

Frequently asked questions #2

Can I expect to braze brass without using flux in a reducing atmosphere furnace?

The answer to this question is 'perhaps', but any responsible brazing specialist would advise against it! This article will present the technical parameters that need to be taken into consideration so that the reader can decide for himself whether or not to try to braze brass in a continuous conveyor-brazing furnace that is sited in his factory!

The first step in the procedure is to refer to **Fig 1** and the associated text.

The effect of water vapour in a furnace atmosphere

The **amount** of water present in an atmosphere is referred to as the **Dew Point** of that atmosphere.

The dew point of a reducing atmosphere has a very marked influence on which metallic oxides the atmosphere will reduce. A consideration of the thermodynamics of the situation makes it possible to produce curves for metallic elements which show the relationship which exists between dew point, temperature, and the intrinsic *oxidising* and *reducing potential* of a atmosphere comprising **only** pure hydrogen with respect to those elements. **Fig 1** shows a series of such curves, (often referred to as Ellingham -Richardson diagrams¹), while **Table 1** shows the direct relationship between Dew Point and the *amount* of water vapour present in the atmosphere.

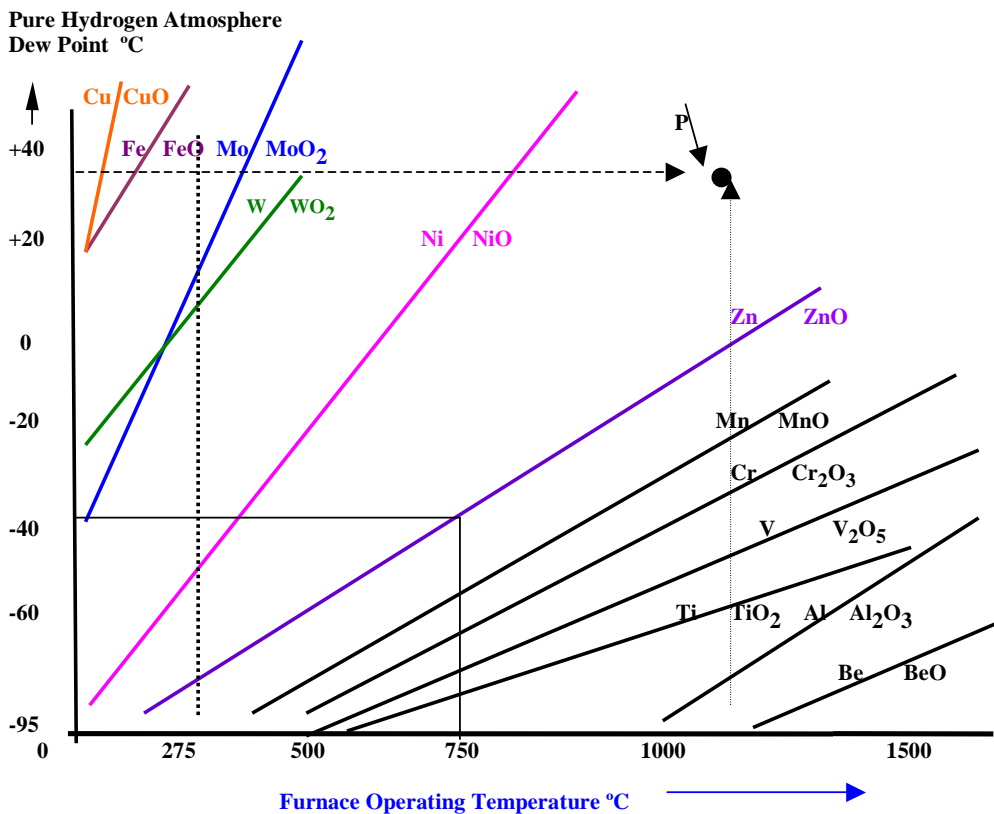


Fig 1: Temperature - Dew Point relationship for a number of metals and their oxides

¹ See Page 318, The International Journal of Powder Metallurgy, Volume 27, No.4, 1991

Dew Point °C	Water vapour content, by volume In parts per million (ppm)
- 70	2
- 60	11
- 55	21
- 50	40
- 40	130
- 30	380
- 20	1000
- 10	2700
0	6000
+10	13000
+30	40000

Table 1: Some values showing the relationship between Dew Point and the water vapour content of a gas

It is particularly important to note from **Table 1** how a relatively small change in the dew point of an atmosphere represents a very substantial change in its water vapour content! Indeed, if the dew point of a gas-atmosphere is plotted against its water vapour content on a graph the shape of the resultant curve is close to being exponential!

It is very important to recognise that the metal - metal oxide 'lines' shown in **Fig. 1** are *not* definitive; they are only approximate representations of the situation that exists in practice for the pure metal. However, they *can* be used to explain the theory of oxide reduction or formation in a hydrogen-containing furnace atmosphere. They are also accurate enough to provide a 'pointer' to the probable reduction potential or, perhaps more correctly, the *oxidation potential*, of an atmosphere in those situations where, against all expectations, a molten brazing filler material fails to wet and flow on the surface of a parent material!

The relationship between dew point and successful brazing!

In order to determine whether an atmosphere is capable of removing the oxides from the surfaces of a metallic assembly intended to be furnace-brazed under a particular reducing atmosphere it is necessary to have **four** pieces of information:

- The Dew Point of the atmosphere gas to be used
- The hydrogen content of the atmosphere gas being fed to the furnace.
- The maximum temperature attained by the assembly while it is in the furnace.
- Which elements at concentrations greater than about 0.75% are present both in the materials to be brazed **and** the filler material that is to be used.

When these four criteria have been established the curves shown in **Fig. 1** can be used to determine which metallic oxides will have the tendency to be reduced, and which will not, under the prevailing atmosphere conditions within the furnace.

The methodology of determining which metallic oxides will tend to be reduced, and those that will not, is as follows.

Taking **Fig 1**, first draw a *horizontal* line at right angles to the dew point axis. The **origin** of this line must be the known dew point of the atmosphere. (*In this example, it is assumed that the dew point of the gas is +35°C, this being typical of the output when a feedstock of natural gas and air is catalytically reacted to produce an exothermic atmosphere..*

Moving now to the 'Furnace Temperature' axis, draw a vertical line at right angles from the known furnace operating temperature, in this example 1100°C, the temperature setting when mild- or stainless steel is to be brazed with copper. It will be noted that the two lines drawn on the figure have intersected at a point. Let us call that point 'P'.

If **reduction** of the oxides present on the mating surfaces of the joint is to occur, point 'P' **must** lie to the **RIGHT of each of the individual metal oxide curves that have to be considered**

In **Fig 1** it is clear that point 'P' is located to the **right** of the lines that represent the elements *Copper, Iron, Tungsten, Molybdenum and Nickel*. As a result of the conditions prevailing in the furnace **all** the oxides of these metals will be **reduced**. However, since point 'P' is located to the **left** of the Ellingham - Richardson curves for **Zinc**, Chromium, Manganese, Vanadium, Silicon, Titanium, Aluminium and Beryllium their oxides will **not** be reduced. This means, of course, that the condition of the furnace atmosphere with respect to these elements is **oxidising**, and hence brazing will **not** occur.

The minimum 'reduction potential' conditions that are needed when brazing mild steel with copper, a process universally known as 'copper brazing', are also abundantly clear from a consideration of **Fig 1**.

It is clear that once the temperature of the part attains **about 330°C** an atmosphere that contains hydrogen, and has a dew point of +35°C, is intrinsically capable of reducing the oxides found on iron and copper. Both of these are the primary metallic elements present in the vicinity of the joint when the 'copper-brazing' of mild steel is being undertaken. Whether it will actually do so is dependent upon the quantity of hydrogen present in the atmosphere, but levels above about 7% are generally considered to be adequate for the task. That is why an **exothermic** atmosphere generated from the catalytic reaction of air and natural gas, where the hydrogen content is typically 10-20%, is so widely used for this type of work.

The second step is to remember that brass tends to melt at a temperature around 850°C. but begins to soften at a temperature of about 300°C. It is therefore clear that if brass is to be furnace-brazed under a reducing atmosphere the operating temperature of the furnace cannot be allowed to be more than about 750°C. Even at this temperature it has to be remembered that the parts to be brazed will be at very close to their melting temperature. Dependent upon the mass and geometry of the components, if the parts get too hot they will tend to collapse under their own weight: hence the fundamental necessity to limit the temperature attained by the parts during processing.

As the reference to **Fig 1** above infers, an understanding of the temperature – dew point diagram lies at the heart of the solution to almost all protective atmosphere furnace-brazing problems. In the case in point it is clear that the oxide of maximum stability that will be encountered will be that of **zinc**, i.e. **ZnO**. Reference to **Fig 1** shows that to ensure that point 'P' is to the **right** of this curve at a temperature setting of about 750°C demands the use of an atmosphere that is both **reducing**, and possessing a dew point that is of the order of at least **minus 40°C!**

As a direct result of this requirement it is clear that the atmosphere will need to contain an appreciable quantity of hydrogen, say about of 60%, and this means using a furnace that is fitted with a muffle. Depending upon the dimensions of the parts that have to be processed, say more than 80mm high, it will also be necessary the use of a furnace of hump-back design. These are expensive, and if such a furnace is not already available the project will probably 'fall' as a result of economic considerations.

In cases where a user is unable to follow this route, and is happy to use a flux, the following points have to be taken into consideration. Certainly a brick-lined muffle could be used, and pure, dry, nitrogen would be an appropriate atmosphere. Clearly, there is no point in using a 'reducing' atmosphere since in such a furnace the incorporation of sufficient hydrogen would provide the potential for a massive explosion as hot hydrogen diffused through the bricks and came into contact with atmospheric oxygen! Unfortunately, the fluxes that will be used will evolve 'fluorides', and these will progressively 'eat' their way through the belt and the lining of the cooling tunnel. To observe the accuracy of this fact simply look at the windows of any brazing shop where fluoride-base fluxes have been used for a number of years. The

'haziness' that you will see has not arisen because the window-cleaner failed to call, it is the etching of the glass due to the effect of evolved fluorine, as hydrofluoric acid. If flux fumes diluted by air can etch glass, it takes little imagination to see what harm will they do when concentrated in the interior of a furnace!

There is also the problem of zinc fumes to contend with. At 750°C the vapour pressure of zinc is about 0.5 atmospheres, and this means that the parts will give off zinc during processing. Clearly, the zinc has to go somewhere and it generally tends to deposit as stalactites of zinc oxide that hang from the roof in the cooling zones of the furnace. These have to be removed at regular intervals otherwise infiltration of both the furnace conveyor belt and the material from which the cooling tunnel is made will occur, this leading to their premature failure!

Finally there is the matter of brazing material selection to be addressed.

In order to avoid liquation problems it is a fundamental requirement that the brazing filler materials used for furnace brazing should have a very short melting range, a figure of 10°C, or less, being ideal. This factor tends to limit the choices! Probably the best material to use will be the one conforming to BS EN1044 Type CP101, the bonus is that in a reducing atmosphere this material will be self-fluxing on brass, the other alloys in the CP family have extended solidus-liquidus intervals that will almost certainly lead to problems of liquation. Clearly, the CP family of materials will be unsuitable for use if either of the parent materials that have to be brazed contains any iron, cobalt or nickel!

None of the conventional low-temperature silver brazing alloys will be suitable for the same reason. In addition, and because of the requirement to use short melting-range alloys, their inherent fluidity will demand that the *radial* joint gaps presented for brazing should not be greater than about 0.05mm!!

From the above comments it is clear that the furnace brazing of brass should be avoided. That the furnace brazing of brass is done is well known. However such cases are almost exclusively limited to the brazing of pieces of 'jewellery proportions' – and even here the procedure is far from being trouble-free!! In short.....the voice of experience says not to pursue this process.

To summarise, there are a number of ways of mechanising the brazing of brass, but the reality is that protective atmosphere furnace brazing is **not** one that the author of this article would be happy to recommend!

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