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A12.5

Flux Valves and Electromagnetic Fields from MetroLink

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Client: Transport Infrastructure Ireland	**Title:** Simulated Magnetic Field Testing of Flux Valve Compass on ATR Aircraft
Attention: Multiple Recipients	

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LIST OF ACRYNOMS

EM	Electromagnetic
EMF	Electromagnetic fields
EMR	Electromagnetic Radiation
EMI	Electromagnetic Interference
DC	Direct Current
AC	Alternating current
RF	Radiofrequency

1.0 Introduction

As part of stakeholder consultations, and with the intention of informing the EIAR for MetroLink, CEI liaised with the Dublin Airport Authority (DAA) in relation to potentially sensitive receptors at Dublin Airport. It was suggested to include the airlines in the discussions.

As part of these discussions, CEI presented modelling of worst-case DC magnetic fields that could emanate from the operation of the MetroLink as it draws current from its traction supply. The only equipment highlighted as a potential concern were flux valves that are considered essential navigational equipment on board certain aircraft (in this case ATR aircraft utilised by Stobart Air).

Study of the effects of the modelled levels on the equipment yielded theoretical values for compass deflections. Again, worst-case was considered where the plane would have one wing (where the pilots flux valve is located) directly over the proposed alignment line and the other wing (where the first officers flux valve is located) the maximum possible distance away i.e. the plane being perpendicular to the proposed alignment. The modelling is discussed briefly in section 2.

By way of verifying these modelled values simulated field testing was facilitated by Stobart Air at their hanger in Dublin Airport.

Section 3 discusses the test setup and field application for the test, while section 4 presents the results and conclusions of this test programme.

2.0 Modelling

There outcome of the modelling did not highlight any effects on planes in flight as the heights involved ensures that any DC magnetic field fluctuations from the operation of the MetroLink would be within background/baseline levels once 20 m above the ground.

The proposed tunnel at Dublin Airport is at a depth of 18 m. The modelled DC magnetic field fluctuations based on full current loading of the traction supply from a single substation is indicated below:

Modelled DC Magnetic Field Levels at North Apron

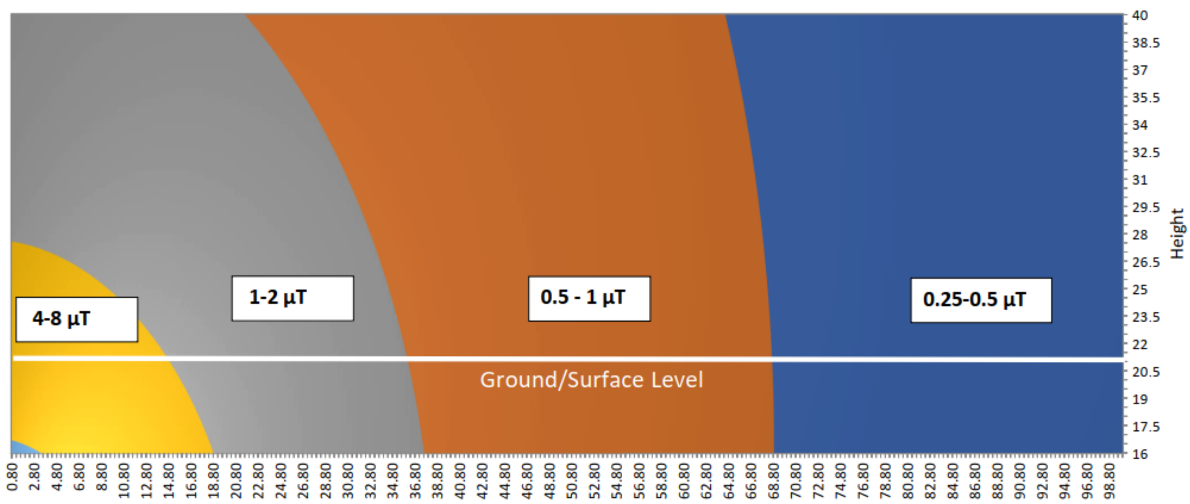

Figure 1: Modelled DC Magnetic Field variations above tunnel

Theoretically a standard needle compass would experience the following deflection based on field strength of a perpendicular field.

DC Field Level / µT	Compass Deflection / Degrees
0.25	0.30°
0.5	0.60 °
1	1.19 °
1.5	1.79 °
2	2.39 °
2.5	2.98 °
4	4.76 °
8	9.46 °

Table 1: Compass deflection based on perpendicular magnetic field

As discussed, there were no concerns in relation to planes in flight. The issue of concern for Stobart was in relation to the surface level magnetic fields and their potential effect on the flux valves mounted on the wings of their ATR aircraft. Expanding the modelling of Figure 1:

Modelled DC Magnetic Field variations above tunnel Table 2: Compass deflections based on distance from the alignment at ground level is the horizontal field at 3m above ground to account for the flux valves height above ground when mounted on the ATR aircraft's wing –

1	Distance from the alignment centre / m	0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
2	Modelled DC Magnetic Field / µT	6.3	5.3	5.2	5	4.8	4.5	4.2	4	3.7	3.4	3.2	2.9	2.7	2.5	2.3	2.1
3	Compass Deflection / Degrees	7.5	6.4	6.2	6	5.7	5.4	5	4.7	4.4	4.1	3.8	3.5	3.2	3	2.8	2.6

Table 2: Compass deflections based on distance from the alignment at ground level

These deflections in row 3 are the effect on a single compass. What the ATR aircraft has are two flux valve compasses. One located on each wing. The pilot views one and the first officer the second. There is often a discrepancy between the two but there are limits to what is allowable before the pilot decides to return to the stands. If the plane crosses the proposed alignment at a right angle the two compasses will experience the same momentary deflection and so no issue will be highlighted by the pilots or the automated system. The maximum possible effect depicted in the table would only occur if the plane were parallel with the tunnel with one wing directly over alignment than the other the distance of the two wings away. Again, this is a worst-case situation and not likely to occur often in practice.

In any event, the levels indicated in the second row of Table 2 were to be simulated on site on the ATR aircraft to determine if the theoretical deflections indicated in the third row were higher and lower in practice.

Two notes in relation to these levels –

1. The Altitude and Heading Reference Unit (AHRU) datasheet stated the following in relation to mismatch flags

    Headings mismatch flag CHECK HDG is displayed below the lubber line when a discrepancy exists between heading data of AHRS 1 and AHRS 2 (discrepancy value is 8 deg). The flag flashes during 9 seconds and becomes steady afterwards.

   In practice, in worst case conditions the aircraft is unlikely to experience a mismatch flag alarm even directly above the alignment based on my understanding of the systems operation. Revisiting the modelling output again (table below) and assuming a wingspan of 24 m. The maximum effect would be if one wing is directly above the alignment while the other is 24 m away. The maximum theoretical difference between the two systems would be, from table 2) 7.5^o - 3.8^o = 3.7^o, **which would not be sufficient to cause a mismatch error**. However, as has been highlighted, regardless of the automated system flagging the mismatch if the pilot notices an unexplained deflection of a significant magnitude they may decide to return to the stands for safety reasons with knock on operational implications. For that reason, the resolution in 04.4” is proposed.

2. The levels of Table 2 are worst case, as explained, and assumed the following scenarios –
    - Only one substation on the MetroLink is operational such that all the traction current is travelling in the one direction.
    - There is maximum current being drawn by two trains on full acceleration

3.0 Test Setup

3.0 Test Criteria

A varying DC magnetic field was generated in proximity to the flux valve sensors during a time when the equipment was energised and being monitored within the aircraft cockpit. It was to be determined through observations, the effect the generated field had, and any deviations noted on the navigational equipment.

3.1 Test Execution

DC magnetic fields were generated in the range from 0.5 µT up to 20 µT.

3.2 Equipment

The DC magnetic field was generated using a cable and current source. The current of the coil was controlled by a high DC current source actuator. The transducers of the equipment under investigation were placed within its magnetic field region which was calibrated for the correct distance use a 3-axis magnetometer.

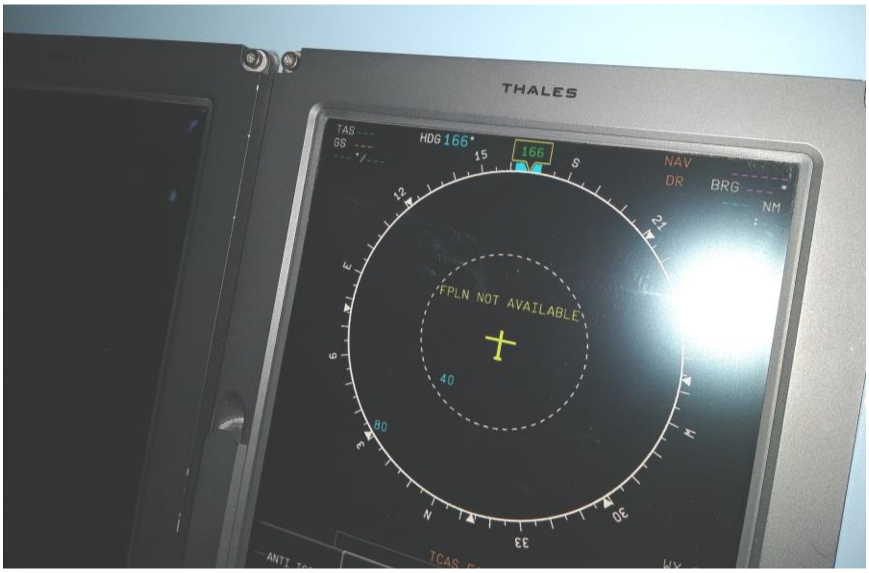

Figure 2: Pilot AHRS (displaying 166°)

Figure 3: Magnetic Field source installed below wing

4.0 Test Results and Conclusions

Due to the metalwork of the building and surrounding equipment the displayed readings of the AHRUs inside are not considered accurate but by way of demonstrating that differentials can occur between the pilots and first officer's AHRUs the following readings were noted on both displays before application of the magnetic field:

- Pilot – 166°
- FO – 171°

On the day of CEIs visit the test time was limited due to the main electrical power supply being removed from the plane under test for maintenance. The electrical systems were run off the backup battery which only had a limited run time. This appeared to have the knock-on effect of reducing the AHRUs response time to changes in bearing (or more accurately perceived changes). However, sufficient evidence was gathered to confirm the anticipated sensitivity of the instrumentation and therefore verify the modelling outcomes.

4.1 Test 1 – Increasing Magnetic Field

For this test, the magnetic field was increased approximately every 5-8 seconds. As it turned out the AHRU took longer to respond to these changes. The results are presented below. One item worth noting is that the First Officers display was unaffected throughout due to its distance from the source.

DC Field Level / µT	Pilots AHRU Display	Deflection	FOs Display
0	166	0	171
1	166	0	171
2	166	0	171
3	166	0	171
4	165	1	171
5	164	2	171
6	164	2	171
7	163	3	171
8	163	3	171
9	162	4	171
10	161	5	171
11	160	6	171
12	160	6	171
13	159	7	171
14	159	7	171
15	158	8	171

DC Field Level / µT	Pilots AHRU Display	Deflection	FOs Display
16	157	9	171
17	157	9	171
18	156	10	171
19	155	11	171
20	154	12	171

After the removal of the field it was noted that the AHRU took longer to respond than anticipated. It was several minutes before it returned to its original reading of 166.

4.2 Test 2 – Selected magnetic field strength application

With limited time available to repeat Test 1 at a slower ramp rate, selected field strengths were applied, and sufficient time given to allow the AHRU to respond to the applied field change. These are outlined below. The AHRU reference on this occasion was 165. Again, the FOs display remained unchanged at 171 throughout –

DC Field Level / µT	Pilots AHRU Display	Deflection	Theoretical Deflection
0	165	0	0
4	162	3	4
6.3	158	7	7

The level was only increased to 6.3 µT for Test 2 as this is the key value we are concerned with as per Table 2 i.e. maximum field strength directly above the line. So, in practice the theoretical deflection was confirmed. The deflections for lower field strengths would be equal or lower to that anticipated through the modelling.

4.3 DC Magnetic Field Environment

Fluxgate compass readings are ignored when inside the hanger due to local metallic structures causing localised disturbances to the lines of flux. This was evident in the differences between the pilot's and FO's displays while the ATR aircraft was parked inside the hanger before the commencement of the test (166 Vs 171 = 5 degrees of a difference). A brief walkaround of the hanger was conducted to prove out the concept that nearby structures can cause these deflections. Figure 4 shows large fluctuations experienced when approaching gantries and metallic stairs, while the building structure and planes would also account for fluctuations. Fluctuations of up to 15 µT were noted with average values being between 1 and 2 µT.

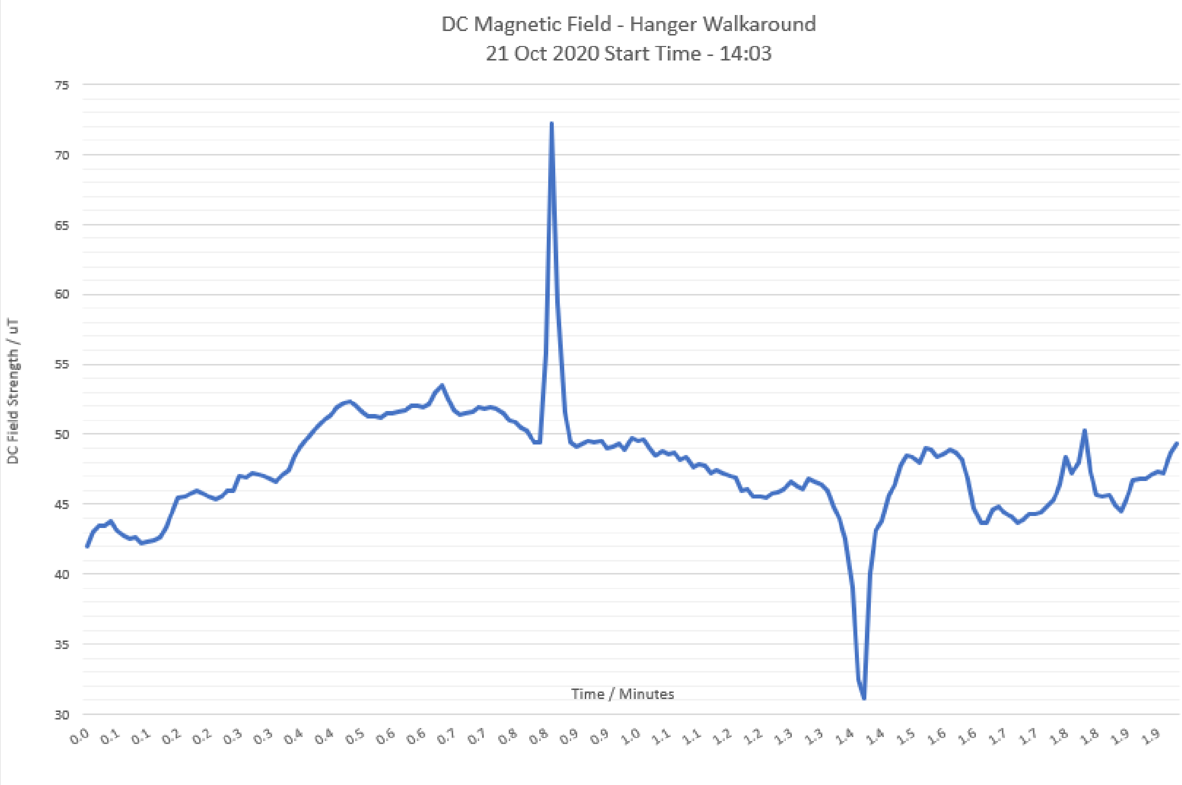

Figure 4: DC magnetic field measured during hanger walkaround

Figure 5: Mobile stairways and gantries surrounding aircraft

4.4 Conclusions

Discussion with Stobart indicated they were already familiar with interference with their fluxgate compass from other sources (buried utilities, fuel trucks etc.). And that these have caused returns to stands at other airports when the source of the interference has not been known.

Being able to attribute an unexpected compass fluctuation to a local source and not an onboard issue is key to continuing normal flight preparation, so a work procedure/bulletin or the equivalent used at Dublin Airport is recommended to be provided for the airlines. This bulletin will outline the MetroLink route through the airport and flag the potential (regardless of the low likelihood of occurrence) for compass deflections directly above the alignment and 20 m either side, which would create a buffer zone of 40 m. In practice the buffer zone could be less than 10 m but it's advisable to include a good safety margin to allow for limits of deviation of the tunnel alignment.

As stated in Section 1.04.3 fluctuations of up to 15 µT were noted inside the hanger with average values being between 1 and 2 µT. The expected fluctuations airside would be in the 1-2 µT range when passing buildings and other aircraft at a distance with higher levels at times attributable to fuel trucks and stairs passing close to the flux valves. These levels from nearby structures and fuel trucks would be as high and higher than those that could potentially be experienced directly above the MetroLink alignment. However, in these instances the pilot or first officer can visually see the source of the disturbance and therefore can carry on their flight preparation. This clearly would not be the case with an underground electrified rail-line and this is the reason an official document outlining a buffer zone along the MetroLink alignment is recommended.