Mangabraze Vs. T-1 (ASTM A514 Grade B (T-1 Type A) – Comparative Analysis

Comparing a generic grade to the custom grade, proprietary chemistry can only be validated through test results. Typical chemical and mechanical property analyses follow. However, the essential results of a comparison do not show the 14% work-hardening capabilities of Mangabraze (T-1 does not work harden), which is the most important measure of strength over wear life. Where T-1 breaks down over the life of the application, Mangabraze actually *strengthens*, lengthening the life of the part by 3-4 times in common applications. Mangabraze will often come out of service with a Brinell hardness of up to 500 BHN. This is achieved through a special Manganese-Nickel chemistry.

	C	Mn	P	S	Si	Cr	Ti	Ni	Mo	V	B	Al
T-1	.15	.85	.025	.030	.25	.52	.001	0	.20	.050	.001	0
Mangabraze	.24	2.0	.015	.002	.30	0	0	1.50	.20	.010	.002	.020

Results of RMI test, February 22, 2002

Elements and Their Properties	The Advantage of Mangabraze
Carbon (C) Carbon is an essential element in steel, it is added in specific amounts to control the hardness and strength of the material. In general, increased carbon content reduces ductility but increases tensile strength and the ability of the steel to harden when cooled rapidly from elevated temperatures. With an increase in the amount of carbon, the hardness and tensile strength of the steel also increase (which slows as the level of carbon rises). An increase in carbon thusly causes a decrease in both ductility and weldability.	The controlled level of carbon in Mangabraze allows for higher hardness while maintaining higher levels of ductility and weldability.
Manganese (Mn) One of the most important constituents of steel in which it fulfils a number of functions. It acts as a mild de-oxidizing agent. It combines with the sulphur present to form globular inclusions of Manganese Sulphide which are beneficial to machining. It increases tensile strength and the hardenability of steel. Will also increase hardness as levels increase, but not to the same degree as carbon. Ductility and weldability are decreased but, again, to a lesser degree than caused by carbon.	Higher level of manganese gives Mangabraze better machining, tensile strength, hardenability, ductility, hardness and weldability characteristics. The high level of manganese promotes better formation of extremely hard alloy carbides, which resist wear similar to carbide tool bits. Combined with Nickel, the higher Manganese level promotes better cold-working hardness and allow for a very high temperature tempering process, which removes mill stresses and adds toughness.
Phosphorus (P) An element that forms 0.12% of the earth's crust, chiefly in the form of phosphates. Its presence in steel is usually regarded as an undesirable impurity due to its embrittling effect, for this reason its content in most steels is limited to a maximum of 0.050%. Benefits machinability and resistance to atmospheric corrosion. It increases strength and hardness, much akin to carbon, but it decreases ductility and impact strength (toughness). Phosphorus is often considered an impurity except in specific situations.	The level of Phosphorus in T-1 may cause the steel to be brittle and more prone to stress fatigue versus Mangabraze.
Sulphur (S) Generally regarded as an impurity in steel as it can have detrimental effects on strength, ductility and weldability as well as producing hot and cold shortness. Its content in most steels is limited to a maximum of 0.050%. Sulphur is beneficial to machining and is added to freecutting steels in amounts up to 0.35% with the manganese content increased to overcome any detrimental effects. Like phosphorus, sulphur is generally undesired, except where machinability is an important goal for the steel. Ductility, impact strength or toughness, weldability, and surface quality are all adversely affected by sulphur content.	Sulphur is a detriment to strength, ductility, impact strength (i.e. toughness), surface quality and weldability. The level of Sulphur in T-1 is 1500% higher than in Mangabraze.
Silicon Silicon serves as a principal deoxidizer in steel. Its content in the steel is dependent upon the steel type. Killed steel has the highest percentage of silicon, upwards of 0.60 percent.	Acts similarly as a de-oxidizer in both steels.
Chromium (Cr) Increases the steel's hardenability, corrosion resistance, and provides wear and abrasion resistance in the presence of carbon. It is largely present in stainless steels, usually ranging from 12 to 20%.	The Chrome-Manganese-Boron formula is a common, cheap substitute for the Manganese-Nickel type of wear plate. The T-1 possesses a low level of Chromium, which has very limited effects in such amounts, and very little Boron, which is required for the AR plate formula to work adequately.
Titanium (Ti) Small amounts added to steel contribute to its soundness and give a finer grain size. In austenitic stainless steels it acts as a carbide stabilizer and is used to prevent intercrystalline corrosion, commonly termed "weld decay". Titanium carbide is also used with tungsten carbide in the manufacture of hard metal tools.	Such a limited amount of Titanium does not significantly affect the steel.
Nickel (Ni) One of the most widely used alloying elements in steel. In amounts 0.50% to 5.00% its use in alloy steels increases the toughness and tensile strength without detrimental effect on the ductility. Nickel also increases the hardenability, thus permitting the steel to be oil- hardened instead of water quenched. In larger quantities, 8.00% and upwards, nickel is the constituent, together with chromium, of many corrosion resistant and stainless austenitic steels.	The high level of Nickel in Mangabraze promotes deeper, more uniform hardness. Not having nearly the Nickel level, the T-1 will develop irregular surface levels of hardness (as shown by the difference in BHN levels above). Mangabraze has actually been shown to increase in hardness toward the steel's center, a very valuable characteristic. Combined with Manganese, the higher Nickel level promotes better cold-working hardness and allow for a very high temperature tempering process, which removes mill stresses and adds toughness.

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Molybdenum (Mo) Its use as an alloying element in steel increases hardenability and in low alloy steels reduces the risk of temper brittleness. When added to stainless steels it increases their resistance to corrosion. It is also used in high speed steels.	Molybdenum adds to the steel's hardenability and increases it tool steel capabilities, allowing it to be worked at high speeds.
Vanadium (V) - Steels containing vanadium have a much finer grain structure than steels of similar composition without vanadium. It raises the temperature at which grain coarsening sets in and increases hardenability where it is in solution in the austenite prior to quenching. It also lessens softening on tempering and confers secondary hardness on high speed steels. Vanadium is used in nitriding, heat resisting, tool and spring steels in conjunction with other alloying elements.	The presence of Vanadium promotes a cleaner grain structure, increased hardenability and facilitates the steel's ability to work-harden, though only in more significant amounts than evident in these steel types.
Boron (B) – Boron is used to intensify steel's hardenability. A very small amount of it is required for a marked increase in the hardenability. Boron treated steels generally possess better hot and cold working characteristics than other alloy steels having equal or higher hardenability.	The presence of Boron increases hardenability and workability.
Aluminum (Al) - Acts as a deoxidizer and for control of inherent grain size.	Higher level of Aluminum provides higher deoxidization in Mangabraze. The T-1 has no Aluminum.

Mechanical Property Comparison

Property	Mangabraze	T-1
Tensile (KSI)	210	120
Yield (KSI)	190	100
% of elongation	18%	16%
Reduction in area	45%	40%

The Need for Hardness AND Toughness

Toughness is not often discussed by distributors of standard grades of AR plate, such as AR400 or AR500 and their various trade names. Hardness is their primary focus for wear resistance. Hardness is defined as the resistance to penetration, and is necessary where hard or sharp materials are in motion against a solid surface.

However, the "harder the better" is not always true. Wear research has demonstrated that the main way solid surfaces wear out cannot be prevented merely by hardness. Most wear is caused by fracture, defined as the abrupt removal of material by breaking, chipping, or cutting. Examples of fracture wear include knife edges, blades and concrete surfaces. These items are worn **not** by a gradual removal of the surface or by penetration by hard, sharp objects, but by a chipping and breaking away of the surface particles by fracture. The property that resists fracture is toughness, largely sacrificed in the making of AR plate, but engineered from the start in Mangabraze.

With hard facing and overlays, other engineers have tried to achieve what has always been there in Mangabraze. But why deal with the numerous problems encountered with overlay?

This custom made plate, exclusive to Baldwin, is specially milled for toughness as well as hardness. The 2% level of Manganese (compared to 1% in generic AR plate) allows for the formation of carbides, highly compact binary compounds of carbon and heavy metals, that promote high degrees of wear resistance such as those used in metal-cutting carbide tool bits.

The 1 $^{1}/_{2}$% level of Nickel (compared to trace - 0.1% in generic AR plate) promotes deeper, more uniform hardening by essentially acting as structural supports within the steel.

What results is a steel that will not crack and will not wear out. *Mangabraze* is a long-lasting plate that can greatly reduce cost over the long term, can save valuable time, and can prevent the headaches that result from applied plate failure.

Useful Terms

· *Wear* is defined as damage to a solid surface resulting from motion between that surface and any contacting substance.

Types of Wear*:

1. *Abrasion* is a type of wear caused by hard particles or protrusions being forced against a surface.
2. *Surface fatigue* or *fracture* occurs when there is extensive and repeated friction between the solid surface and a substance repeatedly sliding or rolling upon it.

Principles of Wear Resistance:

1. *Hardness* is the resistance to penetration or abrasion.
2. *Toughness* is the resistance to internal fracture created by extensive use.

Only Mangabraze has both.

*other types of wear include erosion and adhesive wear