BUGATTI COOLING SYSTEM PIPE – AL ALLOY – FRANCE

Artefact name Bugatti cooling system pipe

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Url /artefacts/670/

The object

Credit He-Arc CR, E.Granget.

Fig. 1: Bugatti water pipe, unknown model,

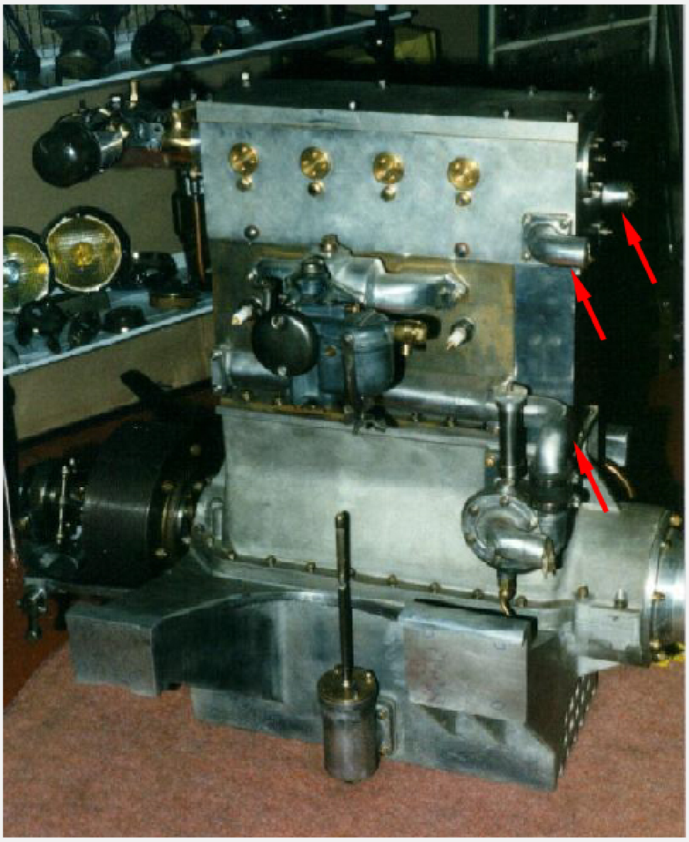


Fig. 2: Examples of water pipes located on a Type 37 engine,

Credit He-Arc CR, E.Granget.

Description and visual observation

Description of the artefact	This section of a pipe was given to the MNAM as study material, without indication of provenance. The pipe is angled, sharply cut on one end and heavily corroded on the other, the inside being clugged by a brittle yellowish deposit. Looking at its shape, it is safe to assume that this is an exit pipe from the upper part of the engine (Fig. 2 and complementary information below).
Type of artefact	Technical object
Origin	MNAM (Musée National de l'Automobile de Mulhouse), Mulhouse, Alsace, France
Recovering date	None
Chronology category	None
chronology tpq	1920 A.D.
chronology taq	1930 A.D.
Chronology comment	
Burial conditions / environment	Outdoor to indoor atmosphere
Artefact location	MNAM (Musée National de l'Automobile de Mulhouse), Mulhouse, Alsace
Owner	MNAM (Musée National de l'Automobile de Mulhouse), Mulhouse, Alsace
Inv. number	None
Recorded conservation data	None

Complementary information

A combustion engine transforms thermal energy into kinetic energy. This process is imperfect and releases a lot of heat through the block of the engine. Therefore, these parts need to be cooled down. A cooling system circulating water between the block [hot] and a heat exchanger (or radiator) [cold] is frequently used to fulfill this function (Poulain, 1995, p.86). Most of the time, the Bugatti inline cylinder engines have aluminium water pipes entering the block from below and exiting it from above, as shown on Fig.2.

This artefact is part of the "Materials for study Library" that the museum collected. It can therefore be sampled.

Study area(s)

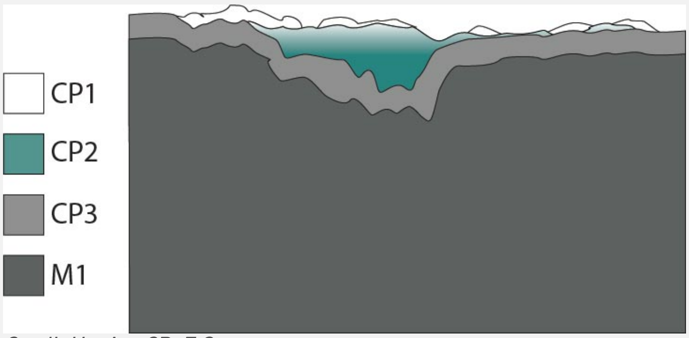
Fig. 3: Heavily corroded side of the Bugatti water pipe showing the sampling area indicated in red,

Credit He-Arc CR, E.Granget.

Binocular observation and representation of the corrosion structure

The schematic representation below gives an overview of the corrosion layers encountered on the Bugatti pipe.

The stratum M is an aluminium alloy. Three CP strata have been identified. CP3 has a greyish mate color and is covering all of the corroded side of the pipe. Scattered over this uniform layer, blue-green (CP2) and white (CP1) spots of corrosion products can be found.



Credit He-Arc CR, E.Granget.

Fig. 4: Stratigraphic representation of the corrosion structure of the external surface of the water pipe in cross section,

MiCorr stratigraphy(ies) – Bi

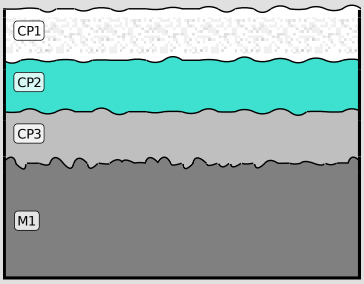
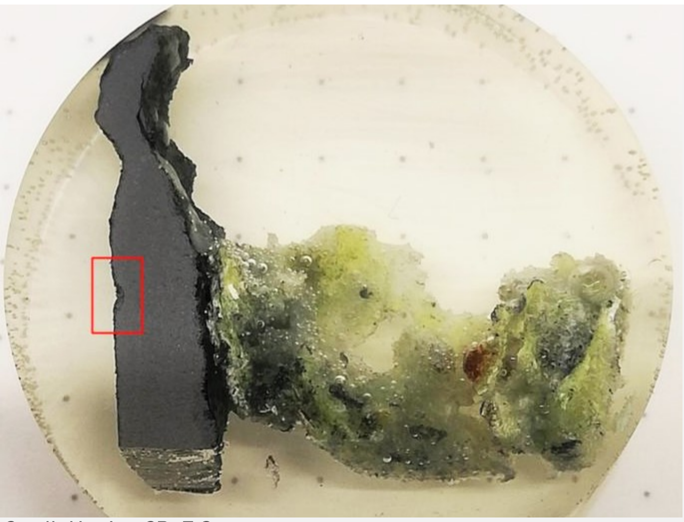


Fig. 5: Stratigraphic representation of the Bugatti water pipe under binocular using the MiCorr application. The characteristics of the strata are only accessible by clicking on the drawing that redirects you to the search tool by stratigraphy representation. This representation can be compared to Fig. 4, Credit HE-Arc CR, E.Granget.

Sample(s)

Fig. 6: Micrograph of the sample taken from the corroded exit pipe of the Bugatti water pump (Fig. 3), showing the location of Figs. 8-9


Credit He-Arc CR, E.Granget.

and 12 to 15 in red,

Description of sample	A radial section of the pipe has been sampled and embedded as shown on Fig.6. The cross-section shows not only the metal sampled but the accompanying thick yellow deposit that was clugging the pipe. Pitting corrosion develops all along the profile of the sample. A selected area (in red) is further investigated in Figs. 8-9 and 12-15.
Alloy	Al Alloy
Technology	Cast
Lab number of sample	
Sample location	HE-Arc CR, Neuchâtel, Neuchâtel
Responsible institution	MNAM (Musée National de l'Automobile de Mulhouse), Mulhouse, Alsace
Date and aim of sampling	31.12.2019 - Sampled for Metallography

Complementary information

The yellow deposit that was clugging the pipe couldn't be properly analysed (see ***Analyses and results*** below). Indeed, the deposit was way softer than the metal and suspected to contain organic compounds coming from the engine's coolant.

Analyses and results

Analyses performed on the pipe
XRF with portable X-ray fluorescence spectrometer (Niton XL3t 950 Air Goldd+ analyser Thermo Fischer (voltage 50V, General metals mode with acquisition times 20s (Main) /20s (Low) /20s (Light).

Sample preparation
Due to a significant difference between the metal and the deposit hardness, and in order to preserve the corrosion layers, the surface preparation was realized with an alcoholic lubricant instead of water. Thus, the quality for the metal and corrosion layers have been priviledged over the deposit, as the alcohol might have corrupted the suspected organic compounds of the deposit. (See ***Sample: Complementary information*** above).

Analyses performed on the cross-section sampled from the pipe
Metallography (unetched), BF and DF imaging.
SEM-EDS (20kV), SE and BSE imaging and semi-quantitative EDX analysis.

Non invasive analysis

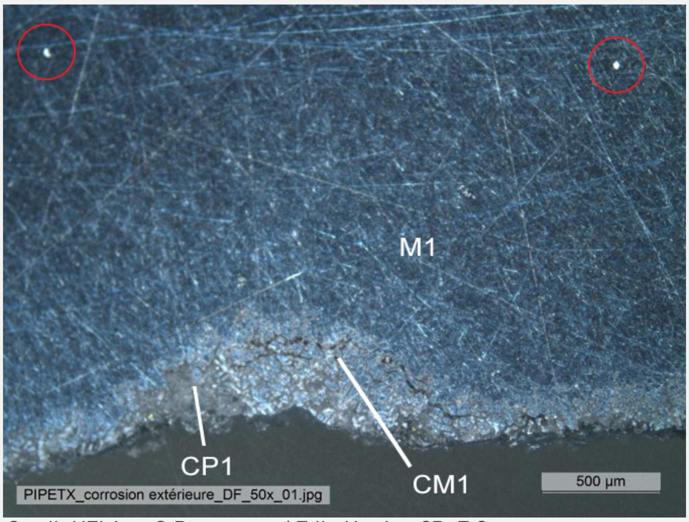
Metal

The metal is slighly porous (Fig. 8, red circles). Its dendritic microstructure is revealed by observation in bright field (Fig. 9) and with SEM (Fig. 10).

Element	mass %
Al	89
Cu	7
Zn	2.5
Fe	1
Si	0.5

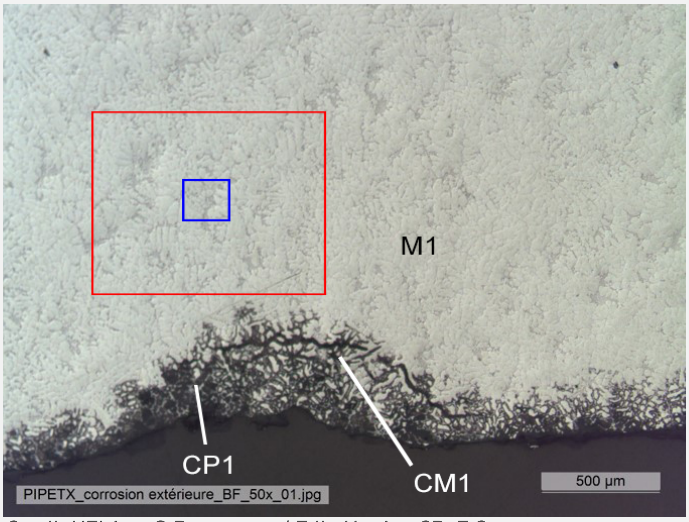
Table 1: Chemical composition (mass %) of the metal the water pump pipe. Method of analysis: SEM/EDS, HE-Arc Ingénierie, S.Ramseyer.

Point analyses of the main dendritic phase showed that it is made of Al, Cu and Zn (Table 1 and Fig. 11). Elemental chemical distribution with EDS allowed to identified the following repartition (Fig. 12): Zn is uniformely present in the alloy. There are two interdendritic phases (Fig. 13): a eutectic phase containing Fe and Cu, and a second phase containing mostly Cu. Additionally Sn and Si precipitates could be identified.



Credit HEI Arc, S.Ramseyer / Edit: He-Arc CR, E.Granget.

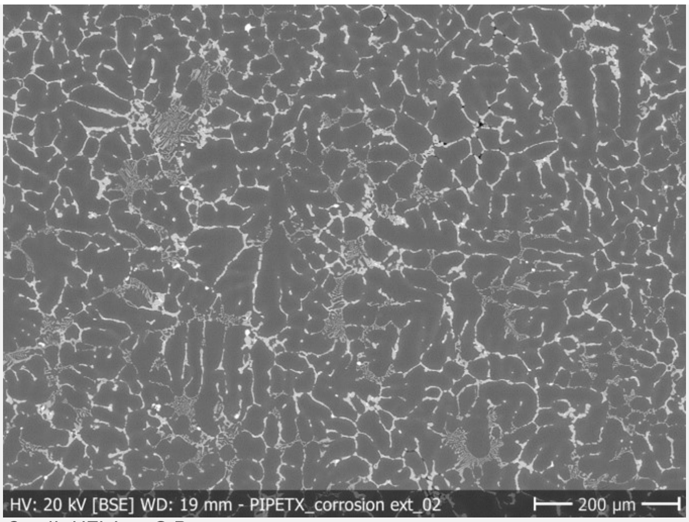
Fig. 8: Micrograph of the selected area shown on Fig.6 (rotated by 90°), unetched, dark field with indication of pores (red circles),



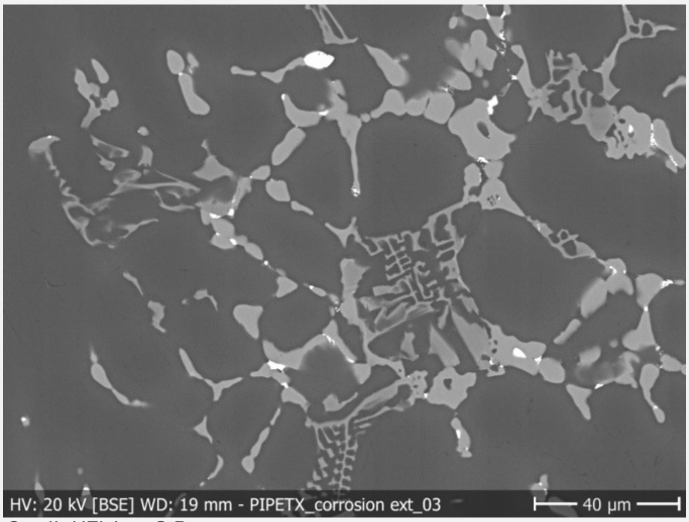
Credit HEI Arc, S.Ramseyer / Edit: He-Arc CR, E.Granget.

Fig. 9: Micrograph similar to Fig. 8, unetched, bright field showing the locations of Fig. 10 (in red) and Fig. 11 (in blue),

Fig. 10: SEM image (BSE mode) of the metal sample from Fig. 9 showing the microstructure of the pipe. Dark grey = main phase (Al), medium grey = interdendritic phase 1 (eutectic Fe, Cu), light grey = interdendritic phase 2 (Cu) and white = precipitates (Si, Sn),

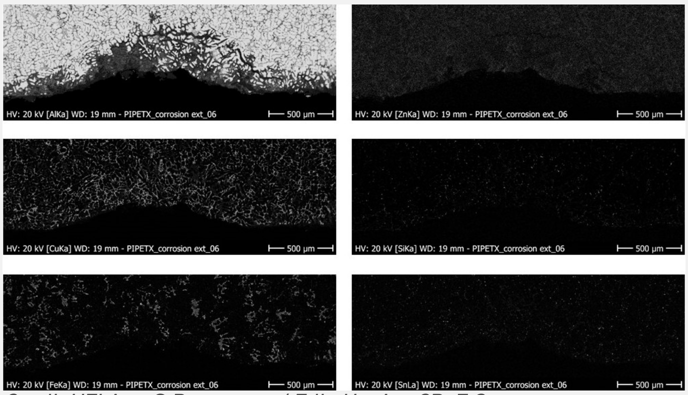


Credit HEI Arc, S.Ramseyer.



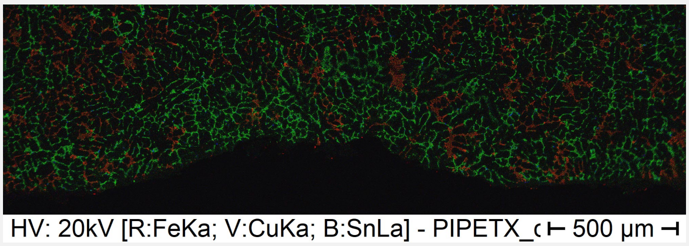
Credit HEI Arc, S.Ramseyer.

Fig. 11: Close-up image of Fig. 10,



Credit HEI Arc, S.Ramseyer / Edit: He-Arc CR, E.Granget.

Fig. 12: SEM image and EDS elemental chemical distribution of main and interdendritic phases of the pipe. 20kV,



Credit HEI Arc, S.Ramseyer.

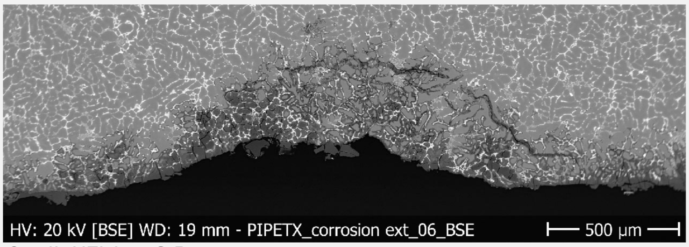
Fig. 13: Fe (red), Cu (green) and Sn (blue) chemical distribution of the area of Fig. 9. Method of analysis: SEM-EDS. Lab. of Electronic Microscopy and Microanalysis, Néode, HEI Arc,

Microstructure	Dendritic structure
First metal element	Al

Other metal elements Si, Fe, Cu, Zn

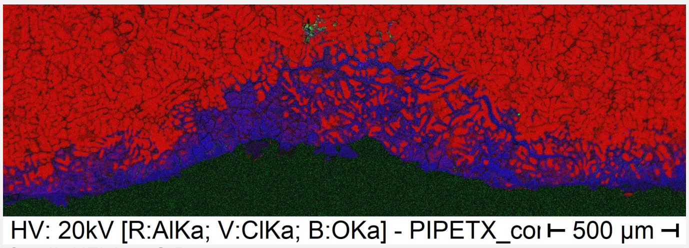
Corrosion layers

The BF and DF images (Figs. 8 and 9) show a few big cracks at the interface between CM1 and M1. The SEM image shows that they expand in a network of additional microcracks (Fig. 14). The pipe suffers from a uniform interdendritic corrosion. The Al, Cu and Zn phase is oxidising preferentially, developing then aluminium oxides, versus the interdendritic phases. In some places, pits of corrosion formed. SEM cartography showed a concentration of Cl at the base of the pit (Fig. 14: Green).



Credit HEI Arc, S.Ramseyer.

Fig. 14: SEM image of the pitting corrosion of the pipe. BSE, 20kV. Black = Cracks, Dark grey = oxydation, Medium grey = main phase, Light grey = interdendritic phase,



Credit HEI Arc, S.Ramseyer.

Fig. 15: SEM cartography of a pit of corrosion developing on the pipe. 20kV. Red = Al, Green = Cl, Blue = O,

Corrosion form Multiform - pitting

Corrosion type None

MiCorr stratigraphy(ies) – CS

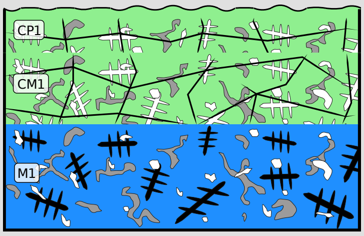
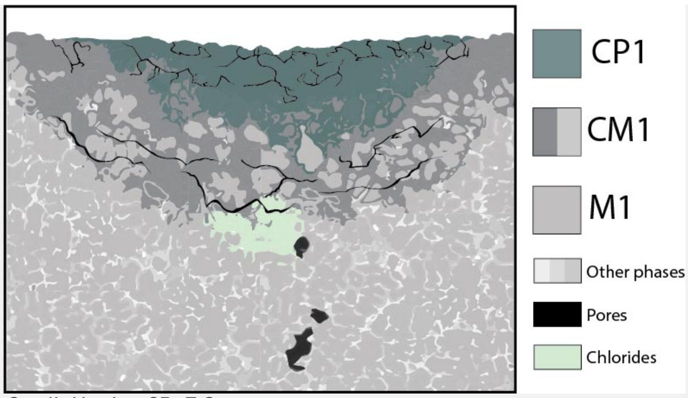


Fig. 7: Stratigraphic representation of the sample taken from the Bugatti water pipe in cross-section (dark field) using the MiCorr application. The characteristics of the strata are only accessible by clicking on the drawing that redirects you to the search tool by stratigraphy representation. This representation can be compared to Fig. 8 and 9, Credit HE-Arc CR, E.Granget.

Synthesis of the binocular / cross-section examination of the corrosion structure

The schematic representation of corrosion layers of Fig. 4 integrating additional information based on the analyses carried out is given in Fig. 16.

Fig. 16: Improved stratigraphic representation of the exit pipe,



Credit He-Arc CR, E.Granget.

Conclusion

This angled water pipe, coming from a Bugatti engine's cooling system, is made of cast Al, Cu, Zn, Fe alloy and shows a slightly porous dendritic microstructure. There are two interdendritic phases, a eutectic Fe, Cu phase and a Cu phase, as well as precipitates of Si and Sn.

One end of the pipe is heavily corroded and entirely clugged by corrosion products and other deposits on the inside. This deposit couldn't be analyzed.

The external surface shows a uniform interdendritic corrosion preferentially consuming the dentritic phase (Al, Cu, Zn). Pitting corrosion has been identified, with Cl pockets at the base of the pit.

References

References on object and sample

References object

1. Poulain, P. and J-M. (1995) Voitures de collection : Restauration Mécanique Editions Techniques pour l'Automobile et l'Industrie (ETAI), Paris.

2. Granget, E. (2020).La corrosion des alliages d'aluminium des circuits de refroidissement à eau de véhicules en contexte patrimonial : Utilisation d'outils open-access dans l'établissement d'un diagnostic des altérations d'un corpus de véhicules conservés au Musée National de l'Automobile de Mulhouse (Collection Schlumpf), Rapport interne MNAM

References sample

3. Granget, E. (2020).La corrosion des alliages d'aluminium des circuits de refroidissement à eau de véhicules en contexte patrimonial : Utilisation d'outils open-access dans l'établissement d'un diagnostic des altérations d'un corpus de véhicules conservés au Musée National de l'Automobile de Mulhouse (Collection Schlumpf), Rapport interne MNAM

References on analytic methods and interpretation

4. Vargel, C. (2004) Corrosion of Aluminium, Elsevier.

5. Degrigny, C. (2018) Etude, identification des objets en aluminium patrimoniaux et classification de leurs formes de corrosion - projet EtICAL, rapport interne HE-Arc CR.