Layman Report

Project LIFE00 ENV/D/000318

Planning and erection of the plant „MRD-Selective-Refining“ for the recovery of used oil

Created by Dipl.Ing. Holger Bretschneider
November 2005
Introduction

"Used doesn't mean waste" – according to this principle the Mineralöl-Raffinerie Dollbergen GmbH (MRD) produces high-quality base oil from used lubricants since 50 years and is the leading European company in this field of business today.

Mineralöl-Raffinerie Dollbergen GmbH, located near Hanover in an area with a distinctly rural character, has been involved in the processing and recycling of used oil and oily liquids since 1955. Beginning with the manufacture of simple dewatering systems for the production of fuel oils, the company soon developed the expertise for continually improving technologies, enabling it to engage in the production of high-quality base oils used in lubricant production.

During this period, processes had to be continually developed so as to keep pace with the ever changing requirements resulting from such interrelated factors as "changes in used oil composition ⇔ recycling processes / technologies ⇔ tougher requirements for base oil qualities".

Today, the refinery has a capacity allowing it to process 230,000 t/a of used oil and oil-containing liquids. 120,000 t/a thereof are used as feedstock for the production of 70,000 t/a of new base oils.

History about the development of MRD’s solvent extraction process

The MRD Solvent Extraction Process is the latest development for refining vacuum distillates from used oils. This process has been developed from a technology which has proven its worth for many years and involves the following process stages:

- dewatering stage (atmospheric distillation for separating water and low-boiling fractions)
- vacuum distillation with production of a gas oil fraction
- gentle flash and thin film evaporation to obtain a vacuum distillate cut constituting the raw base oil fraction
- refining of this cut via clay treatment as well as fractional distillation into several viscosity grades

To improve base oil qualities, a concept for substituting clay treatment with a hydrogenation process representing the state-of-the-art at that time was developed in the '80s. In 1989, the regulatory authorities granted approval for the construction of a hydrogenation plant. Because there were several changes in the composition of shareholders resulting in a reorganisation of the company, construction of the hydrogenation plant was abandoned.
As a consequence of new quality criteria demanded in the market for state-of-the-art lubricants in the middle of the '90s, new studies were initiated with a view to determining an optimum re-refining process. The studies focused, in particular, on such aspects as the future developments to be expected in the composition of used oils and on ways to overcome the negative quality characteristics of the hitherto produced re-raffinates in respect of colour and smell:

- **Extreme increase in the requirements to be met by state-of-the-art motor oils**
  These oils are the most significant, in terms of both quality and quantity, accounting for about 50% of the used oils. Longer oil renewal intervals as well as demands for saving fuel and reducing emissions necessitate the greater use of non-conventional base oils (XHVI, PAO). As these base oils offer significant quality benefits in comparison with conventional base oils (mineral oils), modern technologies must aim to recover these partially and completely synthetic components in the re-raffinates to the greatest possible extent.

- **Longer oil renewal intervals**
  The content of polycyclic aromatic hydrocarbons (PAH) in used oils has increased as a result of the longer oil renewal intervals. Because of the undesirable toxicological characteristics of PAHs, the recovery process must ensure that they will be largely eliminated.

All of these aspects showed that the hydrogenation processes are not optimally suited for satisfying the requirements to be met by a modern processing technology. Extremely severe hydrogenation conditions are required for the quantitative removal of PAHs (OSHA requirement (USA) $T \geq 427 \, ^\circ\mathrm{C}$, $p(H_2) \geq 56 \, \text{bar}$). However, these conditions lead to the cracking and thus destruction of the valuable synthetic base oil fractions (cf. B. Essiger, H. J. Oschmann, S. Brönn, Chem. Technik 47 (1995)). On the other hand, mild hydrogenation conditions will not suffice for eliminating PAHs to a sufficient extent.

In view of this situation, MRD began to develop a new process based on a liquid-liquid extraction technology. In 3 years of research, process parameters appropriate for the extraction of vacuum distillates from used oils were developed, using N-methyl pyrrolidone (NMP), a highly selective solvent for the removal of aromatics and heteroatomic compounds, which is also used in processes for the refining of lubricating oils from crude oil.

The novel process developed by MRD completely satisfies the requirements existing for a modern technology for producing from used oils high-quality base oils, the properties of which in some respects are even superior to those of the classical solvent raffinates produced from petroleum (e.g., viscosity index, low-temperature properties, aromatic hydrocarbon / PAH contents): 

- **Quantitative elimination of polycyclic aromatic hydrocarbons (sum of PAHs according to Grimmer < 1 mg/kg)**
- **High-quality semi-synthetic and fully synthetic base oil fractions such as XHVI oils and PAOs and the associated positive properties are completely retained in the re-raffinate**
- **Customer requirements as regards colour and smell of the products are fulfilled**
- **The process does not produce wastes, because the solvent used is recovered and recycled to the process, while the extracts resulting from the process are used as a fuel oil component**
- **High product yields and excellent product quality ensure high profitability**
- **Process ensures high flexibility, allowing users to respond to changing compositions of used oils and increasing quality requirements to be met by base oils**

Both national and international patents have now been granted for the process.
Technology of the „Enhanced Selective-Refining Plant“

The "Enhanced Selective Refining" process uses the liquid-liquid extraction principle. Vacuum distillates from the flash distillation unit arranged upstream of the "Upgraded Selective Refining Unit" in the lube oil production scheme are used as feed. These distillates are processed in a production cycle which can be adjusted to the quantity to be processed. Before the distillate enters the extraction column proper, any residues of dissolved oxygen contained therein are removed in an absorber using steam. Then the distillate is sent to the bottom part of the extraction column. As the distillate rises, undesirable aromatic hydrocarbons and other contaminants are separated out by the counter-flowing heavier solvent, N-methyl pyrrolidone, which is fed in at the top of the extraction column. The solvent-containing raffinate phase leaves the extraction column at the top and is routed to the downstream raffinate recovery section consisting of a distillation and a stripping column where the solvent is removed. The Kernsolvat® obtained is routed for further disposition to the offplot product tanks.

What is known as the extract phase is continuously withdrawn from the bottom of the extraction column, cooled down to a defined temperature and separated in a separation drum from the separated secondary raffinate. The latter is returned to the extraction column in order to optimise the process yield. The extract phase from the secondary separation drum is sent to the extract recovery section where the solvent is eliminated. The extract recovery section also consists of a distillation and a stripping column. The resulting extract is routed to the offplot intermediate storage tank for use within the refinery as an energy carrier or mixing component for heavy oil.

The dry solvent separated in the distillation columns of the raffinate and extract recovery sections is returned to the solvent tank. The moist solvent separated in the stripping columns of the raffinate and extract recovery sections is returned to the solvent drying column, where excess water is removed. The "dry" solvent which now is free from water is also returned to the solvent tank. From there, the dry solvent can again be used for extraction purposes in the extraction column.
Advantages of the „Enhanced Selective-Refining“ technology

The innovative of this technique is its waste free, environment friendly and resources saving operation. With the successful erection, commissioning and start up of the new demonstration plant the old clay treating process has been replaced. In contrast to the old clay treating process, which required the annual use of 3.500 tons of fresh clay and the disposal of 4.900 tons of used clay, the process of the “Enhanced Selective-Refining” operates completely waste free and odourless at significantly improvement of the base oil qualities. The extract arising during the extraction process is a by-product and can be sold as a heavy fuel oil component or be used within the Mineralöl-Raffinerie Dollbergen as fuel for the steam generation. The average base oil process yield within the “Enhanced Selective-Refining” is about 91 percent. The solvent NMP, which is used in the process is non toxic, soluble in water and biological harmless. Accordingly the solvent can endless and completely recovered and be reused in the process. In comparison to other technologies the extraction process of the “Enhanced Selective-Refining“ does not require renewable helping materials (i.e. catalysts, etc.) but still enables the flexible handling of different feedstock qualities and viscosity levels. The Mineralöl-Raffinerie Dollbergen is middle and long term able to fulfil requirements of the national and international lubricant market by guarantee

- a high viscosity index of the produces base oils as a measure of the lubrication property at different temperature levels,
- a relatively low NOACK-evaporation loss of the base oil as an index for oil losses during its use in different applications,
- a high oxidation stability as an index for the anti-aging resistance caused by thermal treatment or direct light radiation,
- a low content of PNA’s and other aromatics as index for their quantitative elimination from the used oil.
The table shown below indicates the essential quality criterions of a modern base oil and compares these between different technologies.

<table>
<thead>
<tr>
<th>API-Group</th>
<th>Raffinate from Crude SN (Solvent Neutral)</th>
<th>MRD Kernsolvat®</th>
<th>H₂-treated Base Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viscosity Index</td>
<td>O</td>
<td>+ bis ++</td>
<td>O bis +</td>
</tr>
<tr>
<td>Noack</td>
<td>O</td>
<td>+ bis ++</td>
<td>+</td>
</tr>
<tr>
<td>Sulphur</td>
<td>O</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Pourpoint</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Conradson</td>
<td>O</td>
<td>O</td>
<td>+</td>
</tr>
<tr>
<td>Oxidation Stability</td>
<td>O</td>
<td>+</td>
<td>O bis −</td>
</tr>
<tr>
<td>Aromatics</td>
<td>O</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>PNA</td>
<td>O</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td>Neutralisation Number</td>
<td>O</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Demulsification</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Color</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>Odor</td>
<td>O</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

Mineralöl-Raffinerie Dollbergen is successfully recovering high quality base oils from used oil since more than 50 years because base oils can endlessly be recovered. Approximately 70 percent of the collected used oil reflects the base oil which also is containing a significantly amount of synthetic oil components. The production of synthetic oils is extremely raw material (crude oil) and energy intensive. The tendency of the last decades clearly shows, that the amount of synthetic oils within the used oil was continuously increasing.

The technology guarantees the complete preservation of the synthetic oils (XHVI, PAO). With the Kernsolvat® we perspicuously exceed the requirements of the automotive manufacturers regarding quality and occupational health and safety. The positive and qualitatively important characteristics of the proportionately contained synthetic oils are also contained reflected in the Kernsolvat®.
**Project of the „Enhanced Selective-Refining“**

Together with a leading engineering company in the field of refining technology, MRD translated the results of its process development activities into preliminary “basic engineering”, forming an essential basis for all subsequent activities undertaken in preparation for a project for the planning and erection of the "MRD Selective Refining Unit".

Because of the innovative nature of the waste-free, environmentally friendly and resource-saving process, MRD filed an application with the European Union for a grant under the LIFE-Environment programme. The application for a project grant of € 1.55 million was approved by the European Commission in 2001.

Due to lengthy negotiations held during the period from 2001 to April 2003 with the aim of selling MRD to suitable interested parties, the actual implementation of the project was significantly delayed. MRD's project management continuously adjusted its project implementation strategy with the aim of making up for the delays which had occurred since the start of the project on 01.09.2001. The main measures taken in this respect were:

- Determination of the most suitable forms of contract for continuing the detail engineering, procurement and assembly via external support
- Development of a "lean" project organisation structure (laying down the responsibility for project management, project controlling, engineering management as well as the arrangements for the integrated project team including the internal and outside staff needed for project implementation)
- Development of a detailed project implementation schedule
- Determination of an appropriate project cost structure
- Determination of an adequate communication structure
- Determination of the specifications for plant components and shortlisting of potential suppliers
- Execution of special detail engineering works (preparation of material and sealing compatibility reports, expert reports on fire and explosion protection, layout planning, taking into account insurance premium aspects in respect of the integration of the unit in the existing infrastructure of the refinery)
- Well-defined requests for quotations and evaluation of the quotations received with respect to the suitability of the services and supplies offered for the detailed engineering and construction of the unit

It was only when the group of companies at the Dollbergen location was taken over with retroactive effect as of 01.01.2003 by the Mustad International Oil Recycling Group in April 2003 that the path was finally cleared to proceed with the implementation of the project. The Mustad International Oil Recycling Group also has several years' experience in the field of used oil processing and has a share in two other plants in Denmark and Saudi Arabia. By combining the technological know-how of the Mustad Group and MRD in 2003, it was possible to optimise the process concept even further. Accordingly, the project was renamed, the new name being "Enhanced Selective Refining" project. According to MRD's assessments, the overall project would require investments of € 13 million. To obtain the funds needed for financing the project, MRD again filed an application with the government of Lower Saxony in 2003 for subsidies under the "Research and Development Program". The application was approved in 2004, with the government making available subsidies in an amount of € 0.84 million. This was of great help to MRD. Without these subsidies, investments of this magnitude would not be possible for a medium-sized enterprise.

Since the manpower resources of MRD were not sufficient for speedily implementing the project within the period of just 12 months available for planning, building and starting up the unit, support by an outside engineering company with expertise and experience in the field of refinery technology was
Chemieanlagenbau Chemnitz GmbH (CAC), acknowledged as among the best in the business, was the company of choice for tackling this challenge in a partnering relationship with MRD. CAC has 40 years' experience in the field of project execution. In addition to performing the entire detail engineering, CAC was commissioned by MRD to procure all supplies and services needed for the intended plant and to take over site management and to support the construction supervision.

Planning of the plant was carried out by CAC in Chemnitz under the technical and commercial direction of MRD. To ensure that the project objectives would be achieved on schedule and within the fixed budget, a joint project team composed of MRD and CAC staff was formed. Another partner, Prolynx Projektmanagement & Support, was taken under contract to provide project controlling assistance.

Because of the character of a such fast track project and the resulting risk, MRD had exclusively to bear the responsibility. For this purpose MRD was in overall charge of project management. Moreover, all process, owner and maintenance related requirements existing in connection with the planning and construction of the plant had to be duly taken into consideration.

All partners participating in the project had to show a high degree of competence, flexibility and responsibility in handling the engineering, supply and assembly works. This was demonstrated by the overlapping, extremely short project implementation stages for the detail engineering and procurement which were completed after just 6 months as well as by the fact that supply and assembly were completed after only 8 months.

Figure of the fast track project
Since the beginning of assembly works for the "Enhanced Selective Refining Unit", about 1500 cubic metres of earth have been moved and 100 tons of reinforcing bars and 650 cubic metres of concrete used in the construction of the secondary containment structure for the plant. A total of 135 tons of steel elements have been used for erecting the structural steelwork. Next, 88 items of equipment and machines were installed. The total weight of the piping, comprising 325 individual items including brackets, was 89 tons. The electrical as well as the instrumentation and control equipment required for the fully automatic control of the unit (about 520 field devices and 44 drives) had to be installed, wired and tested during winter, making it necessary to take appropriate steps for protecting the equipment from the weather such as enclosing and heating the temporary framework for the unit.

The paint and insulation works carried out during the final stage of assembly overlapped with the commissioning activities started by MRD in March 2005. Mechanical completion of the entire plant took place on 31.03.2005. Throughout the entire construction period, no work accidents occurred although up to 70 fitters had been working at the same time in a constricted area. The external Health and Safety Coordinator who was in charge of safety at the site was full of praise for this fact. It was possible to reduce the impact the works had on the ongoing operations of the existing plant to an absolute minimum.

So far, all project objectives set have been achieved by the integrated MRD/CAC project team thanks to the consistent application of the implementation strategy. Moreover, thanks to the efficient management provided by the MRD project managers, all partner firms involved in the project were able to complete their works in a very high quality on schedule and within budget.

In parallel with the planning and construction of the "Enhanced Selective Refining Plant", the MRD project team successfully completed the infrastructure measures required for tying in the new plant.

Just in time for the 50th anniversary of the foundation of Mineralöl-Raffinerie Dollbergen GmbH (MRD), part of the Mustad International Oil Recycling Group, the new "Enhanced Selective Refining Plant" was mechanically completed at Dollbergen in March 2005. The successful commissioning has opened up a new era for MRD – the era of the "re-refining technology" which allows base oil qualities to be produced for which there is a high demand in the lubricant market. Accordingly MRD is able to continuous its successful strategy in reducing their emissions and wastes for the purpose of the permanent development and improvement of a modern and environmental friendly used oil refinery.