A project started in late 2013 has examined the integrity of welding Grade 91 (high chromium alloy steel) to stainless steel grades 304 and 316. G91 is a commonly used material in high temperature power plants due to its high temperature creep resistance. Tungsten inert gas (TIG) welding was used to ensure a high quality weld with minimal defects/inclusions.

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ASTM/ASME A/SA387 Grade 91 is a modified 9Cr-1Mo steel composed of nitrogen, niobium and vanadium. Although the most common form of Grade 91 material is a plate form, the steel is incorporated into other ASME materials specifications for castings, forgings, fittings, pipes and tubes.

Applications of Grade 91
The most common application of ASTM/ASME A/SA387 Grade 91 material is as a high temperature structure material in the fabrication of intermediate heat exchangers, steam generators, secondary piping of a liquid metal reactor that operates at around 550°C, and boiler components used in ultra-supercritical thermal power plants that operate at around 600°C.

The high creep strength of ASTM/ASME A/SA387 Grade 91 material makes it suitable for use in pressure vessels and in some interior structures of gas cooled reactors. The material is the subject of intense research in a boiler service. It demonstrates a distinct strength advantage at 566°C as opposed to 304H stainless steel and Grade 22 steel. This grade has a superior thermal fatigue and creep resistance over Grade 22 (2¼Cr-1Mo) steel, making it the material of choice for thick-section vessel applications.

Grade 91 has a better fireside corrosion resistance than Grade 22, but inferior
to 300 series stainless steels. The variations in operating and service conditions between one section and another, for instance in a boiler plant, demand the use of different materials for some components for improved structural integrity of the plants. One of the ways to meet this demand is joining two or more materials by welding.

Research on dissimilar metal welds
The School of Engineering at the University of Portsmouth along with Masteel UK Limited examined the possibility of welding ASTM/ASME A/SA387 Grade 91 material to other steels. A group of researchers and students at the school explored the possibility of a dissimilar metal weld, such as Grade 91 and Duplex/stainless steel. According to a research conducted by a group of Korean researchers, the severity of damage at the dissimilar metal welded joints (between Grade 91 and 316L stainless steel) was greater when compared to similar metal welded joints (i.e., between 316L and 316L or Grade 91 and Grade 91). Hence, the school proposed the study to gain insights into whether process control and parameters (before and after welding) significantly affect the final performance of the weld. The chemical compositions of specimen materials are listed in Table 1.

Charpy impact test
The characterization of dissimilar metal welds was conducted by performing a charpy impact test to determine the toughness and the nano-indentation to indicate the difference in the hardness across parent material, the (HAZ) regions and the weld metal. The results suggested an increase in the toughness of non-heat treated weld samples with an increase in the stainless steel filler size (2 sizes were used i.e. 1.6mm and 2.4mm). There was however a reduction in toughness following a PWHT on the weld samples with a larger filler (2.4mm). The highest toughness at room temperature was obtained from the PWHT (SS 304-G91) weld samples with the 1.6mm filler. The nano indentation test indicated increased hardness towards the weld metal (Coarse Grain Heat affected Zone. CGHAZ) in association with the martensitic structure. University of Portmouth also currently conducts research on the corrosion of the dissimilar metal welds.

Conclusions
The results of the research are as follows:
- Nano-indentation indicated increased hardness in HAZ (fine grain martensitic structure)
- PWHT reduces hardness in HAZ
- Charpy test indicates increased toughness in welds 3 and 7 (after PWHT) but reduced toughness in welds 4 and 8 (after PWHT)
- SS304-G91 -1.6mm filler – PWHT, displays highest toughness at room temperature

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<th>Material</th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
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<th>Cr</th>
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