Vacuum purging: a progressive innovation for CAB equipment and processes

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During the last three decades, CAB (Controlled Atmosphere Brazing) has become the basic process for manufacturing automotive heat exchangers with many other applications in HVAC, power generation, household equipment, etc. There are however, areas where VAB (Vacuum Aluminium Brazing) is still used. One of the reasons for investing in this premium option is to improve the quality and appearance of the cores brazed in the controlled atmosphere process. By adapting the vacuum purging operation in the CAB process, the brazing quality may be significantly improved as well as reducing operational utility costs. In some cases, vacuum purging enables the CAB process in applications where VAB was the preferred method. This option can provide valuable savings.

1 Introduction.

Standard CAB process is done under protective atmosphere (nitrogen) at atmospheric pressure. In a standard continuous mesh belt furnace, nitrogen is supplied into many points down the whole length of the system. Air (oxygen) is removed from the areas of the cores and transported outside of the furnace in an opposite direction to the movement of the cores. A proper purity of brazing atmosphere is usually reached before the area of brazing operation.

In semi-continuous and batch CAB furnaces, typically a special chamber is provided where the purging operation takes place prior to moving the load into the brazing chamber.

To get the proper atmosphere parameters, several exchanges of the volume in the chamber is required. Fig. [1] and Fig. [2] shows the number of volumes needed to be exchanged to reach required atmosphere purity. In practice, a purity level of at least 50 ppm should be achieved prior to entering the braze chamber. This typically requires 8 purging chamber volume changes of nitrogen – Fig. [2].

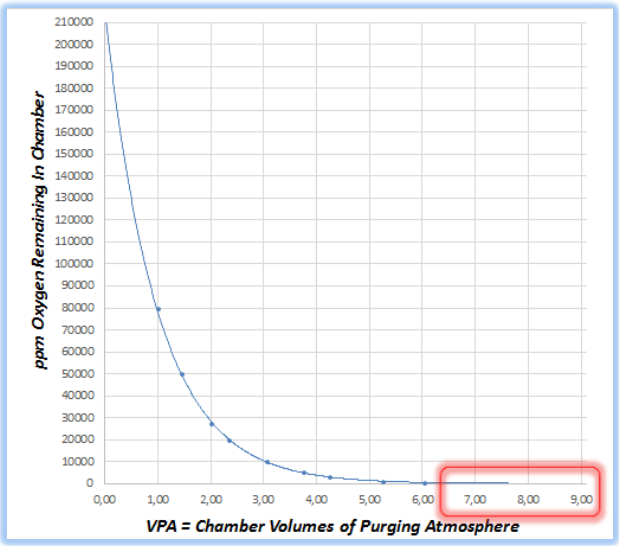

Fig. [1]. Level of oxygen after chamber purging (number of atmosphere exchanges from 0 to 6).

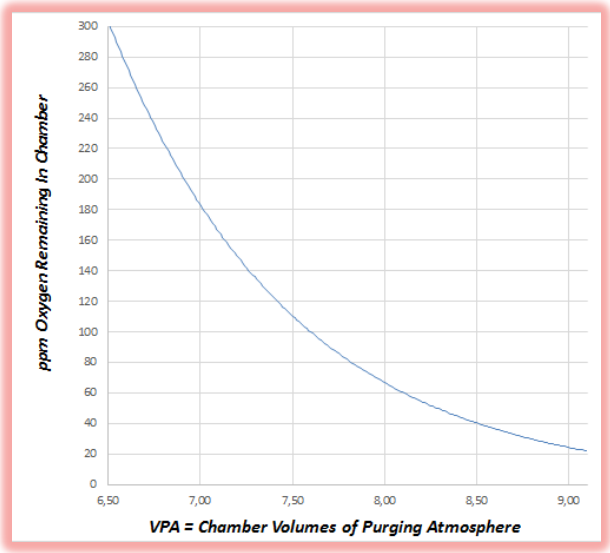

Fig. [2]. Level of oxygen after chamber purging (number of atmosphere exchanges from 6 to 9).

The same level of atmosphere can be reached by using a vacuum purging system. The required vacuum level to achieve the required oxygen concentration after refilling the chamber with pure nitrogen is presented in Tab. [1].

Vacuum level (mbar)	Percent of oxygen (%)	Parts per milion of oxygen (ppm)
101.3	2	20000
10.13	0.2	2000
1.013	0.02	200
0.253	0.005	50
0.1013	0.002	20
0.01013	0.0002	2
0.001013	0.00002	0.2

Tab. [1]. Estimated oxygen concentration after refilling the chamber (after vacuum pumping) with pure nitrogen (5 ppm)

The chamber pumped down to 0.25 mbar results in a purity level of 50 ppm O_2. A typical volume of batch CAB two chamber system size is about 5 cubic meters. A reasonable size of the vacuum pumping system was chosen for that chamber. According to the curve presented on Fig. [3] MV system needs 7 minutes to get proper (0.25 mbar) vacuum level.

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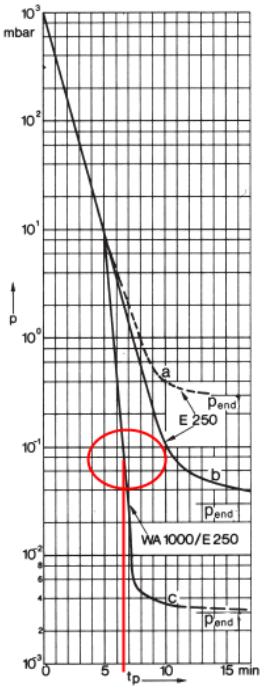

Fig. [3]. 7 minutes - time required to get 0.25 mbar vacuum (50 ppm of Oxygen) for chamber of 5 m^3 volume.- Oerlikon Vacuum technology, 2007 [2]

As a result, the same theoretical atmosphere quality using vacuum purging can be achieved saving 35 cubic meters of nitrogen per cycle.

An additional advantage of using a vacuum system is that any internal, closed volumes of the cores are perfectly purged and refilled with pure nitrogen. While in the case of conventional purging, the oxygen concentration inside the internal volumes can remain on a much higher level and negatively affect the brazing quality.

2 Vacuum and pumping systems.

Vacuum, what is it? The definition of vacuum is “the state of a gas at which its pressure in a vessel and therefore its particle density is lower than that of the ambient surrounding atmosphere or in which the pressure of the gas is lower than 300 mbar, e. g. lower than the pressure of the atmosphere on the Earth’s surface.“

There are several levels of vacuum defined in vacuum technology. Pfeiffer Vacuum; Tab. [2].

Pressure range	Pressure hPa	Pressure Pa
Atmospheric pressure	1,013.25	101,325
Low vacuum (LV)	300…1	30,000…100
Medium vacuum (MV)	1…10^{-3}	100…10^{-1}
High vacuum (HV)	10^{-3}…10^{-7}	10^{-1}…10^{-5}
Ultra-high vacuum (UHV)	10^{-7}…10^{-12}	10^{-5}…10^{-10}
Extremely high vacuum (XHV)	<10^{-12}	<10^{-10}

Tab. [2]. Pressure range in vacuum technology - Pfeiffer Vacuum 2013 [1]

For a CAB system with the vacuum purging option (to prepare brazing atmosphere) lower pressure range system also known as Medium Vacuum – MV is required – Fig. [4].

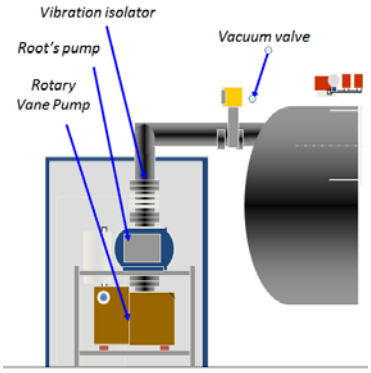

Fig. [4]. Medium Vacuum (MV) system (SECO/WARWICK)

For a typical aluminum vacuum brazing furnace (High Vacuum – HV) a high pressure system is required. An HV system is more demanding and expensive compare to standard MV systems - Fig [5]. Differences between these systems are presented on Fig. [6].

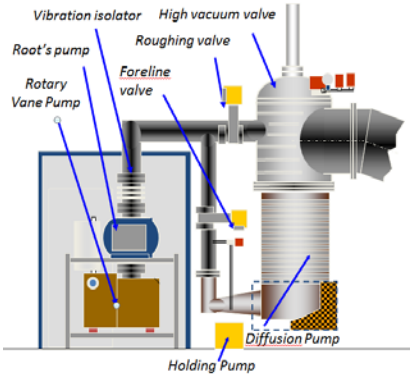

Fig. [5]. High Vacuum (HV) system (SECO/WARWICK)

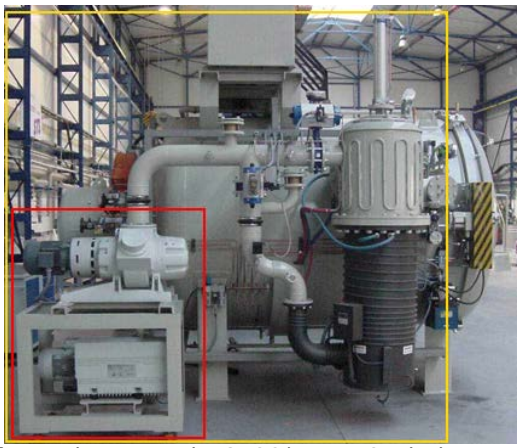

Fig. [6]. Pumping system by SECO/WARWICK (red – MV; yellow HV which includes MV system)

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3 Equipment and processes.

Semi-continuous systems with vacuum purging are available from SECO/WARWICK in both vertical and horizontal orientation of the core during brazing.

For horizontal brazing, a special version of the ActiveOnly® furnace with vacuum purging is available.

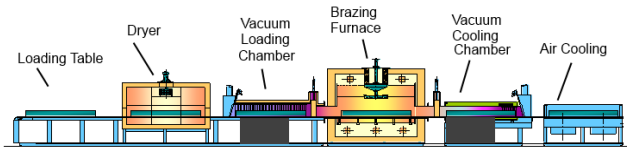

Fig. [7]. Active Only® with vacuum purging.

Before entering the brazing zone, brazing parts are located in Vacuum Loading Chamber where the air/atmosphere is pumped down and then backfilled with pure nitrogen (5 ppm). The vacuum loading chamber is equipped with a heating system to slightly preheat the cores prior to entering the brazing chamber. Also, at the exit of the line, a combined system of vacuum purging and cooling chamber is provided. The cores are perfectly purged including all internal volumes before the brazing operation, The completely closed brazing chamber keeps excellent atmosphere during the whole process (usually better than 10 ppm O_2). Also, the cooling chamber is purged prior to receiving the brazed load allowing initial cooling in high purity atmosphere conditions.

The above system with vacuum purging and load area size 1500 x 500 x 3000 mm, allows brazing loads up to 250 kg per batch and the brazing output is around 3 batches per hour.

An option for brazing in a vertically oriented position is dedicated for Plate and Bar Industrial cores. The furnace is presented on Fig. [7] & Fig. [8].

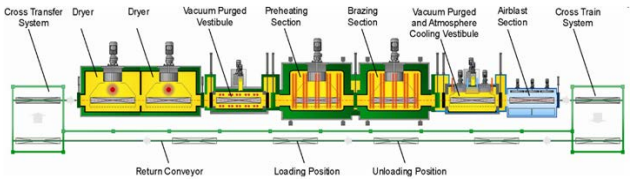

Fig. [7]. Top view of Semi Continuous High Volume furnace with vacuum purging. Load area size 250 x 2100 x 1350 mm, Load mass 400 kg. Output – 4 cycles per hour. (SECO/WARWICK).

The system has a load area of 250 x 2100 x 1350 mm and 400 kg load weight per batch, allowing up to four batches per hour. Consumption of nitrogen is at a level of 95 Nm^3/h providing atmosphere purity in the brazing chamber at a level of 10 ppm.

Fig. [8]. Semi Continuous High Volume furnace with vacuum purging at customer site. Load area size 250 x 2100 x 1350 mm. Load mass 400 kg. Output - 4 cycles per hour (SECO/WARWICK)

Vacuum purging system was also utilized in lower production volume furnaces. An example could be SECO/WARIWICK Universal Batch system Fig. [9], where vacuum purging is offered as an option.

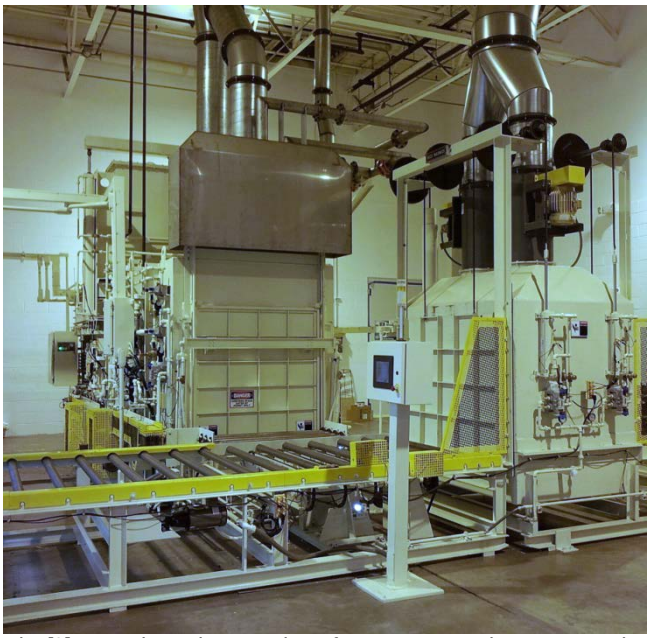

Fig. [9]. Universal Batch furnace. Load area size 1100 x 1100 x 1500 mm. Load mass 250 kg.

For standard size Universal Batch Furnace with vacuum purging with loading area 1100 x 1100 x 1500 mm, the typical cycle time (including purging, brazing and cooling operations) is in a range of 40 - 70 minutes, depending on the load type and weight (250 kg max). Nitrogen consumption is on the level of 30 m^3/h and all of the atmosphere quality in the whole brazing process is also obtained, as in the semi-continuous system.

Another range of CAB furnaces where vacuum purging is used as a standard are Single Chamber furnaces. (Fig. 10 and Fig. 11) Single chamber furnaces are dedicated for R&D laboratories, prototyping, and any initial low volume production.

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Fig. [10]. Single Chamber furnace with working area size 900 x 1900 x 2000 mm. Load mass 100 kg. Output - 1 cycle per hour. (SECO/WARWICK)

Fig. [11]. Single Chamber furnace with working area size 500 x 300 x 500 mm. Load mass 2 kg. Output 2 cycles per hour. (SECO/WARWICK)

Single Chamber Furnaces can be used as an ideal tool for simulating the processes normally executed in mass production equipment. The vacuum purging system allows for fast and low cost preparation of the protective atmosphere – Fig. [12]

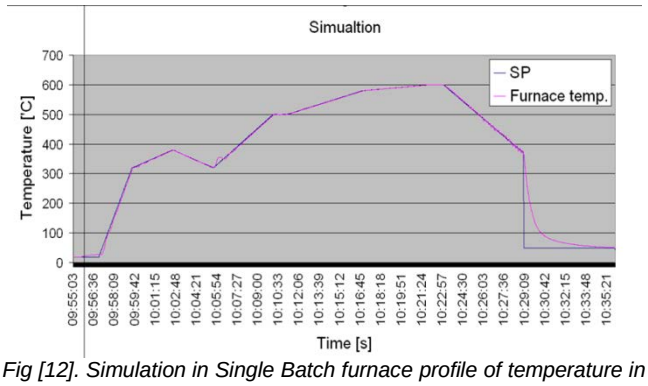

Fig [12]. Simulation in Single Batch furnace profile of temperature in Continuous CAB Line. (SECO/WARWICK)

4 Conclusions.

By utilizing a vacuum purging option in a CAB furnace system a savings in utility consumption as well as an improvement in the brazing quality can be achieved.

- Nitrogen consumption is significantly reduced due to only a single backfill instead of up to 8 exchanges in the purging chambers.
- By reduced nitrogen consumption, excellent brazing atmosphere purity is achieved in the whole heating, brazing and initial cooling process, usually on the level of 10 ppm of oxygen. This provides the highest quality of brazing atmosphere for forming the joints and excellent appearance of the cores after brazing.
- Any internal volume of the core is purged equally as well as the external surfaces of the core.
- CAB process with Vacuum purging in some cases may be considered as a lower cost alternative to VAB.

References:

[1] Pfeiffer Vacuum – The Vacuum Technology Book – April 2013

[2] Oerlikon Leybold – Vacuum Fundamentals of Vacuum Technology – June 2007