Toward Elimination of Cyanide Processes in the Airline Finishing Industry

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United Airlines, like most aerospace repair facilities, used cyanide-based solutions for stripping, cleaning and plating. In May 2001, there was a directive from upper management to remove cyanide from the shop. This paper explains the transition process, replacement products and coordination with vendors and OEM's. United Airlines went from 24,000 pounds of cyanide usage in 2000 to less than 600 pounds of usage in 2004 and is looking at 2006 for total cyanide elimination.

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In May 2001, the Senior Vice-President of Maintenance and Engineering directed the Plate Shop personnel to remove cyanide-bearing solutions from the shop because it would make for a safer workplace, reduce the risk of a toxic spill, and be more environmentally friendly. He wanted it all to be removed by January 2003, but that was not possible. However, about 97% of the cyanide was removed during 2003.

Elimination of cyanide was not an easy task. I will go down each process where cyanide was being used and detail the transition flow.

Cleaning

We used cyanide cleaners at room temperature because we wax mask all the parts and the wax starts getting soft at 135 degrees F and melts at 180 degrees F. We had 4 tanks of cyanide-based electrocleaners for pre-plate preparation. Cyanide did a great job of cleaning at room temperature and the operators were accustomed to very quick, smut free cleaning. In 1993, non-cyanide cleaners were tried unsuccessfully. The shop experienced a huge amount of parts with adhesion problems attributed to poor cleaning. As a result, there was much skepticism when the topic of non-cyanide cleaners was considered.

Many vendors suggested their cleaning products would work well, but when they were told the cleaners had to work below 130 degrees F, they backed off. Our engine supplier had run some experiments on low temperature cleaning after nickel strip prior to nickel plate. I used that as a starting point and set up one tank with an alkaline cleaner at 10-14% concentration and 110-130 degrees F. We extended the time to 3-5 minutes (from the usual 2-3 minutes) and added a light pumice scrub after elctrocleaning. We also extended the time to 1-2 minutes (from the usual (30-60 seconds) in the acid pickle prior to plate or strike to remove any smut that might have built up during the electrocleaning process. With some retraining and closer monitoring, the operators found that the cleaners performed well.

GRAPH 1: CYANIDE USE IN ELECTROCLEANERS BY YEAR

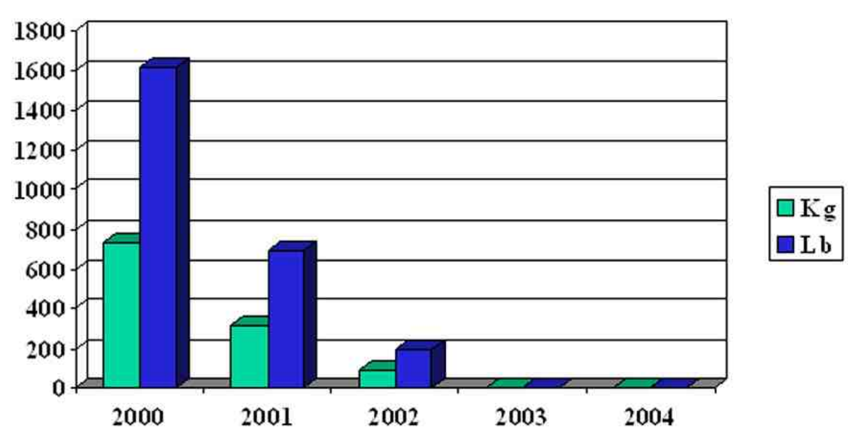

TABLE 1: CYANIDE USE IN ELECTROCLEANERS BY YEAR KG (LB)

YEAR	2000	2001	2002	2003	2004
TANK 95	61(135)	161(355)	50(110)	0	0
TANK 117	61(135)	118(260)	27(60)	0	0
TANK 140	567(1,250)	29.5(65)	7(15)	0	0
TANK 166	45(100)	4.5(10)	4.5(10)	0	0
TOTAL	**734(1,620)**	**313(690)**	**88.5(195)**	**0**	**0**

Early in 2002, we put in our first alkaline cleaner bath and as the year progressed, we switched all the cleaners to alkaline. The cleaner used is classified as a descaler and used in our other cleaning applications.

The OEM's we work with have accepted our use of the cleaner. This cleaner was on their approved products list anyway and we were just using it under slightly different conditions.

Stripping

Our biggest use of cyanide was stripping. We were stripping nickel and metal spray in two very large tanks that we alternately dumped about every six weeks. We also had a cyanide silver strip tank. The cyanide-based stripper was made up with one pound per gallon of sodium cyanide. It was fast and versatile. Any replacement products had to perform well as cycle time is a big factor. Also back in 1993, attempts to replace cyanide strippers were unsuccessful. The change lasted about six months before they went back to cyanide. The non-cyanide solution was slower and kept getting contaminated which required frequent dumping.

Potential replacement products for nickel stripping were studied to better meet cycle time, versatility, ease of use and loading. Before determining which replacement product, I made a process change. When cyanide was used, the parts would go directly into the strip tanks and chemistry was used for the total 10-15 mil thick plating removal. It would be a whole lot more effective to pre-machine to parent metal or to 1-2 mils of plating before parts were chemically stripped. This was a huge success. Although we could do only one part per machine versus many parts in one strip tank, the effective time and cost were less by machining than by stripping. So rather than dumping every 8 weeks, the replacement nickel stripper lasted almost a year before it needed to be dumped. The replacement product was a non-cyanide version from the same vendor as the cyanide product.

The product was a bit slower than its cyanide counterpart as it loaded up with nickel, but since the plate thickness was so much less, the cycle time was not compromised. Although this nickel stripper is being used by other aircraft maintenance facilities, it was not on our aircraft supplier's approved process list. They requested a series of tests for hydrogen embrittlement and base metal

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attack before they would approve it. We verified that there was no attack on base metal and no hydrogen embrittlement problems. Therefore, there is no need for baking after stripping on high strength steel using this product. The vendor had suggested an electrocleaner might be needed for cleanup after stripping, but this has not been necessary.

Contamination issues were addressed by making separate tanks for other stripping applications. Metal spray stripping was the biggest issue for contamination in the past. Our metal spray is mostly tungsten carbide, but can contain chrome and cobalt. These metals would cause the nickel stripper to cease stripping and necessitate dumping. A peroxide based metal spray stripper was chosen that was already approved by our engine supplier. Several strippers were evaluated, but the peroxide based didn't require post stripping treatment and its strip rate satisfied our cycle time requirements. Because the new strippers were sensitive to specific metal contamination, controls were implemented to prevent metal spray parts from being stripped in the nickel stripper. Visual and training aids were introduced to keep parts with chrome, cadmium and silver out of the nickel stripper and to keep parts with nickel, aluminum, cadmium, tin, lead, copper and silver out of the metal spray stripper. Documents were rewritten to specify exactly what stripping chemistry was to be used for what coatings.

Cadmium is stripped with cadmium stripper, which is non-cyanide. Metal spray strip was now non-cyanide and we already had non-cyanide stripper for HVOF (high velocity oxygen fuel) applied coatings. These coatings containing tungsten carbides, chromium carbides, and cobalt, were stripped electrolytically with sodium tartrate and sodium carbonate. We also have nitric acid for nickel, silver, and other specific coatings where appropriate. Silver stripping continued to be cyanide, as approval from our engine supplier for a replacement product was needed. Two potential replacement products were evaluated. The product chosen was faster and longer lasting. The replacement product, which is caustic based, is electrolytic and faster than the cyanide product. Another process change was made in silver plating so the amount of silver being stripped is less.

GRAPH 2: CYANIDE USE FOR STRIPPING BY YEAR

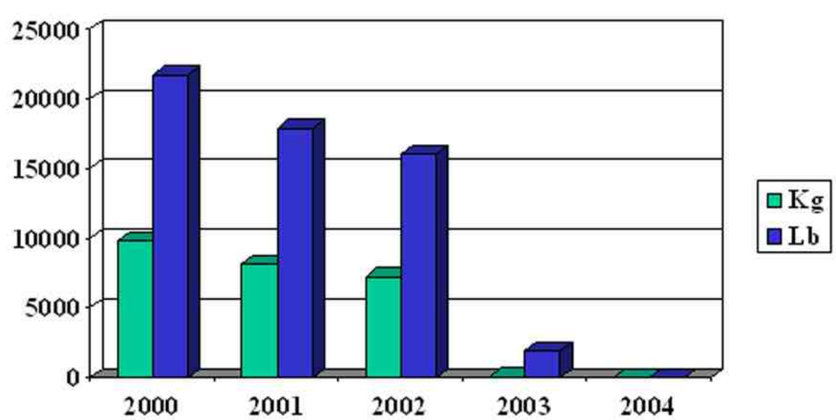

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TABLE 2: CYANIDE USE FOR STRIPPING BY YEAR KG (LB)

Year	2000	2001	2002	2003	2004
Tank 190	0	4,240(9,340)	3,205(7,060)	0	0
Tank 191	5,550(12,225)	3,836(8,450)	4,059(8,940)	885(1,950)	0
Tank 310	3,941(8,680)	0	0	0	0
Tank 165	381(840)	66(145)	27(59)	0	0
TOTAL	**9,872(21,745)**	**8,144(17,935)**	**7,291(16,059)**	**885(1,950)**	**0**

It took a couple years to get the pre-machining in place and all documents changed to reflect the new processes, but all stripping of all coatings was cyanide free early in 2003. All of the non-cyanide strippers have proven to be very cost effective because they last longer and are much cheaper to waste treat.

Plating

We used cyanide for pre-plate processing on aluminum in the zincate and copper strike for aircraft parts. Copper strike is not required for engine parts, but authorization from the engine suppliers to use a non-cyanide zincate was needed. Once that was done, we put in an alkaline copper with a caustic zincate. This change was quite easy, as the processing of parts did not change, only the chemistry. The vendor came out and worked with the operators to assure that their questions were answered and the lab could do the testing. We had one issue of the chemistry of the copper solution dissolving some of the wax from the parts and we had to dump the first bath prematurely. This seems to have resolved itself and the process is working very well. Parts that do not get a copper strike following the zincate, go directly into the nickel sulfamate for a strike before chrome or build up of nickel.

Bright cadmium plating is only done in cyanide solution in the US. We requested the aircraft manufacturer to look at alternatives. They had a formula for zinc-nickel alloy plating that met the requirements for corrosion protection for low strength steel parts. Because of many obstacles, the zinc-nickel bath planned for 2004 is just being made up now. However, the bright cadmium bath was dumped last year in anticipation of the new chemistry and unbright cadmium bath is being used for all cadmium plating requirements. The zinc-nickel has not yet been approved for low strength steel parts with gears, splines or threads or high strength steels over 220,000 pounds per square inch. We are anticipating a release for gears, splines and threads by January 2006.

GRAPH 3: CYANIDE USE IN PLATING PROCESSES BY YEAR

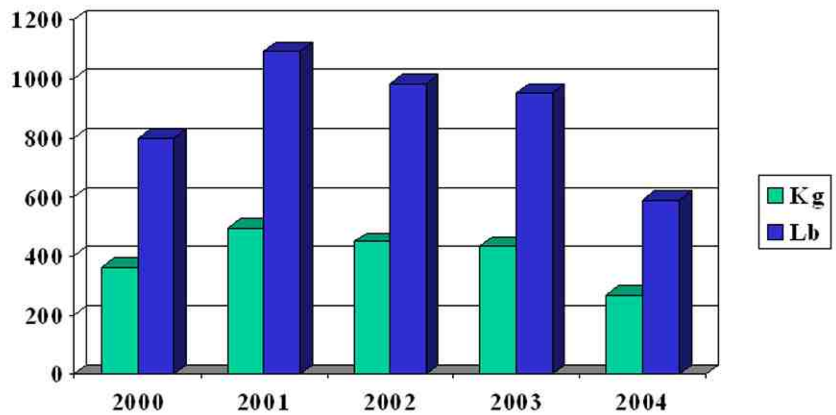

TABLE 3: CYANIDE USE IN PLATING PROCESSES BY YEAR KG (LB)

YEAR	2000	2001	2002	2003	2004
Bright Cd	70(155)	86(190)	100(220)	25(54)	13(28)
Unbright Cd	191(420)	318(700)	236(520)	345(760)	213(470)
Copper	18(39)	13(29)	37(81)	18(40)	0
Ag Strike	55(122)	49(108)	50(111)	30(66)	25(54)
Ag Plate	29(64)	30(65)	24(53)	15(33)	16(35)
TOTAL	**363(800)**	**496(1,092)**	**447(985)**	**433(953)**	**266(587)**

The three cyanide process baths remaining are silver plate, silver strike and unbright cadmium. The engine manufacturer is looking at approving a non-cyanide silver by year-end and the aircraft manufacturer has been working on alternatives to unbright cadmium with a planned date for release early in 2006. All heavy build silver-plated parts were re-evaluated for alternative coatings and many were converted over to nickel or other coatings because non-cyanide silver does not build up well. Some parts that were silver plated were changed to Teflon or Sermetel, depending on the functional application.

Once most of the cyanide was gone, better containment of the remaining cyanide baths was implemented. Of the 3 tanks (out of 13) that are left, two were reduced in size (from 400 gallons to 150 gallons) and the third has additional precautions. We dropped a stainless steel liner tank inside the previous tank for the silver tanks. The unbright cadmium tank had a concrete berm around the base constructed so it would be contained individually and hypochlorite solution can be pumped into the containment. Considering we are in a seismically active area, it is important to address containment.

GRAPH 4: TOTAL CYANIDE USAGE BY YEAR

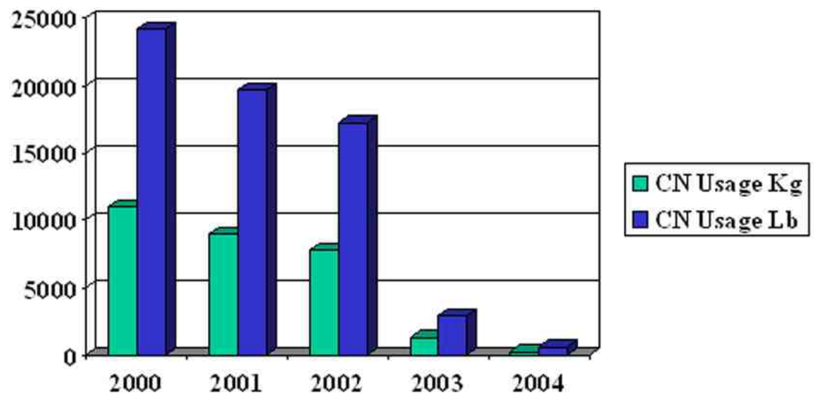

TABLE 4: TOTAL CYANIDE USAGE BY YEAR KG (LB)

YEAR	2000	2001	2002	2003	2004
Cleaning	767(1,690)	313(690)	88.5(195)	0	0
Stripping	9,872(21,745)	8,144(17,935)	7,291(16,059)	885(1,950)	0
Plating	363(800)	496(1,092)	447(985)	433(953)	266(587)
TOTAL	**11,002(24,235)**	**8,953(19,717)**	**7,826.5(17,239)**	**1,318(2,903)**	**266(587)**

Cost

The costs associated with all the process chemistry is the cost of making up the baths, additions made to keep them functioning and the costs of waste treatment.

First, the costs of how much for making up the solutions and how often you dump them. The cyanide nickel strip solution was stripping metal spray and all nickel off the parts and was dumped every eight weeks, so the yearly cost of the stripper was very high. If we had had a separate metal spray stripper and machined off the majority of the nickel prior to chemical stripping, the costs of the cyanide stripper on yearly basis would be comparable. The alkaline cleaners, however, are being dumped more often than the cyanide cleaners were, but their make up costs are very low.

GRAPH 5: MAKE UP COSTS

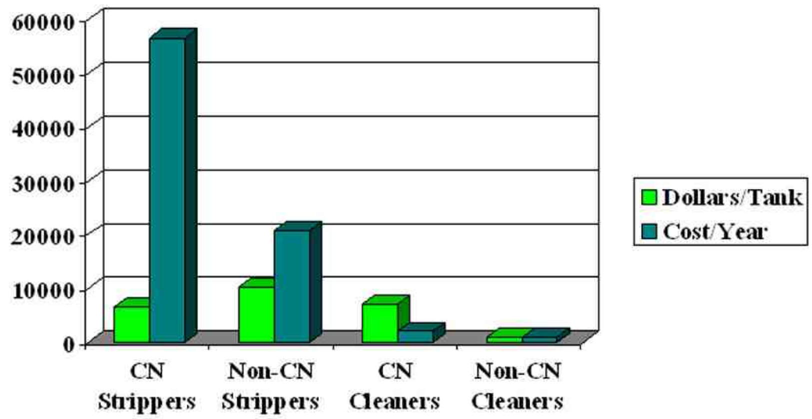

TABLE 5: MAKE UP COSTS PER TANK AND YEAR

	CN Ni Stripper	Non-CN Ni Stripper
Make up per Tank	$6,656	$10,336
Dumps per Year	8.5	2
Make up Costs per Year	$56,575	$20,672
	CN Cleaner	**Non-CN Cleaner**
Make up per Tank	$7,000	$972
Dumps per Year	Every 3 Years	1
Make up Costs per Year	$2,000	$972

The cost savings can also be measured by the cost of waste treating the spent solutions. We send our cyanide containing wastes to an outside vendor for disposal, but do alkaline precipitation with pH adjustment in our shop.

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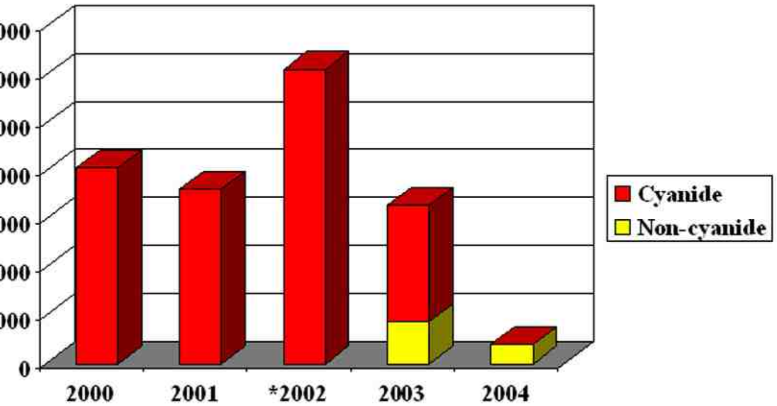
GRAPH 6: OFFSITE WASTE TREATMENT IN GALLONS BY YEAR



***Note higher number in 2002 – reflects gallons dumped due to replacement.**

GRAPH 7: OFFSITE WASTE TREATMENT COSTS IN DOLLARS BY YEAR

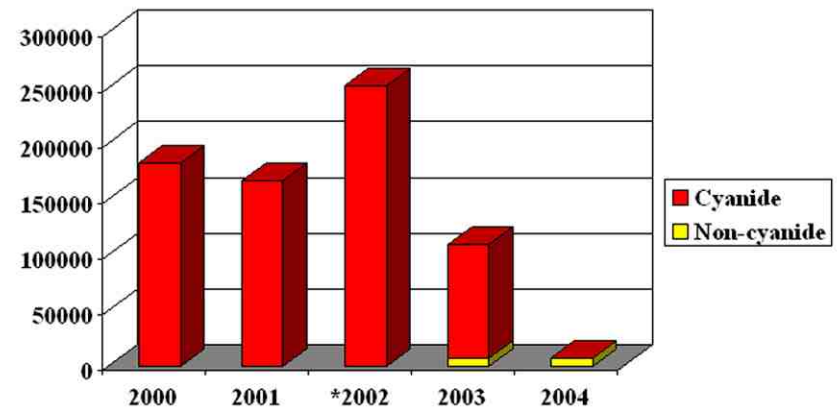


TABLE 6: OFFSITE VENDOR WASTE TREATMENT GALLONS AND COSTS BY YEAR

YEAR	2000	2001	2002	2003	2004
CN gals.	20,4000	18,100	30,600	12,100	-
Dollars	$182,598	$167,025	$252,014	$102,538	-
Non-CN Gals.	-	-	-	4,392	2,025
Dollars	-	-	-	$7,247	$7,025

Since the plating baths are rarely dumped, the make up costs do not really compare in the short run. However, the alkaline copper bath is quite a bit more costly than the cyanide copper to use.

Conclusion:

The change from cyanide to non-cyanide products incur additional expenses associated with stocking the new chemistry, waste treating the old chemistry and tank modifications, such as heaters, venting, liners, etc. The end results are the non-cyanide products cost less to make up, run and waste treat, especially for the stripping and cleaning baths.

I am enthusiastic about the cooperation and support I have received from the staff at United to make these changes. Some changes have been difficult because they require people to do things differently and were previously unsuccessful. However, the people understood the safety aspects of the projects and remained committed to the task/objectives.

We anticipate all cyanide being replaced sometime in 2006. I envision cost effective airplane maintenance without cyanide, providing a safer workplace for the employees and a more friendly environmental impact.