**Fire on the Runway – follow-up to July 2024 newsletter article**

Further to the Newsletter article, I finally got around to perusing the AAIB report.

Interesting read, though much of it is descriptive of known events, and the causes and effects of what we understand more comprehensively today.  We will never be 100% secure, there will always be the known unknowns and unknown unknowns (as one US politician said).

Apart from the descriptive events and the more obvious analysis, I assume from your article about the mind-boggling description of the cans concerns the construction and failure.

I’ll try to elucidate, as best I can:

It’s plain that the cans are tubes with a hemispherical head (at the front) and an exhaust out the other end.  The hemispherical head has vanes inside which swirl the air/fuel mixture to mix and atomise it and encourage a ‘clean’ burn.  There are numerous orifices in the can, upstream of the bit where the fuel burns so that air can enter (for obvious reasons) and other reasons, but a lot of the air by-passes the can entries to cool the cans within their large steel tube.

Now, the can material is nothing like the material you’ll get your baked beans in!  It would be a very complex alloy of elements and materials you’ll have never heard of (so no point in listing them) that will survive, under careful management, the intense heat and conditions in a gas turbine. (as an aside, this is why the Junkers Jumo in the Me262 had a short life between repairs).  As an example, consider two more everyday examples:  the old fashioned incandescent bulb, with it’s tungsten filament.  It glows white hot (generally) but doesn’t oxidise excessively owing to the local environment of either a vacuum or an inert gas within the bulb.  Break the glass, and poof!  Alternatively, consider the old-fashioned electric fire, with a wire wound round a (generally) ceramic core, and glows red hot, throwing out heat (let’s not go into how much!).  That filament is exposed to air and would take ages to oxidise to an extent where the thickness of the wire would diminish until the heat caused by the electrical current caused it to fail, just like an old-fashioned fuse.  In this case the wire is made of a similar sort of alloy to the cans.

Now, if you look at the two examples you will see that in each case, the electric current (the heat source) is clamped to the wire/filament, either by screws or crimping.

The reason?  They’re both a bu\*\*er to weld!

So, going back to the cans, which, apart from the hemispherical head, the ‘tubular’ section is made of rings of various sizes to give the required shape to achieve the fluid flow and desired flame pattern.  Each of which has to be welded to it’s adjacent partners to achieve the gas-tight seal.  In these rings. Each of which would have a joint, since the ring is formed from a flat piece of metal, ad the ends welded together, one over the top of the other (called a lap joint).

So far so good.  However, as in the case of the electric fire, and light bulb, deterioration will occur.  Hence why the items themselves have an expected life cycle, and why they are inspected regularly to determine their condition.  When signs of shortening of their lifespan is observed, the item would be repaired or replaced.  If satisfactory, this would also be noted.  This helps to identify future failures, and potentially extend the lifecycles.  Hence why each can has a unique identifier and has its own history (as do most items on an aircraft).

Now we come to the crux of the matter.

The report details that Pratt and Whitney had modified the cans previously (nothing unusual there – that’s the point of the inspections and analysis) and Can 9 had been replaced by one from another engine.  The P&W modification was to reduce problems with the welding of the cans (see above!).   The report does NOT say whether the replacement cans were to the ‘new’ P&W specification.

Now, since I mentioned earlier about the problems of welding these types of materials, P&W had designed the welds to be Resistance Seam Welds.

A resistance weld is akin to what most people would recognise (maybe) as a ‘spot weld’.  This is used extensively in cars and other things, by introducing a low-voltage, high current between two contacts that causes localised heating between the two contacts, thus creating a ’spot’, where the two materials have melted together in a disc generally about 4mm in diameter.  The spacing of these joints is critical for strength, safety, etc, but need not concern us here.

Obviously, there is no physical joint between the materials in between the ‘spots’ so being fluid tight, it isn’t.  (I use the term fluid because gases and liquids are both fluids and behave similarly). This one reason why older cars corroded at the joints, because water got in between the parts and corroded them.  Theses days the materials are better treated and sealers are applied to the joints before welding.

This technique wouldn’t obviously apply to a gas turbine can with gases at god knows what temperature – they are going to squirt out between the spot welds!

So they used ‘Resistance Seam Welding’.  Same principal, but instead of two probes/contacts they would generally use two wheels, and run them along the seam to provide a gas-tight seal as well as merging the two parts together (or the ends on the rings, in the case of the cans).

Nothing wrong, in principal, with this, P&W obviously refined or changed some elements of the cans or manufacture to improve things as experience and knowledge of the parts was acquired.

BUT – note the penultimate paragraph on Page 15 of the Report:

“*All the above mentioned cracks in the cans were addressed by direct fusion weld repairs during the LMI. Pre-weld Solution Heat Treatment (SHT) and post-weld stress relief (see paragraph 1.17.2) were not carried out*.”

The repairs were carried out by ‘Direct Fusion’.  Now, Direct Fusion isn’t resistance welding.  It comes a multitude, such as gas welding (think oxy-acetylene), arc welding (beloved in films with the arc making a bright light – so much UV you’ll wish you hadn’t looked), and in the latter, inert gas arc welding (often Argon – this excludes air and minimises oxidation).

Now I suspect, from all this that the Direct Fusion Welding would create thermal weaknesses in the can material, cause additional oxidation, and thus weakening the thickness/strength of the can material.  It doesn’t necessarily follow, but to do it well, requires exceptional skill, talent and experience – hence why Resistance Seam Welding was used in production by P&W.  Note also that Post-Weld Stress relief wasn’t carried out – this is where the can would have been subjected to a controlled heat for a calculated period of time to enable the material to ‘relax’ and reduce or eliminate the heat-induced stresses created by the Direct Fusion Welding.

In short, the repair wasn’t carried out in the best possible way!

Note that, generally, the Can-type combustion chamber has been largely superseded by the Annular combustion chamber.  The Can-type probably derives from Whittle’s engines, which, although they were centrifugal compressors and not axial, started the Can combustion chamber lineage by virtue of the obvious thought process involved or the airflow.

Hope this helps and hasn’t confused you further!