**SISTEMAS CENTRALES DE LUBRIFICACION S.A. DE C.V.** May 2, 2004

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Attn: Eng. Andres Rodrigues
Superintendent of Maintenance
Industrial Paper and Conversion Plant

**Subject: Results of the tribological improvements made in the Industrial Paper Machine #4 during operation and scheduled shut-down.**

Dear Engineers,

We would herewith like to submit for your analysis the report on the **Improvement of the Production Reliability for the Industrial Paper #4 Machine** through the packet of Tribological solutions designed and executed by SICELUB.

This report includes:

- Conclusions and improvements made to the system;
- Recommendations to be followed for all equipment in the plant;
- Graph of results and pictures.

Through the interpretation and solutions presented we tried to **Ensure the Tribological Operating Reliability** of the critical equipment through the maintenance of the quality and cleanliness of the oil according to Norms **ISO 4121 – ISO 4406 – ASTM D6224**.

Considering the relevance of this report, we kindly ask for 30 minutes of your time to detail any comments or inquiries that may rise.

We hope the propositions as to improvement in lubrication will be of interest and we are ready to answer any questions.

**Ing. H. Pablo Agostini**
Responsible for the division Lube & Fluids and LubeLab Services, Sicelub SA de CV
**Ing. Ismael Gasca Zenteno**
Responsible for Customers on Central-Eastern Zone

# Executive Outline

## Problem:

Upon several visits to the Kimberly Clark plant, as well as meetings with the plant's personnel, we managed to interpret the tribologic problem presented in the Industrial Paper Machine #4.

Simply put, the lubricating oil used was of the wrong type. It was contaminated with impurities as was the entire lubricating system.

Production was affected due to the tribologic problems of the machine. Sticking servo-valves, non homogenic paper quality, and production stops due to reduction of paper thickness were all results of lubricating contamination.

## Solution Offered:

Due to these problems and after oil analysis, it was concluded that a specific solution consisting of:

- Nanofiltration service for lubricant and system cleaning during operation.
- Chemical Flushing during a planned shut-down to clean the system.
- Change to a better performance lubricant, Class II, hydro fractioned.
- Nanofiltration service for 3 months after the lubricant change.
- Periodic oil analysis for continued improvement.

## Results:

The results obtained were more than satisfactory since the **Tribologic Reliability and Availability of the System** increased considerably with the resulting impact on the machine's production reliability. This is also represented by the Tribologic Tendency Graphs contained herewith.

## Recommendations:

It is recommended that **Reliable Tribological Programs** be implemented similar to this in equipment throughout the plant.

It is recommended that Nanofiltration Equipment be installed on the critical equipment during operation, the lubricant to be changed to Group II hydro fractioned, and chemical flushing for the programmed stops of the machines.

As a result, the reliability and availability of the critical equipment of the plant is increased; thus contributing to increased production at Kimberly Clark.

# DEVELOPMENT

## 1-Introduction:

This final report is an abstract of the oil improvement techniques applied to the Industrial Paper Machine #4 installed in the Industrial Paper and Conversion manufacturing section of the Kimberly Clark paper plant in Mexico during the months of December through May.

## 2-Initial Situation:

During several visits to the Kimberly Clark plant, we were informed that the hydraulic circuit of the reel on Industrial Paper Machine #4 (IPM) was not operating properly, causing serious production issues. This part of the IPM #4 controls the thickness of the paper on the rolls and is a critical component of continuous process. Following a request from the Preventive Maintenance Dept. of this sector, actions were taken to solve the problem. According to the investigations carried out we could detect the problems, the causes of them and the negative effects these problems induced, such as:

- Irregular Thickness of Industrial Paper:

- This induced complaints from the production sector because the quality of paper was not homogenic.
- Successive stops due to cuts on the sheet of paper when the thickness was reduced, with the subsequent loss of time and effective production.
- The reason for the variation in the paper thickness was attributed to the fact that the fluid used had lost viscosity and the system did not yield the adequate hydraulic pressure. Since the fluid was a conventional Class I mineral oil, there were variations of the cinematic viscosity. It had a low Viscosity Index value, poor thermal stability and low oxidation resistance. This oil accentuated even more due to the fact that the fluid was under high temperatures, around 85C.

- Formation of varnish in the interior of the expansion wheel of the reel:

- As a result of using poor quality lubricating oil under continuous cycles at the operating temperature, it degraded faster, oxidized, and generated varnish that blocked the pipes and control elements of the hydraulic system.
- It was necessary to disassemble and clean the interior of the wheels approximately every 6 months, which forced them to have a spare cylinder ready for replacement to reduce the production downtime. Even so, the production hours that were lost were irrecoverable, the reliability of the machine was low and the maintenance, repair, man-hours, personnel availability costs and other expenses associated were high.
- It was determined that the oil operating temperature inside the wheel of the reel oscillated around 85C, a temperature too high for conventional Class I oil.
- The oil was the same used to lubricate gears, Mobil brand gear 627 with a cinematic viscosity of 100 cSt, not recommended for hydraulic systems.

- Sticking valves in the system:

- As a consequence of neglecting the hydraulic system, the reliability was low and valves were sticking without warning, which led to a stop of production and valve replacement in order to continue operation.
- This also brings expenses due to diverse maintenance and unexpected production losses.

## 3 -Proposed Recommendations:

An integral solution to the operative problem of the reel was created, which included the selection and application of an adequate lubricant, deep internal cleaning of the hydraulic system and the implementation of external auxiliary equipment to sustain oil conditions and to remove varnish without having to stop the machine from operating:

a. Treatment of the system with top technology: ISOPur Balanced Charge Technology

- Being that the IPM is a continuous process that cannot be interrupted, it was decided to use equipment capable of removing the varnish present in the system without having to stop the machinery and all while removing and preventing varnish buildup.

- The ISOPur equipment uses a unique technology capable of highly efficient filtration to remove sub-micron particles from the lubricating fluid. These particles are the biggest factors for deterioration of high precision machinery components.

b. Substitution of the present lubricating oil:

- Based on the recommendations of the hydraulic system's manufacturer and respecting the operation of the reel, it was recommended that the superior performance of Class II, hydro fractioned oil was adequate for hydraulic systems.

c. System cleaning by means of a special chemical flushing:

- Due to the fact that varnish covered the inside of the system, it was determined that it should be removed quickly. An internal cleaning was recommended with a special solvent, taking advantage of the same oil of the system as a means of transport for the solvent, for further disposal of the mixture.

d. Following procedures and delivering results:

- The same would allow an evaluation and confirm the effectiveness of what was done.

## 4 -Actions taken:

Once the approval was given by the Superintendent of Maintenance of the area of Industrial Paper and Conversion of KCC, the tasks described above began. The first step was to connect the ISOPur equipment in order to start removing varnish that had been deposited by the previous oil in the system and increasingly improve the reliability of the equipment. It was agreed to do it this way because a scheduled shut-down was necessary to do the special chemical flushing and further change the hydraulic fluid. After the chemical flushing, the hydraulic fluid was changed to the new hydro fractioned. The posterior filtration consisted of the ISOPur equipment with the intention of delivering the fluid with an ISO 4406 cleanliness code, the standard for paper manufacturing equipment. It was agreed to monitor the state and evolutions of the cleaning tasks, nanofiltration and behavior of the oil. A total of 20 oil analyses were performed. Results and tendencies are shown in this report with the intention to assure reliability at all times.

## 5 -Description of the Tasks carried out:

a. ISOPur treatment:

On December 18, 2003, the ISOPur I-600 unit was connected. The unit has a capability of re-circulating 2000 liters of fluid per hour. This allowed the 900 liters of oil in the system to be cycled twice per hour. This would accelerate the process of minimization and removal of all varnish present in the system and obtain visible results in less time.

## **<u>Analysis of the particle content</u>:**

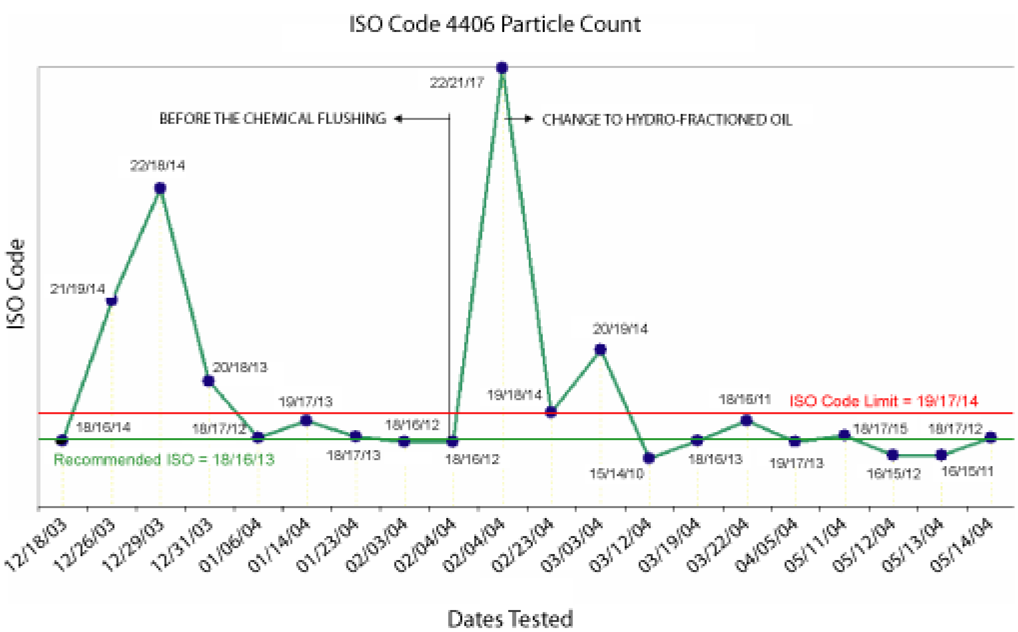
In order to monitor the degree of oil contamination, we usually quantify the content of particles/ml of oil and then code it according to what is established in the ISO 4406 norm. This way we are able to know the cleanliness conditions of the oil and how far we are from the recommended for each application. The recommended ISO code in the case of the paper machines is 18/16/13 and 19/17/14 as the critical alarm value.

It is important to note that when the work in the IPM began, the hydraulic oil in the system was operating for just a few days, since it had been changed with the same previous specifications. The change was due to the fact that the old oil was so deteriorated that the system could not keep an adequate working pressure. This is proved by the results of the first analysis of the oil, on Dec. 18, 2003 when the ISO code value was acceptable: 18/16/14; that led us to think that the system was clean; but, as we are going to see later, this first impression was not correct.

Analyzing the tendency shown on the subsequent analysis, we observe that in some days after the ISOPur equipment was connected, the values of the cleanliness code increased considerably. This was the result of the ISOPur system beginning the removal of varnish from the interior of the system. Following the tendency one can see that the ISOPur equipment rapidly removed these particles from the system and the values of the ISO code returned to low levels.

We also observe some oscillations of the values of code between the Critical and Normal limits. This is also due the system removing particles from the equipment. Note that it is always below the critical limit and the tendency is always decreasing below the recommended limit (18/16/13).

### Graph 1 – Particle Count ISO Code 4460




Note: The ISOPur equipment remained connected for more than 4 months.

a. <u>Chemical Cleaning of the System</u>

On Feb. 4, 2004 the system was chemically cleaned by adding a special solvent to the oil, which would quickly remove interior varnish from the system.

Figure 1

Figure 2

We can also observe in Graph 1 that an oil sample taken this same day, a few minutes after adding the solvent as the oil begins to recycle, the ISO code is 18/16/12. This is lower than the recommended code, thus confirming that the oil was cleaned as a result of the advanced performance of the ISOPur equipment.

After 12 hours of recirculation with the solvent and oil combination, the used oil was removed and replaced with hydro fractioned oil. The system was started and once it reached the working temperature, an oil sample was taken. In Graph 1, the sample analysis indicates a high ISO code: 22/21/17, a result of the cleaning action of the solvent.

This is evidenced by the quantity of particles found on the bottom of the tank and collected in the filters of the system after they were taken off when the system was drained. See Figure 3 and 4.

Figure 3

Figure 4

At this point it is valid to mention that the ideal recirculation of the solvent is 40 hours. Had the system reached this time, the amount of removed particles would have been much greater. The 40 hours could not be reached because the production had an approximate 24 hours of scheduled shut-down only.

The ISOPur equipment was disconnected during the recirculation of the system. Just the filters of the equipment were used. Those were replaced with new ones before starting the recirculation and replaced again before the chemical cleaning - prior to replacing the old oil with the hydro fractioned oil.

Additionally, in Figure 5 we see the state of cleanliness of the tank of the system, which was manually cleaned, and then changed to the hydro fractioned oil.

Figure 5

b. <u>Oil Change</u>:

Once the oil tank was cleaned and the filters were replaced the new oil change was started. The ISOPur equipment was used to filter the oil as it entered the system, which guaranteed an additional cleaning measure. See Figure 6.

Figure 6

As soon as the system started operating, normal working parameters were recorded on the Industrial Paper Machine #4. The ISOPur equipment was kept operating for approximately 3 more months to ensure that the system was totally free of varnish.

The ISOPur I-600 equipment was disconnected and replaced by a smaller one, the ISOPur I-70. This equipment uses the same technology but with a lower flow rate. Duration of installation and the volume of the oil to be treated deemed the I-600 unnecessary.

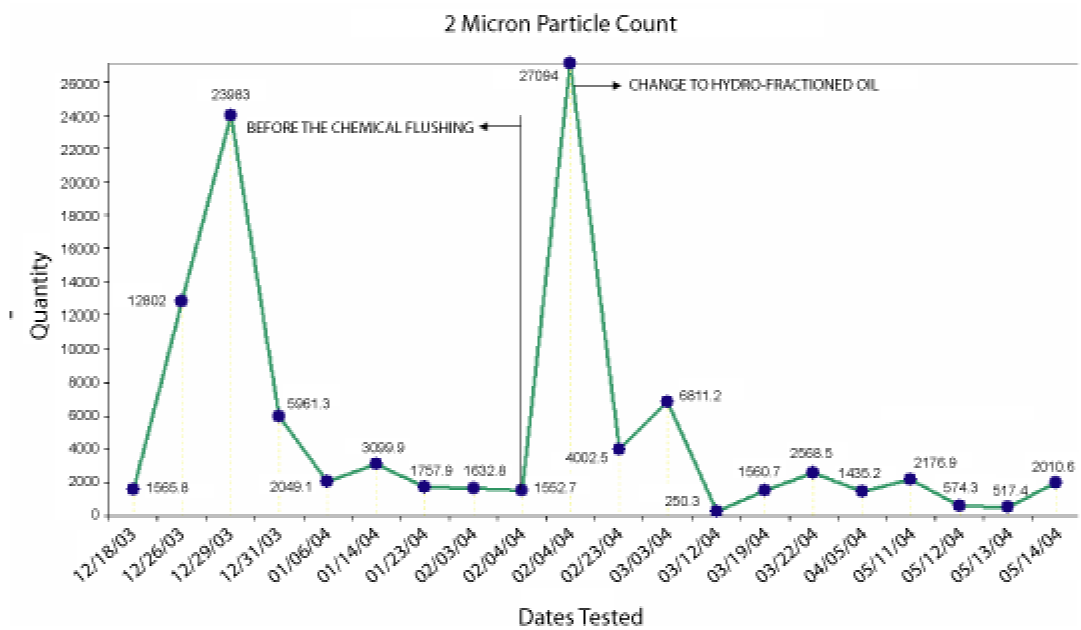
The performance of the ISOPur equipment can be seen on Graph 1. In just a few days the equipment removed the contamination that had not been collected by the system previously due to its low efficiency and low retention power (15 um). The cleanliness code returned to normal values in a short period of time.

There is also proof of a certain oscillation in the value of the cleaning codes in the days after the chemical cleaning until the system stabilized. This is a result of the circulating fluid inside the system caused by the chemical cleaning. This also makes up part of the operation of the ISOPur equipment that constantly eliminates particles by performing removal cycles.

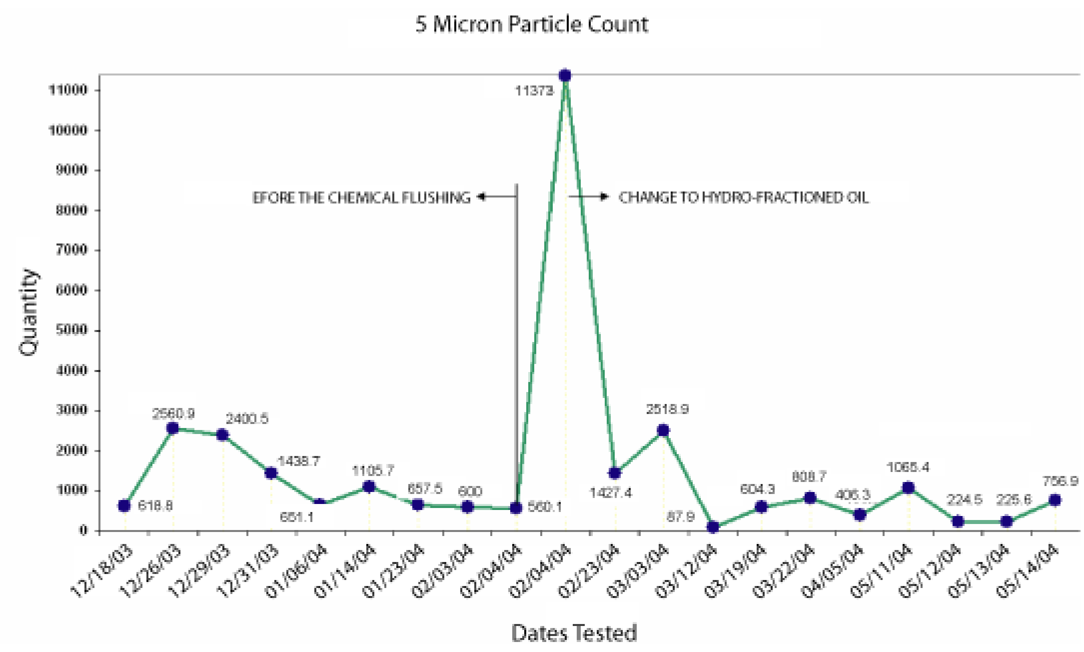
Even with the fluctuating ISO codes, they always remain below the danger zone and with a decreasing tendency to cleaning values below the recommended, providing an operation free of problems and worries.

In Graphs 2, 3 and 4 represent the number of particles measuring 2, 5 and 15 microns per ml of oil present in the system. As we can see, the tendency is the same as the ISO code from Graph 1. At first, high values were obtained when the ISOPur equipment was connected but they then reduce as a result of the equipment operation. The rise is then due to the chemical cleaning. Finally, the general tendency is decreasing and the number of particles lowers with time.

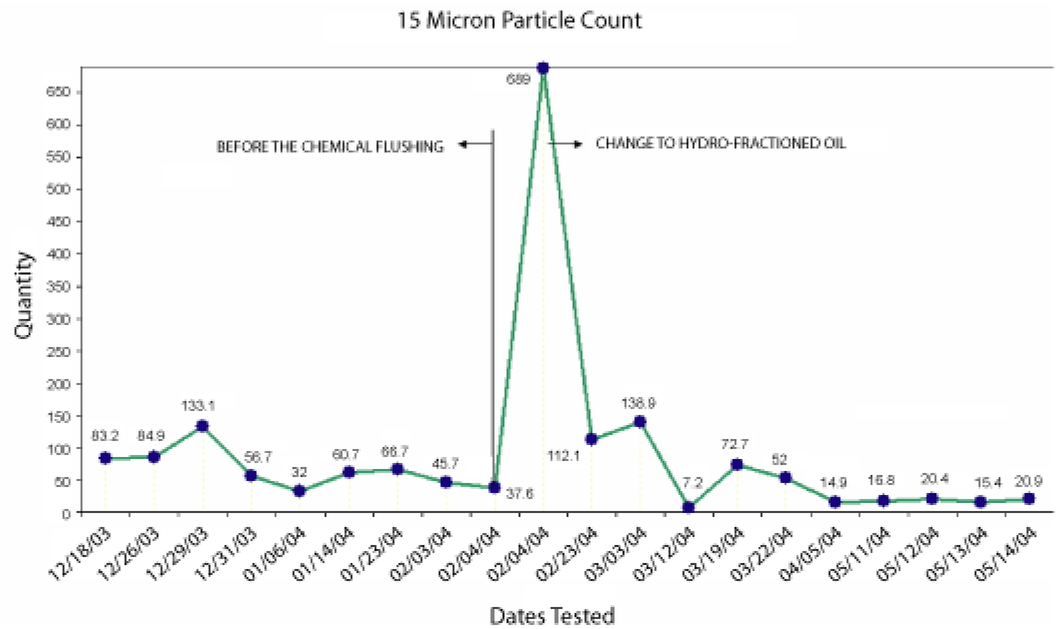
**Graph 2 - Two micron particles**




**Graph 3 - Five micron particles**



**Graph 4 - Fifteen micron particles**




c. <u>Analysis of improvements with implementation of hydro fractioned oil</u>

The selection of the lubricant was made according to the following priorities:

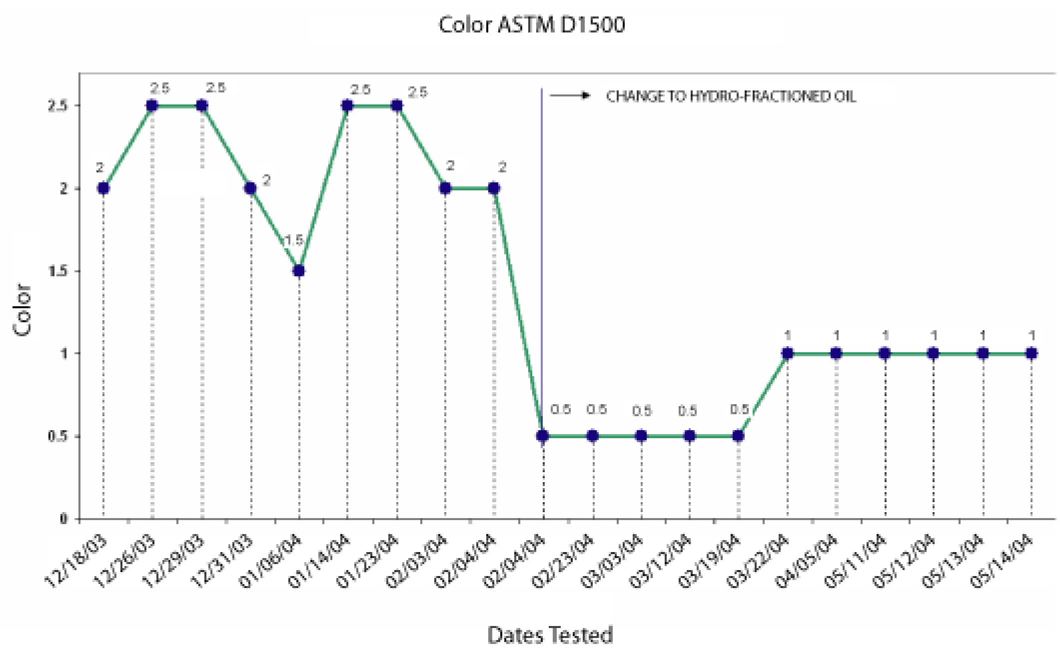
1. <u>Manufacturer Recommendation</u>: the manufacturer recommended the hydraulic type oil ISO VG 100. The oil used was one for gears that has an additive pack specific for this application.
2. <u>Application</u>: since this is a hydraulic system, the manufacturer's recommendation is correct.
3. <u>Operative Conditions</u>: high temperature, high thermal and oxidative degradation, sufficient reasons to recommend a more efficient lubricant and with a higher oxidation and thermal resistance, i.e. the hydro fractioned.

From the lab analysis there are several conclusions that demonstrate the superior quality and better performance of the hydro fractioned oils, as explained below:

1) <u>Oil color</u>:

Graph 5 shows the oil color. We can easily see the amazing change of homogeneity, color and thus its purity when changed to the hydro fractioned. A faintly lighter color is apparent, from 0.5 to 1.0 which is very plausible since this is the first change to the hydro fractioned oil as well as use of the ISOPur cleaning process. With future changes of hydro fractioned oil, the color of the oil will continue to stabilize.

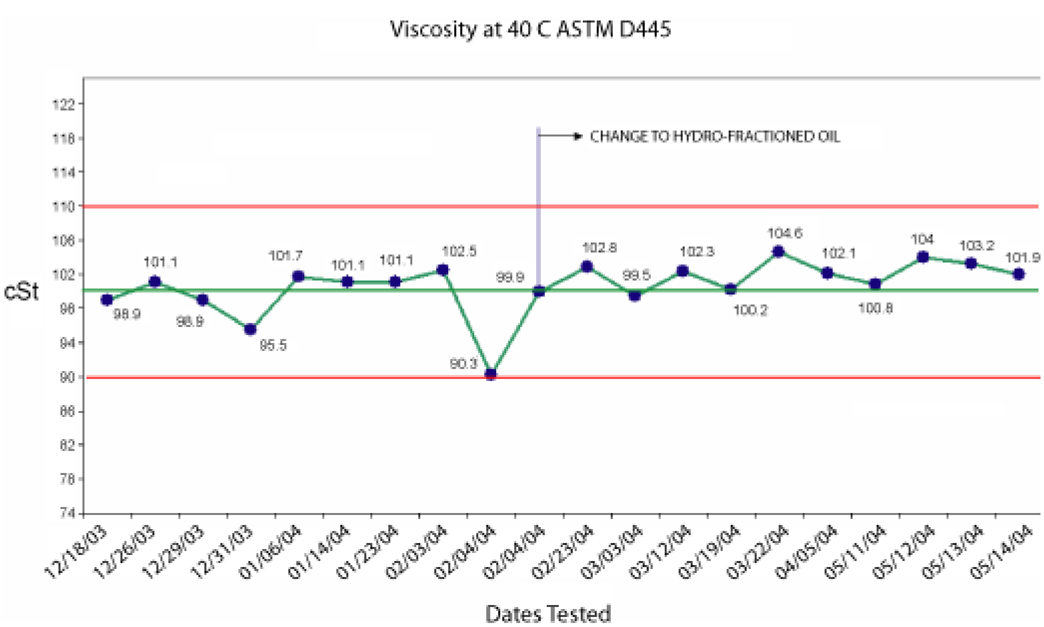
**Graph 5 - Color ASTM D1500**




2) <u>Oil Viscosity</u>:

The viscosity of the old oil in the Industrial Paper Machine #4 represented one of the biggest operative issues, because of the tendency to notably decrease to the point of the hydraulic pressure not reaching operational levels. In the case of the hydro fractioned oil, a stable viscosity was always above 100 cSt., which guaranteed an adequate thickness of lubricant at all times. This is attributed to the higher resistance to changes in viscosity resulting from thermal changes. The hydro fractioned oil has a higher viscosity index. See Graph 6.

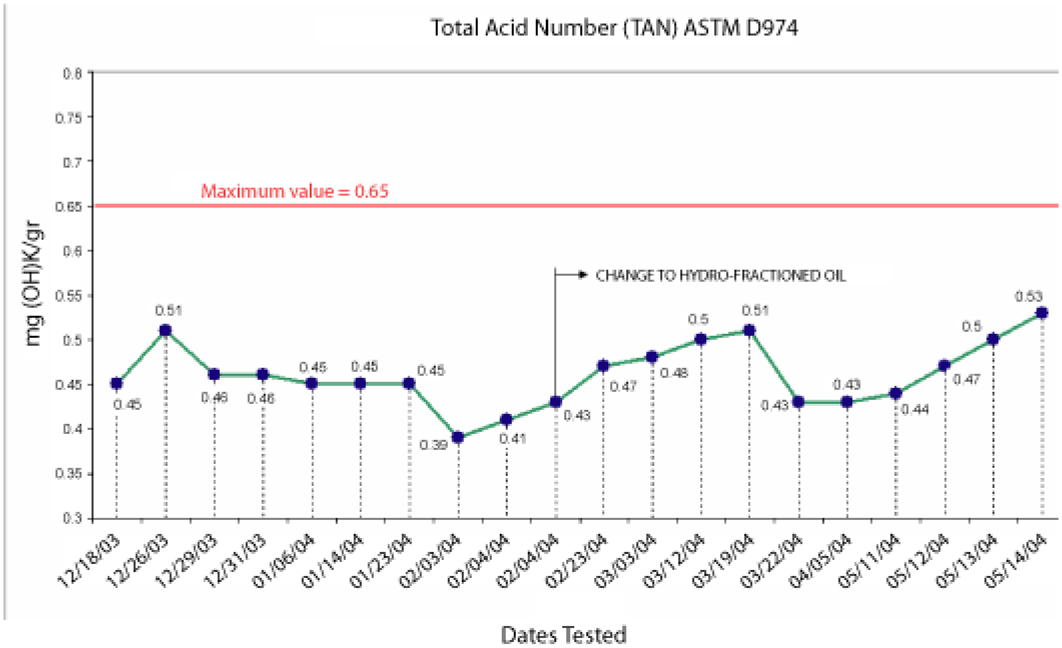
**Graph 6 - Viscosity at 40 degrees C ASTM D445**



3) Total Acid Number (TAN):

In this respect, the TAN value is kept under the recommended values. Note that some hydraulic oils, like those for gears, have special additives, such as AW (anti-wear) and EP (extreme pressure). These present much higher TAN values than the turbine oils, for instance. This is normal since the chemical nature of the anti-wear components (like phosphorus and sulfur) is capable of oxidizing and forming acidic components. See Graph 7.

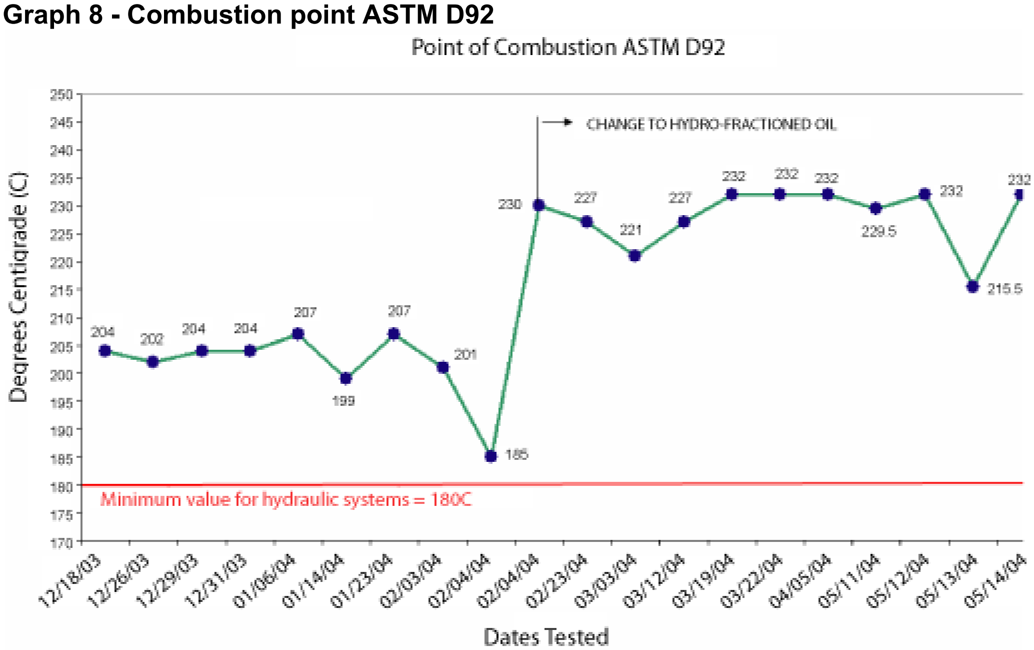
**Graph 7 - Total Acid Number (TAN) ASTM D974**




4) Combustion Point:

Solvents are the notable difference between hydro fractioned and refined oils. This property is especially important in high temperature applications. See Graph 8.

**Graph 8 - Combustion point ASTM D92**

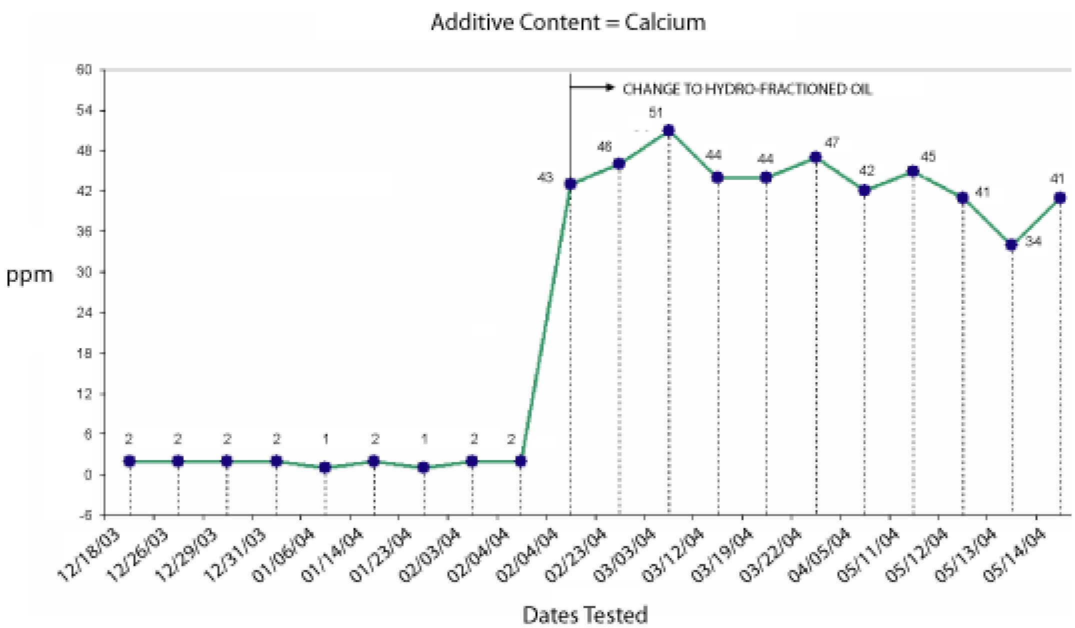


5) Special Additives: Calcium, Phosphorus and Zinc

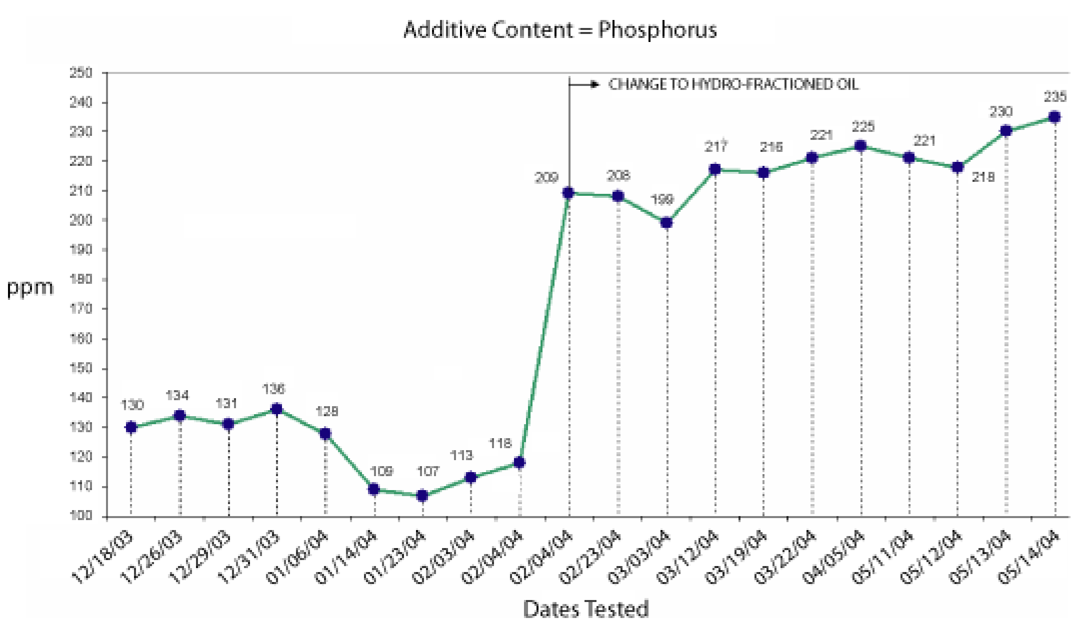
The strong additive pack and purity of the hydro fractioned oil generates less undesirable reactions due to its higher receptivity.

This benefit translates into a longer life for the machine and for the lubricant because of its higher resistance to oxidation and to the formation of varnish. See Graph 9, 10 and 11.

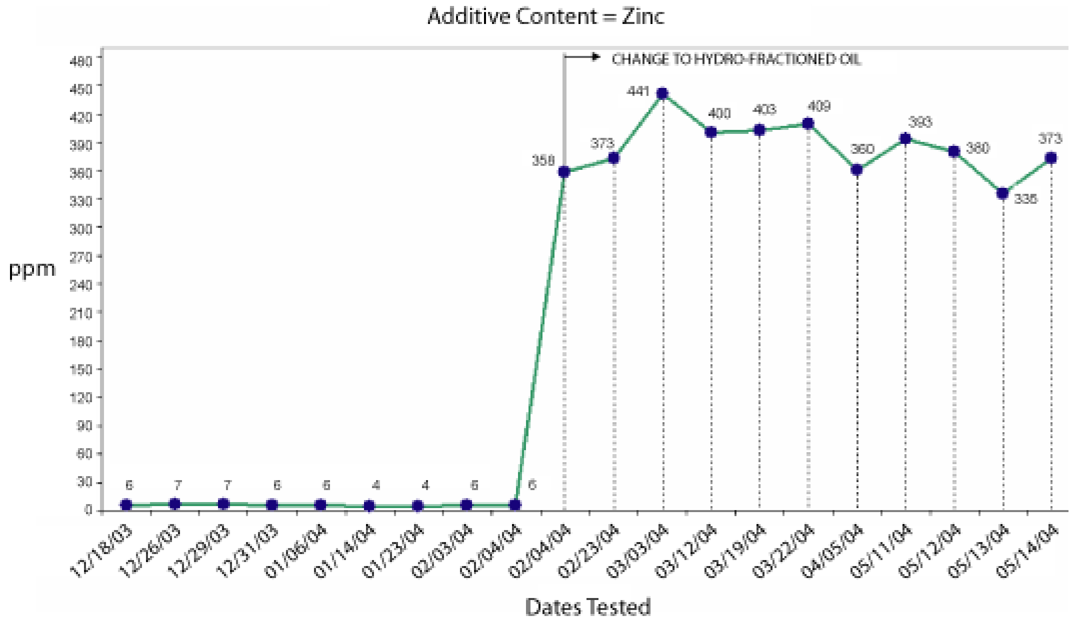
**Graph 9 - Content of Additive: CALCIUM**




**Graph 10 - Content of Additive: PHOSPHORUS**



**Graph 11 - Content of Additive: ZINC**




6) <u>Conclusions and Recommendations</u>:

According to the positive comments received about the high performance of the reel on Machine #4, we conclude that the pack of solutions applied was more than adequate and very successful.

Cleaning the lubricating oil in Machine #4 considerably increased its accountability and consequently its productivity, which resulted in smaller maintenance expenses and a worry-free operation.

Additionally, the quality of the products coming out of Machine #4 is superior, resulting in an integral improvement of the Kimberly Clark Company.

<u>Recommendations</u>:

With the objective that these improvements will continue in the future and may extend to other equipment in the plant, we recommend the following:

- Purchase of Nanofiltration equipment to maintain the cleaning, varnish prevention and production grade of Machine #4. We can also rotate it for use on other machines in the plant, according to a pre established maintenance cycle.
- Change the hydro fractioned oil in the other machines of the plant, which will guarantee superior performance.
- Extend the solution to other industrial paper machines. SICELUB can provide the means and accessories so that the service will be performed by Kimberly Clark's personnel.

Sincerely yours,
Engineer H. Pablo Agostini
Lubricants and Fluids – LubeLab Services