The Filter

News from the C.C.JENSEN Group • N°4 • February 2006
Focus on: Power Generation





The well-oiled power plant

Choosing the right lubrication for power-plant applications is no easy task. C.C.JENSEN met Mr. Hans Møller of Elsam (soon Vattenfall Thermal Power), who explained what is involved, and offers some good advice for anyone in charge of managing oil.

For a complex operation like a power plant, choosing the right oil for all the different applications that require lubrication means understanding oil. Choosing the right oil is essential in keeping equipment running efficiently, safely and in compliance with increasingly strict environmental standards. So where do you start to understand oil?

There are the basics – the difference between the organic oils we use for cooking etc. and the mineral oils used as lubricants in a wide range of general applications. And then there are the various synthetic oils, produced from either mineral oil or natural gas, and then modified to suit highly specific purposes.

Hans Møller during the interview

C.C.JENSEN

Welcome to the 4th edition of the international newsletter from C.C. JENSEN A/S. Its purpose is to create a platform to disseminate technical information, provide a regular flow of news and stimulate interaction and debate around the most important issues that currently challenge our sector. If you would like to participate or comment on the current issue please contact us at:

C.C.JENSEN A/S • Løvholmen 13 • DK 5700 Svendborg
Tel. +45 63 21 20 14 • Fax +45 62 22 46 15
E-mail: filter@cjc.dk • www.cjc.dk

Increased productivity: Rely on yourself!

By Ulrich Ritsing
General Sales Manager
C.C.JENSEN A/S

Worldwide the power industry is in the midst of dramatic changes. In some parts of the world the industry is subjected to vast deregulation and new, stronger, more international power generation and distribution companies are founded. In other parts of the world, power companies are struggling just to supply enough power to accommodate their countries expansion and development. Also alternative energy sources such as wind power, solar power, organic diesel fuels, etc see rapid growth rates.

For more than 50 years C.C.JENSEN has supplied oil maintenance equipment for the power industry, starting with Fine Filters for small, diesel driven municipal generators and continuing with the supply of various large units to leading OEMs and power companies all over the world.

Our long and vast experience enables us to understand what proactive maintenance means to you, our customers within the power industry, and we appreciate your need for producing and distributing power efficiently and at the lowest possible cost per MW.

Our engineers know what it takes to make your lubricating, hydraulic and gear systems operate effectively; to extend component and oil life and to improve the overall economy of your equipment. We can offer on-site training, make oil analyses and assist in calculating return on investments.

However, the best you can do is to listen to the advise, read about the technology and then *rely on yourselves* to make the right decisions - because at the end of the day, you know your systems best!

With that in mind, I hope you will enjoy the articles in this 4th issue of The Filter.

The chart on page 3 provides an idea of just how many power plant applications require lubricants – and how each application has its own special characteristics.

Charting the parameters that need to be considered when selecting a lubricant for the different applications in a power plant, can give an idea of the complexity of the matter. In real life, the situation is even more complicated, as the properties of lubricants actually change with use – for example as temperatures begin to rise.

The oil man

You might think that a power plant would have to hire its own oil specialist to keep track of all these factors and make sure that each application is always lubricated just as it should be. That's exactly what the Danish energy giant Elsam did. Chemical engineer Hans Møller has served as an oil expert for 20 years, with seven power plants and 350 wind turbines benefitting from his expertise.

His job is to ensure that the many power plant systems that use oil are working exactly as they should. Trained as a physicist and chemist, Mr Møller was fascinated with an area of science where chemistry and the physics of surfaces overlap. This somewhat arcane field of specialist knowledge is called tribology.

Tribo-what?

Tribology is the study of interacting surfaces in relative motion, where friction and wear are involved. For Hans Møller, understanding friction is essential to understanding lubricants and selecting the right one for the job, as lubricants serve to reduce friction in all these applications. "In every application", Møller explains, "moving surfaces are at risk

of coming into direct contact, and must be kept apart by lubrication." Wear and other damage to components can result any time friction occurs. At a power plant, with its enormous turbines, gears and hydraulic systems, a lubrication failure can not only lower productivity, but even put safe operations at risk.

How to choose the right oil

Hans Møller sees choosing oil for a given application as a matter of three basic steps: study, select and maintain.

The first step is the most difficult, as it requires in-depth understanding of the application in question and the particular tribology involved, as well as knowledge of the specific conditions in which the equipment is operating. Selecting a lubricant involves investigation into the properties of different oils, and maintenance is the crucial science of ensuring that a lubricant performs as it is supposed to.

Step 1: Study

To know what kind of lubricant to choose for a given type of machinery, you first need to understand how the equipment works and exactly what the lubrication is to achieve. This involves understanding the surfaces requiring lubrication and the various forces and pressures involved – where insight into the field of tribology is

indispensable. It also means considering environmental factors such as the consequences of an oil leak and the working conditions, including temperatures and the effects of water and air in the oil.

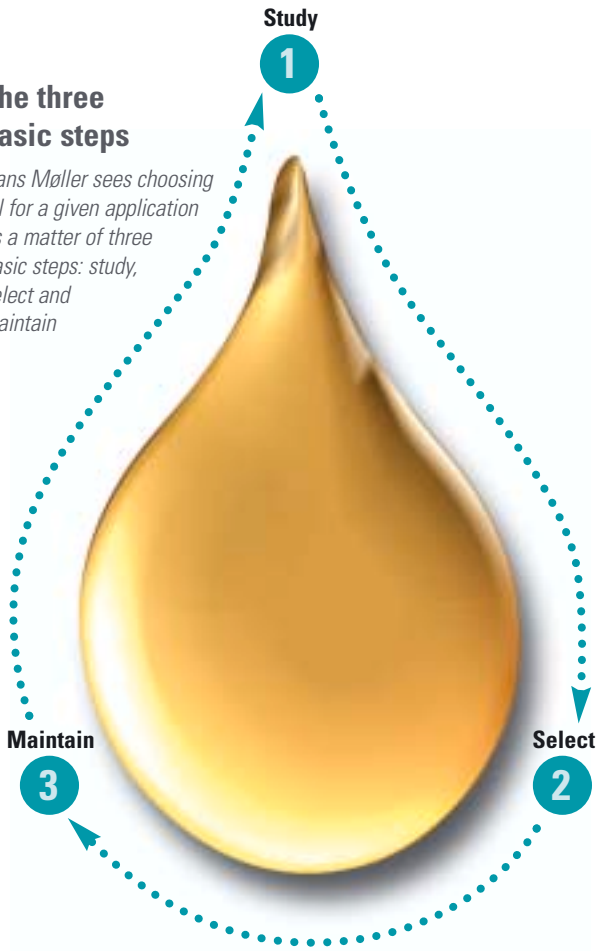
Step 2: Select
Once you have determined exactly what a lubricant must do in a given application, you can then select the best suited lubricant. This requires an understanding of the properties of different lubricants and how these relate to the different aspects of the application. See chart below.

Step 3: Maintain
Finally – and this is a crucial step – all lubricants need to be properly maintained to retain their ability to perform and to keep the application running safely and effectively. Most importantly, oil maintenance is a matter of keeping moisture to a minimum and fighting particles by always using a 3-micron particle filter.

Using the right oil and maintaining it properly is crucial to a power plant today because, ultimately, plants which are not running optimally will not meet today's high standards for safety and environmental protection. Nor will a poorly lubricated power plant be able to supply optimally and reliably – and in today's tough market conditions, plants must deliver. "In the end", says Mr Møller, "oil ignorance is expensive business."

Rely on yourself
"But why do I have to think about all this?" you might ask. "Isn't this what user documentation is for - and don't the oil producers know best what their products should be used for?"

Hans Møller argues that when it comes to choosing lubricants, you can only rely on yourself. Although the equipment manufacturers always recommend that such and such oil should be used for a given product, their focus is primarily on developing and selling new products – and they often lack the expertise in tribology needed to recommend the best lubricant. The oil producers, on the other hand, can describe the oil they produce, but obviously cannot provide information about every possible application, every set of operating conditions and environment in which it might be used. "A power plant can only rely on itself to devote the time and energy needed to really make the right choice", Mr Møller concludes. "And the better the plant understands the ins and outs of lubricants, the better prepared it is to make the right "selection of maintance."



The three basic steps

Hans Møller sees choosing oil for a given application as a matter of three basic steps: study, select and maintain

	Application	Task of the oil	Lubrication	Demands to the oil			
				Viscosity	Oxidation stability	Other demands	Comments
Lube oils	Steam Turbine	1) Lubricate 2) Cool glide bearings in the turbine, generator and feed pumps	Hydrodynamic lubrication	ISO VG 32-68	High	Good demulsification and corrosion protection properties	
	Hydro Turbine	1) Lubricate 2) Cool glide bearings in the turbine	Hydrodynamic lubrication	ISO VG 150-320	High	Good demulsification and corrosion protection properties	Special bio-degradable oils are often used, all though these are less oxidation stable
	Industrial Gas Turbine	1) Lubricate 2) Cool glide bearings in the turbine and the generator	Hydrodynamic lubrication	ISO VG 32-680	Very high	Special GT oils should be used	On aeroderivitive gas turbines special synthetic oil should be chosen
Gear oils	Coal Mill Gearbox	1) Lubricate 2) Avoid metal to metal contact 3) Reduce wear 4) Cool	Hydro elastic and or mixed film lubrication	ISO VG 150-320	Normal	Good anti-wear and scuffing properties Good air release and anti-foam properties	
	Wind Turbine	1) Lubricate 2) Avoid metal to metal contact 3) Reduce wear 4) Cool	Hydro elastic and or mixed film lubrication	ISO VG 320	High	Good anti-wear and scuffing properties Good air release and anti-foam properties	Both mineral and synthetic (Polyalphaoleofins, polyglycols and bio-degradable ester based) oils are used. All have specific advantages and disadvantages
Hydraulic oils	Turbine Governor System	1) Lubricate 2) Avoid metal to metal contact 3) Reduce wear 4) Displace power	Borderline/elasto-hydrodynamic lubrication	ISO VG 32-68	Good	Reduce wearand friction Good filterability also in case of water contamination	As hydraulic oil in steam turbines Phosphate Esters are often used due to their high flame point. This reduces the risk of a serious turbine fire by oil leakage
Transformer oils	Power Transformer	1) Insulate 2) Coolting		Low and stable viscosity index	Good	High break down voltage	
Combustion engine	Diesel Engine	1) Lubricate 2) Separate metal surfaces 3) Reduce wear	Hydro elastic and or mixed film lubrication	SAE 30-40	Good		

Are you prepared to maintain your wind turbines?

As the warranty period for thousands of wind turbines will soon expire, maintenance needs are rising dramatically. C.C.JENSEN met with Carsten Lind Andersen CEO of The Danish Wind Power Academy (DWPA), who is helping wind turbine operators prepare themselves for the future. Their message: ***Don't wait until it's too late.***

Carsten Lind Andersen ready for on-site training in the US

Opposite: Gearbox inspection in Ireland

If you are not seriously considering the maintenance requirements for your wind turbines, there are some good reasons for starting to now.

First, as the use of wind energy becomes more widespread, new wind turbines are being installed at a very fast pace, leading to sharp increases in the need for maintenance staff. Given the complex and highly specialised nature of the technology, qualified maintenance staff are simply not available, meaning that whoever is hired to carry out this work needs to receive training first.

Second, many wind turbines are no longer covered by the manufacturer's warranty, meaning that the operators themselves are choosing to take over maintenance. This places new demands on maintenance know-how, and operators ought to take a serious look at whether they are prepared to meet this challenge.

The Danish Wind Power Academy

Today's need for professional, high-level maintenance training in the wind energy industry was foreseen in the late 1990s, when manufacturers began to provide maintenance checklists with the turbines they delivered. Around this time, the Danish wind turbine manufacturer NEG Micon began to provide field trainers to help train on-site maintenance staff.

In 2004 Carsten Lind Andersen, himself a former field trainer, established the Danish Wind Power Academy (DWPA) to meet this need. The new academy provides technical training solutions for wind-turbine operators and maintenance staff – starting with the specific needs of the individual client.

The DWPA promotes proactive, preventive maintenance – to replace the endless and expensive changing of parts that occurs too often in the industry today.
A typical problem that can be prevented by proactive maintenance is the spreading of dirty gear oil from the gearbox into the system. Insufficiently trained operators often take a "blocked filter" warning as a non-critical indication that the filter should be changed next time the gearbox is serviced. However, a clogged filter can cause a by-pass valve to open, sending dirty oil back into the system. As dirt leads to more wear, this can result in serious problems for the turbine. A thorough understanding of the technology, however, can help maintenance staff take measures to prevent problems from becoming more serious than they need to be.

"Our mission is to ensure that the people who carry out maintenance work learn to see beyond the checklists - that they gain a real understanding of the equipment, so they know what to do to prevent problems from occurring and how to address them

Wind turbine inspection in Ireland

quickly when they do occur", says Carsten Andersen. To maximize relevance and minimize costs, the training is carried out on-site at the customer's premises, focussing on the specific equipment in use on the site.

Running in high gear

The components that are of greatest interest to maintenance staff vary from operator to operator – and depending on the age of the turbine in question. The DWPA is currently seeing a lot of interest in how best to maintain advanced hydraulic pitch systems, lubrication and cooling systems and converter controlled generators, as well as concern about gearbox maintenance in general. And with many wind turbines no longer covered by the manufacturer's warranty, there is good reason for concern.

Carsten Andersen has noticed disturbingly high levels of impurities in these systems at sites around the world. "I've been surprised by this", he says. "Both the operators and the manufacturers really need to understand just how important proper filtering is – without it, the risk of breakdowns and the need for frequent flushing rise dramatically, even in turbines that are only a few years old."

And proper maintenance goes deeper still. The majority of today's wind turbines are supplied with proper filtering equipment, but this needs to be maintained regularly to really add value to the system.

A well-trained maintenance staff pays "off"

Wind turbines are impressive in their ability to generate power with very little human labour involved. The one exception is maintenance – without this critical human involvement, a turbine will eventually grind to a stop. The gearbox is a key component in virtually every wind turbine, and good preventative maintenance should focus on its lubrication and cooling systems, where proper filtering keeps impurities out of the system.

A knowledgeable, well-trained maintenance staff can ensure maximum availability and keep downtime to a minimum, yet maintenance staff are rarely well enough equipped for this job. The DWPA is hard at work to address this problem, providing the training that maintenance staff need to keep the blades turning.

For further information about Danish Wind Power Academy, visit www.danishwpa.com

C.C.JENSEN Inc. wins Clipper Windpower order

Clipper Windpower chooses CJC™ filters for a new generation of its acclaimed Liberty turbines.

By Justin Stover, Sales Engineer

The waiting is over. C.C.JENSEN Inc. has just secured the company's first OEM order for US manufactured wind turbines, and will be supplying an initial 150 CJC™ HDU 15/25 PV off-line filters to Clipper Windpower. The filters will be fitted in Clipper's brand new 2.5 MW Liberty - the fourth generation of this renowned powerhouse of a turbine.

Based in California and listed on the London Stock Exchange, Clipper Windpower is the second largest wind energy company in the US, and has been producing turbines for 20 years.
The company is well known in the industry for its high-quality turbines and technological leadership. The 2.5 MW Liberty is the latest generation of Clipper's flagship commercial turbine.

According to James G. P. Dehlsen, Clipper's Chairman and CEO, every aspect of the Liberty's design has been optimised to deliver more power more cheaper than any other turbine on the market.

Justin Stover, Sales Engineer, C.C.JENSEN Inc.

And if you ask Mr. Dehlsen, it is a market that's heading in the right direction. "As the price of oil and natural gas rise, while supplies keep falling, unlimited, sustainable wind power begins to look even more attractive." He adds:" If we do our job right, we should be able to become a mayor player over the next three to five years."

That's good news indeed for CCJ, which has years of experience supplying filters to the European wind energy industry.

General Sales Manager Ulrich Ritsing, C.C.JENSEN A/S says: "We are worldwide leaders within filtration on wind turbines, however this deal is very important to us as US-based manufacturers now show confidence in our products."

If you are interested in finding out more about C.C.JENSEN, Inc´s services in the US, contact Mr. Justin Stover, justin@ccjensen.com

Oxidation in lubricant base oils

The ageing of the oil

Oxidation is a common problem in many industries. When the oil is being used in a machine, it oxidizes over a period of time depending on the type of oil, the operational conditions and the environment. Oxidation can have negative effects on lubrication and hydraulic system, all of which may have serious consequences for the performance of the machinery. In this article you can read about the problems connected with oxidation.

By Laura Corvinos Ancho, B.Eng. Chemical Engineering, C.C.JENSEN A/S

Deposit formation on key komponent

Oxidation is a complex primary chemical degradation process in the base oil. It can be defined as the chemical breakdown of the base oil molecules with oxygen as reagent where the principle source of oxygen is air.

The following parameters act as a catalyst:

- *Temperature*
- *Wear transition metals (wear particles)*
- *Water (both free and dissolved)*
- *Contaminants (in general and oxidation products)*

This process involves a series of chain reactions producing acid compounds that undergo further reactions forming polymeric compounds, which lead to sludge, lacquer, varnish, i.e. deposit formation.

The anti-oxidant additives, used in most oils, protect the oil from oxidation. They react with the intermediate oxidation compounds (i.e. partly degraded oil) and counteract the acid formation. As the oil oxidizes, the anti-oxidant additives are depleted over time and then the oil is exposed to oxidation. On the other hand, the principle source of oxygen (i.e. the oxygen from the atmosphere) may be inexhaustible.

Oxidation process in lubricant base oils

The base oil consists of a mixture of many different hydrocarbons. The oxidation process occurs when these hydrocarbons react with oxygen. It is a self-propagating process that occurs via free radicals.

Temperature is of great importance in oxidation. At lower temperatures (up to about 150 °C) the pattern of oxidation reactions may differ substantially from those at high temperatures.

In a general case it is assumed that oxidation of oil proceeds in three stages: initiation stage, propagation stage and termination stage.

The following model shows the oxidative degradation in lubricant base oils.

Initiation stage:
The hydrocarbons react with oxygen forming hydrocarbon free radicals. The reaction is catalysed by traces of transition metal ions like copper, iron, cobalt, chromium, etc.

Propagation stage:
The hydrocarbon free radicals react with oxygen forming peroxide radicals, that are highly reactive, and react further with hydrocarbons from the oil. This leads to hydroperoxides and hydrocarbon free radicals, which can react with oxygen.

Termination stage:
The hydroperoxides, formed in the propagation stage, cleave homolytically and form oxygenated compounds like aldehydes, ketones, alcohols and water. These compounds can react further forming organic acids and high molecular weight polymeric products. Further polycondensation and polymerisation of these products lead to insoluble products called sludge, which may precipitate as a thin film forming lacquers or varnish deposits on hot or cold metal surfaces.

Consequences of the oxidative degradation in lubricant base oils

Corrosion and wear
Acid formation will cause corrosion and wear in the internal surfaces of the machine. Water, which is also formed under the oxidation process, increases the corrosive effect of the acids.

Increase in oil viscosity
The oil viscosity increases due to the formation of oxidation products e.g. polymeric compounds and sludge. It will result in friction, wear and loss of energy.

Sludge and varnish
Sludge and varnish can result in valves blocking and orifices clogging. Once varnish deposits are formed on metal surfaces, it is very difficult to dissolve them even at high temperatures. These deposits are like a sticky

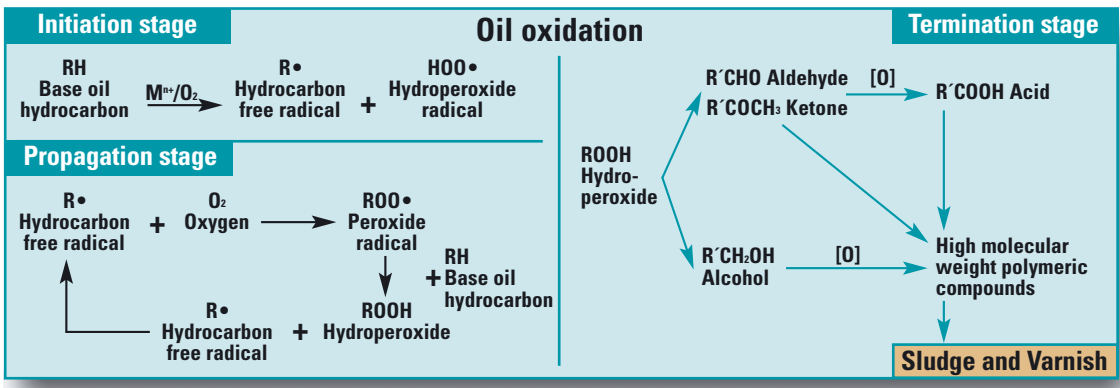


Diagram showing the oxidative degradation in lubricant base oils

References

- "Chemistry and Technology of Lubricants" - R.M. Mortier and S.T. Orszulik - Blackie Academic & Professional
- "Longer life for Hydraulic Fluids" - P.V. Madhavan, Fluid Power Engineering & Technology Guide - Machine design, December 6, 1990

material that will trap hard contaminants creating a "sandpaper surface", which can cause accelerated wear in the components. In addition to this, varnish acts as an insulator, reducing the effect of the heat exchangers which again means higher temperatures and accelerated reaction rates.

Measuring oxidation in lubricant base oils

Oxidation by-products (aka soft particles) are compounds of molecular sizes less than 1 micron, which cannot be measured by conventional particle counting methods.

TAN analysis (total acid number) and viscosity testing can be used as indicators of oxidation but they cannot determine whether or not the oil is oxidized. Dark color, and sour, putrid odor usually indicate oxidation.

There are several methods to monitor oxidation in the oil. Generally, these methods are used to either determine oil degradation products from the oil or the consumption of anti-oxidants in the oil. The latter is used to predict when the onset of oxidation will occur.

The following are examples of methods to monitor the oxidative degradation:

FTIR analysis
(Fourier Transformation Infrared Spectroscopy)
This analysis is based on the principles of molecular spectroscopy. It can verify oxidation in lubricants by identification of functional groups (e.g. ketones, carboxylic acids) in molecules.

QSA
(Quantitative Spectrophotometric Analysis)
The oxidation by-products are isolated from the oil sample and a quantitative spektrophotometric analysis of the isolated contaminants is carried out in order to determine the degree of oxidation.

Ultracentrifuge test
This test uses the gravitatory forces to extract and settle the contaminants of the oil. The sediment is compared with a sedimentation rating system to determine oxidation.

Gravimetric analysis
This analysis examines oxidation by measuring the weight of residual components. The oil sample is treated with the solvents pentane (hexane), toluene and pyridine to determine the oxidation products.

Colorimetric Analysis:
This analysis examines the color of contaminants collected on membrane filters by a colorimetric device.

The following are examples of methods to monitor the consumption of anti-oxidant additives:

FTIR analysis
(Fourier Transformation Infrared Spectroscopy)
This analysis, mentioned above, can monitor the additive depletion.

RULER test
(Remaining Useful Life Evaluation Routine)
It measures the remaining anti-oxidants by voltametric analysis.

RBOT test
(Rotating Bomb Oxidation Test)
It measures the oil´s resistence to oxidation under prescribed conditions.

Removal of oxidation products using filtration systems

The key to prevent oil degradation is to remove the oxidation by-products before they can react further and form insoluble slugde and varnish deposits. These compounds are very difficult to remove by the conventional mechanical filters because we are dealing with submicron particles with a high level of solubility in hydrocarbons.

Electrostatic filters and cellulose filters can remove oxidation products, because oxidation compounds are polar - i.e. have electrically positive and negative poles.

The electrostatic filters remove the oil contaminants using the principles of electrostatic and electromagnetism. The cellulose filters, on the other hand, utilize the characteristic that the cellulose material is also polar. The oil degradation products are attracted and retained by the poles of the cellulose fibers.

Oxidation is a common problem in many industries

Adsorption of oxidation by-products in the CJC™ Fine Filter: Resin in the oil attracts to the polar fibres in the filter mass and are retained

• "Using Oil Analysis to Control Varnish and Sludge" http://www.noria.com/learning_center/category_article.asp?articleid=59
• "New Varnish Test Improves Predictive Maintenance Program" http://www.practicingoilanalysis.com/article_detail.asp?articleid=761&relatedbookgroup=OilAnalysis

Reducing failures caused in transformers

This article is the first of two focussing on transformers. This one gives you an introduction to the mechanisms that cause failures in a transformer and how preventive maintenance can prolong the lifetime of the insulation paper dramatically.

By Ulrikke Brandt Bertelsen

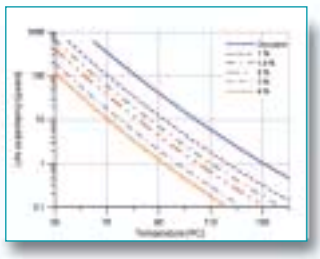


Chart 1: *Life expectancy can be calculated from water content and temparature*

Maintenance needs to be a priority

Without electricity supply, no factory, office or household can operate. Our production, information and recreational platforms are all 100% dependent on a constant supply of good quality power.

Power suppliers have changed. Towards the end of the last millennium they were a source of growth, but they are now at a point where they are largely privatised and debt-burdened giants, operating with short-term financial goals. Amongst other things, this has led to a cut in budgets for maintenance and emergency backup equipment which, in turn, has resulted in reduced power supply stability.

In this article, we will be looking at some of the problems that cause transformer failures - particularly when maintenance is not taken seriously.

Insulation lifetime

A transformer's lifetime is equal to the lifetime of its cellulose insulation. Cellulose (paper) insulation is a key component of any transformer. When insulation loses the mechanical strength to withstand a short circuit, the transformer is likely to fail. Therefore, a key responsibility of maintenance engineers is to ensure minimum wear and tear of a transformer's paper insulation. Electricity companies have to be able to deliver power at any time and, with the introduction of the open electricity market, at a competitive price. With the resulting higher loads and more frequent load changes, there tends to be increased stress on all the mechanical and electrical equipment involved in generating and distributing power.

Transformers, which are some of the most expensive pieces of equipment in the power supply chain, are particularly sensitive to increased load. By optimising maintenance and general operating conditions of transformers, significant savings can be achieved

Oil and paper quality

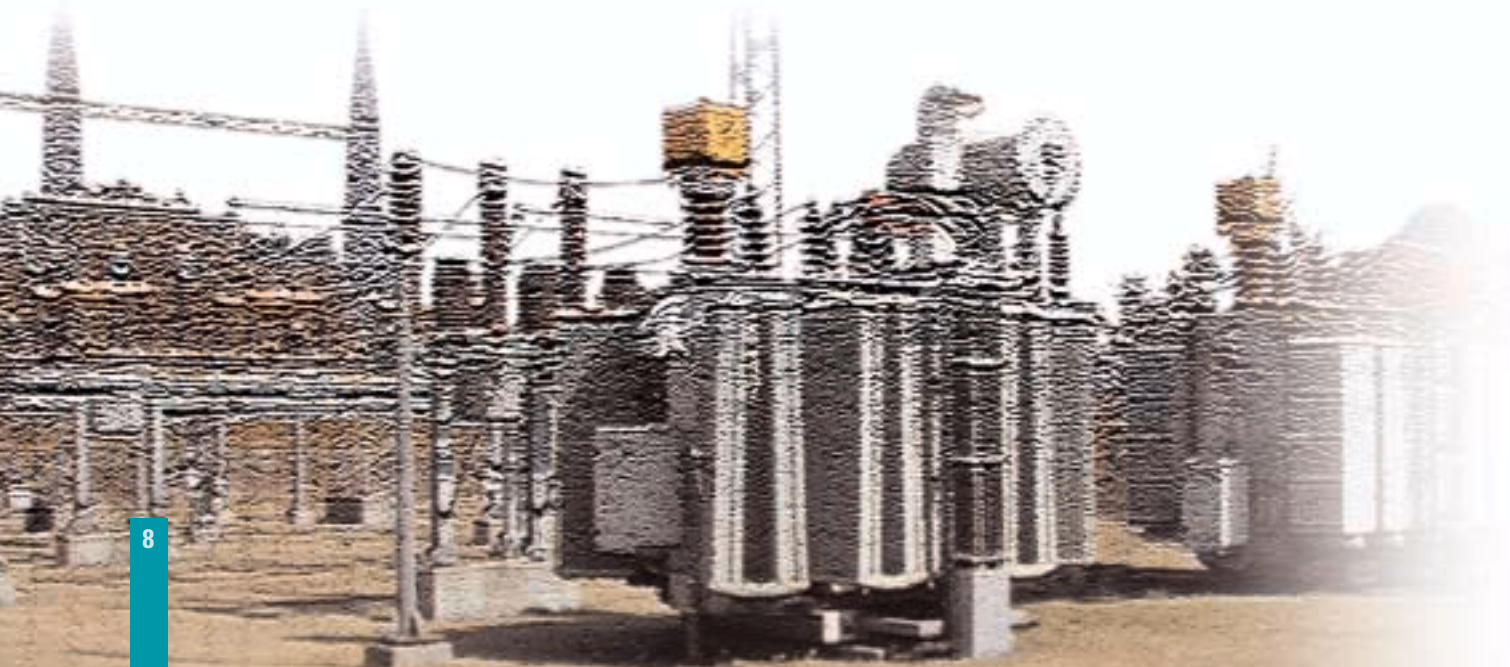
The cellulose-based Kraft paper used as the insulation material is, in most cases, submerged in the oil which is used for the cooling and insulation of a transformer. Consequently, it is not only inaccessible but also directly exposed to any chemical reactions that take place in the oil. The obvious way to avoid degradation of the cellulose is to maintain the oil.

The ageing of cellulose is governed by four main factors:

- Transformer temperature
- The presence of oxygen
- The presence of water
- The presence of acids

Since a transformer's temperature is only partially controllable, transformer maintenance should concentrate on internal chemical reactions.

Oxygen promotes the oxidation of both oil and paper. By-products of the oxidation process are water and acid, which again tend to accelerate the degradation of the cellulose. This degradation



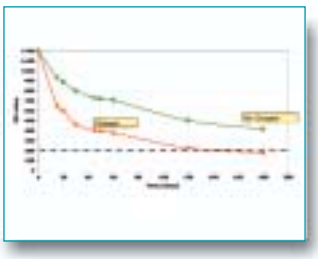


Chart 2: *Lowering the oxygen concentration slows down oxidation*

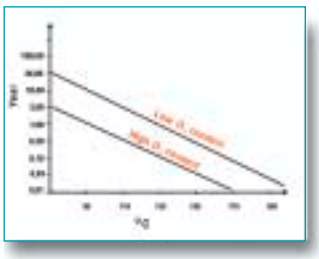


Chart 3: *Oxygen - affecting transformer life length*

needs to be delayed in order to slow down the overall ageing process. The process can not be stopped completely, however, as oxygen is present in the paper molecules themselves. The result is that the paper loses its mechanical strength and becomes porous.

To reduce and slow down degradation of the insulation paper it is vitally important that maintenance engineers delay the final stage of the process as long as possible.

Beware the catalysts

The presence of catalysts in transformer oil kicks off a cycle where paper fibres are weakened by the depolymerisation of the cellulose caused by the ageing process.

The Catalysts are:

- Water
- Copper
- Oxygen

The lower the content of these compounds the less one has to do to slow down their formation. So, if the maintenance programme is able to minimise the compounds in the transformer, the ageing process will significantly slow down to a virtual standstill and the life expectancy as well as the "supply security" of the power supply will increase dramatically.

The catalysts have to be removed from the paper as well as from the oil.

There is a balance between paper and oil: if water is eliminated from the oil, it will start to diffuse from the wet paper into the oil. If this slow process continues, both the paper and the oil will eventually be dry.
Only 0.6 % of the water present in a power transformer is in the oil; the rest lies in the cellulose insulation, which very often contains more than 3 % water. Chart 1 shows that, by eliminating this water, the fibres' life expectancy will increase more than tenfold.

Chart 2 shows the speed of depolymerisation of cellulose when held at constant temperature with or without the presence of oxygen.

The graph indicates that by reducing the oxygen level in the transformer oil to a minimum, the oxygen level in the transformer oil, the mechanical life of the cellulose fibres will be prolonged by a factor of more than 4.5.

Chart 3 indicates that this is the case for all temperature levels from 90° to 170° C.

Bottom line, longer life

In conclusion, limiting the presence of both oxygen and water in a transformer's paper insulation surroundings dramatically improves the mechanical life of the paper, and consequently of the transformer. Not only will power failures be reduced, but power companies' revenues will be improved.

acciona

The C.C.JENSEN "Hands Free" symbol

Ever considered outsourcing your oil maintenance?

C.C.JENSEN Iberica, has recently installed 340 CJC™ Off-line Fine Filters and at the same time signed a new proactive service package deal with Acciona Energía, the world's 2nd largest wind farm developer.

By Thomas Kaare Jensen, Sales Manager C.C.JENSEN Iberica

During 2005 Acciona Energía's (AE) large wind farms in Galicia (Northwest Spain) has installed 340 CJC™ Off-line Fine Filters to reduce wear & tear on the NM750 turbine gearboxes.

"Simultaneously a service package is added to the contract," which signaled the start of an exciting new phase for C.C.JENSEN Iberica, as we launched Hands Free – a innovative, cost-effective oil maintenance service.

The Hands Free agreement is a fully integrated service that includes:

- Automatic yearly replacement of filters
- Oil analyses yearly
- On-line access to the results
- The possibility for AE to create own statistics and predictive diagnoses

Additionally, C.C.JENSEN Iberica offers interpretation of results by an independent laboratory and specific recommendations on how to handle problems related to oil cleanliness.

Hands Free takes a big weight off AE's shoulders: C.C.JENSEN Iberica assumes responsibility for monitoring oil contamination levels and for reminding AE when oil filters need to be checked to secure excellent lubrication conditions with clean oil according to the ISO 17/15/12 level. The highly competitive pricing makes this integrated maintenance solution very economical, generating significant savings for AE.

Less obvious but equally important benefits include lower oil consumption, minimal wear and tear on mechanical components and parts, reduced down-time and improved knowledge about lubrication systems in general.
Since AE's turbines are located all over Spain, the success of this project will rely heavily on continued, excellent cooperation between AE's on-site maintenance staff and C.C.JENSEN´s own service team. To ensure success for the program C.C.JENSEN offers a special training of the maintenance staff, including different practical oil care issues.

Fermin Gil, Acciona Energía (O&M dept) says: "We are very excited about this new agreement. It is a good example of how innovative initiatives with proactive maintenance can create cost-effective solutions."

If you are interested in finding out more about C.C.JENSEN's Hands Free service and outsourcing your oil filter maintenance, contact: Mr. Thomas Jensen, tkj.es@cjc.dk

Thomas K. Jensen at Alabe-Nordés in Galicia, Spain

How dissolved gas analysis (DGA) can determine the age of cellulose

This article is the second of two focussing on transformers where we introduce the DGA to you - a very useful but still not very common tool to determine cellulose breakdown in a transformer.

By Lars Arvidsson, Västerås Petroleumkemi

The formation of cellulose is fundamental to modern life. The manufacture of paper, for example, is a major industry worldwide, and our exploitation of coal and oil is really only another use of this important natural polymer as it has been deposited over millions of years.
Cellulose is produced by trees. They absorb water through their roots and carbon dioxide through their leaves and the wonderful chemical substance known as chlorophyll combines the two. This process can be represented by the following formula:

$6\ CO_2 + 5\ H_2O \Rightarrow C_6H_{10}O_5$ *(= cellulose monomer molecule)* $+ 6O_2$

Thanks to this natural process, a growing tree produces substantial amounts of oxygen - without which we could not survive.

When we burn – or "oxidize" – wood, the opposite reaction takes place, and water and carbon dioxide are formed:

$C_6H_{10}O_5 + 6O_2 \Rightarrow 6\ CO_2 + 5\ H_2O$

This is the reason why more than 99% of the water found in a transformer is generated inside it – the water is formed by decomposing cellulose.

How long does paper last?

The Bible scrolls found at Wadi Qumran by the Dead Sea clearly demonstrate that paper can last a very long time under the right conditions. In this case, a constant temperature and very low humidity prevented biodegradation from occurring.

In transformers, biodegradation is not possible, as the environment is far too harsh for any living matter to survive.
Only chemical degradation occurs, and this under the influence of strong electrical fields that induce reactions.

Parameters of interest are:
- Oxygen access
- Conductor & oil temperatures
- Electrical field strength
- Sulphur access

When cellulose is exposed to heat and no oxygen is present (pyrolysis), it will degrade and form gases:

Low temperature:
$C_6H_{10}O_5 \Rightarrow 3\ CO + 2\ CH_4 + CO_2 + H_2$ *(>200° Celsius)*

Higher temperature:
$C_6H_{10}O_5 \Rightarrow 4\ CO + 2\ CH_4 + H_2$ *(>350° Celsius)*

Very high temperature:
$C_6H_{10}O_5 \Rightarrow 6\ C + 5\ H_2O$ *(>700° Celsius)*

Complete carbonization is often observed for paper located at a fault.

In the presence of water:
$C_6H_{10}O_5 + H_2O \Rightarrow 2\ CO + 2\ CH_4 + 2\ CO_2 + 2\ H_2$

In transformers, temperatures are low during the ageing processes, and only a fraction of the degradation actually generates to its final products (water and carbon dioxide).

The remaining is "trapped" in a long chain of degradation reaction involving, for example, furans which are often analysed but provide very little useful information.

The situation

In insulation cellulose, water is also present, and oxygen is present and continually accessed via the oil.

When there is a fault in the transformer, heat is generated and will start cracking the insulating oil. Gases such as methane, ethane, ethylene, acetylene and many others are formed. This is why methane cannot be used as type gas for detecting paper degradation. Hydrogen is formed in partial discharges and thus cannot be used either.

Carbon dioxide is formed when oil is oxidized, but oil is much less readily oxidized than cellulose is, and can therefore only be used with caution.

Carbon monoxide is the best gas to look for, and if the evaluation is combined with high-quality analyses of insulating oil, it will clearly reveal any problems.

Chemical Formula Directionary

CO = Carbon monoxide
CH_4= Methane
CO_2= Carbon dioxide
H_2 = Hydrogen
C = Carbon
H_2O= Water

Old bibles clearly demonstrate that paper can last a very long time under the right conditions

From theory to practice
The following is an example of how DGA was used to determine the age of the cellulose paper in a transformer.

Transformer data:
Power rating: 40 MV A
Voltage 135/12 kV
Manufactured: 1983
Age: 16 years
Open Breathing
Cooling OFAF
Oil type: Medium refined naphthenic

First an oil sample was drawn from the oil surrounding the cellulose.

The gas analysis showed content of 380 ppm CO and 10250 CO_2 in the oil. Furthermore the Total Acid Number was measured to 0.11 mg KOH/g oil.

The conclusion is that the type of oil used did not have a high intrinsic tendency to form gases in ageing. Consequently, the gases must come from cellulose. The content was very high, and we could assume that the gases had been formed by decomposing cellulose. Therefore a sample of the paper quality was made. When the paper sample arrived, it was determined that the transformer was at the end of its life – only after 16 years.

The reason for this very fast rate of degradation was poor (open) transformer design that allowed oxygen to enter and cause cellulose degradation, combined with pulsating overload.

Conclusions from case study
Dissolved Gas Analysis (DGA) is a very useful for determining cellulose breakdown, as it provides a direct indication of whether hot surfaces exist in the system.
These hot surfaces will crack the oil and form gases, the amount and type of which will reveal the size and temperature of the fault. DGA can be used whenever you suspect there is a fault that can be easily verified, and companies run the analysis as often as once every three months.

Although a DGA can be a very useful tool, more accurate assessments also require an oil analysis. To make it easier to detect cellulose breakdown, use of oil with low intrinsic gas formation is recommended. Always keep oxygen levels as low as possible to keep the cellulose in good condition.

A DGA can also be recommended for all other systems in which oil might be exposed to thermal stresses, such as transformers, tap changers, breakers and hydraulic and lubrication systems.

If you are interested in knowing more about DGA, contact Lars Arvidsson at www.petroleumkemi.se

Saving energy when frying the potatoes!

When McCain Foods Holland had trouble with their fryers, they called C.C.JENSEN to bail them out. 800 kg of sludge and a new filter system later, McCain was back producing high quality potato chips and saving money at the same time.

By Ivan Partono, Sales Engineer, C.C.JENSEN (Netherland) A/S

When the chips hit the fan
To manufacture premium potato chips, you need a lot of oil in a really big pan – and a huge cooker. McCain Foods Holland uses two thermal-fluid heaters in a closed-loop, low-pressure system to transfer heat to their fryers.

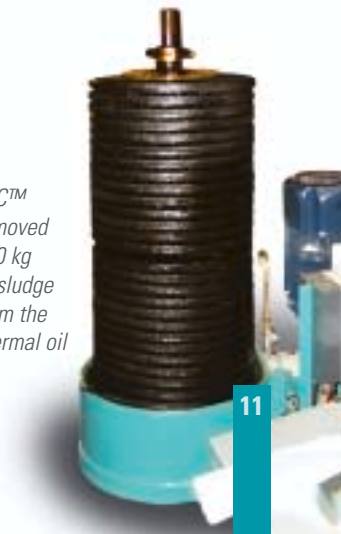
After years of service, the thermal oil had become heavily contaminated, causing increased energy consumption and temperature fluctuations.
To make matters worse, a build up of particles, carbon deposits, sludge and water coated the inside of the heater, leaving McCain Foods with longer heat-up time and lower production rates.

C.C.JENSEN NL was brought in to clean up. Within hours, the first set of filter inserts was saturated – pulling out more than 100 kg of contaminants. After the third set, the thermal oil began to retain the physical properties required and was visibly cleaner. In all, it took seven sets of filters to remove the 800 kg of contaminants and bring the oil back to an acceptable state.

Cleaner, cheaper potato chip production
The new filter does more than just keep the oil clean. As McCain Foods' Maintenance Managers Meindert Kramer & Cees Regterschot explain, "The heater now keeps the temperature constant and there are no more unplanned stops due to high temperatures. We've had return on investment within one year thanks to reduced energy consumption, extended service intervals and the longer life of the oil".

McCain Foods now uses the CJC™ High Temperature Fine Filter HDU 3 x 27/108 with CJC™ F 27/27 Filter Inserts. The unit is equipped with pressure and temperature transmitters and switches, has temperature controlled automatic shut off valves for added safety. Using an expansion tank with temperature and flow sensors, the system cleans the thermal oil in batches – ensuring an efficient and reliable cleaning process.

If you are interested in finding out more about C.C.JENSEN´s products and services in Holland, contact Mr. Ivan Partono, ip.nl@cjc.dk



CJC™ removed 800 kg of sludge from the thermal oil

C.C.JENSEN Ltd is going up!

Turbine warranties are about to expire and customers have asked us to install off-line filtration systems to avoid any potential problems with gearboxes.

By Christian Juhl Thomsen, Marketing Manager, C.C.JENSEN Ltd.

C.C.JENSEN Ltd. is currently retrofitting CJC™ Fine Filters to Vestas and Bonus/Siemens wind turbines in a number of locations throughout the UK.

"This is an exciting new direction for our business – and certainly we are "going up", says Customer Service Manager Mr. Eric Jackson.

For many years, our success has centred on specifying, installing and servicing our customer's CJC™ Filters in various industries. But this year, for the first time, we are offering a service to our UK clients whereby we fit CJC™ HDU 15/25 PV Filters to their existing field locations.

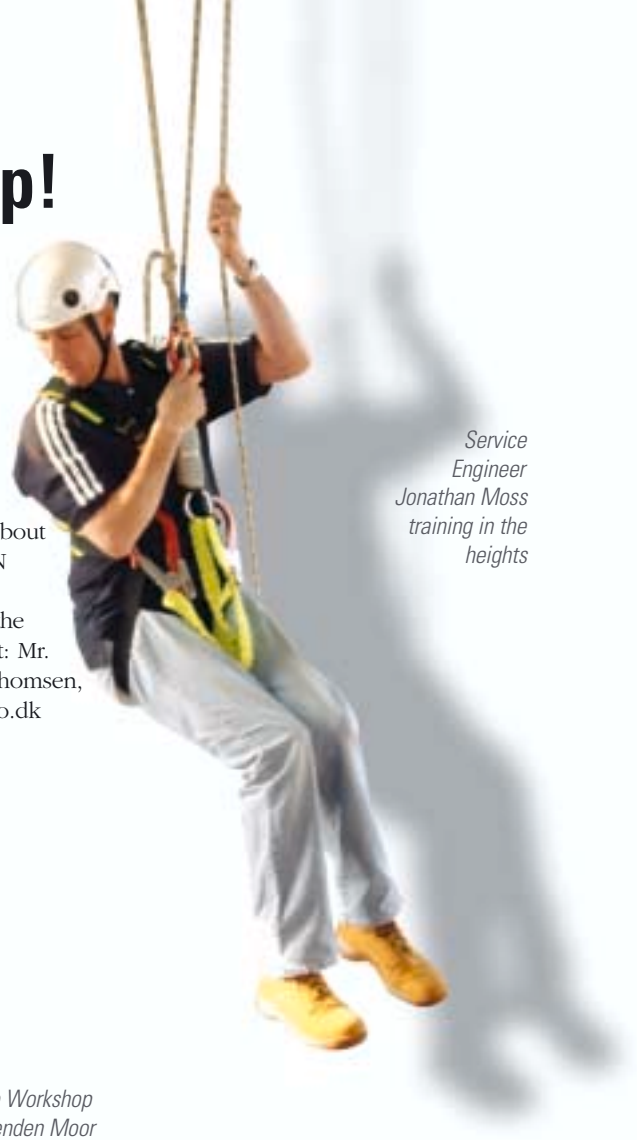
Fitting filters in wind turbines entails climbing ladders and working high up wind turbine towers. The UK service staff have undergone special training at NARC (the National Access and Rescue Centre) to equip them for the challenge. After a physically demanding but very interesting training period, the planning phase could begin. Careful planning is critical for a number of reasons: many wind farms are located off the beaten track and not easily accessible, and many have only limited space. Weather conditions also play a critical factor: inclement weather could make it impossible to scale a wind turbine tower. "Thorough preparation on our part can make all the difference and save us – and our customers – time and money, says Eric Jackson.

Much of the preparation work has taken place at the in-house facilities in Spennymoor, Durham. To offer maximum flexibility, however, we have also built our own CJC™ Mobile Workshop. The workshop is equipped with all the tools and spare parts you need to get any job done, no matter when or where.

C.C.JENSEN Ltd. have already successfully completed the fitting to wind turbines at the Ovenden Moor Wind Farm in Yorkshire and is currently working on a further fittings in St. Breock, Cornwall, with one more wind farm in Cumbria to complete.

Business in the UK is looking great – all we ask for is nice weather so we can get on with the jobs.

If you are interested in finding out more about C.C.JENSEN Ltd's retrofit services in the UK, contact: Mr. Christian Thomsen, cjt@cjcuk.co.dk



Service Engineer Jonathan Moss training in the heights

CJC™ Mobile Workshop on site at Ovenden Moor

Would you like more information?
If you would like to know more about C.C.JENSEN and our products then indicate your interest by ticking the relevant box(es), fill in your contact information and fax the page to: **+45 62 22 46 15**
We will send you the information by mail or e-mail.

Brochures:

- ☐ CJC™ Fine Filter (Solutions for removal of particles, absorption of water, adsorption of oxygen by-products and varnish from oils)
- ☐ CJC™ Filter Separators (Solutions for separation of water, removal of particles, adsorption of oxygen by-products and varnish from oils)
- ☐ CJC™ V30 Vacuum Filter (Solutions for transformer oil maintenance)
- ☐ Clean Oil Guide
- ☐ Information regarding "Hands Free" concept
- ☐ Company Profile

Application Studies, Reference Lists or Contact

- ☐ Power generation related application studies and reference list
- ☐ Wind turbine related application study and reference list
- ☐ Thermal oil related application studies and reference list
- ☐ Have a sales person contact me

Contact Information:

Company: .....
Name: .....
Title: .....
Address: .....
ZIP-Code: .....
City: .....
Country: .....
Phone: .....
Fax: .....
E-mail: .....