# Color Sorting Aluminum Alloys For Recycling—Part I

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**A quick and inexpensive way to sort samples or scraps of mixed wrought aluminum alloys according to their alloy series has been developed. Chemical treatments are used to produce a unique color for each series. This method can be used on shredded aluminum scrap so that alloys are recycled more efficiently rather than blending the mixture together for castings. Part I investigates the use of acidic and caustic etches for identification and separation of some of the alloy families. Part II next month will report on the use of specific tests to differentiate 5xxx and 6xxx alloys and will summarize a successful overall approach.**

As the use of aluminum and its alloys continues to grow, the ability to recycle and reuse scrapped aluminum alloys becomes more important. Currently, aluminum scrap is often a mixture of alloys, and this mixture is recycled into cast products. Mixed alloy aluminum scrap is used for casting applications because the compositional limits are wider and the tolerance for impurities is higher in cast alloys than in wrought alloys. Castings, therefore, can absorb large quantities of mixed alloy scrap and continue to stay on compositional targets. "Absorption" is a common term used in recycling industries. It is simply the percentage of an alloy (or mixture) that can be used to produce an ingot of another desired composition without exceeding the specified alloy compositional limits.

Mixed alloy scrap has poor absorption into wrought alloys because of stricter compositional limits on the wrought alloys; mixed alloys are therefore not generally recycled into wrought products. Moreover, reclaimed mixed aluminum alloys are unsuitable for anodic finishing. As a result of impurities from recycled alloy mixtures, secondary metal is known to degrade finished surface appearance and quality. Wrought alloys typically are a higher value product than cast alloys because they have more stringent performance requirements that include toughness, formability and/or fatigue property specifications. Meeting these performance targets requires tight control of composition, so more expensive primary aluminum is typically used to make wrought alloys.

If alloys of similar composition (usually synonymous with alloys of like series, such as 2xxx or 6xxx, were sorted and gathered together during the scrapping process, the aluminum scrap would be of much greater value to producers and could be recycled into high value wrought products. Aluminum manufacturers would then be able to use scrap to make wrought alloys and replace high cost primary metal, which is currently used to produce wrought products, with much lower cost scrap metal. Ultimately, the energy savings and economic and environmental benefits would be significant.

Methods currently exist to separate cast and wrought aluminum in a scrap stream. The U.S. Bureau of Mines has developed a thermomechanical separation process capable of separating cast alloys from wrought alloys.[1,2] This process makes use of the low-temperature melting reactions in high silicon aluminum casting alloys. At elevated temperatures where cast alloys are partially melted and wrought alloys are still solid, the scrap mixture is subjected to a mechanical force that causes the cast alloys to break apart, while the wrought alloys remain intact. The broken cast alloy scrap can be separated by its smaller size, using screening.

Unfortunately, there are no commercially available means to effectively and efficiently sort wrought scrap into groups of similar alloy compositions. Because of the poor absorption of the unsorted wrought scrap into wrought alloys, it would still be necessary to reuse the unsorted wrought scrap in castings.

As the use of aluminum grows, the ability of the castings industry to use the mixed recycled metal may become limited. If the use of wrought alloys increases more than the use of cast aluminum alloys, as is projected, failure to separate the scrap wrought alloys into different families will pose recycling problems. Without a solution, the scrap pile of both mixed wrought and cast aluminum alloys or just a mixed pile of wrought alloys that cannot be economically converted into wrought alloys would grow and remain unusable.

## Color Sorting

Aluminum alloys are indistinguishable from each other upon visual inspection or by other simple conventional techniques, such as density and/or eddy currents. The concept proposed here is the use of chemical treatments to produce differing colors on the various alloy compositions for identification and sorting of wrought alloys by alloy family or composition.

Figure 1 is a simplified illustration of an envisioned scrap sorting process. It begins with shredded aluminum scrap. Existing thermomechanical separation technology is used to

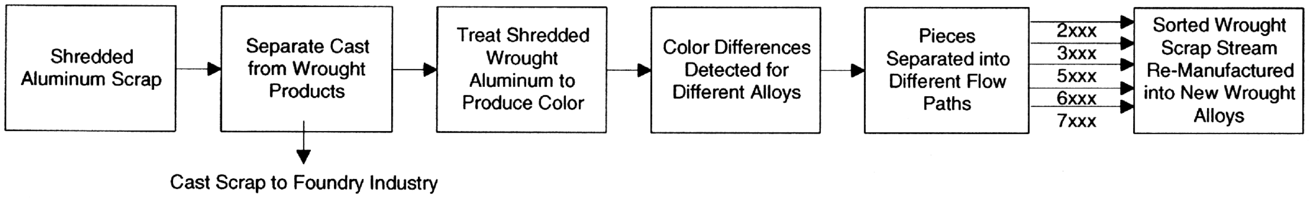


*Fig. 1—Proposed flow diagram for color sorting of different aluminum alloys.*

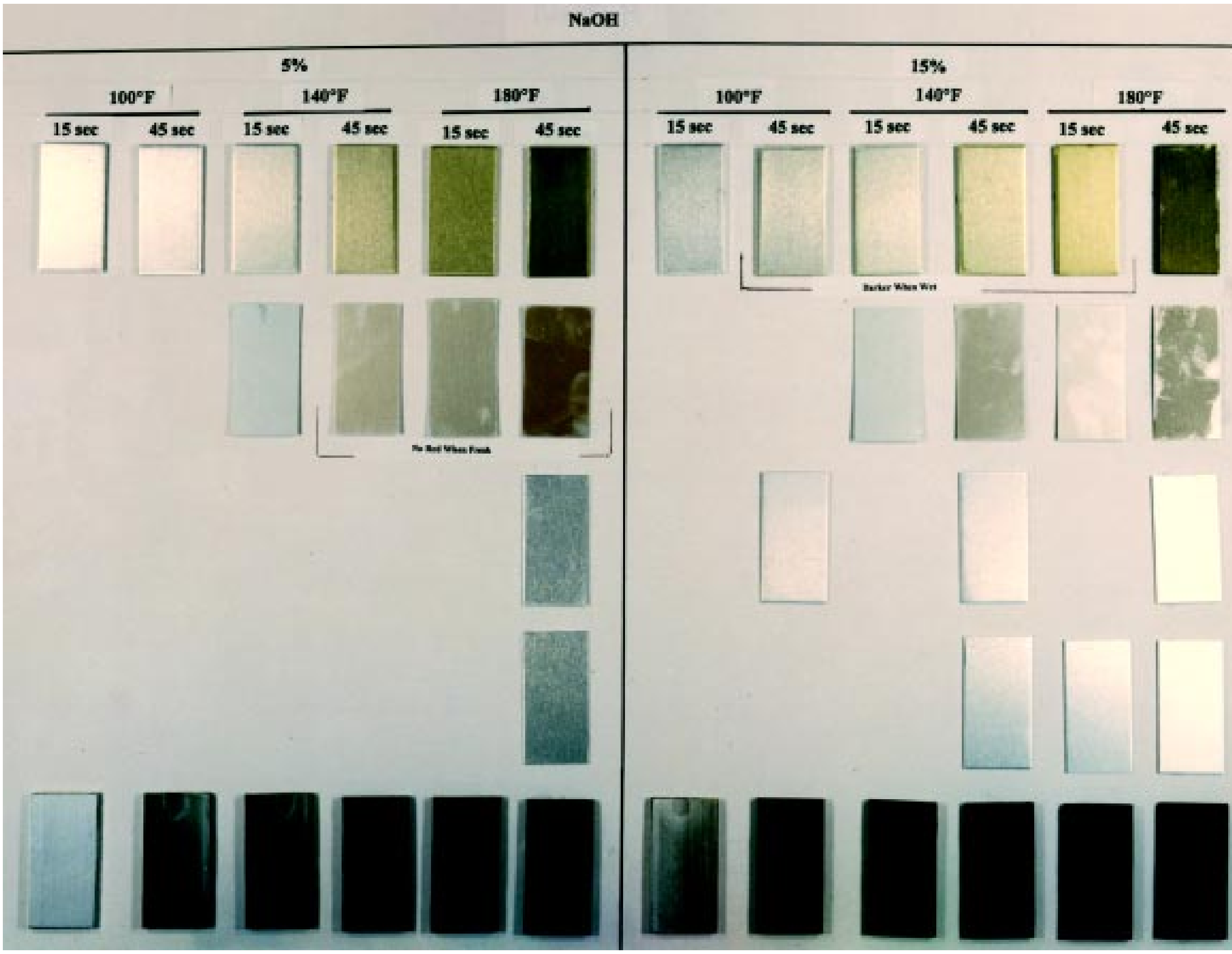

*Fig. 2—Alloy colors after etching.*

separate cast alloys from wrought alloys. The cast alloy scrap would then be diverted to the foundry industry where it would be reused as casting alloys similar to its reuse today. The subsequent processes depicted in this illustration are the focus of this paper. Following the separation of the cast alloys from the wrought alloys, the remaining mixed wrought product is then chemically treated to produce color differences as a function of the alloy composition. The colored scrap mixture is sorted using optical sensors and high speed automated mechanical handling equipment to produce streams of sorted wrought scrap that can be melted and cast into ingot for reuse as wrought alloy products. Such optical sensors and mechanical handling equipment already exist in other applications. All of the present systems, however, use the existing color of the materials as a basis for sorting. The present process attempts to induce a color in materials that are otherwise similar in appearance.

The objective of this study is to define potential chemical etching treatments to enable automated optical sensor equipment to separate 2xxx, 3xxx, 5xxx, 6xxx, and 7xxx aluminum alloy families on the basis of color. Practical solutions were sought that could economically differentiate the alloys with solutions that generate easily treatable wastes.

## Experimental Procedure

The specific alloys studied were 2036, 3003, 5754, 6022, and 7003. This group spans the range of alloys commonly used in automotive applications, one of the larger aluminum markets and a potential major portion of the future scrap stream. Typical applications for these alloys are listed below:

- 2036 outer and inner hang-on body panels, load floors, seat shells
- 3003 braze clad welded radiator tubes, heater cores, radiator, evaporator, and heater fins, heater inlet and outlet tubes, oil coolers, air conditioner liquid lines
- 5754 inner body panels, splash guards, heat shields, air cleaner trays and covers, structural and weldable parts, load floors
- 6022 outer and inner body panels
- 7003 seat tracks and bumper reinforcements

Separation of 1xxx alloys was not considered necessary for economical recycling of aluminum scrap. The presence of any 1xxx series alloy in any scrap sorted by wrought alloy family will not degrade the absorption of the sorted scrap.

All chemical tests were carried out using clean, unpainted 1 x 2 in. coupons. It was assumed that paint on incoming scrap in commercial processing would be largely removed in the thermomechanical sorting process that separates cast from wrought alloys, or by ball milling the shredded scrap. Precleaning for these experiments was fixed as the use of a heated, non-etching, non-silicated alkaline aluminum cleaning solution commonly used in the metal finishing industry. Such cleaning would remove grease and oils from the coupons to expose the aluminum surface, yet not significantly affect the alloys or surface aluminum oxide. Rinsing was used between steps to minimize drag-in of cleaner into the etch, and to prevent contamination of the final sorted scrap with etch chemicals. Room temperature tap water was used in all cases. Drying of the etched aluminum alloys was by forced cold air immediately after processing. This was an attempt to preserve the colors resulting from the etch to the greatest degree possible. In some cases, described later, it was found that such drying did not result in a stable color over the long term.

Optimized processing techniques were beyond the scope of this study. Economic and engineering factors, such as cost, throughput, material consumption and waste treatment can significantly affect the determination of optimum operating parameters, such as reaction temperature, time, solution concentration etc. It was decided, therefore, to confine this study to determination of potential sorting schemes, emphasizing practicality, based on experience, but leaving final definition of parameters to those who might build such a commercial facility.

**Material Appearance of Automotive Alloys After Chemical Etching with 5% & 15% NaOH**

| Solution | Temp | Time | 2036 | 3003** | 5754 | 6022 | 7003 |
|---|---|---|---|---|---|---|---|
| 15% NaOH | 100 °F | 15 Sec | W | Lt gray | | | |
| | 100 °F | 45 Sec | Lt gray | W | Jet black | | |
| | 140 °F | 15 Sec | Gray | W | Jet Black | | |
| | 140 °F | 45 Sec | Dk Gray | Lt Gray | W | W | Jet Black |
| | 180 °F | 15 Sec | Black | Lt Gray | W | W | Jet Black |
| | 180 °F | 45 Sec | Jet Black | Med Gray | W | W | Jet Black |
| 5% NaOH | 100 °F | 15 Sec | W | | | | W |
| | 100 °F | 45 Sec | Lt Gray | | | | Gray/Tan |
| | 140 °F | 15 Sec | Lt Gray | | | | Gray/Tan |
| | 140 °F | 45 Sec | Dk Gray | V Lt Gray | | | Black |
| | 180 °F | 15 Sec | Dk Gray | V Lt Gray | | | Black |
| | 180 °F | 45 Sec | Black | Lt Gray | W | W | Black |

*Colors listed for samples of 2036 are the colors immediately after cold forced air drying of the treated panels.
** Colors of 3003 panels are those seen immediately after drying by any technique.
W = uncolored shiny white metallic, Lt = Light, Med = Medium, Dk = Dark
blank = not tested because more severe conditions resulted in white panel

### Results

To cover a broad range of possibilities for screening purposes, a relatively small number of widely varying parameters was selected to define the most likely operating ranges. Caustic etch solutions were the first method attempted to etch the surfaces of the various aluminum alloys and impart a color.

Fairly high sodium hydroxide concentrations of 5 and 15 percent were used to minimize processing time. Approximate temperatures of 100 (40 °C), 140 (60 °C), and 180 °F (80 °C) were selected to generate a wide range, but higher temperatures than 180 °F could lead to a variety of processing difficulties and expenses in the plant engineering stage. These difficulties include corrosivity of the reagent toward the equipment, heating costs, and difficulty of maintaining solution temperature above 180 °F if the solutions are ultimately spray applied. Treatment times were 15 and 45 sec, with the latter being close to the maximum economical time for many continuous process metal finishing operations.

The color of the alloys after these etching experiments is given in the table and shown in Fig. 2. The 2036 turned gray or black in the etching process, the 3003 series was light to medium gray, the 7003 turned black, and the 5754 and 6022 both retained their silver metallic color. Among the conditions tested, 15-percent sodium hydroxide at 140 °F for 45 sec provided the best color differentiation. It easily separated 2036, 3003, 7003, and the group consisting of 5754 plus 6022. The conditions were not only technically successful in separating a number of aluminum alloys, but the conditions used were also viable for commercial processing. Time, temperature, raw material cost and waste treatability were all not only within normal practical ranges, but had existing equipment and systems already in commercial use for similar treatments, albeit for different purposes.

### Changes in Color with Time

Colors of samples of 2036 are significantly lighter after bake drying, or after the cold forced-air-dried metal has been allowed to stand at room temperature for more than one week. These heat-dried or age-dried panels are various shades of gold. It is suspected that a dehydration process is taking place, lightening the color of the material coating the panel.

Within 1-2 days of cold, forced-air drying, panels of 3003 that originally turned gray will often turn reddish brown. Oven-baked 3003 panels are more likely to retain their original color. It is speculated that retained water in the cold-dried deposits is aiding further oxidation of the surface of the alloy over a few days, whereas the hot-dried deposits retain less water to promote further oxidation. Colors of 5754, 6022, and 7003 change little over several weeks time or with different drying techniques. After several months, 7003 panels lighten to medium gray colors.

These color changes could be relevant in a commercial situation where scrap is colored and dried for later sorting.

### Galvanic Effects

In a batch processing situation, scrap pieces of various alloys would probably be processed together in electrical contact, creating the potential for galvanic cells which may affect the color generated. When the alloys 2036, 6022, and 7003 were bolted together for electrical contact and simultaneously immersed in caustic solutions, each produced its respective color independent of the color produced on the other alloys. Within a few millimeters of the contact, some color difference was noted, but the balance of the surface area was unaffected by the electrical contact.

### Acid Tests

Tests with 15-percent sulfuric acid, 15-percent phosphoric acid, or mixtures of the two acids (6-percent sulfuric acid plus 4-percent phosphoric acid) were tried in attempting to separate the alloys under similar conditions of time and temperature to those tried with caustic. Most alloys remained white metallic, but 2036 turned light gray in 15-percent phosphoric acid at 180 °F in 45 sec. Fifteen-percent HCl was also tried, and it has the ability to differentiate 3003 and 7003. Alloy 3003 turns light gray in 45 sec at 180 °F, and 7003 turned various shades of gray at 140 °F for 45 sec, and 180 °F for 15 or 45 sec, but otherwise all metals remained white metallic.

## Summary of Acid/Alkali Tests

The results at this point indicated that sodium hydroxide under the proper conditions (approximately 15% conc., 140-160 °F, 30-60 sec) would provide a good separation for most of the alloys of interest, but 5754 and 6022 were not easily differentiated in this way. Subsequent tests, however, using actual automotive scrap instead of small mill sheet samples, yielded small but significant color differences between treated 5754 and 6022. Because separation of these two alloys in caustic was uncertain, a second test technique was sought to separate them. Although a two-stage separation process is not ideal, it was felt that separation of these two alloys, with little or no transition metal constituents, would be the most difficult aspect of the experiments.

***Editor's note:*** *Manuscript received, March 1999; revision received, June 1999. Next month, the issue of separating the 5754 and 6022 alloys will be addressed.*

## References

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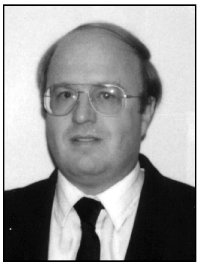
## About the Authors



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