



EHC Fluid Recovery
Case Studies using ICB™, TMR™, & ECR™





EHC Fluid Recovery
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Case Study #1

Fluid Type: Fyrquel® EHC

OBJECTIVES

In this example, a heavily contaminated phosphate ester EHC fluid from a 1000 MW Steam Turbine was tested and cleaned using EPT's three core purification technologies: TMR™-N2, ECR™, and ICB™. Details on the starting fluid condition (as found) and the incremental improvements associated with each of the cleaning technologies is reported.

INITIAL CONDITION

Initial EHC fluid quality was analyzed with the results reported in Table 1. The fluids most immediate problems included extremely high levels of water, low fluid resistivity, and elevated acid number (AN). Non-routine testing also revealed an elevated level of particulate (reported as high patch weight), and an alarming Deposition Tendency.

Table 1: EHC Fluid Condition and Targets

FLUID PROPERTY	INITIAL VALUE	TARGET VALUE
water (ASTM D7546)	8672.2 ppm H_2O	200-500 ppm
resistivity at 20° C (ASTM 1169)	<1.0 Gohm·cm	>10 Gohm-cm
acid number (ASTM D664)	0.17 mgKOH/g	<0.10 mgKOH/g
patch weight (Mod. ASTM 4898)	0.0277 g/50 mL	<.004 g/50 mL
deposition tendency (Exelon method)	See Figure 5	no visible deposition

Water content during the use of TMR™-N2 on PE fluid

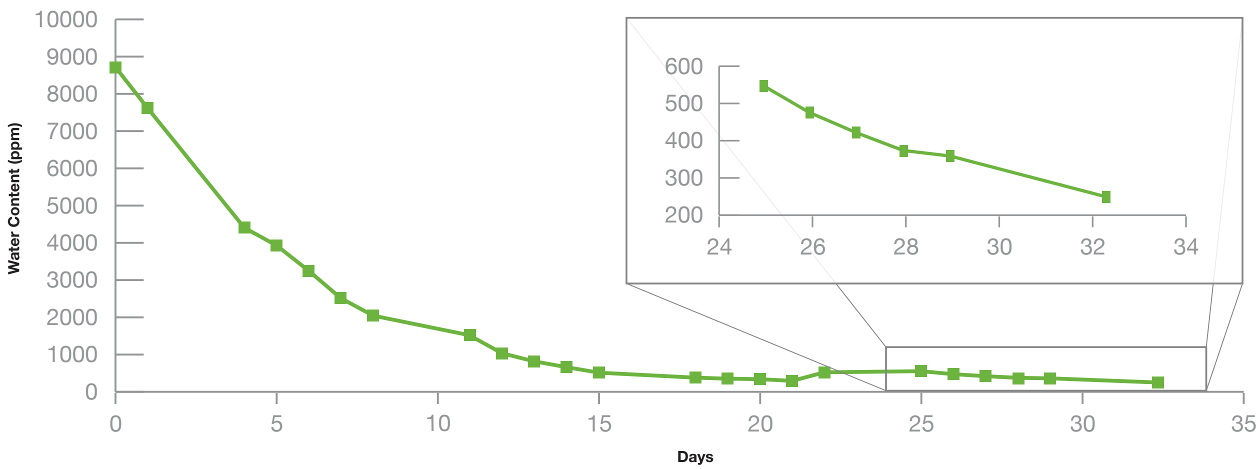

Fig. 1

EHC Fluid Recovery

Case Studies using ICB™, TMR™, & ECR™

TMR™-N2 INSTALLATION

When cleaning or restoring EHC fluid, water removal is always the first priority. EPT's TMR™-N2 product was installed to reduce the water content in the EHC fluid. TMR™ water removal products are designed as a water removal solution that will remove all forms of water including: dissolved, emulsified, and free. Ideally TMR™ products are applied when water ingression rates are <400 ppm per day.

Starting water levels were almost 9000 ppm which is highly unusual in the EHC application. Normally in such situations, vacuum dehydration equipment would be required as hydraulic systems using servo-valves cannot tolerate such high water levels even for short period. In this non-operating example, TMR™-N2 was used to reduce water levels to target with results outlined in Figure 1 on page 1. As expected, TMR™-N2 worked very well removing approximately 300-400 ppm per day over the testing period while increasing fluid resistivity from <1.0 gohm.cm to 3.52.

ECR™ INSTALLATION

EPT's ECR™ technology removes insoluble particulate contamination, down to the sub-micron level, from phosphate ester-based EHC fluids using electrostatic filtration. As an electrostatic oil cleaning technology, ECR™ requires water levels to be below 600 ppm before it can be used effectively.

Since ISO 4406 particulate analysis only reports particulates >4 microns, the applicability and effectiveness of ECR™ is measured using a patch weight test, at 0.45 micron which measures the total solids in a sample by weight. The performance of the ECR™ was monitored daily with results reported in Figure 2. An exponential drop in the patch weight following ECR™ treatment is observed in the first 72 hours with an 84% drop in patch weight. As ECR™ usage continued over the next 2 weeks, patch weight was reduced by an additional 12%, for a total reduction in patch weight of 96%. The quick result in this example is related to the small reservoir volume and with a typical reservoir volume of 400 gallons/1520 liters, these results would normally occur over a 2-3 month period.

The removal of fine particulate can impact the fluids resistivity value. In this example, the use of ECR™ increased EHC fluid resistivity from 3.52 Gohm-cm, a value below the condemning limit, to 7.99 Gohm-cm, which represents an additional improvement of 228%.

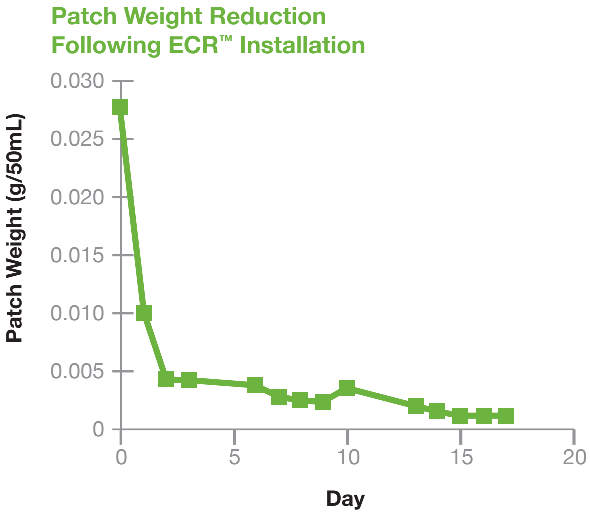

Fig. 2

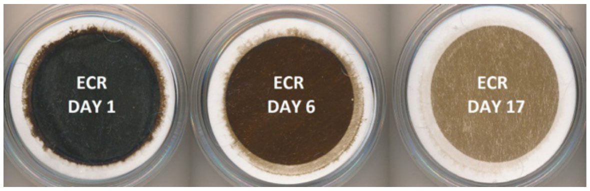

Fig. 3

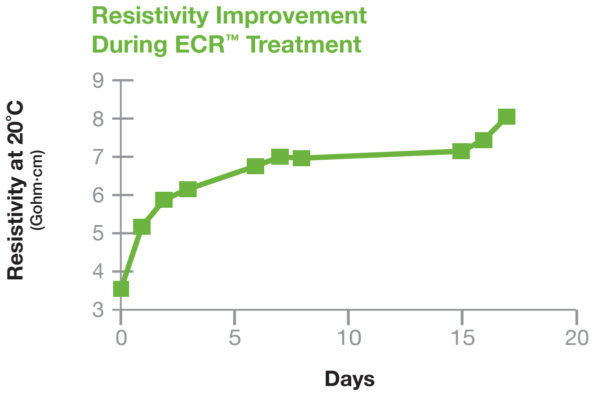

Fig. 4

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Since ECR™ removes fine particulates, its use does not usually reduce AN since acids are dissolved lubricant breakdown products. As expected, the use of ECR™ in this example had a minor impact in Acid Number (AN) which was reduced from 0.17 to 0.15 mgKOH/g.

ICB™ TREATMENT

While Fuller's Earth and Selexsorb™ have been widely used in the past as acid removal filters in phosphate ester based EHC fluid applications, an entirely new level of EHC fluid purification is available through the use of ICB™. ICB™ is a specialized ion exchange product developed by EPT that removes acids, but more importantly removes the dissolved contamination responsible for servo-valve sticking. This additional benefit is a game changer for phosphate ester-based EHC fluid maintenance. For the past 40 years, steam turbine EHC operators have worked to manage acid numbers and fluid resistivity values, without the ability to remove the contamination responsible for servo-valve sticking. ICB™ removes this limitation, allowing for significantly improved servo valve reliability and, as a secondary benefit, offers extraordinary improvements in fluid resistivity.

In Figure 5, results of the deposition tendency test are shown. In this test, a solvent (hexane) is mixed with EHC fluid which forces dissolved contamination out of solution and into a form which can be readily visualized or trapped on a filter patch. While solvent forces this contamination from solution, pressure changes in an EHC system (i.e. when a servo valve opens) can have a similar effect, resulting in a propensity for deposit formation on servo valve components. Note that in Figure 5, the initial EHC fluid sample shows a significant tendency towards deposit formation while no such deposits are observed following ICB™ treatment.

Figures 6 and 7 show significant improvements in AN and fluid resistivity resulting from ICB™ treatment; in both cases, these properties were improved to values superior to new fluid specifications.

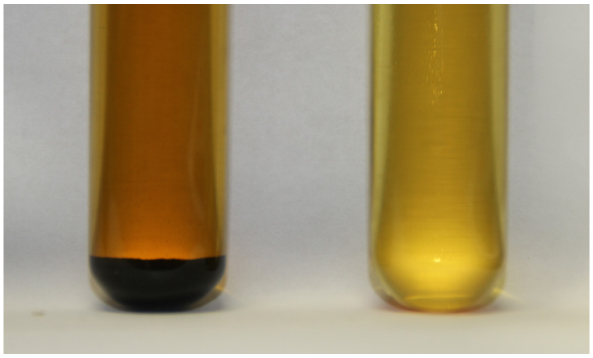

Fig. 5—Deposition Tendency Test before and after the use of ICB™

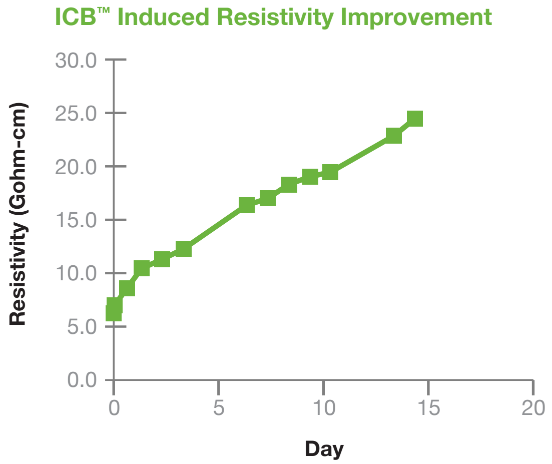

Fig. 6

Fig. 7— Photos of EHC fluid sample before and after using TMR™, ECR™, and ICB™

Selexsorb™ is a registered trademark of BASF

EHC Fluid Recovery
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SUMMARY

Overall, EPT's three technologies were able to fully restore the parameters of the Phosphate ester fluid. TMR™-N2 reduced the water levels from 8000 to 242 ppm. ECR™ reduced the total solids as measured by patch weight by 96%, and ICB™ reduced Acid number to specification, and increased resistivity by over 600%. Furthermore, ICB™ completely eliminated the deposition tendency of the EHC fluid. Table 2 summarizes the initial, target, and ending EHC fluid values. In Figure 7, The incremental color change associated with the use of TMR™, ECR™, and ICB™ is shown.

Table 2: EHC Fluid Condition and Targets

FLUID PROPERTY	INITIAL VALUE	TARGET VALUE	ENDING VALUE
Water (ASTM D7546)	8672.2 ppm H_2O	200-500 ppm	242 ppm
Patch Weight (Mod. ASTM 4898)	0.0277 g/50 mL	<.004 g/50 ml	0.0012 g/50 ml
Acid Number (ASTM D664)	0.17 mgKOH/g	<0.10 mgKOH/g	0.09 mgKOH/g
Resistivity at 20C (ASTM 1169)	3.52 Gohm·cm	>10 Gohm-cm	24.31 Gohm-cm
Deposition Tendency	Heavy deposition	no visible deposition	No visible deposition

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EHC Fluid Recovery
Case Studies using ICB™, TMR™, & ECR™

Case Study #2

Fluid Type: Reolube Turbofluid 46 XC

OBJECTIVES

In this example, a heavily contaminated phosphate ester based EHC fluid was assessed and cleaned using EPTs three core purification technologies: TMR-N_2™, ECR™, and ICB™. Starting fluid conditions and improvements are detailed below.

INITIAL CONDITION

The fluid's most immediate problems included high levels of water, an elevated patch weight, high acid concentration (measured as acid number, AN) and poor resistivity at 20°C. TMR-N_2™ was installed to bring the water to an acceptable range (200–500ppm) and maintain that level. Consequently, an ECR™ was then engaged to lower the patch weight (target level is <0.0040 g/50mL). ICB™ was then installed to reduce the acid concentration (target level is <0.10 mgKOH/g), but it is also the primary mechanism for improving fluid resistivity (target level is >5.00 Gohm·cm).

Table 1: Initial condition of the fluid "as is"

FLUID PROPERTY	INITIAL VALUE
Water Content (ASTM D7546)	1213.0 ppm H2O
Patch Weight (Mod. ASTM 4898)	0.0055 g/50mL
Acid Number (ASTM D664)	0.29 mgKOH/g
Resistivity at 20°C	1.64 Gohm·cm

TMR-N_2™ IMPLEMENTATION

The TMR-N_2™ was used to lower the water content in the oil. With water levels as high as 1200 ppm, it took just over a week to reduce it to an ECR™ friendly level (about 500ppm). The effectiveness of TMR™ is clearly illustrated in Figure 1; we can see that at moderately elevated levels of water, TMR-N_2™ functions.

Water Content During the Use of TMR-N2™on PE Fluid

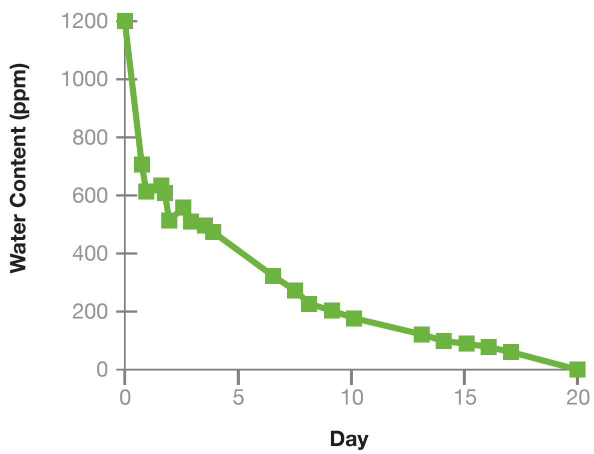

Fig. 1

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Case Studies using ICB™, TMR™, & ECR™

ECR™ INSTALLATION

EPT's ECR™ technology removes insoluble particulate contamination, down to the sub-micron level, from phosphate ester-based EHC fluids by electrostatic filtration. This can be monitored using a patch weight test, a 0.45 micron solvent (usually hexane) assisted filtration. The activity of the ECR™ was monitored daily and is in Figure 2 shown below.

Observing Figure 2, one can clearly see the exponential drop in the patch weight following ECR™ treatment. A 45% drop is seen in the first 24 hours, already meeting the patch weight target. After a couple of days, the patch weight has dropped by 84% of the initial value, reaching a patch weight as low as that of brand new oil. ECR™ activity was terminated.

Figure 3. Patch weight at 0.45 microns was decreased by 84% through ECR™ utilization. This change can be seen visually (from left to right) as the dark color (due to carbon) is dissipated.

As impressive as ECR™ was on reducing patch weight, the absence of the insoluble particulate contamination also works to improve fluid resistivity and lower acid concentration (particulate acids). The drop in acid number was not very substantial (a drop from 0.29 mgKOH/g to 0.24 mgKOH/g), resulting in a decrease of 17% over the 6 day period.

In Figure 4 the rise in resistivity is demonstrated. Resistivity was initially measured at a value of 1.64 Gohm·cm, a value well below the condemning limit of 5.00 Gohm·cm. In this particular instance, ECR™ alone was capable of raising the resistivity by 60% to a value of 2.62 Gohm·cm.

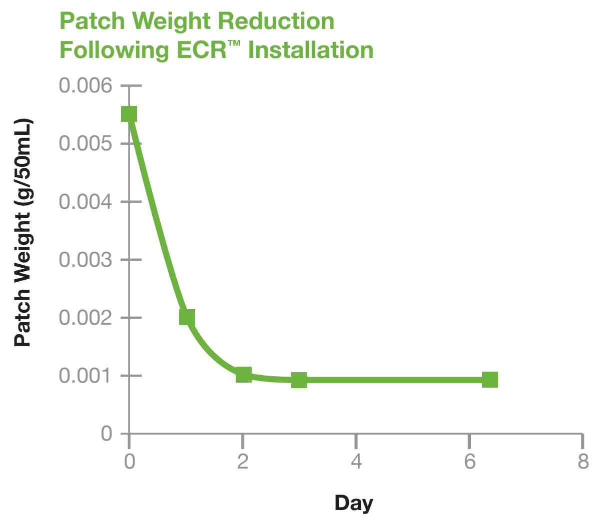

Fig. 2

Fig. 3

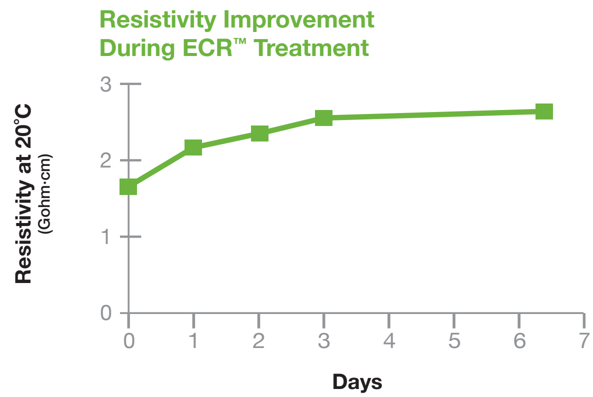

Fig. 4

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EHC Fluid Recovery

Case Studies using ICB™, TMR™, & ECR™

ICB™ TREATMENT

EPT's ICB™ is a product that helps remove oxidation degradation by-products. Most of these by-products are usually acidic in nature. Along with the removal of these contaminants, ICB™ promotes the resistivity of the fluid. Figure 5 below outlines the acid number decrease over the course of the ICB™ treatment. For phosphate ester based fluid, a general acid number target is 0.10mgKOH/g. This was reached after 9 days of ICB™ treatment, corresponding to a reduction of 42%. The final acid number reached at the end of the ICB™ treatment was 0.07 mgKOH/g, yielding a total reduction of 71% by ICB™

Figure 6 shows the drastic resistivity improvements with the application of ICB™. The resistivity of the oil reached 5.23 Gohm·cm, an increase of roughly 200% of the post-ECR™ resistivity, which puts the resistivity above the condemning limit. ECR™ and ICB™ both combined for a resistivity surge of over 300%.

CONCLUSION

Overall, EPT's three technologies were able to fully restore all the parameters of the PE fluid. TMR-N2™ was able to bring water levels to the range of 200– 500ppm, the patch weight was reduced well below the target of 0.0040 g/50mL via ECR™, acid number was reduced to the target value of 0.10mgKOH/g by the ICB™ technology, and resistivity was increased above the condemning limit of 5 Gohm·cm with the help of both the ECR™ and ICB™, successively.

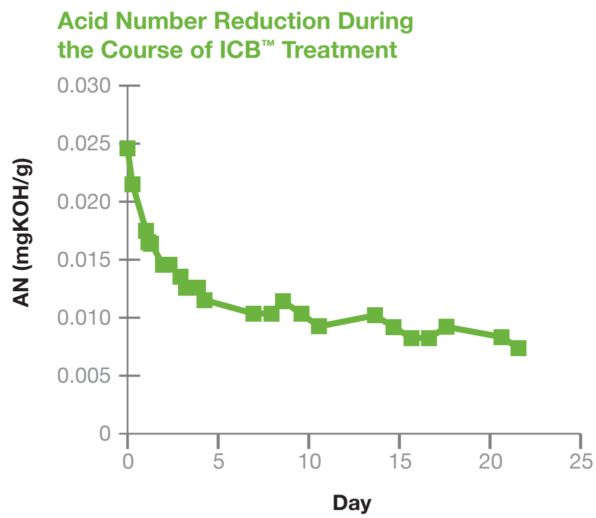

Fig. 5

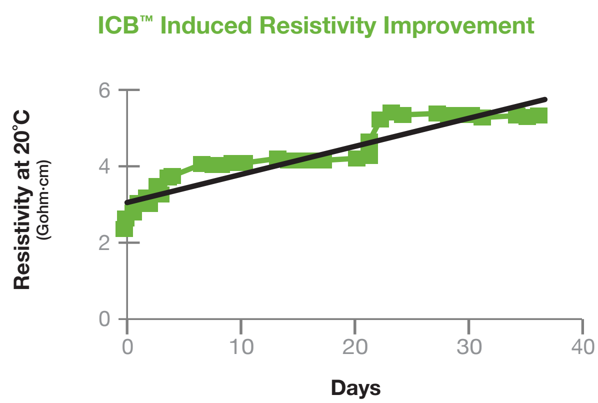

Fig. 6

Table 2: EHC Fluid Condition and Targets

FLUID PROPERTY	INITIAL VALUE	TARGET VALUE	ENDING VALUE
Water (ASTM D7546)	8672.2 ppm H_2O	200-500 ppm	242 ppm
Patch Weight (Mod. ASTM 4898)	0.0277 g/50 mL	<.004 g/50 ml	0.0012 g/50 ml
Acid Number (ASTM D664)	0.17 mgKOH/g	<0.10 mgKOH/g	0.09 mgKOH/g
Resistivity at 20C (ASTM 1169)	3.52 Gohm·cm	>10 Gohm-cm	24.31 Gohm-cm
Deposition Tendency	Heavy deposition	no visible deposition	No visible deposition

** ICB™ further reduced patch weight to 0.0004 g/50mL from 0.0009 g/50mL after ECR™ termination*

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Case Study #3

Fluid Type: Fyrquel EHC

BACKGROUND

In this example, a contaminated phosphate ester based EHC fluid was assessed and cleaned using ICB™. Starting fluid conditions and improvements are detailed below.

RESULTS

Acid Concentration Reduction Via ICB™ "A" Treatment

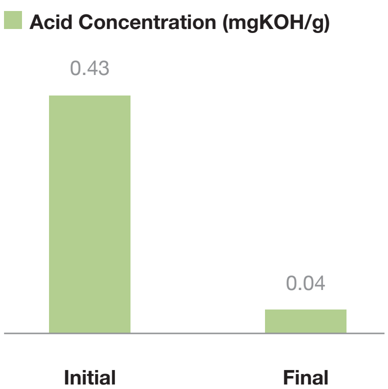

Fig. 1

Resistivity Enehancement Via ICB™ "A" Treatment

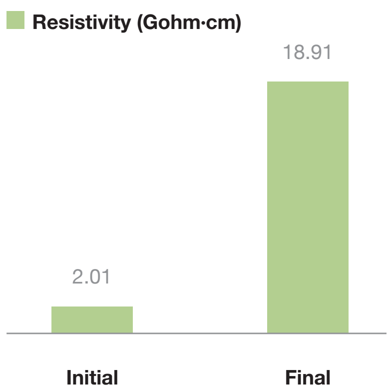

Fig. 2

Patch Weight Decline Via ICB™ "A" Treatment

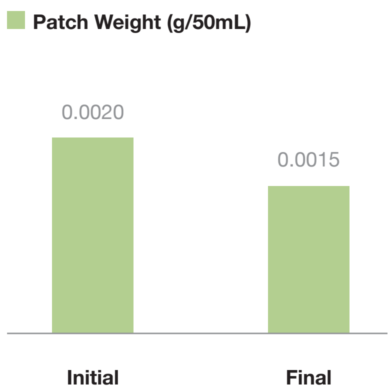

Fig. 3

DISCUSSION

The ICB™ "A" treatment proved to be very successful.

Substantial reductions in acid number were achieved, down to within the new oil spec of the fluid (0.05 mg KOH/g). There was a 91% decrease in AN (ASTM D664), as it went from 0.43 mg KOH/g to 0.04 mg KOH/g. A fluid's resistivity (ASTM D1169) is a measurement of the contamination that is present in the oil. A high resistivity is indicative of low content of free ions in the oil. The condemning limit for resistivity has been set to 10 GΩ·cm by the fluid manufacturer. Initially, unit 2 was below this limit with an initial resistivity of 2.01 GΩ·cm. Upon ICB™ "A" treatment, unit 2 saw an astronomical increase of 841 % as it rose to 18.91 GΩ·cm. The patch weight (measured according to a modified version of ASTM D7843) is a combination of unclassified dissolved impurities and fine particulate (including carbon). The patch weight was already below the target of 0.0040 g/50mL; however, it also saw a 25 % decrease to 0.0015 g/50mL.

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EHC Fluid Recovery
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Case Study #4

Fluid Type: Castrol Anvol PE 46 XC

BACKGROUND

In this example,2 different phosphate ester based EHC fluid reservoirs were assessed and cleaned using ICB™. Starting fluid conditions and improvements are detailed below.

RESULTS

Acid Concentration Reduction Via ICB™ "A" Treatment (mgKOH/g)

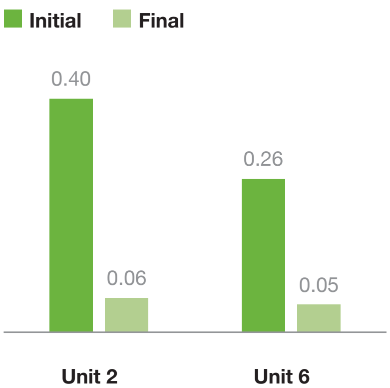

Fig. 1

Resistivity Enhancement Via ICB™ "A" Treatment (Gohm·cm)

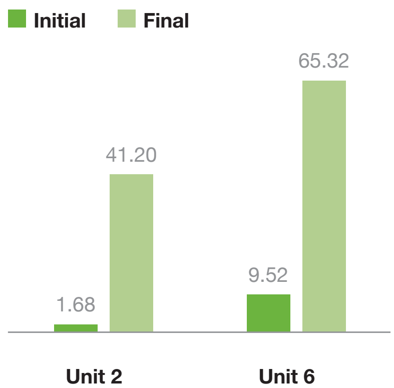

Fig. 2

Patch Weight Decline Via ICB™ "A" Treatment (g/50mL)

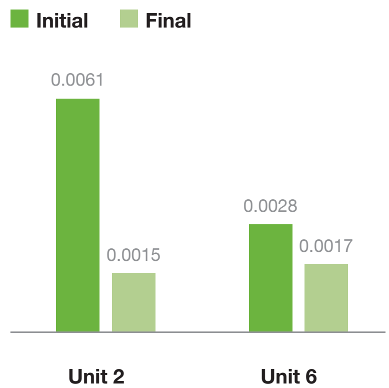

Fig. 3

DISCUSSION

Both units saw substantial reductions of acid number, down to within the new oil spec of the fluid. Unit 2 saw an 85% decrease in acid number while an 81% decrease was noted in Unit 6. The condemning limit for a fluid's resistivity is set to 5.0 GΩ·cm by the fluid manufacturer. Upon ICB™ "A" treatment, unit 2 saw an astronomical increase of 2352 % as it rose to 41.20 GΩ·cm. Unit 6 also saw an exceptional increase as it climbed by 586 % to 65.32 GΩ·cm. The patch weight of unit 6 decrease by 39% to 0.0017 g/50mL. Unit 2 patch weight decreased by 75% to 0.0017 g/50mL.

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Case Study #5

Fluid Type: Fyrquel EHC

BACKGROUND

The client has recently experienced a problem with a plugged pencil filter within their EHC system.. While the fluid sample from EHC 2 was found to be in reasonably good condition, that from EHC 1 had a slightly elevated acid number and patch weight. Moreover, solvent extraction tests demonstrated the presence of a brown sludge consistent in appearance with that responsible for the plugged filter. ICB was utilized to clean this fluid, initial assessment and results are provided below.

RESULTS

Acid Concentration Reduction Via ICB™ "A" Treatment

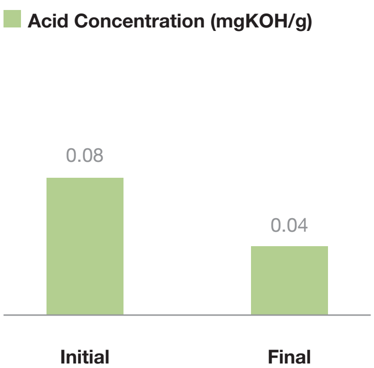

Fig. 1

Resistivity Enhancement Via ICB™ "A" Treatment

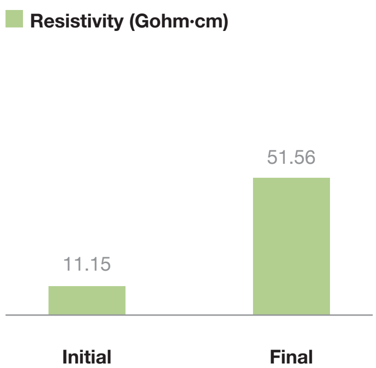

Fig. 2

Patch Weight Decline Via ICB™ "A" Treatment

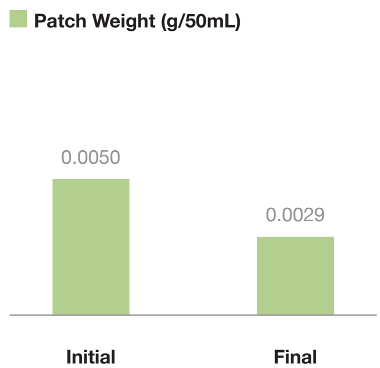

Fig. 3

DISCUSSION

ICB™ "A" treatment of the fluid from EHC 1 proved to be very successful. A substantial reduction in acid number (AN) was observed as the acidity of the fluid decreased by 50% during treatment. Following the ICB™ "A" treatment, the acid number of the fluid was lower than that of new oil of the same brand. The fluid manufacturer recommends that the resistivity of in-service fluids be maintained at a level no lower than 10 GΩ·cm (the condemning limit). Although the fluid from EHC 1 was initially above this limit, ICB™ "A" treatment was significantly improved fluid quality with the fluid's resistivity increasing by 362%.

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The patch weight provides an indication of the level of contaminants including dissolved impurities (sludge) and fine particulates. Initially, the patch weight was above the target value of 0.0040 g/50mL. After ICB™ "A" treatment, it decreased by 42%. The observed reduction in patch weight is primarily due to the removal of dissolved impurities/ sludge present in the oil by ICB™ "A".

To more effectively demonstrate the removal of sludge, a hexane extractions test was performed (Figure 4). The results provide visual evidence that corroborates the observed drop in patch weight. The sludge that was likely responsible for the filter problems encountered on-site is obvious at the bottom of the untreated test tube (left). Following ICB™ "A" treatment, the sludge is no longer present.

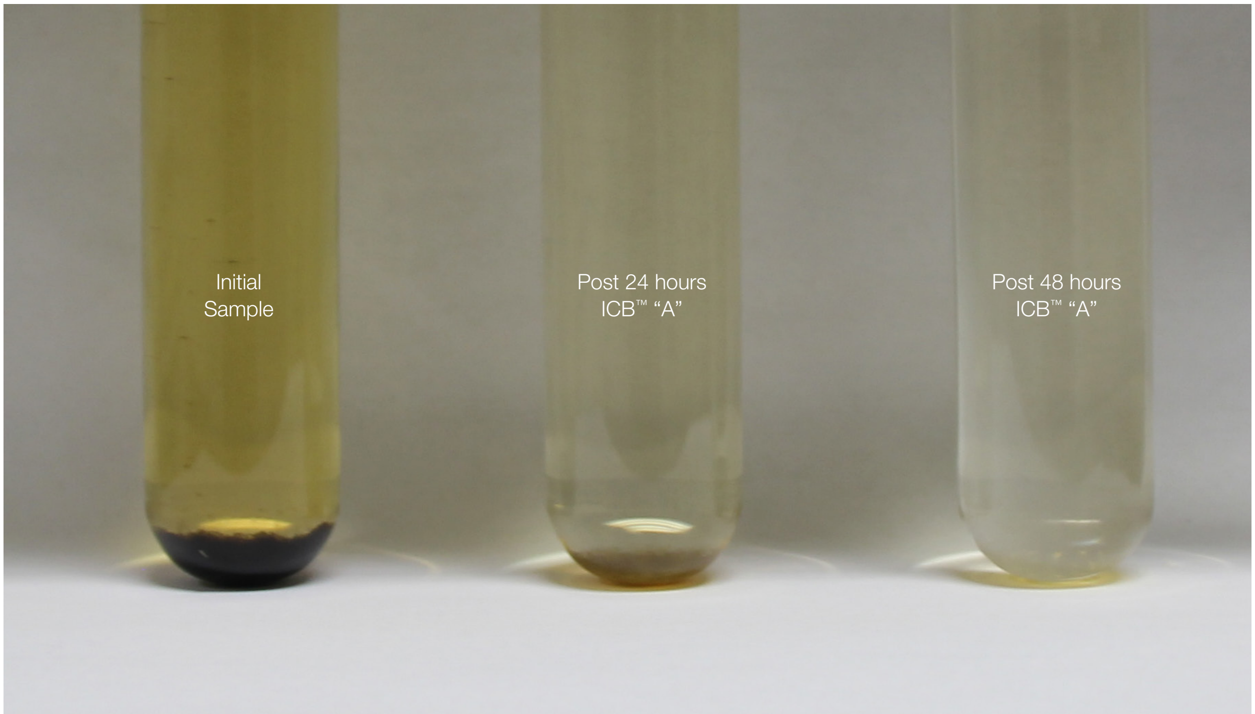

Fig. 4: The hexane extraction test performed upon: the initial sample from EHC 1, followed by the ICB™ "A"-treated fluid.

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Case Study #6

Fluid Type: Fyrquel EHC

BACKGROUND

In this example, a contaminated phosphate ester based EHC fluid was assessed and cleaned using ICB™. Starting fluid conditions and improvements are detailed below.

RESULTS

Acid Concentration Reduction Via ICB™ "A" Treatment

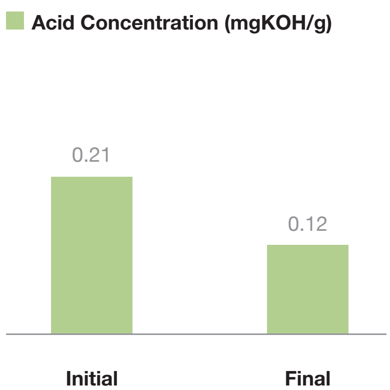

Fig. 1

Resistivity Enhancement Via ICB™ "A" Treatment

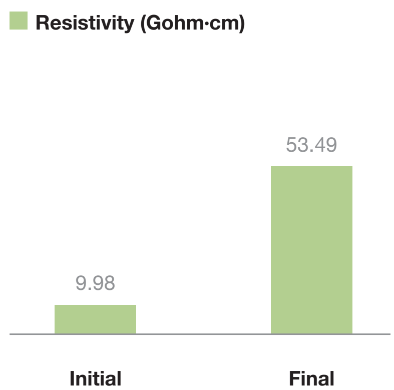

Fig. 2

Patch Weight Decline Via ICB™ "A" Treatment

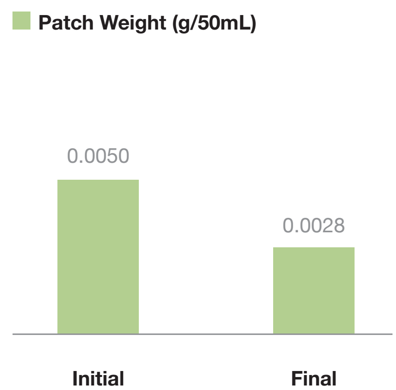

Fig. 3

DISCUSSION

ICB™ "A" treatment was effective in reducing the AN, improving resistivity, and decreasing patch weight. ICB™ "A" was able to reduce the initial 0.21 mg KOH/g acid number by 43%, down to 0.12 mg KOH/g in 48 hours. ICB™ "A" treatments resulted in a significant improvement in the fluid's resistivity as it increased by an impressive 436%. Initially, the patch weight was above the target value of 0.0040 g/50mL. After ICB™ "A" treatment, a decrease of 44% was seen as the patch weight was reduced to 0.0028 g/50mL. This was enough to bring the patch weight to a level that is below the recommended target.

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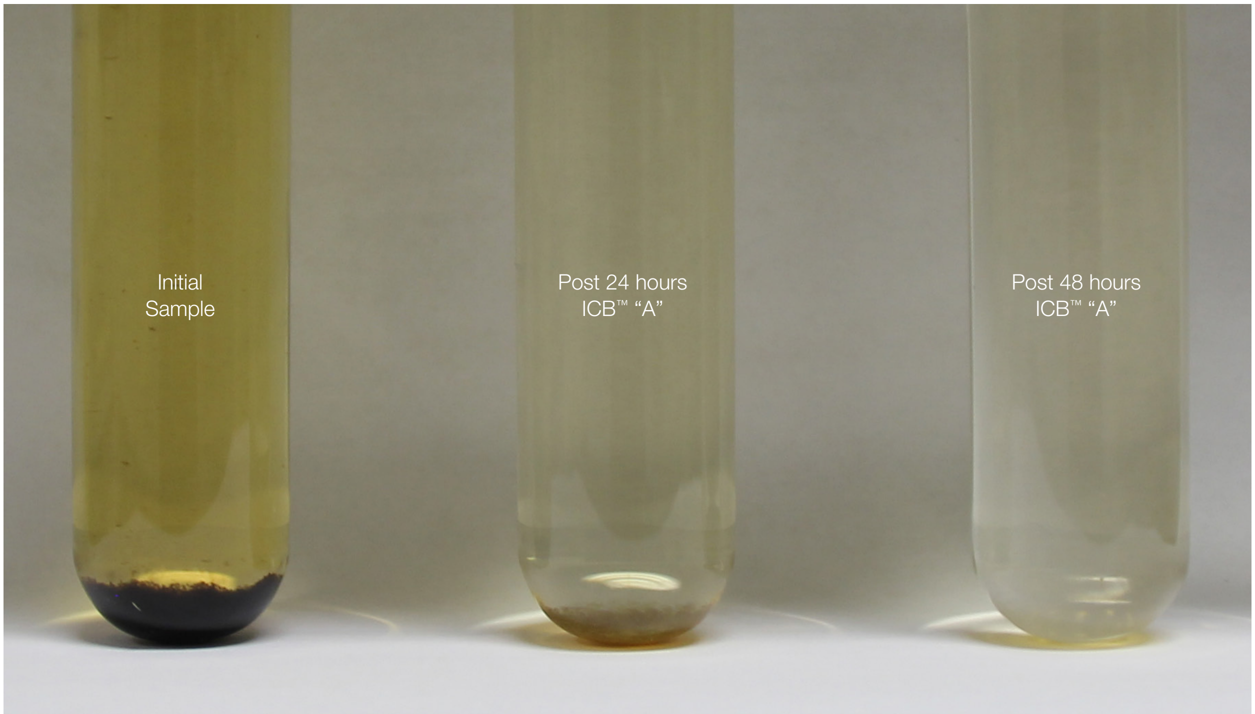

Fig. 4: The hexane extraction test performed upon: the initial sample from EHC 7 followed by the ICB™ "A"-treated fluids.

Visually, the ICB™ "A" treatment was able to reduce the amount of visible sludge seen in the hexane insolubles testing (Figure 4). The results provide visual evidence that corroborates the observed drop in patch weight. Sludge contamination can be clearly observed at the bottom of the untreated test tube (far left in the figure). Following the ICB™ "A" treatment, the sludge was considerably reduced.

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EHC Fluid Recovery
Case Studies using ICB™, TMR™, & ECR™

Case Study #7

Fluid Type: Fyrquel EHC

BACKGROUND

In this example, 2 different phosphate ester based EHC fluid reservoirs were assessed and cleaned using ICB™. Starting fluid conditions and improvements are detailed below.

RESULTS AND DISCUSSION

ICB "C" media was used in this situation as the starting acid numbers were very high (>0.50) The reductions observed were (83% and 85%, respectively). ICB increased fluid resistivity values significantly (165% and 237% respectively).

Acid Concentration Reduction Via ICB™ "C" Treatment (mgKOH/g)

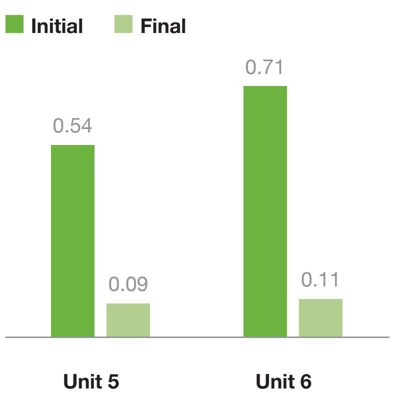

Fig. 1

Resistivity Enhancement Via ICB™ "C" Treatment (Gohm·cm)

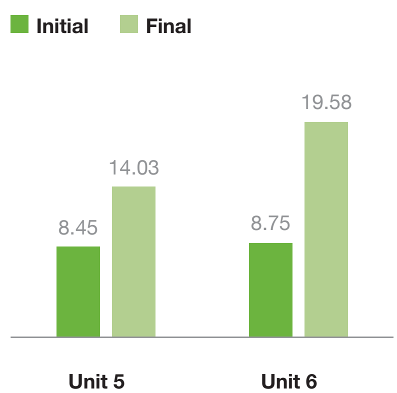

Fig. 2

ADDITIONAL RESOURCES AND INFORMATION

Phosphate Ester White Paper

EHC Fluid Resistivity White Paper

ICB™ Filter Element Upgrades

TMR™-N2 Total Moisture Removal

ECR™ For EHC Application

EHC Case Studies using ICB™, ECR™, TMR™-N2

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