WELDAPRIME
Anti-Corrosion Zinc-Free Primer for Steel

PROJECT DELIVERABLE REPORT

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WeldaPrime

Self-repairable zinc-free weldable anti-corrosion primer for steel protection

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Authors	Geoff Melton
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Project coordinator	Prof. Luisa Coutinho
Tel	+351214228113
Fax	+351214228122
E-mail	mlquintino@isq.pt
Project website address	WeldaPrime.com

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PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	X

Contents

1 Introduction

The majority of primers used in the industry today are high zinc content primers, which work via the zinc acting as a sacrificial metal in the coating that oxidizes in preference to the iron in the steel, due to its lower electrochemical potential. A metal that has a more negative electrode potential than iron will provide electrons in preference to the iron, and therefore corrode first. Only when all the zinc has been oxidised does the iron start to rust. Hence, these coatings are typically very high zinc content, up to 85% of dry film weight in some cases. This high level of zinc comes with its own challenges, including an effect on weld quality and health and safety issues for the welders. Zinc based primers produce porosity in the weld, which weakens the structure and zinc fume causes flu like symptoms if the welder inhales it.

Whilst the composition of the primer will make a contribution to the fume produced when welding is carried out, the primer may also cause instabilities in the arc leading to an increase in fume from the steel welding wire and plate itself.

The WeldaPrime project focuses on the development of a weldable anti-corrosion primer that is zinc-free. The development of a zinc-free anti-corrosion weldable primer cannot be achieved via galvanic protection (afforded by the zinc) and therefore an approach based on enhanced barrier properties appears as the best one, especially with good adhesion to the substrate.

The WeldaPrime project has developed a new zinc-free weldable anti-corrosion primer for steel protection using sol-gel chemistry and taking advantage of recent advances in nanotechnology. One of the advantages of the primer is the ability to weld through the primer without having to remove it by expensive and cumbersome blasting or other methods. This allows for not only ease of welding but also reduces cycle time and lowers overall costs for the end-user. However, it is necessary to make sure that welding through the primer does not lead to any negative impacts in terms of environmental and health aspects for the people using the primers.

This WeldaPrime primer has been assessed for various environmental health and safety aspects of the primer during manufacturing of the primer as well as during use (for example, during welding). D6.2 reported on the health and safety aspects of the primer formulation and its components and its industrial production. This report covers the health and safety aspects from a post-processing i.e. welding aspect once the steel substrate to be protected has already been covered by the primer and the steel is being welded.

2 Welding fume

Conventional welding primers generate welding fume which in addition to the normal constituents is generally rich in zinc or aluminium oxides which are hazardous to health. Depending on the formulation of the primer, it may produce additional constituents which may be of concern, including organic components.

Furthermore, a primer may introduce instabilities in the arc, leading to increases in welding fume from the steel welding wire and plate which in itself is hazardous to health. Welding fume consists primarily of metallic oxide particles, gases and when a primer is introduced, organic compounds.

The particulate fume is quite easy to measure by welding under test conditions and collecting the fume particles on a filter paper. This is then weighed to calculate how much fume is produced and can be analysed for chemical composition. Gases (e.g., NOx and COx) are more difficult to measure and there is poor correlation between laboratory tests and workplace exposure. Therefore, gases were not assessed for the primer. The organic content of the fume is assessed by heating the coating and analysing the fume emitted, rather than welding.

The primer was tested using recognised European standards:

- EN ISO 17652-4:2003 Welding. Test for shop primers in relation to welding and allied processes. Emission of fumes and gases.
- EN ISO 15011-5:2011 Health and safety in welding and allied processes. Laboratory method for sampling fume and gases. Identification of thermal-degradation products generated when welding or cutting through products composed wholly or partly of organic materials using pyrolysis-gas chromatography-mass spectrometry

3 Test Methods

Testing for particulate fume was carried out in accordance with EN ISO 17652-4:2003. Stringer beads were deposited on steel bars (S275) of 500mm by 50mm by 10mm, coated with the primer to be tested. Welding was carried out using a 1.2mm diameter A18 wire and a shielding gas of argon 20% carbon dioxide at a travel speed of 330mm/min. Fume samples were collected on filter papers installed in a hood which collects the fume. A typical filter paper is shown in Figure 1.

Figure 1 Filter paper with particulate welding fume.

For each test, five consecutive samples of fume were collected on filter papers. These filter papers were weighed before and after welding to assess the fume emission rate (FER). FER is calculated based on the weight of fume deposited on the paper and the time for which welding was carried out.

An additional sample of fume of at least 0.1g was collected on a filter paper and samples of the fume particles then analysed for composition using Inductively coupled plasma atomic emission spectroscopy (ICP-AES). The fume particles were analysed for a full range of oxides to confirm that the analysis was correct and the main fume composition was then reported.

Separate tests in accordance with EN ISO 15011-5:2011 were carried out to assess the degration products from the primer. Samples of the dry primer were removed from the steel substrate by scraping. The samples weighed between 350-407µg. The samples were heated to 600ºC and 800ºC and gas chromatograph-mass spectrometry (GC-MS) was used to measure the emission products.

4 Results of the testing

4.1 Particulate fume

The fume emission rate (FER) was established using the method in Section 3.

The mean FER for three samples was 8.2mg/s, which is the same as that obtained for the uncoated steel plate. The results comparing the primed steel to the uncoated steel and benchmark primers is shown in Figure 2. The FER for the WeldaPrime primed steel is lower than the benchmark products but only significantly less than for the deoxaluminite primer. However, it should be noted that the WeldaPrime coating tested had a 60µm coating thickness whereas the final coating thickness is about 20 µm thick. However, since the value even at 60 microns is about the same as the unprimed steel and is lower (or similar to) than the benchmark primers, there is no concern about the fumes emitted from the WeldaPrime primer, in terms of the FER.

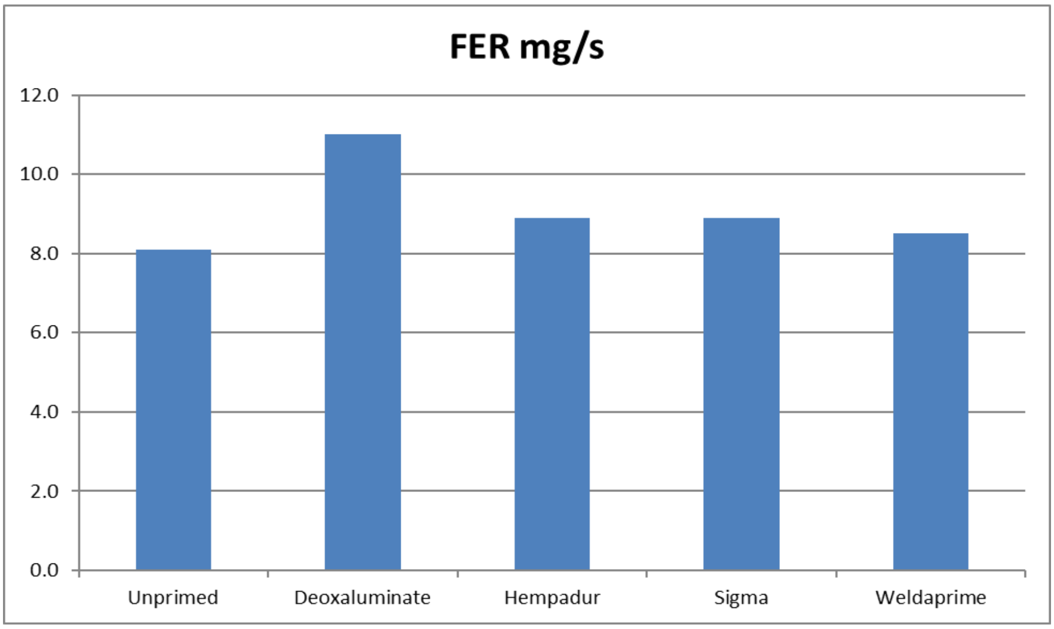

Figure 2 Fume emission rate results in mg/s.

Samples of the fume were collected and sent to an independent laboratory for analysis. The results are presented in Figure 3, for the main constituents. These were chosen as they have workplace exposure limits (WELs).

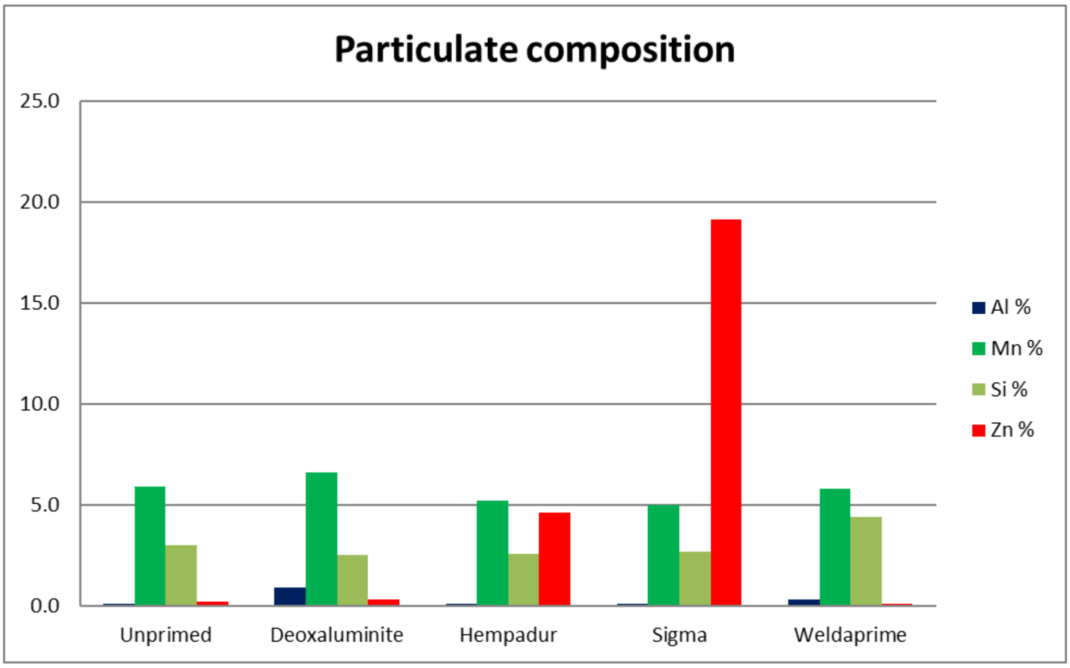

Figure 3 Fume composition analysis results.

The levels for manganese which comes form the steel are similar as expected although the deoxaluminite is slightly higher possibly associated with the increased FER. Silica was higher in the WeldaPrime primer which can be attributed to its composition. Levels of aluminium were very low exept for the aluminium containing deoxaluminite primer as expected and zinc was high for the Sigmaweld 199 primer again as expected.

The WeldaPrime primer did not produce significantly higher levels of compounds controlled by WELs than the unprimed steel.

It should be noted that these results cannot be compared directly to WELs which are expressed in mg/m^3 and require a workplace assessment over the period of a shift to establish. However, no increased risk is expected based on these results.

4.2 Degradation products

Samples of coated steel were sent to an independent laboratory for assessment of degradation products of the primer and the results are presented in Table 1. The EN 5011-5:2011 standard states that two types of pyrolyser have been found to produce satisfactory results, filament type pyrolyser and oven type pyrolyser. A filament type pyrolyser was used in these studies.

Table 1. Degradation products for the WeldaPrime primer

Component	Retention time (min)	Percent at 600 ^{o}C	Percent at 800 ^{o}C	WEL (ppm)
Propylene	1.18	25	29	-
Acetone	1.50	13	8	500
Acetaldehyde	1.26	10	9	20
Acrolein	1.47	10	5	0.1
Butadiene	1.29	4	9	10
Ethylene	1.16	3	7	-
Benzene	2.77	3	5	1
Ethanol	1.38	3	3	1000
Toluene	4.08	3	3	50
Others		26	23	-

Components are listed in order of abundance. The results show the components produced from heating the primer and indicate the compounds that need to be measured in a workplace assessment for comparison with the WELs. Benchmark primers were not subjected to this test, so comparison is not possible. Also, it should be noted that no direct comparison is possible from these results in terms of comparing the percent of component measured by GC-MS and the corresponding WEL test. However, it provides guidelines for which organic components to expect and provides guidance for adequate PPE needed during welding through the primer.

5 Welding fume control

Most welding processes produce a certain amount of fume and for manual processes control methods need to be put in place to minimise exposure. General ventilation is normally insufficient for the MIg/MAG process so the next step is to use local exhaust ventilation (LEV) to capture the fume at source, see Figure 4.

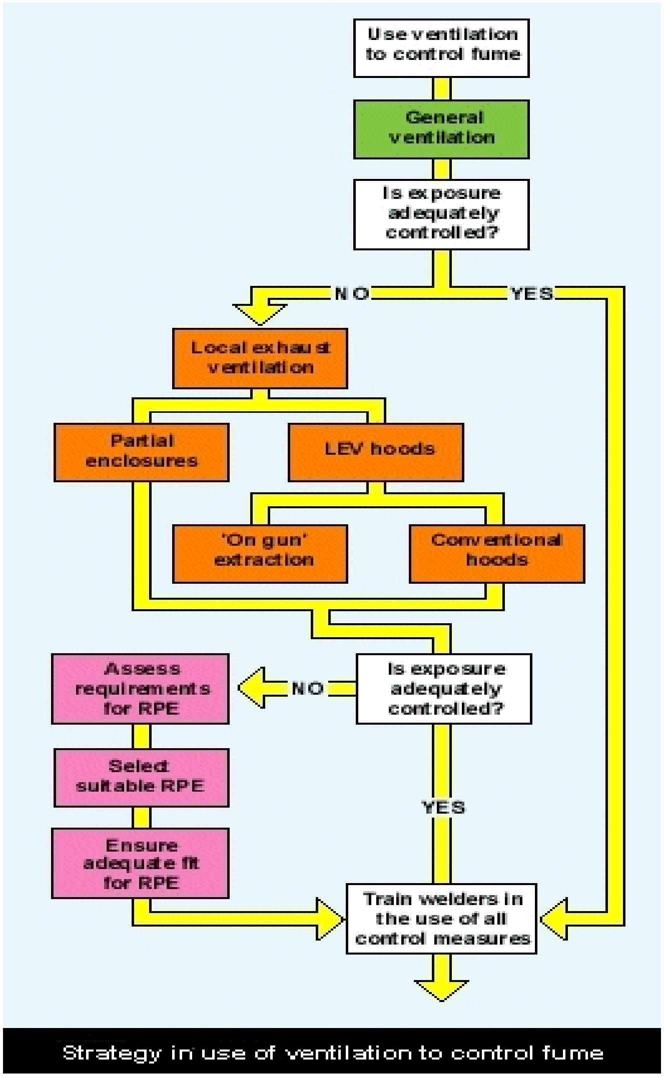

Figure 4 Controlling welding fume. [TWI Ltd.]

If this is judged to be insufficient, by workplace monitoring, appropriate respiratory protective equipment is recommended for prevention of exposure to fumes.

Based on the results presented in Sections 4, the WeldaPrime primer does not change the control measures that would be required for uncoated steel.

6 Other hazards in the welding workplace

Other hazards in the welding workplace include;

- Ultraviolet light
- Electric shocks
- Hot metal particles
- Electromagnetic fields (EMF)
- Heavy lifting.

The WeldaPrime primer does not increase the risk to any of these hazards.

7 Conclusions

These tests have shown that fume emission rate (FER) is not increased by the primer and no significant changes in the composition the welding fume arise from welding over the primer. Workplace monitoring would be required over a shift to establish compliance with workplace exposure limits (WELs) but these results show that no additional control methods for welding fume are required.

The WeldaPrime primer is not believed to increase the risk of other hazards in the welding workplace.

Thus, from an health and safety standpoint for welding, no hazards or risks beyond the usual ones associated with welding unprimed steel are anticipated. When compared to other benchmark primers used in the industry, the WeldaPrime primer has some advantages in terms of lower zinc and aluminium in the fumes, which is expected based on the composition of the various primers.