Brazing of aluminium can broadly be classified into two main areas.

- Brazing in an enclosure i.e. Furnace brazing either in a Vacuum furnace (without flux) or Controlled Atmosphere Brazing CAB (with flux)
- In air brazing i.e. brazing with a flux in open air by Flame or Induction

What is common to all these processes is the need to understand the technical detail of each type of application method and importance of collecting process data and then learn how to read the data.

The author has been involved in flame brazing aluminum since 1991 and delivered many theoretical, practical training sessions, plus troubleshooting on many different flames brazing applications’…..on various complexity of machine designs from many different “flame brazing equipment manufacturers” around the world.

During which I have been asked many time “what are the most common problems associated with flame brazing?” ……..my answer is also the same……PEOPLE…… first not fully understanding the basic rules and then not knowing how to apply them to their application.

The presentation will concentrate on the key aspects of flame brazing including.

1. Service condition and environment
2. Material selected
3. joint design and tolerances
4. alloy and flux selection
5. flame selection
6. flame process complexity scale of 0 to 10 (open and closed loop temperature control)

“PEOPLE”

People make decisions, but they don’t really intentionally set out to make wrong decisions. They might not have all the data necessary to make the right decision at the time they need to make some initial decisions.

The different stages of a project can be

Concept……..design……..development……..specification……..manufacturing

And its very common for different people to make decisions as the project moves from concept right through to manufacturing.

When I get asked to troubleshoot it is normally later on in the project when lots of decisions have already been made…..at this stage the first thing to do is start collating process data…. 
In a 30 min presentation it is impossible to go into all the detail regarding flame brazing. Therefore, I have selected a few slides which I use when delivering Flame brazing training seminars for the European Association for Brazing and Soldering ..EABS (more slides will be used during the presentation)

**The six fundamental rules for successful brazing**

**N.B.** There are only **six** ‘rules’:

1. Have a **clean surface**
2. Heat the joint **evenly** to brazing Temperature
3. Choose the right **brazing alloy** for the job
4. Select the appropriate means of removing the oxide skin from the faying surfaces of the joint
5. Use a capillary gap of the **appropriate size**
6. Apply the brazing alloy to the **last part of the joint** to reach brazing temperature.

Follow these rules and you **will** achieve the results you want!

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It’s easy to say but how do we get started.........
Process Analysis

What are the four critical parameters of your requirements?

- To identify, and then prioritise your needs.
- To identify the variables that are present.
- To identify any particular parameter of your process that will impose a limit on the actions that you can take.
- To determine the level of process complexity that you actually need in order to meet your production objectives.

With these parameters determined you can move on the final, and vital, stage:
- YOU can develop an ‘Action Plan’ that will enable you to implement the ‘best practice’ solution to your brazing problem.

The Process Analysis Format

There are nine steps in the Analysis.
These are as follows......!

1. The Service conditions and environment !
2. The parent materials that are to be brazed !
3. The joint design that will be used !
4. The dimension of the joint gap at brazing temperature !
5. The selection of the filler material !
6. The method to be used to remove the surface oxides in the joint area !
7. The design of the fixture that will cradle the assembly during brazing !
8. The heating method that will be used to raise the joint to brazing temperature !
9. The level of process complexity needed to achieve the production objectives !
As we start to collate process data we need to put it somewhere...create a simple file/portfolio and simply index it 1-9.

Start to look for potential variables in each section.....if you don't look you won't find any! And there will potentially be quite a few!

Then ask the question if I change anything in one section what effect will this have in others sections....simple colour coding can illustrate this very well.

Brazing is a time temperature process, and our objective is to heat the surfaces of two components uniformly so the flux melts and removes the surface oxides allowing the filler metal to form a joint between these two surfaces.
**Terminology**

**Process Window**

- Temperature of exterior surface
- Temperature of interior surface
- Ideal heat pattern

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The flame is the heat source touching the external surface of the parent material to transfer heat to the surface then conduction transfers the heat through the material to the internal surfaces of the joint……carefully ensuring you do not melt the external surface of the parent material while waiting for the internal surface to reach brazing temperature.

The flame needs to be stable on the burner head and there are many relationships upstream of the flame.
Any equipment used will fall within the simple complexity scale of 0 to 10.
0 being manual operation with a hand torch….10 being the most complex machine possible……

**Process Analysis**

**Stage 9: The process complexity scale**

- **10**: Fully automatic machine
- **9**: Step-indexing machines with most of the production operations mechanised
- **8**: Rotary indexing machines with automatic application of the filler material and flux, together with automatic removal of the brazed assembly
- **7**: Rotary indexing machines, probably with automatic application of the filler material and flux
- **6**: Machines with a continuously moving work track. The machine design can be either in-line or rotary
- **5**: Shuttle machines with independent control of the work-tracks. It is probable that the machines will incorporate radiation-pyrometry temperature control
- **4**: Double-shuttle machines with independent control of the heating stations
- **3**: Single shuttle machines of various designs
- **2**: Simple bench-mounted fixed torch arrangement
- **1**: A manual brazing operator
Material Selection

<table>
<thead>
<tr>
<th>Material</th>
<th>Solidus</th>
<th>Liquidus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube</td>
<td>3003</td>
<td>643</td>
</tr>
<tr>
<td>Block</td>
<td>6063</td>
<td>616</td>
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<td>580</td>
</tr>
<tr>
<td>Block</td>
<td>6082</td>
<td>575</td>
</tr>
<tr>
<td>Filler alloy</td>
<td>4047</td>
<td>577</td>
</tr>
<tr>
<td>Corrosive Flux</td>
<td>Melting range Approx 500</td>
<td></td>
</tr>
<tr>
<td>Non-Corrosive Flux</td>
<td>Melting range 565 - 572</td>
<td></td>
</tr>
</tbody>
</table>

Care must be taken when selecting material due to close range of melting temperatures.
Filler metal and flux options

Separate alloy and flux
• Solid wire, manual or wire feed or solid ring?
• Flux, corrosive or non-corrosive, application by brush or manual/auto dispense?

Combined alloy and flux
• Flux cored or composite material, alloy + flux (non-corrosive only) wire or ring?
• Braze paste, alloy + flux + binder (corrosive or non-corrosive) manual/auto dispense?

Selection very dependant on actual application

Summary

• Need to understand the technical details.
• Importance of collating process data.
• Identify variables then control them.
• Look for interrelationships between variables and limiting parameters.
• ……Go on, have a play like Mr “0”

Thank you for your attention