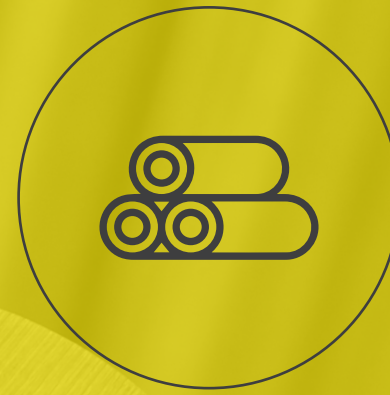


MATERIAL SELECTION

Some considerations



“Judicious selection of materials is based on relationships among technical and economic facts either type of which may be relatively unimportant in individual applications. Appraisal of the pertinent facts seldom follows a fixed formula; procedures and practices vary widely in industry”. ⁽¹⁾



INTRODUCTION

As a supplier of a wide range of specialised materials, a question frequently asked of us is “What can I use for..... ?”.

More often than not the information provided is insufficient and a dialogue ensues before some guidelines can be provided. The purpose of this publication

is to provide a ready reference for 5 Considerations that may need to be defined in order to aid material selection. There is a bias towards the practical based on our experience rather than a formal systematic method.⁽²⁾

The approach used here is not the only

one but it’s simple, logical and has a generic format. The headings used may be re-configured to create a decision tree.

Preliminary design should precede material selection which then is considered integral to both design and manufacturing.⁽²⁾

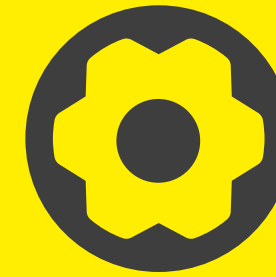


CONSIDERATION 1: FITNESS FOR PURPOSE / PRODUCT ANALYSIS

This is essentially the first step in taking a concept to a final design or completed product and it will be affected by the bigger picture. When looking at new concepts or customised manufactured equipment and parts it is important that the following are considered at the outset: ^(2,3)

- What does the product / equipment do and how does it function?
- Is the product performance driven or cost driven?
- What are the operating conditions?
- When will it be needed and where?
- What should it cost?
- Are there extra – ordinary Health and Safety considerations?

When it comes to the question of cost this must be looked at as both the initial cost and on a life-cycle cost basis. Whilst the latter is preferable, thorough testing of materials for new applications is not always possible and thus the performance data for a meaningful lifecycle cost analysis may not be possible. In these circumstances initial cost may be the criteria as of course is also the case when the final product has a price cap.



CONSIDERATION 2: SHAPE REQUIREMENTS

Realising the final component, product or item of equipment will require starting material of various shapes and dimensions and inevitably this would be subjected to one or more manufacturing operations and its just as well that these considerations are known early on in the material selection deliberations. Practical matters that arise are:

- Many grades are not available in a wide range of product forms. eg 3CR12 plate is available off the shelf but long products are not. This grade is widely used with adaptations being made to compensate for the absence of certain product forms.
- Cast vs wrought product forms. Items that need to be cast need to be made from grades that are intended for casting and usually these will have properties that will differ from those of the nearest standard wrought grades, being superior in some cases. Or, the corollary, it may be risky to substitute a casting for

a wrought item if the selection was done on the basis of the latter.

- Inevitably forming, welding and machining will be required as part of manufacture / production and providing information regarding the metals and these fabrication processes are FAQ's

Modern technology, in the form of additive manufacturing, has of course significantly increased the means available for attaining the shape requirements for many components in specialised grades.



CONSIDERATION 3: OPERATIONAL REQUIREMENTS

It is at this point that there is a focus on physical, mechanical and chemical (corrosion) properties that the candidate materials must have. This may be done with an emphasis on a specific parameter or set of parameters but equally there may be a preference to find an optimum combination of properties.

Many of the physical and mechanical properties are “fundamental” to the material, well documented and available from hand books, data sheets, material standards and design codes. Once again there are practical matters that arise and some of these are:

- There are important properties that are not “fundamental” and thus may not be well documented and all the more so in a given set of conditions. Some of these properties are creep and resistance to wear and corrosion.
- Physical properties such as density, stiffness, thermal and electrical conductivity and the coefficient of thermal expansion may be key in many applications that involve “special alloys”.
- In situations in which the operating conditions

cannot be fully defined it is useful to highlight “Red Flags” – parameters that may pose risks.

- For elevated temperature applications material properties may change with time as a reflection of the structural changes that can occur in the metals.
- Corrosion Tables, Scatter Diagrams, Engineering Charts facilitate material selection by illustrating key properties of many candidate materials in simple graphical format. Fig 1 and Table 1 are examples of these.
- Heat treating metals can be used to alter their properties thereby further enlarging the options of materials – properties available. Surface hardening and the use of coatings, galvanising etc are effectively processes which generate the requisite “properties” where they are required.

Figure 1: (From Ref 7)

Engineering diagram indicating the maximum temperatures and chloride concentrations allowed for some stainless steels in slightly chlorinated (< 1 ppm) water.

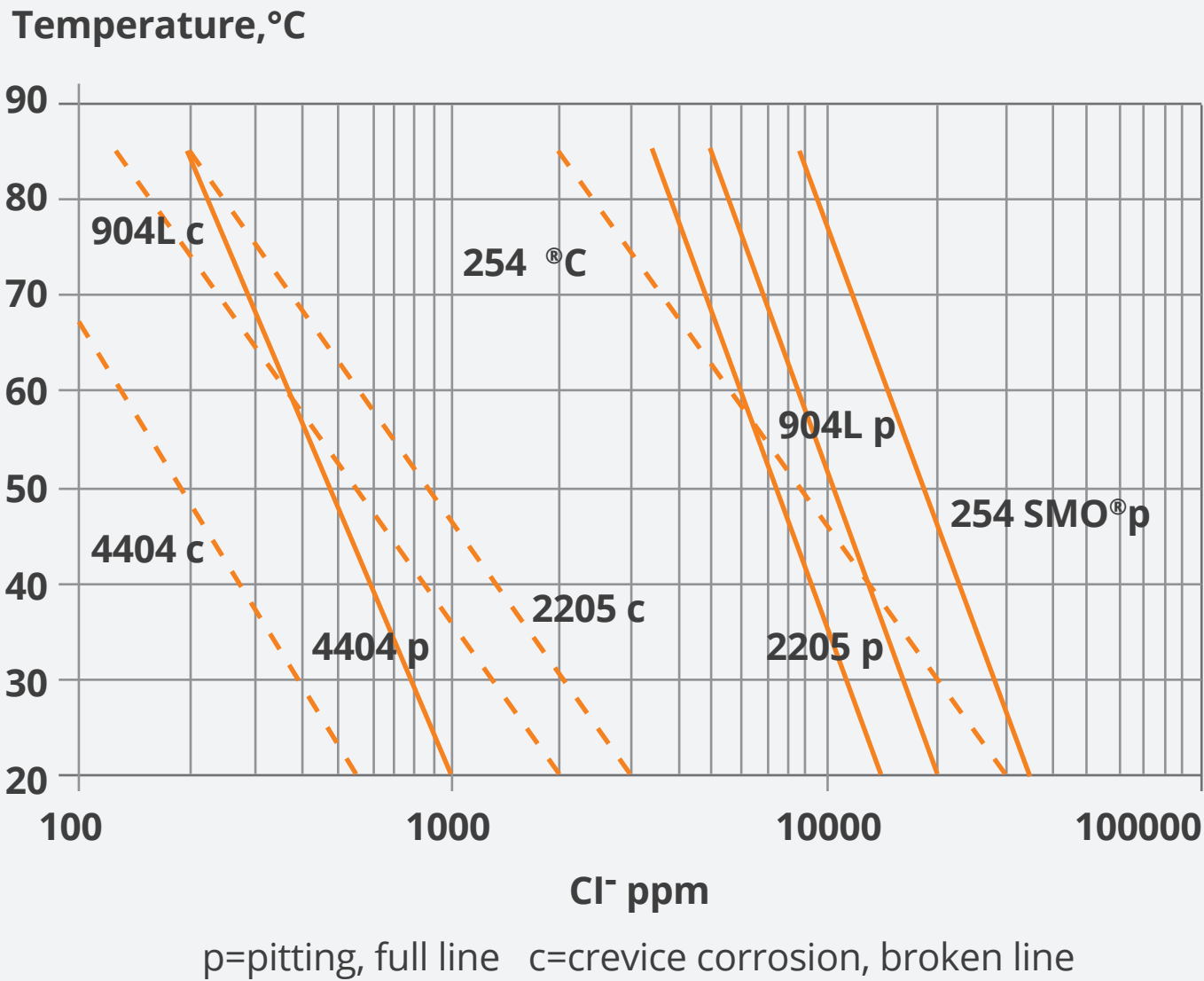


Table 1: (From Ref 8)

Table 1. Effect of alloying additions in nickel alloys on high-temperature attack										
Mode of attack	Ni*	Fe	Cr	Mo	Co	W	Cb	Si	Al	Ti
Oxidation	↑	↓	↑	↓	↑	↓	↓	↑	↑	↓
Sulfidation	↓	↑	↑		↑			↑	↑	
Chloridation	↑	↓	↑	↑↓	↑↓	↑↓		↑↓		
Fluoridation	↑		↓	↑			↓	↓		↓
Carburization	↑	↑	↑	↑			↑	↑	↑	↑
Nitridation	↑	↓	↑↓		↑			↑	↑↓	↓
	↑	= Improves resistance;								
	↓	= Lowers resistance;								
	↑ ↓	= Dependent on specific conditions;								
	*	= Effect of increased nickel content.								



CONSIDERATION 4: CANDIDATE MATERIALS

Very often this point of producing a short list of candidate materials is arrived at without a formal review process outlined thus far. Instead material selection may be based on industry standards for the same or similar applications. After all this is often a reason for the existence of organisations such as API, NORSOK and similar. However even in such instances it's important that some consideration be given to the preceding steps in order to ensure that "local conditions" are taken in to account.

This may include maintenance and a slight variation in the operating conditions. A further factor may be the emergence of new materials and classes of materials which may not be incorporated in existing practice and yet offer some significant advantage.

A few practical pointers are:

- The compatibility of different materials may arise in some applications. A risk of Galvanic corrosion is an instance that is often queried but 2 others are
 - hardness differences and their affect on friction and wear for surfaces in contact.
 - Coefficient of expansion differences in designs using dissimilar materials.
- Changing materials. A not unheard of situation has been the selection of materials in maintenance situations without full consideration of the operational requirements and why the original material was selected in the first place. A loss of "corporate memory". One such situation resulted in 316L being substituted for a nickel alloy in a hot hydrochloric acid application.
- The emergence of sustainability as a societal value may mean that materials that are recyclable or have low carbon footprints may be preferred.
- There exist demanding applications for which technology and equipment suppliers have collaborated with alloy developers to offer "an intellectual property package" – metals optimised for the equipment or technology in question. These proprietary grades may thus not be available for ad - hoc use.



CONSIDERATION 5: FINAL DESIGN AND CONSTRUCTION / MANUFACTURE

Final design and construction / manufacture is the last step to achieving functional components or equipment / plant. Essential outputs at this stage are drawings, specifications and procedure for the construction and operation. Further practicalities that arise are:

- Again codes, standards specifications and “corporate memory” are essential to achieving a workable solution.
- Design and operation need to allow for inspection and maintenance the extent of which may be a function of cost – performance compromises in the choice of materials.
- The necessary transfer of information is achieved by means of drawings, data books and operating manuals which may need to be sufficiently detailed to cover mothballing and disposal / salvage. If toxic substances

are present during operation, the logic for this is readily appreciated but even if they are absent the ethos of minimising environmental damage requires that “end of life” considerations be given forethought.



CONCLUSION

The ready access to search engines and vast data bases would indicate that material selection should be easy and seemingly it is. Difficulties that arise are a result of a combination of poorly presented information, inadequately defined search criteria and the uninformed being swamped with information that may include some that is biased. This last point is not always recognised. Knowledgeable partners in the supply chain can have a role in demystifying some of the considerations highlighted and assisting with the detail required for a sound decision.

The following (from Ref 1 Electrical Contact Materials, pg 801) provides a useful illustration of what may be required from an ideal material or, in the absence of which the trade-offs that must be made.

If an ideal material could be found for universal use in all electrical contacts, it would have (Precis)

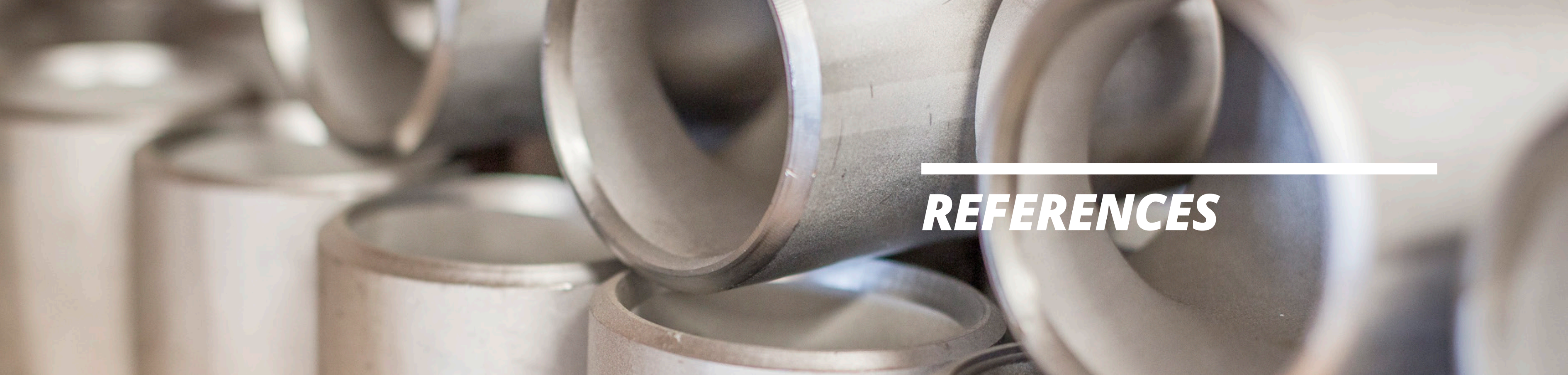
- high electrical conductivity to minimise the heat generated during the passage of current;
- high thermal conductivity to dissipate both the resistive and arc heat developed;
- high reaction resistance to all environments in which it was to be used, avoiding formation of insulating oxides, sulphides and other compounds;
- resistant to arcing damage on the make or break of the electrical contact.
- The force required to close the contact would be low.
- Electrical resistance between mating members would be low.

- The melting point of the material would be high to limit arc erosion, metal transfer, and welding or sticking.
- The vapor pressure would be low to minimise arc erosion and metal transfer.
- Hardness would be high, to give good wear resistance, and yet ductility would be high enough to assure ease of fabricability.
- Finally the material would be available at a low cost in any desired form.

Since no metal has all the desired properties, some compromises are necessary and a selection based on reliability, availability, life and cost must be made for each specific application.



“The optimum materials are those which provide the lowest cost to life ratio when corrected for tax rates and accounting procedures and which incorporate certain aspects of safety, health, and environmental considerations, and reliability. The desired end result includes profitable operations with a minimum of unscheduled shutdowns and regularly scheduled refurbishing or replacement.”⁽⁵⁾



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