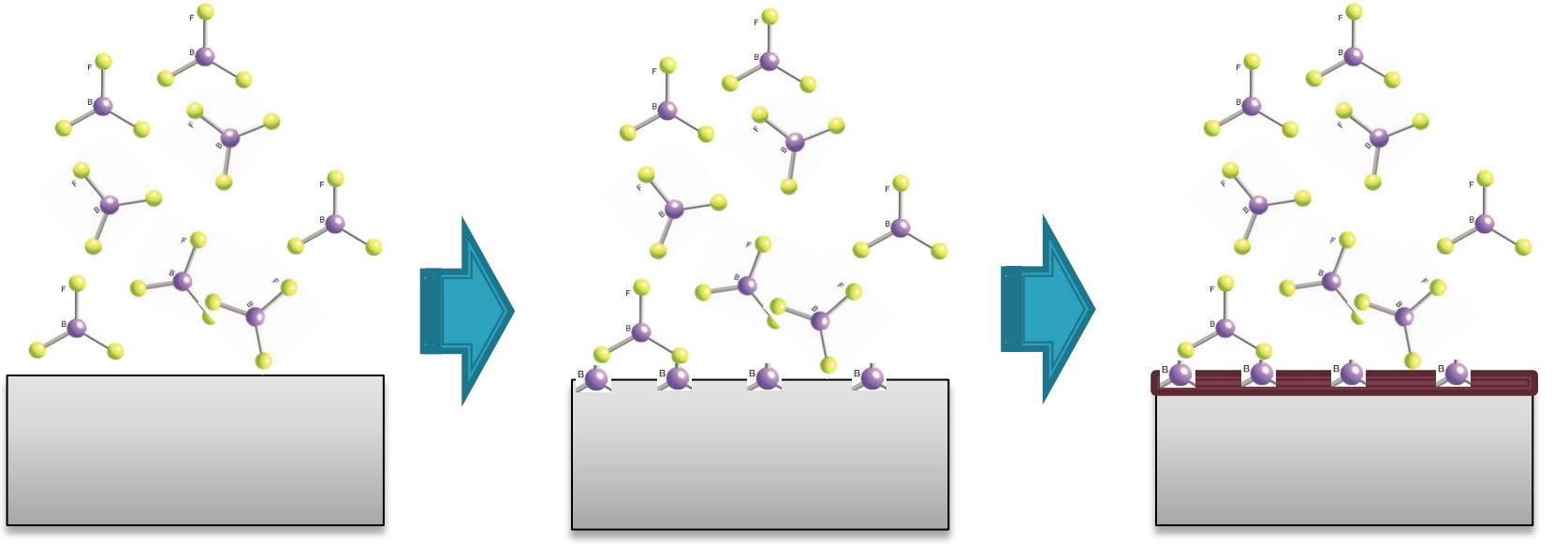
What is diffusion alloy?

- A diffusion alloy is a layer of inter-metallic compound formed by the addition of elements to the surface of the part, and the simultaneous reaction of those elements with that surface. Thus, elements from the part and the elements added comingle to form the new material. In reality it is a material, not a “coating”. A conversion of the surface.

Diffusion Alloy Process



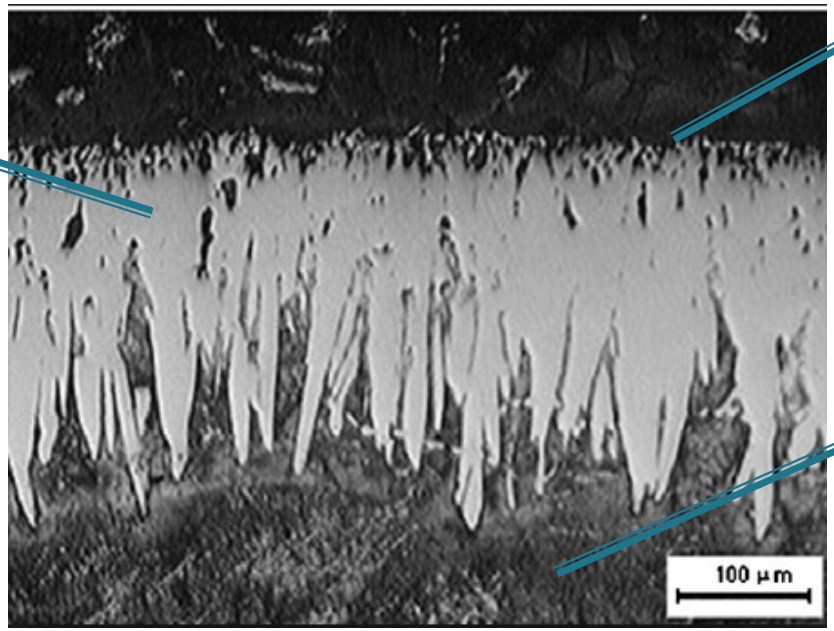
Part is heated in retort where an activator reacts with boron donor

Boron is deposited on the surface of the part and reacts with the base metal

Boron continues to deposit and diffuse into the surface forming a layer of boride

TMT-601 Coating on Cast Steel

Boride Layer



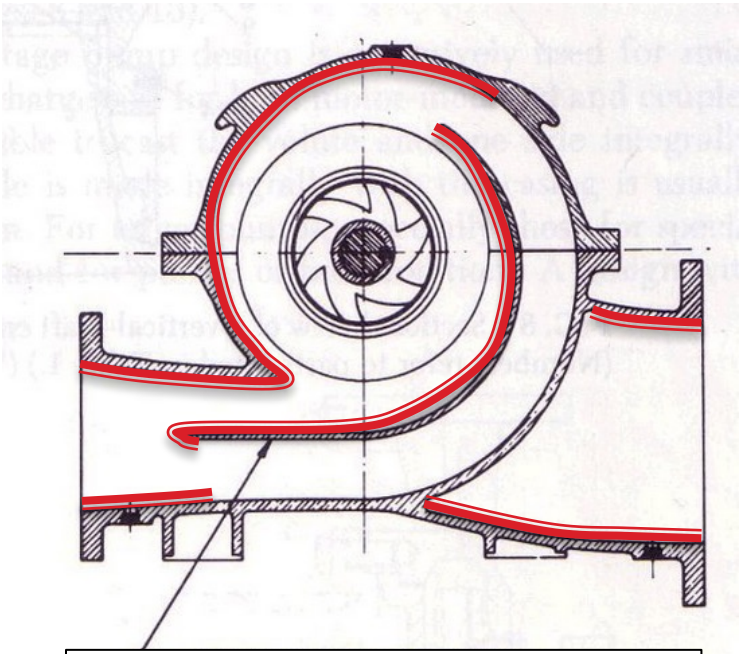
Surface

Base metal

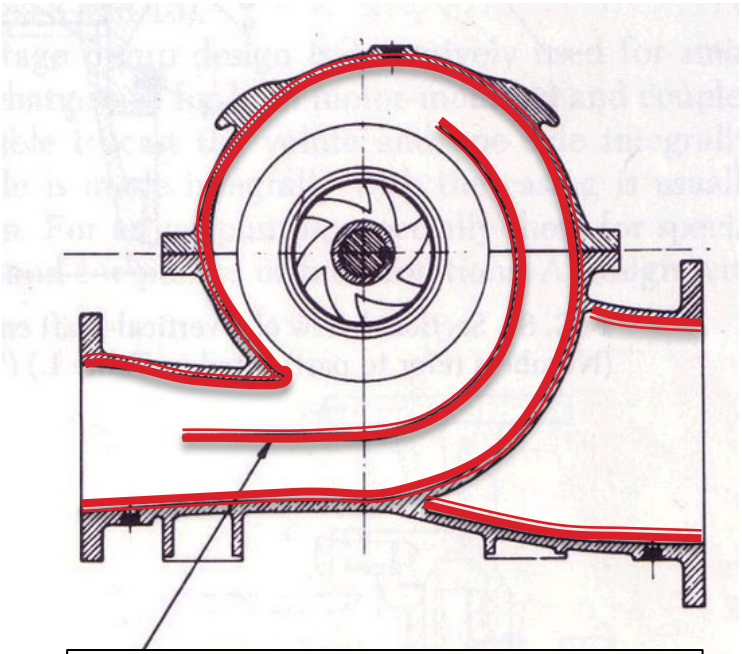
Benefits of Diffusion Alloys

- Not limited to line-of-sight application like many coatings.
- Monolithic, single phase surface is not subject to erosion of soft binder phase like some coatings.
- Metallurgically bonded layer is not subject to delamination as with some coatings.
- Surface roughness matches base metal surface so post coating finishing is not required as with many coatings.

Line of Sight Restrictions



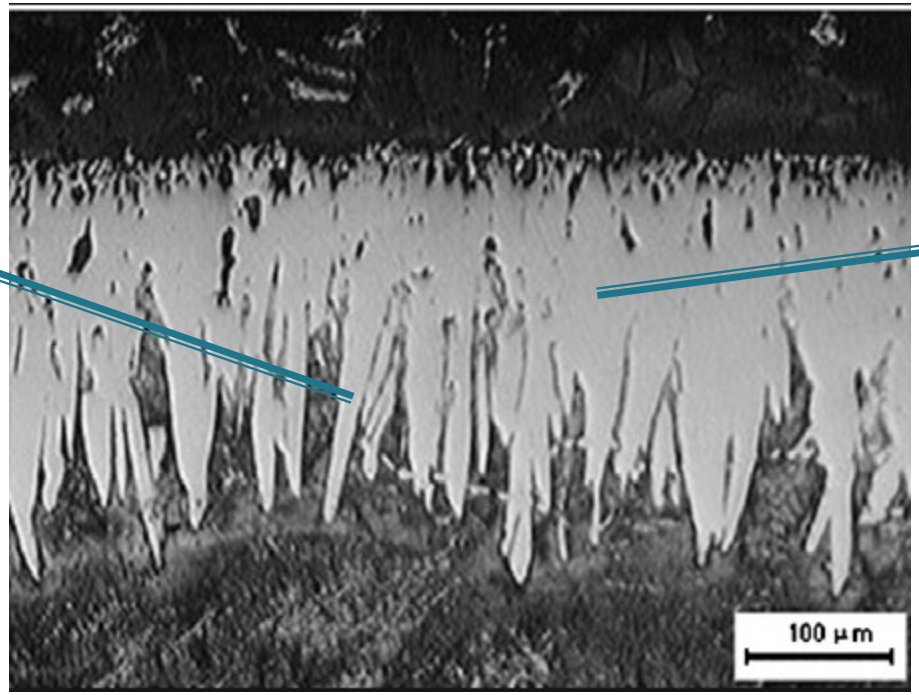
Line-of-sight Application



Gas Phase / Pack Process

Monolithic–Chemically Bonded Layer

No mechanical bond to fail/de-laminate



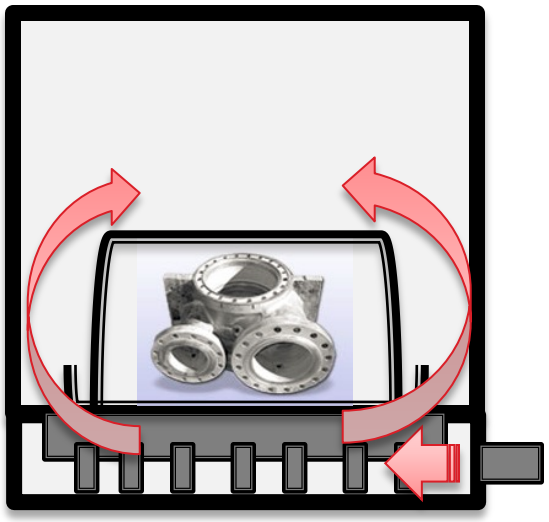
No soft binder phase to erode

Limitations of Diffusion Alloys

- Some limitations of part size due to furnace/retort size.
- The coating process involves a high temperature thermal cycle that can cause distortion or affect material properties (post coating machining or HT may be required).
- The thickness of the hard layer is limited by the base metal chemistry.
- Not all base materials can be coating with diffusion alloys.
- Applications with impact or point loading are not suited to diffusion coatings.

How does the coating process work?

- TMT 601 and TMT 56 are diffusion coatings. They are applied by heating the parts inside a sealed retort that contains a proprietary blend of powder. Once at temperature the powder will react with the surface of the parts and diffuse into the material to form a hardened layer. Because the base metal is involved in the diffusion process the properties of the hardened layer will be dictated by the chemistry of the base material.



How can a thin diffusion alloy adequately prevent erosion?

- Nothing totally prevents erosion, but erosion can be greatly slowed by a diffusion alloy. As pointed out previously, this is a single phase system. In a hardened metal coating, the hard precipitate is slowly eroded, but the soft matrix in which it is held erodes away very quickly. As soon as the support is eroded the hard particle is worn away and simply drops off. By producing a hard, single phase system on the surface, there is no soft matrix to erode and much slower erosion rate results. That rate is so slow that increases in life of three to thirty times are common.

How does a diffusion alloy prevent wear?

- Wear can be divided into two basic types, adhesive wear and rubbing wear. Adhesive wear usually occurs when two metals rub against each other under very heavy pressure or extremely de-oxidizing conditions. In both cases metal migrates across the interface of the parts, resulting in an actual weld. Further movement tears a piece of the material from one or the other part. This is usually called seizing or galling. Again, the high bond strength between the atoms of an inter-metallic compound prevents their migration across the interface with the mating part. When there is no migration there is no welding.

- Rubbing wear rates, in general, are a function of the amount of energy generated by the friction between mating parts. Since the friction force is directly related to the coefficient of friction, a decrease in that coefficient results in a decrease in the energy produced. Inter-metallic alloyed parts rubbing against bare metals commonly produce coefficients of friction of 0.1 – 0.2, while a lubricated diffusion alloyed part will commonly give a coefficient of .001.

How corrosion resistant are diffusion alloys?

- Different combinations of metals in the part and elements introduced by our process give differing results in corrosion. Generally the diffusion alloys are acid resistant and various combinations will yield resistance to hydrochloric acid, sulfuric acid, and nitric acid. Oxidation resistance can be imparted to over 2000 F. Most of the diffusion alloys are resistant to hydrogen sulfide and mercaptans. Diffusion alloys can be tailored for specific properties. An inter-metallic compound behaves chemically very differently from those elements of which it is composed.

What metals can be diffusion alloyed?

- Almost any alloy of iron, nickel, or cobalt can be diffusion alloyed. Naturally, some alloys are preferred for specific systems, but the general rule holds. Aluminum, copper, zinc, and cadmium cannot be diffusion alloyed.

Where are TMT diffusion alloys in use?

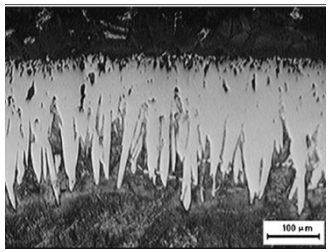
- Industries currently using our diffusion alloys include petroleum refining, petroleum production, oil well completion, petrochemical, chemical, synthetic fuel from coal, fossil fuel steam power plants, geothermal power, nuclear power, paint handling, and gas turbines.

Since this is a high temperature process, how is a high strength alloy affected?

- In general, when a part is diffusion alloyed it is in the annealed state. If high strength is required, the part is heat treated following alloying. With some simple precautions, the heat treating can be carried out in a normal manner.

Process Control

- Coating Thickness/Uniformity
  - Temperature Control
  - Process time
  - Pack concentration
  - QC = Destructive Testing on Coupons



- Distortion
  - Temperature Control
  - Fixturing
  - Pre-Annealing (after rough machining)
  - Final machining (leaving material on critical diameters)

TMT-601 vs. TMT-56

- TMT-601
  - Boride based Diffusion Alloy
  - Single thermal cycle
  - Applicable to Fe/Ni/Co base metals
  - Excellent Erosion / Wear properties

- TMT-56
  - Boride Diffused over Carburized Surface
  - Multiple thermal cycles required
  - Applicable to Carbon and Alloy steels
  - Increased base metal hardenability improves coating life
  - Excellent Erosion / Wear properties