SCANDIUM INTERNATIONAL
MINING CORP.

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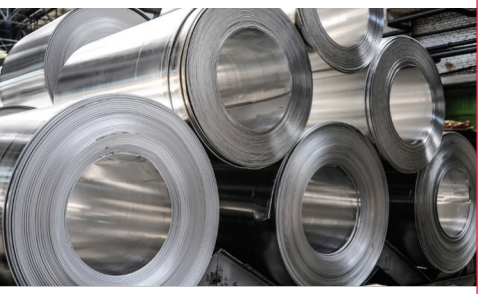
TSX: SCY
www.scandiummining.com

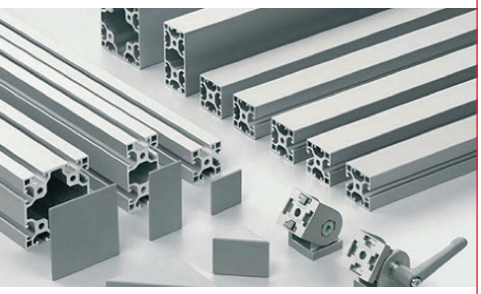
The Aluminum-Scandium Alloy Advantage

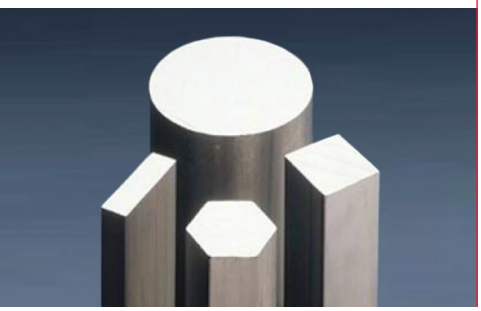
WHAT DOES SCANDIUM DO?

Scandium, like other metals alloyed with aluminum, ***imparts strength and desirable properties to aluminum, and does so in some measure to each of the eight alloy families*** (Series). Scandium additions generate strength by promoting a smaller, even-sized grain structure in alloys during solidification. Scandium shows better strength response in some alloy families than others, but almost always with quite small additions – between 0.1% and 0.45% Sc.

ALUMINUM ALLOY FORMS







SCANDIUM – HISTORICALLY SUPPLY CONSTRAINED

Most scandium is produced today as a by-product of other mineral refining processes, and very little is available for purchase. The Chinese currently recover scandium (mostly as oxide) from rare earth and pigment plant (TiO2) production as a by-product. Other minor sources come from various tailings stockpiles or small refining circuits that are sourced by end users, so they don't always reach the market for re-sale. Scandium has also been sourced from Russian military/commercial stockpiles that are by-products of phosphate and uranium production. They are sold more often as master alloy (AlSc2%) than oxide. Historic scandium prices have made its use expensive as an aluminium alloying agent, even in small additions, although the price today is half or less than peak prices a decade ago.

These supply and cost constraints have prevented scandium from being introduced into commercial aluminium alloy applications to date—but this limitation is changing quickly. ***Australia hosts a new, mineralized district*** of primary mining-sourced scandium, enriched in lateritic clays, in NSW. ***These deposits will change the dynamic that has kept scandium out of reach*** of significant users, until now. ***Scandium International owns what is planned to be the first-to-market primary scandium mining project in this district.***

STRENGTH MATTERS FIRST

Strength is undoubtedly the single most important determinant in alloy selection for a particular manufactured part or application. Strength determines design, weight, and often defines the manufacturing process required to form a particular part on the manufacturing floor. High strength alloys achieve strength with careful heat treatments, once in final form, which adds both cost and the potential for process failure. That failure can occur either by process deviation that generates poor metal microstruture, or by non-correctable warpage of finished parts. ***Proper mechanical performance is achieved by controlling grain growth***, keeping metal grain size small, and relieving internal stresses in the microstructure. ***Scandium is excellent at this***. It promotes a small, equiaxed grain structure, and does so during the solidification process—rather than requiring complex and specific heat treatments post manufacture.

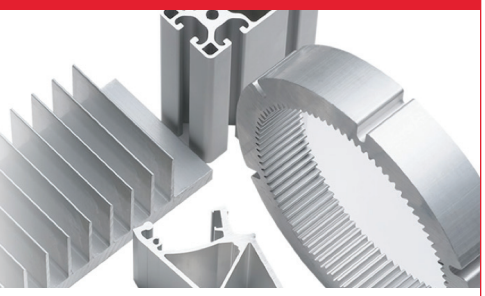
OTHER METAL PROPERTIES MATTER TOO

Other measurable properties also play a key role in aluminum alloy application, affecting usability and alloy price. Alloy properties are what determine tolerance to harsh operating environments, damage resistance, life-cycle estimates, weldability, and overall performance. They also determine (or dictate) specific manufacturing techniques, to achieve part designs and meet production cost targets. Alloy properties translate either into direct part build cost – or cost savings – on the manufacturing shop floor. In short-they significantly influence the fit-for-purpose selection process. Therefore, ***once minimum strength requirements are met*** for a given design, ***the alloy selection process then becomes one of preserving the greatest number of usable properties***, or sometimes, simply finding the alloy that can meet the essential property requirement for a particular application. Scandium alloys are fully recyclable, and won't pollute recycle streams if combined with other alloys – although it may make economic sense to segregate based on value.

STRENGTH VS. PROPERTIES TRADE-OFF

Copper and zinc have been alloyed with aluminium since the 1930's and both are very effective at increasing strength. Unfortunately, while they make aluminum 'useably strong', they degrade many of aluminum's other

ALLOY PRODUCTS



desirable traits. ***Typically, as strength improves, alloys become brittle, and other properties have a tendency to degrade.*** This makes alloys subject to damage, tearing, and sensitive to fatigue after repetitive cycle stress. Copper adds density to alloys, as does zinc, and both make them very difficult to weld successfully. Both require heat treatment to reach peak strength, and zinc in particular makes an aluminum alloy very susceptible to corrosion. To combat this erosion of desirable properties, most high strength alloys become complicated recipes, with numerous trace metal additions that can partially minimize loss of various desirable properties, while maintaining strength. However, this recipe complexity makes the alloys more difficult and more expensive to manufacture.

WHERE DO SCANDIUM ADDITIONS HAVE GREATEST EFFECT?

The 5000 Series alloy family (AlMg) offers the best combination of strength and properties response when alloyed with scandium. This aluminium-magnesium combination is characterized as a soft alloy-it has relatively low strength, often below usable limits in demanding applications. While magnesium doesn't cause the alloy to respond to solution heat treatment strengthening techniques, it does show a good strength response to cold work techniques. However, 5000 Series (AlMg) alloys do exhibit a very desirable basket of properties, which make them appreciated both for their ease of manufacture and application to shapes and parts. These are 'low error' aluminium alloys both in formation and in application.

Scandium gives the 5000 series alloys the most dramatic strength push per unit scandium addition of any alloy, while preserving or even enhancing the best properties in the series. Scandium delivers transformative strength without the need for problematic and costly heat treatments. Specifically, scandium additions can increase yield strength on a 5000 Series to between 300Mpa and 450Mpa, depending on the amount of addition, while maintaining elongation (ductility) figures of 12-15. This combination of strength and plasticity is uncommon.

MORE SPECIFICITY ON 5 SERIES PROPERTIES-WHY SO UNIQUE?

- **Weldability** – 5000 Series alloys weld easily and show good weld integrity, a property enhanced with scandium additions. While most aluminium alloys are weldable, the process can be difficult, error-prone, and usually requires costly repair to damaged alloy structures via heat treatment. Different alloy series have different weld challenges, but a 5000 Series would be the clear best choice for a 'field-serviceable' weldable alloy.
- **Extrusion Properties** – Scandium's grain refining qualities will assist in extrusion flow rates, and the lack of heat treatment requirements means the alloy is more tolerant of heat cycles caused by high pressure extrusion systems. Fine grain structure enables thin-wall extrusion shapes, and a no heat-treat finish eliminates the concerns for shape deformation.
- **Corrosion Resistance** – The AlMg combination is particularly resistant to salt and atmospheric corrosion, in fact, its the best performing series in this area. This series also has the lowest galvanic response to dissimilar metals, making it easier and more effective to combine 5000 Series alloys with other metals that would have damaging effects through electrolysis on other aluminium alloys. Scandium improves corrosion resistance in a 5000 Series, making it the stand-out high performer on this propert.
- **Hydro-Formability** – This pressure-forming technique works best with highly ductile alloys, and since the AlMg family is the most ductile, and scandium strengthens with minimum loss of ductility, this technique for forming complex shapes from tubes would be very much advantaged by a stronger 5000 Series alternative. By gaining worked strength through extrusion, offering low cost, complex hydro-formability from extruded shapes, and weldability to build up precise, light component shapes with strengthened assembly features and attach points, the AlMgSc properties all come together here to make real savings on the manufacturing floor.
- **Anodization** – The 5000 Series shows the best response to anodizing of all alloy families. Scandium additions and the attendant small grain refinements that result, actually improve the anodization result. They permit a deeper, richer colour capture with greater brilliance. A highly durable finish with better visual result—definitely of value where surface presentation is important.
- **Heat Working Temperature** – Heat-treated alloys lose their strength when exposed to environments that approach that of the heat treatment system that captured their strength. They can be quickly and permanently weakened by even short exposures, meaning engineers need to over-design for strength in hot environments, or in environments that might get hot when they shouldn't. The 5000 Series shows the highest heat-working tolerances (approx. 450 C) of any alloy. Because strength in an AlMgSc was not achieved by heat treatments, heat can't undo the strength until the alloy is practically at its melt point.

SO, WHAT IS THE BOTTOM LINE?

Scandium may give you a strength increase or properties improvement in whatever alloy it is you are using today, and that may prove economic. It won't probably change your manufacturing process, so overall savings are not likely achieved, but you will improve your product. **That's GOOD.**

A 5000 Series AlMgSc may be a direct substitution for another alloy you use today, and the better properties could give some cost savings in manufacturing processes, and better performance in application based on properties as well. **That's BETTER.**

Where the greatest substitution benefit is to be found is in using a strong AlMgSc where that alloy didn't previously meet the minimum strength spec. The improved alloy properties that come with this choice may then allow design change and/or manufacturing technique change that results in significant savings on the manufacturing floor. Make a better product, with less material, and lower fabrication cost, with full offset to the expense of scandium alloy additions. **That's a WINNER.**

YOUR APPLICATION DETERMINES YOUR SCANDIUM ADVANTAGE-DOES THIS GIVE YOU IDEAS?