SUBSTITUTION PLAN

Public version

Name of applicants:	$CrO_3$4UK Group: Aalberts Integrated Piping Systems Ltd Borough Ltd Quality Plated Products Ltd Samuel Heath & Sons plc
Submitted by:	$CrO_3$4UK Group
Prepared by:	$CrO_3$4UK Group Technology Sciences Group Consulting Ltd (TSG Consulting) Risk & Policy Analysts Ltd (RPA)
Date:	30th June 2022
Substance:	Chromium trioxide (EC no. 215-607-8, CAS no. 1333-82-0)
Use titles:	Use 1: Industrial use of chromium trioxide for the etch pre-treatment step for functional chromium plating with decorative character for automotive, sanitary, heating and other applications Use 2: Industrial use of chromium trioxide for functional chromium plating with decorative character for automotive, sanitary, heating and other applications
Use numbers:	1 & 2

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Declaration

We, the Applicants (Aalberts Integrated Piping Systems Ltd, Borough Ltd, Quality Plated Products Ltd and Samuel Heath and Sons plc), are aware of the fact that further evidence might be requested by the Health and Safety Executive ('the Agency') to support the information provided in this document.

Also, we request that the information blanked out in the "public version" of the Substitution Plan is not disclosed. We hereby declare that, to the best of our knowledge as of today (30th June 2022), the information is not publicly available, and, in accordance with the due measures of protection that we have implemented, a member of the public should not be able to obtain access to this information without our consent or that of the third party whose commercial interests are at stake.

Signatures: **Date, Place:**

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Aalberts Integrated Piping Systems Ltd

30th June 2022
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30th June 2022
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List of abbreviations

ABS	Acrylonitrile butadiene styrene
AfA	Application for Authorisation
AIAG	Automotive Industry Action Group
AoA	Analysis of Alternatives
BS	British Standard (published by the British Standards Institution, BSI)
BS EN	British Standard, European Norm, i.e. a British Standard that implements a European Standard
BS EN ISO	British Standard which implements an identical European and International Standard
CJEU	Court of Justice of the European Union
Cr(O)	Metallic chromium
Cr(III)	Trivalent chromium
Cr(VI)	Hexavalent chromium
CrO_3	Chromium trioxide
$CrO_3$4UK	The group of four applicants applying for authorisation (Aalberts Integrated Piping Systems Ltd, Borough Ltd, Quality Plated Products Ltd and Samuel Heath and Sons plc)
CSR	Chemical Safety Report
CTACSub	Chromium Trioxide REACH Authorisation Consortium
DIN	Deutsches Institut für Normung (German Institute for Standardisation)
EC	European Commission
ECHA	European Chemicals Agency
EEA	European Economic Area, i.e. the EU plus Norway, Iceland and Liechtenstein
EN	European Norm, i.e. European Standard (published by the European Committee for Standardisation, CEN)
EU	European Union
GB	Great Britain
HSE	Health & Safety Executive
IATF	International Automotive Task Force
ISO	International Standard (published by the International Organisation for Standardisation, ISO)
NUS	Non-use scenario
OEM	Original Equipment Manufacturer
PC	Polycarbonate
PP	Polypropylene
PVD	Physical vapour deposition
R&D	Research and development
RAC	Risk Assessment Committee
REACH	Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals

	(References in this report to REACH should be taken as referring to UK REACH, as retained EU law following Brexit and the end of the Implementation Period on 31 December 2020, unless otherwise specified.)
SAGA	Suitable alternative generally available
SEA	Socio-economic analysis
SEAC	Committee for Socio-economic Analysis
SOP	Standard operating procedures
SP	Substitution Plan
SVHC	Substance of very high concern
WRAS	Water Regulations Approval Scheme
UK	United Kingdom

1. Introduction

Chromium trioxide is listed in Annex XIV of REACH (entry 16) and is subject to authorisation. Its latest application date was 21 March 2016 and its sunset date was 21 September 2017.

This application for authorisation (AfA) is being made jointly by a group of four companies established in Great Britain (GB) who undertake electroplating using chromium trioxide:

- Aalberts Integrated Piping Systems Ltd (Doncaster, England)
  https://www.pegleryorkshire.co.uk/
- Borough Ltd (Leigh-on-Sea, England)
  https://www.borough.co.uk/
- Quality Plated Products Ltd (Birmingham, England)
  http://www.qppltd.co.uk/
- Samuel Heath and Sons plc (Birmingham England)
  https://www.samuel-heath.com/

The applicants have formed the $CrO_3$4UK group and are submitting a joint AfA under Article 62(2) of REACH. While the products the applicants manufacture and the sectors they serve differ, each company uses chromium trioxide to electroplate articles (referred to as substrates) made from metals and plastics to create a metallic chrome coating. The outer chrome coating is free of chromium trioxide and provides the coated articles with a resistant, durable and safe finish, normally with a bright or matt silver finish although occasionally other finishes such as black are produced. This is referred to as functional chrome plating with decorative character.

Two of the applicants also use chromium trioxide for 'etching', which refers to specific type of pre-treatment activity undertaken on plastic substrates. This is an essential step to prepare the substrate for subsequent metal plating and involves roughening the surface of the plastic by removing material from the surface of the substrate. The etching pre-treatment step is generally inter-related in a way that it cannot be separated or individually modified without impairing the overall process or performance of the final product.

The applicants are all currently in compliance with REACH as a result of the AfA made by the Chromium Trioxide REACH Authorisation Consortium (CTACSub). The CTACSub AfA is the joint upstream application submitted by seven applicants under EU REACH that covers all their downstream users for six defined uses of chromium trioxide[1]. The applicants are amongst these downstream users and use chromium trioxide for functional plating with decorative character (use group 3). The European Commission has published its decision on the CTACSub application for use groups 1, 2, 4, 5 and 6, but not use group 3 (application ID 0032-003). The transitional arrangements under UK REACH are such that this route to compliance is only available until 30 June 2022. To continue operations beyond this date, the applicants must submit an AfA to the Health & Safety Executive (HSE) under UK REACH.

One of the applicants of the $CrO_3$4UK group (Borough Ltd) is a former member of the CTACSub and has the right to use the information gathered by the CTACSub for this AfA (on their behalf and on behalf of all $CrO_3$4UK group members).

[1] The uses covered are: (1) formulation (2) functional chrome plating (3) decorative chrome plating (4) surface treatment for aeronautics & aerospace industries (5) miscellaneous surface treatment and (6) passivation of tin-plated steel.

This AfA is for two uses of chromium trioxide, namely:

- Use 1: Industrial use of chromium trioxide for the etch pre-treatment step in the electroplating process for functional chromium plating with decorative character for automotive, sanitary, heating and other applications ('etching').

- Use 2: Industrial use of chromium trioxide for functional chromium plating with decorative character for automotive, sanitary, heating and other applications ('plating').

Use 1 (etching) is a necessary pre-treatment step that must be undertaken for plastic substrates prior to the main processes relating to use 2 (plating). Both processes are performed by the same workers and are located in the same production areas in each applicant's premises (they form part of a continuous production line). While this substitution plan considers each use separately, etching is a pre-treatment and not a stand-alone process, necessary to prepare the surface of plastic substrates for subsequent electroplating. This means substitution for each use is closely linked, in that successful substitution of the use of chromium trioxide for etching must not impact on the successful substitution of the use of chromium trioxide for plating, and vice versa.

Not all applicants undertake etching and so Figure 1 below shows which applicants are applying for which uses. Where etching is undertaken, it occurs on the same lines as plating and is part of the overall process of applying metallic chrome coatings to substrates. Amalgamating both etching and plating within one overall use has been considered for the purposes of this AfA. However, it has been ruled out on the basis that the challenges associated with identifying potential alternatives are significantly different between etching and plating which are explored further in the Analysis of Alternatives (AoA) and which have subsequent implications for the socio-economic analysis (SEA) and this substitution plan (SP).

Applicant	Use 1: Etching	Use 2: Plating
Aalberts Integrated Piping Systems Ltd		✓
Borough Ltd	✓	✓
Quality Plated Products Ltd	✓	✓
Samuel Heath and Sons plc		✓

***Figure 1**: Applicants and uses applied for*

This Substitution Plan (SP) relates to the applicants' use of chromium trioxide for etching (use 1) and in the electroplating process (use 2). It forms part of the demonstration made in support of the applicants' AfA to allow for continued use of chromium trioxide following the end of the transition period on 30 June 2022.

Following the judgment of the General Court in the lead chromates pigments case[2], businesses applying for authorisation for the continued use of a substance where there is a suitable alternative generally available (SAGA) are expected to submit a substitution plan. Despite the UK having since left the European Union (EU), the European Union (Withdrawal) Act 2018 provides that relevant cases of the Court of Justice of the European Union (CJEU) form part of retained EU law in the UK. This means that UK courts and tribunals should still refer to pre-exit CJEU case law, unless the senior courts decide to depart from pre-Exit CJEU case law or retained EU law is modified.

[2] EU General Court judgment of 7 March 2019 in Case T-837/16, *Sweden v. Commission*, upheld on appeal in the EU European Court of Justice judgment of 25 February 2021 in Case C-389/19 P, *Commission v. Sweden*

Based on the applicants' analysis, there are currently no such alternatives available for etching or for plating, as demonstrated in the AoA submitted as part of this AfA. The AoA considers a range of potential alternatives to chromium trioxide for etching and plating. For **plating**, the most promising and realistic of these is electroplating based on trivalent chromium-based solutions (chromium sulphate and chromium chloride). Other potential alternatives considered include processes based on physical vapour deposition (PVD) which was explored in relation to producing matt black chrome finishes for sanitary ware specifically, because trivalent chromium-based electroplating alternatives are not currently capable of replicating this effect. For **etching**, the position is less certain and while alternatives based on sulphuric acid and permanganate-based solutions are being actively explored, the results remain less promising at this stage of development.

All of the alternative technologies and processes considered currently fail because they are not technically and economically feasible. In other words, there is no 'drop-in' alternative at the current time. As a result, if the applicants' use of chromium trioxide were to cease then their only options are 'managerial' in nature. The AoA and the socio-economic analysis (SEA) explore the non-use scenarios in further detail.

Nevertheless, the applicants still intend to substitute the use of chromium trioxide for etching and plating with a suitable alternative if they can, and therefore will continue to commit time and resources to research and development (R&D) into alternatives. For these reasons, the applicants have still decided to prepare a substitution plan (SP) which is described in this report. The SP is submitted as part of this AfA to demonstrate the commitment the applicants are making to take the actions required to substitute chromium trioxide with suitable alternative substances and technologies for etching and plating within a specified timetable. The SP also demonstrates the complexities associated with substitution and provides detail about why the review period requested is necessary.

For **plating**, substitution efforts currently centre on trivalent chromium processes (plus PVD-based processes for matt black chrome finishes only) in an attempt to address their current performance weaknesses. It is hoped that the issues with these alternatives can be resolved in the future although at this point in time this is not clear and cannot be guaranteed. For **etching**, efforts will continue to focus on mineral acid-based and permanganate-based etching solutions but these are considered to be even further away from successful substitution and it is not clear that the issues they present will ever be overcome.

As a result, **a review period of 10 years is requested for plating (use 2) and 12 years for etching (use 1)**. These periods are based on what is considered by the applicants to be the schedule required to industrialise alternatives to chromium trioxide for functional chrome plating with decorative character for key applications.

2. Factors affecting transfer to the substitutes

The applicants use chromium trioxide for functional chrome plating with decorative character in order to meet the strict performance criteria necessary for regulatory compliance, public safety and customer expectations. The applicants' products are used across numerous sectors, including automotive, sanitary ware, heating/plumbing products, consumer goods, medical devices (e.g. ventilators for Covid-19 treatment), architectural hardware, packaging, signage and other consumer and commercial applications. However, the focus of this SP will be on three sectors in particular, namely products used for automotive, sanitary and heating applications, as this covers the majority of sectors into which the applicants' products are supplied. Detailed analysis on other sectors is therefore less productive for the purposes of this SP so a proportionate approach has been taken. However, **to successfully substitute chromium trioxide in etching**

and plating processes then any potential alternative must prove suitable across the range of the applicants' products, not just those in the sectors of focus.

Replacing chromium trioxide in etching and electroplating applications has challenged businesses and scientists for decades. Metallic chrome coated products produced using chromium trioxide-based processes (including use of the substance for etching of plastic substrates, where required) fulfil key functionalities across all sectors and offer safe, long-lasting and reliable performance. The chemical characteristics of chromium trioxide for etching and coating, combined with its relatively low cost, efficacy of waste treatment and decade's worth of experience in use, have so far proven impossible to replicate in any one alternative substance or technology, as the AoA demonstrates.

The applicants are all downstream users (as defined by REACH) of chromium trioxide and use it in electroplating processes with the chemicals and technologies provided by specialist suppliers, e.g. MacDermid Enthone and Atotech. The applicants can be quite rightly regarded as having expertise in producing their products for the applications and sectors to which they supply and will determine key functionalities and set performance standards for the products they manufacture. However, their suppliers are the holders of the expert knowledge regarding electroplating technologies and any changes or improvements are driven by their activity. The applicants are aware of the efforts being expended on R&D activities to identify possible alternatives for chromium trioxide in both plating and etching although it is not reasonable to expect the applicants themselves to drive this, as they do not have the necessary expertise and personnel in-house.

Conversely, specialist technology providers often do not have the practical expertise in the application and use of their technologies to manufacture products for various applications / sectors of use. This means the development of new or improved technologies must be undertaken in cooperation with downstream users who do have that expertise. Indeed, the applicants are highly supportive of the drive towards alternatives to chromium trioxide and are actively engaging with specialist suppliers and technology providers. Some of the applicants have been researching and trialling alternatives to hexavalent chromium since the 1980s, although all have found issues with corrosion and chemical resistance, abrasion and aesthetics (colour matching). As customers of the technology providers, the applicants can help facilitate and even initiate change, e.g. through requesting different specifications, performance standards etc. However, the unique functionalities of Cr(VI) as component in chromium trioxide make it an ideal and hard-to-replace substance where superior requirements for aesthetics/colour, corrosion and chemical resistance, abrasion resistance and other key functionalities are required, given the demanding conditions in which their products will be put to use.

2.1. Electroplating (use 2): factors affecting transfer

Current and future customers, end users and regulatory authorities will require the applicants' products to meet the requirements below regardless of which process or technology they use:

- Corrosion resistance
- Chemical resistance
- Wear and abrasion resistance
- Adhesion
- Thermal cycle resistance
- Sunlight / UV resistance
- Compliance with regulatory requirements
- Colour and cosmetic surface appearance (aesthetics)
- Longevity

Any alternative process will require extensive research and development to ensure that it will meet all the above-mentioned requirements. These requirements are explored in further detail in the AoA, although it should be stressed that these requirements are highly interconnected with each other and therefore it is essential that a potential alternative sufficiently fulfils every minimum requirement to achieve a high-quality surface under the conditions of use.

The discussion below highlights the challenges the applicants face (as downstream users) in terms of successful substitution of the use of chromium trioxide for electroplating. This reflects substitution to Cr(III)-based alternatives, which the applicants believe represents the most promising alternative. Even then, this will not provide a successful alternative for all types of finishes produced by the applicants, e.g. matt black chrome coatings for sanitary ware.

2.1.1. Technical challenges

<u>Modifications to plant, equipment and chemistry</u>
One of the principal technical challenges is that there is no 'drop-in' alternative to chromium trioxide-based plating which can be applied using identical process equipment, identical wastewater treatment systems and which allows manageable process control (e.g., bath analytics) on a commercial scale. Cr(III)-based alternatives follow the same process 'philosophy' as Cr(VI)-based plating, in that both are forms of electroplating based on the principle of electrolysis. However, they need different process equipment and wastewater treatment systems.

In addition, process control and process stability are more complex[3] than chromium trioxide technology and require additional equipment (e.g. ion exchangers) and support from specialist technology providers. Increased process monitoring is needed to ensure consistent product quality; slight variations in the chemical bath composition can cause colour differences between production batches, resulting in a higher scrap rate.

<u>Ensuring key functionalities are met</u>
The technical performance of products would also need to be tested to ensure they meet the relevant performance standards relevant to the key functionalities required requirements, e.g. in terms of corrosion and chemical resistance, abrasion etc.). Such testing would need to be factored into any substitution timetable and it is likely that various iterations would be required, where parameters are changed to explore the impact on technical performance. For the automotive sector, this becomes further complicated by different Original Equipment Manufacturers (OEMs) having different approval (qualification) processes and requirements. This affects substitution timelines because the complete switch to an alternative technology by downstream users can only be possible once all (indispensable) customers have accepted the change, i.e. the products can be shown to have met their individual technical test requirements.

<u>Process implementation challenges</u>
The transfer of technology from Cr(VI)- to Cr(III)-based processes will involve substantial and costly reconstruction of the applicants' plants (and, in some cases, also premises). Cr(III) technology has significant higher space requirements (plating lines are 10 to 15 m longer) which means additional space needs to be created at the sites, assuming this is possible. If plant modification results in the need for building work, including extensions or additional buildings, this may require additional regulatory consent such as planning permission.

[3] For instance, Cr(III)-based electrolytes have a narrow operating window regarding their chemical composition, the concentration of chemicals, additives, pH level and so on. In addition, Cr(III)-based electrolytes are very sensitive to impurities carried over from previous processes.

These challenges are exacerbated because the existing Cr(VI)-based process would need to run in parallel during the transition period, i.e. during the phase-out of Cr(VI)-based serial production and introduction and ramp-up of Cr(III)-based production. Wastewater treatment systems also need to be substantially upgraded as the chemicals involved in Cr(III) processes require significantly more complex technologies (e.g. wastewater evaporation, UV / peroxide treatment systems etc.) to be reduced to levels which comply with environmental permits and trade effluent consents.

2.1.2. Economic challenges

The technology transfer from Cr(VI) to Cr(III) would require significant investments to be made by the applicants. Costs per plating line upgrade / installation (not accounting for etching) could cost upwards of £2 million, excluding costs of R&D, field tests, regulatory approvals etc that would also be required.

Economic challenges are not merely associated with the capital costs of switching from Cr(VI)- to Cr(III)-based processes, but also ongoing operational costs. Market prices for Cr(III)-based products are up to 30% higher than for Cr(VI)-based products due to increased production & running costs, such as higher wear of parts (e.g. anodes), process chemicals, process control and process time (which is approximately three times higher, resulting in lower production output and higher energy consumption). This does not take into account the need to recoup investments in plant and equipment changes, building modifications, regulatory approvals etc. As a result, the applicants are unlikely to remain competitive against EU-based businesses who already have authorisations for continued use of chromium trioxide (often for up to 12 years) or who are covered by applications for authorisation that are still pending, nor against non-EU businesses who are able use chromium trioxide without being subject to comparable authorisation requirements in their respective territories.

2.1.3. Customer-related challenges

The additional costs outlined above are not easily passed on to customers, who would not be willing to accept higher prices caused by regulatory requirements that affect certain suppliers so long as cheaper alternatives remain available, i.e. from EU-based suppliers or suppliers based in the rest of the world. In addition, any drop in the quality of finished products, e.g. worse chemical resistance or corrosion resistance etc, caused by a move to an 'inferior' Cr(III)-based alternative would also likely encourage customers to turn elsewhere. If a Cr(III)-based coating cannot replicate the same surface properties as a Cr(VI)-based process, especially when it comes to aesthetics (particularly colour), then it is very difficult to switch to a Cr(III)-based alternative when supplying customers who will source from a range of different suppliers and for whom colour-matching will be imperative.

The situation is further complicated for those sectors where customers do not allow their suppliers to change specifications if this presents a risk to existing product approvals (e.g. in the absence of tests proving sufficient durability of the product/coating). In other words, the applicants would need to allow for sufficient time to phase out the use of chromium trioxide for existing applications so as not to breach contractual requirements.

Using the automotive sector as an example, before a product can be sourced from a supplier, it needs to pass through a series of steps referred to as 'qualification'. Qualification of a product or process is needed when a current product or technology needs to be replaced or improved in an existing application while maintaining or improving form, fit and function. It is also needed when incorporating a new product or technology into a new product or application. Qualification aims to establish feasibility of use, demonstrate performance requirements are met and address potential supply chain risks. The process of qualifying products and technologies is important to OEMs whose safety, quality, reliability and performance expectations are always high. A part failure in a running vehicle can risk lives and /or prove costly for the OEM in the event of recalls and legal issues.

Before a newly-developed product or technology can be used for automotive applications, it needs to be evaluated and qualified by the OEM. The process of qualification is often governed by industry standards such as IATF 16949, a global automotive industry standard for quality management systems, and the automotive industry generally expects parts to be manufactured, assembled and tested in IATF 16949-qualified facilities. As part of this, suppliers are often required to follow the AIAG's Production Part Approval Process (PPAP). This is a standardised method developed for use by suppliers to automotive customers to submit approvals for new or changed parts to their customers prior to fulfilling production orders, to ensure engineering design and product specification requirements are met. Suppliers will be expected to obtain PPAP approval from vehicle manufacturers whenever a new or modified component is introduced to production, or the manufacturing process is changed. In addition, OEMs will often supplement these standards with their own specific requirements.

The approval process (qualification) for a move away from Cr(VI)-based etching and plating will take 2 years as a minimum because, generally speaking, any new process must be subject to a full process review. The longest tests the OEMs will run are the Arizona desert test and/or the Florida test. Both will take at least 24 months as they are long-term weathering tests that all OEMs need to complete, usually as part of a full vehicle test, in addition to the individual parts testing that is required. Even when approval has been given, the OEMs will then need to plan a switch date to any new process. Sometimes this can be done as a running change but a move to a Cr(III)-based coating process would need to be done in conjunction with all other parts in the vehicle, because OEMs would need to ensure colour harmonisation. Given that a number of different suppliers would be involved in supplying multiple, approved parts at the same time for a product launch, the switch date could well be a further 12-18 months after testing is complete. This is to allow sign-off at board level of the changes, new part numbers to be created, drawings issued, samples provided and so on. It means the whole process could take 36-48 months as a minimum from start to finish.

After this, industrialisation (scaling up) of the alternative technology can only be successfully implemented once OEMs start placing new supply contracts for automotive parts. After new or upgraded plating lines have been ramped-up to full-scale, these lines will then need to be approved by OEMs (although this particular approval process is not comparable to the approval and qualification process described above). The lead time from order placement to full sign-off of any new plating plant and supply of new parts is typically 24 months. Following this, a typical production timespan from the start of production to the end of production is about 7 years and is followed by a guarantee on legacy spare parts of approximately 10 to 15 years, in some cases even longer[4] (see Figure 2 below).

[4] ACEA & CLEPA, 2016, p4.

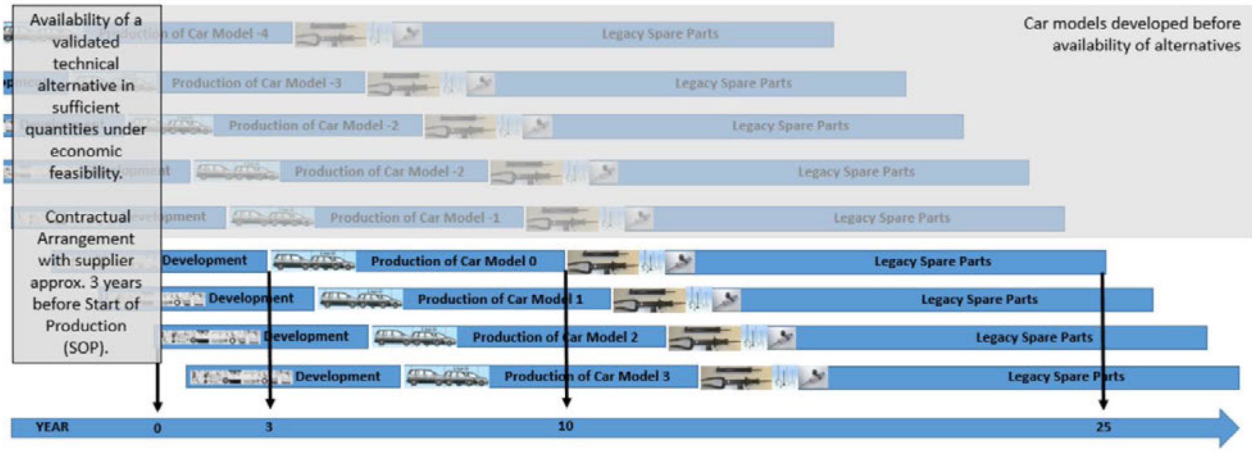

***Figure 2**: Example of the schedule needed to introduce chrome-plated plastic parts in the serial production of car models once a qualified alternative is available (source: ACEA-CLEPA)*

Figure 2 above notes that contractual arrangements with suppliers will be made approximately 3 years before the start of production. The reference to 3 years tends to come from nomination of winning the work at concept of any new vehicle. From this point onwards, tooling is made, trialled, approved dimensionally, plated, fitted to mating parts as sub-assemblies, fitted to a full assembly, and fitted to a car. This is all undertaken in the 3 years prior to vehicle launch. However, for the purposes of this AfA, the 3-year period is less relevant because it involves existing products, although there will still be a requirement for some of this work to take place. This Substitution Plan therefore considers a 2-year period as a more appropriate lead time from contractual arrangements / order placement to full sign-off of any new plating plant and commencement of production using the alternative process.

Even so, this still results in a time period covering qualification to the industrialisation of suitable alternatives to using chromium trioxide for current vehicle parts of 5 to 6 years. This timescale does not take into account the period prior to qualification where R&D must be performed on an alternative process to ensure that, at least at laboratory or pilot plant stage, the performance and aesthetics appear to deliver key functionalities required.

2.1.4. Regulatory challenges

As indicated above, any switch to Cr(III)-based technology requires significant plant reconstruction for which additional space is needed. This is likely to prompt the application of regulatory requirements around planning permission and will require review of existing environmental permits and trade effluent consents. The latter is made more complicated by the current uncertainty concerning the effectiveness of wastewater treatment from Cr(III)-based processes, e.g. the issue of potential chemical cross reactions, caused by the complexity of Cr(III)-based formulations, the availability of different formulations from different formulators and the resulting lack of experience from full-scale manufacturing.

Applicants producing products for sanitary applications will also need to ensure new Cr(III)-based products comply with requirements under the Water Fittings Regulations and the Water Quality Regulations, e.g. by successfully achieving certification of new products. Similar considerations will apply to heating / plumbing products which must achieve compliance with the Building Regulations and the Construction Products Regulations, as required. These legislative requirements are described in further detail in the AoA.

2.2. Etching pre-treatment (use 1): factors affecting transfer

For plastic substrates, an adequate etching pre-treatment is required to prepare the surface for subsequent electroplating to achieve a high-quality end product with the key functionalities outlined above. Etching is not a stand-alone process and will be undertaken on the same plating line that produces the final metallic chrome-coated products. Nevertheless, any alternative to the use of chromium trioxide for etching will need to achieve the following key functionalities, which are explored in further detail in the AoA:

- Good surface roughness (avoiding under- or over-etching)
- Long-term bath stability
- Reusability / recyclability
- Rack / jig compatibility
- Selective etching

The discussion below highlights the challenges the applicants face (as downstream users) in terms of successful substitution of the use of chromium trioxide for etching on plastic substrates as a required pre-treatment step for functional chrome plating with decorative character. The factors/limitations/obstacles discussed below are not related to a specific alternative but cover the general limitations for the alternatives discussed in the AoA.

2.2.1. Technical challenges

<u>Modifications to plant, equipment and chemistry</u>
As with plating, for the etching pre-treatment, there is currently no drop-in alternative available on the market that can replace the existing Cr(VI)-based technology, i.e. process equipment, wastewater treatment system etc. In addition, any etching technology that does not use chromium trioxide will inevitably be specific to the technology supplier (formulator), highly complex in its composition and will require the alternative etch process to be specifically adjusted. For the applicants, this greatly restricts their choice of supplier and will mean the actual switch of technology (involving new plant and equipment, upgraded wastewater treatment etc) will be undertaken for one specific formulation. In other words, the selected alternative technology must work on a commercial scale, because it will not be viable to continue investing in repeated technology changes.

This assumes the required alternative technologies appear on the market in the first place. The applicants, as downstream users, are not specialist technology suppliers (formulators) themselves and so are reliant on others developing and introducing suitable alternatives in the future.

<u>Ensuring key functionalities are met</u>
Current potential alternatives to Cr(VI)-based etching still show significant deficiencies, principally due to issues with adhesion. In addition, alternatives do not currently allow for multi-component (selective) etching of 2K or 3K parts. These issues are described further in the AoA. Considerable further R&D effort is required before any alternatives can be considered suitable enough for industrial implementation. Any alternatives would need to be internally validated by the applicants, which would include verifying not only that key functionalities and performance standards are met but also that the production process itself is capable of providing the required production capacity and flexibility.

<u>Process implementation challenges</u>
The implementation of an alternative etching process would have to occur alongside the existing Cr(VI)-based process until the last series production of Cr(VI)-based parts is completed, given that the applicants will have contractual supply obligations with their customers. Running two processes alongside each other

would require considerable additional space (an increase from c. 10 baths required for Cr(VI)-based etching to c. 13 – 15 baths required for Cr(VI)-free etching) and some applicants do not have sufficient free space at their sites to avoid having to construct extensions to accommodate this.

2.2.2. Economic challenges

As indicated above, the transition to Cr(VI) etching would ideally require both the ‘old’ and the ‘new’ processes to overlap. This would require high initial investment, e.g. plant and wastewater treatment modification, most likely involving building extensions, estimated to cost between £2.5m to £4m. It would also involve higher ongoing operational costs, and not just those associated with running two processes simultaneously. The higher prices for alternative formulations would lead to higher process costs (the CTAC consultation estimated these would be in the region of 50-100% higher compared to Cr(VI)-based etching process). This in turn would impact the price of the finished product which would have adverse effects on the applicants’ competitiveness, as customers would be unlikely to accept these higher costs given the availability of products from alternative (non-GB) sources and the ‘safety’ that customers would have in continuing with existing, proven technology versus switching to newer, less certain alternatives.

Assuming a technically feasible alternative emerges onto the market, then it is reasonable to anticipate a short-term shortage of resources at specialist technology providers (formulators) and equipment manufacturers. This is because the applicants are not the only businesses that would need to implement the alternative in a relatively short period of time.

2.2.3. Customer-related challenges

As with plating (described above), changes in the etching step may have large impacts on the performance of finished parts, especially in the automotive sector where the applicants are not allowed to make any changes to the production process without prior OEM approval. If changes are proposed to the production process that could influence the agreed part specifications (e.g. adhesion, visual appearance, etc.), these will need to be re-approved by the applicants’ customers. Such changes are rarely undertaken in practice; for one thing, costs for re-approval of a part in series production would need to be borne by the applicants proposing the change. Even if one alternative for the etching pre-treatment of all parts is identified, not all OEMs might approve this alternative at the same time which makes the entire approval and requalification process even more complicated.

2.2.4. Regulatory challenges

As with plating, any switch away from Cr(VI)-based etching would require significant plant reconstruction for which additional space is needed. This is likely to prompt the application of regulatory requirements around planning permission and revisions to existing environmental permits and trade effluent consents.

3. Electroplating (use 2): actions and timetable

The substitution of Cr(VI)-based electroplating is, in most cases, expected to be to a Cr(III)-based alternative (for matt black chrome finishes, a PVD-based process is likely to be required). Substitution will be a lengthy process comprising numerous activities, with uncertainties associated with each and possible technical or other issues that may affect the actions or the timing of actions. Nevertheless, the applicants have prepared the following plan and timeline which comprises five phases, from conducting R&D activities to the final market introduction of product produced with the alternative substances / technologies. These phases are discussed in further detail below and summarised in Figure 3 with associated timescales.

Some of these timescales involve variable periods of time, e.g. because of different sectoral requirements or where it is not certain how long a particular phase might take. In order to achieve a suitable balance between 'best-case' and 'worst-case' scenarios, Figure 3 depicts the phases overlapping where appropriate. This demonstrates that, even taking uncertainties into account to a certain extent, there is good justification that **a review period of at least 10 years is needed until substitution of chromium trioxide in electroplating can be achieved**.

***Figure 3**: Substitution roadmap for plating (use 2)*

3.1. Phase 1: Identification of potential alternatives

Timescales: N/A (already complete)

For electroplating, this phase is already complete. Alternatives have been reviewed for their feasibility, safety and availability to the applicants. A shortlist of potential alternatives was created. The manner in which alternatives were identified and screened is described in further detail in the AoA. As a result, the applicants aim to move to a Cr(III)-based electroplating alternative, except in respect of producing matt black chrome finishes, for which such technology is unable to offer a solution and so a PVD-based process must be considered.

3.2. Phase 2: In-house process development

Timescale: 1 to 3 years (up to three iteration loops, each taking one year)

Although Cr(III) plating technology is already quite advanced in terms of R&D, challenges still remain in relation to colour consistency, corrosion resistance, chemical resistance and so on (described further in the AoA). PVD-based technologies are less advanced and issues with technical and economic feasibility more uncertain still. Any potential alternative must sufficiently fulfil every key functionality to achieve a high-quality surface under reasonably foreseeable conditions of use. Therefore, this phase involves detailed investigation of potential alternatives to ensure they sufficiently fulfil all key functionalities to achieve a high-quality surface under the required conditions of use.

As the applicants are downstream users of chromium trioxide and will remain downstream users of relevant alternatives, successful execution of this phase will strongly depend on the specialist technology providers (formulators) and their development activities. It is reasonable to expect those formulators to be the driving force in this process as the applicants themselves are not experts in this area. Conversely, it is reasonable to expect the applicants to fully cooperate with the formulators and support their activities where possible, e.g. by providing feedback on tests conducted with the alternatives in-house.

In order to further improve the most promising alternative (Cr(III)-based electroplating), the approach will be to vary different parameters (e.g. electrolyte composition, process parameters) and investigate the influence on the performance of the resulting coating. Variations include the type and composition of the multi-layer plating system, the composition of different electrolytes (e.g. chloride- and sulphate-based systems) and the process parameters such as the duration of parts to be coated, temperature, current density and electrolyte concentration. Different additives and the insertion of foreign metal ions into the final chromium layer must also be considered.

The aim is to conduct the investigation and evaluation of alternatives over a three-year period. As the outcome of this work is unknown, particularly with respect to PVD-based alternatives, it is appropriate to plan on the basis of there being up to three iteration loops, each taking one year. Each iteration loop will include the following steps:

- detailed evaluation of parameters / process variables to determine the effects on appearance and performance attributes;
- determining whether performance attributes meet key functionalities and performance standards;
- evaluation of production capacity of the alternative (verification of process times etc);
- verification of expected costs of the new production process; and
- a decision on whether it will be necessary to repeat the cycle with different parameters or move onto the next phase.

For these purposes, it is assumed key functionalities will be met and so the plan can proceed to phase 3. However, there are considerable uncertainties, in that the technology may not fully meet appearance or performance requirements or the process may have an unidentified manufacturing issue for full production. This could impact on timescales significantly.

3.3. Phase 3: Customer acceptance and regulatory approvals

Timescale: 3 to 4 years

It is currently noted[5], and generally agreed within the industry[6], that Cr(III)-based processes, even though the best alternative option, exhibit reduced levels of performance and colour attributes in comparison to Cr(VI). There is risk that these issues cannot be technically overcome within several years of investigation and development (a risk which also exists in relation to PVD-based alternatives required for niche applications such as matt black chrome finishes). There is also the potential risk that positive laboratory / pilot plant test results may not describe or translate fully into field use by customers. This could result in field failures and serious discontent by the applicants' customers.

For these reasons, this phase is necessary to gain customer acceptance of parts produced with Cr(III)-based electroplating, once the technical and economic feasibility of the alternative has been proven in-house. Obtaining the relevant regulatory approvals will also be required and this is anticipated to take place during this phase. The way this is achieved is described below in relation to the automotive, sanitary and heating sectors.

3.3.1. Sector-specific considerations: automotive sector

In this phase, OEMs will qualify the properties of the supplied products and perform tests according to their standards in order to check the performance of the products under 'in-use' conditions, e.g. field testing in prototype models. The process of OEM qualification (approval) is described in further detail earlier in this report though in summary, the process aims to confirm the suitability and applicability of the alternative for serial production. This is critical because, without approval, contracts will not be signed and orders will not be placed. Typically such approvals will take longer when the alternative is first introduced (i.e. when Cr(III)-based alternatives are new to the OEM).

As noted earlier, qualification will take 2 years as a minimum and, even when approval has been given, the OEMs will plan a switch date to the new process that will be a further 12-18 months after testing is complete. Contracts can then be placed and the plating line can be scaled up to full production based on the Cr(III) alternative and approved by OEMs. This means that the time period covering qualification to the commencement of industrialisation of suitable alternatives (phase 4 below) will be 3 to 4 years.

3.3.2. Sector-specific considerations: sanitary and heating sector

Regulatory approvals such as Water Regulations Approval Scheme (WRAS) certification or BuildCert approval will need to be obtained to ensure compliance with the Water Fittings Regulations and Building Regulations respectively for parts coated with the alternative technologies (Cr(III)-based or PVD-based alternatives). Products subject to the Construction Products Regulations will need to be tested under the relevant standards and a Declaration of Performance obtained. In terms of the Water Quality Regulations, long-term tests will need to be developed for all parts with respect to nickel leaching and to evaluate new materials in contact with drinking water. This will involve "real-life" tests for a small number of parts at the customer level to evaluate their performance under typical conditions of use and to identify any significant technical limitations. Depending on the results, the process may need to be adapted and re-testing performed until sufficient performance to meet regulatory requirements is achieved.

[5] See, e.g., Gharbi et al, 2018, p2.

[6] Müller et al, 2020, p17.

The regulatory requirements outlined above are described in more detail in the AoA. However, it should be borne in mind that these only relate to the UK market, whereas the applicants sell to the EU and the rest of the world. Regulatory requirements relating to other territories are not described in the AoA but are just as relevant to the applicants, who would need to ensure they meet relevant standards for all markets which they supply.

Field trials will also be required because laboratory tests might not yield reliable results of the performance of coatings under real conditions. If products with coatings using alternative technologies were simply introduced to the market following laboratory tests, deficiencies that subsequently become apparent would result in customer complaints and a loss of image/reputation. In addition, field trails provide the applicants with more certainty for decision-making processes prior to making the significant investments required in phase 4 (see further below). Field trials will involve the following:

- Conducting the trials.
- Requesting and obtaining feedback from customers (EU and non-EU) about the technical performance of the products.
- Analysing the feedback received from customers (EU and non-EU) and planning corrective actions to solve any critical issues encountered by customers on products made with alternatives.
- Implementing corrective actions.
- Further iterations of the above, as needed based on data received and the effectiveness of corrective actions.
- Gaining all necessary approvals.

At this stage of the process there are considerable uncertainties. For example, field trial learnings may be difficult to correct and customer responses may be unpredictable (the willingness of customers to transition to Cr(III)-based or PVD-based alternatives is not guaranteed). For this reason, obtaining all of the necessary regulatory approvals and conducting field trials in the sanitary and heating / plumbing sectors is estimated to take up to 3 years.

3.4. Phase 4: Scale-up to production

Timescale: 2 to 3 years

This phase involves making the required technical modifications to facilities, plant, equipment, services and utilities (including wastewater treatment) that are required in order to industrialise the chosen alternative. The precise details of the modifications that are required will differ from applicant to applicant but will cover the following:

- Building extensions where required, to ensure sufficient space can be made available to accommodate upgraded or new plating lines. The applicants estimate such work could take up to 1 year to complete although this does not include the time initially required for obtaining the necessary planning permissions, which could take up to 6 months, perhaps even longer.

- Plating line upgrades, such as the installation of additional, dedicated rinse tanks, post-plate passivation and reduction tanks, the replacement of anodes, the installation of ion exchangers and so on. Reprogramming of automatic control systems will also be necessary. For some applicants, instead of upgrading the existing line, it will instead be necessary to install an entirely new plating line alongside the existing line, to allow for parallel production of Cr(VI)-based parts and Cr(III)-based parts to ensure existing contracts can be fulfilled. In addition, for applicants needing a PVD-based process to achieve niche finishes, installation of a PVD process line will be required. For applicants upgrading their existing line, additional time would also be required to build up sufficient back-stock to cover the period of down-time for plating line upgrades to be completed. Upgrading an existing line or installing a new line will also need to include sufficient lead time from ordering to installation. In total, the applicants estimate that plating line upgrades / installation of a new plating line could take up to 1.5 years (for applicants also requiring building extensions, some of this could be undertaken in parallel).

- Ancillary modifications would be required, such as changes to wastewater treatment plant, extraction, utilities etc. For applicants needing to run Cr(VI) and Cr(III) processes in parallel, wastewater treatment plants will need to be able to cope with the demands of both processes simultaneously.

- Compliance with the requirements of health, safety and environmental protection legislation. This will include conducting / updating risk assessments, implementing any new risk management measures required, introducing / updating procedures, providing staff training and so on. It will also include applying for variations to existing environmental permits and trade effluent consents, which could take up to 6 months, perhaps longer, to be approved.

- Conducting tests on products made with the new technologies to make sure the process lines are stable and the products meet the required standards. This includes resolving any teething issues with Cr(III) chemistry make-up, confirming the production-scale appearance attributes, performance testing and sharing the collected data with customers, possibly involving implementing further test phases with them. The applicants estimate this may take a further 6 months to 1 year.

- Planning transitional logistics associated with the switch from Cr(VI) to Cr(III)-based technologies, including determining manufacturing build needs and inventory needs.

Again, there are considerable risks and uncertainties involved at this phase. For instance, ongoing production may be inhibited. ‘Industrialised’ process may yield unexpected results from results of earlier testing. Delivery and installation time of equipment might be impacted by demand of the applicants’ competitors who are assumed to also require authorisation. Issues may be encountered with regulatory authorities when applying for permissions or variations. These could all impact on the timelines above and indeed the viability of the project.

3.5. Phase 5: Production transition to alternative

Timescale: 4 years

This phase represents a state of transition between Cr(VI)-based plating and its Cr(III)-based replacement (or PVD-based replacement for niche applications). New contracts will be entered into for supply of Cr(III)-based coated parts as customers begin to accept the alternative. However, existing contractual obligations for Cr(VI)-based parts will still need to be fulfilled.

This final phase will involve:

- Building a Cr(VI)-based back-stock to ensure existing supply commitments can be kept, e.g. for warranties, post-production replacements etc.
- Building the inventory of new products & filling the customer supply chains.
- Converting all Cr(VI) production to the alternate process.
- Decommissioning the Cr(VI) process.

This phase will be considered complete when the logistics associated with inventory transition are complete and the Cr(VI) process has been fully decommissioned.

For the automotive sector in particular, given that production of new vehicle models will typically commence around 3 years after qualification and continue for up to 7 years after the start of production, then contractual obligations to supply Cr(VI)-based parts will remain for a considerable time into the future. This phase envisages a shorter period of time than that for supply of Cr(VI)-based parts to the automotive sector on the assumption that OEMs will accept a change to Cr(III)-based parts during this period, including a change to arrangements for the supply of legacy / spare parts following the end of production. However, this is not guaranteed; there is considerable uncertainty in this respect as it depends on negotiations and OEM acceptance of Cr(III)-based processes. As a result, to achieve a balance between 'best-case' and 'worst case' scenarios, the applicants consider 4 years for this phase to be reasonable.

4. Etching (use 1): actions and timetable

At their current stage of development, none of the shortlisted alternatives to chromium trioxide for etching are sufficiently mature (see further discussion in the AoA) and will require extensive further development before they can be considered for industrialisation. This means the route forward for substitution of chromium trioxide is significantly less clear for etching than for plating. It is not expected that a feasible alternative will become available for some time. Even if a major technical breakthrough does occur within the next few years, it will not be possible to shorten any review period because similar considerations to plating (above) will apply in order to develop it further, obtain the necessary regulatory and customer approvals, industrialise it and then phase out chromium trioxide.

Nevertheless, the applicants have prepared the following plan and timeline which comprises five phases, from identification of the potential alternative to the final market introduction of product produced with the alternative substances / technologies. These phases, which follow the same overall approach as the substitution plan for Cr(VI)-based plating, are discussed in further detail below and summarised in Figure 4 with associated timescales. As with plating (use 2, above), some of these timescales involve variable periods of time and so Figure 4 depicts the phases overlapping where appropriate, to try and achieve a balance between 'best case' and 'worst case' scenarios. However, because no promising alternative has yet been identified for etching, there is a high degree of uncertainty surrounding the duration of the individual phases. The estimation of the lengths of the various phases can therefore be said to lean more heavily towards a 'best-case' scenario.

Taking all of this into account, there is good justification that **a review period of at least 12 years is needed until substitution of chromium trioxide in electroplating can be achieved** (and in all likelihood, a longer period may well be required in practice).

***Figure 4**: Substitution roadmap for etching (use 1)*

The largest market for the applicants in terms of products that require an etching pre-treatment, i.e. involving plastic substrates, is the automotive sector. The following discussion therefore focuses on the automotive sector in particular, although it must be borne in mind that the applicants produce chrome-plated plastic products for a wide variety of other markets, such as sanitary ware, heating, brewery, domestic appliances, point of sale and electronic applications. This means that to successfully substitute chromium trioxide in etching, any potential alternative must prove suitable across the range of the applicants' products.

4.1. Phase 1: Identification of potential alternatives

Estimated timescales: Up to 5 years

The aim of this phase is to identify the most promising alternative that fulfils all key functionalities required by the applicants. At the time of application for authorisation, the AoA demonstrates that at the current stage of development, no alternative has been able to fulfil all key functionalities and meet the associated performance standards. There are still many uncertainties in the process, including:

- Ensuring adequate surface roughness across the range of plastic raw materials that are used to produce parts.
- Rack technology and the influence of PVC coatings on the rack, including rack coating in pre-treatment.
- Determination of economic feasibility to ensure any alternative can work economically.
- Behaviour of the alternative chemistries and the necessary equipment under permanent bath load.
- Capability of any alternative to handle multi-component parts such as 2K or 3K parts or resist-painted parts.

Substantial further R&D effort is therefore require to identify and implement an alternative that fulfils all requirements. The applicants are, to a very large degree, reliant on specialist technology providers (formulators) to identify and propose alternatives, for reasons discussed earlier in this report.

This phase is likely to involve the following steps:

- Market screening of possible alternatives with existing and other suppliers.

- Supporting R&D undertaken by suppliers (formulators) by participating in multiple trials, allowing them to use the applicants' parts and facilities to further investigate how to replace chromium trioxide in the etching process. Note: the applicants themselves will not be able to conduct more detailed investigation of the kind described in phase 2 until a promising alternative has been identified. This is because the applicants, as downstream users, cannot commit resources for more intensive investigation and in-house process development of alternatives that are merely at experimental stage.

- Assessing suitability on ABS and PC/ABS substrates and multi-component parts.

The goal of phase 1 is to identify a suitable chromium trioxide-free process for further investigation and in-house process development at the applicants' sites. Given that no drop-in alternative has been identified to date, the duration of this phase is highly uncertain. Based on the applicants' experience, a timescale of up to 5 years is estimated for this phase (indeed, the duration indicated in substitution plans included in similar applications for authorisation under EU REACH relating to etching using chromium trioxide are often for a slightly longer period of 6 years).

4.2. Phase 2: In-house process development

Timescale: Up to 3 years

This phase involves detailed investigation of the most promising potential alternative identified through phase 1 to ensure it can sufficiently fulfil all key functionalities. Process development will likely be performed first on parts made of ABS because in general this plastic is easier to etch due to higher reactivity compared with PC/ABS. Assuming acceptable results are obtained, the same will then be done on parts made of PC/ABS and then multi-component (2K and 3K) parts. The duration of this phase is estimated to be up to three years to allow one year for process optimisation of each of these part types.

This phase is expected to involve:

- Reconstruction of production lines (or use of a pilot line) in order to conduct tests under realistic conditions by applying the most promising Cr(VI)-free etching alternative. There are likely to be several adjustments of the production line needed, complicated by the need to ensure production of existing parts can continue.
- A combined process, i.e. etching pre-treatment in baths located out of the 'main' production line and completion of the surface coating within the 'main' production line;
- Consideration of further relevant aspects, such as required racks, anodes, ion exchangers and wastewater treatment measures. This includes strong collaboration and cooperation with suppliers for each of these aspects.
- Initial discussions with regulatory authorities concerning obtaining required permissions.
- Initial discussions with customers concerning the new technology and qualification etc.
- Discussions with equipment suppliers regarding required reconstruction of production lines for industrialisation.

For these purposes, it is assumed key functionalities will be met and so the plan can proceed to phase 3. However, in reality this phase will need to continue until parts pass performance standards and OEM specifications, and acceptable production capacity and scrap rate can be verified in-house. Considerable uncertainty surrounds the actual timing of this phase given the number of different automotive and other parts produced by the applicants (different substrates, different shapes and sizes etc).

4.3. Phase 3: Customer acceptance and regulatory approvals

Timescale: 3 to 4 years

This phase is necessary to gain customer acceptance of parts produced with Cr(VI) etching processes, once the technical and economic feasibility of the alternative has been proven in-house. Obtaining the relevant regulatory approvals will also be required and this is anticipated to take place during this phase.

The details of this phase are similar to phase 3 of the substitution plan for plating (use 2, above). In particular, for the automotive sector, the move to alternative etching technologies will represent a significant change, so OEMs will need to qualify the properties of the supplied products and perform tests according to their standards in order to check the performance of the products under 'in-use' conditions, e.g. field testing in prototype models. The process of OEM qualification (approval) is described in further detail earlier in this report though in summary, the process aims to confirm the suitability and applicability of the alternative for serial production. Only once approval has been obtained can contracts be signed and orders placed.

Typically such approvals will take longer when the alternative is first introduced, i.e. when Cr(VI)-free alternatives are new to the OEM. This means that qualification can be expected to take 2 years as a minimum and, even when approval has been given, the OEMs will plan a switch date to the new process that will be a further 12-18 months after testing is complete. Contracts can then be placed and the process can be scaled up to full production based on the etching alternative. OEMs will also need to approve the new production line. This means that the time period covering qualification to the commencement of industrialisation of suitable alternatives (phase 4 below) will be 3 to 4 years.

4.4. Phase 4: Scale-up to production

Timescale: 2 to 3 years

Following customer and regulatory approval, the applicants can then start with the conversion of production lines and other work needed to industrialise the Cr(VI)-free etching alternative. This phase involves making the required technical modifications to facilities, plant, equipment, services and utilities (including wastewater treatment) that are required. The precise details of the modifications that are required will differ from applicant to applicant but will cover the following:

- Building extensions (assuming this work has not already been undertaken as part of substitution of Cr(VI)-based plating). This is to accommodate the upgrades to the production line that are needed, which involve additional baths to the existing process. This could take up to 1 year to complete although this does not include the time initially required for preparing calls for tender and obtaining the necessary planning permission, which could take up to 6 months, perhaps even longer.

- Upgrading the existing production line or installation of a new plating line incorporating etching upgrades. This is required because additional baths are required for non-Cr(VI) etching, with corresponding heaters, agitation systems, filters, local exhaust ventilation, pumps, utilities pipework and so on. Reprogramming of automatic control systems and upgrading / readjustment of wastewater treatment facilities will also be necessary. Where an existing line is being upgraded, additional time may be required to build up sufficient back-stock to cover any period of down-time or reduced production capacity that might result. Upgrading an existing line or installing a new line will also need to include sufficient lead time from ordering to installation. In total, the applicants estimate that production line upgrades / installation of a new line could take up to 1.5 years (for applicants also requiring building extensions, some of this could be undertaken in parallel).

- Compliance with the requirements of health, safety and environmental protection legislation. This will include conducting / updating risk assessments, implementing any new risk management measures required, introducing / updating procedures, providing staff training and so on. It will also include applying for variations to existing environmental permits and trade effluent consents, which could take up to 6 months, perhaps longer, to be approved.

- Conducting tests on products made with the new technologies to make sure the production line is stable and the products meet the required standards. This includes resolving any teething issues with chemistry make-up and process parameters, undertaking further performance testing and sharing the collected data with customers, possibly involving implementing further test phases with them. The applicants estimate this may take a further 6 months to 1 year.

- Planning transitional logistics associated with the switch from Cr(VI) to non-Cr(VI) etching technologies, including determining manufacturing build needs and inventory needs.

Again, there are considerable risks and uncertainties involved at this phase. For instance, ongoing production may be inhibited. 'Industrialised' process may yield unexpected results from results of earlier testing. Customer reaction to products produced using the alternative process may be negative. Issues may be encountered with regulatory authorities when applying for permissions or variations. These could all impact on the timelines above and indeed the viability of the project.

4.5. Phase 5: Production transition to alternative

Timescale: 4 years

This phase represents a state of transition between Cr(VI)-based etching and its non-Cr(VI) alternative. New contracts will be entered into for supply of parts that can be produced without the use of chromium trioxide for etching, as customers begin to accept the alternative. However, existing contractual obligations will still need to be fulfilled.

This phase will involve:

- Building a sufficient back-stock of Cr(VI)-etched plastic parts to ensure existing supply commitments can be kept, e.g. for warranties, post-production replacements etc.
- Building the inventory of new products & filling the customer supply chains.
- Converting all Cr(VI)-based etching to the alternative process.
- Decommissioning the Cr(VI) etching process.

Phase 5 can be considered complete when the logistics associated with inventory transition are complete and the Cr(VI) etching process has been fully decommissioned.

For the automotive sector, this transition is envisaged to occur in two separate but related sub-phases as follows, and is based on the assumption that electroplating itself will have already been substituted to a Cr(III)-based alternative:

(1) Contractual phase

The production of a new vehicle model requires a complex coordination of different actors in the supply chain, of which the applicants are but one. These actors will usually be asked to sign contracts for future production with 'old' parts (i.e. parts manufactured using Cr(VI)) at least two years before production of a new model starts, in order to secure the business. For the applicants, this means they will be 'locked in' to the use of chromium trioxide for etching (even though plating may have already moved to a Cr(III)-based alternative by then) for up to two years. However, this period of time is not accounted for in this particular phase because it is assumed it will run concurrently with phase 4 above (industrialisation).

(2) Production phase (≥ 4 years)

A series production generally runs for up to 7 years, depending on the OEM involved. During this period, it is not possible to implement any change in the production process of series parts without explicit permission from customers and re-approval, as process changes might result in different performance of the affected part during its lifecycle. In theory, seeking re-approval is possible but rarely happens in practice; any changes would be entirely at the applicants' expense and their costs would not be covered through existing contractual arrangements, meaning it would not be considered economically feasible. However, in the substitution timeline presented in Figure 4, this phase is given a length of four rather than seven years, based on an assumption that OEMs will accept a change to non-Cr(VI) etching during this period (including a change to arrangements for the supply of legacy / spare parts following the end of production). It is hoped that OEMs will accept a move away from chromium trioxide as they realise its use is subject to authorisation in the UK and EU, but they will still need to be satisfied that the new parts pass performance standards and meet their specifications. OEMs will most likely begin transitioning with new models, because this includes sufficient time periods to conduct the required tests. Once new vehicles are approved, they will look to implement the same transition for existing vehicles, but the basis and timescale for this is unclear.

The series production described here refers to Cr(VI)-etched and Cr(III)-plated parts. This means that at least four years of series production must be taken into account when developing the substitution timeline. This time is required by the applicants in order to guarantee business continuity and to comply with existing contractual requirements while introducing the Cr(VI)-free etching of plastic substrates to the market.

5. Monitoring implementation of the substitution plan

The implementation of the substitution plan will be monitored by each of the applicants. This will involve different processes and systems because of the differences in the applicants' company structures and differing types of complexity involved in the project, e.g. based on sectors into which the applicants supply products, the need to substitute etching as well as plating for some applicants, the customer and regulatory approvals processes and so on.

Each applicant will therefore break down the overarching substitution plan into an individual plan, suitable for their own requirements and business structures. Project monitoring will then be undertaken according to the individually-established project management systems of each applicant. All applicants are certified with at least the ISO 9001 management system standard and most others also follow the environmental management standard ISO 14001. In particular, the ISO 9001 standard ensures establishment of effective structures and processes to manage different kinds of projects within an organisation, including complex change projects.

All applicants have dedicated project teams that will be employed to execute the substitution plan. These teams will be led by a dedicated project manager and will report the project status to the company's management on a regular basis. During review meetings, directors / senior managers will, for example, approve necessary spending, take action to resolve issues and obstacles, and provide support to the project team on different matters. Customers are also likely to be involved in the process, with the project team seeking feedback from customers on development of products using alternative processes and results of field testing etc. Action trackers will be put in place and reporting of key performance indicators (KPIs), i.e. achievement of milestones, percentage of chromium trioxide that has been substituted, investment spending curve etc, will ensure transparency of the project.

6. Conclusions

This Substitution Plan demonstrates the commitment of the applicants to identify, develop, test, trial and ultimately industrialise and transition to alternatives to the use of chromium trioxide for etching and electroplating. To achieve this, substantial efforts and investments will be required.

There are currently no suitable alternatives to chromium trioxide either for etching or for plating, as demonstrated in the AoA which considers a wide range of potential alternatives. For **plating**, the most promising and realistic of these is electroplating based on trivalent chromium-based solutions (chromium sulphate and chromium chloride). Other potential alternatives considered include processes based on physical vapour deposition (PVD) which was explored in relation to producing matt black chrome finishes for sanitary ware specifically, because trivalent chromium-based electroplating alternatives are not currently capable of replicating this effect. For **etching**, the position is less certain and while alternatives based on sulphuric acid and permanganate-based solutions are being actively explored, the results remain less promising at this stage of development.

All of the alternative technologies and processes considered currently fail because they are not technically and economically feasible. In other words, there is no 'drop-in' alternative at the current time. As a result, **a review period of 10 years is requested for plating (use 2) and 12 years for etching (use 1)**. These periods are based on what is considered by the applicants to be the schedule required to industrialise alternatives to chromium trioxide for functional chrome plating with decorative character for key applications.

However, given that the substitution process involves numerous uncertainties, technical challenges and substantial economic investment, in reality these substitution periods may well become significantly longer. The challenges and uncertainties associated with substitution have been described in this report and close cooperation between downstream users specialist technology providers (formulators) will be required to overcome them. It should also be noted that substitution represents a long-term solution which is not guaranteed to be successful. In the event that an authorisation is not granted, the most likely non-use scenario (NUS) involves managerial rather than technical options, such as outsourcing production, with no guarantee production will ever be brought back to the UK.

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