MIDWEST TUNGSTEN SERVICE

Tips

How Far To Pump Down

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We are frequently asked what the best vacuum level is for metallizing. There are several factors that must be considered when choosing the proper vacuum level. We will examine them here.

First, we must ask why we evaporate in a vacuum at all. There are three main reasons. First, by eliminating the air in the chamber, you eliminate the oxidation/discoloration that would occur when heating metal to such a high temperature. Second, you lower the temperature required for the metal to vaporize. Third, you increase the distance that this metal vapor can travel through space. This last phenomenon is known as the mean (average) free path. There is a rather complex equation for computing mean free path, which for our purposes can be simplified to:

mean free path (inches) = 1.91/ pressure in microns

The table below uses this formula to provide values that will be helpful for vacuum metallizers.

Mean Free Path by Vacuum Level

Pressure (microns)	Pressure (torr)	Mean Free Path (inches)
10	1.0×10^{-2}	.191
5	5.0×10^{-3}	.382
2.5	2.5×10^{-3}	.764
1	1.0×10^{-3}	1.91
.5	5.0×10^{-4}	3.82
.25	2.5×10^{-4}	7.64
.1	1.0×10^{-4}	19.1
.05	5.0×10^{-5}	38.2
.025	2.5×10^{-5}	76.4
.01	1.0×10^{-5}	191.0

What conclusions can we draw from this data? If we are to use 48" to 72" as a typical chamber size and the filaments are placed in the center, the distance to the part will be no more than 24" to 36" and may be considerably less. Given this, we need a maximum vacuum level of .1 to .05 microns. This is only an approximation, as there may be other issues, such as outgassing from parts or fixtures, that play a role. However, we should also be aware that pumping down to a vacuum level that provides mean free path greater than the radius of our chamber has no benefit. In fact, it is to be avoided. Do not fall into the trap of thinking that if a 10^{-4} vacuum is good that a 10^{-5} or deeper vacuum must be better. That is rarely the case. As vacuum increases, pumping slows and cycle times rise, decreasing

production output. Leaks may appear as the force of the greater vacuum draws harder on seals and pockets of trapped gas in the chamber. Parts may begin to outgas. Pump as far as necessary, but no farther.

How is the evaporation of various materials affected by the vacuum level? The general rule is that the deeper the vacuum, the lower the temperature required for vaporization. As a source of reference, a table has been included showing the temperature at which various materials vaporize as a function of vacuum level. This table is a useful reference when specifying a power supply or designing a firing sequence

Vapor Points for Common Materials Under Vacuum

Material	Symbol	Melt Point (°C)	10^{-4} torr	10^{-6} torr	10^{-8} torr
			Temperature at Vapor Pressure (°C)		
Aluminum	Al	660	1010	821	677
Copper	Cu	1083	1017	857	727
Gold	Au	1062	1132	947	807
Indium	In	157	742	597	487
Nickel	Ni	1453	1262	1072	927
Nichrome	NiCr	1395	1217	987	847
Silver	Ag	961	1105	958	847
Tin	Sn	232	997	807	682
Tungsten	W	3410	2757	2407	2117

Why do materials vaporize (boil) at lower temperatures as the pressure decreases? The air pressure pushing on the surface of a hot material keeps the molecules from escaping. Remove this pressure and molecules can escape once they have acquired sufficient energy (heat) to overcome the attractive forces binding the molecules to one another. We can see evidence of this in nature. A mountain climber will tell you that water boils at a lower temperature as he climbs higher into the mountains. This is because the thinner air imposes less pressure on the surface of the hot water, requiring less energy for a water molecule to break free of the surface and evaporate. The same holds true in the vacuum chamber. As the air is removed, there is less pressure on the surface of the molten metal, making escape from the surface easier. Once free, a molecule moves outward in a straight line until it encounters a gas molecule, hardware in the chamber, or the parts which are being metallized. In some instances, the metal can make it to the part even if it hits another molecule along the way. This often happens if there is a leak or some outgassing from the parts. The films which deposit on the part in this case are usually discolored (yellow or black) and poorly adherent. See our TIPs on **Troubleshooting the Batch Vacuum Metallized Part** for more information.

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