Response to: Interactive comment on "The Effect of Construction Material on the Thermal Gain Dependence of a Fluxgate Magnetometer Sensor" by David M. Miles et al. by M. Moldwin (Referee) on 16 May 2017

We thank Dr. Moldwin for his constructive comments which we have incorporated into the manuscript. Dr. Moldwin raised several methodological questions which we address below; Dr. Moldwin's comments are in plain text, our responses in *italics* and any content added to or change in the manuscript are in *"quoted italics".*

This paper describes a systematic test on the thermal properties of material used for the base and bobbins to hold wire windings for fluxgate magnetometers. It is inspired by a desire to find a replacement for MACOR ceramic that is very difficult to machine. MACOR was used in many early magnetometers especially those from Acuna/NASA- GSFC. The paper is a good reference for not only validating the use of PEEK for the sensor housing, but also provides in the appendix useful material that was previously found in a difficult to find Report.

(1) Title. Suggest replacing "Construction" with "sensor housing" or "winding and core support" or some other words to describe what the material is used for "Bobbin and Winding Support"?

Change made – The title now reads "The Effect of Winding and Core Support Material on the Thermal Gain Dependence of a Fluxgate Magnetometer Sensor"

(2) Line 10, add a comma before "but"

Change made – the text now reads "… and space physics, but are typically sensitive"

(3) Page 2, Line 25, the Ukrainian's have looked at the temperature dependence of material (including MACRON) on fluxgate gain though they don't publish in easy to find journals. KOREPANOV, V. and MARUSENKOV, A.: Modern flux- gate magnetometers design, International Conference on Magnetism, Geomag- netism and Biomagnetism : Conference Proceedings, Sezana, 2008. p. 31-36. http://www.viviss.si/download/viviss/ZBORNIK%20MGB/Korepanov_paper_31_36.pdf

The suggested reference (Korepanov and Marusenkov, 2008) has been added to show the historical context of the adoption of MACOR in fluxgate sensors. Korepanov and Marusenkov, (2008) specifically reference the small magnetometer in low-mass experiment (SMILE) instrument which is already referenced later in the paragraph as Forslund et al., (2008).

Change made – the next now reads "MACOR machinable ceramic has been used extensively and successfully in a variety of fluxgate applications often as a substitute for marble or quartz (e.g., Korepanov and Marusenkov, 2008)."

(4) Page 2, Line 33. Though the sensor housing material is not explicitly named in publications, UCLA's fluxgate magnetometers have used Lexan (DSX) and have moved to PEEK. Mark B. Moldwin, "Vector Fluxgate Magnetometer (VMAG) Development for DSX," UCLA, Final Report, June 3, 2010, URL: http://www.dtic.mil/cgi- bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA529004 for exactly the reasons described in this research article (cost, ease of machining, and good thermal behavior).

That is a useful addition especially since, as mentioned by Dr. Moldwin, the material is not explicitly named in the publication.

Change made – the text now reads "… the miniaturised SMILE instrument (Forslund et al., 2007); the Vector Fluxgate Magnetometer (VMAG) for the Demonstration and Science Experiment program (Moldwin, 2010); a prototype radiation tolerant fluxgate (Miles et al., 2013) …"

(5) Page 8, Line 5, "Reference values. . ."

Change made – the text now reads "Reference values for general purpose acetal…"

(6) Page 11, Line 20, to be consistent with British English Spelling used throughout "Characterised"

Change made – the text now reads "the thermal effects being characterised."

(7) Page 12, Line 12. To be consistent, use SI (or at least mm/cm) as used in other dimensions in text instead of symbol for inch.

Change made – the text now reads "… was constructed from ~5 cm thick …"

(8) Figure 11. What reasons have you eliminated for the large amplitude harmonics at 2, 3, and 4 Hz seen in the data? Is there a mismatch in the driver circuit that isn't exactly tuned to give 1 Hz signals?

Reviewer 2 raised the same question so we have reproduced a common response here.

The harmonics don't appear on a direct measurement of the output of the signal generator and so are thought to be instrumental. The working hypothesis is that the test signal, added to the ambient magnetic field, occasionally passes the threshold at which the instrument updates the magnetic feedback in the channel under test. By design, the instrument updates the magnetic feedback at a 1 Hz cadence by updating the digital to analog converter and hence creating a step in the feedback current. The transient effect of the step in feedback current is compensated inside the instrument; however, this compensation may have been partially defeated by the removal of transmission line transformer in the experimental setup. It would be interesting to experiment with different, non-integer, test signal frequencies to try and separate the source from potential instrument ranging artifacts. Unfortunately, with this experimental setup we were restricted to a 1 Hz test signal to preserve the source synchronization and prevent frequency beating in the spectral analysis.

As acknowledged in the manuscript, "the large amplitude harmonics of the controlled source was not expected"; however, we argue that one of the strengths of the spectral analysis technique is that power at other frequencies should not affect the measurement. Regardless of how the power is getting into the harmonics it will be excluded by the quantitative spectral analysis as it is well separated from the source in frequency space. Further, assuming that the harmonics are an instrumental effect, such as from feedback updates, because the instrument hardware is constant throughout the experiment the comparison between the sensors should be unaffected.

Change made – the relevant text now reads "The large amplitude harmonics of the controlled source were not expected and remains unexplained. The authors suspect the harmonics may result from the instrument updating the digital magnetic feedback, which also occurs at a 1 Hz cadence, in response to the 1 Hz test signal aggravated by a impedance mismatch due to the removal of the transmission line transformer. However, because the instrument hardware is constant throughout the experiment the comparison between the sensors should be unaffected especially as the harmonics are well-separated form the test signal in frequency and will excluded by the spectral analysis."

(9) Figure 13, Are there any other potential explanations of the Y offsets of the different trials? Any simple tests that you can do? Is the alignment of the Helmholtz coils thought to be due to a temperature effect? Do you get similar variations of off-set without the thermal test set up?

We suspect that the offset between trials results from a small change in the alignment between the sensor and the Helmholtz coil which is incurred when the insulating box is opened to add dry ice. The Y offsets of 0.01 to 0.04 nTrms on a 234 nTrms signal would only require only a miniscule angular offset between runs. This agrees with the data shown in Figure 14 replotted here as a function of time rather than frequency. There is scatter comparable to all experimental runs; however, there is no long term trend suggestive of, for example, drift in the source amplitude. We have amended the text to clarify and further describe the suspected cause.

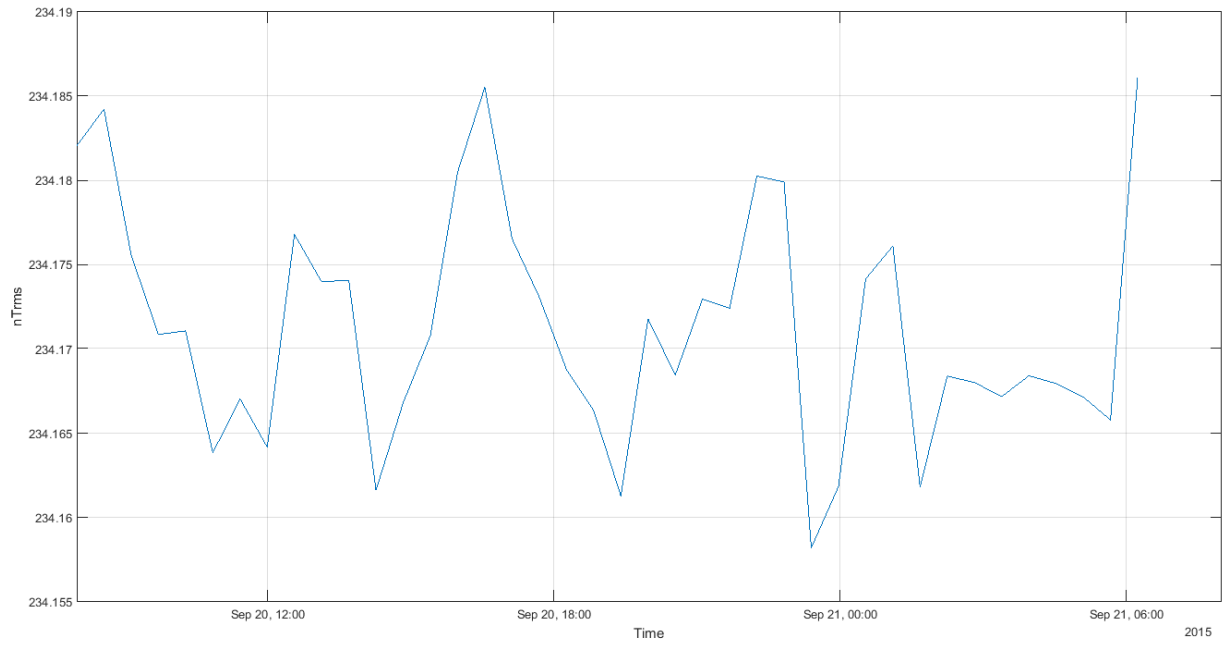

Figure 1: Data from manuscript Figure 14 plotted against time rather than temperature. Note scatter in apparent amplitude but no significant long term trend.

Change made – the text now reads "The visible Y offsets between the trials are not well understood but may result from a small change in the alignment between the sensor and the Helmholtz coil that is incurred when the insulating box is opened to add dry ice. In the absence of temperature change or accessing the box, the measured amplitude of the test signal (e.g., the data shown in Figure 14) has scatter in the apparent amplitude but no long term trend suggestive of effects like drift in the source amplitude which would affect the results of the test."

(10) Page 23, Line 17, "Data are. . ."

Change made – the text now reads "the data in this manuscript are available from …"

(11) Page 30, Line 16 "localised"

Change made – the text now reads "well behaved localised resistor"

(12) Page 31, Line 8, "PEEK"

Change made – the text now reads "Overall, the 30% glass filled PEEK was"

We believe we have addressed the concerns of the Reviewer and hope that Dr. Moldwin can now recommend our manuscript for publication in Geoscientific Instrumentation, Methods and Data Systems.