

'BACK TO BASICS'

In the third of a 'Back to Basics' series, Martin Williamson of independent oil analysis and machinery lubrication training and consultancy firm Noria UK, looks at the issues of tackling contamination in gearboxes....

Controlling Gearbox Contamination

"Wear and tear" is an expression frequently used to describe the ageing of a mechanical system, though "use and abuse" might be more correct. Wear commonly occurs as a result of the contamination and degradation of the lubricant. The wear rate can be reduced quite dramatically as a result of some basic measures to protect the gearbox from the wear, tear or abuse it generally receives.

Proactive maintenance is a well documented and widely understood concept that has helped a number of plants achieve considerable benefits from their maintenance programmes. This article addresses basic contamination control measures to help the engineer achieve life extension, not just on the gear oil, but also on the equipment itself.

A main point to consider is that gearboxes exist in a variety of formats, but all require lubrication because they all have moving components that transmit power through rotation. This means that contaminants can not only cause a breakdown in the health of the lubricant (and thus a failure in the lubricant's ability to perform efficiently), but will also interact with the moving surfaces to cause wear, leading to component failure. Adhesion, abrasion and corrosion of component surfaces will typically result from oil contamination, as will poorly specified or unhealthy lubricants.

Here are two essential proactive aspects of lubrication management: The oil must be right for the job, and must be free of contaminants. Therefore the oil introduced to a gearbox should be of appropriate quality given the demands of the application, and should be stored properly before dispensing it into the gearbox.

Bear in mind that gearbox design and manufacture has changed significantly in recent years. New surface hardening techniques and metallurgy have enabled the manufacture of smaller gearboxes for a given horsepower rating. However, these changes have resulted in much more aggressive surface loading, and the thickness of super-hard material is often razor-thin. These harder surfaces are more resistant to particle-induced sliding wear, but they are highly susceptible to particle-induced rolling wear, which occurs at the pitch line of the gear tooth where load is transferred.

When a particle is squeezed in the load zone, it can fatigue the hardened material, resulting in spall formation or dent, producing a proud area around the dent's crater. The plastic deformation that occurs where a surface is dented can dramatically alter the material's physical properties, making it more susceptible to wear and fatigue. Making matters worse, new gearbox designs tend to run hot, increasing the risk to the lubricant.

Due to these and other changes in gear design, it is more critical than ever to focus contamination control efforts on gearboxes. No longer can we limit contamination control to hydraulic systems, bearing systems and turbo machinery. Choosing to take charge of gearbox contamination control can result in substantially improved reliability record and reduced maintenance costs.

Identifying the Sources of Contamination

Briefly, contamination is any foreign body or matter that infiltrates the systems and causes harm to the unit, or substantially reduces its effectiveness or adversely affects operation. Common contaminants include hard particles, moisture, high temperature and aeration. Other examples include radiation, or process chemical or physical matter from the environment.

There are several easily identifiable ingress points on a gearbox, namely the seals and the breathers. Other less obvious sources of ingress are the result of maintenance activities, such as top-ups, complete drain and refill, or other intrusive servicing of the unit. Keep in mind that the rate at which contaminants enter the unit will depend to some extent on ambient conditions, the contaminant type and the conditions in which the machine

will operate.

In wet conditions, the likelihood of moisture ingress significantly increases; however, the ingress of hard dust particulate from the environment is reduced accordingly. On the other hand, given a hot, dry and windy day, the risk of moisture ingress is minimised for outdoor equipment, but the risk of ingested hard atmospheric silica-based particulates is greatly increased. Depending on the nature of the organisation, some contaminants may be unique, such as coal dust, iron ore dust, or process chemicals in a petrochemical or paper mill environment. Another contributor to contamination is nearby activity. Consider the risk of cement dust around a construction site, and again the risk will be greater in windy or dry conditions.

Dealing with Sources of Contamination

The following is a bulleted list of items to guide efforts for achieving contamination control in gearboxes. It is always advised to address both contaminant exclusion and removal, paying special attention to exclusion. An old rule of thumb is that it costs ten times as much to remove a particle than it does to exclude it. Experience proves this.

Review this list and talk with the OEM to see if some of the required changes can be engineered into the scope of new gearboxes. For existing gearboxes, the modifications will likely need to be done onsite. Call on experts to help devise the plan and execute the implementation if required. There are tricks to prioritising one's efforts and finding the path of least resistance that can be learned only through experience.

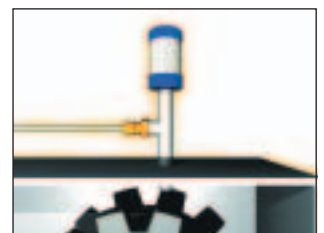
Whether you choose to implement yourself or set up an ongoing improvement program, consider the following:

Seals - Standard lip seals are a low-cost item, but require frequent replacement. Their ability to seal against oil leakage and dirt/water ingress is poor by comparison to labyrinth seals. In addition, double-lip seals will also offer better protection than a single lip seal.

Although labyrinth seals cost more initially, their superior performance will ensure minimal risk from water or dirt ingress, as well as minimising lubricant loss and potential process/environmental problems. Typically, their lifecycle cost is lower. Of course, training the maintenance staff to avoid the use of high-pressure wash-down sprays directly on the seals is necessary. If this cannot be avoided, such as in food and drug related environments, a seal guard can prove beneficial. **(Figure 1)**



Breathers - In many cases, older units still have an open tube (snorkel type) for breathing, although newer units now incorporate a vent plug. When it comes to stopping large bodies (rocks, rags and rodents) from falling into the gearbox, these serve their purpose, but they will not stop a destructive 10µm particle from entering. That would be like a snooker ball rolling through an open doorway.



In most cases, upgrading the vent to a proper contaminant-exclusion breather should minimise the ingestion of hard particles and moisture. There are several ways to achieve this. The first would be to fit a good quality breather, such as a 1µm filter to remove as much of the airborne particulate as possible. In fact, a standard spin-on filter will perform effectively as a breather **(Figure 2)**.

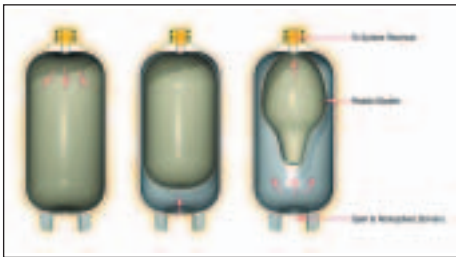
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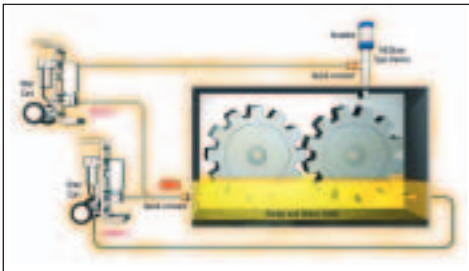
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If in a moist environment, then the use of desiccating breathers is recommended. There are two schools of thought on desiccating breathers. Some believe that the exhausted air should be directed straight to the atmosphere, while others believe the warm, dry air can be used to regenerate the desiccant. However, on gearboxes (as compared to hydraulic reservoirs), there is little airflow through the breather. Their general purpose is to allow for changes in volume as a result of top-ups, leakage and temperature-related volume changes (usually during start-up and shutdown).

For applications where volume changes are minimal, such as in a gearbox, the bladder type (also known as expansion chamber) of breather is an option. This effectively seals the inside of the gearbox from the atmosphere. The bladder allows for expansion and contraction of the air within the casing as a result of temperature changes. These are especially ideal where high levels of particulate or moisture occur in the environment (Figure 3).



Breathers/Filters/Samplers - Where regular sampling or the use of a filter cart is needed, it is useful to combine the functions, particularly where cost and space constraints dictate. It is imperative to make sure the oil is delivered clean to the gearbox. This may mean dispensing through a filter cart (Figure 4) or using a one-shot type sealed lubricant container supplied at a certified level of cleanliness. The fill port must also be clean prior to use. Any type of protection against contamination that can be added to the fill area is beneficial. The use of quick-connect couplings is ideal. Like Minimesm sampling ports, these combination units minimise the risk of ingested contamination. (Figure 5)



Portable Off-line Filtration - While some gear units may incorporate a small pump and perhaps even a filter, many gearbox lubricants are not filtered. Sometimes, it is not possible to make the necessary upgrades or modifications without lengthy downtime.

Filter carts can usually be adapted by replacing the fill and drain plugs with quick-connect fittings. Select filter carts for easy manoeuvrability and that allow for a selection of filter ratings (including small amounts of water removal) within the design constraints of the pump on the unit. It is best to dedicate a cart to one oil type or family of oils to avoid cross-contamination of fluids.

To select the right flow rate, etc., the differential pressure across the filter unit must be within operational allowances, and selecting a lower flow rate pump is advised for higher viscosity gear oils. At least five to seven times the volume of the oil in the system should be passed through the filter cart to ensure adequate clean up. Be sure that all safety considerations have been covered to avoid deadheading of pumps or exploding filter canisters.

Permanent Off-line Filtration - On larger units, or particularly where large volumes of oil and/or high levels of cleanliness must be maintained, a permanent off-line circuit should be employed. An extra benefit of the permanent mount is that it can continue to operate while the gearbox is not in use, although the optimum filtering time is during the higher operating temperatures. It is often a good idea to incorporate a cooling system to reduce the oil temperature and increase the oil's life and improve its performance.



The choice between a portable unit and a permanent mount unit comes down to criticality of production (the need for reliability), safety and severity/penalty of failure. Also, the accessibility of the unit for periodic filtration should weigh in the decision. If these factors are important, then achieving a reasonable life extension within a limited budget is based on contamination improvement. Absolute levels of cleanliness should not be quoted as individual units within the same site; they may have differing needs imposing higher or lower cleanliness limits. However, it is safe to say that in the majority of cases, there are areas for improvement from the typical ISO α /23/20 often seen by the author. The stringent cleanliness levels required by complex hydraulics are not necessary with gearboxes unless circumstances are exceptional, but aiming at a cleanliness target of ISO α /16/13 is reasonable. With improvements to that level, machine life extensions in excess of three times are realistic.

The cleanliness of units at the commissioning stage is crucial to ensuring successful long-term reliability and increased life of the unit. It is not uncommon to find manufacturing debris (casting sand, machining swarf, etc.) present in a new gearbox. At least one OEM states that this is normal, and if the client wishes to have it removed, there is an extra charge. This is unacceptable and as a client, vote with your order book. Unfortunately, reality sometimes means staying with the supplier.

At the very least, the client should ensure that when specifying new units, the best quality breather and seals are fitted as standard. Check that any openings in the casing, etc. are plugged and the shafts and gears are covered with a protective film of grease or oil, which is thoroughly removed before use. Make use of the portable filter cart to flush the gearbox before it is turned. The best way to flush is to use compatible low-viscosity base oil, or a low-viscosity variation of the service oil that can flush through the box ensuring that all the dead zones are cleaned and the filter cart removes any debris dislodged. If you are requesting the OEM to do this before delivery, ensure that the OEM flushes in accordance with the appropriate standards and shows certification or proof of achieving required levels. While these additional specifications may add to the initial purchase cost, the savings incurred in the increased reliability and life of the unit can far outweigh the penalty.

The same stringent flushing techniques should be applied following the intrusive service of a gearbox. Whenever the machine is opened for repair, significant contaminant ingress is a certainty. Flush the box before putting it back into service.

It is a new world for gearbox lubricant maintenance. New gearbox designs cannot operate reliably with contamination. This combined with ever-increasing demand for equipment reliability makes contamination control a new and significant concern for gearbox maintenance. Be sure you are properly protected.

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Martin Williamson is a graduate Mechanical Engineer and has managed an oil analysis programme in a mining environment, more latterly supported oil analysis products in a wide variety of industries, and is currently managing Noria UK Limited, based in Chester. Noria Corp, the parent company, based in Tulsa, OK is an independent body of experts in all matters lubrication. Noria provides training and consultation globally through their offices in the US, Canada and the UK and Middle East, and through their partners in over ten countries. Noria publishes two journals bi-monthly; *Practicing Oil Analysis* and *Machinery Lubrication*, and these are available free on subscription. Their web-site at www.practicingoilanalysis.com is one of the most comprehensive sites for independent lubricant information.



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SWITCHING FROM MONOGRADE TO MULTIGRADE HYDRAULIC FLUID CAN IMPROVE ENERGY EFFICIENCY FOR FUEL AND COST SAVINGS

Many mobile equipment operators in the construction, forestry, mining and transportation industries across the northern United States and Canada continue to change out hydraulic fluids for summer and winter use. However, recent evaluations have shown that switching to a single multigrade fluid for year-round operations can improve fuel efficiency for greater cost savings while maintaining, and even improving, lubrication protection. And some multigrade fluids provide greater savings than others.

Petro-Canada recently participated in a program to determine the impact of hydraulic fluid viscosity on fuel consumption of engines that power hydraulic equipment. The results showed that the proper selection of hydraulic fluid can result in energy savings of five to 15 per cent. This translates into potential fuel cost savings for fleets of thousands of dollars annually.

This article discusses hydraulic fluid performance in low and high temperature conditions and the impact it has on the energy efficiency and performance of hydraulic pumps and motors. It then describes the evaluation undertaken to compare the performance of commonly used summer and winter monograde hydraulic fluids to multigrade hydraulic fluids, and the fuel efficiency results obtained. It concludes with a brief discussion about the differences among multigrade hydraulic fluids.

HIGH AND LOW TEMPERATURE IMPACT ON VISCOSITY

When it comes to hydraulic fluids, overall pump efficiency relies on obtaining the ideal balance between hydro-mechanical efficiency and volumetric efficiency. More simply stated, the viscosity of the hydraulic fluid must be thin enough for the hydraulic pump to start easily, especially at low temperatures, and to prevent it from working too hard (mechanical efficiency), but thick enough to prevent internal pump leakage, loss of pressure and effective lubrication (volumetric efficiency).

Excessive viscosity at low temperatures can result in reduced mechanical efficiency of the hydraulic system and, in more extreme situations, to lubricant starvation and cavitation. During lubrication starvation, the loss of the thin lubricant film protecting parts creates high contact temperature, excessive wear, and ultimately results in pump seizure. Cavitation is created due to excessive pressure drop at the pump inlet. This eventually leads to metal fatigue and spalling, generating abrasive metal particles in the fluid and reducing pump life.

If viscosity is too low when oil temperatures increase, volumetric efficiency drops due to increased internal leakage. Also, if the fluid is too thin, moving parts are not properly protected resulting in metal-to-metal contact, overheating, parts wear and eventual pump seizure.

Thus, if viscosity is either too high or too low, the resulting wear in parts leads to an additional decline in volumetric efficiency. As a result, the hydraulic pump must work harder to produce the required flow to hydraulic actuators. The engine must, therefore, burn more fuel to produce the desired amount of hydraulic work. Higher fuel consumption equals higher costs. It also equals greater carbon dioxide (CO₂) emissions, which are damaging to the environment. An ideal hydraulic fluid self-adjusts to the widest possible changes in temperature, ensuring a smooth startup as well as efficient peak-temperature operation.

Multigrade hydraulic fluids are formulated with high viscosity index base oils and additive packages to do just that - self-adjust to a wider temperature range than monograde hydraulic fluids. The viscosity of a multigrade is lower below 40°C (104°F) than a monograde oil having the same ISO viscosity grade. This means the hydraulic fluid will flow faster in cold temperatures, thus contributing to improved mechanical efficiency. In increasing temperatures, the viscosity of a multigrade fluid decreases less than that of a monograde fluid thus providing the necessary volumetric efficiency at higher temperatures. Hydraulic fluids with very high viscosity index (VHVI) base oils provide the best performance.

ENERGY EFFICIENCY EVALUATION

The hydraulic fluid energy efficiency evaluation in which Petro-Canada participated was based on a Denison T6CM Mobile Vane Pump at 200 bar. This pump is typically found on a wide variety of mobile equipment in the construction, forestry, mining and transportation industries. A range of commonly used monograde hydraulic fluids, including ISO 22, 32, 46 and 68 grades, were compared to Petro-Canada's HYDREX™ XV All Season multigrade hydraulic fluid. For the purposes of this article, we discuss the performance of an ISO 22 monograde (commonly used in winter season conditions) and an ISO 46 monograde (commonly used for summer season conditions). It was necessary to estimate typical average oil temperatures at the pump cartridge under continuous operating conditions for typical mid-size, mid-flow-rate hydraulic pumps during both seasons. This was accomplished by averaging the results of field measurements and incorporating an adjustment for internal heating at the pump itself.

The evaluation showed that 23.8 kW were required to power a hydraulic pump using a winter season ISO 22 hydraulic fluid with a flow rate of 45.3 litres (12 gallons) per minute. This compares to Petro-Canada's HYDREX™ XV, which required 24.2 kW of power with an actual flow rate of 55.3 litres (14.6 gallons) per minute. The data was calculated at an operating oil temperature of 70°C (158°F), a pressure of 200 bar and a speed of 2,000 rpm.

The power needed to drive a hydraulic pump using a summer season ISO 46 hydraulic fluid measured 23.9 kW with a flow rate of 46.2 litres (12.2 gallons) per minute. This compares to Petro-Canada's HYDREX™ XV, which required 23.9 kW of power but with an actual flow rate of 48.4 litres (12.8 gallons) per minute. This data was calculated at an operating oil temperature of 90°C (194°F), a pressure of 200 bar and a speed of 2,000 rpm.

The energy required to deliver the same volume of fluid under a given pressure and pump speed (energy efficiency savings) is calculated using the following formula:

$$\text{Energy}_{(\text{Monograde})} / \text{Energy}_{(\text{Hydrex XV})} = P_{(\text{Monograde})} \times Q_{a(\text{Hydrex XV})} \div [P_{(\text{Hydrex XV})} \times Q_{a(\text{Monograde})}]$$

where P = Power (kW) needed to drive the pump and Q_a = actual flow rate (l/min).

Using this formula with the winter season set above, the energy efficiency savings of the VHVI multigrade (HYDREX™ XV) can be calculated versus the ISO 22 hydraulic fluid.

$$\begin{aligned} \text{Energy Savings} &= (23.8 \times 55.3) \div (24.2 \times 45.3) \\ &= 1,316.14 \div 1,096.26 \\ &= 1.2005728 \\ &= 1.2005728 - 1 \times 100 \\ &= 20.1\% \end{aligned}$$

For the summer season set above, the energy efficiency savings of the VHVI multigrade (HYDREX™ XV) versus the ISO 46 hydraulic fluid is:

$$\begin{aligned} \text{Energy Savings} &= (23.9 \times 48.4) \div (23.9 \times 46.2) \\ &= 1,156.76 \div 1,104.18 \\ &= 1.047619 \\ &= 1.047619 - 1 \times 100 \\ &= 4.8\% \end{aligned}$$

Knowing the energy efficiency savings percentages, the diesel fuel savings that results from switching from an ISO 22 hydraulic fluid in winter and an ISO 46 hydraulic fluid in summer to a VHVI multigrade (HYDREX™ XV) year round can be calculated. Diesel fuel savings are calculated based on litres (gallons) of fuel used for a given amount of work.

Summer: 23.9 kW X 0.048 X 1,000 hours = 1,147.2 kWh X 0.2618 litres of diesel fuel/kWh = 300.3 liters (79.3 gallons) of fuel saved

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Winter: $24.2 \text{ kW} \times 0.201 \times 1,000 \text{ hrs} = 4,864.2 \text{ kWh} \times 0.2618 \text{ litres of diesel fuel/kWh} = 1,273.4 \text{ liters (336.3 gallons) of fuel saved}$

Total = $300.3 + 1,273.4 = 1,573.7 \text{ liters (415.6 gallons) of fuel saved}$

Assuming a diesel fuel cost of \$0.68/litre (US\$1.72/gallon) the cost savings would be: $1,573.7 \text{ litres (415.6 gallons)} \times \$0.68/\text{litre (US\$1.72/gallon)} = \$1,070.12 \text{ per pump (US\$715.00)}$

With a fleet of 100 vehicles (total of 200 pumps) the total cost savings to perform the same amount of work would be: $\$1,070.12 \text{ (US\$715.00) per pump} \times 200 \text{ pumps} = \$214,024 \text{ (US\$143,000) annually.}$

When considering environmental impact, a fleet of 100 vehicles would conserve 314,740 litres (83,123 gallons) of fuel, corresponding to a reduction of approximately 830 metric tonnes (817 tons) of CO₂ emissions.

The result shows that by selecting the proper multigrade hydraulic fluid, an operator can significantly reduce fuel use in hydraulic pump operations, for a given amount of work, thereby reducing operating costs. For the owner of a medium-sized fleet, this can translate into an annual savings of approximately \$214,000 (US\$143,000). For larger fleet operations, the savings are significantly greater.

In preparing to change from monograde hydraulic fluids to a single multigrade fluid, the key factors to examine are maximum operating pressure, minimum and maximum operating temperatures and the viscosity recommendations provided by the pump manufacturer. This will likely include the maximum start-up viscosity under load, the range of optimum operating viscosity, and the minimum and maximum operating viscosity.

The relative performance of available multigrade fluids should be compared before one is selected. All multigrade fluids are not created equal. A VHVI multigrade hydraulic fluid such as Petro-Canada's HYDREX™ XV will not only provide better energy efficiency than leading competitors, it also has additional performance benefits over competitive high viscosity index multigrade hydraulic fluids.

HYDREX™ XV is a very high viscosity index, premium performance, long-life, anti-wear hydraulic fluid, designed for all season use in heavy-duty hydraulic

systems. It starts with the patented HT purity process to produce 99.9 per cent pure, crystal-clear base oil. By removing the impurities that can hinder the performance of conventional oils, and blending in specialty additives, HYDREX™ XV lasts longer than competitive fluids. It allows hydraulic systems to start at temperatures as low as -40°C (-40°F), under no-load conditions.

Petro-Canada's HYDREX™ outperformed the leading North American competitor in two critical performance tests. The ASTM D943 standard test for oxidation stability shows that HYDREX™ XV resists degradation over three times longer than the leading North American competitor, which may mean fewer change-outs and lower maintenance costs. The Vickers 35VQ25 Hydraulic Pump Wear Test demonstrates that HYDREX™ also offers more than double the wear protection compared to the same leading North American competitor. For HYDREX™ XV, this should translate into even greater wear protection and equipment life than other multigrade fluids.

In today's operating environment where maximizing equipment productivity is essential, switching to a multigrade hydraulic fluid is a significant step to reducing costs. Fuel consumption for a given amount of work may be significantly reduced, seasonal oil changes eliminated and maintenance time decreased. At the same time greenhouse emissions can be lowered. Switching to a VHVI premium multigrade fluid can improve equipment protection even further, resulting in even greater cost savings and equipment protection.

By Brenda Jones, Petro-Canada Lubricants, with acknowledgement to RohMax USA, Inc. for research information and consultation.

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PROPOSALS FOR NEW AMENDING REGULATIONS ABOUT THE CLASSIFICATION, PACKAGING AND LABELLING OF CHEMICALS: CHIP 3.1

CONSULTATION DEADLINE 8TH APRIL 2005

This consultative document seeks comments on Regulations proposed by the Health and Safety Commission to amend the Chemicals (Hazard Information and Packaging for Supply) Regulations 2002 (CHIP 3).

The Regulations need to be amended for two reasons. Firstly, the UK's must implement the 29th Adaptation to Technical Progress (ATP) of the European Community's Dangerous Substances Directive as part of our European treaty obligations; and secondly, a number of minor changes to the text are desirable. These are largely editorial and will clarify and correct; they will not alter the existing requirements of CHIP. The new Regulations will be known as the Chemicals (Hazard Information and Packaging for Supply) (Amendment) Regulations 2005 (CHIP 3.1).

The CHIP regulations underpin Great Britain's chemical management framework. CHIP implements the Dangerous Substances Directive, the Dangerous Preparations Directive, and the Directive on Safety Data Sheets. These Directives, through CHIP, place a number of duties on chemical suppliers. They include ensuring that dangerous substances and preparations ("chemicals") are correctly classified (a process which identifies all hazards to human health and/or the environment), labelled accordingly, and safely and appropriately packaged. A further duty requires suppliers who are supplying dangerous chemicals for use at work to provide a safety data sheet.

The changes proposed in this consultation document do not affect these basic duties in anyway. They reflect routine updating of the classification and labelling requirements for dangerous substances based on up to date scientific information, which has been agreed by all Member States. Some existing classifications have been revised and classifications have been agreed for dangerous substances new to the market. The revised classifications may be significant enough to require increased measures to ensure that users are properly protected from the newly recognised dangers. These measures may incur a cost to chemical suppliers and their customers. This consultation document, as well as informing the industry of the proposed changes to the CHIP regulations, also seeks industry's views on the costs of these changes.

The Health and Safety Commission (HSC) has a statutory duty to consult to seek stakeholders' views on proposals. HSC believes that this enables an open and transparent approach to decision-making, which is essential if policies and decisions are to have widespread ownership and reflect needs and aspirations of the people they will affect. The Commission then decides the best way forward based on interpretation and analysis of the results of the exercise.

