exceeds* the requirement of the EU Directive for PM –30 mg/N^3. If one accepts that MSAR® characteristics will be similar to Orimulsion® behaviour, and there is every reason to draw this conclusion, and references Orimulsion® data as above then one would anticipate that the ESP equipment being installed as part of the modernization of the Elektrenai power station will be equally effective for MSAR® considering it has been appropriately designed and operated.

[26] PDVSA Bitor – Environmental Manual

Question 9

Compare the MSAR™ process to Orimulsion® in the specific application inclusive of carbon intensity.

The writer will concentrate on the carbon in MSAR® and the intensity of carbon to green house gas emissions. The scope of this analysis will not delve into the theory of the complete life cycle analysis or the influence of formation or possible destruction of the ozone layer. In combustion of all fossil fuels nearly all of the carbon is converted to carbon dioxide (CO_2) or to carbon monoxide (CO) if some of the carbon is burned incompletely which is a common combustion control feature. The CO is eventually oxidized to CO_2 downstream in the gas path or in the atmosphere. CO_2 emissions produced from the combustion of fossil fuels make up over half the man-made greenhouse gas emissions and are therefore identified as a major contributor of greenhouse gas.

The emissions of CO_2 from combustion of a fuel are based on the concentration of carbon in the fuel. One can reference the following table to compare the percent of carbon in MSAR® with that in Orimulsion® and HFO specified for the Lietuvos Elektrine power station.

Lithuanian Fuel Specification

Characteristics	MSAR® [27] QFI Expected	MSAR® [25] Delivered	Orimulsion® 400 [28]	Heavy Fuel Oil [25]	Test Method [25]
Carbon %, w/w	**60.3**	**63.0**	**62.5**	**86**	ASTM D- 5291
Sulfur, % w/w	2.0	1.9	2.8	1 - 4	ASTM D-1552
Hydrogen, % w/w	6.6	6.8	7.6	11	ASTM D- 5291
Nitrogen, % w/w	0.6	0.63	0.50	0.4	Chemiluminiscene or ASTM D - 5291
Sodium, % w/w	70	30	10	0 - 30	Atomic absorption / ASTM D - 5863
Vanadium, % w/w	240	176	320	32 - 300	Atomic absorption / ASTM D - 5863
Nickel, % w/w	70	53	70	20 - 50	Atomic absorption / ASTM D - 5863
Ash, % w/w	0.1	0.1	0.1	0.1	ASTM D - 482
Water content, % w/w	31	30	28.6	0.3	ASTM D-4006 / D95
Gross Heating Value, MJ/kg	29.0	30.2	30.1	43	ASTM D-240 / D-4809
Net heating Value, MJ/kg	27.0	28.0	27.8	40	ASTM D-240 / D-4809 Calculated

There are numerous references available on green house gas emissions that compare Orimulsion® to heavy fuel oil (HFO) and other fossil fuels. In this way one can reference data for carbon intensity and CO_2 emissions as a green house gas from Orimulsion® and draw the comparison with what could be the expected CO_2 emissions from MSAR®. The only data available for comparison considers the assessment of the entire life cycle of the process. The life cycle approach is to consider the cumulative impacts of the fossil fuel on the environment to quantify the impacts of the extraction,

[27] QFI

[28] Bitor Orimulsion 400 – general information, referenced test methods not confirmed for HFO

processing, transporting and disposal in effect overall “cradle to grave” approach. The following reference Table 7.2 presents a portion of the data, the CO_2 equivalent as a result of such a life cycle analysis. The table considers a comparison of Orimulsion® with other fuels on the basis that 1 million tonnes of each fuel was fired in a 500 Mw thermal power plant fitted with the full scope of emission abatement equipment and producing an equal amount of electricity - 3.11 TWh annually.[29]

Fuel Characteristics	Units	**ORI®**	**HFO**	**Coal**	**Gas**	**Gas CC**	**LNG CC**
Higher Heating Value	kJ/kg	30,302	41,951	27,785	51,407	51,407	51,407
	Btu/lb	13,027	18,035	11,945	22,100	22,100	22,100
Carbon	% weight	60.1	85.5	66.9	73.9	73.9	73.9
Sulphur	% weight	2.8	3.0	1.0	-	-	-
CO_2 equivalent	mg/kJ	73	75	88	53	53	53
	lb/mmBtu	169	174	205	123	123	123
Generation: 3.11TWh Net	Technology	Thermal	Thermal	Thermal	Thermal	Comb	Comb
Net Heat Rate (HHV	kJ/kWh	9,723	9,723	10,023	10,181	7,280	7,280
	Btu/kWh	9,215	9,215	9,500	9,650	6,900	6,900
Net Efficiency	%	37.0%	37.0%	35.9%	35.4%	49.5%	49.5%
Heat Input	MJ/yr	3.02E+07	3.02E+07	3.12E+07	3.17E+07	2.26E+07	2.26E+07
	mmBtu/yr	2.87E+07	2.87E+07	2.95E+07	3.00E+07	2.15E+07	2.15E+07
Fuel consumption	Million tonnes	1.0	0.7	1.1	0.6	0.4	0.4

Table 7.2 – Assumptions for life cycle GHG emissions

Note: CC = Combined Cycle Gas Turbine

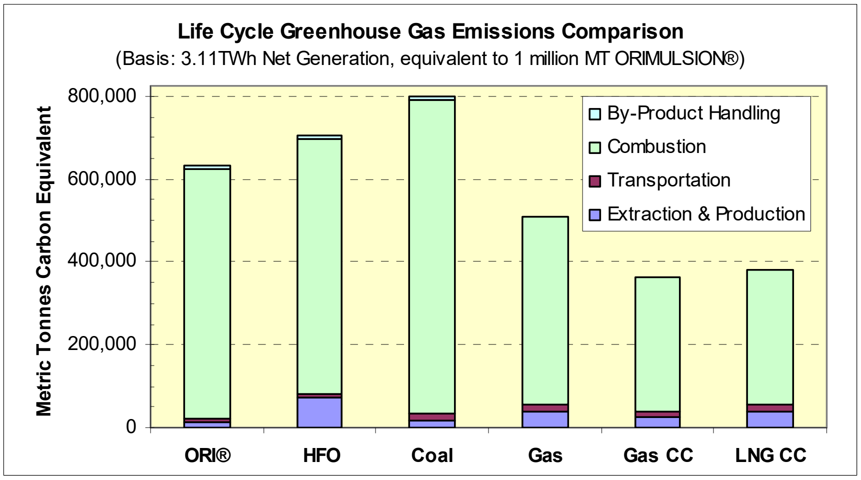
It has been identified that the primary source of greenhouse gas emissions is from the combustion of fossil fuel. A very small percentage is generated in the FGD in the sulphur removal process.

It may be important to note an observed difference, although minor, when comparing life cycle GHG emissions between MSAR® and Orimulsion®. The life cycle analysis considers GHG emissions from activities other than the combustion of the fuels and these activities include resource development, production and transport and are noted to contribute up to 10 % of the total life cycle GHG emissions. The report differentiates the fact that Orimulsion® is derived from the natural bitumen dispersed in water and does not involve substantial amounts of processing. The reports estimate the elimination of the processing for Orimulsion® results in an approximate 4% reduction in GHG emission.

The contributions of these other activities are presented in graphical form below. [30, 31, 32]

[29] Extrapolated from Golder (Kosky), Intevep & PDVSA, June 2000,, Golder & Associates – Life Cycle Analysis
[30] Electricity Association Services Limited, Environmental Briefing, England, March 2000
[31] Golder & Associates , Life Cycle Analysis of Power Plant Greenhouse Gas Emissions, USA 2000
[32] PDVSA Bitor, Environmental Manual, 7. Greenhouse Gas Emissions, CYT-MA-03-001

Figure 7.2 – Comparison of Life Cycle Greenhouse Gas Emissions



Greenhouse Gas Emissions		ORI®	HFO	Coal	Gas	Gas CC	LNG CC
Extraction & Production	TCE	10,870	71,510	17,471	37,998	27,170	37,486
Transportation	TCE	11,566	8,355	17,822	15,847	11,332	16,571
Combustion	TCE	600,488	617,013	754,291	456,038	326,090	326,090
By-Product Handling	TCE	9,597	7,297	11,358	0	0	0
Life Cycle GHG Emissions	TCE	632,522	704,175	800,942	509,883	364,592	380,147

MSAR® is produced from residues at the refinery after processing so it would be reasonable for one to include this additional 4% GHG emissions noted from the processing in any comparison.

Therefore in this respect it may be more reasonable to compare MSAR® with heavy fuel oil and expect life cycle GHG emissions of MSAR® should be similar to life cycle GHG emissions of HFO.

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Question 10

Provide a summary of risk assessment.

As part of an assessment and critical review of the risks associated with the Lietuvos Elektrine power station demonstration project the writer has toured the power station and spoken with their staff; has obtained data including environmental data on the modernization; has reviewed the technology involved and the information that is available on MSAR® and has compared this information with pertinent information available on Orimulsion®. It can be noted the writer is aware the power station has a previous 10 years of successful operating experience on Orimulsion®.

The technical review of MSAR® is based on similarities with Orimulsion® behaviour and has referenced these data. The available data on Orimulsion® consistently states the combustion of Orimulsion® can be adequately controlled using commercially available best control technologies. The technologies being installed as part of the modernization are similar best control technologies used with Orimulsion®.

The writer has noted the project EIA was approved by the regulator and the approved document indicates the modernization project will meet or exceed EU requirements.

On the basis of the risk assessment of the MSAR® technology and one accepts that MSAR® characteristics will be similar to Orimulsion® behaviour, and there is every reason to draw this conclusion, and reference Orimulsion® data then one anticipates if the equipment being installed is appropriately designed and operated then one should not expect any greater risk with the MSAR® technology.

Appendix

John Sturgeon CV

John Sturgeon is a Registered Professional Engineer in Mechanical Engineering with a Bachelor of Science in Mechanical Engineering and over 30 years experience in the electric power utility industry with the operation and design of power stations operating on heavy fuel oil, Orimulsion® and coal. His experience includes project environmental approvals, expertise on selection and use of air emission control technologies, health risk assessments, fuel handling management and expert testimony at public hearings. John's experience specific to the technical due diligence assignment for the Lithuanian project are listed below:

- 1987 - Test of Orimulsion® in a 50 mmBtu/hr pilot scale facility.
- 1988 - First Orimulsion® demonstration project on a commercial size test in a 100 MW unit.
- 1994 - First commercial scale project to convert a 315 MW unit to Orimulsion® including addition of emission control technology, ship offloading and pipeline transport of the emulsion fuel. This project in 1995 was awarded "*Power Plant of the Year*" by *Power Magazine*.
- 1996 - Bitor Orimulsion® technical support speaking at an international conference; met with potential clients about their use of Orimulsion®;
- 2004 - Conversion of 1000 MW heavy fuel oil fired power station to Orimulsion® including addition of emission control equipment, ship offloading and pipeline transport of emulsion fuel; projected was impacted by the decision to end Orimulsion® production.
- For two years has operated his own consulting firm that specializes in emulsion fuels.
- 50 mmBtu/hr demonstration test of emulsified asphalt.