Most paraffinic crude oils contain a significant amount of wax across the entire lube fraction viscosity range. Since the wax in base oil has a high melting point, as temperatures drop, the wax crystallizes and thickens the lubricant until it finally stops flowing. Therefore, dewaxing processes are used during lube refining to remove waxy components from base oils to ensure that lubricants formulated with these base oils will continue to flow at low temperatures. One of the two most common dewaxing processes is solvent dewaxing.

**Solvent dewaxing**

In the solvent dewaxing process, the raffinate (a mixture of base oil and wax) is first diluted with a chilled solvent system using either propane or ketone/toluene.
In both types of systems, the solvent is used to provide favourable conditions for the growth of wax crystals and to dilute the resultant chilled slurry so as to permit continuous oil wax separation using filter equipment. The mixture is further chilled and then enters a rotary drum filter where it is sprayed with more cold solvent and subjected to a vacuum. The wax crystallises and collects on the surface of the rotating drum and is then scraped off as slack wax. The liquid phase, called filtrate, passes through the filter. The solvent is then removed both from the dewaxed filtrate and from the slack wax, which is retained as a valuable byproduct that can be further processed into high margin hard wax.

Due to its complexity, the dewaxing of lubricant base oils is the most difficult and costly process in lube manufacturing. The waxy material in lube oil fractions is macrocrystalline (or simply crystalline) and/or microcrystalline, but under certain conditions may behave like a colloid. When the raffinate with solvent is chilled rapidly with moderate stirring, a wax is precipitated that is often difficult to separate by filtration. The conditions under which the wax crystals are grown are among the most important considerations in the dewaxing process. The size and shape of the crystals are affected by the nature of the paraffinic hydrocarbons in the oil, the nature of the precipitating solvents, the speed of chilling, and the agitation during chilling. While less economical, filtration of the precipitated wax can be facilitated by adding more solvent to the solution or reducing the cooling rate.

Paraffinic hydrocarbons from heavier lube oil fractions tend to form smaller crystals called microcrystalline wax that trap oil in pockets between crystals, to the detriment of achieving a good separation of wax from the filtrate. Thus the cake of the microcrystalline wax contains a relatively high percentage of oil, resulting in lower economic value for the recovered wax. Note, however, that these processes can be considerably improved with the use of an appropriate dewaxing aid.

**Dewaxing aid (wax crystal modifiers)**

A dewaxing aid is a polymeric material that cocrystallises with the wax and helps to develop larger, more uniformly sized wax crystals that enable higher filtration rates due to the improved filtrate separation from the agglomerated crystals. An appropriately selected and applied dewaxing aid thereby provides increased throughput, increased dewaxed oil yield, decreased oil in wax for the slack wax, and a decreased rate of filter blinding.

Two mechanisms have been proposed to explain the observed benefits of dewaxing aid treatment. Both are believed to be operative and depend on the ability of the wax crystal modifier to gain entry to the wax crystal lattice. One mechanism, called nucleation, treats the dewaxing aid as a seed which initiates wax crystal formation. As a seed crystal, the dewaxing aid promotes more controlled crystallisation. The second mechanism, absorption, takes the view that the dewaxing aid adsorbs onto the surface of the growing crystal and alters its subsequent size and shape.

**Figure 1.** Solvent dewaxing by drum filter.

**Figure 2.** Solvent dewaxing by drum filter with VISCOPLEX® DWA.

**Figure 3.** Group I lube refinery process flow diagram.

Solvent dewaxing units (SDUs), are often the bottleneck in base oil refining, but the right additives can prevent this. Evonik Oil Additives’ large portfolio of VISCOPLEX dewaxing aids are based largely on proprietary polyalkyl methacrylate (PAMA) technology, which increases the rate of dewaxing to reduce the percentage of oil in wax, even with difficult stocks. By improving SDU efficiency, VISCOPLEX can reduce refining costs markedly.

A VISCOPLEX dewaxing aid consists of carefully designed long polymer chains with a variety of paraffinic R groups branching off at intervals.

Both the lengths of the alkyl R groups and the intervals between them affect their suitability for particular applications. The paraffinic wax molecules have an affinity for the alkyl R groups and cocrystallise with them as the feedstock/solvent/additive mixture is chilled. Generally, the longer alkyl R groups interact best with longer alkane wax molecules and the shorter alkyl R groups interact best with shorter wax molecules.

Thus the best wax crystal modifier for a particular feedstock will have a range of R groups that correspond well
with the wax molecules in the stock. The wax crystals that grow onto the PAMA polymer are larger and more uniform in size than they would be without it and are unable to agglomerate tightly, which leads to much less oil trapped in the crystal matrix. This means that both the yield of dewaxed oil and the quality of the slack wax produced increase.

Case study
A solvent dewaxing unit has many process variables, including the type of solvent(s), solvent to raffinate ratio, the speed of the filter, cooling temperature, cooling rate, vacuum pressure applied, and of course, the raffinate being dewaxed. Evonik Oil Additives specialists partner with refinery staff to characterise all the relevant processes, identify improvement levers, and set goals together. They take samples of the feedstocks back to Evonik Oil Additives' laboratories and subject them to a number of tests with a variety of VISCOPLEX dewaxing aids, using the refinery's process conditions, to determine the additive that will best enhance a specific plant's dewaxing operation. They then deploy the recommended product in a field trial at the facility itself.

In one instance, a Group I base oil refinery hoped to increase revenues by raising production of bright stock (demand for this product generally outstrips supply), but their SDU was inefficient and limited both the throughput and output of dewaxed base oil. The refinery was seeking a higher yield in less time without significant capital investment, while maintaining the quality specifications, especially the pour points, of the base oils they produced. They asked an Evonik Oil Additives dewaxing specialist to visit the plant and recommend the best solution. The specialist discussed the specific process conditions and variables with engineers and operators and studied the facility. Together, they completed a detailed process questionnaire to have a comprehensive understanding of the refinery's operations.

Using samples of the relevant feedstocks and the processing variables of this refinery's SDU, a series of laboratory and analytical tests were conducted to identify which product in the portfolio of VISCOPLEX dewaxing aids was best suited to this particular plant. After determining that VISCOPLEX 9-321 was the most promising candidate for increasing throughput and yield of dewaxed oil, they proposed a field test.

Specialists worked closely with the refinery staff to develop a rigorous protocol to test the efficacy of VISCOPLEX 9-321 by three different criteria: throughput, yield of dewaxed oil, and the amount of oil in the slack wax extracted. They were determined to conduct the trial with little or no disruption to the plant's demanding production schedule. For these types of site trials, standard practice is to use quarantined feedstock from a single upstream campaign, to obtain the most accurate validation when comparing results with and without the additive. On the first day, the SDU is run without any additive; on the second day, the VISCOPLEX dewaxing aid, or wax crystal modifier, is added at the recommended treat rate, but otherwise the SDU is operated exactly as usual. As the trial proceeds, the percentage of oil in the wax is checked at least once per shift and the treat rate of the dewaxing aid is adjusted as needed, then run steadily to the end of the test, once the best value is found. In this case, the wax crystal modifier was used at a rate of 900 ppm or 0.09%.

The process advantages of VISCOPLEX 9-321 were evident in that it met or exceeded targets set for all three criteria. The production rate of the SDU increased more than 40%, the yield of dewaxed oil went up more than 5%, and the percentage of oil in the slack wax went down 60%. All three measures of the PAMA additive's efficacy produced added value for the plant. The pour point of the dewaxed bright stock remained at the stipulated -3 °C, with or without the use of the dewaxing additive. Before the trial, dewaxing specialists from Evonik Oil Additives came to the refinery and helped set up the necessary dosing equipment in the SDU, remaining available for technical support as needed.

In the final analysis, it was determined that the refinery's margin had expanded by US$ 7 000 000/y with the addition of the VISCOPLEX dewaxing aid.

This case was not unique. In a field trial at another bright stock refinery, the addition of a VISCOPLEX dewaxing aid increased production volume by 14%/y, with dewaxed oil yield rising 16%/y. In an onsite test on a heavy grade oil at this same facility, the throughput of dewaxed oil went up 6%, while yield increased by 17%. While it is difficult to accurately predict the exact benefit of employing VISCOPLEX dewaxing aids at a given refinery, the field tests strongly suggest that, with the proper selection, positive and significant results can be achieved.

Conclusion
Demand for bright stocks and other high quality base oils is likely to keep growing as world population increases and developing countries become increasingly mechanised. Even today, the availability of bright stock is less than demand. As Figure 4 indicates, the value of bright stock varies between two to three times the value of brent crude oil. Carefully selecting the right VISCOPLEX dewaxing aid from the 20 or so offered significantly increases the capacity to convert crude to bright stock. It does so by increasing base oil production capacity, increasing the yield of base oil from feedstock and improving the quality of the separated wax.