EPT
CLEAN OIL

LUBRICANT CHEMISTRY MANAGEMENT

Case Studies: **VOL 1**

EHC Fluid Recovery

Studies using ICB®, TMR® N_2 & ECR®

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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 Clean Oil's three core purification technologies: TMR® N_2, 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 N_2 on PE fluid

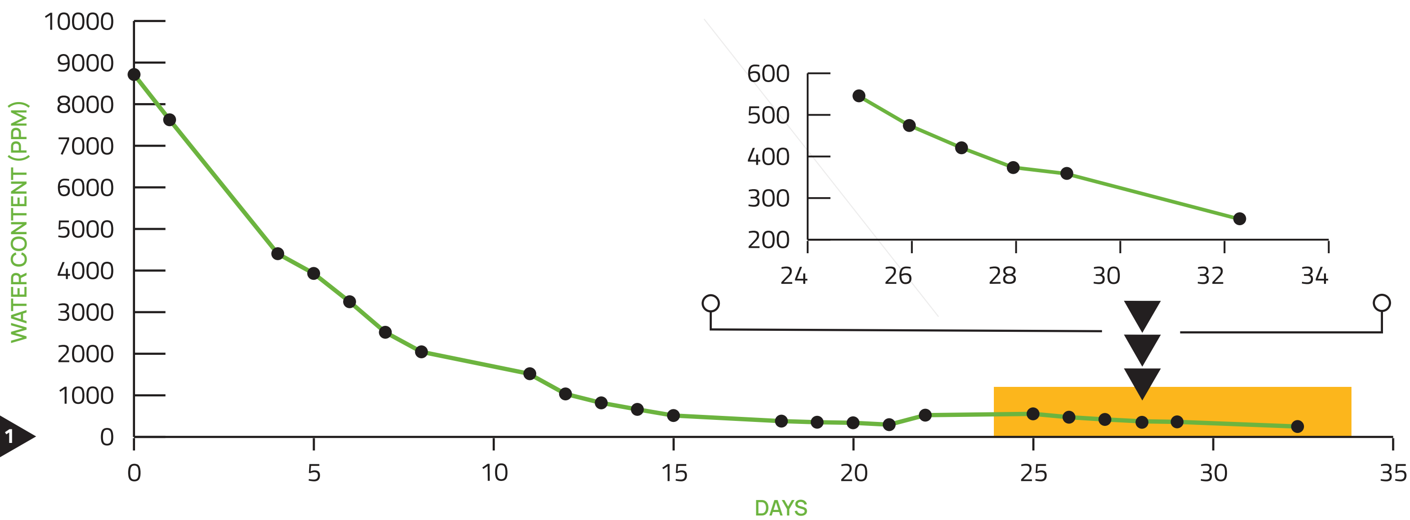

Fig. 1

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TMR N_2 INSTALLATION

When cleaning or restoring EHC fluid, water removal is always the first priority. EPT Clean Oil's TMR N_2 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 N_2 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 Clean Oil'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%.

Patch Weight Reduction Following ECR Installation

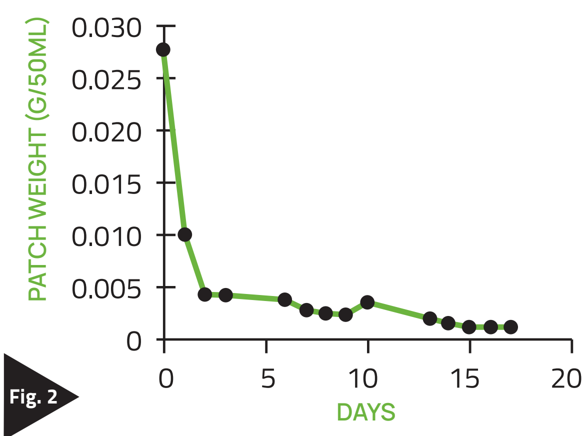

Fig. 2

Fig. 5

Resistivity Improvement During ECR Treatment

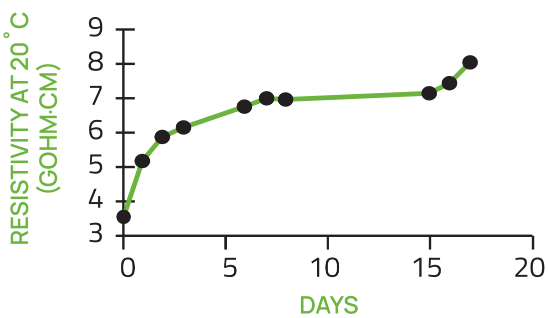

Fig. 4

CASE STUDY: 1...

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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

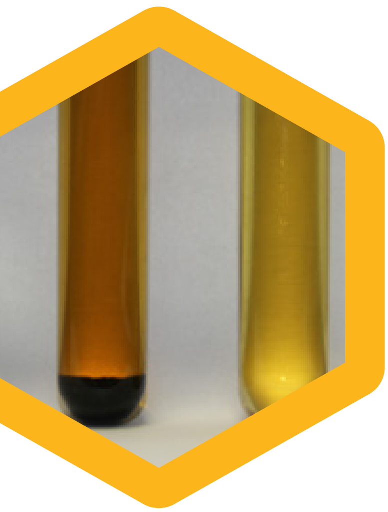
While Fuller's Earth and Selexsorb® have been widely used in the past as acid removal filters in phosphate ester based EHC fluid applications, an entirely new level of EHC fluid purification is available through the use of ICB.

ICB is a patented ion exchange product developed by EPT Clean Oil 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®**



ICB Induced Resistivity Improvement

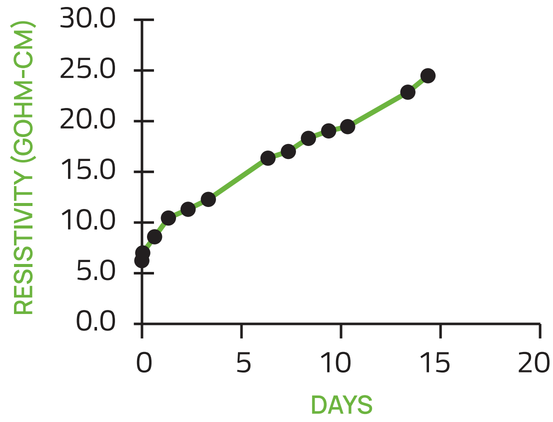


Fig. 6

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

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CASE STUDY: 1...

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SUMMARY

Overall, EPT Clean Oil'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.

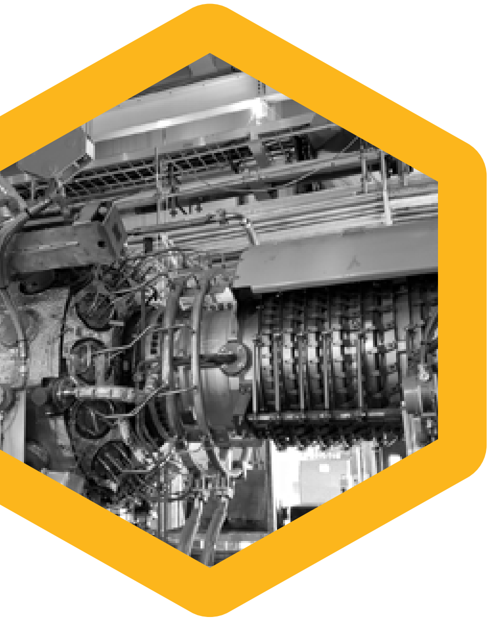
TABLE 2: EHC FLUID CONDITION AND TARGETS

Fluid Property	Initial Value	Target Value	Ending Value
water (ASTM D7546)	**8672.2 ppm**	**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 20°C (ASTM 1169)	3.52 Gohm-cm	>10 Gohm-cm	24.31 Gohm-cm
deposition tendency	**heavy deposition**	**no visible deposition**	**no visible deposition**

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 EPT Clean Oil's 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 (200–500 ppm) 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).

TMR N_2 IMPLEMENTATION

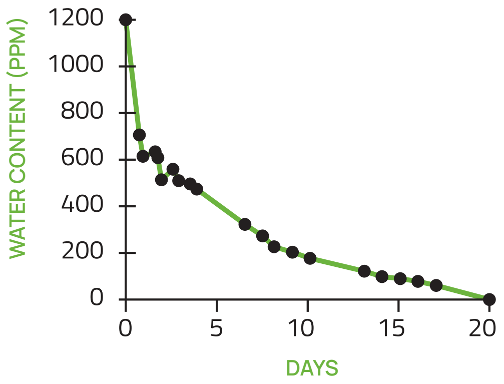
The TMR N_2 was used to lower the water content in the oil. With water levels as high as 1200 ppm, it took just over a week to reduce it to an ECR friendly level (about 500 ppm). The effectiveness of TMR is clearly illustrated in **Figure 1;** we can see that at moderately elevated levels of water, TMR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

TABLE 1: INITIAL CONDITION OF THE FLUID "AS IS"

FLUID PROPERTY	INITIAL VALUE
water content (ASTM D7546)	1213.0 ppm
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

Water Content During the Use of TMR N_2 on PE Fluid

Fig. 1



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CASE STUDY: 2...

ECR INSTALLATION

EPT Clean Oil'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. 3

Patch Weight Reduction Following ECR Installation

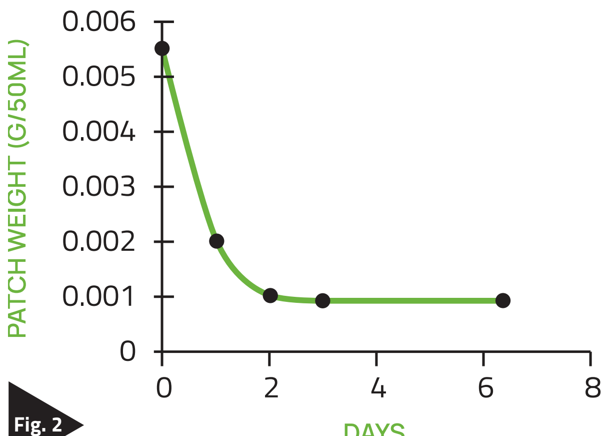

Fig. 2

Resistivity Improvement During ECR Treatment

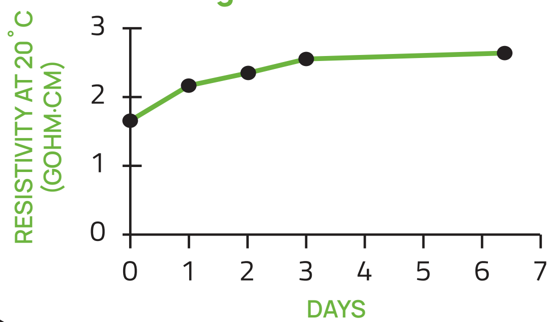

Fig. 4

CASE STUDY: 2...

ICB TREATMENT

EPT Clean Oil'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 0.10 mgKOH/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 Clean Oil's three technologies were able to fully restore all the parameters of the PE fluid. TMR N_2 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 0.10 mgKOH/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.

Acid Number Reduction During the Course of ICB Treatment

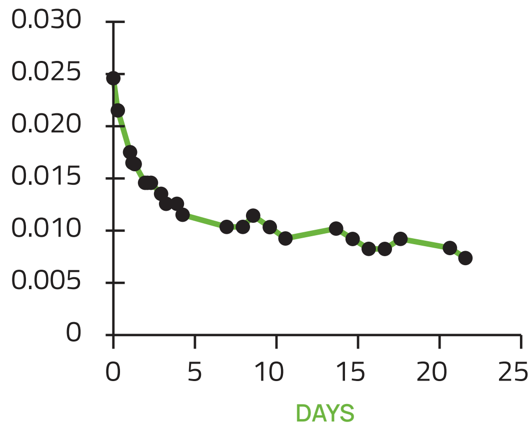

Fig. 5

ICB Induced Resistivity Improvement

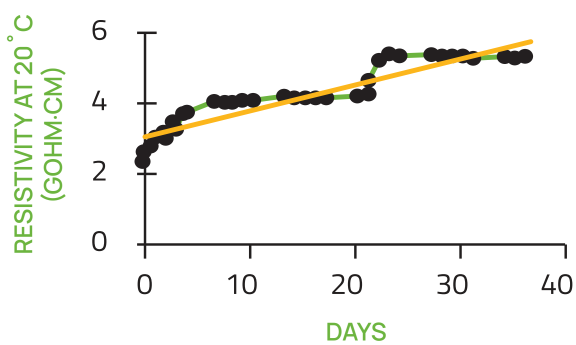

Fig. 6

TABLE 2: EHC FLUID CONDITION AND TARGETS

FLUID PROPERTY	INITIAL VALUE	TARGET VALUE	ENDING VALUE
water (ASTM D7546)	8672.2 ppm	200-500 ppm	242 ppm
patch weight (mod. ASTM 4898)	0.0277 g/50 ml	<.004 g/50 ml	0.0012 g/50 ml
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deposition tendency	heavy deposition	no visible deposition	no visible deposition

Fig. 7

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 FRF Treatment

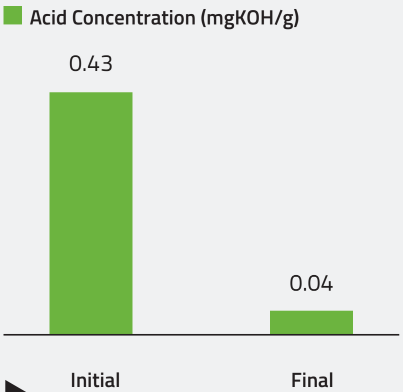

Fig. 1

Resistivity Enhancement Via ICB FRF Treatment

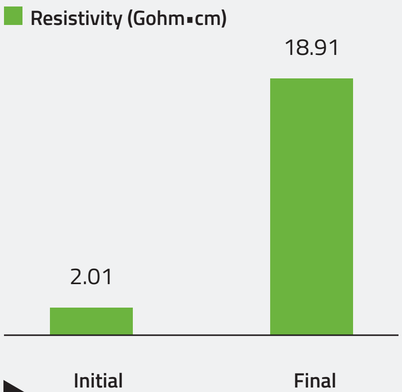

Fig. 2

Patch Weight Decline Via ICB FRF Treatment

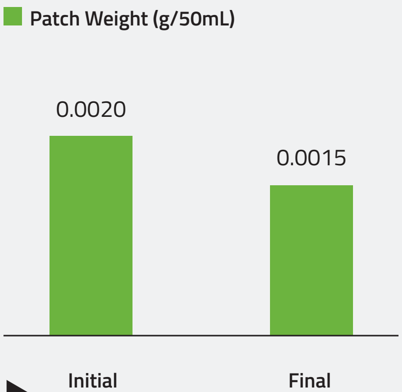

Fig. 3

DISCUSSION

The ICB FRF 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 Gohm-cm by the fluid manufacturer. Initially, unit 2 was below this limit with an initial resistivity of 2.01 Gohm-cm. Upon ICB FRF treatment, unit 2 saw an astronomical increase of 841 % as it rose to 18.91 Gohm-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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