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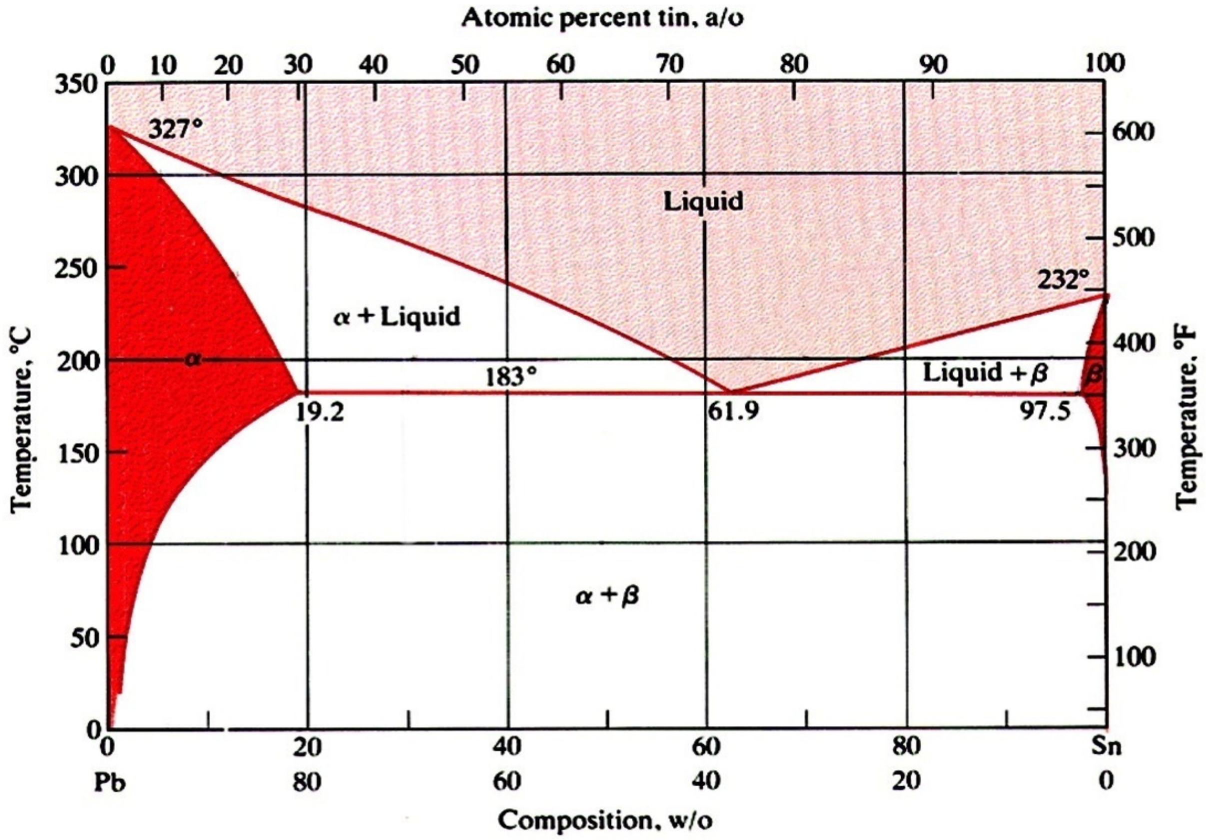
Hypo-Eutectic, Eutectic, Hyper-Eutectic

The term Eutectic is a metallographic reference to the composition and temperature of a binary alloy (i.e. two elements) at which it changes from a single liquid solution into two solid phases or visa-versa. Theoretically, this change from liquid to solid or visa-versa, happens at a single temperature point and composition. This special property of metals has practical applications. Metallurgists develop 'maps' of the phases present at any particular temperature or composition of a binary or ternary composition at equilibrium, i.e. when all reaction is completed. These 'maps' are called Equilibrium Phase Diagrams and are relatively simple for binary compositions, but become quite complex for ternary (i.e three elements) composiitons. A simple but useful binary phase diagram for the purpose of understanding the Eutectic concept is that for Lead (Pb) and Tin (Sn).



Pb-Sn Equilibrium Binary Phase Diagram

The important point here is marked 61.9 and this is the Eutecic Point for the Pb-Sn Phase Diagram. It can be seen that with a composition of 61.9% Sn (Tin) and 38.1% Pb (Lead), the alloy will entirely melt or solidify over an extremely short temperature range centred on a low 183°C. This property of Pb-Sn alloy is what gives '60-40 solder' it's special and useful properties in electrical circuitry. It must solidify or melt over a very short temperature range with a consistent and predictable microstructure, with a minimum of heating.

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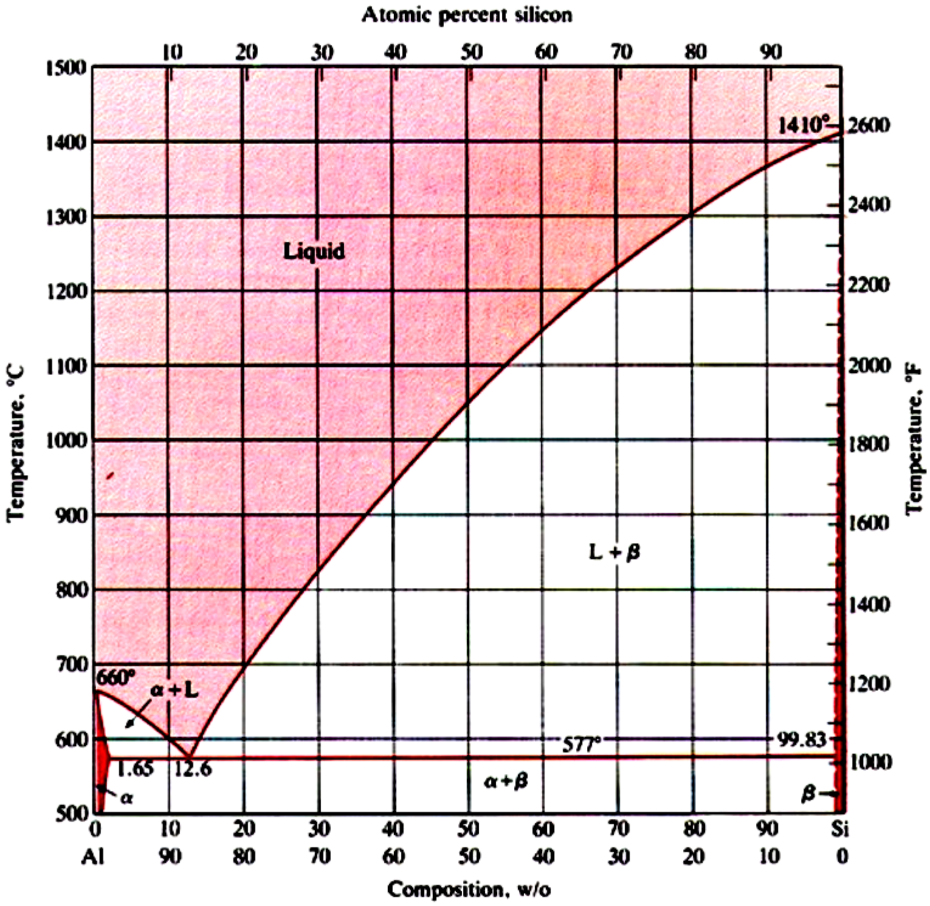
If the percentage of Sn. is less than the Eutectic composition, then the alloy is said to be Hypo-Eutectic (e.g. Hypo as in Hypodermic - *under* the skin). If the percentage of Sn. is more than Eutectic composition, then the alloy is said to be Hyper-Eutectic (e.g. Hyper as in Hyperactive - *over* active).

While piston aluminium alloys typically contain about nine elements, for many metallurgical purposes they can be considered an Aluminium (Al)-Silicon (Si) binary alloy, with approximately 87% Al and 13% Si. The Al-Si Equilibrium Phase Diagram is shown below.



Al-Si Equilibrium Binary Phase Diagram

An Al. piston alloy with 12.5 - 13.0% Si. is called a Eutectic Aluminium alloy. Less than 12.0% Si. is an Hypo-Eutectic Aluminium alloy and greater than 13.0% Si. an Hyper-Eutectic Aluminium alloy. In reality, the Eutectic point moves both in terms of composition and temperature with the addition of other elements. Piston alloys may contain Copper (Cu), Magnesium (Mg), Nickel (Ni), Manganese (Mn), Iron (Fe), Zinc (Zn) and Titanium (Ti). The most common piston alloys for automotive and light diesel pistons are Eutectic composition. Diesel pistons are typically made from alloy JIS AC-8A, which has a specification of 11.0 - 13.0% Si., 0.8 - 1.3% Cu., 0.7 - 1.3% Mg., 1.0 - 2.5% Ni., 0.1% Zn. max., 0.8% Fe. max., 0.1% Mn. max., 0.2% Ti. max. and the remainder Al. Forged Aluminium high performance petrol pistons are usually made from Hypo-Eutectic Aluminium with around 7.0 - 9.0% Si. Many year 2000 and later petrol pistons are made from Hyper-Eutectic Aluminium alloys with 16.0 - 18.0% Si. With the top ring grooves placed higher on the piston in late model engines for emission reasons, the top rings and ring grooves are exposed to higher temperatures. With the higher temperatures there is a tendency for ring to groove micro-welding resulting in ring and groove wear and increased clearances. The higher percentage of free Si. in the Hyper-Eutectic Al. alloy reduces the amount of ring to groove welding and wear. However, it has no significant effect on either strength or thermal expansion. If extra high-temperature strength is needed, a Eutectic Al. alloy with increased Cu. (5%) is used.

So, while there is sometimes a lot of marketing hype about the use of a Eutectic or Hyper-Eutectic Al. alloy in pistons, it is all very straight-forward and only refers to the composition required for the particular application.