EXTRUSION PERFORMANCE FLUIDS - CRUCIAL IN MAINTAINING WATER-COOLED EXTRUDER EFFICIENCIES

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Abstract

Many manufacturers of water-cooled extrusion equipment typically recommend that either distilled water or properly-treated water [1,2] be used to control barrel zone heater/cooler temperatures. While many industrial water treatment professionals treat and maintain cooling towers, chill rolls and other Utility Water Systems in extrusion plants, few, if any, have attempted to solve the corrosion, fouling and mineral deposition issues typically experienced in extruder barrel cooling systems (Process Water Systems).

This paper summarizes our experiences over the past fourteen years developing and successfully applying Extrusion Performance Fluids (EPF) as safe and effective coolants in water-cooled extrusion applications. Key documented case studies and simple extrusion maintenance procedures will be discussed which form the basis for a pending US Patent [3] on EPF and its associated technologies.

Extrusion Water Management

The successful and continuous operation of water-cooled extrusion equipment has associated with it five key water management operational objectives. These objectives are virtually identical to those industrial water treatment professionals recommend for virtually all cooling water systems [4]. From an extrusion perspective they include:

- Maintaining optimum zone temperatures.
- Preventing system corrosion.
- Preventing mineral deposition and fouling.
- Eliminating unscheduled down-time.
- Extending equipment life.

Even though the majority of water-cooled extruder components are manufactured with corrosion resistant alloyed steels, the high surface temperatures encountered in zone heater/coolers and the galvanic couples existing between two or more dissimilar metals within the system contribute to potentially very serious corrosion issues. In addition, the metallic corrosion products that are formed foul the small diameter zone heater/cooler water passages, the zone flow regulating valves, and the supply/return hoses. Many water-cooled extrusion metallurgies have been tabulated by their relative cathodic or anodic behaviors in an aqueous environment [4].

Water Qualities

Water quality is a vital issue in the operation of water-cooled extruders. Untreated and Conventionally Treated Raw Waters will almost always lead to unwanted mineral and/or chemical deposit accumulations in the cooling passages of zone heater/coolers. Case Study I documents this deposition problem. In addition, under-deposit corrosion can develop as a consequence of the deposit formation. Zeolite Softened Waters pose a very serious threat due to their enhanced ability to conduct galvanic corrosion currents and their inherent corrosivity. Distilled, Deionized, Demineralized, and other Unbuffered, High Purity Waters often contribute to system corrosion and subsequent component failure. Distilled water qualities vary considerably, some of which could contain sufficient dissolved solids and be fairly conductive for galvanic corrosion currents. Some high purity water qualities are listed in Table 1.

Table 1. Pure Water Specific Conductance's Versus Dissolved Solids Concentrations.

	µmhos/cm	**ppm**
USP Distilled	300,000	3.5
3X Distilled	1,000,000	0.5
Demineralized	18,000,000	0.03
Theoretical	26,000,000	0.02

Water Issues

In most water-cooled extruders using distilled or softened waters as the heat transfer fluid, component corrosion is the most frequently encountered water-related issue. As system corrosion continues the corrosion products that are formed foul narrow water passages, deposit on heat transfer surfaces, impede zone valve operations, and accelerate corrosion due to their physically abrasive action on softer metal surfaces such as those of brass and copper. In the pitting corrosion of mild steel it has been estimated that the volume of iron oxide corrosion products produced is approximately seventeen times the volume of the metal lost. A ⅜" diameter stainless steel zone inlet coupling plugged with corrosion and mineral deposits illustrates the severity of this issue in water-cooled extrusion equipment (Figures 1 and 2, respectively).

Extruder barrel cooling systems contain a variety of different metals and thus provide viable sites for galvanic corrosion reactions. In addition to corrosion-resistant alloyed steels and nickel alloys, copper, brass, mild steels, and cast iron pump housings, some extruder operators utilize zinc sacrificial anodes in their reservoir tanks to minimize the corrosion processes [1].

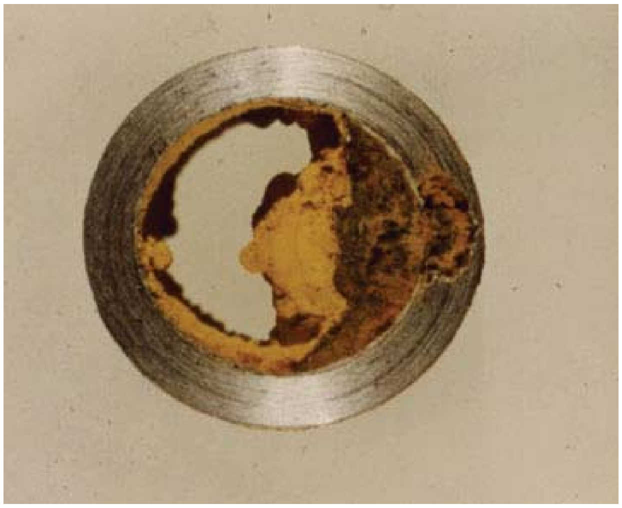

Figure 1. Iron oxide formation in the pitting corrosion of mild steel.

Figure 2. Plugged extruder ⅜ inch zone inlet coupling.

In many instances when critical extruder components fail, less corrosion resistant replacement parts are used in order to minimize downtime. Unfortunately, the more anodic nature of these parts causes them to corrode and fail at even faster rates, leading to additional system fouling, more premature part failures, and reoccurring unscheduled outages. While many alloyed steel components can be expensive, their availability in extrusion plant maintenance shops is recommended.

Some extrusion plants utilize untreated raw waters as barrel coolants. Invariably they experience frequent heater/cooler failures due to hard water mineral deposition on the heat transfer surfaces. Usually an inventory of heater/coolers is maintained in their maintenance shops to minimize downtime while repairs are made. Zone heater/cooler failures become predictable and are often routinely replaced. The costs associated with these maintenance practices becomes a predictable expense item in the extrusion department's annual operational budget.

Conventional Water Treatment Coolants

Case Study I. A large specialty chemical manufacturer operated two Werner and Pfleiderer twin 91.8-mm diameter screw water-cooled extruders in the manufacturer of thin fibers of grafted thermoplastic polyolefin heat-seal coatings for use as adhesives. Each extruder had twelve zones with the fifth zone reaching the highest operational temperature of approximately 580°F. Initially demineralized water was utilized as the zone coolant (Figure 3), often being supplied to the zones at temperatures between 165 to 185°F from the system's water reservoir tank.

Figure 3. Demineralized water extruder barrel coolant.

The barrel coolant water reservoir tank, supply and return manifolds, and each zone heater/cooler section was carefully flushed with an organic acid-based cleaner followed by repeated flushes with demineralized water until all system debris and cleaning agents were removed. The system was refilled with fresh demineralized water and charged with a conventional closed system multi-metal corrosion inhibitor package. The extruder was placed back into service and sampled daily to track treated water total dissolved solids and inhibitor treatment levels.

At the end of about two weeks of operation, both the treatment level and the inhibitor residual concentrations dropped considerably. On the seventeenth day of operation a second application of the treatment was made, with a corresponding spike in dissolved solids and treatment residuals, only to again be followed by a gradual decline in each over the next ten days (Figure 4).

The consistent and gradual loss of treatment additives in the barrel cooling water indicated possible deposition on the interior surfaces of the cooling water coils embedded in the zone heater/coolers. In addition, there were repeatedly variations in demineralized water qualities being provided throughout the plant, as well as the absence of a method to add inhibitors in proportion to system makeup water additions. Establishing such a program would require sophisticated chemical feed equipment as well as frequent in-plant sampling and testing of cooling water samples.

The treatment of water-cooled extruder barrel cooling water systems with conventional water management approaches was abandoned in favor of an all-organic chemistry treatment approach. Those chemistries have been refined and are the basis for a Patent application filed with the U.S. Patent and Trademark Office [3].

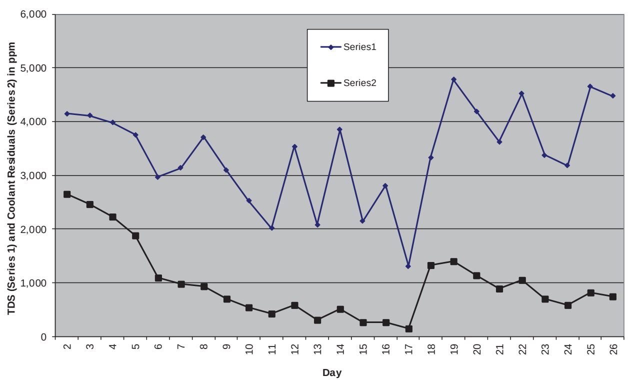

Figure 4. Conventionally treated extruder barrel coolant.

Distilled Water Extruder Coolants

Case Study II. A new sheet extrusion and thermoforming facility with four single screw water-cooled co-extrusion lines, was commissioned using commercially available distilled water as the barrel zone coolant. System metallurgies were similar to those previously noted.

Seven months after plant start-up every barrel cooling system was plagued with excessive corrosion and particulate metal oxide deposition in the zone cooling water passages. In addition, zone cooling water regulator valve operation was erratic and unreliable, and continuous recirculating pump seal failures resulted in leaks and interrupted production. The on-going parts replacements, the unscheduled outages, and the frequent system restorations were very costly.

An initial investigation confirmed the obvious: excessive metal corrosion was occurring throughout the cooling water systems. Deposits from two systems were analyzed and found to contain predominantly metallic oxide corrosion products (Table 2). Coolants from both lines were also analyzed and found to contain acidic pHs and significant concentrations of iron and chloride salts (Table 3). As anticipated, the alloyed metal zone barrel cooling water passages appeared to be less affected by the corrosive environment as evidenced by the virtual absence of nickel and chromium in the coolants. Unexpectedly, constituents of some inorganic salts typically present in raw waters were found in both the system deposits and the distilled water coolants.

Table 2. Elemental Analysis of Water-Cooled Extrusion Deposits (%).

	Line 1	Line 2
Iron (as Fe)	71.2	78.0
Copper (as Cu)	5.9	0.0
Zinc (as Zn)	3.7	5.3
Oxygen (as O)	17.8	13.5
Silica (as Si)	1.0	1.2
Phosphorus (as P)	0.4	0.2
Sodium (as Na)	0.0	1.8

Table 3. Water-Cooled Extruder Coolant Analyses (ppm).

	Line 1	Line 2
pH	5.22	4.54
Chloride	21	3
Chromium	0	0
Iron	103	790
Nickel	0.32	0.70

Corrosion in high temperature, mixed metal, pure water systems can be difficult to control. In the presence of very small concentrations of ionic impurities, galvanic corrosion currents can be sufficient to cause very serious metal corrosion. Both the chloride content and the acidic pH's of the coolants were sufficient enough to cause the serious corrosion observed.

To restore these systems to optimum operating condition, each extruder cooling water system was thoroughly cleaned and flushed with a proprietary organic-based chemical descaler, followed by several flushes with tap water, and concluding with at least one high-purity water flush. After each system was cleaned following this procedure, it was charged with Extrusion Performance Fluid, a water-based, all-organic corrosion and deposit inhibition coolant. Typical 'before-and-after' coolant clarity is illustrated in Figure 5.

During the next few weeks of production, pump and system auxiliary component replacements ceased to be the weekly tasks that they had been for the first seven months of operation. For the next eighteen months there had been zero unscheduled line shutdowns attributed to zone heater/cooler cooling system water-related issues.

Figure 5. Fouled extrusion system distilled water coolant (left) and one maintained with EPF (right).

Extrusion Maintenance and Downtime Costs

Case Study III. A manufacturer of food packaging products operates a 6.0" diameter 36:1 Welex water-cooled extruder in conjunction with three other Welex co-extruders (two 2.5" and one 3.5" diameter). The main extrusion line was installed in 1997. A fifth 4.5" diameter line was installed two years later. The extrusion plant produces HIPS sheet which is then thermoformed into various packaging products.

Demineralized water had been used as the barrel zone heater/cooler cooling water. In a recent twelve month period the plant experienced a total of fifty-four unscheduled extrusion outages due to corroded and failed system components and/or plugged and fouled zone valves and heater/cooled sections. The average outage lasted 4.29-hours for maintenance to repair the system and restore it to service. Total unscheduled extrusion maintenance costs for the twelve month period were $136,000.

In the costs previously identified, no dollar amount had been estimated for lost finished packaging product sales revenues. This particular extrusion/thermoforming plant was designed and planned to operate 24-hpd, 361-dpy. If only the costs for bulk plastic are considered for a 4,000-pph extruded sheet capability, potential lost revenues in material costs alone can exceed hundreds of thousand dollars annually!

Four of the five extrusion lines were restored by following the recommended chemical cleaning procedure briefly described previously. Due to the design of the fifth extruder's reservoir tank, that system has not, as yet, been restored. During the restoration phase of the extrusion lines, each reservoir tank was found to contain approximately two inches of compacted corrosion product debris. Each tank was manually cleaned and most of the system component parts (supply and return hoses, etc.) were replaced with manufacture-specified items. A sample of one of the original extruder coolants is illustrated in Figure 6. Analyses of the aqueous phase of that sample and its suspended solids are tabulated in Tables 4 and 5.

Figure 6. Initial extruder reservoir tank samples.

Table 4. Case Study III coolant analyses before restoration and five weeks after EPF start-up (ppm).

	Before	After
Iron (as Fe)	20.8	2.5
Copper (as Cu)	19.6	0.7
Aluminum (as Al)	0.5	0.8
Zinc (as Zn)	25.7	0.4
Lead (as Pb)	0.6	<0.1
Nickel (as Ni)	0.6	<0.1
Chromium (as Cr)	0.3	<0.1
Manganese (as Mn)	0.2	<0.1
Suspended Solids	~100,000	34.0

Table 5. Case Study III 'before coolant' suspended solids analysis.

	Percent
Iron (as Fe_2O_3)	67.5
Copper (as CuO)	8.3
Aluminum (as Al_2O_3)	6.4
Zinc (as ZnO)	10.3
Lead (as PbO)	0.6
Nickel (as NiO)	0.6
Chromium (as Cr_2O_3)	0.7
Manganese (as MnO)	0.4
Molybdenum (as MoO_3)	0.3

After cleaning and restoration the four extruders were placed back into service. Extrusion Performance Fluid was employed as the sole barrel cooling medium. After approximately five weeks operation each of the restored extruder systems were re-sampled and analyzed, primarily to evaluate the success of the cleaning and restoration procedures. One such analysis is summarized in Table 4 confirming the effectiveness of the cleaning operation.

Four months post cleaning and restoration plant engineering reported that they have had a total of three unscheduled outages of the extrusion equipment compared to an average of eighteen for an equivalent period the year before. The failures were to the older supply and return coolant hoses for which replacement parts were unavailable when the equipment was restored this past summer.

On-going Extruder Maintenance and Reliability

Case Study IV. In 2004 a new Processing Technologies International 6.0" eight zone water-cooled extruder with a 4.0" five zone co-extruder was commissioned to extrude HIPS sheet for a food packaging and thermoforming operation. Extrusion Performance Fluid was used as the start-up coolant in the barrel zone cooling system and throughout the past ten years of operation. Maintenance of the system typically employed a short list of weekly, monthly and quarterly checks. Periodic extruder coolant samples were submitted for analysis to evaluate system corrosion and fouling inhibition. One recent analysis is summarized in Table 6.

Table 6. Case Study IV coolant analysis after ten years utilizing an EPF coolant (ppm).

	ppm
Iron (as Fe)	<0.1
Copper (as Cu)	0.3
Aluminum (as Al)	<0.1
Zinc (as Zn)	0.2
Lead (as Pb)	<0.1
Nickel (as Ni)	<0.1
Chromium (as Cr)	<0.1
Manganese (as Mn)	<0.1
Suspended Solids	<5.0

In stark contrast to the extruders in Case Study III, the extrusion system cited in this case study has not had a single water-related maintenance failure in the ten years that it has been in service! The analytical data summarized in Table 6 strongly collaborates this observation in that there are virtually no corrosion products nor are there any metal oxides suspended within the coolant

The required maintenance for an EPF Coolant-treated barrel cooling water system is typically very minimal. The recommendations summarized in Table 7 should be utilized as a 'maintenance guide'. Also note that if for any reason a barrel coolant does not 'look good' or its origin suspect, samples should be submitted to the Laboratory for evaluation. It is very important to the success of this program that only EPF Coolant is to be used in a given extrusion system.

Table 7. Recommended water-cooled extruder maintenance checks

	Maintenance Tasks
Weekly	Check water reservoir EPF levels.
	Verify zone on-off cycling.
Monthly	All weekly checks.
	Visually check coolant condition.
	Check recirculating pump(s) for seal wear and coolant losses.
	Check all line connecting fittings for leaks.
Quarterly	All monthly checks.
	Examine regulatory valves for operational difficulties.
	Submit coolant samples for Laboratory analysis, if necessary.
Annually	All quarterly checks.
	Inspect and clean water reservoir tank(s).
	Submit all coolant samples for Laboratory analysis.
	If advised, perform a routine annual maintenance flush of barrel cooling system as directed.
	Inspect pump seals for leaks.
	Assess reliability, flow and cleanliness of heat exchanger external cooling water.
	Inspect barrel cooling side of heat exchanger for scale and/or deposition.

Conclusions

- Excessive corrosion and fouling can occur in water-cooled extruders using distilled or other high purity, unbuffered waters as the cooling medium.
- Wide quality variations exist in high purity waters.
- Untreated and conventionally treated raw waters readily deposit inorganic salts in zone heater/coolers, impeding heat transfer and coolant flows.
- Fouled extruder cooling systems can be readily restored to optimum operating conditions using a non-hazardous, organic cleaner.

- Metal corrosion product and scale deposition are virtually eliminated when a water-cooled extruder utilizes an Extrusion Performance Fluid as the system coolant.

- A simple maintenance program based on a chemical cleaning restoration and an Extrusion Performance Fluid application approach insures dependable extruder performance and service, and eliminates downtime due to cooling system corrosion and fouling.

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