Capital Avionics

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AIRCRAFT HEADING SYSTEMS TEST AND MAINTENANCE – PART 2

LEGACY DILEMMA

Above is a picture of a Pan Am Sikorsky S-40 Clipper, circa 1931. What is not well known in the aviation industry today is that this aircraft, and other similar types, which flew routes in the Caribbean and Northeast USA, used directional heading systems (compasses) that were tested and aligned by the two most common methods still used today - the Compass Rose and the Sight Compass. What is further surprising is that the same technology has been accepted without incremental improvements in basic design from 100 years ago.

In other words, the aviation industry, with astonishing improvements in aerodynamics, propulsion and avionics, still uses as foundational calibration standards, small mechanical wet compasses and painted lines.

The reason is simple – overcoming the limitations of these two methods is neither economical nor functionally feasible.

Both methods have been analyzed in Part 1, so we will look at their limitations from a different angle.

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Sight Compass

From **Part 1**, the average expected error is 2.0 degrees, ***but only if you have aligned the aircraft within the defined limits, the test equipment meets the defined tolerances, and the technician correctly interprets the Sight Compass heading rounded to within one degree, with the engine(s) running.***

For any procedure to be considered a benchmark, multiple technicians should be able to provide the same initial headings, adjust the compass and create similar correction cards.

This isn't possible for several reasons. Let's begin with a little background.

To perform any maintenance using electrical, pressure/vacuum and/or mechanical measuring equipment, the calibration specifications become important. First and foremost, what must be known is the value and tolerance of the system parameter being measured.

Example: Tire pressure and tolerance 90 PSI +/- 3 PSI

Next is the tolerance of the measuring equipment.

Example: Tire Gauge pressure and tolerance 20-120 PSI +/- 3 PSI

From these two tolerances we have a TUR (**T**est equipment to **U**nit under test **R**atio) of 1:1. That is, the required tolerance of the tire is 3 PSI, and the tolerance of the measuring device is 3 PSI.

The problem with a TUR of 1:1 is that you cannot meet the +/- 3 PSI tire requirement with confidence because if the ***in-calibration*** Gauge reads 87 PSI, the actual pressure can vary as low as 84 PSI, which is out of the tire's tolerance. At the other extreme, a Guage reading of 93 PSI could be 96 PSI, again out of the tire's tolerance. In this example, the only acceptable reading from the gauge is 90 PSI.

In the aviation industry and calibration world in general, the TURs range from 4:1 (optimal) to 1:1 (minimal).

Now, let's go back to Sight Compass.

First and foremost –*What are the tolerances allowed for the aircraft's wet compass? Each individual heading?*

After taking these measurements, the results are recorded with a typical 1-degree resolution, but their accuracy is much lower than the required recorded headings (2 degrees actual verses 1 degree specified).

It is tantamount to trying to paint a line with a brush that is twice as wide as the line.

For typical Sight Compass errors of 2 degrees, for a TUR of 1:1, the recorded headings are only accurate to 2 degrees when the acceptable error is less than or equal to 1 degree.

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For a TUR of 2:1, a heading standard must be accurate to 0.5 degrees, which provides more statistical confidence that the readings are within one degree.

The dilemma here is that for 100 years industry has accepted this level of TUR (0.5:1 or less) because there was no alternative offered and it has become the Gold Standard.

Compass Rose

From **Part 1**, the average expected error is 1.65 degrees, ***but only if you have aligned the aircraft within the defined limits (1 degree), the ramp magnetic anomalies are within defined limits, the compass rose is no more than several years old since its last certification, the diurnal effect is not extreme, and the Sun is not experiencing exceptional solar disturbances, all with the engine(s) running.***

Once again, for any procedure to be considered a benchmark, multiple technicians should be able to provide the same initial headings, adjust the compass and create similar correction cards.

This isn't possible because of one significant, fundamental limitation.

The single largest issue is the alignment of the aircraft on the specified radial lines. Only Mil-Std 765A provided two quantitative procedures, which are impractical, using plumb bobs or opposing (90 degree) radials to affect a 0.17-to-0.5-degree alignment accuracy. These procedures can only be performed on paper, not in the real world, so the industry has taken the path of least resistance whereby technicians align the aircraft with a visual "looks good to me" calibration standard.

Looking at the prevailing aerospace heading requirements of 0.5 to 1 degree for initial installations and/or periodic tests, and real-world compass rose accuracy; we have again failed to achieve a TUR of 1:1 or greater.

Summary and Conclusion

In the late 1920s and early 1930s, the S-40 and its peers were state-of-the-art aircraft with accompanying engines, aerodynamics, and avionics/instrumentation. The maintenance industry has since evolved to meet these challenges without corollary compass system advancements.

As a result, there is a reluctance to deviate from these tried and proven methods because they have been in use since the dawn of aviation (with subsequent acceptance/approval status). But it is now time to address their shortcomings and take a good hard look at alternative methods.

This includes a fresh review of magnetic field dogmas and associated practices prevalent without quantitative, scientific analysis.

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The shortcomings of the legacy testing methods addressed here became apparent to Capital Avionics during a period when it was tasked with supporting new Piper aircraft with Meggitt® AHRS (MEMS-based gyros, etc.).

As a result of continual trips to the compass rose and other inconveniences, the CA-320 Digital Compass was conceived, designed, and certified with production starting in 2005.

Over the years, it has been replaced with the CA-420 Digital Compass with similar performance. Due to its non-traditional method of testing, with laser alignment, state-of-the-art magnetic sensing and Wi-Fi datalink, it has become popular within the industry.

However, this uniqueness also presents a reluctance to those experienced with the legacy systems to try something new.

In conclusion, digital compasses are not a replacement for legacy systems/methods but another option where there is demand for greater accuracy and efficiency.