APPENDIX B

LABORATORY QUESTIONNAIRE ON FERROUS ARMOUR CORROSION PRODUCTS:

RESULTS & ANALYSES

INTRODUCTION

The questionnaire was tailored to mostly address the area of this research dissertation: ferrous armour corrosion products on undecorated ferrous armour. It did not necessarily emphasise the determination of original surface limits as this would have excluded surveying different approaches undertaken; rather the questionnaire was left open so as to determine the variety of approaches followed. It was anticipated that some respondents would document approaches that are relevant to determining original surface limits, thereby providing insights to this aspect.

The ferrous armour corrosion product questionnaire was designed to gain a consistent overview of the trends only. Compared with the literature review, an advantage of the Ferrous Armour Corrosion Product Questionnaire was the ability to simultaneously and systematically obtain a greater level of detail on specific questions from more numerous sources. The questionnaire did not aim to record all the individual conservation possibilities influenced by the unique conditions presented by each armour artefact, its management, intended use and environments: this would be the task of an individual armour's conservation condition and treatment report. It is difficult to expect more from a short series of questions that do not permit direct personal inspection of artefacts referred to in the text.

OBJECTIVES

The objectives of the questionnaire were twofold. To determine:

1. Current armour conservation practices towards ferrous corrosion products; and
2. Ideas behind the above undertaken practices.

The first objective covered the range of approaches applied to armour, interventive or preventive, and if interventive methods were used, then determining the level of intervention was of further interest. The second objective covered the philosophy and motivation behind such practices.

FORMAT, DISTRIBUTION/RETURN METHODS & BACKGROUND OF RECIPIENTS

The questionnaire was formatted in Microsoft Word™ using the *forms* tool to allow the respondent to complete the form on-screen in the appropriate spaces, while protecting the questions and formatting from alterations. Questionnaires were distributed by email (for economical reasons) as an attachment to a brief introductory and individually[1] addressed email. In addition to completing the questionnaire on-screen and returning it via email, respondents had the possibility to print a paper copy, complete it by pen and post it by regular mail. Only two questionnaires (representing 8% of the total) were returned as paper copies and are indicative of the fact that actually receiving a questionnaire necessitated email/computer access, and that its return would most probably be conducted similarly by email. It is assumed that the electronic method of distribution would have unfortunately precluded contributions from progressively higher percentages potential respondents from older generations who could have been more experienced.

Questionnaires were sent to 109 persons having probable connections with armour artefacts since they were known to work for armour collecting institutions, e.g. armouries, museums and art galleries, or are in private practice and are contracted by armour custodians. Half of these questionnaire recipients were known to have a particular interest in the field since they were attendees of the International Conference on the Conservation Arms & Armour Malta 2002. Of the 109 contacts, 78 were armourers/conservators/restorers[2] while the remainder were either curators (25) or scientists (6). Curators and scientists studying armour collections were contacted since it was expected they could play a role in the distribution and support for completing the questionnaire. Also, curator and scientist questionnaire participation was not excluded since it was realised that exact job descriptions vary from country to country. The prerequisite was consequently to question "conservation professionals" with experience in ferrous armour conservation.

[1] To minimise delivery failure caused by spam filtering.

[2] For the purposes of the questionnaire armourers, conservators and restorers are grouped together. Differing backgrounds in training and approaches between these categories of professionals are difficult to accurately define, as in reality differences are largely dependent on the individual and their experiences.

Nonetheless, it was expected that the majority of respondents would fall under the job title of armourer, conservator or restorer.

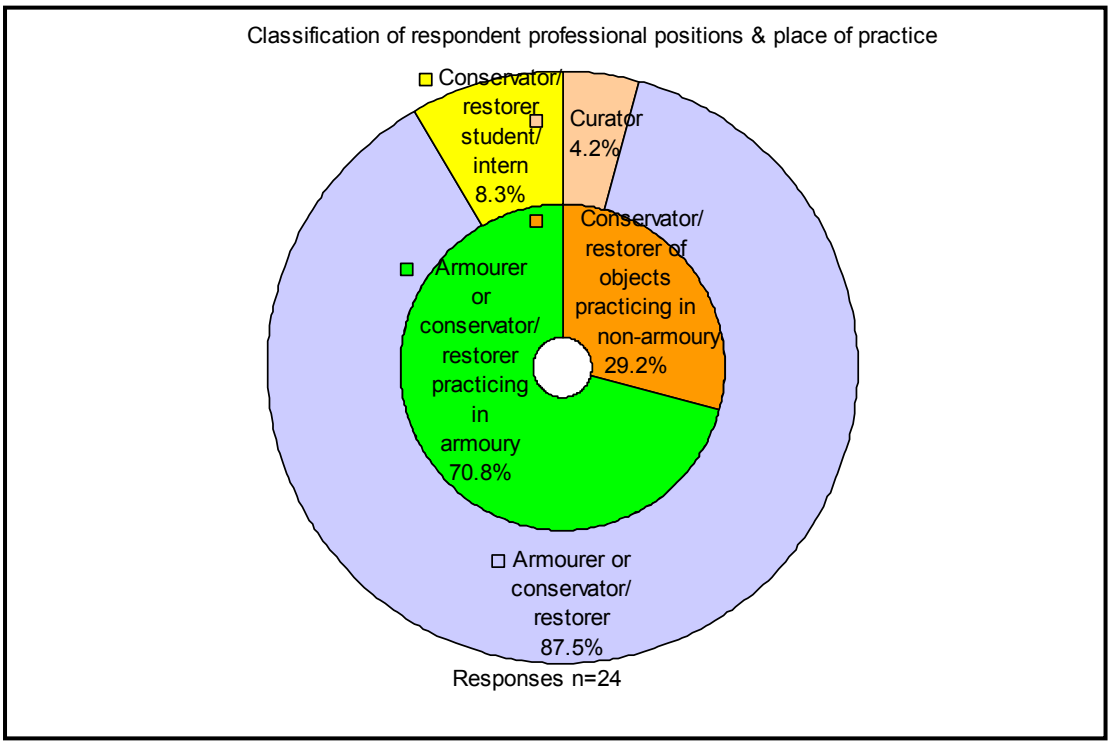
Despite fundamental material similarities occurring with other indoor wrought ferrous artefacts and their corrosion products, conservation professionals of these other types of artefacts were not targeted since it was anticipated that other genre specific considerations might inappropriately survey practices that are inapplicable to armour.

The professionals receiving the questionnaire were located in the western continents of Europe (94), North America (13) and Australia (2).

RESPONDENT DEMOGRAPHICS AND ASSOCIATED ORGANISATION TYPES

Twenty-five persons having experience with working on ferrous armour each returned a questionnaire – a 31% response rate, if only including the number of armourers and conservator-restorers. One questionnaire was excluded in the results analysis since they did not have experience with ferrous armour corrosion products – the focus of the questionnaire. From the remaining pool of 24 (n) questionnaire respondents, one was a curator (4.2%) practicing so-called armourer/conservator/restorer duties, two were student/intern conservators (8.3%) of arms and armour, while the remaining twenty-one were armourers/conservators/restorers[3] (peripheral data series of chart in Graph 1).

[3] Included in this count is a questionnaire completed by a curator in conjunction with non-Anglophone armourers.



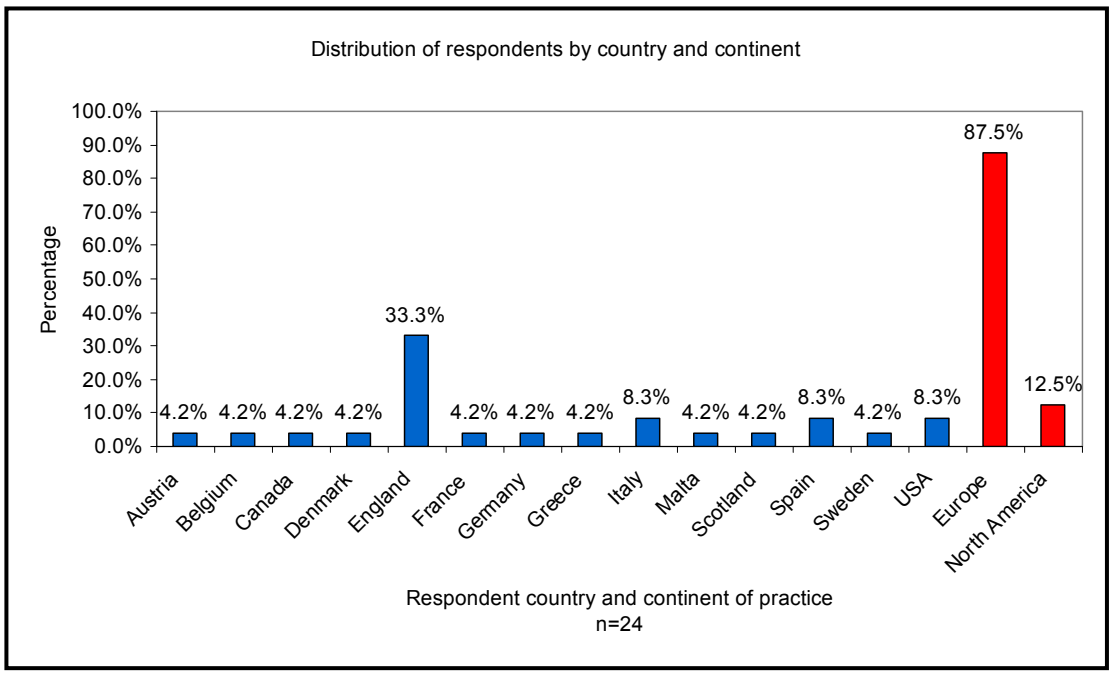
Graph 1 Summary of respondent professional positions (peripheral circle) and place of practice (inner circle)

While all of the included respondents have experience with ferrous armour corrosion products it can reasonably be expected that encounters and subsequent experience will vary considerably. One *possible indication* of experience is the respondents' position title and the type of organisation they are practicing in. The majority (70.8%) of respondents were either armourers or conservator-restorers working in an armoury or an institution predominated by arms and armour (central data series of chart in Graph 1). The remaining 29.2% can be described as conservator-restorers of artefacts that include (not necessarily exclusively) arms and armour.

Five questionnaires, completed by 5 different staff members/interns were returned from 2 of the same organisations, thereby making representation of the questionnaire by a total of 21 participating organisations (institutions or private contracting organisations). The majority of respondents (87.5%) were engaged in armour collecting institutions, while 2 persons (8.3%) were exclusively privately contracted and one respondent (4.2%) was divided between an institution and a private organisation.

The questionnaire respondents were predominantly practicing in Europe (87.5%) and North America (12.5%) (red columns in Graph 2). No responses were

received from Australia. Of the European countries representation includes: Austria, Belgium, Denmark, England, France, Germany, Greece, Italy, Malta, Scotland, Spain and Sweden. Both Canada and the United States of America are represented for North America. The bias towards European contributions is closely reflected by the initial distribution list (Europe 86.3%, North America 11.9% & Australia 1.8%) and is merely a logical reflection of the inherent relative distribution of armour collections between Europe and North America: it makes sense that more armour collecting institutions are close to their place of historical production and use, typically Europe.



Graph 2 Questionnaire respondent representation by country (blue) and continent (red)

Initially it was anticipated to make correlations between countries and continents where differing schools of thought might have become evident from the responses. However the response numbers for most categories are too low for valid general comparisons. Due to a large proportion (33.3%) of responses coming from England the armour conservation-restoration practices there could have skewed the overall statistics.

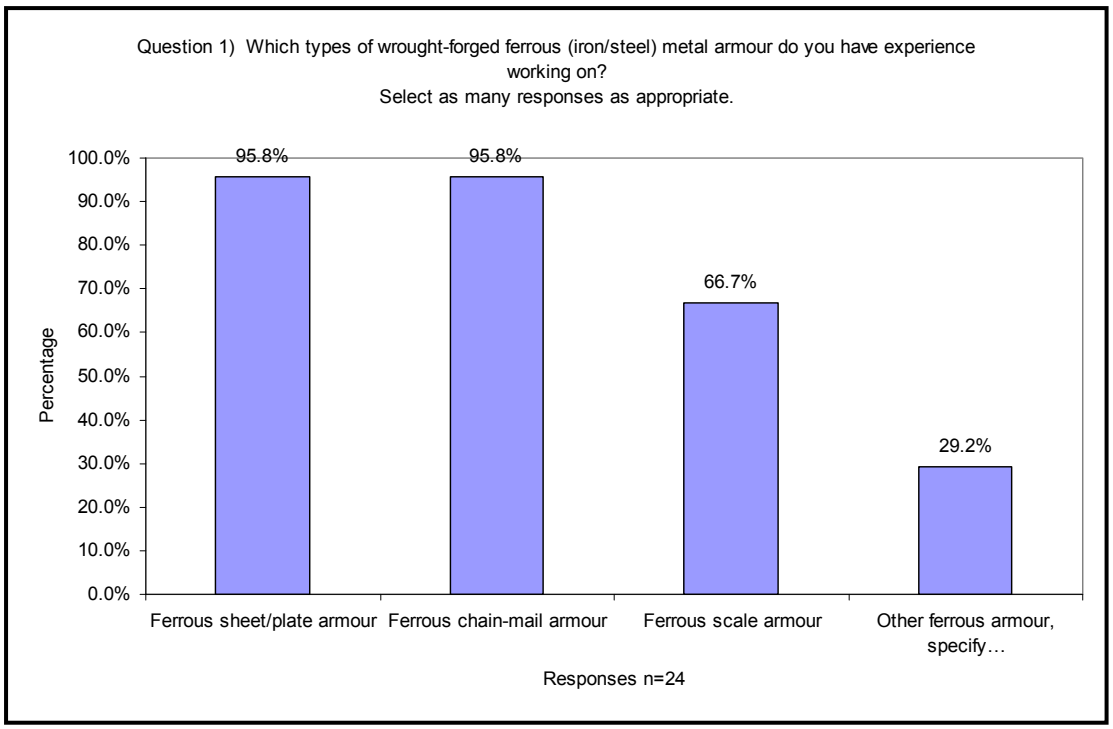
QUESTION RATIONALES AND RESPONSE RESULTS AND ANALYSES

This section will consistently present, per question, the rationale behind the question, a text and chart summary of the main data determined and, if appropriate, analysis and/or consequences of the response results.

QUESTION 1

The main objective of Question 1 was not to determine information, but rather acted to reinforce in the respondent's mind that the questionnaire would only seek to determine information about ferrous armour. Of secondary interest this question helped determine the proportions of experience by ferrous armour *structure* types.

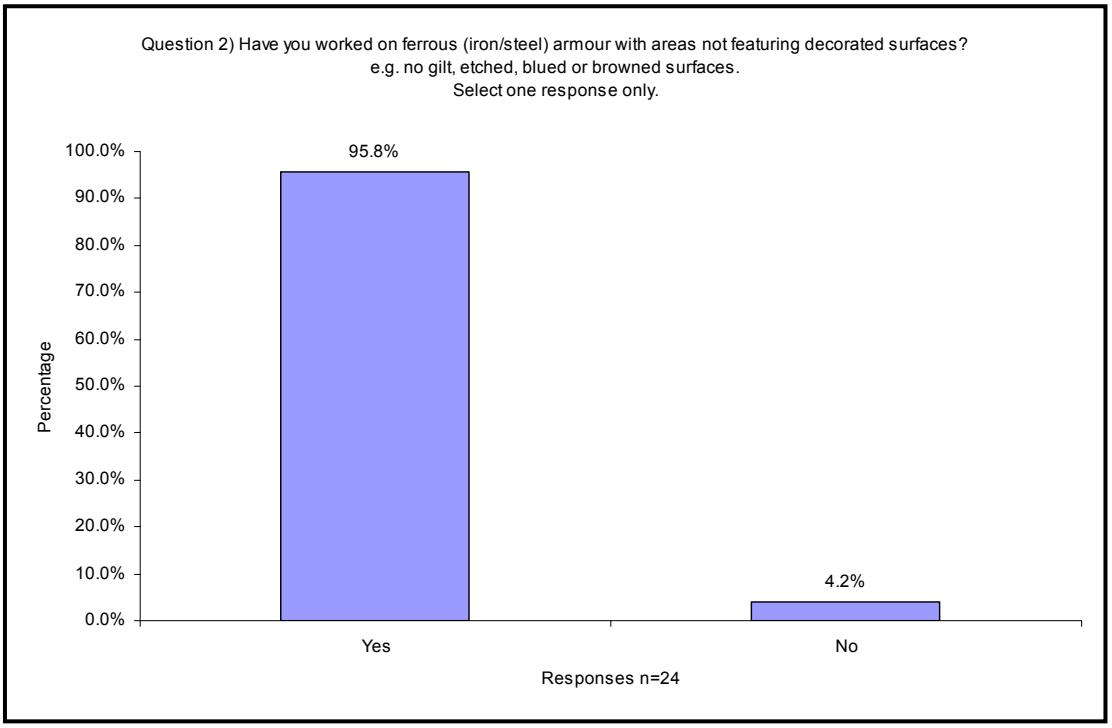
Respondents' experiences with ferrous armour were equally dominated by ferrous plate armour (95.8%) and ferrous chain-mail armour (95.8%) (Graph 3). Meanwhile 66.7% of respondents had experience with ferrous scale armour and 29.2% stated having other types of ferrous armour experience including, "Japanese armour" and "Jacks & brigandines armour associated with organic materials / tinned ferrous". It is presumed that intervention approaches to ferrous materials might be similar, but not identical, since *structural* shape variations might necessitate modified approaches. For example, accessing all facets is more challenging on chain mail than for ferrous scale armour and sheet/plate armour, and might lead to altering techniques.



Graph 3 Summary of responses for Question 1

QUESTION 2

The main objective of this question was to distinguish between types of experience the respondent had with ferrous armour *surface* types and to divert the respondent to the end of the questionnaire if they did not have experience on undecorated armour (4.2%) (Graph 4). Advantageously, for this research the far majority (95.8%) of respondents claimed to have experience on undecorated ferrous armour: the armour surface type in the research focus.

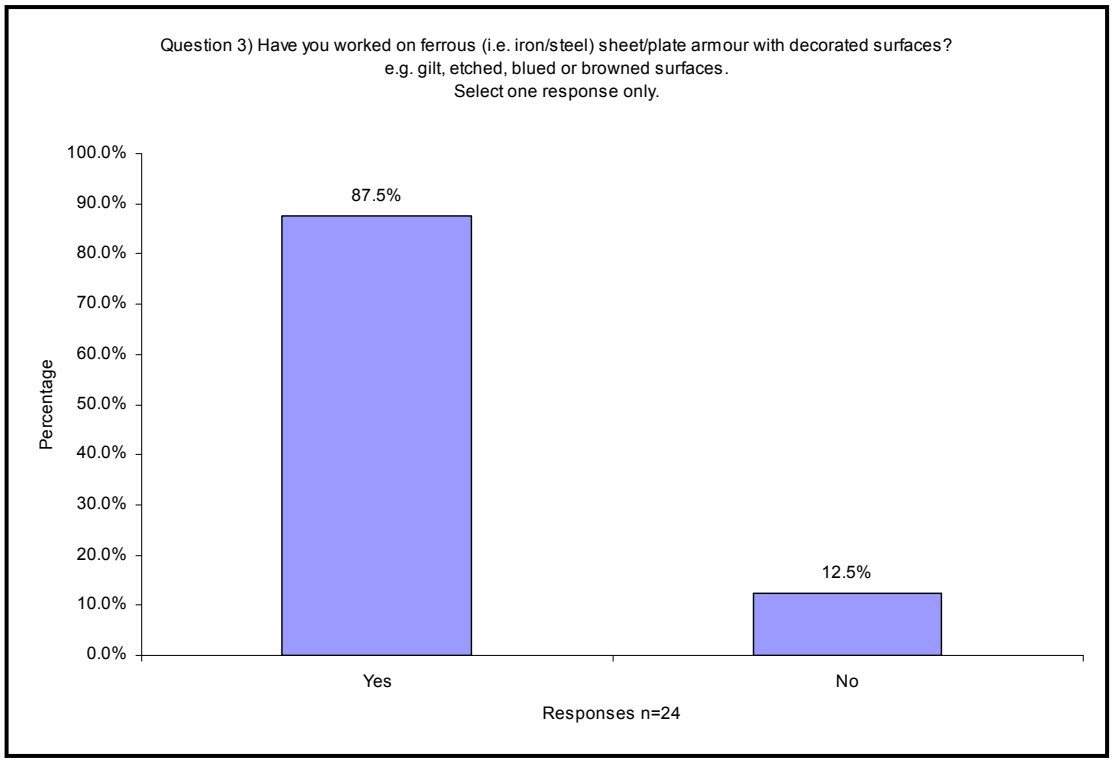


Graph 4 Summary of responses for Question 2

QUESTION 3

The objective of this question was a continuation of the former question since it aimed to distinguish between types of experience the respondent had with ferrous armour *surface* types.

The question was designed to retain (via question routing instructions) questionnaire respondents who recorded having experience with both decorated *and* undecorated armour (87.5%) and to remind these respondents to only consider undecorated armour for the remainder of the questionnaire (Graph 5). Surfaces decorated via material depletion and/or addition techniques multiply the conservation approaches necessary and makes the scope too wide for this research.

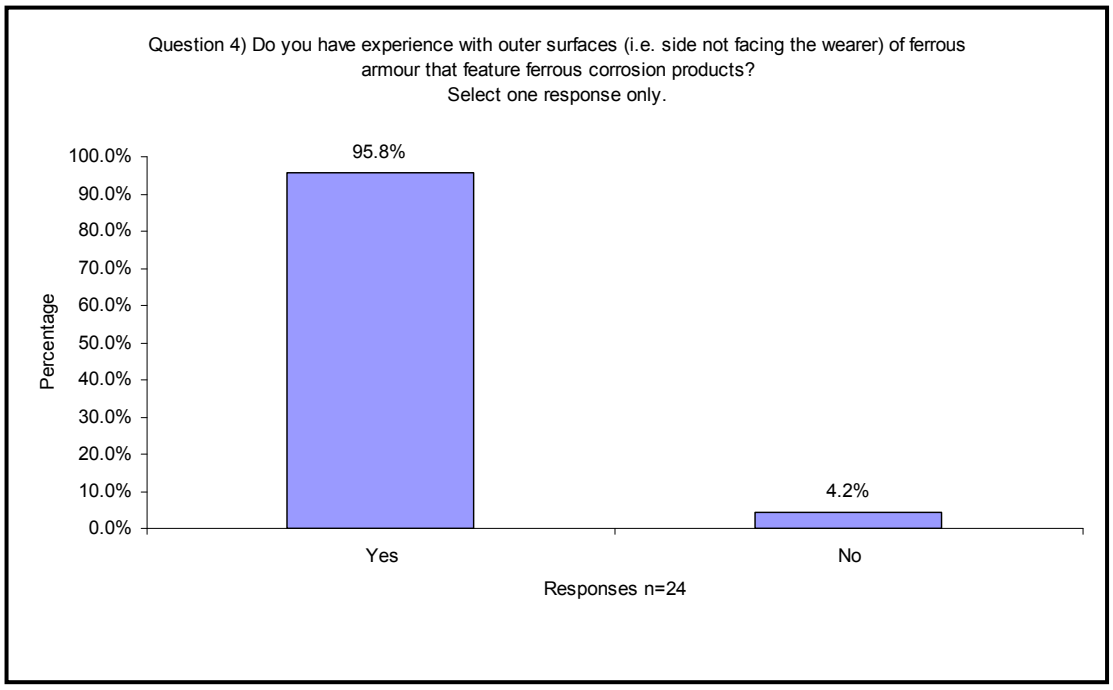


Graph 5 Summary of responses for Question 3

QUESTION 4

This question was designed as a prelude to the subsequent 5 questions (5-9) that relate to outer surfaces of armour. These questions are all of high relevance to the research dissertation since they focus only on the outer surfaces of ferrous armour.

Again, advantageously for this research the considerable majority of respondents (95.8%) were experienced with outer surfaces of ferrous armour with ferrous corrosion products (Graph 6).



Graph 6 Summary of responses for Question 4

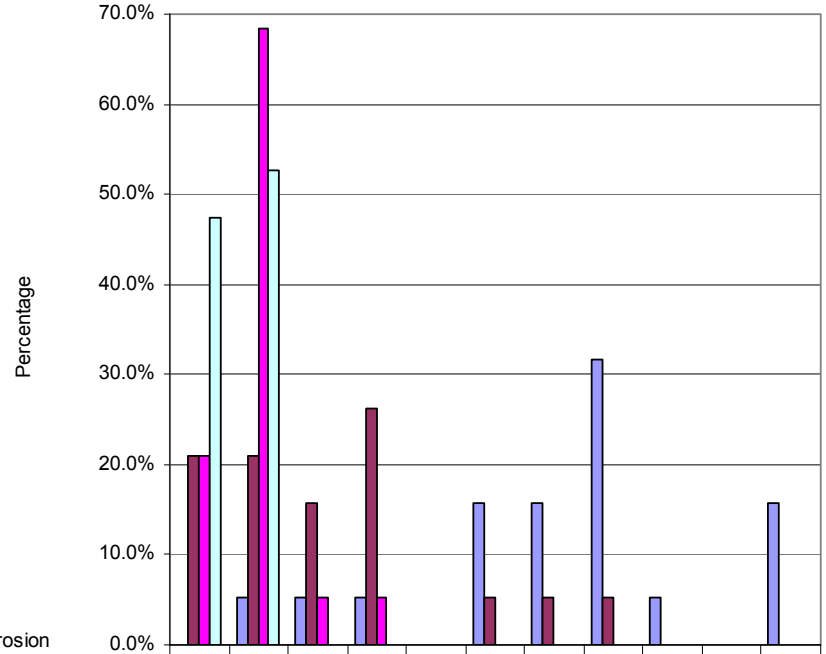
QUESTION 5

This question was designed to obtain an indication, from the respondents' experiences, of the amount of ferrous corrosion product coverage on ferrous armour in the international arena. In this way the average corrosion condition of the armour in various international contexts could be tentatively compared with the armour of the Palace Armoury (PA), Malta. This might help indicate how applicable the subsequently outlined methods of corrosion product removal might be to the amount of corrosion products present in the PA collection.

Predominant trends from the respondents' experiences show a prevalence of corrosion products with relatively[4] thinner layers and lesser distribution, while corrosion products layers that are thicker and have greater/total distribution are in the minority. Over half (68.4%) of respondents considered that 50-80% of corroded armour in their experience fell under classification "A", while 84.2% of respondents considered that 0-30% of corroded armour in their experience fell under classification "B" (Graph 7). One hundred percent of respondents considered that 0-30% of corroded armour in their experience fell under classification "C", while 100.0% of respondents considered that 0-10% of corroded armour in their experience fell under classification "D". The Palace Armoury respondent's answers[5] consistently fall within these predominant trends. Importantly, the comparable alignment of the PA respondent's indicated levels of corrosion products with the majority of respondents' experiences suggests that the armour corrosion conditions are not dissimilar and arguably might[6] mean that any of the subsequently detailed techniques and materials could indeed be applicable to the corrosion on the PA collection.

[4] According to the question's classification system.
[5] Permission was granted by the Head Curator of the Palace Armoury to identify this contribution to the questionnaire
[6] The high subjectivity of the initial question and this subsequent correlation is a guideline that is not unquestionable.

Question 5) Regarding only armour you have experienced with areas of ferrous corrosion products on outer surfaces (i.e. side not facing the wearer), indicate below in the given categories approximately the amount of corrosion products present and its relative frequency (%).



Amount of corrosion products present	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
A Areas with very thin layers of corrosion products that obscure/conceal some areas of the metal surface underneath	0.0%	5.3%	5.3%	5.3%	0.0%	15.8%	15.8%	31.6%	5.3%	0.0%	15.8%
B Areas with thin layers of corrosion products that obscure/conceal many areas of the metal surface underneath	21.1%	21.1%	15.8%	26.3%	0.0%	5.3%	5.3%	5.3%	0.0%	0.0%	0.0%
C Areas with thick layers of corrosion products that obscure/conceal most areas of the metal surface underneath	21.1%	68.4%	5.3%	5.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
D Areas with thicker layers of corrosion products that obscure/conceal all areas of the metal surface underneath	47.4%	52.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

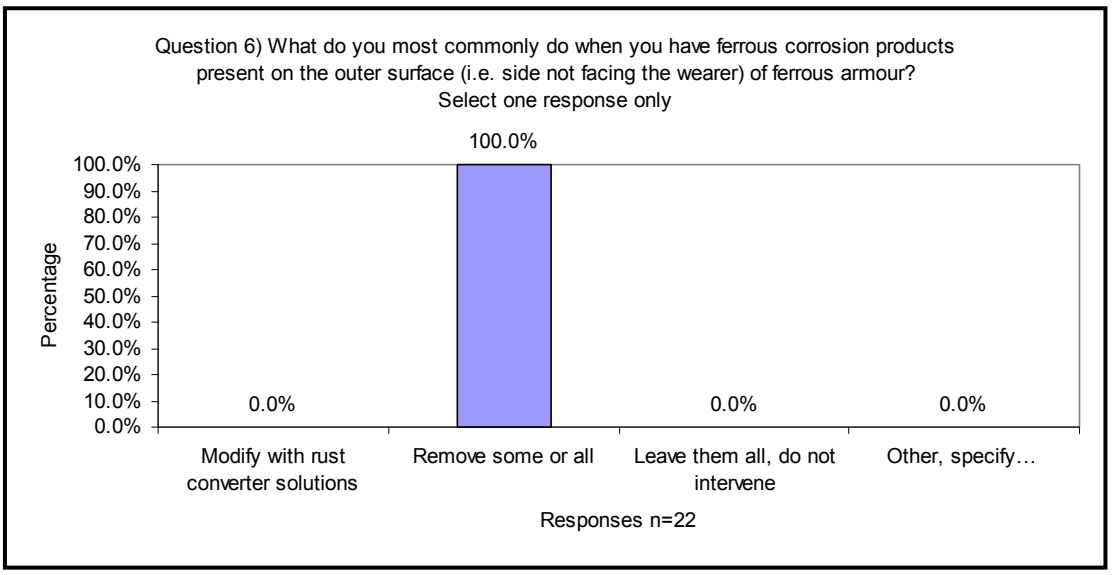
Relative frequency
Responses n=19

Graph 7 Summary of responses for Question 5

QUESTION 6

This question was designed to establish the predominant approaches to corrosion products on armour outer (i.e. side not facing the wearer) surfaces.

The approach *most commonly* employed approach towards corrosion products on the outer surfaces of ferrous armour was unanimously (100.0%) to "Remove some or all" (Graph 8). One respondent preferred to indicate *two* most commonly used approaches, rust conversion and removal of corrosion products (this contribution is not recorded in the statistics since it is unsure which is the more commonly applied approach – it is presumed that the superlative wording of the question was overlooked).



Graph 8 Summary of responses for Question 6

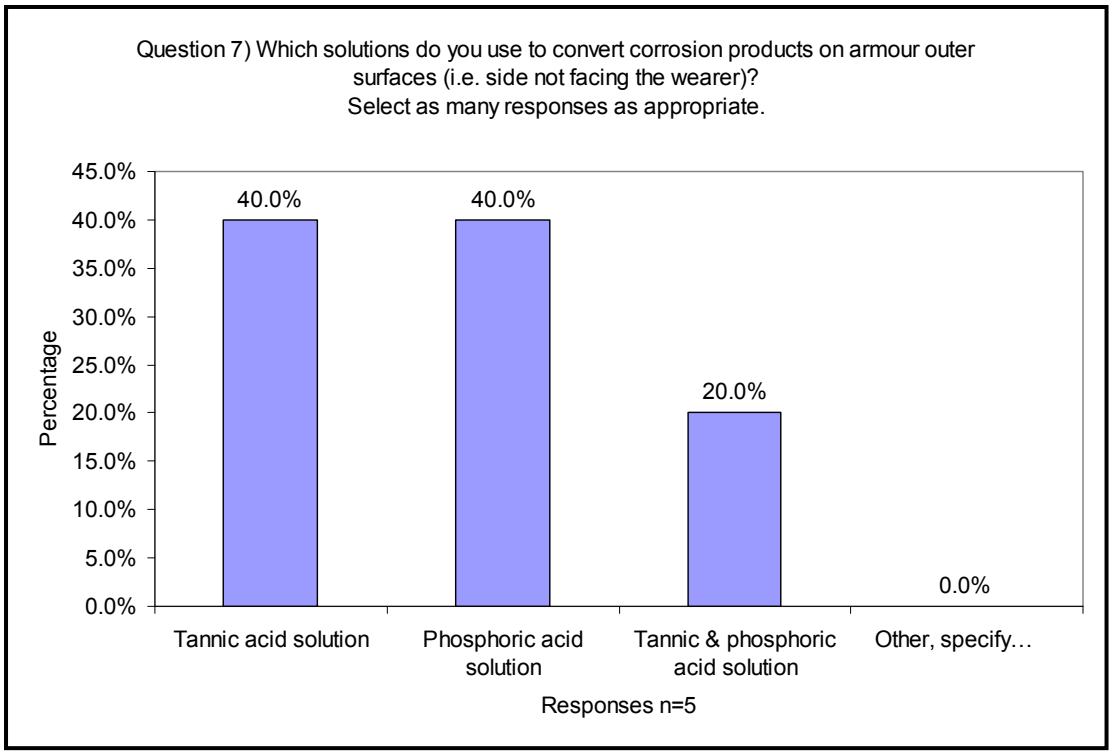
The unanimous trend for removing some or all corrosion products proves that this conservation-restoration procedure on undecorated armour is omnipresent. Understanding the effects of this dominant and irreversible action is of importance to long-term armour conservation and validates the motivation of the research dissertation.

QUESTION 7

This question was designed to determine any types of corrosion converter solutions (i.e. solute and solvent) used on armour outer surfaces, their concentrations and application method.

Despite *not* belonging to their *most common* approaches to ferrous corrosion products on armour outer surfaces, two respondents indicated they apply these solutions to this situation (Graph 9). One respondent specified their formulations and application techniques:

1. Tannic acid concentration 2.5-5 or 10% dissolved in ethanol applied by brush; &
2. Phosphoric acid concentration 5-10% dissolved in deionized water applied by brush.



Graph 9 Summary of responses for Question 7

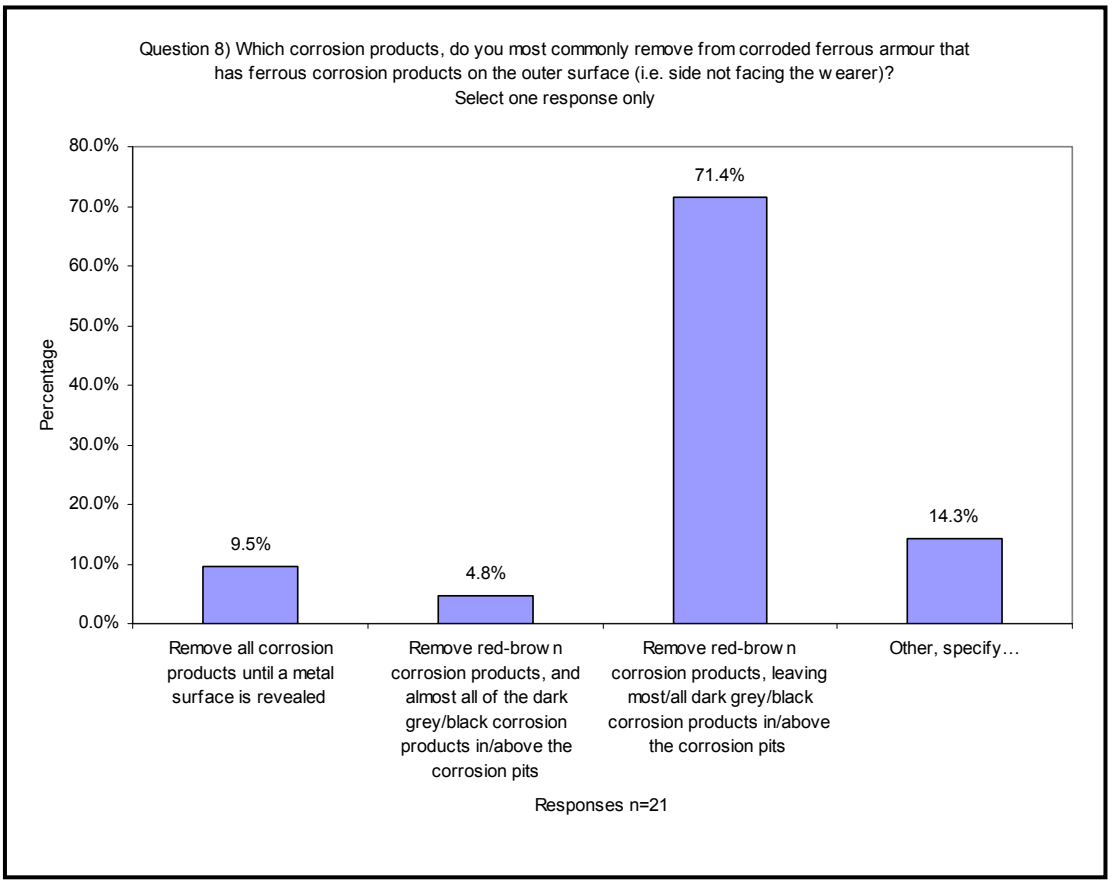
These answers document that approaches to corrosion products other than removal are indeed undertaken, if only on a lesser scale.

QUESTION 8

This question was necessary to indicate the level of corrosion product removal *most commonly* undertaken on armour outer surfaces and is the most important question relating to the dissertation topic.

The majority of respondents (71.4%) selected option "C", "Remove red-brown corrosion products, leaving most/all dark grey/black corrosion products in/above the corrosion pits", while 2 respondents (9.5%) selected option "A", "Remove all corrosion products until a metal surface is revealed" and 1 respondent (4.8%), from the Palace Armoury[7], selected option "B", "Remove(s) red-brown corrosion products, and almost all of the dark grey/black corrosion products in/above the corrosion pits" (Graph 10). Here it can be seen that the practices performed at the Palace Armoury fall between these two levels of corrosion product removal. Alternative specified responses (14.3%) that seemed to prefer not to generalise or take into account the inclusion of the question wording *most commonly* included: "It depends", "Between B and C, depending on object" and "Definitely not A, but otherwise the decision would always be based on the individual object".

[7] Permission was granted by the Head Curator of the Palace Armoury to identify this contribution to the questionnaire



Graph 10 Summary of responses for Question 8

It can be seen from this question that at least the majority of these ferrous armour conservation professionals are aware of the *general* vertical stratigraphy of ferrous corrosion products as it appears by colour, at least on a macroscopic scale for pitting corrosion morphology.

QUESTION 9

This overall question,

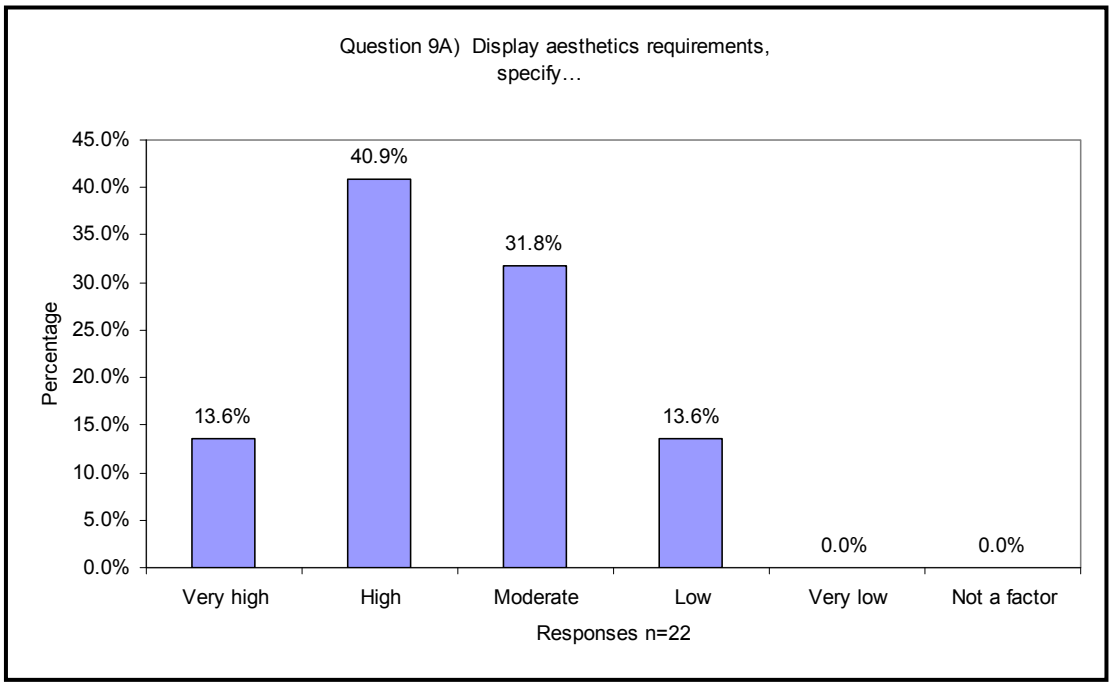
> "Which factors determine which corrosion products you remove from corroded ferrous armour that has ferrous corrosion products on the outer surface (i.e. side not facing the wearer)?"

…was related to the philosophy and motivation behind the performed conservation practices and was designed to help reveal a variety of possible factors that might influence why corrosion products are removed from exterior surfaces of corroded ferrous armour and to also indicate the relative level of influence of each factor. It was decided to separate approaches to outer and inner (Question 14) armour surfaces since it was realised they could be approached differently. A list of 7 potential general factors was formulated as sub-questions so as to stimulate the respondents' consideration. A prompt, to further specify in free-form text, was used to determine how the respondent specifically felt the factor under question would relate to the levels corrosion product removal undertaken. A minority of more or less 1 in 3 respondents completed the free-form text specification, with the proportions varying according to the question.

SUB-QUESTION 9A

This question was included since it is generally known that corrosion products on *historical*[8] artefacts are less tolerated in terms of aesthetics than *archaeological*[9] artefacts. This is largely due to the contrast between shiny metallic surfaces and dull mineralised surfaces. Commonly, the surfaces of metal archaeological surfaces are entirely covered with or formed of corrosion products and this contrast does not occur.

It can be concluded from these responses that display aesthetics are always (i.e. 100.0%) a factor determining which corrosion products are removed from corroded ferrous armour that have ferrous corrosion products on their outer surfaces (Graph 11). The factor is mostly considered of a high (40.9%) or moderate (31.8%) degree of influence.



Graph 11 Summary of responses for Sub-question 9A

Relevant specified comments associated with their level of influence are listed:

- Very high: "For handling collection therefore aesthetics very important has to appear nearly new"
- High: "In order to get uniform surfaces" and "Avoiding the alive metal, I stop myself to the intimate level"

[8] Historical artefacts are here defined as those that have remained in an atmospheric environment e.g. museum, house

[9] Archaeological artefacts are here defined as those that have been recovered from a burial environment e.g. terrestrial, underwater

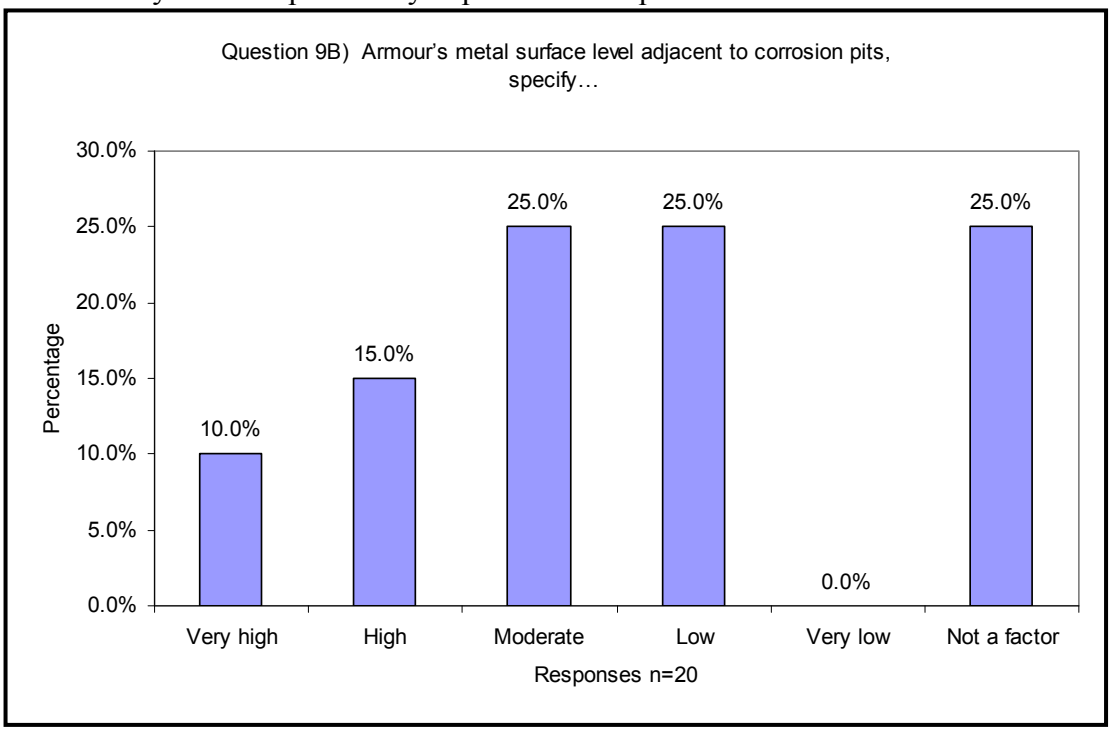
- Moderate: “To museum curatorial specifications”, “The surface appears as even as possible” and “To client's specifications”
- Low: “The armour is conserved to a stable condition. Curators views are considered and the armours general appearance. The over riding principle is stability. Staining on armour is no longer polished out for display but is lightly abraded to remove surface corrosion. Light surface corrosion is removed to give the armour a better appearance”

Aesthetics are a subjective matter that is in the *eye of the beholder*. From the specified responses, the person’s nominated as possibly making such judgements explicitly include curators and clients, whereas museum visitors and armourers/conservators/restorers are not explicitly cited, but are possible candidates.

SUB-QUESTION 9B

This question was included since it was known that corrosion processes not only involve formation of corrosion products inside corrosion pits, but also the deposition of corrosion products on metal surfaces. This uncorroded adjacent metal surface *could* therefore serve as a reference point to level the topography of the corrosion products on top of corrosion pits.

The armour's metal surface level being adjacent to corrosion pits is sometimes (25.0%) not considered a determining factor, while in cases where it was a factor the degree of influence is mostly moderate (25.0%) or low (25.0%) (Graph 12). The response rate from this question was lowered since the question's meaning was not understood by all respondents (as specified by 3 persons). It is possible then that more respondents had similar difficulties with the meaning of the question. The reasons for this incomprehension could include awkward question structure and unfamiliarity with the previously explained concept.



Graph 12 Summary of responses for Sub-question 9B

Relevant specified comments associated with their level of influence are listed:

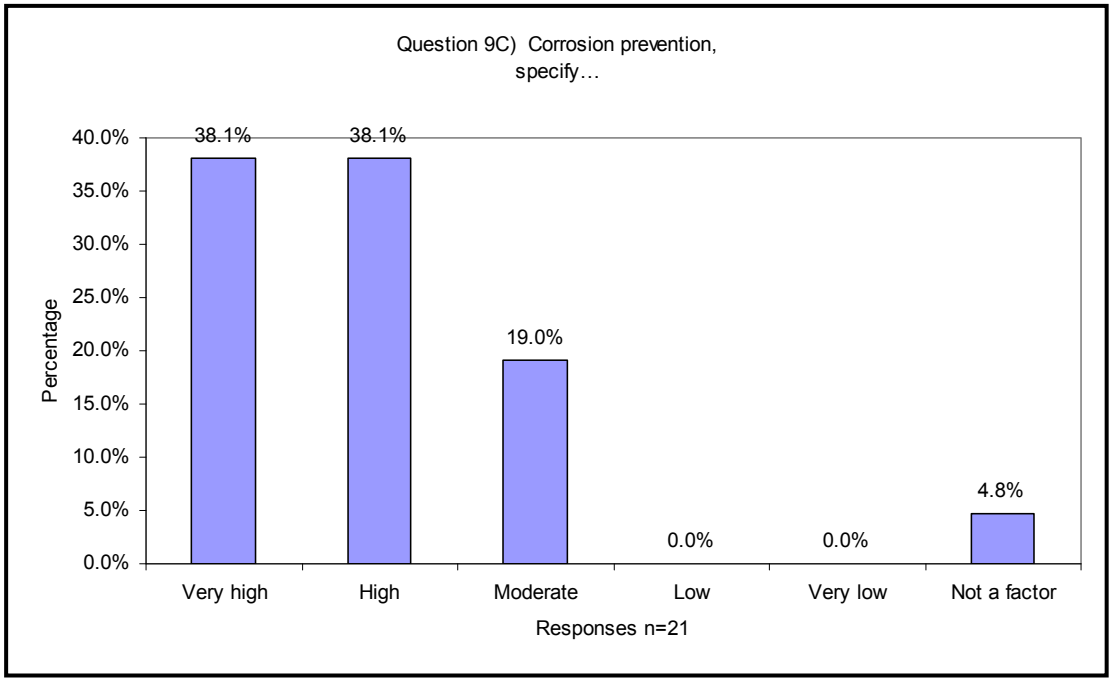
- High: "We try to leave the pits "filled" with dark corrosion in order to create an even surface"
- Low: "The areas adjacent to the corrosion are usually lightly polished to the same sheen as the corroded areas to give an overall impression of evenness. This does not mean that the staining is removed."

Both of these specified responses highlighted the common factor that achieving a surface with corrosion products adjacent to a metal surface, results in an overall surface that is uneven in colour.

SUB-QUESTION 9C

The effects of corrosion products directly or indirectly acting as corrosive agents via a variety of mechanisms (e.g. galvanic coupling, differential aeration, lowering critical humidity, harbouring corrosion accelerants such as oxidants and electrolytes) are well known[10]. These potential corrosion influences were not cited in the question since it was felt this could bias their responses; instead it was left open for the respondents to specify.

The majority (95.2%) of respondents deemed corrosion prevention to play a factor in corrosion product removal while the degree of influence is mostly very high (38.1%) or high (38.1%) (Graph 13).



Graph 13 Summary of responses for Sub-question 9C

Relevant specified comments associated with their level of influence are listed:

- Very high: "Corrosion is hygroscopic"
- High: "To stop corrosion spreading" x 2, "That thick layers of corrosion harbour moisture and salts/contaminants"

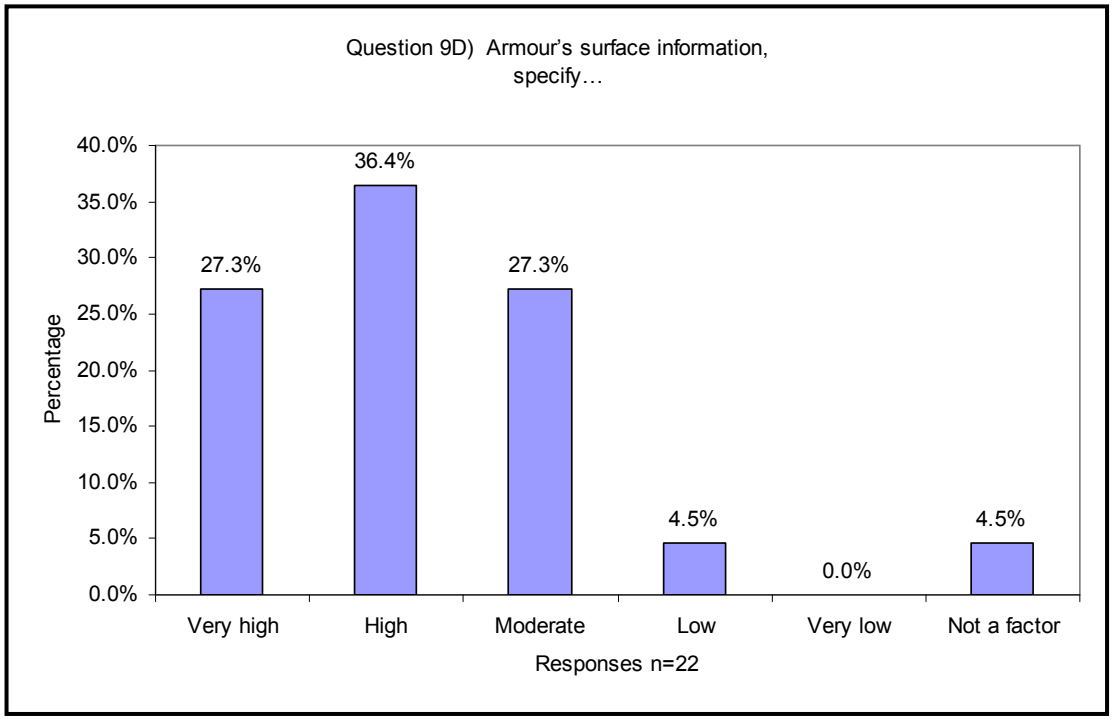
The emphasis of corrosion prevention playing a predominantly very high to high factor in corrosion removal is noteworthy and it is speculated how much these approaches also consider corrosion prevention via environmental control.

[10] 2.2.2 Indoor atmospheric ferrous corrosion: definition, processes & factors

SUB-QUESTION 9D

This question was the most relevant in this question to the dissertation research. The question used the term "Armour's surface information" so as to leave it open for interpretation and specification by the respondent.

Armour surface information is considered by the majority of respondents (95.5%) as a factor determining which corrosion products are removed. Most respondents (36.4%) consider it to be a factor of high regard, while others felt it to be of very high (27.3%) and moderate (27.3%) regard (Graph 14).



Graph 14 Summary of responses for Sub-question 9D

Relevant specified comments associated with their level of influence are listed:

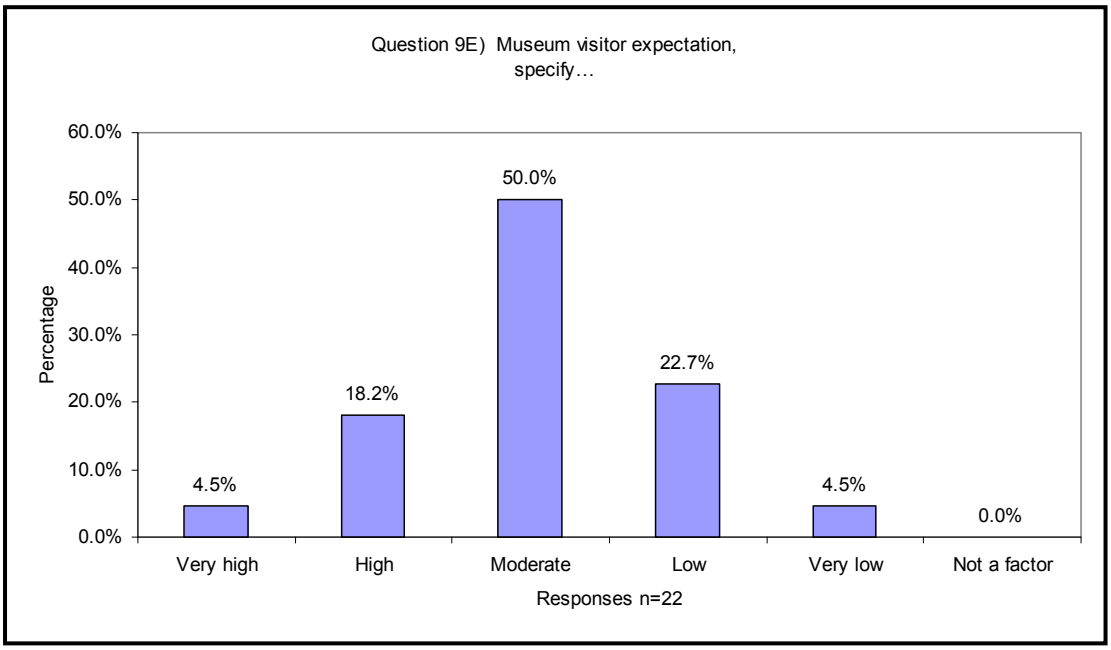
- Very high: "Most necessary to reveal and keep technical and metallurgical information", "Information about the production processes and the original tools used by the master, the artists idea for surface design, the masters working out of this design, the masters level as artist. The artists idea for the whole armour as a suit for a special person for a special kind of events. The individual history of this object and different ways of former conservations/restorations/repairings and also formal changings of detailed areas restorers worked on in different centuries", "Marks, decoration eg etching, evidence of manufacture very important to maintain",
- Moderate: "So as to reveal marks/decorative surface features to museum curatorial specifications", "In order to approximate to the original aspect", "So as to reveal marks/decorative surface features"
- Low: "The original surface finish of the armour is of the greatest importance. If the corrosion is obscuring the original finish and can be removed without damaging this surface then it could be removed if this is beneficial to the object".

These specified responses indicate that in spite of the fact that most armour has been accessible over the last centuries and many periodic interventions such as polishing have occurred, different types of surface information (e.g. original manufacture or subsequent maintenance/restoration) is still considered of major influence during corrosion product removal procedures.

SUB-QUESTION 9E

This question was included as an attempt to relatively gauge how museum visitors influence corrosion product removal. The motivation for the question's inclusion is largely due to the popular, if not sometimes incongruous, image of the proverbial *knight in shining armour*.

Museum visitor expectation is unanimously (100%) a factor determining the level of corrosion product removal, while the distribution is largely (50%) moderate (Graph 15).



Graph 15 Summary of responses for Sub-question 9E

Relevant specified comments associated with their level of influence are listed:

- Very high: "Expect to look as new and be safe to handle"
- High: "To museum curatorial specifications (eg. not physically dirty or actively corroding … clean and presentable, but not visibly over-cleaned)", "Visitors expect original armours as realistic as they were when its owner bought and wore them. They hope for exact information. They nearly never understand qualities of materials and very seldom they understand corrosion processes. So conservators have to work with the idea of basic informations for people who want to learn about museum objects. Conservators are not allowed to forget the aesthetic point of view. From the visitor's view (and also if you try to face the original design of the armour !!) it is not interesting to celebrate our conservation work on the objects themselves. Our work was good when nobody asks about it."
- Moderate: "That the object should appear cared for and looked after", "Aesthetical aspect"
- Low: "Red/brown corrosion products on the surface would usually be removed. I have left armour in a case with severe staining and have had no complaints. The objects do need to look cared for and mounted professionally."

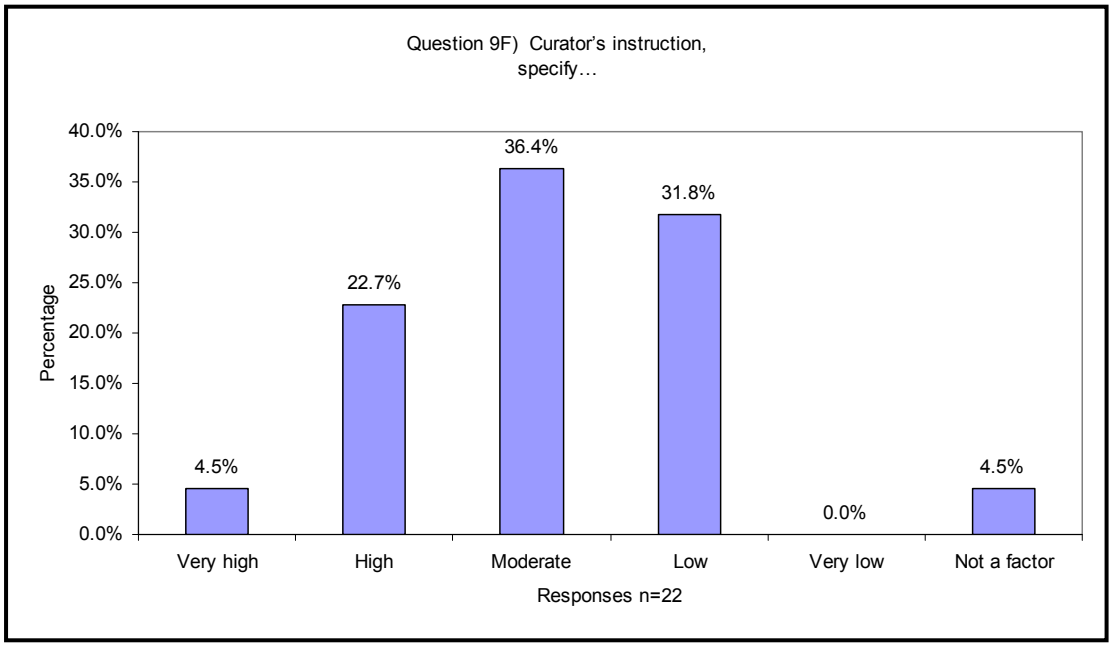
A well-distributed bell-curve has been formed with the relative influence of museum visitor expectation factors. However, of important note is that two divergent types of visitor expectations appear to prevail according to the specified responses:

1. Corrosion products are acceptable if well-maintained (i.e. dust-free, no active corrosion)
2. Armour should look new appear as new and corrosion free.

SUB-QUESTION 9F

This question was included since it is realised that internationally there exist different hierarchical structures in organisations. In some institutions a curator is superiorly positioned and in others conservators and curators are placed on an egalitarian field. This does not suggest curators would not necessarily respect the advice of a lower-positioned conservator.

Curator's instruction is largely (95.5%) considered a factor determining corrosion product removal; most respondents (36.4%) considered it a moderately influential factor, while others felt it was of low (31.8%) and high (22.7%) influence. (Graph 16).



Graph 16 Summary of responses for Sub-question 9F

Relevant specified comments associated with their level of influence are listed:

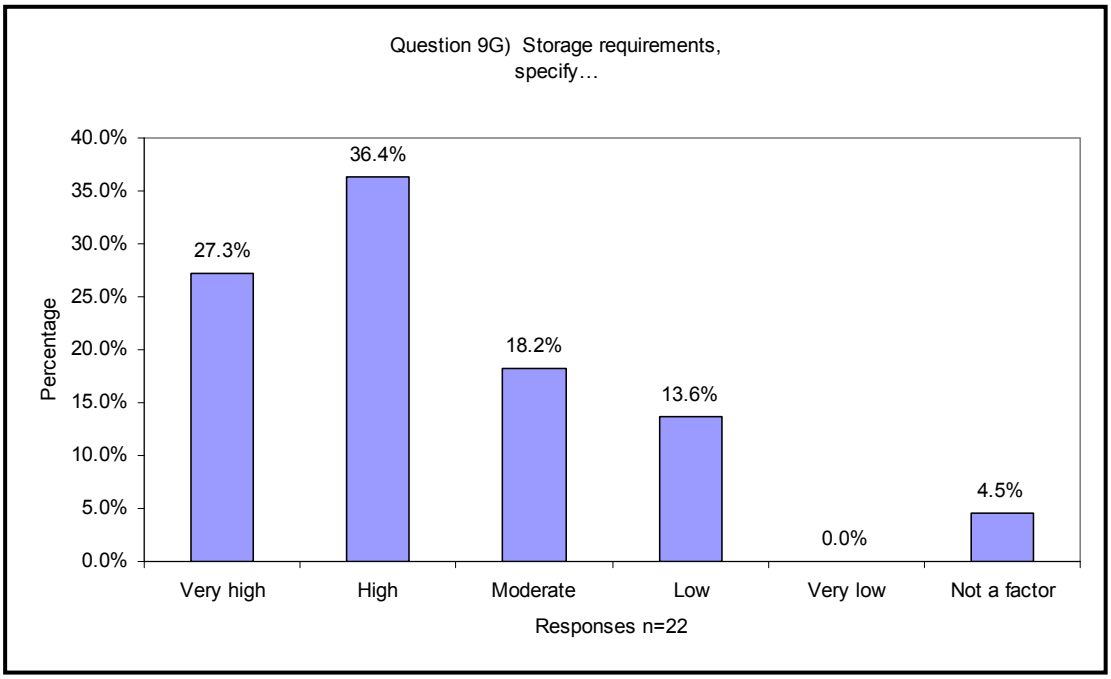
- Very high: "Curators want to have the highest standard of information, but sometimes they forget that all the traces on original materials give the most direct informations about a piece of art. Not very often they care about aesthetic problems. They want to find out the specialities of different masters and artists…"
- Moderate: "Conservators are guided in all matters by curators"
- Low: "Curators have learnt that the object has to be stable and the finish of the armour is left to the conservator"

Again, the specified responses indicate divergent opinions, especially in terms of the respective roles of the curators and conservators in guidance and decision-making.

SUB-QUESTION 9G

The inclusion of this question was to serve as a prompt for the respondent in the case that they felt there might be motivations for corrosion product removal related to storage requirements.

The majority (95.5%) of respondents indicated that storage requirements are factors determining which corrosion products are removed. This factor is mostly considered of a high (36.4%) or very high (27.3%) degree of influence (Graph 17).



Graph 17 Summary of responses for Sub-question 9G

Relevant specified comments associated with their level of influence are listed:

- Low: "Active corrosion may be removed but on the whole the objects are coated in wax and put into controlled environments and left".

Judging by the following specified responses, it appears that by the end of this extended sub-question the original question's meaning had been confused. Several specified comments irrelevant to corrosion product *removal* are listed:

- High: "Monitoring for corrosion, especially in store; ensuring that the condition of objects in store does not become overlooked", "That objects are clean", "Stabilising corrosion to accommodate bad storage conditions"
- Moderate: "Long term conservation reasons", "Stored in open conditions for ease of access"

One respondent stated that storage requirements were irrelevant to this question, yet also strangely indicated that this factor was very high:

- Very high: “The problems of storage requirements I mean are for another question in your questionnaire. It is clear that certain climate conditions determine corrosion products depending on them. But you can speak about the same problems for all the other possible environments for historic armours. - Climate control, lighting control, conservation materials control, display materials control”

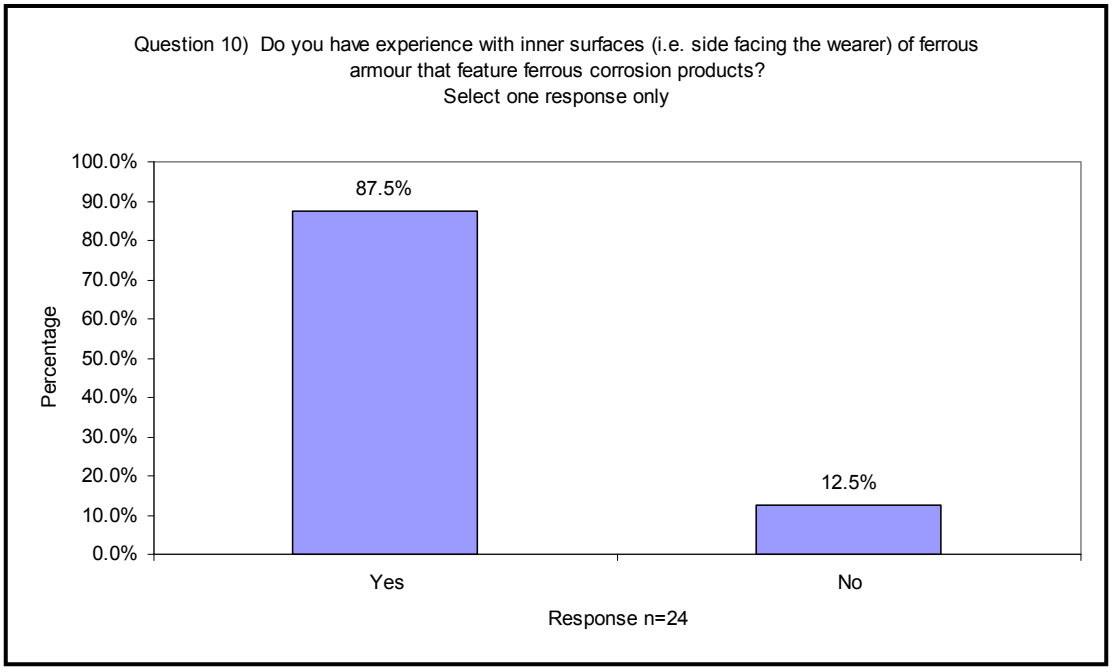
The data accrued for the storage requirement factor is therefore not considered reliable and will be discounted from the overall conclusion analyses.

QUESTION 10

This question was designed as a prelude to the subsequent 5 questions (11-14) that relate to inner surfaces of armour. While these questions are not of high relevance to the research dissertation, since they focus only on the inner surfaces of ferrous armour, the inner surfaces cannot be ignored for overall conservation purposes since the armour are three-dimensional artefacts that must be considered as whole units.

This question was included to also determine if there were any differences in approaches taken between the outer and inner surfaces of armour. Refer to Extended results analysis for a comparison of approaches between armour's outer and inner surfaces.

The majority (87.5%) of respondents had experience with inner surfaces (i.e. side facing the wearer) of ferrous armour that feature ferrous corrosion products (Graph 18).



Graph 18 Summary of responses for Question 10

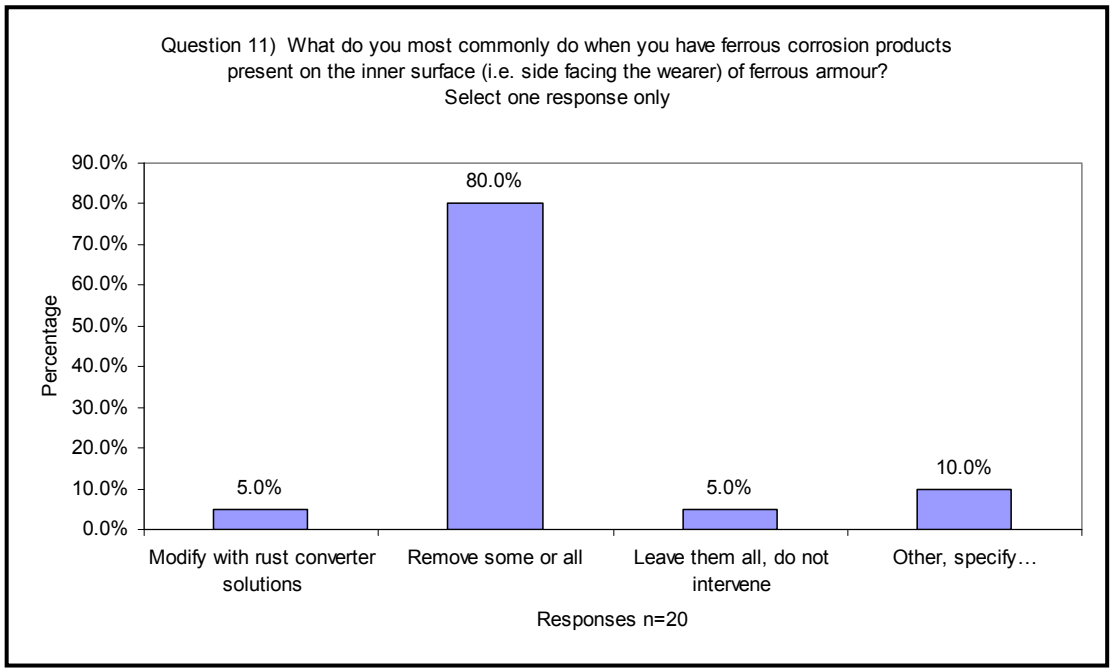
QUESTION 11

This question was designed to establish the predominant approaches to corrosion products on armour inner (i.e. side facing the wearer) surfaces.

The approach *most commonly* employed towards corrosion products on the inner surfaces of ferrous armour was for the majority (80.0%) "to remove some or all" (Graph 19). One respondent (5.0%) indicated that they most commonly modify them with rust converter solutions, while another respondent (5.0%) prefers to leave them and not intervene. The remaining 10.0% is accounted for by two respondents who specified that they:

1. "remove (corrosion products) sometimes and leave sometimes depending on experience, conditions, purpose of conservation"
2. "(apply) protection (of) microcrystalline wax"

One respondent indicated *two* most commonly used approaches, rust conversion and removal of corrosion products (this contribution is not recorded in the statistics since it is unsure which is the more commonly applied approach: it is presumed that the superlative element to the question wording was overlooked or they could have intended to mean that these different approaches are taken depending on the particular case. While corrosion product removal is the predominant trend, it is notable that other approaches are also practiced even if considerably less.



Graph 19 Summary of responses for Question 11

QUESTION 12

This question was designed to determine any types of corrosion converter solutions (i.e. solute and solvent) used on armour outer surfaces, their concentrations and application method.

The one respondent who *most commonly* converted corrosion products present on the inner surfaces of armour used three types of solutions in unspecified solvents (Graph 20):

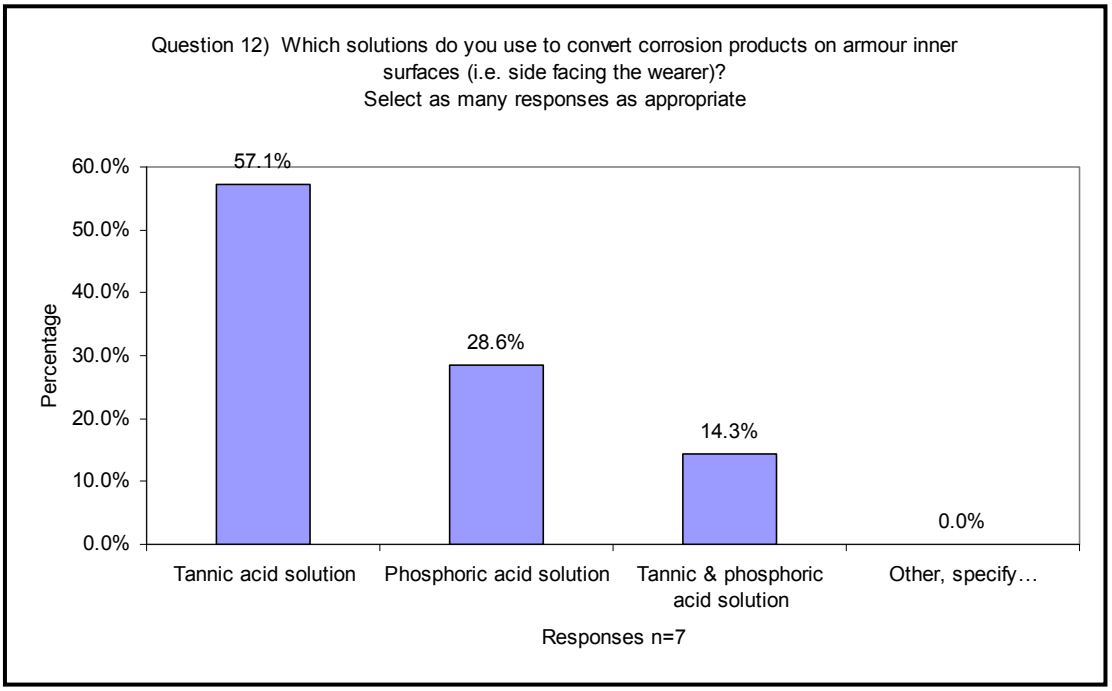
1. Tannic acid
2. Phosphoric acid
3. Tannic & phosphoric acid

Despite not being their most common approaches to ferrous corrosion products on armour inner surfaces three respondents indicated they use converter solutions:

1. Tannic acid x 3 (one of these cases was a unique occasion)
2. Phosphoric acid x 1

One of these respondents specified the concentration, solvent and application method:

1. Tannic acid 2.5-10 or 10% dissolved in ethanol applied by brush
2. Phosphoric acid 5 or 10% dissolved in deionised water applied by brush



Graph 20 Summary of responses for Question 12

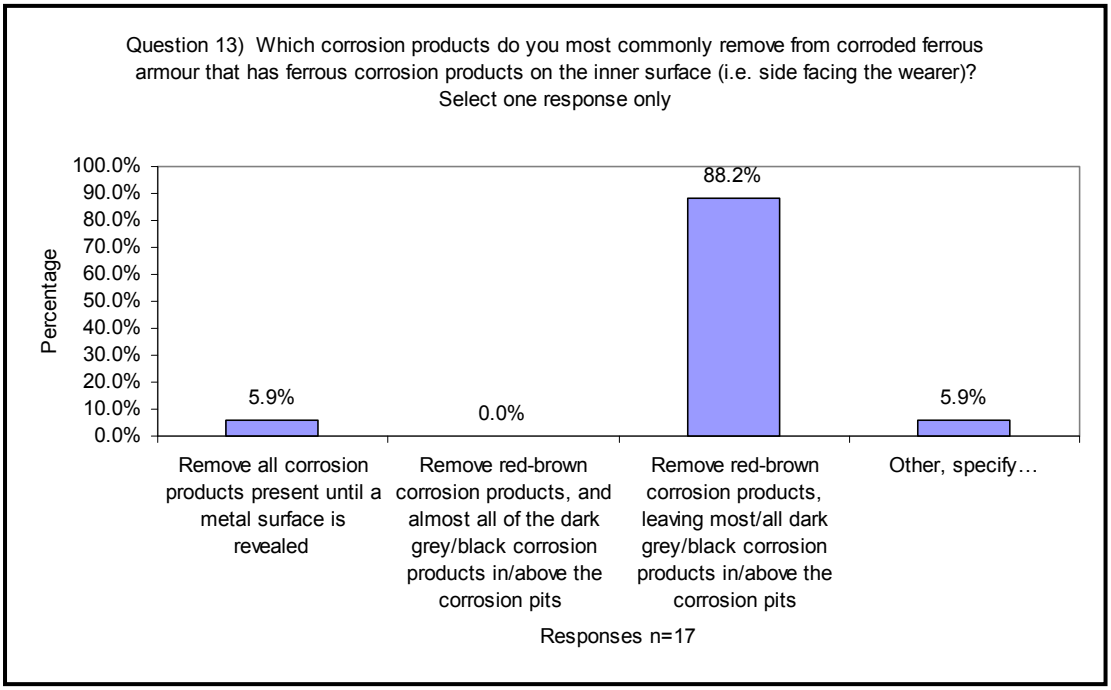
QUESTION 13

This question was necessary to indicate the level of corrosion product intervention *most commonly* undertaken on inner surfaces of armour.

The majority of respondents (88.2%) "Remove red-brown corrosion products, leaving most/all dark grey/black corrosion products in/above the corrosion pits", while one respondent (5.9%) "Remove(s) all corrosion products until a metal surface is revealed" and one respondent (5.9%), "Remove(s) only loose, powdery corrosion products" (Graph 21). One respondent preferred to indicate *two* most commonly used approaches:

B) Remove red-brown corrosion products, and almost all of the dark grey/black corrosion products in/above the corrosion pits; &
C) Remove red-brown corrosion products, leaving most/all dark grey/black corrosion products in/above the corrosion pits

This contribution is not recorded in the statistics since it is unsure which is the more commonly applied approach: it is presumed that the superlative element of the question was overlooked.



Graph 21 Summary of responses for Question 13

QUESTION 14

This overall question,

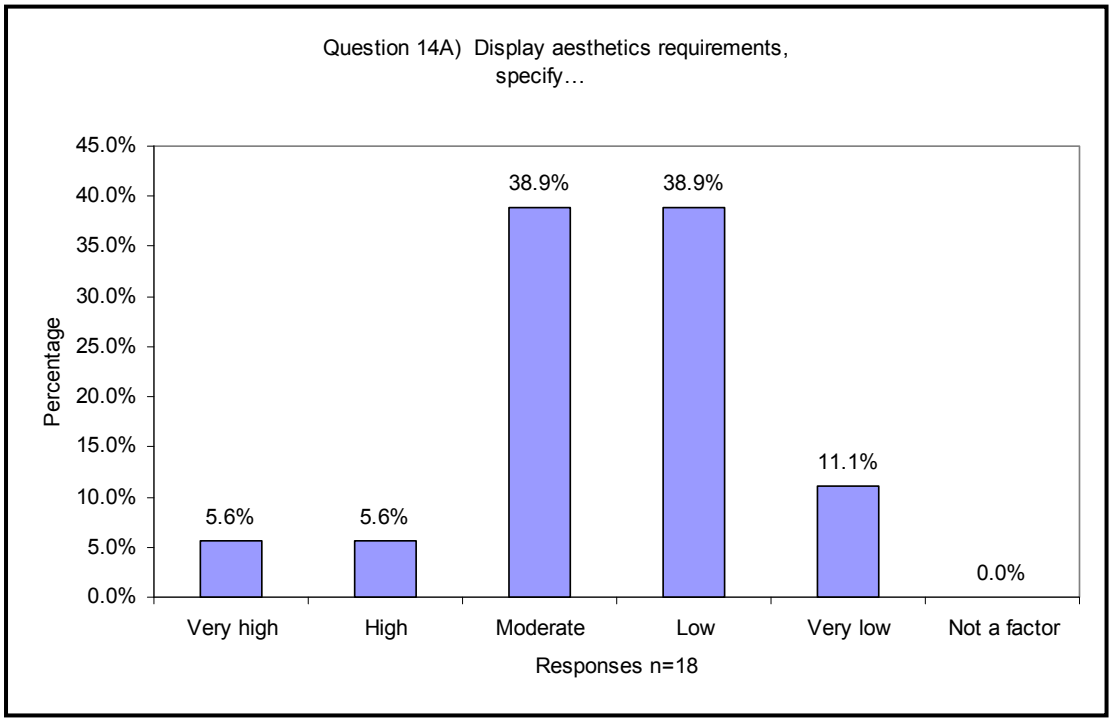
> "Which factors determine which corrosion products you remove from corroded ferrous armour that has ferrous corrosion products on the inner surface (i.e. side facing the wearer)?"

… is again related to the philosophy and motivation behind the conservation practice, but is specific to the inner surfaces. Like Question 9 concerning armour outer surfaces, the subsequent sub-questions were designed to help reveal a variety of possible factors that might influence why corrosion products are removed from inner surfaces of corroded ferrous armour and to also indicate the level of influence of these factors. The listed factors are the same as for Question 9 while the specific rationales behind each sub-question are more or less the same and are not restated.

Comparisons of practice between outer and armour inner surfaces are presented in Comparison of responses between Questions 9a-g & 14a-g.

SUB-QUESTION 14A

Importantly, it can be concluded from these responses that display aesthetics are always (i.e. 100%) a factor determining which corrosion products are removed from corroded ferrous armour that has ferrous corrosion products on the inner surface (Graph 22). However the factor is mostly considered of a moderate (38.9%) or low (38.9%) degree of influence.



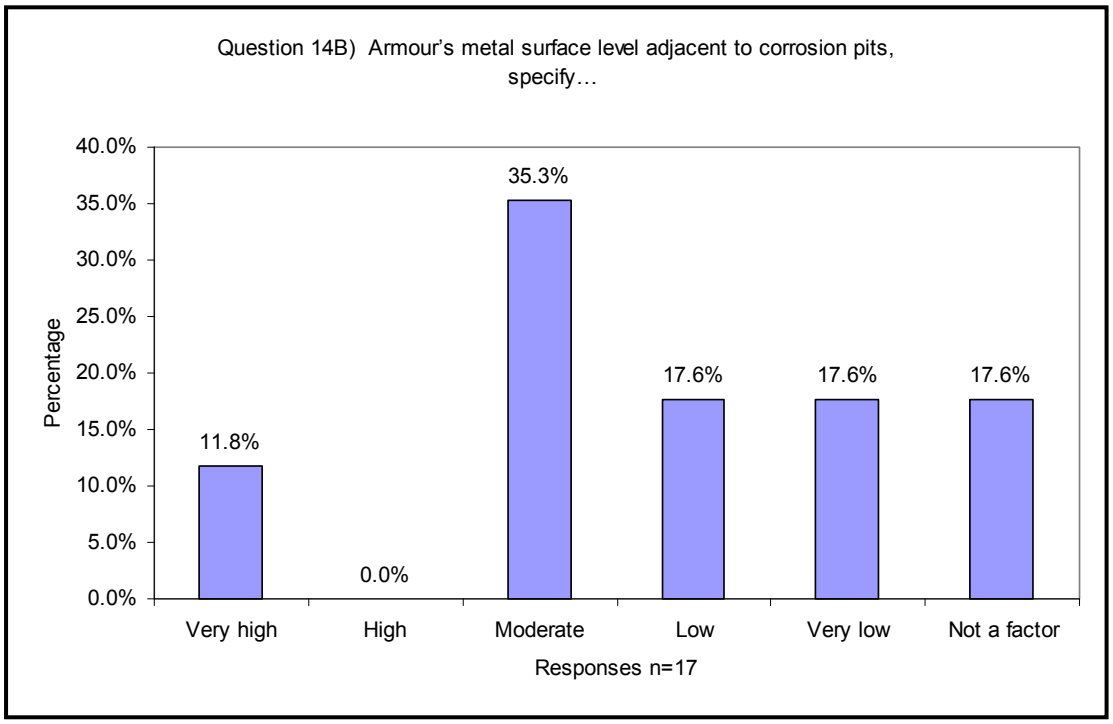
Graph 22 Summary of responses for Sub-question 14A

A relevant specified comment associated with its level of influence is given:

- Moderate: "That the inner surface looks tidy and well cared for"

SUB-QUESTION 14B

The armour's metal surface level being adjacent to corrosion pits is mostly (82.4%) considered a determining factor, however the degree of influence is mostly moderate (35.3%), low (17.6%) or very low (17.6%) (Graph 23).



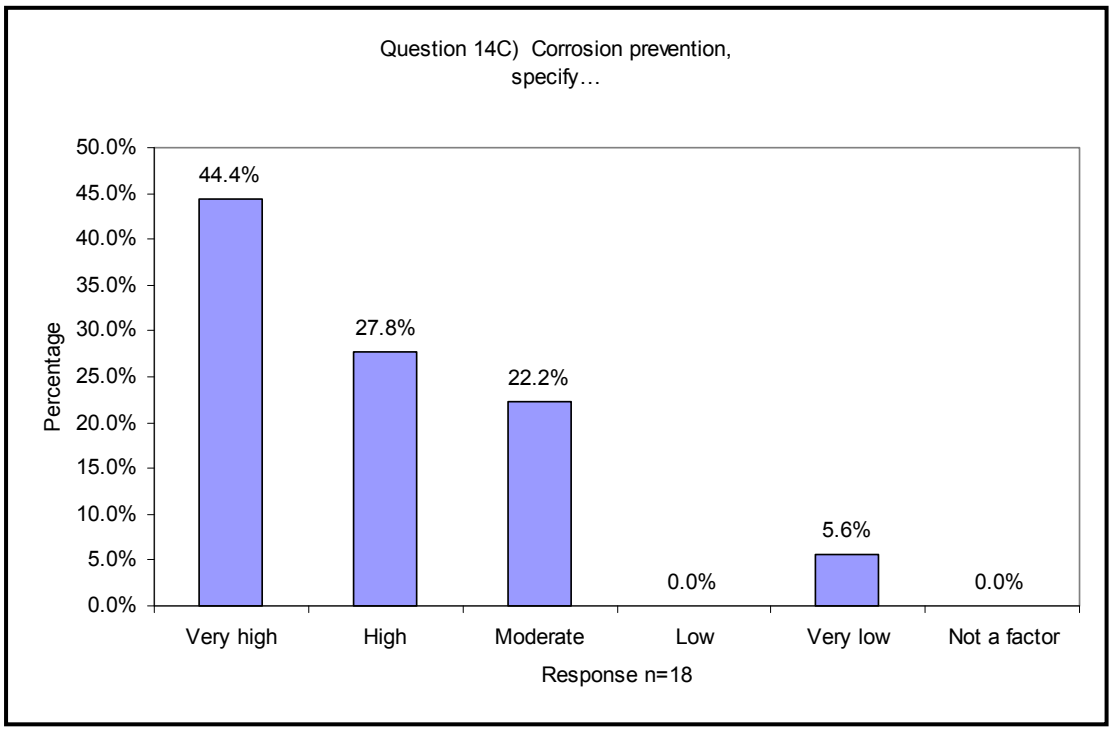
Graph 23 Summary of responses for Sub-question 14B

A relevant specified comment associated with its level of influence is given:

- Very low: "The insides of armour are generally stable and the raised corrosion may be scraped with a scalpel."

SUB-QUESTION 14C

Unanimously (100.0%) of respondents deemed corrosion prevention to play a factor in corrosion product removal, while the degree of influence is mostly very high (44.4%) or high (27.8%) (Graph 24).



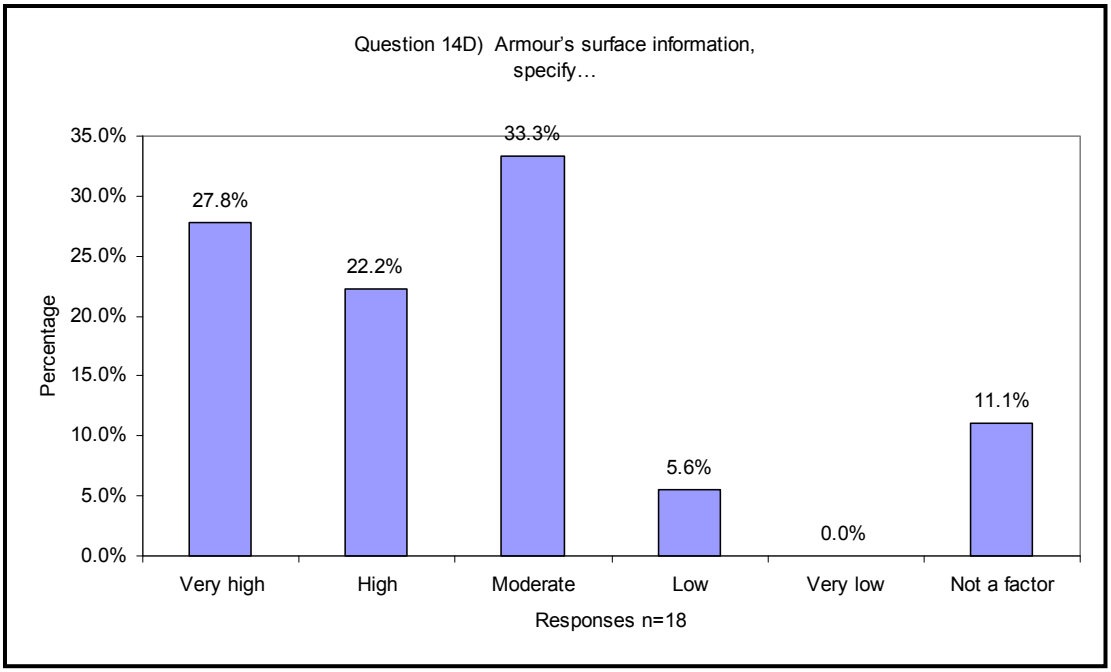
Graph 24 Summary of responses for Sub-question 14C

Relevant specified comments associated with their level of influence are listed:

- Very high: “Corrosion is hygroscopic”
- High: “That thick layers of corrosion harbour moisture and salts/contaminants and should be removed”

SUB-QUESTION 14D

Armour surface information is considered by the majority of respondents (88.9%) as a factor determining which corrosion products are removed. Most respondents (33.3%) consider it to be a factor of moderate regard, while others felt it to be of very high (27.8%) and high (22.2%) regard (Graph 25).



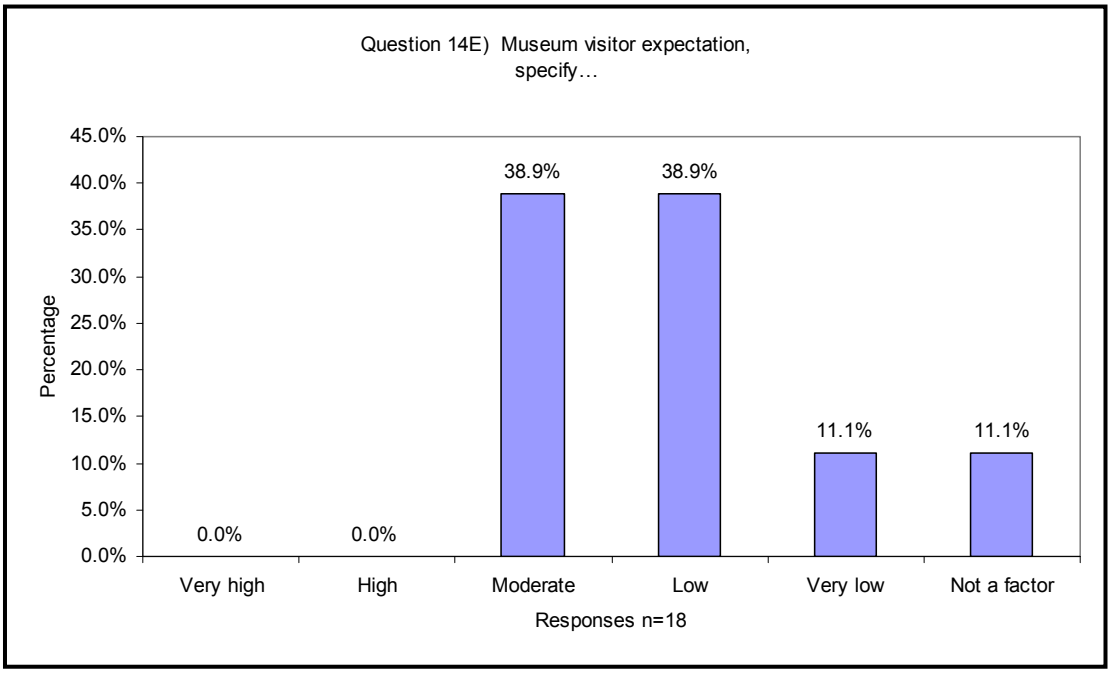
Graph 25 Summary of responses for Sub-question 14D

Relevant specified comments associated with their level of influence are listed:

- Very high: "Information about the production processes and the original tools used by the master, the artist's idea for surface design, the master's working out of this design, the master's level as artist. The artist's idea for the whole armour as a suit for a special person for a special kind of events. The individual history of this object and different ways of former conservations/restorations/repairs and also formal changes of detailed areas restorers worked on in different centuries".
- High: "That any old painted inventory numbers are left on, keep any blacking from manufacture on etc"
- Moderate: "To reveal forging tools".

SUB-QUESTION 14E

Museum visitor expectation is mostly (88.9%) considered a factor determining the level of corrosion product removal, while the distribution is moderate (38.9%) and low (38.9%) (Graph 26).



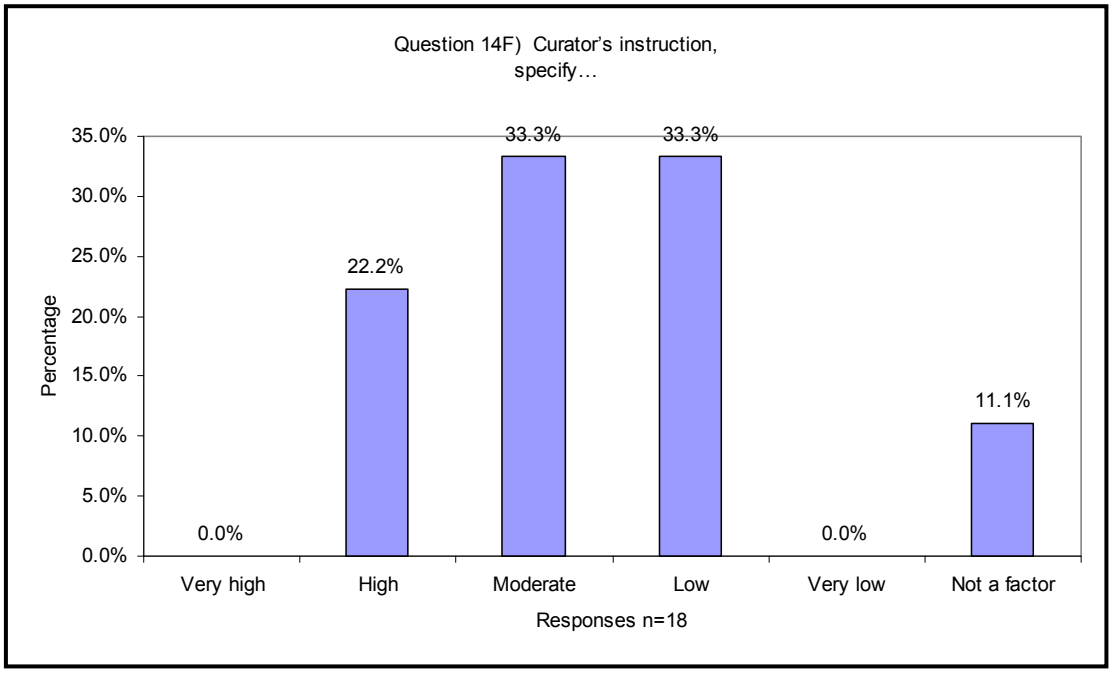
Graph 26 Summary of responses for Sub-question 14E

Relevant specified comments associated with their level of influence are listed:

- Moderate: “To museum curatorial specifications” & “The object should look well cared for”
- Very low: “Nearly no museum visitor is thinking about inner surfaces of armours. Of course, they want to trust on the museum's conservator's treatments”

SUB-QUESTION 14F

Curator's instruction is mostly (88.9%) considered a factor determining corrosion product removal, respondents considered it a factor of moderate (33.3%) and low (33.3%) influence, while others felt it was of high (22.2%) influence (Graph 27).



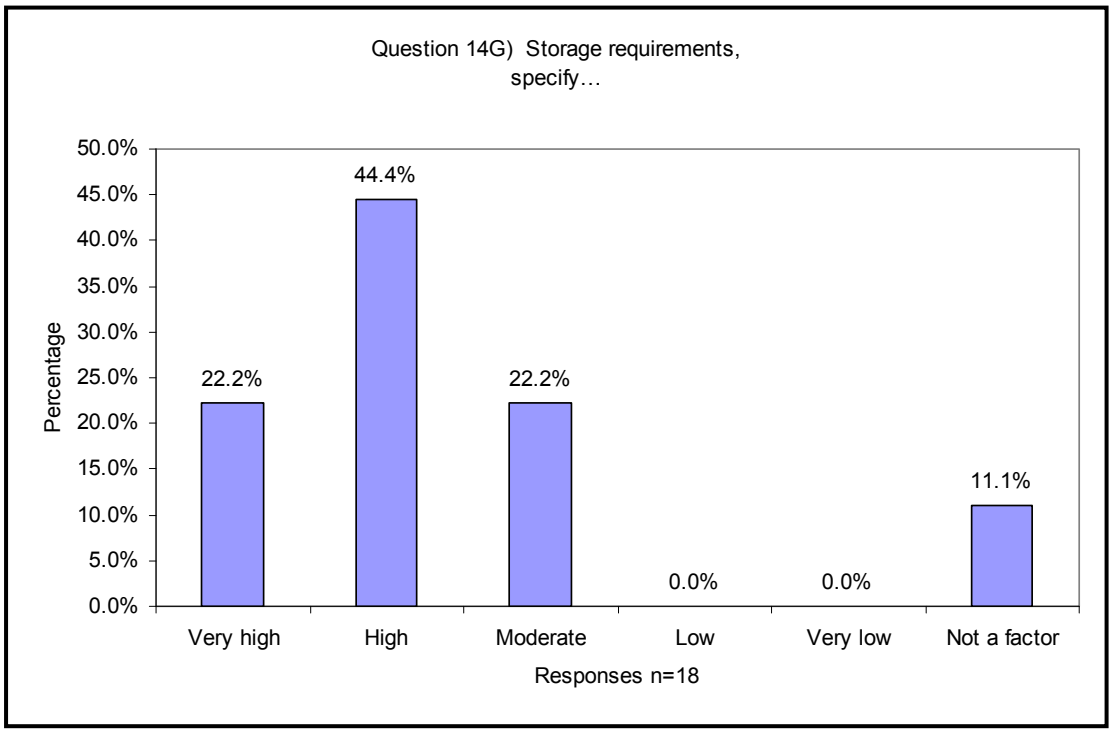
Graph 27 Summary of responses for Sub-question 14F

Relevant specified comments associated with their level of influence are listed:

- High: "Conservators are guided in all matters by curators" & "That old marks and labels are kept on the object".
- Moderate: "Conservators are guided in all matters by curators".
- Low: "Curators want to know the traces of tools and of using the object in original times. They are not really interested on traces of former restauration/conservation treatments. They wish best conservation treatment for the whole piece".

SUB-QUESTION 14G

The majority (88.9%) of respondents indicated that storage requirements are a factor determining which corrosion products are removed (Graph 28). This factor is mostly considered of a high (44.4%), very high (22.2%) and moderate (22.2%) degree of influence.



Graph 28 Summary of responses for Sub-question 14G

A relevant specified comment associated with its level of influence is given:

- High: "In principle all works-of-art storage areas are 'open access', so in theory objects in store should be as visible and are as important to the museum visitor and the concerns of both curators and conservators as those items on display in the public galleries".

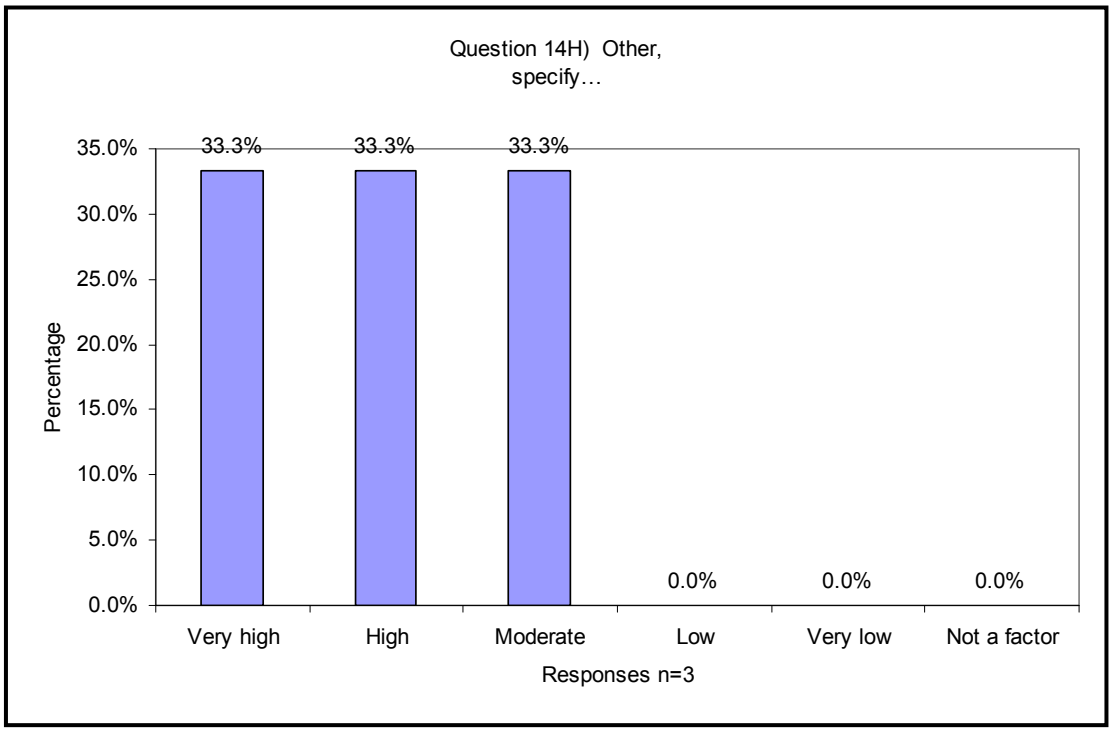
The respondent of the specified response above has realised that the inference of the question is that artefacts in storage might be approached differently to those on exhibition.

Again, judging by the majority of specified responses, it appears that by the end of this extended question (14) the original meaning had been confused. Several specified comments irrelevant to *corrosion product removal* are listed:

- High: "The object is clean"
- Moderate: "Long term conservation reasons"
- Very low: "Climate control, lightening control, conservation materials control, display materials control"

QUESTION 14H

Three respondents specified other reasons where corrosion products might be removed from the inner surfaces (Graph 29).



Graph 29 Summary of responses for Sub-question 14H

Relevant specified comments associated with their level of influence are listed:

- Very high: "Type of exposition support"
- High: "If an action might risk threatening the safety or integrity of any surviving original strapping, textile linings etc."
- Moderate: "If it interferes with a lining"

Two of the above cited factors are similarly expressed and are particularly relevant to the armour inner surfaces where lining can be present.

QUESTION 15

The question,

> "Which equipment/materials and application methods do you use to remove corrosion products (from outer or inner armour surfaces)?"

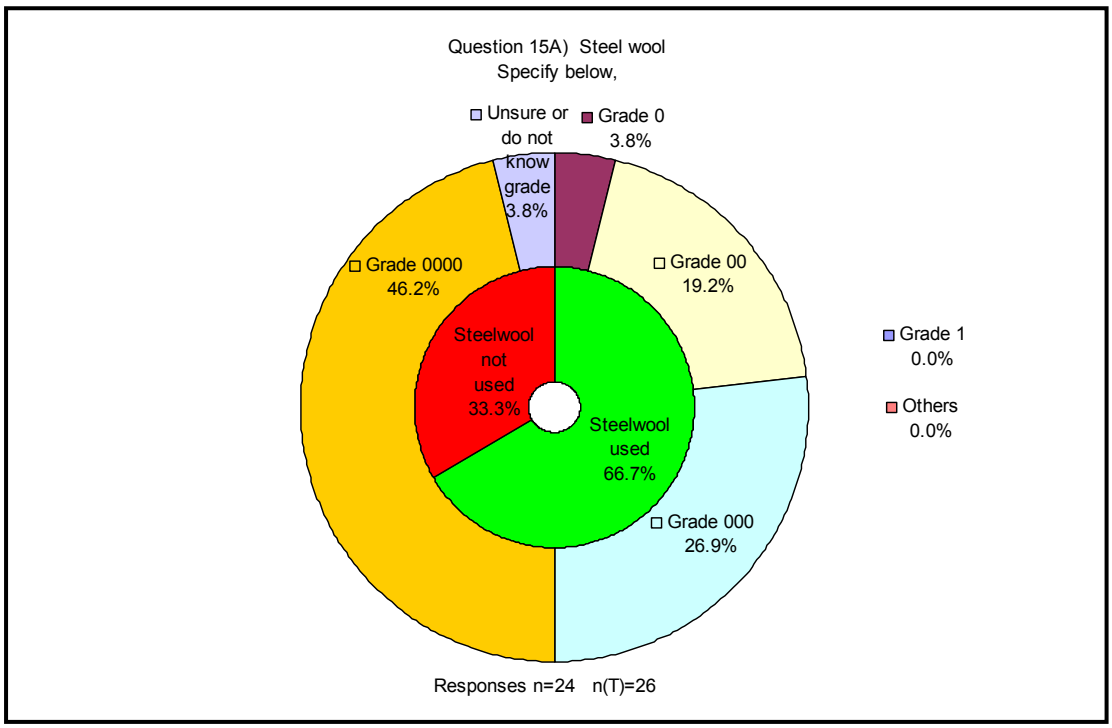
…is concerned with documenting and quantifying the numerous practical *techniques* (i.e. tools/equipment and materials + application method) used to achieve ferrous corrosion product removal from ferrous armour.

The tools/equipment and materials are first categorised per question sub-section (15A, 15B etc) and then the summary of the application technique (e.g. hand/machine, speed, time, immersion etc) and complementary materials and procedures (e.g. lubricating liquids, rinsing methods) used for the equipment/material procedure are specified as semi-structured free-form text. No attempt by the questionnaire was made to gauge the preference for or frequency that such techniques are being used since it was deemed a too complex question to add this factor onto the already detailed series of questions. Nonetheless, on occasions respondents have opted to specify incidence via the free-form text, especially for exceptional cases where frequency of use is low.

Notably, the representation of the two sets of quantified data for these questions is achieved on one graph. The central chart represents the total population of respondents, n, surveyed for this question, while the peripheral chart represents the total population of types, n(T), of equipment/materials used (including replicate responses).

SUB-QUESTION 15A

Steel wool is used by 66.7% of respondents, n=24, and the prevalence of the grades (or types) of steel wool in use, n(T)=26, increases with its fineness (0-0000), while grade 1 is not used (Graph 30).

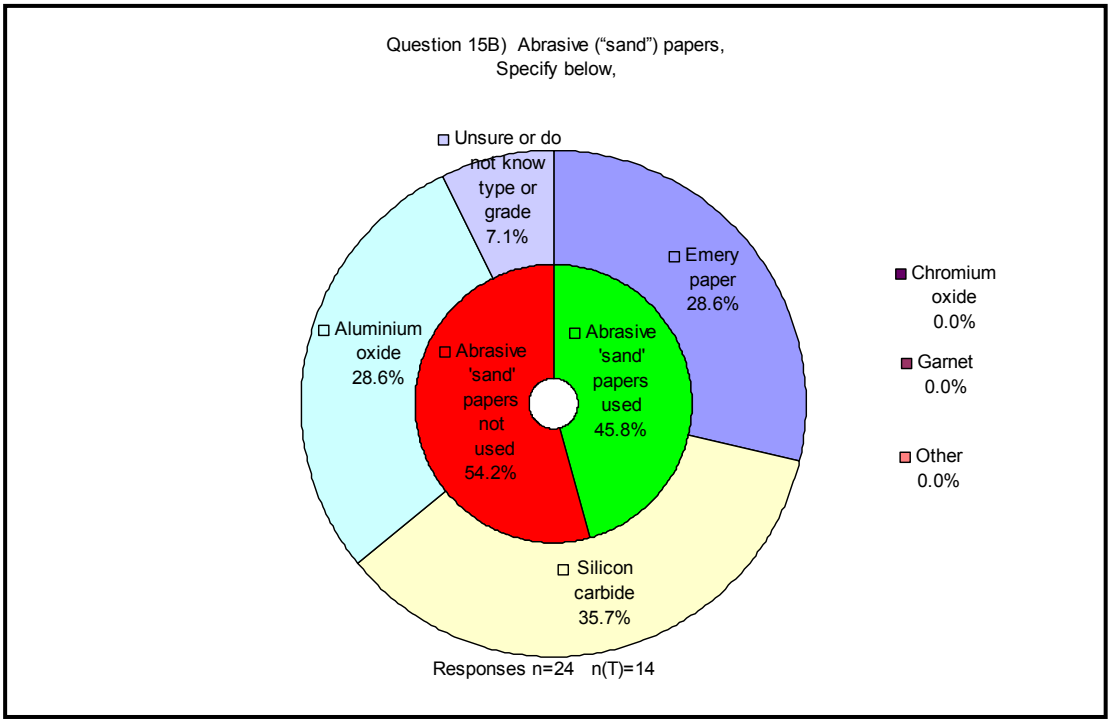


Graph 30 Summary of responses for Sub-question 15A

Steel wool has been specified as being used dry on its own or with liquid materials such as solvents (industrial methylated spirits, mineral spirits, white spirits, acetone), oils (Ballistol®, WD40®, Vaseline®, 3-in-1®), abrasive pastes (Solvol Autosol®, PreLim®) or wax (microcrystalline). All noted applications methods were as a small ball by hand or assisted with a bamboo skewer and were either in a back-and-forward or circular motion. Oil residue has been noted as being removed with acetone on cotton.

SUB-QUESTION 15B

Just less than half (45.8%) of respondents use abrasive so-called "sand"-papers, while the greatest proportion (35.7%) of users choose silicon carbide papers (Graph 31).

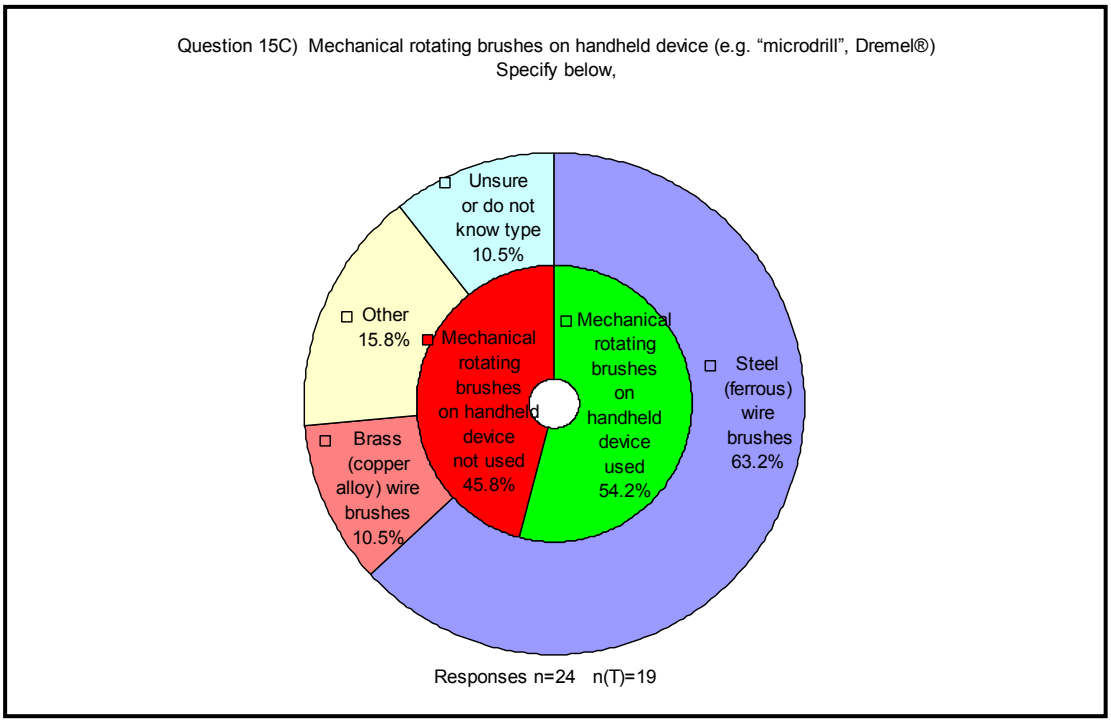


Graph 31 Summary of responses for Sub-question 15B

"Sand"-papers were recorded as being applied by hand or using "a few square millimetres of abrasive agitated with the point of a soft wood stick" or with "small wooden applicators usually in a back and forward motion". Complementary materials included mineral spirits, microcrystalline wax, sewing machine oil, water and Vaseline® oil. The quoted grades included 240, 400+, 800, 1500, 1800, 2400, 3200 and "very fine grades", while one respondent specified that the grade was "depending on the level of corrosion and purpose of the conservation".

SUB-QUESTION 15C

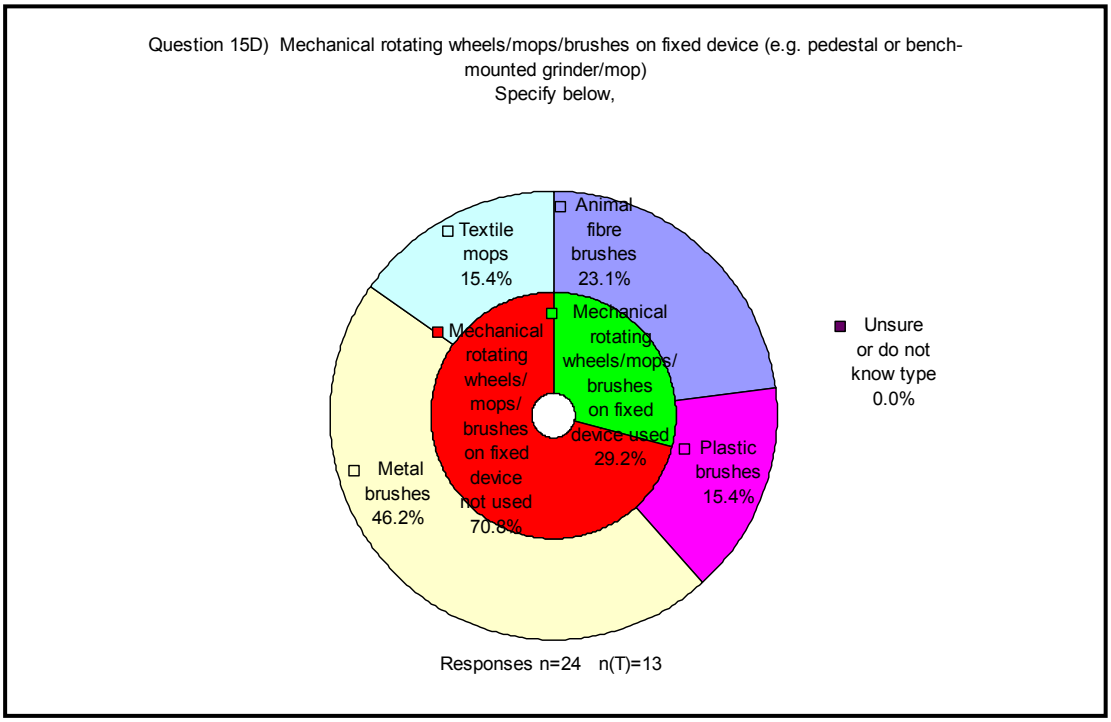
Just over half (54.2%) of respondents use mechanical rotating brushes on handheld devices (Graph 32). The majority (63.2%) of the brushes used are steel (ferrous) wire brushes of varying diameters (1.5, 2.0, 2.5, 5.0cm) and application speeds (variable, low, 500-3300, 2000, 6000-10000rpm). Brass (copper alloy) brushes (10.5%) of 20 and 25mm diameters were recorded being used at "variable" speeds. Two centimetre diameter fibre brushes at medium speed and 0.5cm diameter silicon and rubber rotating abrasives 6000-8000rpm were also noted (15.8%).



Graph 32 Summary of responses for Sub-question 15C

SUB-QUESTION 15D

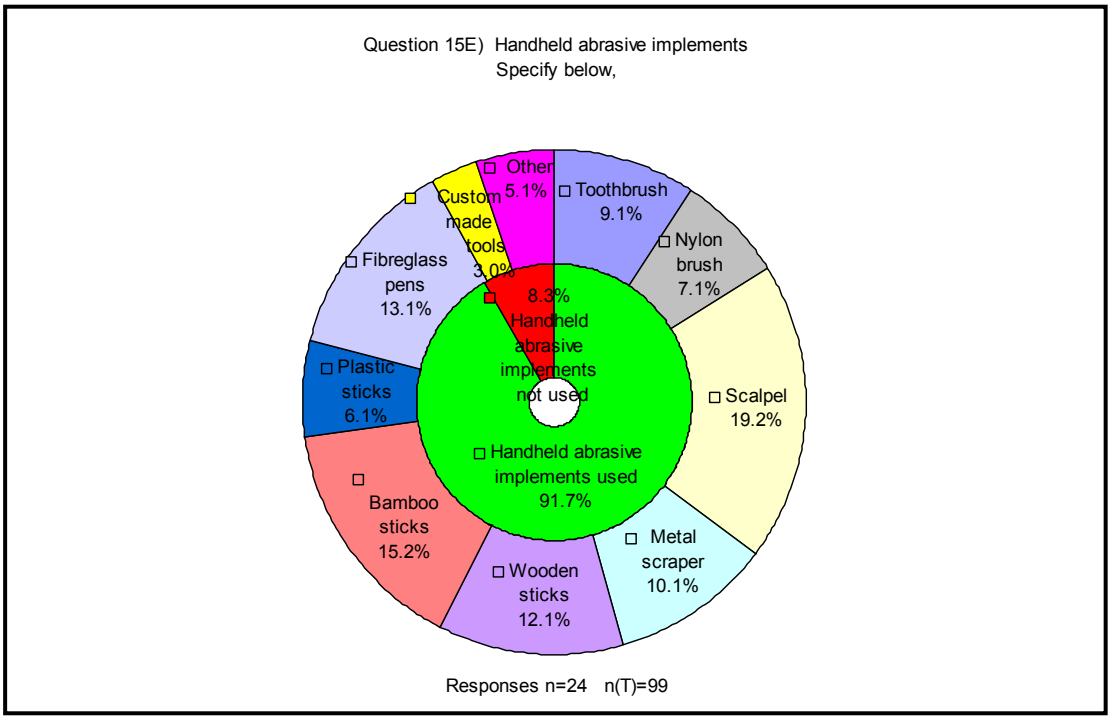
The majority (70.8%) of respondents do not use mechanical rotating wheels/mops/brushes on a fixed pedestal device (Graph 33). Of the 29.2% who do, metal brushes were mostly (46.2%) chosen. Animal fibre brushes (23.1%) and plastic brushes (15.4%) rated less frequently. From the two respondents who use textile mops (15.4%) only one specified the use of a polishing compound such as “rouge”, while the other did not specify either way.



Graph 33 Summary of responses for Sub-question 15D

SUB-QUESTION 15E

The high majority (91.7%) of respondents use handheld abrasive implements to remove corrosion products (Graph 34). Frequency of each of the many tools is quite similar and is best represented by the graphical interpretation. The scalpel rated highest (19.2%). The "custom-made" and "other" tools included implements of carbon fibre, mother of pearl, Perspex®/Plexiglass® acrylic, and specified metal implements such as bistouries, dental picks and handmade brass-copper alloy probes, scrapers and chisels.



Graph 34 Summary of responses for Sub-question 15E

One respondent emphasised how the amount of corrosion products and the variety of tools available simply determines "…the tool that will do the job". Specified complementary materials and approaches for the handheld tools are listed:

- Toothbrushes: metal abrasives/polishes, oil, solvents (acetone, white spirit, industrial methylated spirits)
- Nylon brushes: metal abrasives/polishes, oil, solvents (acetone, white spirit)
- Scalpel: "Rarely and for thick deposits", "sometimes in 3-in-1 Oil® or WD-40®", "sometimes with microscope", "different sizes and shapes, sometimes hand-polished profiles", "most important method, combined with other methods", "hand under microscope"
- Metal scraper: "most important method", "brass and steel scraper", "sometimes in 3-in-1 Oil® or WD-40®"
- Wooden sticks: "alone or with cotton wool tips", "steel wool, oil", "cotton swab and acetone", "wire wool sometimes"
- Plastic sticks: "alone or with cotton wool tips"

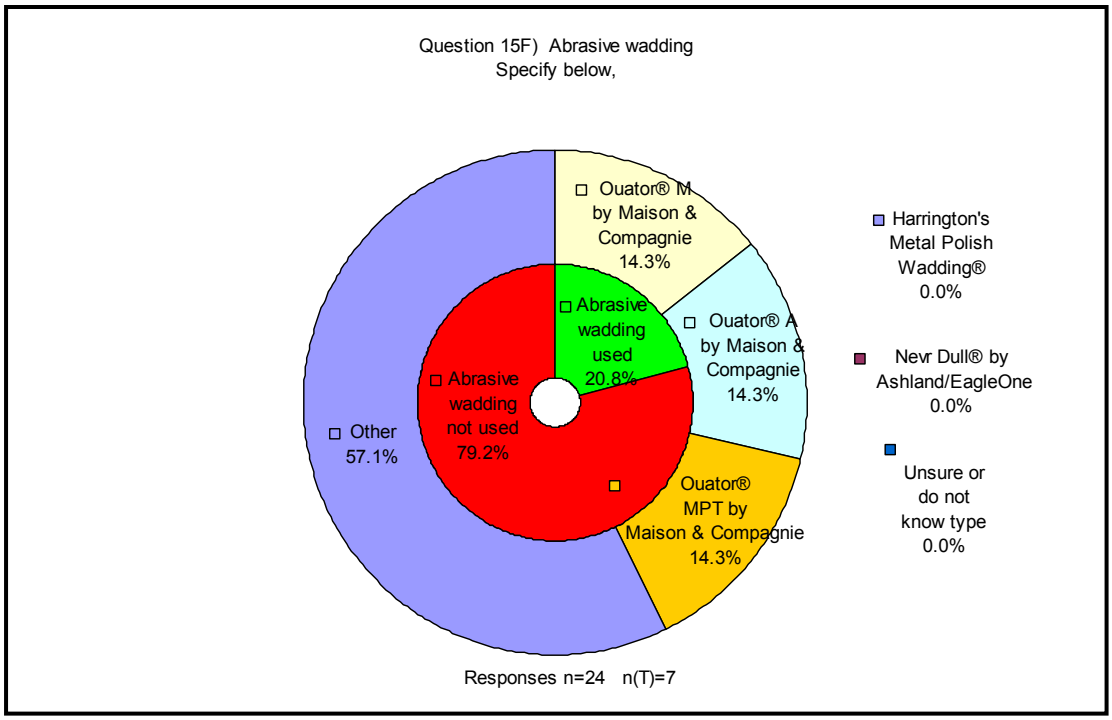
- Fibreglass pens: “alone”, “and fibreglass sticks for cleaning and delicate abrasive work”
- General remark: “Applied alone or in combination with chemical cleaning”

The level of observation that these procedures (and others outlined in other questions) are undertaken was not asked. Procedures could practically be achieved on a macroscopic (i.e. naked-eye) level or magnified by a desk mounted magnifying lamp or microscope. Only in questions 15E, did two respondents specify that a microscope is used (in the case of using scalpels). It is presumed that the other hand-tools and other procedures outlined in Question 15 are performed on a macroscopic scale, although explicit confirmation of this supposition is required. In Question 21, where respondents had the option to further specify any comments, one respondent stated, “Corrosion removal is carried-out very carefully and final corrosion removal is sometimes done under the microscope to ensure that the area is not over cleaned/polished.”

SUB-QUESTION 15F

Abrasive wadding, always as a type of proprietary product, is used by the minority of respondents (20.8%) (Graph 35). Of those that use wadding, a variety of products were nominated once each, with only Duraglit featuring twice:

- Duraglit (14.3%)
- Ouator® M by Maison & Compagnie (14.3%)
- Ouator® A by Maison & Compagnie (14.3%)
- Ouator® MPT by Maison & Compagnie (14.3%)
- Silvo or Duraglit polishing wadding (14.3%)
- Brasso wadding (14.3%)
- Metarex (Estalin AG Basel) (14.3%)

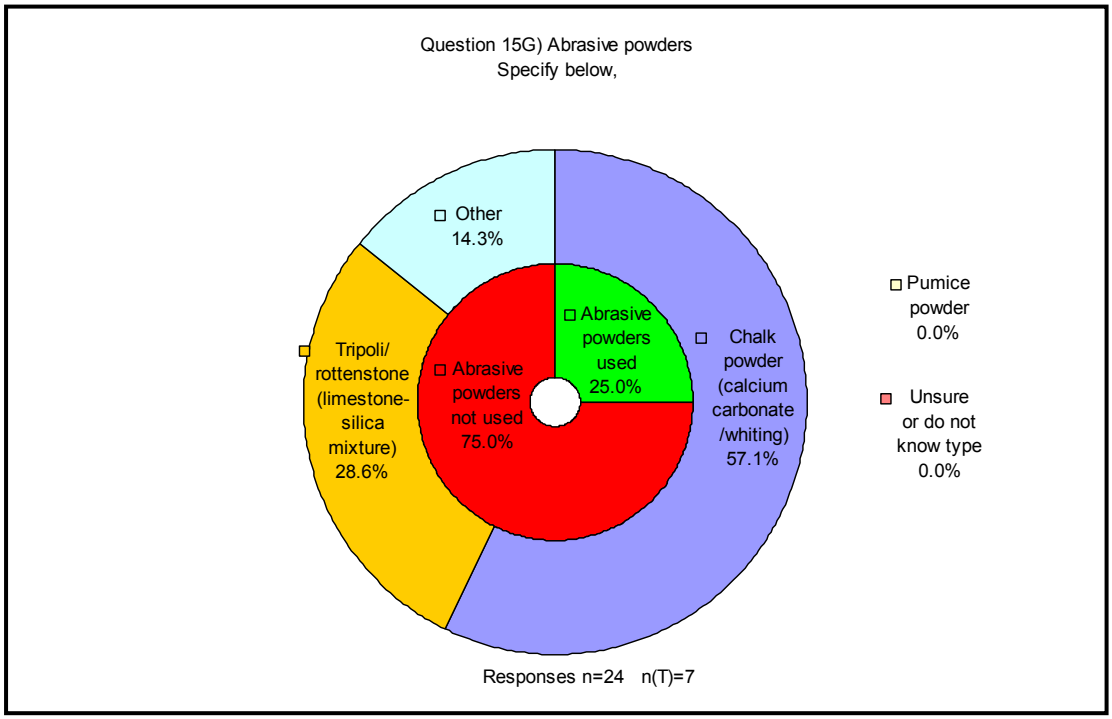


Graph 35 Summary of responses for Sub-question 15F

One respondent specified the procedure of its use, "applied as a ball, sometimes with a bit white spirit. Cleaning with e.g. acetone is necessary".

SUB-QUESTION 15G

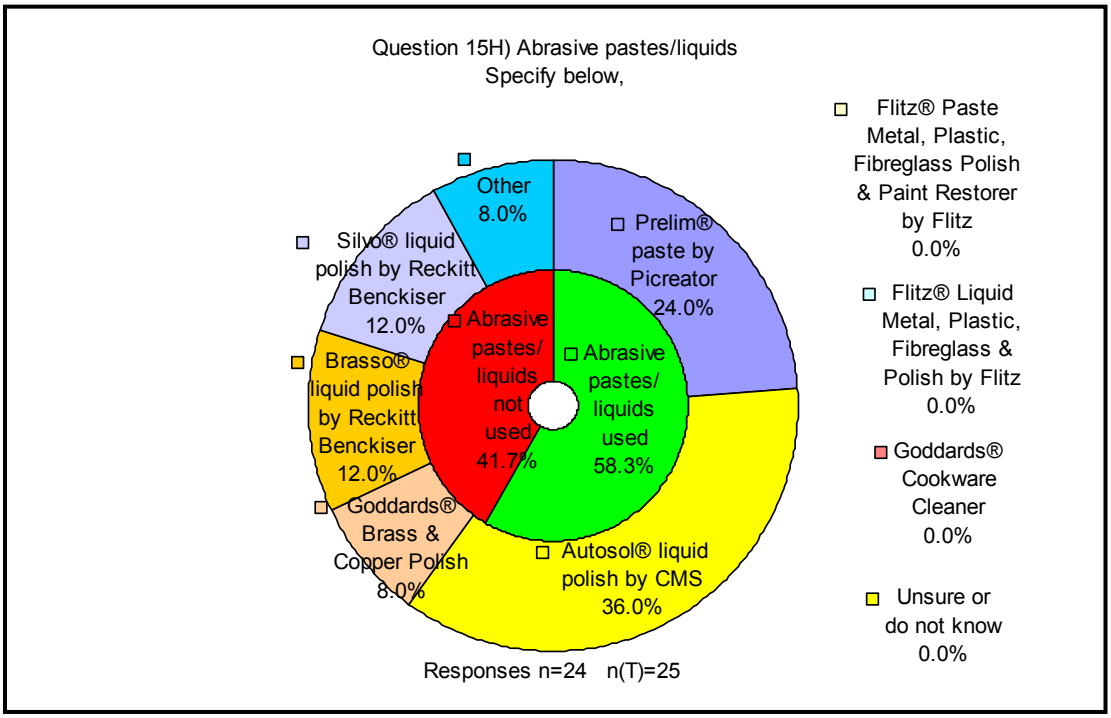
The majority (75.0%) of respondents do not use abrasive powders, while the remaining (25.0%) respondents most popularly cited chalk powder (57.1%) as being in use, followed by Tripoli powder (28.6%) (Graph 36). The only specified chalk grade was "precipitated", while chalk was applied in solvents ("ethylic alcohol (ethanol?)", "ethanol", "appropriate solvent") and applied with a "felt or cotton cloth or cotton wool tipped swab" or "a brush is sometimes used". The other cited abrasive was alumina (14.3%). The alumina grade was specified as "various grades 10-.01 microns" and applied with a "felt or cotton cloth or cotton wool tipped swab and an appropriate solvent".



Graph 36 Summary of responses for Sub-question 15G

SUB-QUESTION 15H

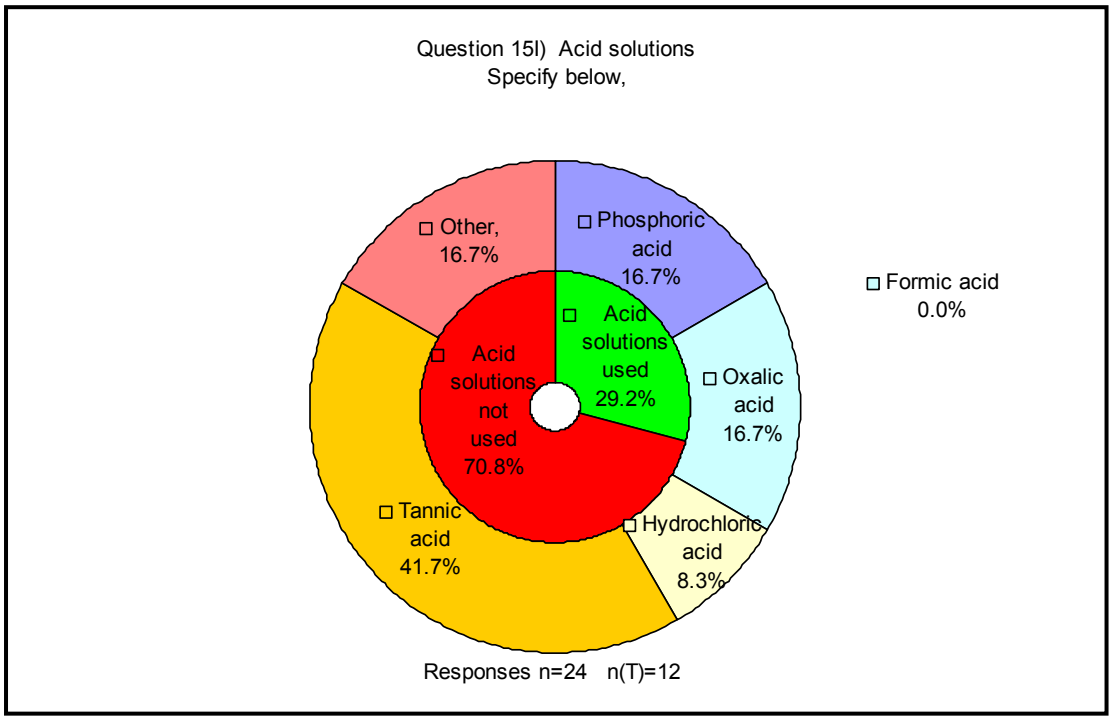
The slight majority (58.3%) of respondents use abrasive liquids and pastes, while the most selected was Autosol® (36.0%), followed by Prelim® (24.0%). Goddard Glow® and Dursol® were the polishes recorded in use as "Other" (8.0%) (Graph 37). The abrasive pastes/liquids are described as being applied locally by hand with cotton cloth, with jewellery textile, with cotton tipped swabs, with small balls/wads of cotton or with steel wool ("0000" or "fine"). One respondent indicated that polish is "often diluted in white spirit".



Graph 37 Summary of responses for Sub-question 15H

SUB-QUESTION 15I

The majority (70.8%) of respondents indicated that they do not use acid solutions to remove corrosion products from armour (Graph 38). Tannic acid was the most often cited as being in use (41.7%), followed equally by phosphoric (16.7%) and oxalic acid (16.7%). While tannic acid is commonly viewed as a corrosion inhibitor and/or product converter[11], not a corrosion product remover, it was included in the context of this question since the intended use and specific perceived action is dependent on the perspective of the user, not necessarily the actual effect.



Graph 38 Summary of responses for Sub-question 15I

Specified solution concentrations/application methods are listed by acid:

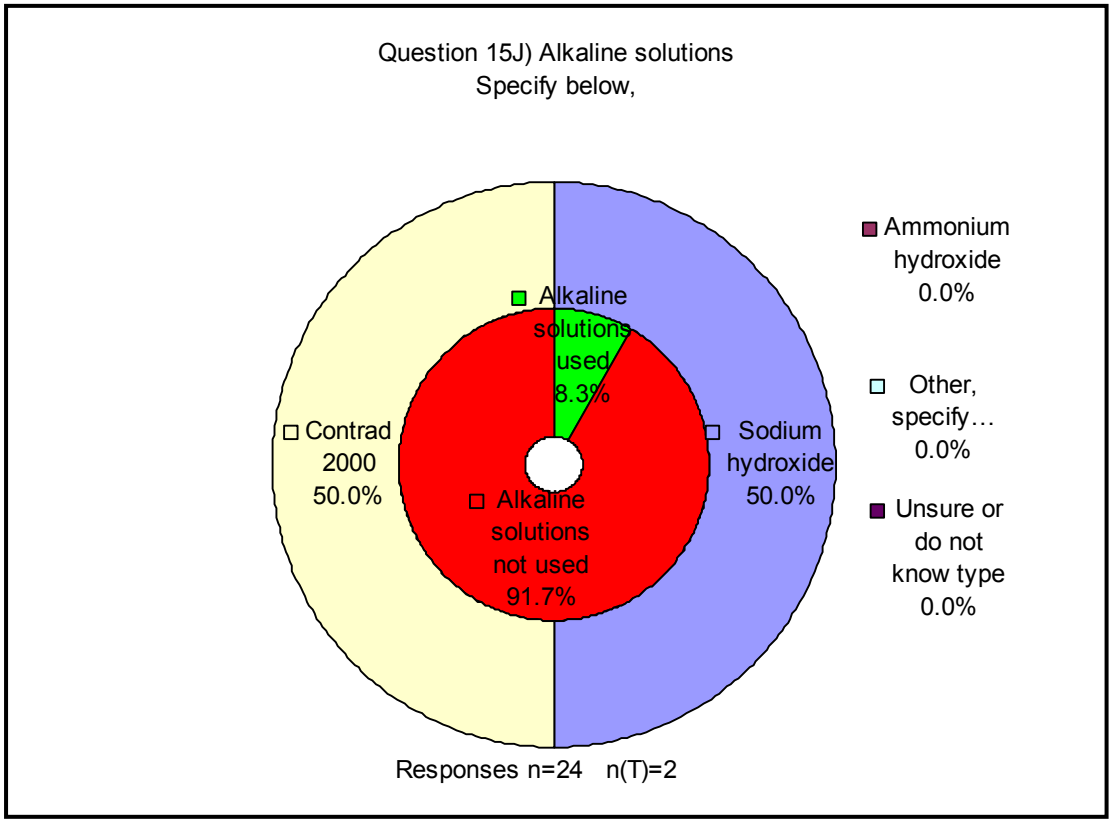
- Phosphoric acid: "concentration 0.5-15% cotton tipped swabs or cloth", "2.5 or 5-10% applied with cotton swab on a cocktail stick"
- Oxalic acid: "concentration 10% applied by localised application, to corrosion patches on mail (but only very VERY rarely… mechanical methods are usually preferred)", "concentration 5-10% applied with cotton swab on a cocktail stick"
- Hydrochloric acid: "concentration 5-10% applied with cotton swab on a cocktail stick"
- Tannic acid: "concentration 1-8% applied by/with paint-brush", "(unspecified) concentration applied with cotton swab or brush"
- Citric acid: "concentration 10% applied by cotton or paint brush"
- Nitric acid: "concentration 5% applied by cotton swab"

From the application techniques specified all were local, rather than by immersion. No respondents specified if the acids were uniquely in aqueous solutions or if other solvents (e.g. ethanol were added).

[11] Morcillo et al., 1992, pp. 1032-1033

SUB-QUESTION 15J

All but two respondents (8.3%) indicated that they do not use alkaline solutions to remove corrosion products from undecorated ferrous armour (Graph 39). One respondent uses sodium hydroxide of "(unspecified) concentration applied by cotton swab on a cocktail stick". And one respondent noted the use of a proprietary anionic alkaline surfactant, "CONTRAD 2000 concentration 8% applied by/with paintbrush or supported with solvent gel".



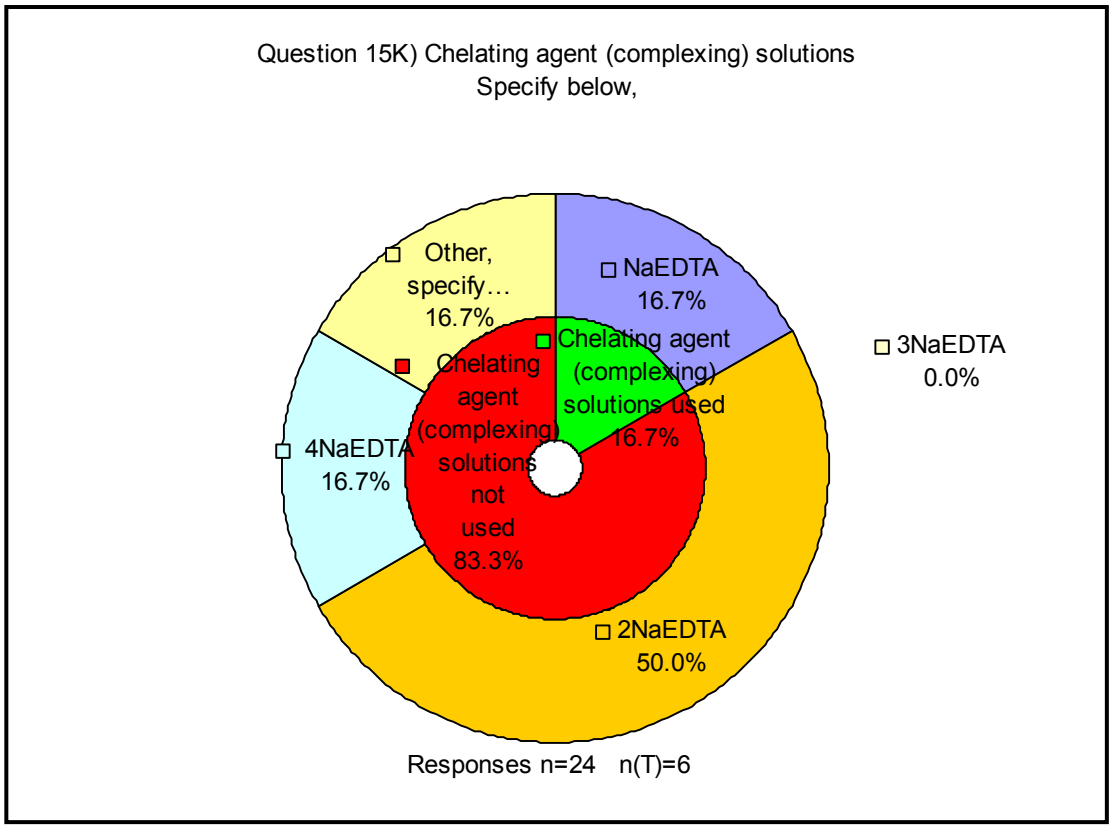
Graph 39 Summary of responses for Sub-question 15J

SUB-QUESTION 15K

The minority (16.7%) of respondents use chelating (complexing) solutions, while the most selected was 2NaEDTA (disodium ethylene diamine tetra-acetic acid) (57.1%) (Graph 40).

Specified concentrations and application techniques are listed by material:

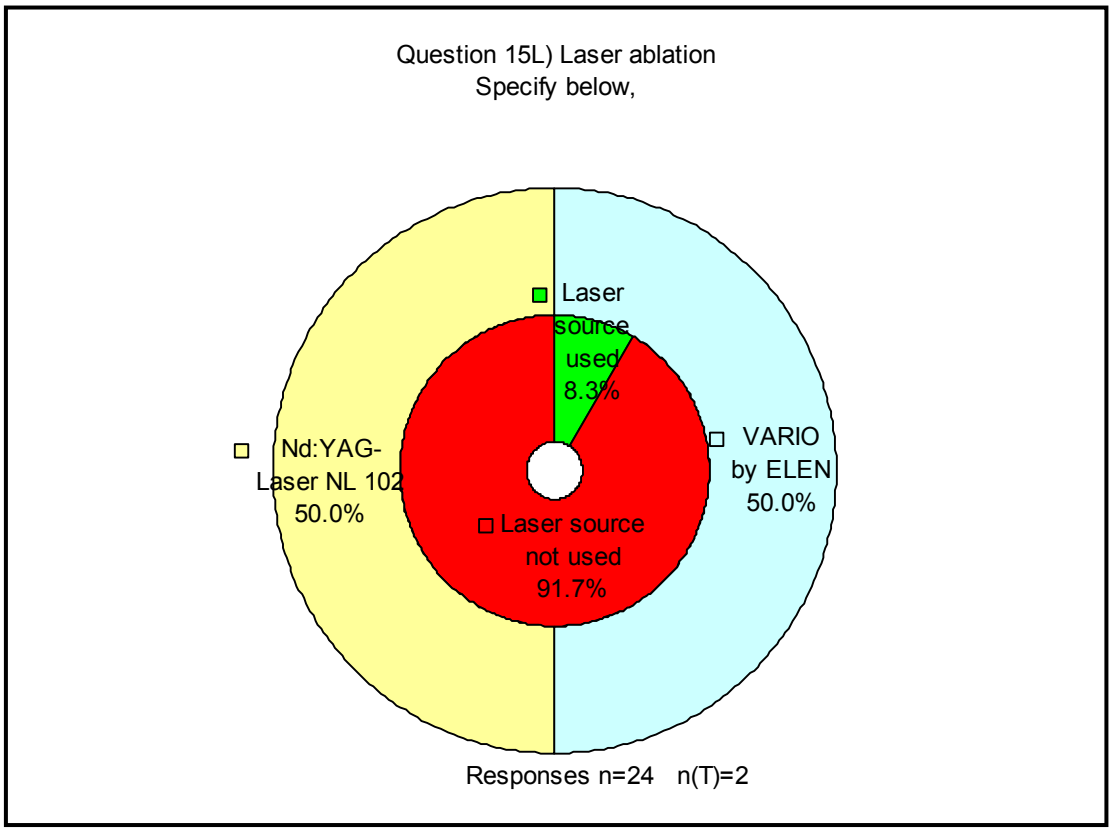
- NaEDTA (sodium ethylene diamine tetra-acetic acid): “applied by cotton swab on a cocktail stick”
- 2NaEDTA (disodium ethylene diamine tetra-acetic acid): “concentration 0.5-15% applied by with poultice, gel, liquid and possibly other modifiers”, “applied with supportants”, “applied by cotton swab on a cocktail stick”
- 4NaEDTA (tetrasodium ethylene diamine tetra-acetic acid): “concentration 0.5-15% applied by with poultice, gel, liquid and possibly other modifiers”
- Other: “exchange ionic resins applied with supportants or Japan paper”



Graph 40 Summary of responses for Sub-question 15K

SUB-QUESTION 15L

A minority (8.3%) representing two respondents use laser ablation to remove corrosion products (Graph 41). Of these, one stated that, "This method we had to work with only one object of our collection, it was a special case!!" The source was a "Nd:YAG-Laser NL 102, B.M. Industries Wavelength 1064nm Fluence 0.6 J/cm^2". The second respondent using laser employs the model, "VARIO by ELEN" at "variable" wavelengths and fluence range.



Graph 41 Summary of responses for Sub-question 15L

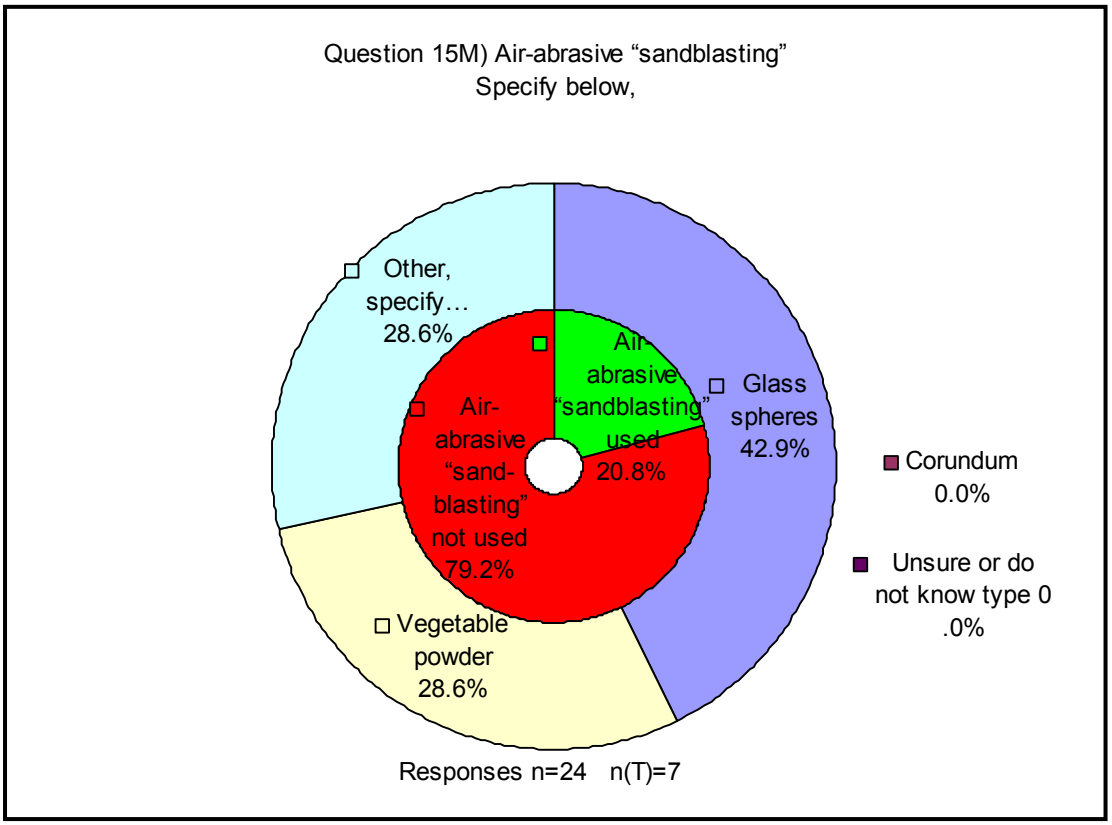
One organisation represented by two respondents in the questionnaire indicated that laser was previously tested, but not currently in use since they stated that "…laser left porous and matt surfaces which didn't prove satisfactory".

Two notable researchers working on laser for conservation applications were contacted for their questionnaire feedback on ferrous metal armour – neither replied.

SUB-QUESTION 15M

A minority (20.8%) of respondents use air-abrasive "sandblasting". Of those that do use air-abrasives, the majority (42.9%) use glass-spheres (Graph 42). Vegetable powders (28.6%) of varying types were also cited, while the remainder (28.6%) consisted of sodium bicarbonate, alumina and a proprietary abrasive called EXADO. Specified specifications and conditions of use included:

- Glass-spheres: "unknown size and 2 bar pressure", "forgotten size, but only used extremely infrequently"
- Vegetable powders: "nutshell unknown size 2 bar pressure", "coconuts, maize, nut/walnut, size: variable pressure: 2-4 Bar",
- Other: "sodium bicarbonate and alumina (alumina grade 10-30 micron)
- "Pressure? Visual adjustment", "EXADO, Size: 65-150 micron, Pressure : 2 -4 Bar"



Graph 42 Summary of responses for Sub-question 15M

SUB-QUESTION 15N

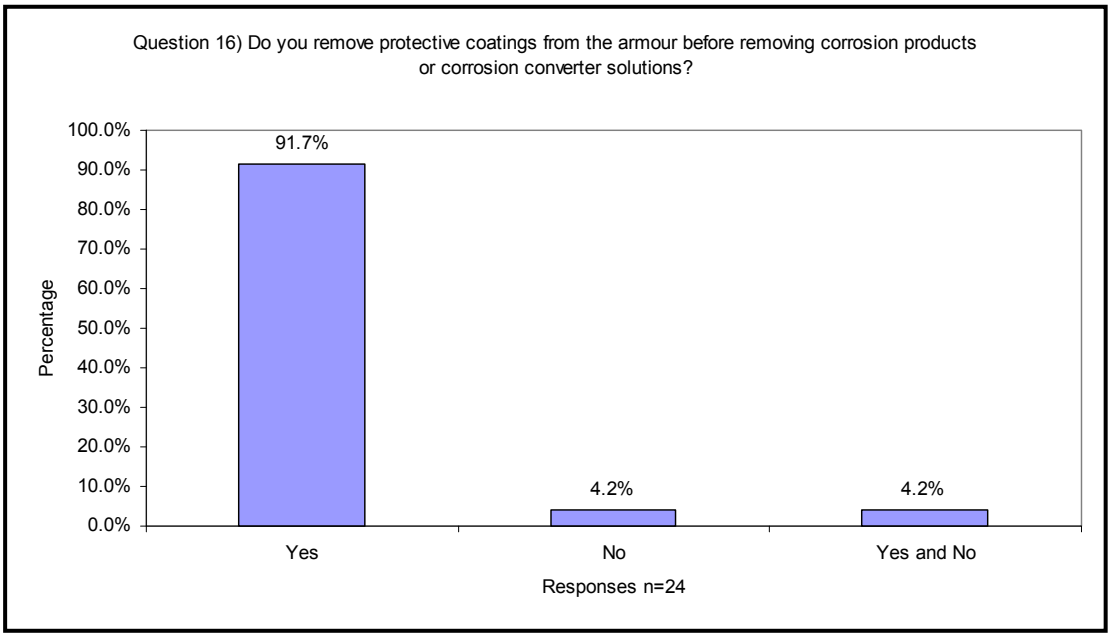
Five respondents described in brief any corrosion product removal technique (i.e. materials/equipment & application method) not described in Question 15:

- Handheld polymers with or without abrasive particles: “Seldom we use blocks made of rubber mixed with corundum, but not often (they are very abrasive and reduce original surface marks)”, “Garryflex abrasive block applied by hand” “Abrasive rubbers”, “3M Scotch Brite green and white polish pads with LPS 1”
- Local electrolysis: “object made cathode by contact with stainless steel plate and local reduction using a carbon anode either inside of an electrolyte saturated cone of sponge or pressing through a wad of saturated cotton”

It is unclear whether the local electrolysis method stated above applied potentials below or above hydrogen evolution for an increased cleaning action/corrosion product removal via gas evolution at the armour metal/corrosion product interface.

QUESTION 16

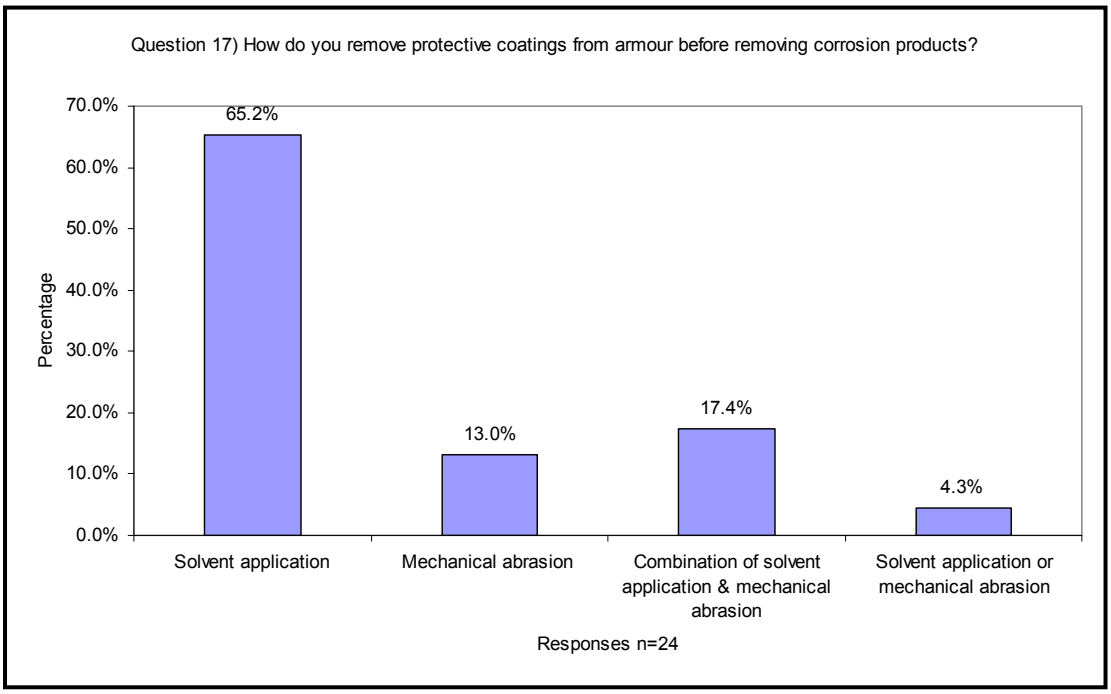
The majority (91.7%) of respondents remove protective coatings before removing corrosion products or (applying) corrosion converter solutions (Graph 43). One respondent (4.2%) specified conducting both practices depending on the object. This contribution was included in the statistics since it was not specified to answer only one response.



Graph 43 Summary of responses for Question 16

QUESTION 17

The majority (65.2%) of respondents reported using solvents to remove protective coatings before removing corrosion products (Graph 44). Some respondents specified that they use mechanical abrasion (13.0%). New categories were deduced from the option "Other, specify…" and comprise: using a combination of solvent and mechanical abrasion (17.4%) and one respondent (4.3%) specified that it depends and that they might use solvent or mechanical abrasion.

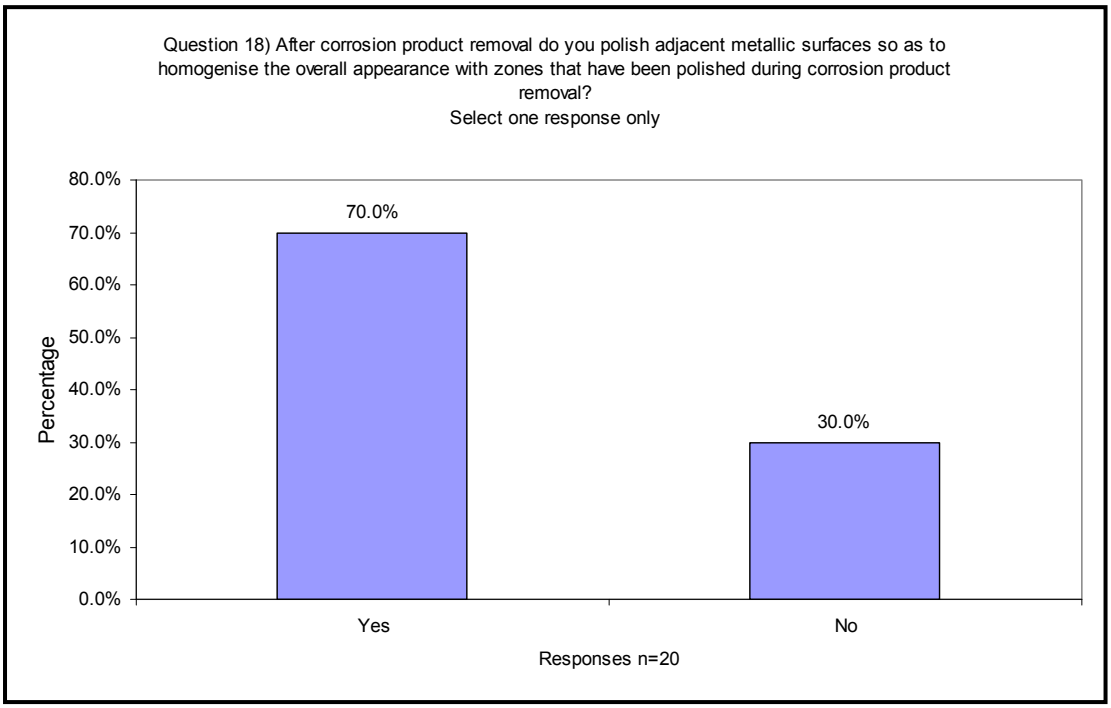


Graph 44 Summary of responses for Question 17

QUESTION 18

This question was included since the effect of corrosion product removal procedures on areas adjacent to uncorroded metal is often not localised enough and causes polishing of the metal. As a result differences in surface lustre can be homogenised by an additional polishing procedure.

The majority (70.0%) of respondents stated that they polish adjacent metallic surfaces after corrosion product removal (Graph 45). One respondent specified in Question 21 (where respondents had the option to further specify any comments) that, "We never have to polish the rest of the object to match the cleaned area where there once was corrosion." Two respondents preferred to indicate both responses "Yes" and "No". One of these respondents specified further, "The answer to question 18 is very definitely YES and NO, but mostly NO." These contributions are not recorded in the statistics since the question structure was not followed. Nonetheless they provide valuable insight into the fact that approaches vary and that the available question responses did not accommodate this consideration. Given the option, it is possible other respondents would have responded similarly. Nonetheless, the important aspect shown by the data is that most respondents perform polishing to homogenise the overall appearance of armour after corrosion product removal.

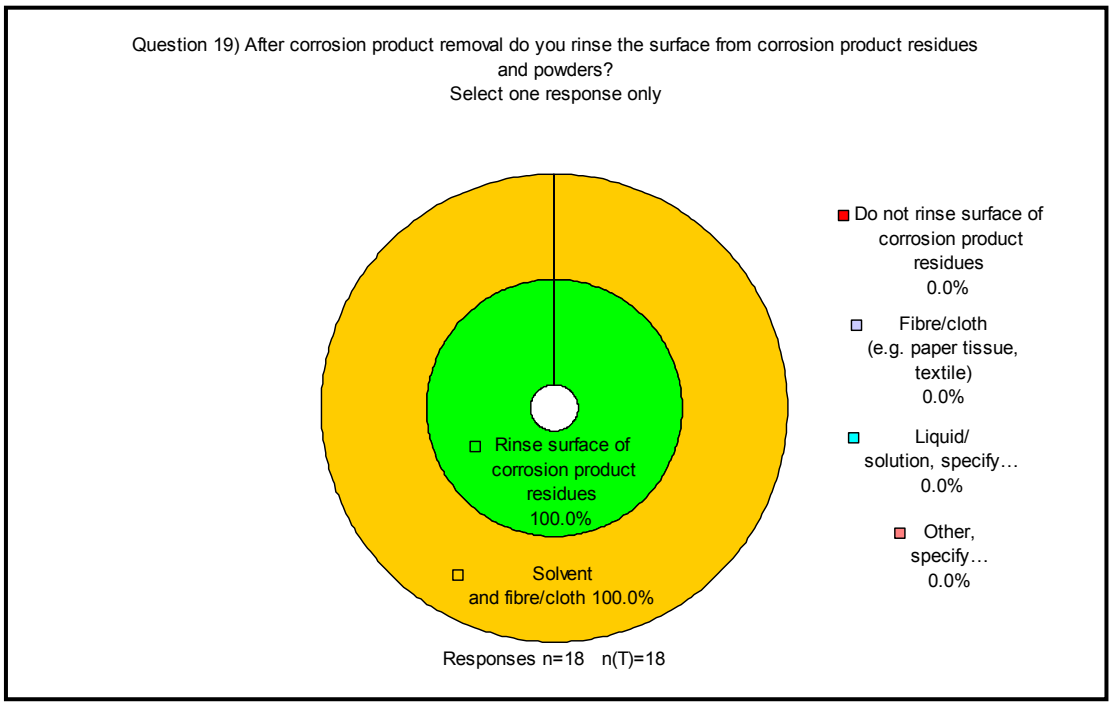


Graph 45 Summary of responses for Question 18

QUESTION 19

This question was included since the cleaning away of corrosion product remnants, as a final procedure for corrosion product removal is an important step for minimising recorrosion facilitated by surface particles or improper surface preparation for coatings.

All respondents (100.0%) remove corrosion product residues from surfaces after corrosion product removal procedures, while their techniques are all (100.0%) by solvent and fibre/cloth (Graph 46). Four respondents preferred to indicate both responses "Fibre/cloth" and "Solvent and fibre/cloth", while one of these indicated the use of "Liquid/solution". Two other respondents indicated the use of "Solvent and fibre cloth" and "if necessary: with pure water, depending of solvent agent used before" or "air pressure". Again, these contributions are not recorded in the statistics since the question instruction of selecting one response only was not followed. Nonetheless, they reinforce the fact that approaches vary and that the available question responses did not accommodate this consideration. Given the option, it is possible other respondents would have responded similarly. The main point demonstrated is that efforts are always made to remove remnant corrosion product powders.

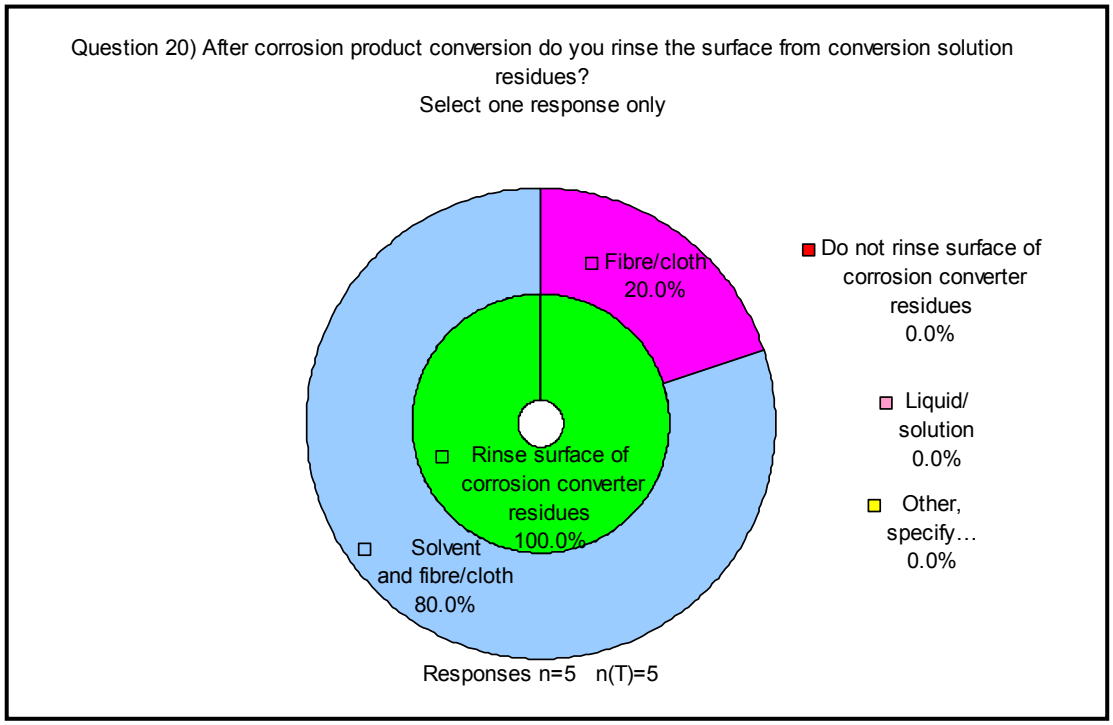


Graph 46 Summary of responses for Question 19

QUESTION 20

The cleaning away of corrosion product conversion residues, as a procedure for corrosion product interventions, is an important step for minimising recorrosion facilitated by remnant acid or improper surface preparation for coatings.

All (100.0%) respondents carry out procedures to remove corrosion converter residues from surfaces (Graph 47). The majority (80.0%) perform this task with solvent and fibre/cloth, while the difference (20.0%) uses a fibre/cloth.



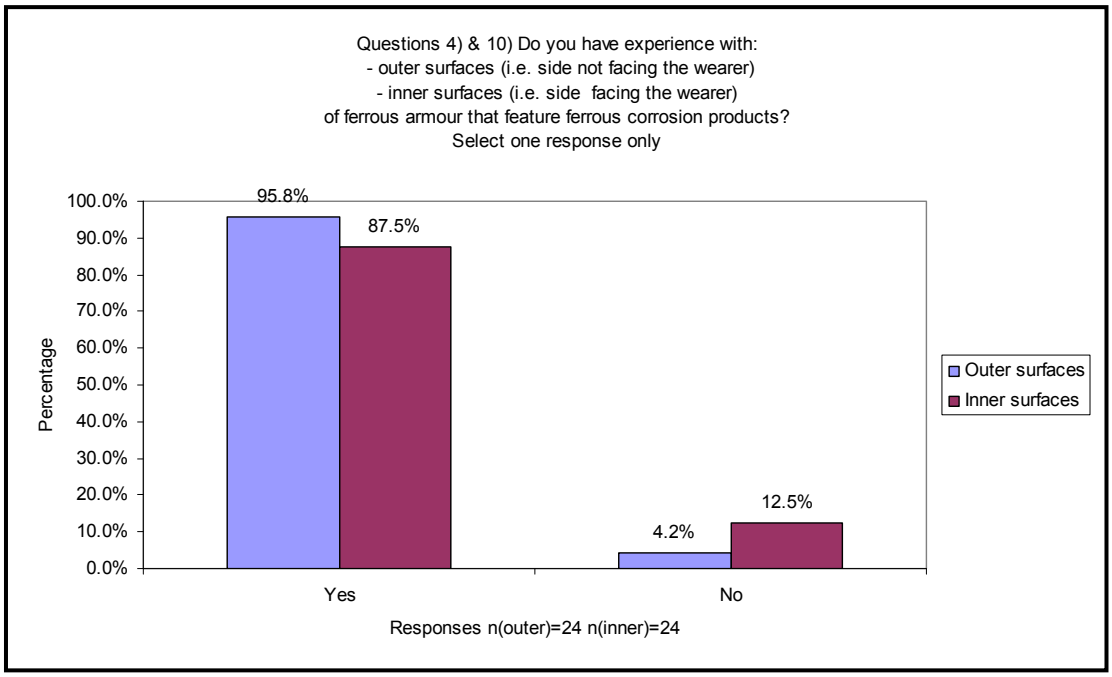
Graph 47 Summary of responses for Question 20

EXTENDED RESULTS ANALYSIS

In order to determine any differences between practices employed on outer and inner surfaces of munition armour a series of comparative graphs and analyses are presented here.

COMPARISON OF RESPONSES BETWEEN QUESTIONS 4 & 10

A slightly greater percentage of respondents have experience on the outer surfaces (95.8%) of armour rather than inner surfaces (87.5%) (Graph 48).

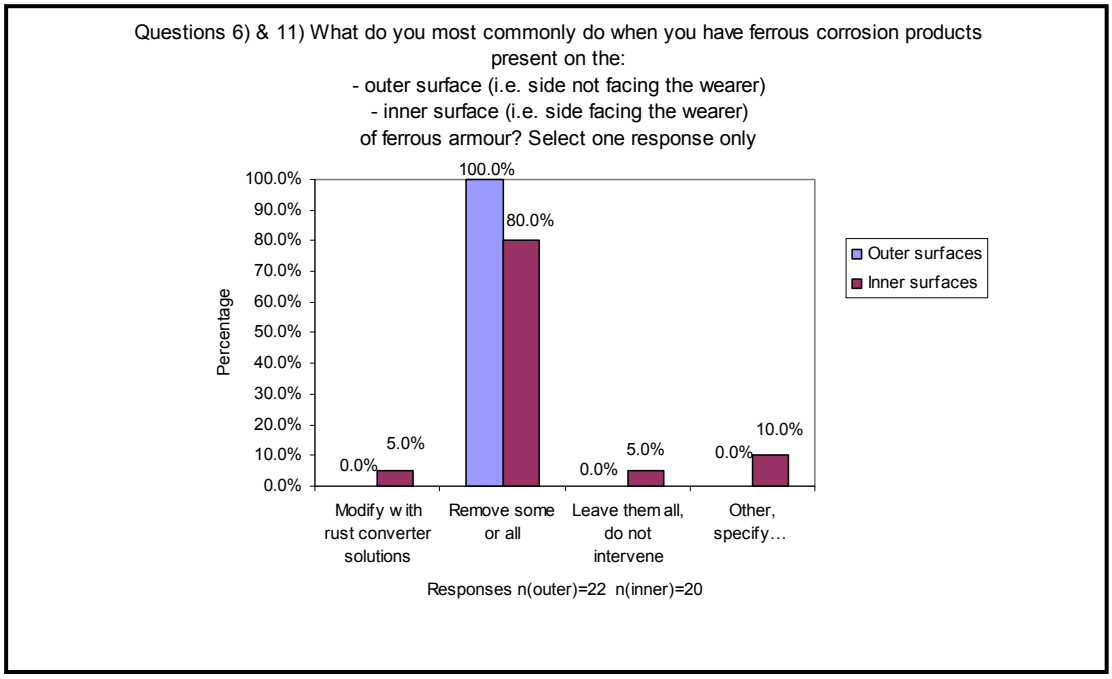


Graph 48 Comparative summary of responses for questions 4 & 10

A simple unsubstantiated rationalisation for this occurrence might be due to the inherently increased attention the more visible outer surfaces of armour receive from the public and museum personnel.

COMPARISON OF RESPONSES BETWEEN QUESTIONS 6 & 11

As the most commonly practiced option, a smaller percentage of respondents (80.0%) remove ferrous corrosion products present on the inner surfaces than on the outer surfaces (100.0%) (Graph 49).

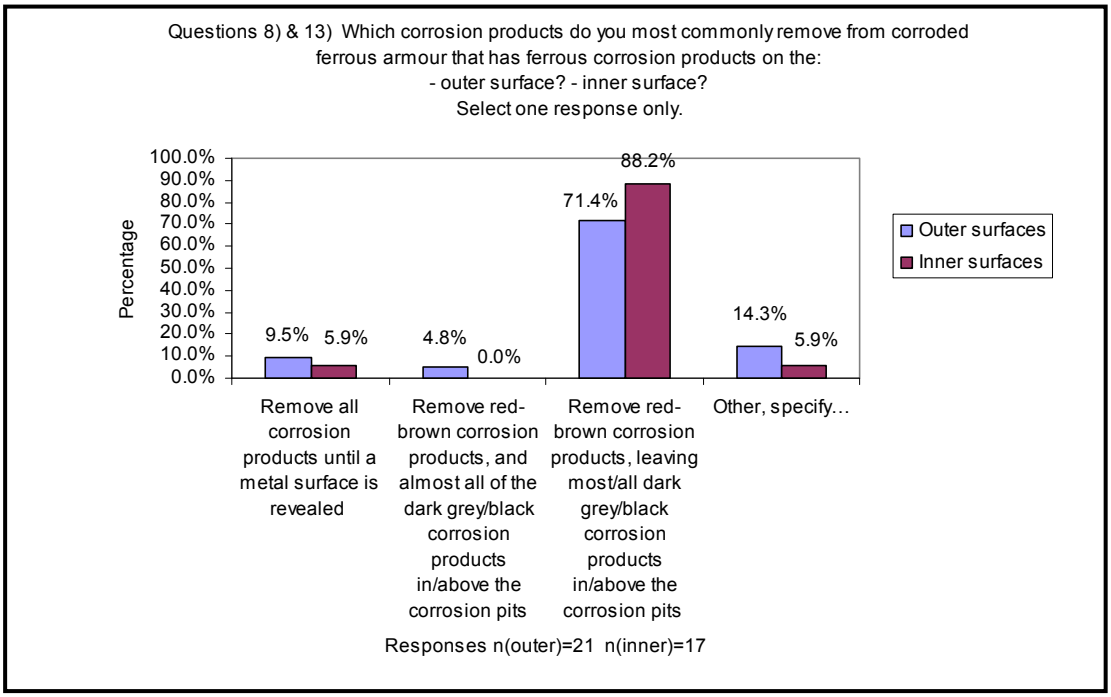


Graph 49 Comparative summary of responses for questions 6 & 11

An explanation for this occurrence might be due to the inherently decreased attention the less visible inner surfaces of armour receive from the public and museum personnel. Leaving corrosion products in place, protecting them, or converting them, indicates that they are more tolerated on armour inner surfaces.

COMPARISON OF RESPONSES BETWEEN QUESTIONS 8 & 13

The distribution of responses indicates that the level of corrosion product removal undertaken between outer and inner surfaces is quite similar, but not identical (Graph 50). Greater quantities of corrosion products are generally removed from outer surfaces than from inner surfaces.



Graph 50 Comparative summary of responses for questions 8 &13

This practice is probably related to the fact that many outer surfaces of munition armour were typically corrosion product-free after manufacture (while in service and while maintained on display). Meanwhile in service, inner surfaces could still feature hammerscale oxides from manufacture[12] and were usually not observable due to the organic inner lining[13]. While out of service and on display, inner surfaces continue to receive less attention than the outer surfaces due to their geometry; thus approaches towards inner surfaces retain more corrosion products.

[12] 2.1.2.4 Munition armour surface finishing
[13] 2.1.2.5 Munition armour assembly & articulation

COMPARISON OF RESPONSES BETWEEN QUESTIONS 9A-G & 14A-G

The comparative responses to the respective questions 9a-g and 14a-g:

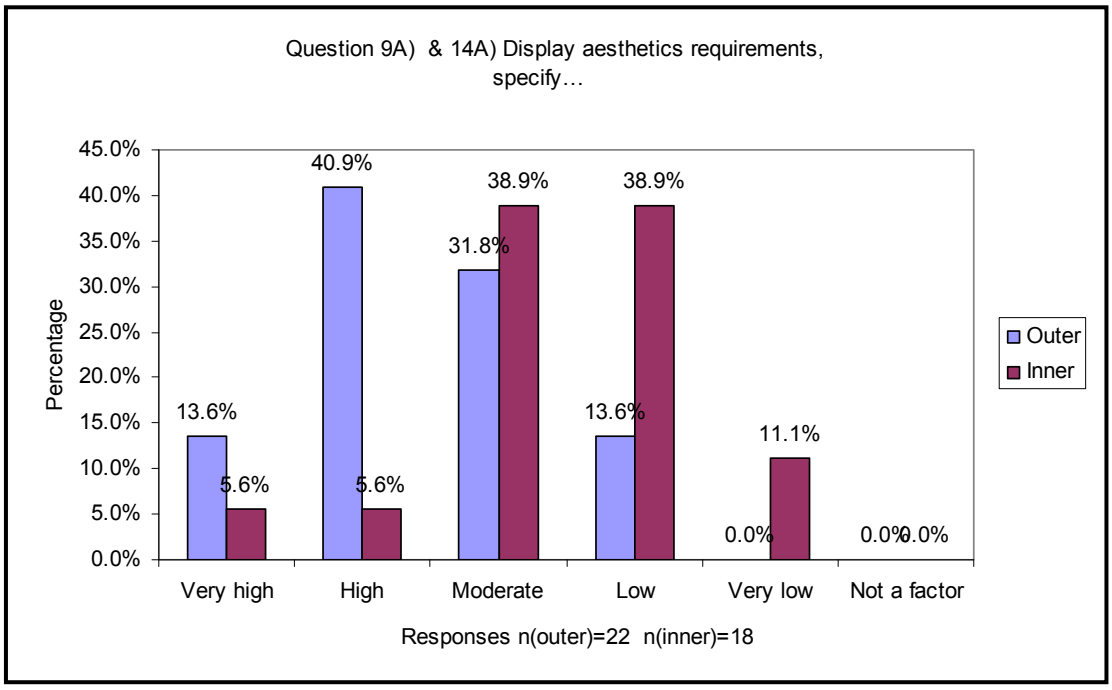
> "Which factors determine which corrosion products you remove from corroded ferrous armour that has ferrous corrosion products on the outer surface (i.e. side not facing the wearer)?"

> "Which factors determine which corrosion products you remove from corroded ferrous armour that has ferrous corrosion products on the inner surface (i.e. side facing the wearer)?",

…are presented on graphs that individually feature each factor under question.

COMPARISON OF RESPONSES BETWEEN QUESTIONS 9A & 14A

While display aesthetic requirements always remain a factor in which corrosion products are removed (0.0%, not a factor both for inner and outer surfaces) the spread is reversed (Graph 51): display aesthetics are of low (38.9%) to moderate (38.9%) influence for inner surfaces, while they are of high (40.9%) to moderate (31.8%) influence for outer surfaces.

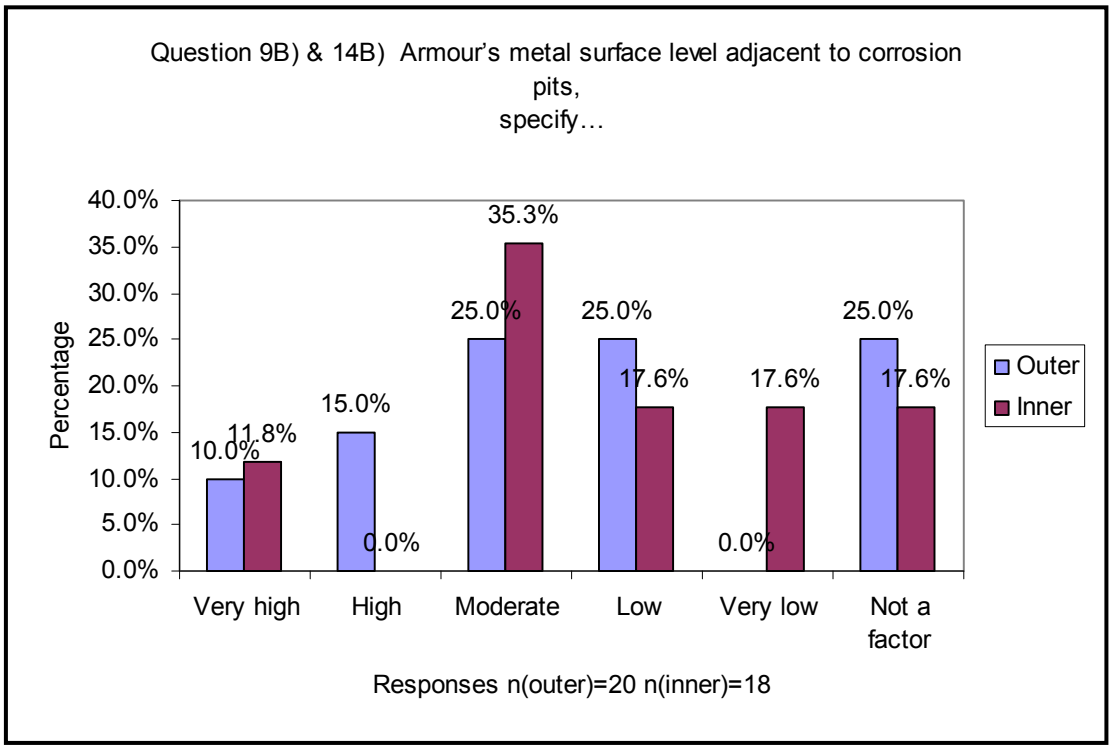


Graph 51 Comparative summary of responses for questions 9a & 14a

The most obvious possible explanation for this bias in influence is that the outer surfaces of armour are much more apparent to the museum visitor than the inner surfaces.

COMPARISON OF RESPONSES BETWEEN QUESTIONS 9B & 14B

From the results it would appear that there is a marginal difference in the influence of this factor (Graph 52). The low and more or less even spread of responses and the large number of responses to "Not a factor" indicate some doubt about the quality of the question and subsequent responses.

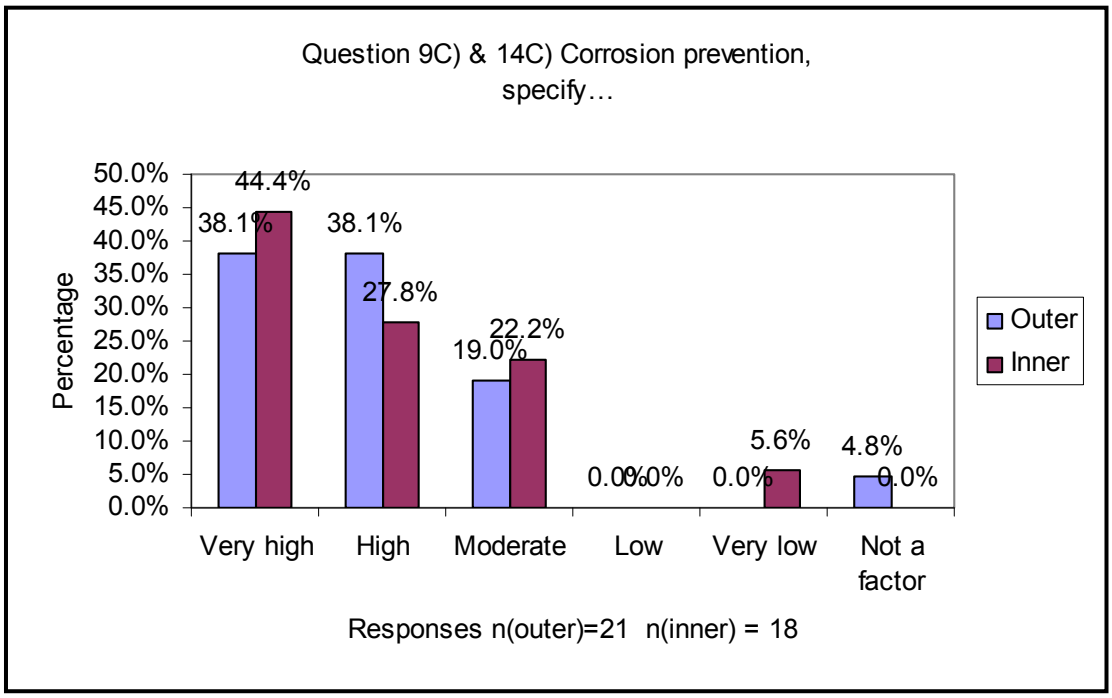


Graph 52 Comparative summary of responses for questions 9b & 14b

There is continued doubt about the level of comprehension for this question. The question requires rewording and requestioning to improve reliable analysis. The intended meaning of the question was inferring that the uncorroded surfaces (i.e. metal around corrosion pits) of the armour might provide a reference point that influences or aids the level of performed corrosion product removal.

COMPARISON OF RESPONSES BETWEEN QUESTIONS 9C & 14C

Corrosion prevention appears largely to be a “very high” to “high” factor for both outer and inner surfaces (Graph 53).

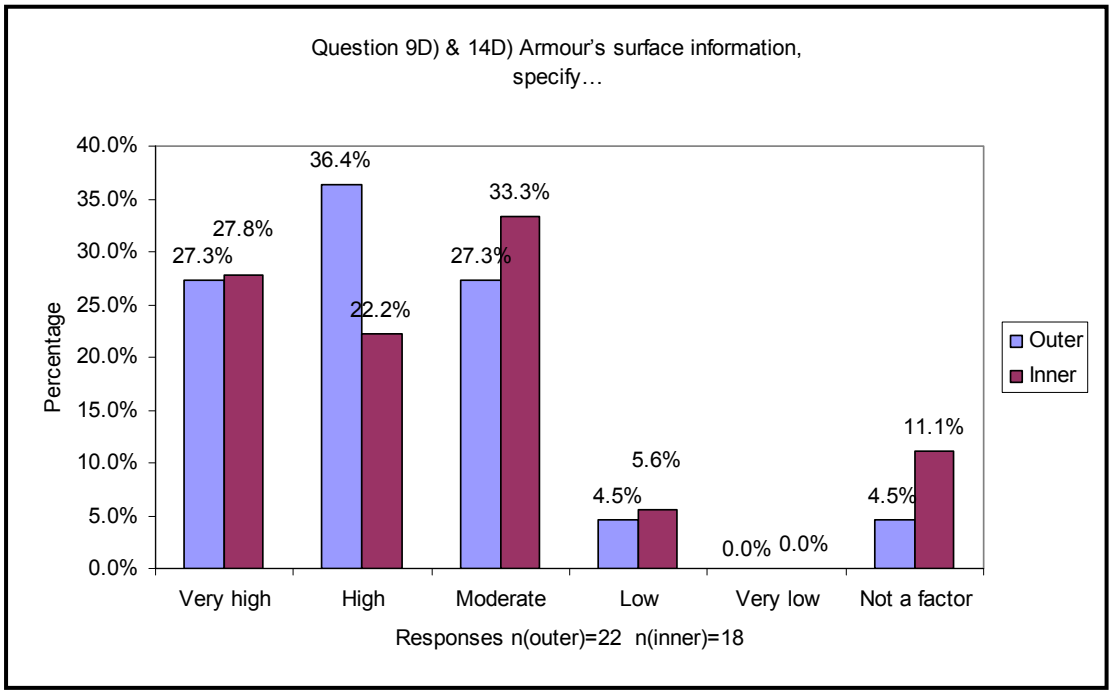


Graph 53 Comparative summary of responses for questions 9c & 14c

The perceived influence of corrosion as being a phenomenon that can occur on both the armour outer and inner surfaces is inferred by these responses. There does not appear to be an important bias for corrosion prevention according to the surface location on the armour.

COMPARISON OF RESPONSES BETWEEN QUESTIONS 9D & 14D

The influence of surface information as a factor affecting which corrosion products are removed is largely consistent for both outer and inner surfaces (between "moderate" and "very high") (Graph 54).

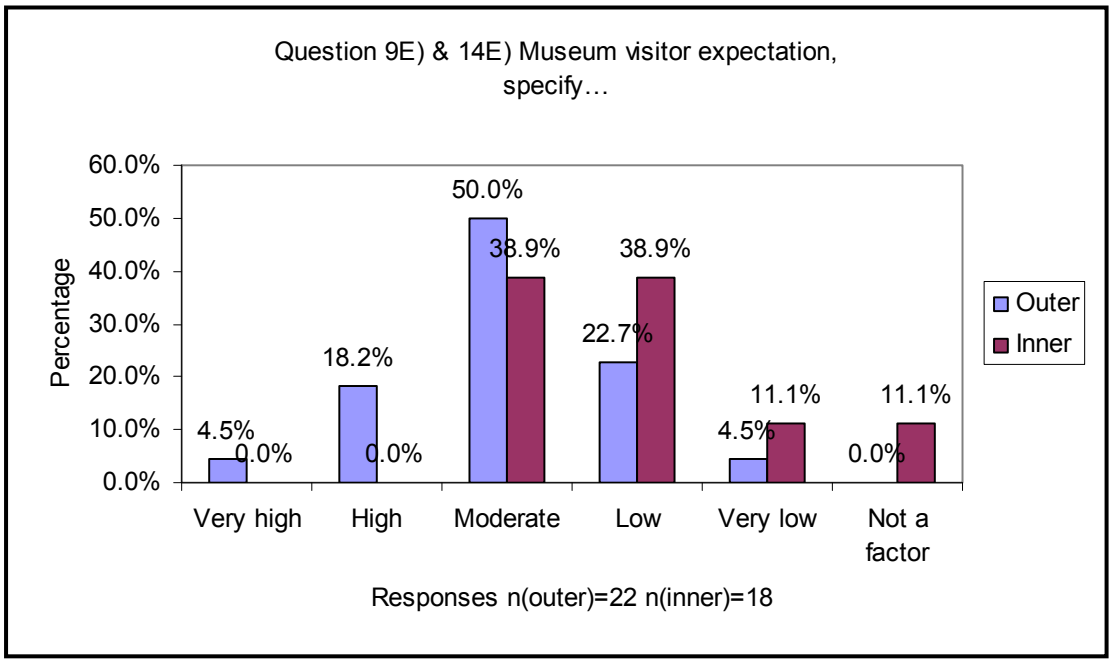


Graph 54 Comparative summary of responses for questions 9d & 14d

The respect for surface information appears to not waiver greatly, regardless of which surface plane it might be present on. A slightly greater percentage of respondents felt that armour surface information on the inner surfaces (11.1%) was not a factor when compared with the responses given for the outer surfaces (4.5%).

COMPARISON OF RESPONSES BETWEEN QUESTIONS 9E & 14E

The influence of museum visitor expectations determining which corrosion products are removed from outer surfaces is rather equally spread when compared with inner surfaces: where a distinct bias towards "moderate" to "not a factor" prevails (Graph 55).

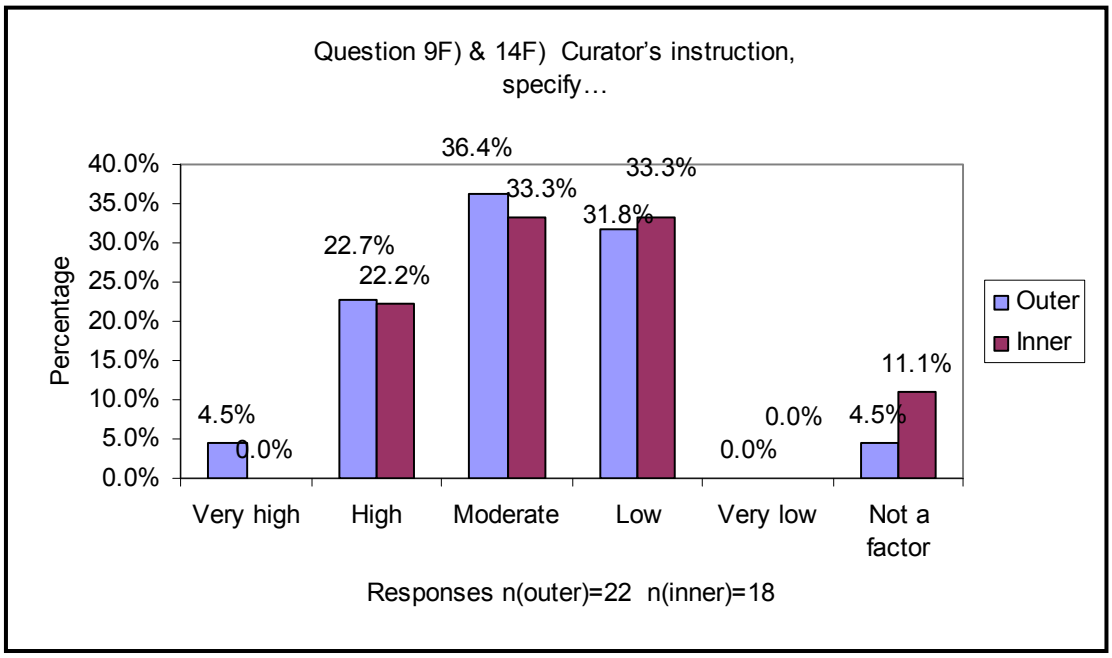


Graph 55 Comparative summary of responses for questions 9e & 14e

The generally less observable inner surfaces of armour are deemed to again be an influence on the discrepancy between approaches to corrosion products on outer and inner surfaces.

COMPARISON OF RESPONSES BETWEEN QUESTIONS 9F & 14F

The results for the curatorial influence on which corrosion products are removed from the armour outer and inner surfaces are almost identical (Graph 56).

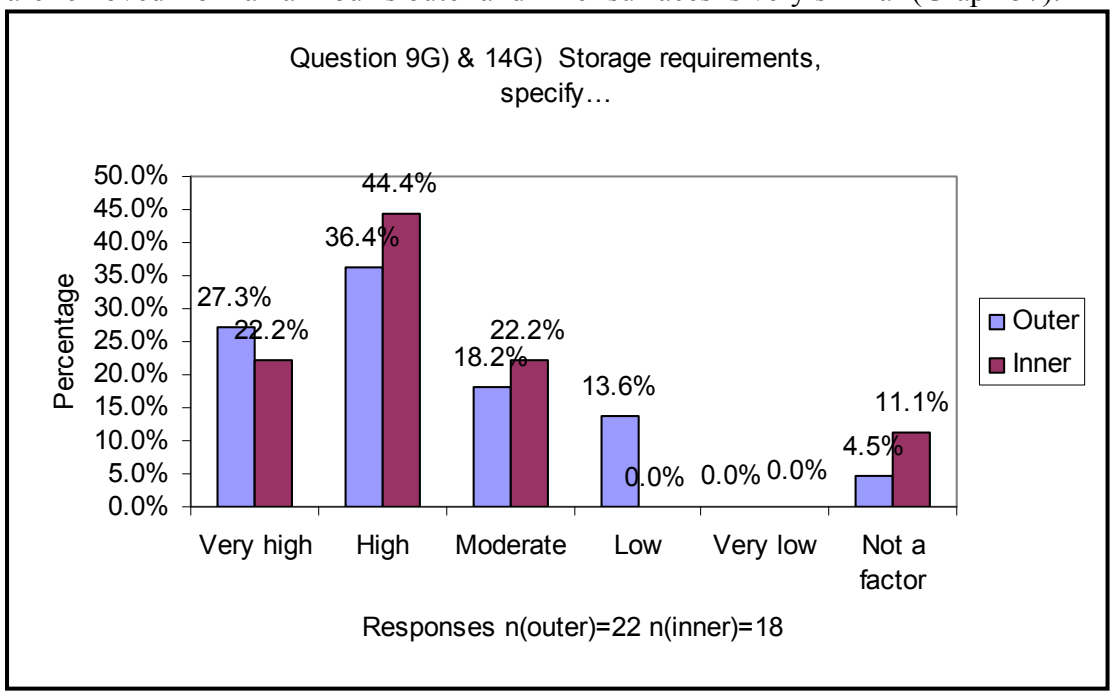


Graph 56 Comparative summary of responses for questions 9f & 14f

The curator's instruction does not appear to hold any greater or lesser influence between the outer and inner surfaces.

COMPARISON OF RESPONSES BETWEEN QUESTIONS 9G & 14G

The spread of results for storage requirements as an influence on which CPs are removed from an armour's outer and inner surfaces is very similar (Graph 57).



Graph 57 Comparative summary of responses for questions 9g & 14g

Storage requirements do not appear to make an important influence on which corrosion products are removed from outer and inner surfaces of armour. The reliability of these responses, however, remains under question[14].

EXTENDED RESULTS ANALYSIS SUMMARY

The factors influencing, or not, which corrosion products are removed from the outer and inner surfaces of armour are very similar with two exceptions:

- Display aesthetic requirements
- Museum visitor expectation

These two factors could be considered as being closely interrelated. The definition of display aesthetic requirements was left open for interpretation and is likely to also incorporate museum visitor expectations. The similarity of diverging biases in the results (between outer and inner surfaces) from these two factors indicates consistency between these questions' responses. More importantly, in terms of the questionnaire's findings, corrosion product removal from outer surfaces is more liable than inner surfaces to be influenced by external subjective expectations.

[14] Sub-question 9G

COMPREHENSION LIMITATIONS

From the level of English recorded in the free-form sections of the questionnaire and in email correspondence it was estimated that most respondents (95.8%) demonstrated they were proficient in written English. This might have a correlation that could indicate the level of language comprehension, although it is not possible to draw definitive conclusions since reading comprehension and writing abilities are not necessary equivalent. Due to the international nature of the questionnaire it would have been beneficial to include a question determining the number respondents having English as a first/native language. Just over half (54.2%) of the respondents are practicing in countries that either have English as the first official language (45.8%) or as the dual official language (8.3%); if this can be considered as an indication contributing to comprehension. Even so, comprehension is also dependent on the phraseology of each question and the complexity required for articulating very specific questions. Clarity of questionnaire structure and formatting also plays a role in comprehension. The wording of one particular question proved difficult to understand even for three respondents, having English as a first language, who explicitly commented on the question. Two specified responses also indicated that some respondents had not fully understood that the questionnaire was exclusively concerning *ferrous corrosion products* on *undecorated ferrous armour*, since they referred to gilt elements or copper corrosion products.

CONCLUSIONS

The questionnaire's seven main findings are listed in the main body of the dissertation: sub-section 2.4.2.1 Laboratory questionnaire summary and conclusions.

Reference:

Morcillo, M., Feliu, S., Simancas, J., Bastidas, J. M., Galvan, J. C., Feliu, Jr. S. and Almeida, E. M. (1992). "Corrosion of Rusted Steel in Aqueous Solutions of Tannic Acid". NACE Corrosion, 48, 1032-1039.