Angry Ass

Tech Tuesday

S38 Inconel Myth Part 1 | February 2020

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From all of the asses at Angry Ass, thanks for joining us on this Tech Tuesday!

We're tackling the myth that's recently permeated the E34 M5 community, which is that the S38B36 and S38B38 headers are constructed of some grade of Inconel. This myth gained wings after internal marketing material from BMW that mentions the "special steel" construction of S38 headers was circulated online. As enthusiasts, we live, love, and breathe the S38, all the cars motivated by it, and even the cars in which it should be transplanted (cough, cough, E9). So we at Angry Ass were honestly biased, and hoped to prove this myth correct, bolstering our bragging rights at the next car meet. However, we had our concerns due to BMW's unspecific references and lack of scientific measurement.

In case you aren't a metallurgist, or for some strange reason were not aware, "Inconel" is only a tradename coined by Special Metals Corporation for nickel-chromium superalloys. Used extensively in environments in which oxidation-corrosion resistant materials are required, this stuff can also handle extreme temperatures and stresses. In the general transportation industry, typical and famous applications are in the space shuttle, jet turbine components, portions of the McLaren F1 and Porsche 918 exhausts, Formula 1 cars, and some NASCAR exhaust systems. Although Inconel is a tradename like Kleenex, also like Kleenex, the name is now used ubiquitously to refer to all nickel-based superalloys even if manufactured by other companies. For instance, our standards (detailed below) are manufactured by Carpenter under the tradename "Pyromet", but they are still the widely available nickel-based superalloys of 625, 680, and 718.

Our method for testing this myth is simple: we used an industry-standard XRF (X-ray fluorescence) analyzer to examine the elemental makeup of our three known Inconel alloys and six different grades of stainless steels, compared to our S38B36 header section. If the header section is Inconel it will have a dominant elemental makeup of nickel (Ni). If it is made of a grade of stainless steel, it will have a dominant elemental makeup of iron (Fe). Inconel may be a rocket material, but this ain't rocket science.

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In Part 1 of the S38 Inconel Myth, we will determine the metallurgical makeup of the S38B36 header section, paving the way for part 2, in which we will scan an S38B38 header section.

Now, let's get to it. (Skip to the last page for instant gratification!)

Our setup of materials is shown on the next page in Figure 2, and not on this page in Figure 1 where you'd expect, because we won't hide anything: we messed up. . .We placed the alloy standards and the header on a maple butcher block table that we have in the machine shop, so as to avoid as much elemental contamination as possible (which was perfect). Unfortunately, we bought too small of test samples, so the XRF analyzer picked up too much of the table and gave repeated dominant elemental percentages of LE. . . LE stands for "light elements", which basically means the air and carbon → as in wood → as in our table top. The good news is we have officially determined that there is air and wood is made from carbon, and with that ground-breakin discovery, see Figure 1.

Figure 1

This severely irritated our wonderful, volunteer chemist, who tried to keep the XRF focused on the tiny ½” OD alloy standards that constantly rocked and rolled during the measurements. Luckily, this doesn’t affect our results in a manner that precludes us from making a determination of composition of our standards or the header samples, because Inconel will still be predominantly nickel (Ni) and stainless will be predominantly iron (Fe). Good ol’ lumber (LE) will just show #1.

Figure 2

In Figure 2 above, we have the S38B36 header section with the 3 Inconel standards in the center, and the 6 stainless steel standards to the right, and the material certs from Carpenter for the 3 different Inconels (Pyromet).

Our first test was Inconel (Pyromet) 625 (Figure 3).

Figure 3

The elemental composition of our Inconel (Pyromet) 625 with contamination from the table (get used to this) is shown in Figure 4.

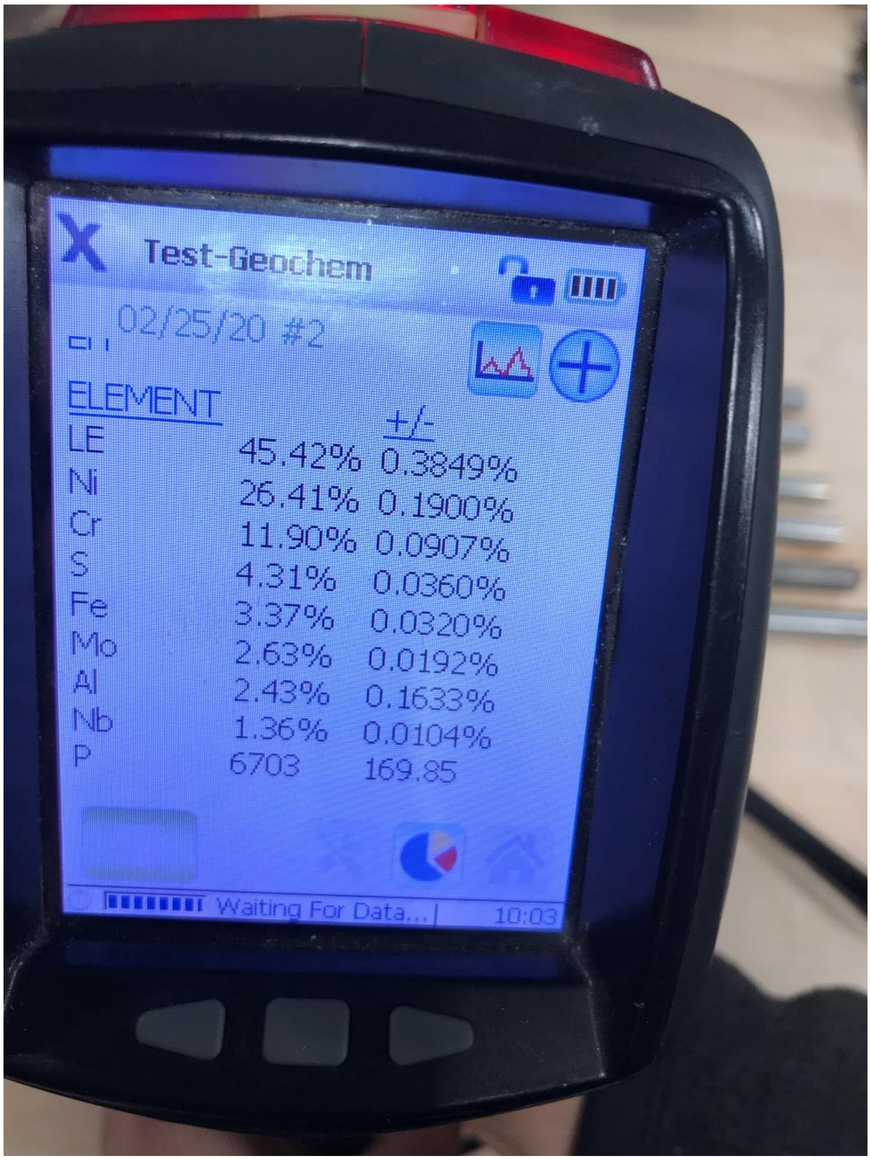

Figure 4

Notice that in Figure 4, the dominant element of this standard is nickel (Ni) . . . (well, behind the damn table, shown as LE [Light Elements]). This is consistent with a nickel-based superalloy.

Our next test was Inconel (Pyromet) 680. Figure 5 shows the elemental composition (again with contamination from the table). Funny enough, the iron (Fe) composition was higher than chromium, which doesn't quite match the standard certification. But it's still an Inconel variant.

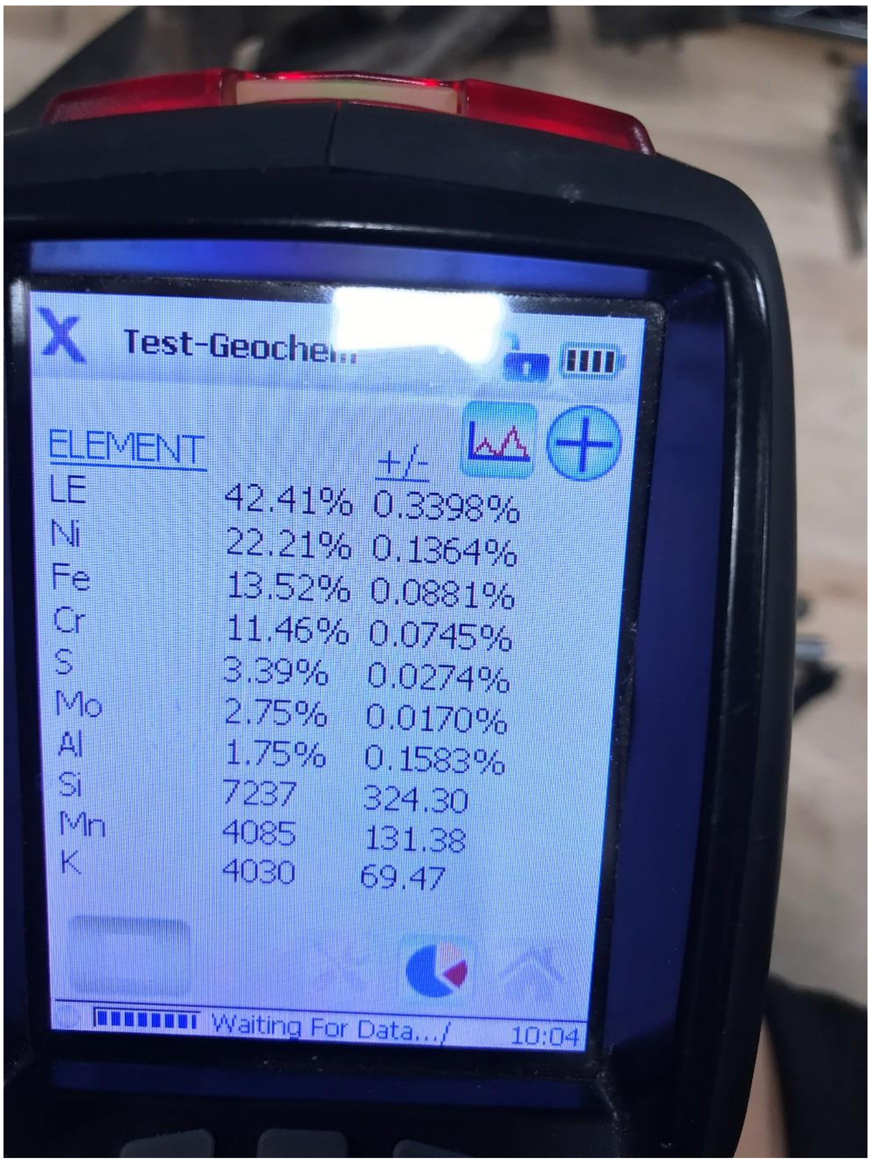

Figure 5

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Our final Inconel (Pyromet) test was alloy 718. The elemental composition of 718 is shown in Figure 6. Again, notice the dominant nickel (Ni) content.

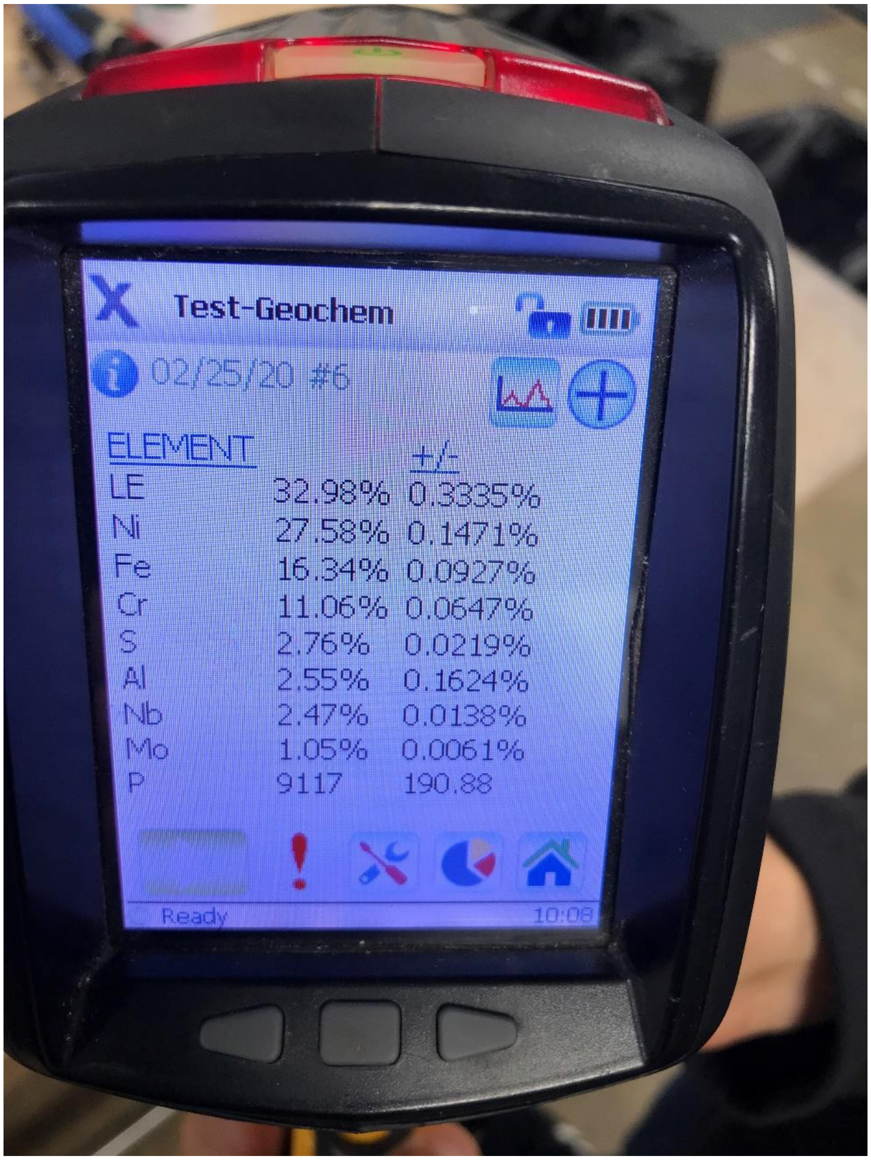

Figure 6

The first stainless standard was alloy 303. Stainless steel 303 is known as a free machining stainless due to the addition of sulfur (S). The elemental composition of stainless steel 303 standard is shown in Figure 7. Notice the dominant iron (Fe) content, as expected. The relatively lower LE reading is due to our chemist developing a better technique to aim at the tiny standards, also notice the sulfur (S) content.

Figure 7

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The second stainless standard was alloy 304. Stainless steel 304 is the typical stainless used in most performance exhaust headers, with good oxidation corrosion resistance and containing both chromium (Cr) and nickel (Ni). Figure 8 shows the elemental composition. Notice the lack of sulfur (S) compared to the stainless steel 303. LE readings are low again thanks to that improved scanning hand technique.

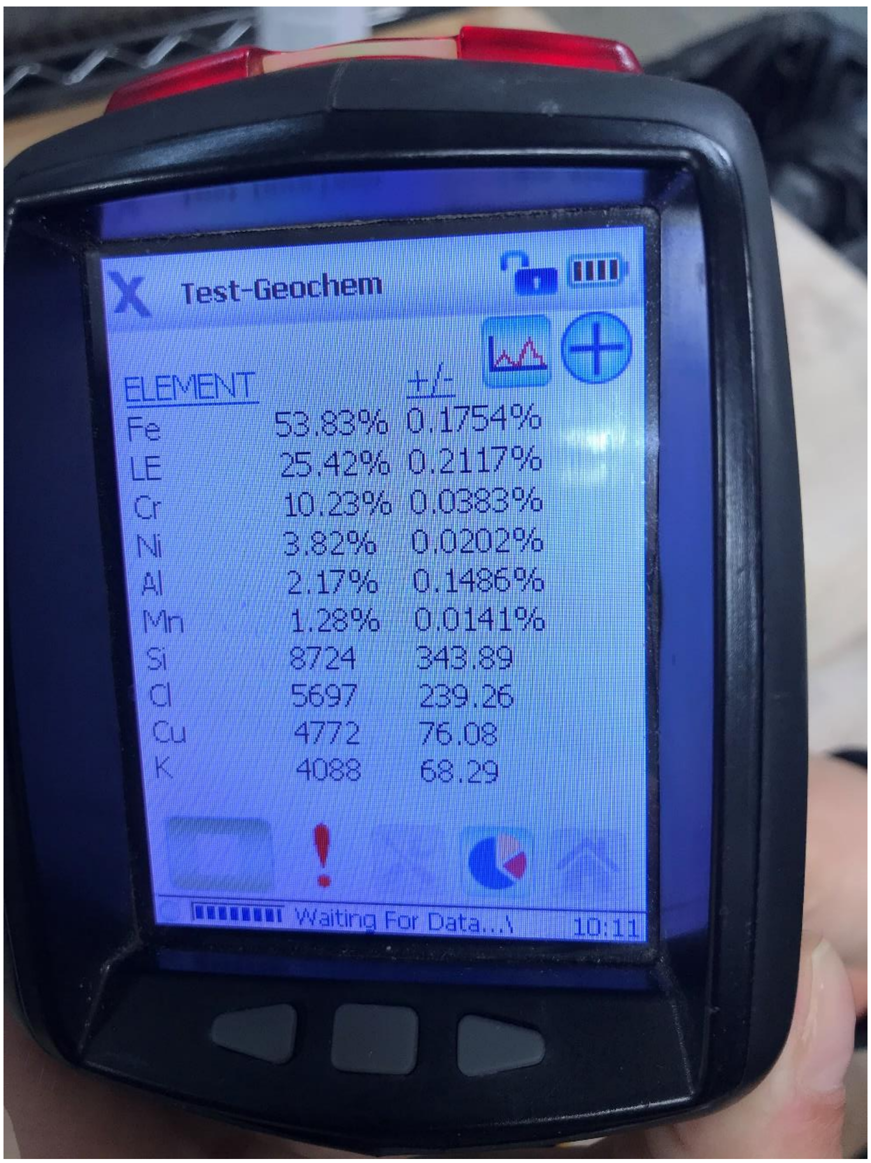

Figure 8

Our next stainless standard was alloy 316. Stainless steel 316 has a higher molybdenum content than 303 and 304, which increases corrosion resistance. The elemental composition is shown in Figure 9. Notice the uptick in molybdenum (Mo).

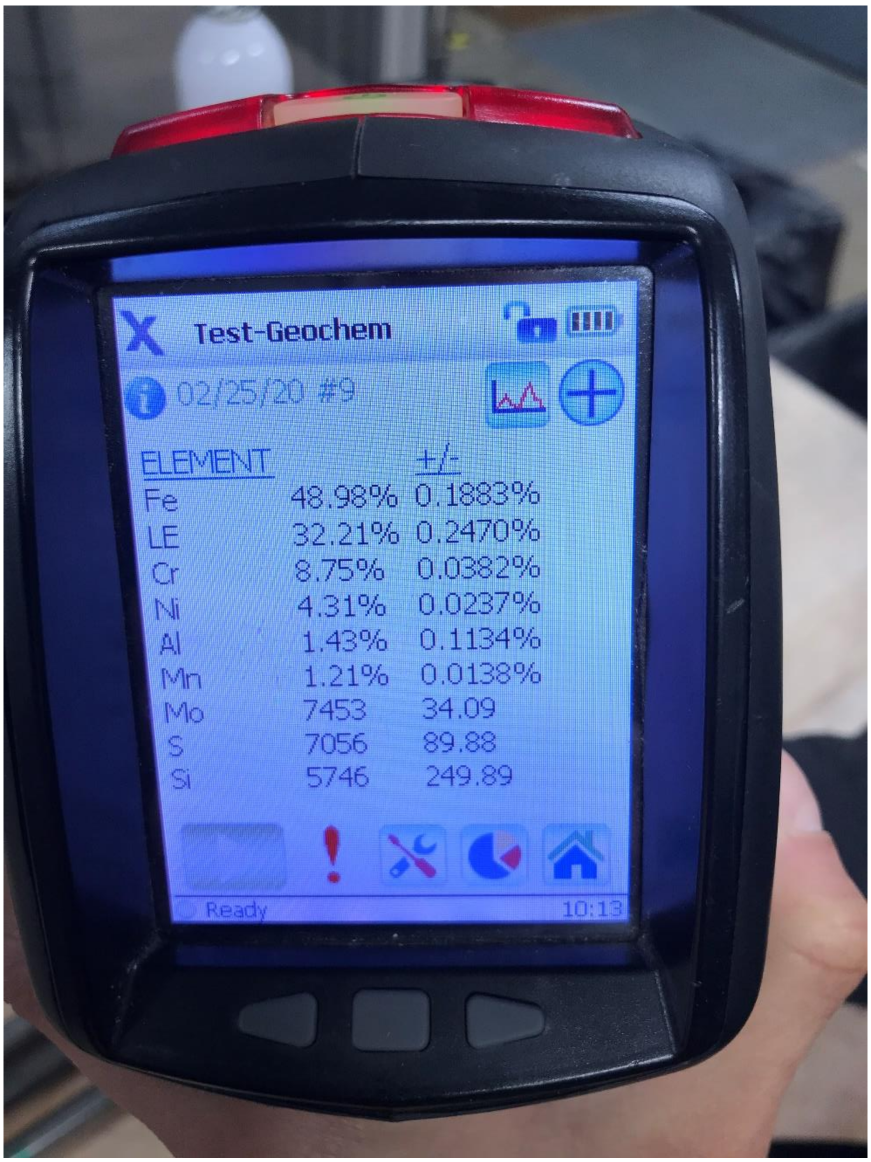

Figure 9

After stainless 316 comes stainless 321, used heavily in higher temperature environments (especially in premium exhausts and high-performance turbo headers). Figure 10 shows the elemental composition of the stainless steel 321 standard.

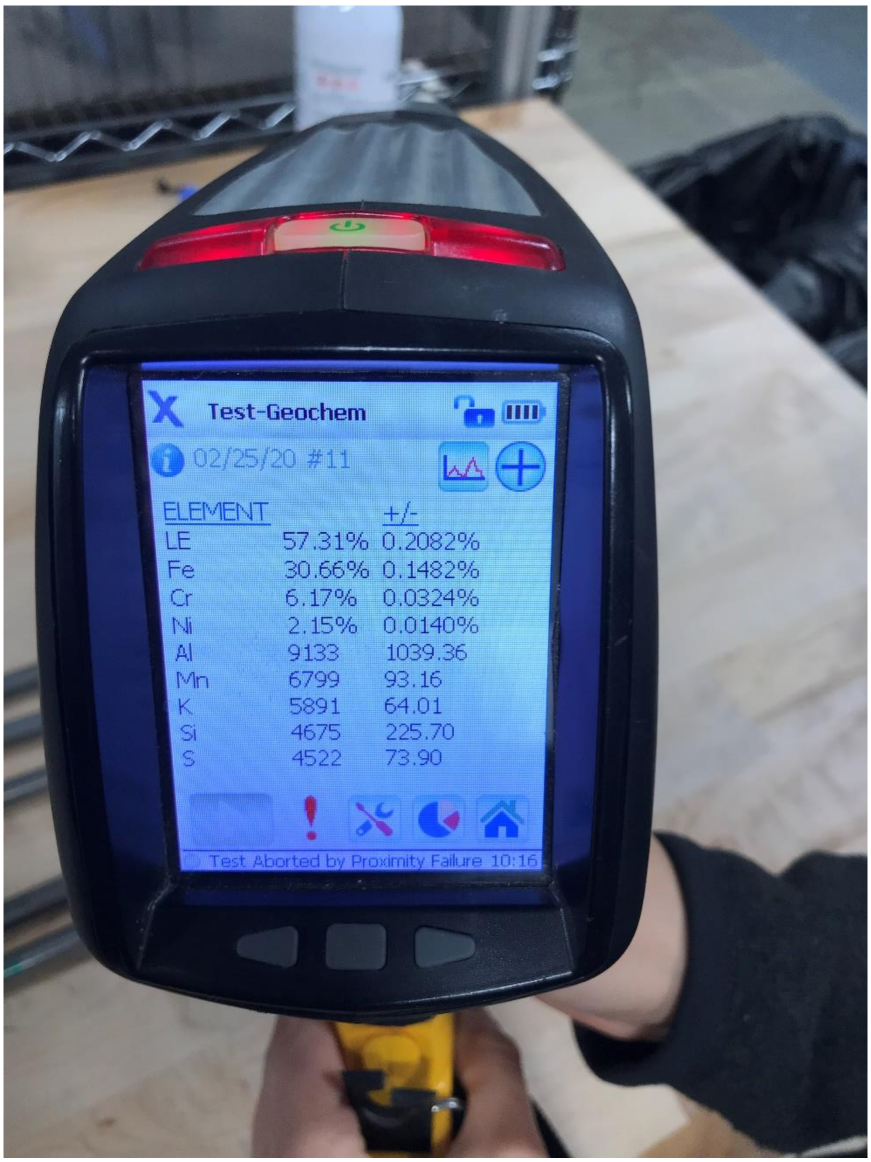

Figure 10

With stainless 321 covered, we added in stainless 309, a high temperature-capable stainless steel. The elemental composition of 309 was dominated by iron (Fe) as with all the stainless steels. See Figure 11.

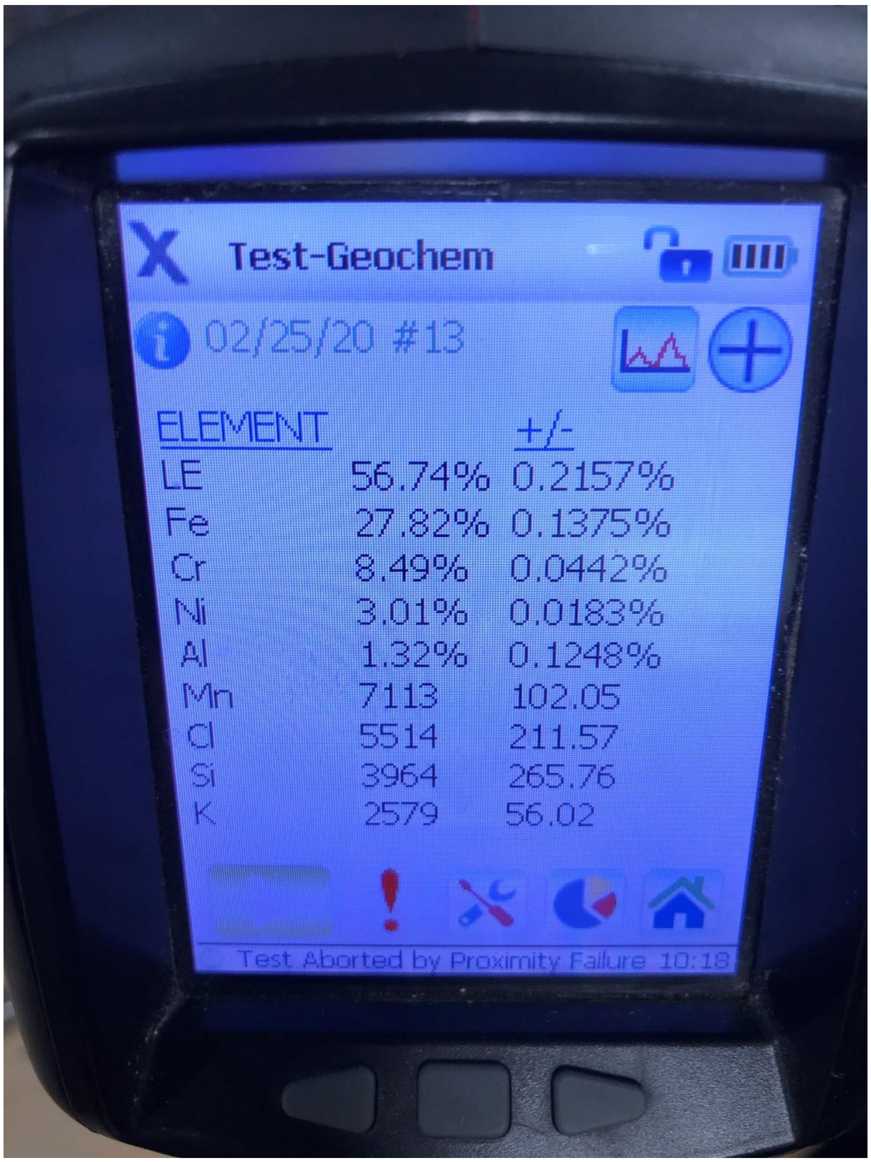

Figure 11

Last of the stainless standards was 416, which is a high temperature-capable stainless steel that is free machining, similar to stainless 303 (due to the addition of sulfur). The elemental makeup of 416 was again primarily constituted of iron (Fe), with a side of sulfur (S) for ease of machining. See Figure 12.

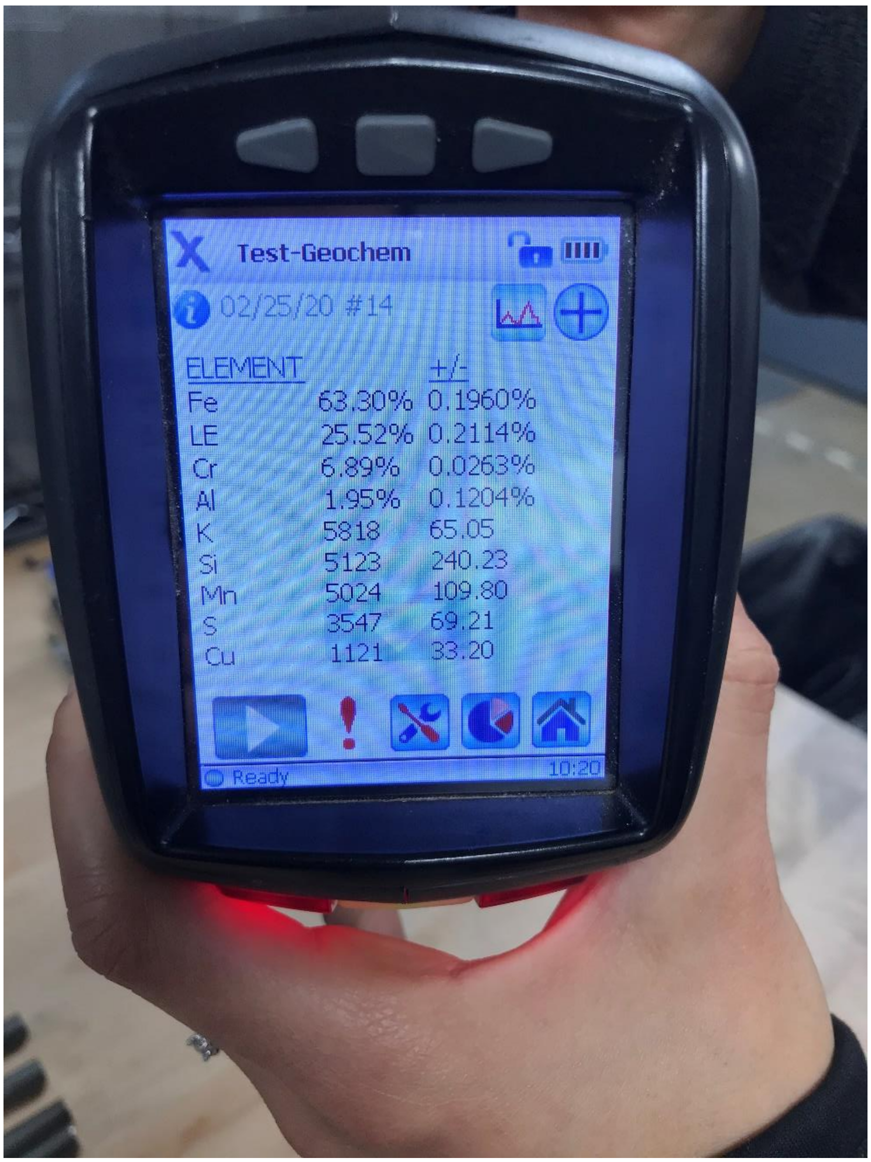

Figure 12

Our last reading was taken on the S38B36 header segment itself, after a thorough cleaning of as much oxidation and filth as possible using a ScotchBrite pad and solvent/flux remover. See Figures 13 & 14.

Figure 13

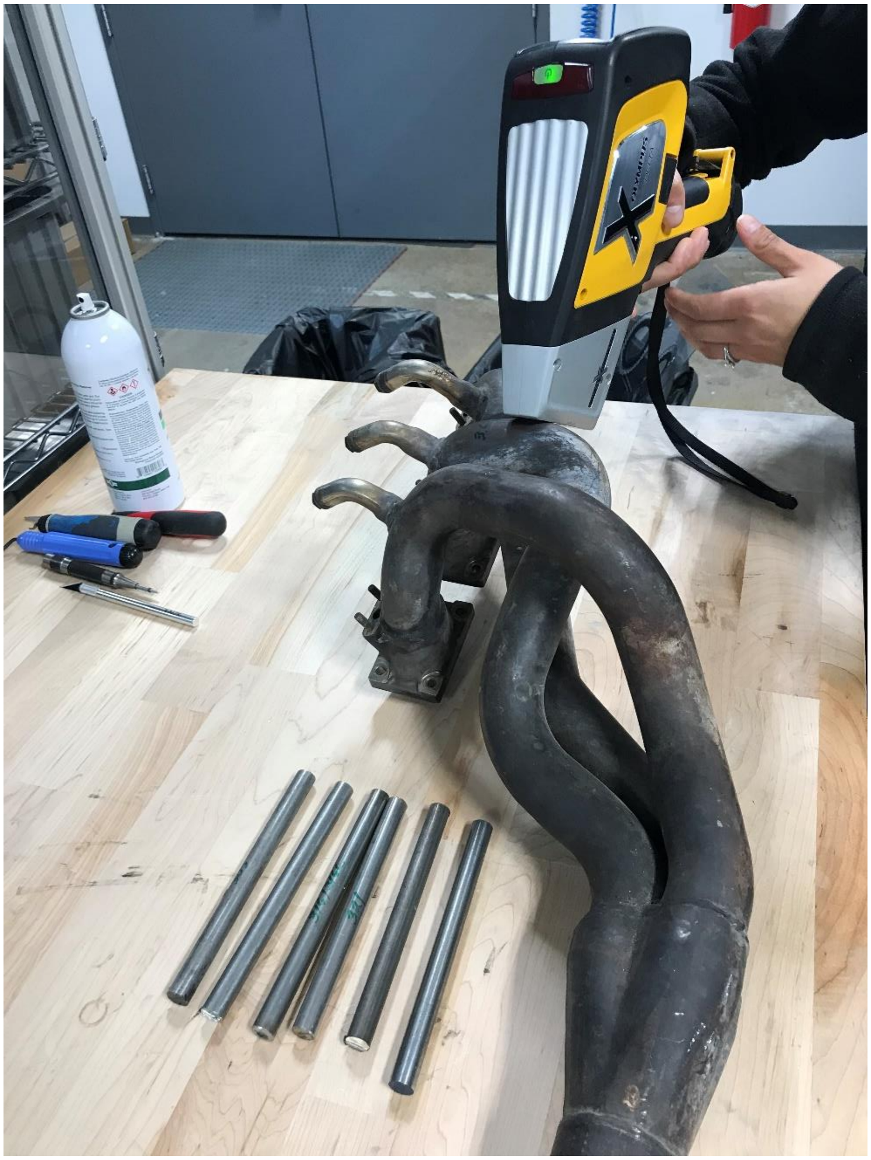

Figure 14

The elemental composition of the S38B36 header is shown in Figure 14.

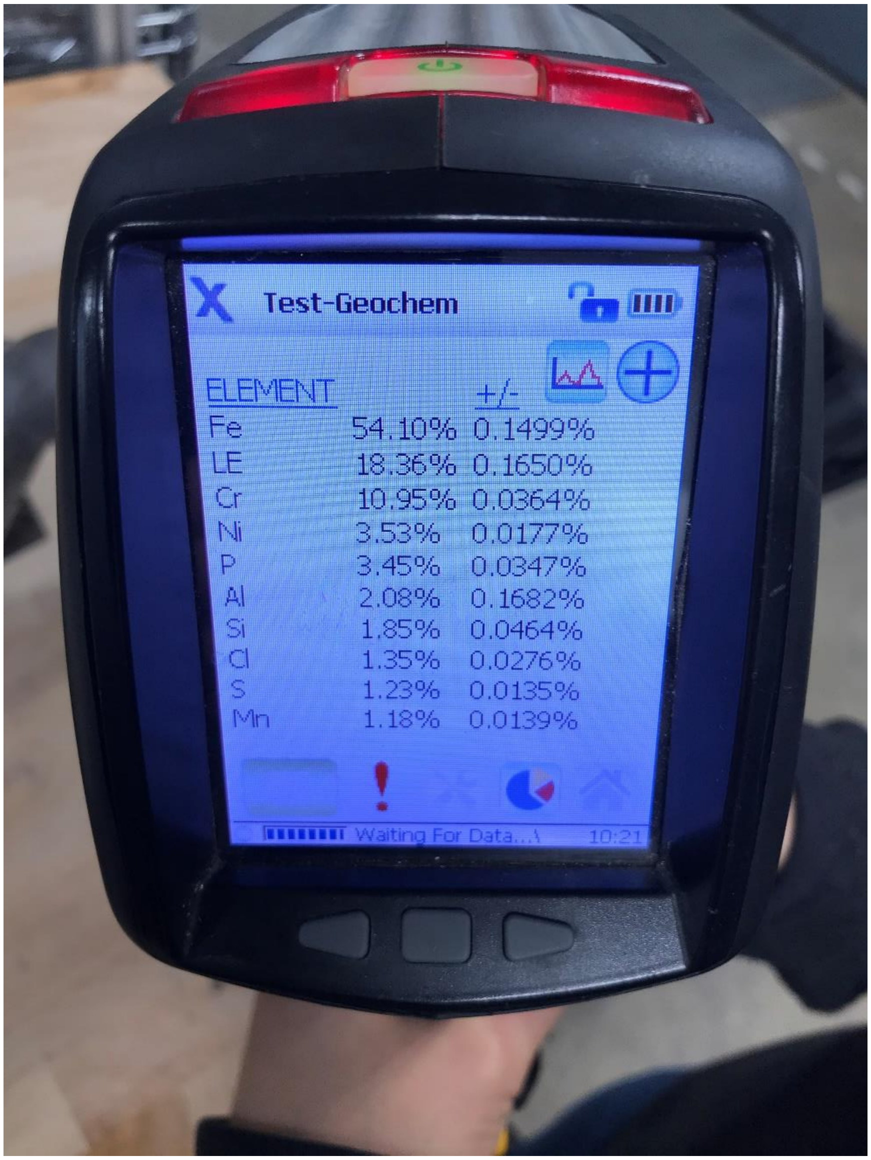

Figure 14

It's pretty clear to see with the dominant iron (Fe) content, medium chromium (Cr) content, and very low nickel (Ni) content, that the header is a stainless steel alloy, and not an Inconel alloy (which would have a dominant nickel (Ni) composition).

Myth, busted!

In Part 2, we will analyze a B38 header segment and compare it to these same standards. Our hypothesis is that the B38 header will be made of the same materials, bolstered by the fact that BMW uses the same part number for both S38B36 and B38 headers. However, we think it's imperative to scientifically compare a period-sourced S38B38 segment to the S38B36 segment, because we have seen BMW apply the same part number across both engines in modern times (even to parts we know were different, in period).

If you'd like to see anything else covered in Part 2, please let us know, and we'll do our best to accommodate requests.

Thanks for reading!

- Angry Ass