SUBSTITUTION PLAN

Public version

Name of applicant:	TCL Manufacturing Ltd (trading as Perrin & Rowe)
Submitted by:	TCL Manufacturing Ltd
Prepared by:	TCL Manufacturing Ltd Technology Sciences Group Consulting Ltd (TSG Consulting)
Date:	28th June 2022
Substance:	Chromium trioxide (EC no. 215-607-8, CAS no. 1333-82-0)
Use title:	Industrial use of chromium trioxide for functional chrome plating with decorative character for sanitary applications
Use number:	1

Contents

Declaration ... 4
List of abbreviations ... 4
1. Introduction ... 6
2. Factors affecting the transfer to the substitute ... 7
3. List of actions and timetable with milestones ... 8
3.1. Phase 1: Identification of potential alternatives ... 10
3.2. Phase 2: Investigation and qualification ... 10
3.3. Phase 3: Detailed investigation of process variables ... 11
3.4. Phase 4: Scale-up to production trials ... 11
3.5. Phase 5: Production transition to alternative ... 12
3.6. Conclusions ... 13
4. Monitoring implementation of the substitution plan ... 13
5. Conclusions ... 14
References ... 16

Figures

Figure 1: Overview of substitution activities and timescales 9
Figure 2: Phase 4 timescales, activities, milestones and uncertainties 12
Figure 3: Overview of FB WI project management process 14

Declaration

We, the Applicant (TCL Manufacturing Ltd), 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 (28th 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.

Signature:

Andy Hampson
Director of Operations (EMEAA), FBHS WI

Date, Place:

28th June 2022
TCL Manufacturing Ltd
Wolverhampton

List of abbreviations

AfA	Application for Authorisation
AoA	Analysis of Alternatives
CJEU	Court of Justice of the European Union
Cr(O)	Metallic chromium
Cr(III)	Trivalent chromium
Cr(VI)	Hexavalent chromium
CrO_3	Chromium trioxide
CSR	Chemical Safety Report
CTACSub	Chromium Trioxide REACH Authorisation Consortium
EC	European Commission
ECHA	European Chemicals Agency
EEA	European Economic Area, i.e. the EU plus Norway, Iceland and Liechtenstein
EU	European Union
FB	Fortune Brands
GB	Great Britain
HSE	Health & Safety Executive
IAPMO	International Association of Plumbing & Mechanical Officials
NUS	Non-use scenario
R&D	Research and development
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 (Please note that 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
SKU	Stock-keeping unit
SOP	Standard operating procedures
SP	Substitution Plan
UK	United Kingdom
WI	Water Innovations (part of Fortune Brands)

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.

TCL Manufacturing Ltd (trading as Perrin & Rowe and referred to as such in this report) designs and manufactures high-quality bathroom and kitchen products for the luxury sector. Their product portfolio includes kitchen taps, bathroom and basin brassware, kitchen and bathroom accessories, and chinaware. Perrin & Rowe's products are all handmade in their UK manufacturing facility in Wolverhampton, combining state-of-the-art manufacturing technology with traditional processes and methods.

Perrin & Rowe's brassware products are available in a number of different finishes, the hardest and most durable of which is chrome. Perrin & Rowe achieves this finish by electroplating brass products using chromium trioxide to create a metallic chrome coating which has a brilliant silver appearance with a hint of blue. This means Perrin & Rowe's use of chromium trioxide is subject to the authorisation requirements in REACH.

Perrin & Rowe is currently in compliance with REACH as a result of the application for authorisation (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]. Perrin & Rowe are one such downstream user 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, Perrin & Rowe must submit an AfA to the Health & Safety Executive (HSE) under UK REACH.

This Substitution Plan (SP) relates to Perrin & Rowe's use of chromium trioxide in the electroplating process. It forms part of the demonstration made in support of Perrin & Rowe's 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.

Based on Perrin & Rowe's analysis, there are currently no such alternatives available, as demonstrated in the Analysis of Alternatives (AoA) submitted as part of this AfA. The AoA considers a range of potential alternatives to chromium trioxide, the most promising and realistic of which is electroplating based on trivalent chromium-based solutions (chromium sulphate and chromium chloride). However, these and all other 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.

[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.

[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*

As a result, if Perrin & Rowe's use of chromium trioxide were to cease then its only options are 'managerial' in nature. The AoA and the socio-economic analysis (SEA) explore the non-use scenarios in further detail.

Nevertheless, Perrin & Rowe still intends to substitute the use of chromium trioxide with a suitable alternative if it can, and therefore will continue to commit time and resources to research and development (R&D) into alternatives. These efforts currently centre on trivalent chromium processes initially, in an attempt to address their current performance weaknesses. It is hoped that the issues with trivalent chromium-based alternatives can be resolved in the future although at this point in time this is far from clear and not guaranteed.

For these reasons, Perrin & Rowe has developed and is in the process of executing a substitution plan (SP) which is described in this report. The SP is submitted as part of this AfA to demonstrate the commitment Perrin & Rowe are making to take the actions required to substitute chromium trioxide with a suitable alternative substance and technology within a specified timetable. The SP also demonstrates the complexities associated with substitution and provides detail about why the review period requested (10 years) is necessary.

2. Factors affecting the transfer to the substitute

Current and future customers and regulatory authorities will require sanitary ware products to meet the requirements below regardless of which process or technology Perrin & Rowe uses:

- Corrosion resistance
- Wear and abrasion resistance
- Adhesion
- Chemical resistance
- Colour and cosmetic surface appearance (aesthetics)
- Thickness
- Thermal cycle resistance
- Sunlight / UV resistance
- Prevention of nickel leaching
- Longevity
- Regulatory compliance

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. This includes being able to provide a chromium-like appearance (where the alternative does not result in a chrome finish) even if all other functionalities are achieved, due to customer / consumer preferences and from the perspective of replacement of products/parts where replacements must colour-match other sanitary ware in the same area.

The most promising alternatives to the hexavalent chromium electroplating process found during the analysis of alternatives were trivalent chromium electroplating processes. These are based on a similar technology to hexavalent chromium electroplating, where equipment with wet-in wet bath technology is used. This means it is the closest alternative, although there are key differences, e.g. in plating line organisation, chemistries, equipment and wastewater treatment. As a result, substituting the existing Cr(VI)-based process with a Cr(III)-based process would require significant changes that will influence economic feasibility. The AoA describes in further detail how a switch to Cr(III) production would entail high costs in terms of capital (development and upgrade) costs and additional, ongoing manufacturing (operating) costs.

Nevertheless, Perrin & Rowe has been very engaged in R&D on Cr(III)-based alternatives and has presented results obtained so far in the AoA, which describes results of testing on trivalent chromium coatings applied on brass substrates against key functionalities required for sanitary ware. However, these (and all other identified alternatives) currently fail on a technical basis because of critical performance weaknesses, particularly in the areas of corrosion resistance, chemical resistance and aesthetics. Perrin & Rowe plans to continue supporting R&D activities relating to Cr(III)-based electroplating to further improve the coating properties with the aim of fulfilling the required functionalities.

Cr(III)-based electroplating techniques and different kinds of electrolytes have already been commercially available for a number of years. However, Cr(III)-coated parts for sanitary ware which are available on the market do not meet Perrin & Rowe's requirements and customer expectations, as illustrated in the AoA. Despite the increasing efforts in R&D and performance improvements during the last years, Cr(III)-plated parts are still not comparable to Cr(VI)-plated parts for sanitary applications. The problem is exacerbated when used, for example, in hotels and other hospitality settings such as spas, where premises are visited frequently and by numerous people, with frequent and more intensive cleaning regimes, meaning that technical limitations become even more obvious after a shorter period.

For these reasons, Perrin & Rowe does not currently produce or supply Cr(III)-based products due to the demonstrable quality issues. Cr(VI)-based products offer better performance and a higher quality aesthetic and also ensures availability of spares and colour-matching of replacements in a kitchen or bathroom environment. As a result, if Perrin & Rowe were to switch to Cr(III)-based product, it would not expect to enjoy product sales and market share comparable to its current position. Even if sales volumes could be kept at the same levels, the price Perrin & Rowe could command per product would fall substantially and would be too low to cover production costs. These production costs are heavily associated with traditional, time-served manufacturing processes with an emphasis on hand-made and finely crafted products, aimed at the luxury sector of the market.

The AoA demonstrates that the most likely outcome would be that customers would switch either to alternative suppliers in the EU who hold an authorisation for the use of chromium trioxide (or whose application for authorisation has been made but a decision is still pending) or to non-EU suppliers. This would result in an almost total loss of market share to competing Cr(VI)-based imports. It is not likely that customers will change their purchasing behaviour in the near future when there is continued availability of imported Cr(VI)-based products. In addition, Perrin & Rowe is bound to honour existing contractual obligations which typically provide a guarantee period of 10 years.

3. List of actions and timetable with milestones

The substitution of Cr(VI)-based electroplating to a Cr(III)-based alternative 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, Perrin & Rowe has prepared a timeline which comprises five phases, from conducting R&D activities to the final market introduction of Cr(III)-based product. These phases are discussed in further detail below and summarised in Figure 1 with associated timescales. 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.

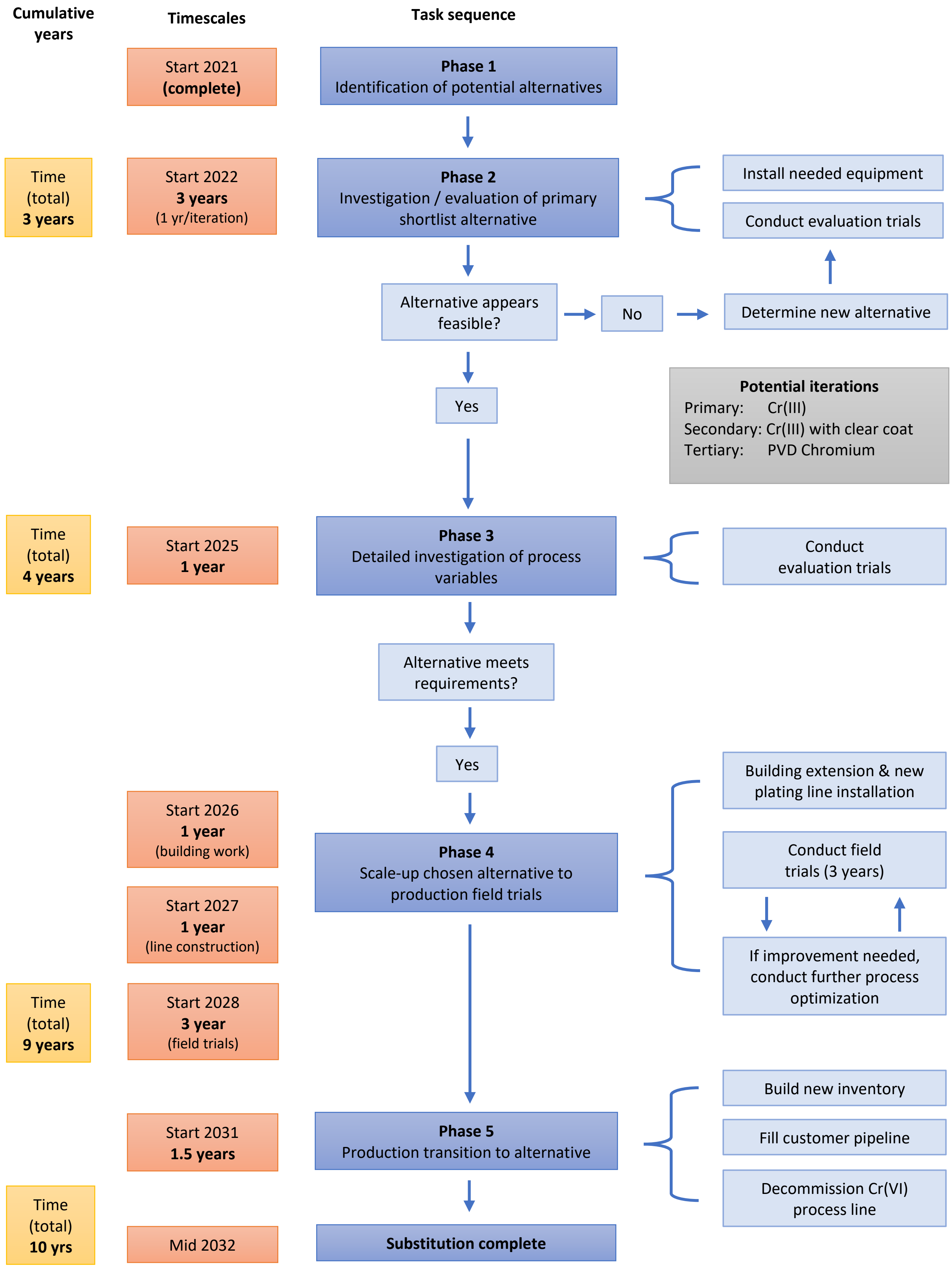

***Figure 1**: Overview of substitution activities and timescales*

Perrin & Rowe's parent organisation, Fortune Brands Water Innovation (FB WI), does have experience in replacing hazardous materials in this magnitude. Through this experience, FB WI recognises that the development of a viable alternative will require:

1. Extensive research and development efforts.
2. Development of a recipe for the alternative process.
3. Consistently repeat the outcome of the process recipe in a laboratory environment.
4. Duplicate the process in a limited manufacturing environment, e.g. pilot plant.
5. Field / actual use environment test.
6. Scale up of manufacturing in the plant and distribution across the supply chain.

The above list is not a comprehensive set of activities, but rather a high-level overview of the expected steps in the development process. Perrin & Rowe may find that additional steps are required to ensure that the new alternative will meet customers' and regulatory authorities' expectations in addition to being financially feasible.

3.1. Phase 1: Identification of potential alternatives

This phase is already complete; alternatives as reported by others within the industry were reviewed for their potential and relevancy to Perrin & Rowe's particular application. A shortlist of potential alternatives was created. The manner in which alternatives were identified and screened is described in further detail in the AoA.

3.2. Phase 2: Investigation and qualification

Perrin & Rowe / FB WI has already commenced this phase and completed certain aspects of it. At the time of submission of the AfA, Cr(III) chemistry and equipment needs have been investigated and quotes obtained. Management approval was gained and a pilot Cr(III) plating line for experimentation has been installed, readied for trials that commenced in Q1 2022. A number of R&D studies have already been conducted.

The plan is to conduct the investigation and evaluation of shortlisted alternatives over a three-year period between 2022 and 2024. As the outcome of the R&D studies and initial qualification trials are unknown, Perrin & Rowe is planning on the basis of several iteration loops, each taking one year. Each iteration loop will include:

- Initial evaluation of chemistry and process
- Initial testing program for performance attributes
- Initial review of appearance attributes
- Initial evaluation of production capacity of the alternative (verification of process times)
- Initial verification of expected costs of the new production process

Upon completion of the 1 year evaluation, Perrin & Rowe / FB WI will determine if the potential alternative meets key functionality requirements. If it does, then phase 3 can commence. If not, an evaluation of the secondary short list alternative will be undertaken. There are a number of assumptions and uncertainties around this phase and the timescales, principally concerning whether the chosen process will meet appearance or performance requirements.

3.3. Phase 3: Detailed investigation of process variables

Phase 3 is expected to commence in 2025 and last for 1 year. This phase involves further R&D studies, conducting detailed investigation and qualification trials involving the following steps:

- Conduct detailed evaluation of chemistry and process variables and interactions to determine combined effects on appearance and performance attributes.
- Conduct a testing program for performance attributes.
- Evaluation of production capacity of the alternative (verification of process times).
- Verification of expected costs of the new production process.
- Review of appearance attributes (multiple iterative loops are likely to be needed).
- Determination of alternate process for production trials.

Any potential alternative must sufficiently fulfil every key functionality to achieve a high-quality surface under reasonably foreseeable conditions of use. This means the shortlisted alternative must be subject to detailed investigation and qualification. In particular, for Cr(III)-based electroplating, the approach will involve varying different parameters, e.g. electrolyte composition, the type and composition of the multi-layer system, operating parameters such as coating duration, temperature, current density and so on, to investigate and understand the influence these have on the performance of the resulting coating.

Upon completion of the 1-year evaluation, Perrin & Rowe / FB WI will determine if the alternative meets key functionalities. For these purposes, it is assumed it will and so the plan will proceed to phase 4. However, there are considerable uncertainties, in that the chosen process may not fully meet appearance or performance requirements or the chosen process may have an unidentified manufacturing issue for full production. This could impact on timescales significantly.

3.4. Phase 4: Scale-up to production trials

This phase involves technical modifications at Perrin & Rowe to accommodate Cr(III) plating alongside existing Cr(VI) production and conducting field trials with customer involvement. Figure 2 below sets out the anticipated timescales and duration, activities involved, milestones and uncertainties.

Start / end	Activities involved	Milestones	Uncertainties
2026 **12 months duration**	Building extension to accommodate new Cr(III) plating line. This is expected to take 12 months as it must cover the time required for building design, obtaining planning permission, selection of contractor and construction of extension	Construction of extension completed.	Planning permission is assumed to take up to 3 months but could take up to 6 months, perhaps longer
First half of 2027 **6 months duration**	New Cr(III) plating line installation and other modifications (e.g. to waste-water treatment) to allow parallel production of Cr(III) product without inhibiting continued Cr(VI) production	Line and other modifications completed.	Ongoing production may be inhibited. Delivery and installation time of equipment might be impacted by demand of Perrin & Rowe's competitors who are assumed to also require authorisation.

Start / end	Activities involved	Milestones	Uncertainties
Second half of 2027 **6 months duration**	Cr(III) chemistry make-up, resolution of teething issues. Confirmation of production-scale appearance attributes and performance testing. Sharing the collected data with customers to implement a test phase with them. Begin production of customer field trial SKUs.	Completion of chemistry make-up and resolution of process issues Field trial details determined.	Ongoing production may be inhibited. 'Industrialised' process may yield unexpected results from results of earlier testing.
2028 - 2030 **3 years duration**	**Conduct field trials** Request and obtain feedback from customers (EU and non-EU) about technical performance on products Analysis of the feedback received from customers (EU and non-EU) Planning corrective actions to solve critical issues encountered by customers on products made with alternatives Implementation of corrective actions in the industrial-scale plant Iterate the above, as needed based on data received and effectiveness of corrective actions Gain all necessary regulatory and other approvals, i.e. IAPMO Determine transitional logistics planning, including manufacturing build needs and inventory needs Implement above transition plan	Produce and implement SKUs for field trials. Collect customer feedback. If positive feedback, move into production. If feedback indicates issues, then initiate corrective action improvements and conduct follow up field trial for confirmation.	Field trial learnings may be difficult to correct. Customer response may be unpredictable (the willingness of customers to transition to Cr(III)-based alternatives is not guaranteed).

***Figure 2**: Phase 4 timescales, activities, milestones and uncertainties*

3.5. Phase 5: Production transition to alternative

The final phase involves a transition from production using the existing Cr(VI) process to the approved alternative process. This is expected to take 1 to 1.5 years and will involve:

- Building a Cr(VI)-based back-stock for warranties etc.
- Converting all Cr(VI) production to the alternate process
- Staff training
- Modifications to SOPs
- Building the inventory of new products

- Filling the customer pipeline
- 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. Based on the above timescales and durations, it is hoped that this can be achieved during 2032.

3.6. Conclusions

Perrin & Rowe hopes that transition to an alternative (at this stage, anticipated to be a trivalent chromium based plating process) will be completed during 2032. The substitution plan attempts to accommodate uncertainties to some degree, e.g. in the iterative loops associated with phase 2, although in other phases, timescales represent somewhat of a 'best-case' scenario. In other words, substitution is anticipated to take **a minimum of 10 years** and may end up taking longer in reality.

It is currently noted[3], and generally agreed within the industry[4], 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. There is also the potential risk that positive laboratory test results may not describe or translate fully into field use by customers. This could result in field failures and serious discontent by Perrin & Rowe's customers. For this reason, it is proposed to include an extended field trial to capture any of these potential issues.

Planned, multi-year investigation and development activities will require considerable expense to cover the labour, parts, chemistry and testing needed for the development process. In addition, customers may continue to want Cr(VI)-based products, in which case they will turn to importing such products which will still remain available from non-EU sources and perhaps even EU sources for a time, based on authorisations that have been granted or are likely to be granted for the continued use of chromium trioxide for functional chrome plating with decorative character. The NUS is considered in further detail in the SEA but given that the most likely NUS involves outsourcing production, there is no guarantee production will ever be brought back to the UK.

4. Monitoring implementation of the substitution plan

The implementation of the substitution plan by Perrin & Rowe would be managed as an internal project using a well-established and widely used FB WI process. The process is scaled such that the level of governance is aligned to the level of risk. For a project of this nature, a Project Manager would be appointed and a multi-disciplinary team would be assembled, which would include members of the R&D engineering team, finishing engineers, sales and marketing personnel, procurement, site-based representatives from Perrin & Rowe (operations, maintenance, safety and quality personnel), and senior level corporate stakeholders. The project team will vary depending on the specific phase of the plan, for example, a higher degree of technical input will be required in the earlier phases while in the later phases a greater degree of input from sales and marketing experts will be needed in terms of market introduction of new products.

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

[4] Müller et al, 2020, p17.

The process involves splitting a project into various stages, each of which is designed to collect specific information and complete required tasks to help move the project to the next stage or decision point (see Figure 3).

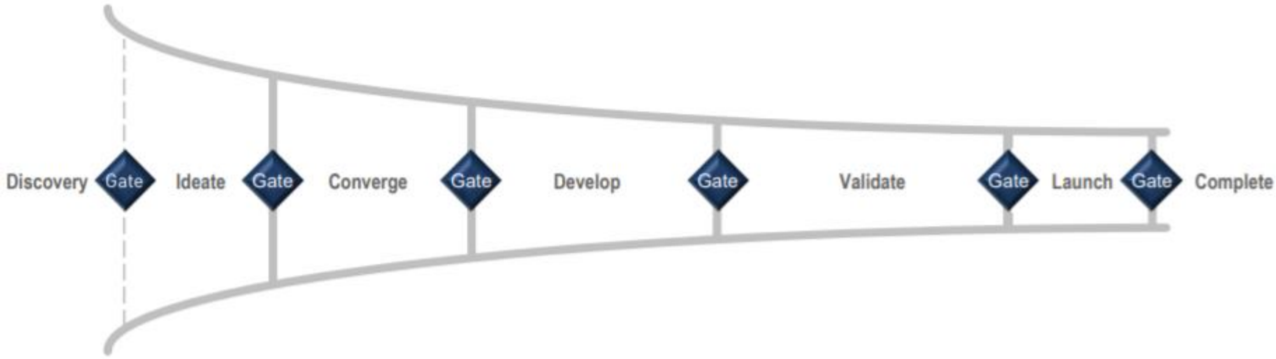

***Figure 3**: Overview of FB WI project management process*

Each stage is defined by the activities within it, which are designed to gather information and progressively reduce uncertainty and risk. Each stage is increasingly more costly and emphasizes collection of additional information to reduce uncertainty. Preceding each stage, a project passes through a gate where a decision is made whether or not the project can proceed to the next stage. These gates serve as quality-control checkpoints with three goals: ensure quality of execution, evaluate business rationale, and approve the project plan and resources.

Each gate is structured similarly and is comprised of:

- A set of required deliverables – the results of an integrated analysis, the Project Manager and Project Team must deliver to the gatekeepers in advance of a gate meeting.
- An approved project plan for the next stage (complete with people required, estimated money, and a time schedule).
- A list of deliverables for the next gate.

5. Conclusions

Perrin & Rowe considers that trivalent chrome-based electroplating is the most promising alternative but this will take many years to develop further. The investigation and testing by Perrin & Rowe / FB WI has shown that Cr(III)-coated products are not currently a technically viable alternative to Cr(VI) electroplating for several reasons. In particular, the appearance of articles produced with Cr(III) present aesthetic problems due to a darker, yellowish / brownish hue of the coating. This can be caused both by iron ions incorporated into the metallic chrome deposition from bath constituents, as well as other impurities entering the Cr(III) process chemistry. This darker, yellower appearance does not meet the high aesthetic standards required by customers. Cr(III) also presents critical problems with regards to corrosion and chemical resistance. Testing undertaken to date on Cr(III)-based products did not meet the necessary requirements, showing a generally significantly lower chemical and corrosion resistance than coatings derived from Cr(VI) based electroplating technology. This means that Cr(III) coated parts for sanitary ware do not meet longevity expectations which would be especially problematic with long-term, high-quality, high-use applications, for example in hotels or other hospitality settings.

This substitution plan has explored the steps that would be required, and the time that would be anticipated, to conduct further research, qualification and ultimately industrialisation of Cr(III)-based electroplating, in the hope that this can provide a suitable alternative to the use of chromium trioxide. Substitution is anticipated to take **a minimum of 10 years** and, in reality, may end up taking longer. However, this represents a long-term solution which is not guaranteed to be successful. In the event that an authorisation is not granted, the most likely NUS involves outsourcing production, with no guarantee production will ever be brought back to the UK.

References

Court of Justice of the European Union (CJEU), 2019. *Judgment of the General Court (Fifth Chamber) of 7 March 2019 in Case T-837/16, Kingdom of Sweden v. European Commission.* Available from https://eur-lex.europa.eu/collection/eu-law/eu-case-law.html

Court of Justice of the European Union (CJEU), 2021. *Judgment of the Court (First Chamber) of 25 February 2021 in Case C-389/19 P, European Commission v. Kingdom of Sweden.* Available from https://eur-lex.europa.eu/collection/eu-law/eu-case-law.html

Gharbi, O., Thomas, S., Smith, C. and Birbilis, N., 2018. *Chromate replacement: what does the future hold?*. npj Materials Degradation, 2(1), pp.1-8. Available from https://www.nature.com/articles/s41529-018-0034-5.pdf

Müller, A., Nicolai, H., Luther, W., 2020. *Survey on technical and economic feasibility of the available alternatives for chromium trioxide on the market in hard/functional and decorative chrome plating*. 1st edition. Dortmund: Baua (Federal Institute for Occupational Safety and Health, Germany). Available from https://www.baua.de/EN/Service/Publications/Report/Gd101.pdf