Environmentally Acceptable Lubricants: safe or a safety hazard

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Q&A Summary

KD | Kevin Duncan, Croda Europe
PG | Patrick Galda, PANOLIN INTERNATIONAL
RH | Rob Harrison, Shell Marine
VGP will be replaced by VIDA in about 2 years. How will it impact EALs?

PG | The new US law called VIDA (Vessel Incidental Discharge Act) was signed into law by President Trump in early December 2018. In summary: VGP2013 rules, although now under the umbrella of VIDA, remain in force. The new Act does require that new rules cannot be any less stringent than current VGP. The US EPA has been given the task of creating National Standards of Performance (NSPs) and the USCG has been given the task of creating the means to enforce these NSPs. The deadline for this was approx. 4 years (early 2023). We believe that the basis of the work done to specify what EALs are and to categorise their use in 'oil-to-sea' interfaces is not likely to change, but the Creation of NSP's 'for each type of discharge incidental to normal operation' and particularly their enforcement, will lead to greater control and monitoring of vessels' lubrication logbooks.

KD | Not sure at the moment. The UN SDG 14 life below water is all about reducing marine pollution, so there will be a general drive/pressure to make regulations more strict.
Should we only be looking at EALs for stern tubes oils? What other oils should be EALs?

**PG** | US EPA VGP2013 (now VIDA) states that EALs MUST be used for all 'oil-to-sea' applications on a vessel, if entering US Waters - such as: Stern Tubes, Rudders, Fin Stabilisers, Deck Machinery..... where oil, or grease can leak, or get washed, into the sea. Therefore, Stern Lube lubricant, Gear oil, Hydraulic Fluids and Greases should be EAL type when used in these pieces of equipment.

**RH** | EAL's can be used in many applications besides stern tubes. According to the VGP 2013 all oil-sea interfaces (thrusters, stabilisers, wire ropes etc) are required to use EAL's when in US waters. More countries are encouraging this approach, although it's not law as yet. More applications may require EAL's in the future (eg deck equipment).

**KD** | Currently all below deck lubricants should be EAL's going forward. This could include all on-deck lubrication, hydraulics, gears, greases, etc
Are new ships coming up with void seals? Will it not have adverse impact on EALs demand?

PG | There has been an increase in the incorporation of Void Space Seals (also known as Air Seals) on newbuildings, where Capital Expenditure is large and Seal makers offer low pricing to get their products specified on the newbuilds - to claw back money on the spares and service business over the next 20 years of the vessel's operational life. Conversions from 'Standard' lip type seals to Void Space Seal on existing ships tend not to be commercially viable from 'maintenance' budgets. The Void Space Seal requires trained personnel to operate/monitor it. However, an Air Seal may not cope with severe external damage, which could cause loss of mineral oil. Note the EPA statement Updated April 22, 2015 : EPA cannot provide any type approval or "clean" endorsement that an alternative seal system [Void Space seal] would eliminate the discharge. Some vessels now incorporate separate Aft Seal systems with their own small capacity (30~50 litre) header tanks, in case of seal wear or fishing line damage, such that Environmentally Acceptable oil leaks, but not the main volume of mineral oil. Some vessel owners who use Void Space seals and look at risk analysis, opt to have the complete stern tube system converted to EAL to have no concerns about leaking mineral oil into the sea - and benefit from the cleaner, higher thermal resistance offered by PANOLIN saturated synthetic ester technology, maintaining more efficient system operation and long oil life (like you probably use a modern synthetic engine oil in your car!). The selection and use of PANOLIN EALs has been increasing year-on-year.

RH | Initially newbuild vessels had the option, but not many were used. The pay back time is approx 5 years from our calculations.

KD | Possibly but can you guarantee no losses to the sea? If not then you would still need to employ an EAL. Most of the associated issues with EALs are from interaction with water, if water is taken out of the equation then there are still performance benefits from using the right EAL.
Can the panel elaborate on saturated and unsaturated stern tube lubricants.

PG | The difference between a Saturated Synthetic Ester base oil lubricant and an Unsaturated Synthetic Ester is in the molecular (carbon) chain of the oils. The Unaturated ester has a 'double bond' in the carbon chain, whereas the Saturated ester has no double bonds in the molecular chain. The 'double bond' in unsaturated ester is a weakness in the chain that is affected (broken) by temperature and oxygen and can exhibit greater risk of hydrolysis (the breakdown of the ester molecule by water), hence their tendency to turn acidic (higher Total Acid Number). Vegetable oil (Oil seed rape/Canola oil, palm oil, olive oil) are NATURAL unsaturated esters. Synthetic Unsaturated esters are just man-made versions of the same chemical structure as natural unsaturated esters. They do not have the temperature resistance that Saturated Synthetic esters have, so they darken on heating. They also increase in viscosity (thicken) due to contact with the air, which leads to gumming (or varnish), as indicated by the cap of your olive oil bottle sticking (oxidation) and becoming difficult to remove. This is what happens in the stern tube system. These varnish deposits in the pipework system of your stern tube (and other high temperature items of equipment, such as gearboxes and hydraulics) suffer this 'cholesterol' lining, which reduces equipment efficiency, causing sticking of actuator valves etc.

KD | Saturates are more stable against oxidation and therefore should increase the lifetime of the fluid, this needs to be balanced with the fluidity as saturates historically have poor cold temperature properties. New developments in ester technology have changed that.
Are EALs only required in US coastal waters currently? Or other areas? Plans for them to be mandated elsewhere?

PG | The US EPA has mandated that EALs MUST be used in equipment that have oil-to-sea interfaces where the oil can be leaked into the sea. This, in fact, has GLOBAL impact reach, as any vessel leaking oil anywhere in the world greater than normal designed operational leakage to ensure correct seal/equipment operation, must enter this discharge into the Ship's Lubrication Logbook, such that it is visible for the USCG Inspection Teams to determine if the vessel is 'at risk' of causing oil pollution discharge if it intends to enter US Waters. In January 2017 the IMO Polar Code came into force. The Polar Code 'prohibits any discharge of oil or oily mixtures' into Arctic Waters. The Code states for lubricants that vessel Owner 'Consider using non-toxic biodegradable lubricants or water-based systems in lubricated components outside the underwater hull with direct seawater interfaces'.

RH | See line 4.

KD | VGP legislation only covers US waters but most large vessels are global therefore need to have the ability to move in and out of US waters with out restriction.
Is it true that you should go for a higher viscosity when switching from Non EAL to EAL?

PG  | Not entirely - it depends on the age of the vessel and under what DNV GL design Rules the ship was designed. DNV GL has published new ship design guidelines: rule compliance and recommendations (EAL use) - Newbuilds and vessels in service.
To maintain the margins as it would be for mineral oil applications for same installation.......  
- Vessels with applicable DNV GL rules July 2019 or later – Mandatory.  
- Vessels with applicable DNV GL rules older than July 2019 – Not mandatory (but recommended to switch to the next higher viscosity grade above design specification)  
- All vessels – Ensure seal compatibility and carry out proper system monitoring in accordance with oil and seal maker’s recommendations  
  See .. DNV GL article 'Environmentally acceptable lubricants show reduced capabilities under certain conditions' - 11 October 2019, relating to shaft alignment due to slow steaming, heavier propellers and the use of EALs.

RH  | Not necessarily. Depending on the OEM you may have the choice of many viscosity grades. The failures of stern tubes seen are all during sea trials or with single bearing design in bulkers.

KD  | Only on new vessels and only with the consent of the OEM as they will have specified lubricants for a reason.
VGP differentiate between ships less than 79 feet length and longer than 79 feet. Do you need different EALs for these ships?

**PG** | No - the same (high performance = Saturated synthetic ester) EALs are suitable for all classes/sizes of vessels.

However, the US EPA 'Vessels-sVGP' webpage states.... 'The Vessel Incidental Discharge Act (VIDA), enacted on December 4, 2018, repeals the Small Vessel General Permit (sVGP) issued on September 10, 2014 for the control of incidental discharges for vessels less than 79 feet in length (i.e., small vessels). Small vessels and fishing vessels of all sizes are now exempt from permitting under NPDES for all incidental discharges except for ballast water. Small vessels and fishing vessels of any size must follow ballast water discharge requirements established in the EPA 2013 Vessel General Permit (VGP), the U.S. Coast Guard (USCG) ballast water regulations, and any applicable state and local government requirements.'

**RH** | Vessels less than 79 feet do not require EAL's. You may use them and they will be the same products as larger vessels.

**KD** | There is no specific requirement for vessels less than 79 feet to use EALs but it is best practice to use EALs in any application where there is potential for fluid to enter the environment.
What were the stern tube failures that have been mentioned and how were they caused and remedied?

PG | The Stern Tube Bearing failures were overheating and wiping (melting) of (typically) the aft end of the aft stern tube bearing from around the 4 o'clock to the 8 o'clock position. This is indicative of high edge loading - possibly due to shaft bending due to heavy propeller, or Shaft : Bearing misalignment, or high lateral forces due to hard turns on sea trials causing the shaft to operate in the oil lubrication washway areas at the 3 and 9 o'clock positions.. This forms part of the DNV GL investigation into Stern Tube Bearing Failures, that has been widely publicised.

The remedies have been:
- to use a higher viscosity EAL (e.g. using 150 cSt viscosity for the lower performing base oils) in place of the 100 cSt viscosity mineral oil;
- or use a high performance saturated synthetic ester base oil lubricant that has proven to be problem-free such as PANOLIN STELLA MARIS saturated synthetic ester;
- or to complete sea trials with mineral oil and 'bed' the stern tube bearings in using mineral oil and then convert to an EAL that has proven to work.

RH | See line 8. Remedy was to change the lubricant to a mineral oil during sea trials and revert back once Class has signed off.
Thanks for the presentation Rob. You mentioned that all esters are biodegradable. Could you explain a little more there? I thought it was massively dependent on viscosity and molecular weight?

RH | All lubricants are biodegradable, not all are within the required time scale. The most biodegradable are of ester type which are also non-toxic and non-bioaccumulative.

KD | In the current definition of biodegradability, not all lubricants are biodegradable. There are strict guidelines for EALs with respect to specific test protocols that define biodegradability, this is usually a minimum breakdown of 60% within 28 days according to OECD301 or 306.
Secondly, what will happen in VIDA for this differentiation between smaller and larger ships?

PG | The US EPA 'Vessels-sVGP' webpage states... 'The Vessel Incidental Discharge Act (VIDA), enacted on December 4, 2018, repeals the Small Vessel General Permit (sVGP) issued on September 10, 2014 for the control of incidental discharges for vessels less than 79 feet in length (i.e., small vessels). Small vessels and fishing vessels of all sizes are now exempt from permitting under NPDES for all incidental discharges except for ballast water. Small vessels and fishing vessels of any size must follow ballast water discharge requirements established in the EPA 2013 Vessel General Permit (VGP), the U.S. Coast Guard (USCG) ballast water regulations, and any applicable state and local government requirements.'
What is majority of EAL viscosity now? The ISO VG shall be determined by ship design. However, ISO VG 100 has been a majority but, it seems that 150 is becoming more in use.

PG | As far as PANOLIN sales are concerned, the vast majority of vessels filled are using PANOLIN STELLA MARIS 100, for both newbuildings and conversions from mineral oils and 'failed' EALs. Only one vessel has opted for a 150 viscosity for a newbuild - since the advent of the DNV GL recommendations. Some vessels have been filled with PANOLIN STELLA MARIS 68, with no reported problems. It is not known whether these vessels using PANOLIN STELLA MARIS are classed as slow steamers, or have only one aft bearing, or are double slope-bored?

RH | DNV GL recommended a ISO 100 or 150 EAL for all newbuilds as they have revised the vessel design to prevent failures. The most common is still ISO 100.
Can the various types of EALs be interchangeable? i.e. Lack of availability when replenishment / top up of system needed.

PG | It is not advisable to mix any different EALs - certainly if they are of different base oils like Ester and PAO and particularly PAG which does not mix with any other base oil type. This also applies to not mixing different makes of ester-based oils using Natural ester (vegetable), Unsaturated Synthetic ester and Saturated Synthetic ester, as the overall performance of the mixture will be the lowest of the oils' performance characteristics. There is also a certain risk of additive incompatibility.

However, in a dire emergency, synthetic ester types could be mixed, as could (possibly) PAO and ester base oils, but you should contact the oil makers to confirm acceptance of this practice, based on the specific set of 'emergency' circumstances.

The best practice is to keep a couple of drums of the EAL stern tube lubricant you use in the stern tube available on-board (below deck) for top-up, but keep them unopened until needed, or keep them well protected if opened, to prevent dirt and moisture entering the drums.

RH | Lubricant companies spend at lot of time & effort conducting compatibility testing. Please check with your supplier.
What are your thoughts on the DNV GL report which advises a higher grade of viscosity compared to mineral oils

PG | We think that the DNV GL Report into the failures of (some) EALs in stern tubes is a very valuable piece of work, highlighting the effect of higher bearing pressures and higher temperatures on oil viscosity, to respond to and give guidance to, those vessel owners who have suffered by using the low performance base oil stern tube lubricant technologies. But..... NOT ALL EALs ARE THE SAME and, as DNV GL also advises for seal compatibility, liaise with the Oil Makers for recommendations. A stern tube lubricant lubricant, however, does not just 'prove itself' on a V : P characteristic, its thermal stability, oxidation stability (anti-ageing), shear stability and hydrolytic stability - together with the additives selected for the applications - all combine to make a good all-round lubricant for the operational requirements of the stern tube. The use of a higher viscosity base oil may lead to a hotter running stern tube due to 'internal frictional shear' of the oil - particularly if the stern tube bearings are resin bonded in position, causing a thermal insulating jacket around the bearings. This makes the lubricating oil work even harder to carry the heat away from the bearings. This means that a fully saturated ester is the only really sensible stern tube lubricant base oil to use.

As far as PANOLIN sales are concerned, the vast majority of vessels filled are using PANOLIN STELLA MARIS 100, for both newbuildings and conversions from mineral oils and 'failed' EALs.
Can any of the speakers quantify how much of a problem EAL failure really is?

PG | We have been informed that the probable number of stern tube bearing failures on sea trials has been in the low hundreds. There have also been probably double, or treble that number of operational failures of stern tube sealing systems due to seal overheating, incompatibility and water issues such as hydrolysis (increased acidity of the oil) and emulsification (increased viscosity and bacterial growth) of the oil and equipment corrosion issues.

RH | Very very few vessels have suffered issues.

KD | The evidence is limited at the moment.
Can additives help in reducing failure of EALs? If yes, what kind of additives is needed?

**PG** | This cannot be answered in 2 or 3 sentences, so I would appreciate a direct contact of the interrogator.

In general: EAL failure is linked to many phenomena; some of them might be solved by the right choice of EAL base fluid type, some are linked to differences in the base chemistry and cannot be influenced in a positive way by use of additives.

As presented, a good performance is linked to an optimised formulated product - this means: choosing the right base fluid(s) in combination with the best cooperating additives. Most often, it does not help to just add one special additive in case of a failure in order to overcome the failure mode.

**RH** | There will be some lubricants that have Extreme Pressure (EP) additives, although these are not normally required for journal bearings. EP additives are for shock loading.

**KD** | Additives and base oils that promote improved film formation at the interface between the journal and the shaft will help minimise the potential issues.
To Patrick: deterioration of shear stability? Do you mean ester-based EALs are not shear stable? Aren't they monograde lubricants?

PG | No, in my presentation shear instability was clearly linked to PAO. There is a rare base of hydrocarbons which are biodegradable, all of them are of low viscosity. But to formulate an ISO VG 150, it is necessary to add big molecules to thicken the oil. And those big molecules are prone to shear forces; their break-down results in a viscosity loss, sometimes of more than one ISO VG class - with dramatic consequences for fluid film properties and increasing wear or overheating.
What makes a product stable against Hydrolysis?

**PG** | The best way to "stabilise" your lubricant against hydrolysis is: keep the water out - this is true for any lubricant if it is based on mineral oil or on EAL base oil types.

**KD** | Chemical structure and the designing of molecules that are resistant to breakdown from water but which are capable of the minimum biodegradability requirements.
Are EALs recommended only for stern tubes or are there any other applications for EALs on the vessel?

Typical applications that we at PANOLIN supply our EALs for are: Stern Tubes, Tunnel Thrusters, Azimuth Thrusters, Rudders, Steering Gear, Fin Stabilisers, Deck Machinery such as: Davits, Winches, Mooring cables, Pipe and Cable laying equipment, loading ramps, Dredging 'spuds'..... where oil, or grease can leak, or get washed, into the sea. Therefore, PANOLIN 'EAL' Stern Lube lubricant, Gear oil, Hydraulic Fluids and Greases are used in these pieces of equipment.
Are additives used in stern lube products also biodegradable?

PG | Additives are highly specific functional molecules and are used in small amounts. Within additive chemistry biodegradable types are found as well as non-biodegradable ones. The choice of the right additive chemistry is much more related to the performance upgrade such an additive will bring into the product than to its biodegradability.

RH | Additives used in EAL's will also meet the requirements of biodegradation, toxicity and bioaccumulation.
What do you think is the main driving force when choosing an EAL over another EAL?

PG | The main thing to do is simply to select the lubricant base oil (whether it is for a stern tube, or a gear box, or a hydraulic system) that has proven to perform well. You must talk with the oil makers and ask them what their base oil technology is (don’t just accept ‘ester’, as only one of the three ester type base oils has proven to work) and if you are looking for a stern tube lubricant, ask what failures they have had - better if you can be face-to-face with them, or at least screen to screen with them in these Covid times, to watch their eyes and facial movements. Don’t buy the cheapest - you get what you pay for - and you will be spending your money unwisely on a low value-for-money lubricant with a short life expectancy.

KD | I think at the moment cost is probably the main driving force and unfortunately that is probably why there are issues and failures occurring.
Can stern tube lubricants be monitored online for condition by sensors commonly used in automotive use in internal combustion engine sumps?

PG | Up to now, oil condition monitoring in a laboratory provides most detailed analysis about the oil condition. Analysis in the lab is based on a set of different test methods, each test method linked to one single test parameter. Only the assessment of all test parameters will finally give a complete overview about the oil condition.

Online monitoring is mainly based on sensors delivering one measurement variable (e.g. humidity, permittivity or cleanliness) in combination with operating temperature. A change in this single variable might be related to more than one oil parameter. With different parameters influencing the single variable it will be difficult to find out what has caused the change and therefore to suggest the correct action afterwards.

KD | Total acid number could be used as an indicator for hydrolysis but more testing and understanding of the issues before limits can be put in place.
Besides regulations, are there any drivers (performance etc.) for use of EALs?

PG | There are 5 base oil technologies 'typically' accepted as 'generally' meeting the requirements of an EAL. However, most of these 'EALs' and blends of these base oils have had problems in operational service. The main thing to do is simply to select the lubricant base oil (whether it is for a stern tube, or a gear box, or a hydraulic system) that has proven to perform well. The only base oil technology that has the capability to out-perform the others is SATURATED SYNTHETIC ESTER. Most of the 'failed' unsaturated synthetic ester based stern tube lubricants have been converted/upgraded/re-invented/re-launched, now using Saturated Synthetic ester. However, there are many different saturated synthetic ester base oils available, with different thermal and hydrolytic performance - and with different additives - so it is very difficult for a vessel owner/operator/Tech Dept to understand all the 'smoke and mirrors' of what the Salesman is bombarding you with. Seek out those oil makers who can tell you they use saturated synthetic ester for all their EAL products and get to talk with them about why they are different from the rest and what, if any, problems they have had with their lubricants.

RH | Some companies have environmental or sustainability targets to meet. This is the main driver. Performance benefits will depend on each individual EAL.

KD | It is widely known that esters are better lubricants than mineral oil, so at normal running conditions there should be performance improvements when using an ester-based product. The only potential issue is the additive pack used in EALs due to the limitation on biodeg, toxicity etc
VGP 2018 is to be replaced by VIDA.

**PG** | US EPA VIDA (Vessel Incidental Discharge Act) was signed into law by President Trump in early December 2018. The VGP2013 rules, although now under the umbrella of VIDA, remain in force.

**KD** | Yes
How do you respond to OEMs giving technical infeasibility letters. How common are they?

PG | We are in dialogue with many, many, OEMs regarding the conversion of mineral oils they have known, used and loved for a century, to our EALs. There should be no reason for a Technical Infeasibility letter to be provided for a stern tube, or a tunnel thruster, or a rudder/steering gear, or a fin stabiliser, or most deck machinery - there are high performance EALs more than capable of doing the job. The last to fully be happy with the use of EALs in their equipment are the large Azimuth thruster makers. They are still issuing Letters of Technical Infeasibility due to problems with the earlier EAL offerings of lubricant makers that whilst they have 'passed the test specification', they appear to not have had the longevity of performance expected. Another issue has been the unavailability of sealing material upgrade parts - mainly due to the high cost of investment in mould tooling to produce the parts. Whilst production 'cost' is an issue, it is not a Technical Issue, and cannot be the subject of an Infeasibility Letter. However, we fully endorse the supply of Technical Infeasibility Letters - on performance grounds - if the OEM is not 100% confident in the use of an EAL in their equipment - lives are at risk!!

RH | Not very common these days. OEM's have had 7 years to alter the seals in use, check performance via testing to eliminate Technically Infeasibility Letters.

KD | As we have explained there are a lot of different types of EALs, unless the OEM can prove that none of the product classes or variants within them classes work it would be very difficult to claim technically infeasible, also the ship operators want to be more environmentally responsible.
Would VIDA requirements support bio-degradable ester stern-tube lubrication, like Panolin Stella Maris 100?

PG | PANOLIN STELLA MARIS is fully compliant with the requirements of US EPA VGP2013 / VIDA. Statements of compliance with these regulations are available for all PANOLIN GREENMARINE lubricants.
I would like to get recommendations regarding mixture of Bio-degradable synthetic grade of the same ester base but different brands?

**PG** | Generally, it is not advisable to mix any different makes of ester-based oils using Natural ester (vegetable), Unsaturated Synthetic ester and Saturated Synthetic ester, as the overall performance of the mixture will be the lowest of the oils’ performance characteristics. There is also a small chance of additive incompatibility. If you need to top-up with a different oil brand, enquire whether the top-up brand is a (pure) specific base oil type already in the equipment, or if it is a blend of saturated and unsaturated ester. Some ester based lubricants are re-brands of other oil makers' products - ask if their oil is available under a re-branded oil label.
In a DNV newsletter from July 2013, they advised that there should be a means of removing water from EALs to prevent a build up of water, resulting in hydrolysis. Does the panel agree with this?

PG | Yes, definitely! To keep your lubricant 'asset' in top condition, any contaminants such as: dirt, metal wear/corrosion products, sludge and water must be removed - it is just Best Management Practice and good housekeeping. You wouldn't want these contaminants in your car transmission. There are several makers of in-line, or portable oil filtering equipment on the market, but some EALs will separate from water when the stern tube system is not operating and un-agitated, to allow water to be drained of from under the oil in the header tank. However, if you are using an 'emulsifying' stern tube lubricant, then water cannot be easily removed unless the oil is heated, which is not a realistic option. Select a non-emulsifying stern tube lubricant that readily separates from water (there is a recognised ISO test) in less than 30 minutes and most water ingress that would be manageable, maintaining your oil in top condition for optimum longevity.

RH | By removing water you prevent or at lease reduce the onset of hydrolysis resulting in less acidity (which will attack seals) and maintain the lubricants life.

KD | Yes, eliminating water from the lubricant system not only minimises hydrolysis but also reduces the likelyhood of corrosion and bacterial degredation of the lubricant.
What are the market trends for EALs? Are a lot of vessels switching to void seals due to poor performance of EALs since 2013?

PG | Poor operational performance is only occurring with SOME specific, low performance base oil types - NOT ALL EALs GIVE POOR PERFORMANCE. The market for 'the BEST' EALs is growing. They are environmentally compliant and can offer problem-free operation - if looked after properly - and are cost-effective compared with the equipment expense and monitoring/maintenance costs of void space seals. As previously stated for another question on Void space seals above - there has been an increase in the incorporation of Void Space Seals (also known as Air Seals) on newbuildings, where Capital Expenditure is large and Seal makers offer low pricing to get their products specified on the new builds - to claw back money on the spares and service business over the next 20 years of the vessel's operational life. Conversions from 'Standard' lip type seals to Void Space Seal on existing ships tend not to be commercially viable from 'maintenance' budgets. Some vessels now incorporate separate Aft Seal systems with their own small capacity (30~50 litre) header tanks, in case of seal wear or fishing line damage, such that Environmentally Acceptable oil leaks, but not the main volume of mineral oil. This is a very good environmental option to minimise loss of toxic mineral oil, but, this small volume of EAL gets worked hard and is most prone to water ingress, so the thermal and oxidation and hydrolysis resistances of the oil must be top performance. Lower performance EALs have proven to fail after a couple of years in this system. However, some vessel owners who use Void Space seals and look at risk analysis, opt to have the complete stern tube system converted to EAL to have no concerns about leaking mineral oil into the sea - and benefit from the cleaner, higher thermal resistance offered by PANOLIN saturated synthetic ester technology, maintaining more efficient system operation and long oil life. The market for the BEST EALs is growing!
Do you expect VGP/VIDA regulations to be ratified in other geographies in future (Europe, Asia etc.)?

PG | Over the past few years there have been 'writings' of VGP 'type' legislation in Canada and Brazil for the offshore sector in their waters, but these appear to now be how to deal with 'clean-up' after an oil spill, not for the advanced use of environmental lubricants. The Polar Code came close to setting a high environmental 'bar', but failed miserably when stating that Vessel Operators should CONSIDER using biodegradable oils. Currently most initiatives (particularly in Asia) are for control/reduction of air pollution from the marine sector.

KD | Yes, the UN SDG 14 life below water is all about reducing marine pollution.
Any recommendation about the minimum/right viscosity to avoid failures at low speeds/high bearing loads?

PG | This is really a question for the equipment manufacturers, but, YES! - there can be a case made for increasing the viscosity from say 100 to 150 cSt for high pressure applications requiring an EAL, at LOW SPEED, but it depends on the Viscosity Index of the lubricant being used. DNV GL has highlighted the fact that under cold start conditions, for example, a tunnel thruster, a high VI EAL oil has a low viscosity (and proportionally lower oil film thickness) at low ambient temperature compared with mineral oil. With a cold start and to push away hard from the dock to meet the next sailing timetable, the thruster bearing and oil film, are under high pressure. A higher viscosity oil would help here. But, when equipment is up to normal, or sometimes maximum, operating temperature this higher viscosity oil can suffer from higher internal friction/shear which can lead to further equipment overheating and thermal degradation of the oil over time, reducing the life of the lubricant. PANOLIN saturated ester based lubricants have a VI closer to mineral oil, so exhibits a thicker oil film at lower ambient temperatures - and a lower viscosity (less frictional shear temperature generation at higher operating temperatures) than high VI EALs. It is all a thermo-dynamic balance!

RH | This will depend on bearing size, speed etc. Refer to the shipyard’s calculations.

KD | Selecting the correct lubricant with high-film forming properties should reduce the potential for failure.
What would be the criteria to allow/prevent mixture between different brands ester synthetic bio-degradable lubricants for stern tube?

PG | Generally, it is not advisable to mix any different makes of ester-based oils using Natural ester (vegetable), Unsaturated Synthetic ester and Saturated Synthetic ester, as the overall performance of the mixture will be the lowest of the oils' performance characteristics. There is also a small chance of additive incompatibility.

KD | If the lubricant falls into the same ISO class ie HEES then there shouldn't be an issue with compatibility.
When will EAL products be available globally given it is clearly a pressing issue?

PG | Different makes of EALs are 'generally' available in the main bunkering locations around the world - but less so in more remote locations. EALs are not 'commodity' products, available at every port, like mineral oils. The key issue here is ADVANCED PLANNING. Conversions need to be planned, to ensure sufficient volume of EAL is available to flush out the old spent toxic mineral oil (or failed EALs); top-up volumes need to be planned to be kept on board (a couple of additional drums with the first conversion order); oil loss from equipment needs to be monitored and replenishment quantities ordered for collection at the oil makers' strategic stocking centres around the world. PLANNING helps reduce cost of ownership of the lubricants, throughout the life of your vessel.

RH | EAL's are available globally now. Please give an example?

KD | They are already!
Could you give recommendations regarding mixture of Bio-degradable synthetic grade of the same ester base but different brands?

PG | If you need to top-up with a different oil brand, enquire whether the top-up brand is a (pure) specific base oil type already in the equipment, or if it is a blend of saturated and unsaturated ester. Some ester-based lubricants are re-brands of other oil makers' products - ask if their oil is available under a re-branded oil label.
PAO's being non biodegradable, how can be considered as EAL?

PG | You have stated a very good point! Polyalphaolefins (HEPR, otherwise known as PAOs, or Synthetic Hydrocarbons or ‘man-made’ mineral oils), are biodegradable, but ONLY in very low viscosities (5~15 cSt.); any thicker, then it cannot be broken down. Therefore PAOs need to have 'thickeners' to produce a 100 viscosity stern tube oil, or a 150 viscosity gear oil. This is done with the use of Viscosity Improvers (polymers), or to produce an EAL, the PAO is blended with a higher viscosity ester (normally lower cost unsaturated ester) to provide the target blend viscosity. NOTE that PAOs were not included in the EPA list of Biodegradable Base Oils in their Environmentally Acceptable Lubricants document EPA 800-R-11-002 Section 2, of Nov 2011, or in their Presentation “Overview of the Final 2013 VGP“ of Nov 6th 2013. However, PAOs have become 'generally' accepted as an EAL due to their inclusion in the International Standard ISO 15380 (for Hydraulic lubricants, industrial oils and related products) that added HEPR to the other 3 lubricant types (Triglycerides, PAG and Esters), as ISO 15380 is not involved with environmental performance of lubricants, only with technical properties and conversion recommendations from mineral based oils.

RH | Some PAO's are biodegradable.

KD | There is a limit to PAO biodegradability which is linked to viscosity, therefore they have to be supplemented with ester to create a viable product.
**How do EALs compare with mineral oils in price?**

**PG** | Generally, EALs are in the range of 3 to 5 times the price of mineral oils - depending on whether you opt for a low performance oil prone to short operational lubricant life, or a top quality, long life, problem free EAL. The more care you take to look after your oil, the longer it will last..... care meaning.... regular oil sample testing, for the oil maker to advise you of ther condition of your oil and what, if any, actions such as filtering out dirt and water contamination. Regular oil sampling also gives you advanced warning of problems potentially emerging in your machinery. PANOLIN STELLA MARIS can provide long-life performance - as long as the oil is in good condition after 5 years (confirmed on oil sample test), it can be drained from the stern tube, stored in IBCs and after the tailshaft survey and seal condition is confirmed, the STELLA MARIS can be filled back into the stern tube, to continue service. PANOLIN STELLA MARIS is not a 'disposable' product - it is a ASSET, to be looked after, to give best performance, cost-effectiveness and life.

**RH** | This will depend on the lubricants that are being compared. Typically a factor of 1.5 - 3.
How resistant to additive "washout" are EALs should water ingress occur?

**PG** | This is a point which is corresponding to water-soluble or water-miscible systems, only. Pure oil-based systems are not miscible with water. Oil-based products consist of ingredients all soluble in the base oil. So, in case of water ingress, oil soluble ingredients do not solve in water; result: no water wash-out. This is completely different for water-soluble or water miscible systems. Here the ingredients mix with water and therefore are water soluble. In case of continuous water ingress there might be a risk of water wash-out.

**KD** | Most of the additive will be water insoluble therefore it is unlikely.
Is the year of vessel build important for the type of EAL recommended for stern-tube lubrication?

The year of vessel build is somewhat of a guide to the condition of the stern tube - in terms of the condition of the bearings and seals, but more particularly in the state of the stern tube internal surfaces and pipework. If the vessel is 20 years old and has used engine oil in the stern tube all its life it is likely have significant gumming (varnish) in the pipes and a lot of zinc from the engine oil additives and possibly tin from bearing wear, and iron from possible corrosion. A younger vessel using specific stern tube lubricant will exhibit less debris. When preparing for a conversion, we like to see the last oil sample analysis to gauge the degree of cleanliness of the stern tube and its previous history of samples.
According to panel what is considered as the best chemistry for formulating EALs?

**PG** | From PANOLIN perspective, only SATURATED SYNTHETIC ESTER provides the best performance requirements for the Marine (and other industrial) Sector, but it is selecting the right one(s) from the many available, that is important. But the selection of the correct Additives is also vital - whether it is for low friction, sliding for a stern tube bearing/seal system, or for anti-wear and extreme pressure in a thruster gearbox, or for cold temperature additive solubility in a lifeboat davit hydraulic fluid on an Expedition Cruise ship in the Arctic regions. The knowledge gained over the past 35 years of designing and making EALs and experience of our Doctors of Chemistry has given PANOLIN Customers no causes for concern, or complaint for any of PANOLIN's GREENMARINE products.

**KD** | The most widely used are esters, as they give the best lubrication and match the criteria for VGP qualification.
What is the data number of failure of stern tubes due to EAL every year? How could we choose the right EAL to prevent such problem?

PG | We do not know that current level of detail - but I do think that the Classification Societies have some idea, gained from feedback/complaints from their Members about failures of seals that have 'been approved' for use with certain EALs. All we do know is that we are still being approached by vessel owners who have problems after approximately 2~2 1/2 years of stern tube operation with seal issues, and bad smelling sludge (bacterial growth) of competitors' EALs. The right starting point for selection of an EAL is a SATURATED SYNTHETIC ESTER. Contact those oil makers whose lubricants are based on that technology and ask them if they have had any problems with their oils and ask about their vessel filling reference base. However, you also have a responsibility to look after your EAL, with basic good housekeeping with regular oil sample testing.

RH | See line 16

KD | Selection of the correct lubricant will minimise all potential issues.
What is your take on stop leakage additives (e.g Abcon)?

PG | From PANOLIN's point of view - we have had discussions with companies who provide stop leakage additives for stern tubes and we do know that they work, in practice, with our PANOLIN STELLA MARIS. You need to ensure that you get their additive that is EAL (saturated ester) compatible. But - there is always a 'but' - once this additive is used in the stern tube, the additive will retain seawater and bacteria, which, in the long term could lead to hydrolysis of the oil. These products are fine for an emergency situation, and to give time to arrange for a dry docking slot, but after the repair the STELLA MARIS/stop leakage additive would need to be disposed of and replaced with fresh STELLA MARIS. More specific detail/advice should be sought from these stop leakage additive suppliers.
What would be the limitations for seals’ compatibility for the different brands of the same base synthetic biodegradable oils?

PG | There should not be significant differences of seal materials compatibilities with different brands of the same base oil. In the case of esters, this specifically means NATURAL, UNSATURATED and SATURATED esters should be considered as 'different' bases from a compatibility point of view. Additives may also have some small effect on seal compatibility. Note that over the past decade, all seal makers have better understood the differences of the compatibility of EALs with different sealing material polymers, starting with NBR, then moving to FKM, but then finding some incompatibilities and finally introducing BIO FKM seals. Today, most main-stream seal makers use BIO FKM sealing materials.
Where should EALs be made available where they are not currently available?

To ensure best availability of our GREENMARINE products for our Customers, PANOLIN INTERNATIONAL has been in dialogue with our vessel owning customers to understand where they prefer to have their lubricants available from. We have a network of strategic warehouses and Distributing Partners of PANOLIN GREENMARINE lubricants around the world, but if a new location is required, we are prepared to organise for appropriate stock to be made available, to service the demand.
A lot of discussion is about the lubricity of esters being inferior to mineral oils especially at low speeds on plain. Which scientific tools methods are accepted to shed light on such debates?

PG | This can't be answered in a short way. First of all: how do we define "lubricity" of an ester? and is such a definition valid for other base fluids, too?

"Lubricity" of a fluid describes different properties of a fluid in one word: the fluidity of the liquid; the ability to spread on a surface and form a homogenous film on it; the ability to form a film between to metal parts, stable enough to permanently separate them; and, thus, to reduce friction or wear.

So, there are different methods like friction tests, wear tests, tests to check temperature- and pressure-relationships - I therefore refer to the DNV-GL study.

But it is a difficult matter to investigate performance at low speed/high pressure as we then talk about boundary lubrication and non steady-state conditions which are difficult to measure.

RH | Lubricity is not the issue with esters. The issue is the pressure-viscosity coefficient. An ester does not have the same viscosity under pressure compared to a mineral oil when the ISO viscosity grade is the same.

KD | This will depend on the chemical structure, and will be dependent on the film forming properties of the final product. It is not clear that all ester-based products will have the same pressure viscosity coefficient at the same viscosity.
What role do you see oil monitoring/analysis moving forward?

PG  Regular oil monitoring is key to minimising operational problems with machinery, but sometimes this task appears to receive low priority in the operation of a vessel. It is vital to look at trends in oil viscosity, viscosity index, water content, Total Acid Number and dirt/metallic particles. With this data, the health of the oil can be confirmed, or warnings can be given - with some guidance on timescale for action - all to maximise the longest possible lifetime of the oil and the efficiency/operational condition of the equipment. Oil monitoring/analysis has to be capable of being done on the vessel... a) for the vessel's Engineers to take ownership and understanding of the health of their vessel's lubricants and .... b) to cease the posting bottles of oil around the world to Laboratories and speed-up the availability of oil condition data for the Engineers to take decisions on. Analysis equipment makers will have to comment more on the capability/availability of such equipment.

RH  Stern Tubes are required to have Oil Condition Monitoring according to Class rules. Oil analysis will highlight issues before they become a problem, giving time to introduce a corrective action.
How should operators keep the lubricant "dry"?

PG | To keep your lubricant 'asset' in top condition, any contaminants such as: dirt, metal wear/corrosion products, sludge and water must be removed. There are several makers of in-line, or portable oil filtering/drying equipment on the market, but some EALs will separate from water when the stern tube system is not operating and un-agitated, to allow water to be drained off from under the oil in the header tank. However, if you are using an 'emulsifying' stern tube lubricant, then water cannot be easily removed unless the oil is heated, which is not a realistic option. Select a non-emulsifying stern tube lubricant that readily separates from water (there is a recognised ISO test) in less than 30 minutes and most water ingress that would be manageable, maintaining your oil in top condition for optimum longevity. You should contact the Lubricant Drying Equipment companies for more specific advice regarding drying equipment types to suit your specific lubricant type (some EALs cannot be dried), oil volume and amount of water contamination in your system.

RH | For lubricants in drums, correct storage is essential with the correct orientation of the dispensing tap not allowing any moisture to enter the drum. For lubricants in use correct water draining facilities, purifiers or filters are recommended.

KD | I presume this is within the stern tube; it is very difficult due to the design and lubrication of the stern tube and using high quality seals.