Internship report

Material overview and documentation update, with identification of elimination candidates

J.A.N. Heijs

Student number s1388401
Period: 23 April – 6 July 2018

UNIVERSITY OF TWENTE.

Thales Nederland
Hengelo, The Netherlands
Mechanical and Electrical Engineering
Supervisor: dr. ir. J.H. Mulder

University of Twente
Faculty of Engineering Technology
Department of Design, Production & Materials
Mechanical Engineering
Specialisation in Design Engineering
Supervisor: ir. M.P. Zwier

Page intentionally left blank

Table of Contents

Cover images credit: Thales Nederland

Left: STING-EO Mk 2 director

Right: S1850M, aboard HMS Daring (UK Royal Navy)

1. SUMMARY

The set of standardized materials at Thales Nederland has been deemed too large from an economic point of view. Besides the materials (which are barely stocked by Thales Nederland anymore) corresponding processes and documentation have to be maintained, resulting in complexity and costs. This report describes the process of identifying materials that can be eliminated and if required provides suggestions for alternatives. This is done as an internship assignment for the MSc. programme Mechanical Engineering at the University of Twente.

In order to identify elimination candidates from this stock an overview of all standardized materials is made, with inclusion of relevant material properties. These are presented in and Excel worksheet and in printed form in the appendices of this report. Background information is presented which also functions as a reference work for these tables.

The identification and evaluation of elimination candidates is done in two steps: first based on usage and subsequently based on properties. During the first step the amount of 12ncs per material are determined and considered a measure for its usage. If these are limited, 'Single Level Implosions' are executed in KIS to determine the number of applications. The application fields are also determined, in order to differentiate between materials used in currently marketed systems and older systems. The second step is more elaborate, since relevant properties have to be compared and possible applications considered. This finds that some standardized materials can be replaced by other standardized materials, further reducing the amount of stock. Overall 20% of the standardized materials are identified as elimination candidates, either through lack of current usage or because of overlapping properties.

Limitations to this approach are the lack of application data of castings and property data of plastics. Castings and forgings are not linked to their base material in KIS and are therefore excluded from the identification based on usage. Properties of plastics are only prescribed in HSNs for a limited number of the total stock and are therefore excluded from the phase based on material properties.

Finally a documentation update is executed. HSNs refer to external standards which are regularly updated. However the reference in the HSN cannot be updated until it has been verified that the relevant properties have not changed. This verification is executed allowing simple updates of many references and identifying the standards that have to be evaluated more thoroughly. The overview of honeycomb sandwich cores has been found incomplete and an expanded overview of honeycombs is created. Throughout the project minor inaccuracies in the documentation have been identified and suggestions for changes are also given in this chapter. The designation of materials on drawings is no simple matter and a proper evaluation is outside the scope of this assignment. However arguments for different methods are presented, which can be a basis for a future evaluation.

With respect to the internship I look back at a period in which I have learned a lot. Both on a personal level as on the application and expansion of the knowledge obtained during my education. The company culture and its people suited me well and every morning I was looking forward to the day ahead.

2. INTRODUCTION

As part of the Master study Mechanical Engineering at the University of Twente an internship has to be conducted. This provides students the opportunity to apply their (theoretical) knowledge in a real-world situation and gives them the experience of functioning in a company. Thales Nederland was my first choice for this internship as it is regarded as one of the leading companies in its sector. Since my specialisation is in Design Engineering, I hoped that the rigorous demands on military hardware would expose me to a knowledgeable and experienced organisation. Another personal field of interest is materials science and Thales proposed an assignment that would allow me to expand my knowledge in this field. This report presents the findings of this assignment and my time at Thales Nederland.

The first chapter describes the background of each material group as an introduction to the material overview tables, which can be found in appendix D. This chapter can also serve as a reference document for the rest of the report. Subsequently elimination candidates are presented, based on usage and on overlapping properties. Finally in the documentation update references to external standards are updated, an overview of honeycomb materials is made, proposed changes are described and arguments for different methods of material notation on drawings are collected. The appendices include a description of the employer, a personal reflection, additional information on certain stainless steel grades and the overview tables of standardized materials.

Relevance

Thales Nederland is a class-leading technology company producing mainly military radar systems. The equipment is constructed from a large set of standard materials. While this offers a wide range of options, this set is too large from an economic perspective since it requires stock, may need different surface treatments and documentation needs to be kept up to date. By making an overview the identification of elimination candidates will be easier and the documentation is also evaluated. A more elaborate description of Thales Nederland can be found in appendix A.

Besides the fulfilment of the assignment, an important element of the internship is the exposure to a working environment at an engineering company. A personal reflection on my time at Thales Nederland is given in appendix B.

Objectives

The primary goal for this assignment is to make an overview of all current standard materials, including relevant properties. This provides the basis for the identification of elimination candidates. This can be based on (lack of) current usage or based on overlapping properties, such that the candidate can be replaced by another standard material.

At the midway review it was concluded progress was going well and secondary objectives were identified and decided upon. A documentation update with respect to the referenced standards was required. The documents refer to a certain (international) standard, but there is no longer a protocol to identify updated standards and check for relevant changes. Also some minor inconsistencies have been found in the documentation and the overview of honeycomb materials was not complete. Finally, the method for material notation on drawings is not undisputed. While it is well outside the scope of this assignment to come to a conclusion, it is possible to make an overview of arguments which can form the basis for a future evaluation.

Thales nomenclature

To uniquely identify products and accompanying documentation Thales Nederland uses 12 numerical codes, or 12nc's. For ordering from external suppliers purchase specifications or PS are used, which are more commonly referred to by their Dutch name "bestel specificatie" or BSP. Thales also has internal company standards, which may be referred to in this report. The most relevant ones for this report are:

- HSN Material specification
- HSV-R Design and engineering instructions
- HSV-N Article standard
- HSV-P Process specification

Besides these company standards, which are stored on the intranet, the software programs KIS and Windchill contain a lot of documentation.

International nomenclature

There may be references to terms from organisations other than Thales. The most commonly used standards in Europe are EN (European Norm) and ISO (International Organization for Standardization). There are also national standards, such as NEN for The Netherlands, BS for the UK and DIN for Germany. If the subject is also covered in an European standard, national standards of EU member states are required by law to conform to the European standard.

While there are multiple systems in use for designation of materials, one system that is used for multiple material types is that of the material (or Werkstoff) number. It consists of 5 numbers in the form A.BBCC, with A the main material group, BB the grade class and CC the count number. For example, 1.4401 is stainless steel AISI 316. Finally the number can be followed by a dot and two more digits, representing a production method/temper and heat treatment [1].

In North-America most relevant standards are governed by ASTM (American Society for Testing Materials) and SAE (Society of Automotive Engineers), which have both expanded their field of operations outside the scope indicated by their name. They jointly manage the UNS (Unified Numbering System) which also identifies a wide range of metals. It consists of a letter representing a material type, followed by 5 digits to identify the alloy [2]. E.g. S31600 is again AISI 316.

Specific materials can have their own customary standard organizations. Stainless steels are commonly referred to by their AISI/SAE designation, while aluminium is mostly identified by the Aluminium Association (AA) designation. Finally, it is quite common to describe alloys by their chemical composition, sometimes with the (nominal) contents of each element. E.g. bronze CuSn8 consisting of copper with 8wt% tin.

Please note that during the report often references are made to alloy grades, such as stainless steel 316 or aluminium 6061. While these give an indication of the chemical composition and corresponding mechanical properties, these are not specifications. A specification is given, usually in international standards, with explicit requirements for the composition, properties, treatment, form or quality. This is further discussed in section 5.4.

3. MATERIAL OVERVIEW

For the material overview some background knowledge is required. It is assumed that the reader has a basic materials science background. The most commonly used classification systems are presented in this chapter. This is expanded upon to provide information on properties and nomenclature, with a focus on the materials in use by Thales Nederland. Therefore this chapter can be seen as both an introduction and a reference work for the material tables in appendix D. These tables are the actual overview and provide all relevant information. Unless referenced otherwise, properties are taken from the respective HSN or the standard the HSN refers to.

3.1. Irons and steels

Steel is an iron-carbon alloy, with typically up to 1wt% carbon. When the carbon content is over 2,14wt% it is classified as cast iron. Iron and steel are produced in larger quantities than any other metal and widely used in engineering applications. It is a relatively economical material and can be tailored to a wide range of mechanical properties. The main downside is its sensitivity to corrosion [3].

Steels

There are multiple systems in use for the classification of steels [4]. The two systems described in this report are based on application area or chemical composition.

The system based on application, as described in EN 10027-1, typically consists of a main letter indicating its usage and followed by a 3 digit number representing a mechanical property, typically the yield strength. Two groups can be added to indicate additional properties for steels. Some meanings are listed in Table 1. The prefix “G” can be added for cast steel [5] [6].

For example S235JRC indicates Structural steel, yield strength of 235 MPa, impact strength J = 27 J at temperature R = room temperature, condition C = cold worked. Another example is E355, an Engineering steel with a yield strength of 355 MPa. Note that this strength is for the smallest size described in the standard, while typically strength decreases for larger sizes.

Main letter	Group 1	Group 2
S = Structural	J = 27 J impact energy	C = Cold formability
E = Engineering	K = 40 J impact energy	D = Hot dip coatings
D = Flat products	L = 60 J impact energy	E = Enamelling
P = Pressure vessel	R, 2, 3, 4, 5, 6 = test temperature for impact	F = Forging
L = Pipeline	A = Age hardening	L = Low temperature
B = Reinforcing	M = Thermomech. rolled	P = Sheet piles
M = Magnetic	N = Normalized	S = Shipbuilding
	Q = Quenched	T = Pipes
	G = other features	W = Weather resistant

Table 1. Steel designations based on usage [6] [7].

AISI categorises steel into four basic groups, based on their composition [8].

- Carbon steel.
- Alloy steel.
- Tool steel.
- Stainless steel.

Carbon steel typically has very little alloying elements apart from carbon. Typically steel is considered unalloyed if it contains less than 1,5wt% carbon, 0,8wt% manganese, 0,5wt% silicon and limited other impurities [9]. They can be further classified based on carbon content [8]. Low carbon (mild steel) with carbon contents of 0,04-0,30wt%, has many applications and can be fine-tuned with the addition of other elements. Medium carbon steel with 0,31-0,60wt% carbon and 0,06-1,65wt% manganese, is stronger but harder to process and typically requires a heat treatment. High carbon steel (or carbon tool steel) has 0,61-1,50wt% carbon, is very difficult to process and is extremely hard and brittle after heat treatment.

Alloy steels are steels to which elements, other than carbon, are added to obtain specific properties. They can be further classified according to the amount of alloying elements into low alloy (less than 5wt% alloying elements) and high alloy (more than 5wt%) [9]. Common alloying elements and their effect are given in Table 2. Examples include High Strength-Low Alloy (HSLA) with improved strength, toughness and heat treatability as compared to carbon steel, and weathering steel with improved corrosion resistance [10].

Tool steels are suitable for working or processing materials, handling and measuring workpieces. They typically have high hardness, wear resistance and/or toughness. ISO 4957 differentiates the following types according to their usage.

- Cold-work tool steels: non-alloy or alloy tool steels for applications in which the surface temperature is generally below 200°C.
- Hot-work tool steels: alloy tool steels for applications in which the surface temperature is generally over 200°C.
- High-speed tool steels: used mainly for machining and for forming processes and which have the highest high-temperature hardness and temper resistance up to about 600°C.

Stainless steel contains at least 10,5wt% chromium (according to EN 10088-1) and is very corrosion resistant. It is discussed separately in section 3.2.

Finally the condition of a material should be indicated. Some common suffixes are given below in accordance with ISO 4957:1999(E) and EN 10305-1:2010.

+U: untreated
+A: (soft) annealed
+A+C: annealed and cold drawn
+A+CR: annealed and cold-rolled
+QT: Quenched and tempered
+C: cold drawn/hard (no HT)
+LC: cold drawn/soft (limited drawing after HT)
+SR: cold drawn + stress relieved
+N: normalized

Element	**Effect**
Carbon	Main alloying element in steel, increases strength and hardenability, decreases ductility and weldability.
Silicon	Used during smelting, increases strength, hardenability, wear resistance, yield point, decreases deformability.
Manganese	Increases strength, surface hardness, strain-, hammering- and shock resistance, improves hardenability by reducing required quench rate.
Chromium	Increases hardness, toughness, wear- and corrosion resistance, hardenability (reduces quench rate), may form carbides.
Molybdenum	Increases strength, toughness, hardenability, shock- and heat resistance, reduces risk of temper embrittlement, limits grain size, improves weldability, may form carbides.
Nickel	Increases strength, toughness, impact strength and corrosion resistance, austenite promoter.
Tungsten	Increases hardness and heat resistance, improves grain structure.
Vanadium	Increases strength, toughness, ductility, shock- and corrosion resistance, limits grain size and may form carbides.
Chromium-vanadium	Greatly Increases strength, hardness, but can still be cut & bend well.
Cobalt	Increases hot hardness by limiting grain growth at elevated temperatures.
Phosphor	Increases strength and corrosion resistance, risks temper embrittlement.
Sulphur	Improves (automatic) machinability by forming MnS_2 or MoS_2.
Lead	Improves machinability, minor mechanical effect, limits weldability.
Copper	Increases corrosion resistance, allows precipitation hardening.
Tungsten	Increases melting temperature, toughness, wear- and corrosion resistance, limits grain growth.
Boron	Increases hardenability, wear resistance (small amounts).
Aluminium	Limits aging and grain size.
Niobium	Increases creep resistance, supresses recrystallization, may form carbides.

Table 2. Influence of alloying elements in steel [10] [11] [12] [13].

Cast irons

By casting complex geometries can be produced in a single step or ingots can be cast which are subsequently forged. Cast iron is typically classified according to the form the carbon takes, the most common variants are as follows.

- Cast steel.
- Lamellar (grey) cast iron.
- Nodular cast iron.
- White cast iron.
- Black cast iron.

Thales Nederland only uses cast steel and (perlitic) grey cast iron, therefore only these two are further considered.

Cast steel is an iron-carbon alloy with up to 1,7wt% carbon and typically some Mn and Si. This can be further alloyed to obtain desired properties. If no casting defects occur, the resulting product has similar mechanical properties as hot formed wrought steel of the same composition and heat treatment [4]. This means the strength and toughness are typically better than of cast irons. However the castability is significantly less good.

Grey cast iron is so called because of the colour its fracture surface has. While it should contain at least 2wt% carbon, this is typically around 3,5wt%. It is characterised by the lamellar form the graphite in the microstructure takes. It properties are dependent upon the chemical composition, cooling rate and heat treatment, but general properties are: excellent castability, good machinability, good compressive strength but much smaller tensile strength [4]. The graphite lamella result in brittleness due to the stress concentrations around them, but also provide dampening properties to mechanical vibrations and provide lubrication, making grey cast iron suitable as bearing material.

3.2. Stainless steels

Stainless steel is only a subset of all steels, but may provide distinct benefits over other materials [14]. While they are not corrosion-proof, they typically have good corrosion resistance against acids, moisture and other aggressive environments. They have high strength (compared to mild steels and non-ferrous metals) and can be used at both low and high temperatures. These properties make for durable and low-maintenance products. A wide range of production processes such as machining, cold forming, forging, welding or casting allow for flexible fabrication. The international standard EN 10088-1 defines stainless steel as an iron alloy with at least 10,5wt% chromium and a maximum of 1,2wt% carbon, but to be really corrosion resistant steel should contain at least 11-12wt% chromium [15].

There are multiple systems in use to name stainless steel types. The most commonly used system is that of AISI, which have defined multiple series, based on their properties. For example, a widely used grade is AISI 316. A suffix can be added to indicate a variation, e.g. L for lower carbon content, H for higher carbon content or F for additional sulphur for machinability [15]. The three major series are as follows.

- 200 series: chromium-nickel-manganese alloys.
- 300 series: chromium-nickel alloys.
- 400 series: chromium alloys.

In Europe the material number (or Werkstoff number) is commonly used. Stainless steels start with 1.4XXX. In North-America the UNS system is used more often. In this report stainless steels will be mostly referred to by their AISI name.

Categorization can also be made based on the metallurgical structure, which is as follows. The inclusion in the AISI series are also given.

- Austenitic – 200 and 300 series.
- Ferritic – 400 series.
- Martensitic – 400 series.
- Duplex – combination of austenitic and ferritic, no particular series.
- Precipitation hardening – included in 600 series (630-635).

Austenitic steels are obtained by including chromium, nickel and sometimes manganese. These elements stabilize the austenitic phase such that is remains present at and below ambient temperatures. The 200 and 300 series are quite similar, only in the 200 series part of the nickel is replaced by cheaper manganese. The corrosion resistance of the 200 series is lower than that of 304 [15]. No 200 series steels are used at Thales Nederland.

The austenitic structure of 300 series steels means that they are not hardenable by heat treatment, but can only be hardened by cold work. They are non-magnetic, but can become slightly magnetic due to cold work. They have better corrosion resistance than martensitic and ferritic stainless steels, the addition of molybdenum can increase pitting resistance [15].

Ferritic stainless steels typically have high chromium and low nickel content, limiting structure transformation, which means they are also not hardenable by heat treatment, only by cold work. They have good ductility and corrosion resistance. Ferritic stainless steels are magnetic and perform especially well against stress corrosion cracking [15].

Martensitic stainless steels also have low nickel contents, but higher carbon-to-chrome ratios. Rapid cooling from elevated temperatures allows for the formation of martensite, allowing heat treatment for increased strength. They have high strength and hardness and are magnetic. Their corrosion resistance is lower than that of ferritic stainless steels [15].

Duplex stainless steels typically consist of about 50% austenite and 50% ferritic phase. They have excellent strength and corrosion resistance. The grades containing nitrogen have good weldability. They cannot be hardened and are slightly magnetic [14] [15].

Precipitation hardening stainless steels contain (besides chromium and nickel) also alloyed copper or aluminium. In (solution) annealed condition a limited number of precipitates are present, allowing for good machinability, while an aging treatment (at relatively low temperature) causes precipitate formation resulting in high strength and hardness. During this treatment only limited deformation takes place, which is favourable for size-tolerances. These are also referred to by their nominal Cr-Ni content with the suffix PH, such as 17-4PH. The corrosion resistance is lower than that of duplex stainless steel, about equal to 304 (or the low end of the 300 series) [14] [15].

The formation of these structures can be graphically depicted in a Shaeffler diagram, as shown in Figure 1. The nickel and chromium contents of the alloy influence the formation of certain phases. Other elements have similar effects, only with other magnitudes. Therefore nickel and chromium equivalences are given on the axes, the other elements are weighted according to their influence on the phase formations.

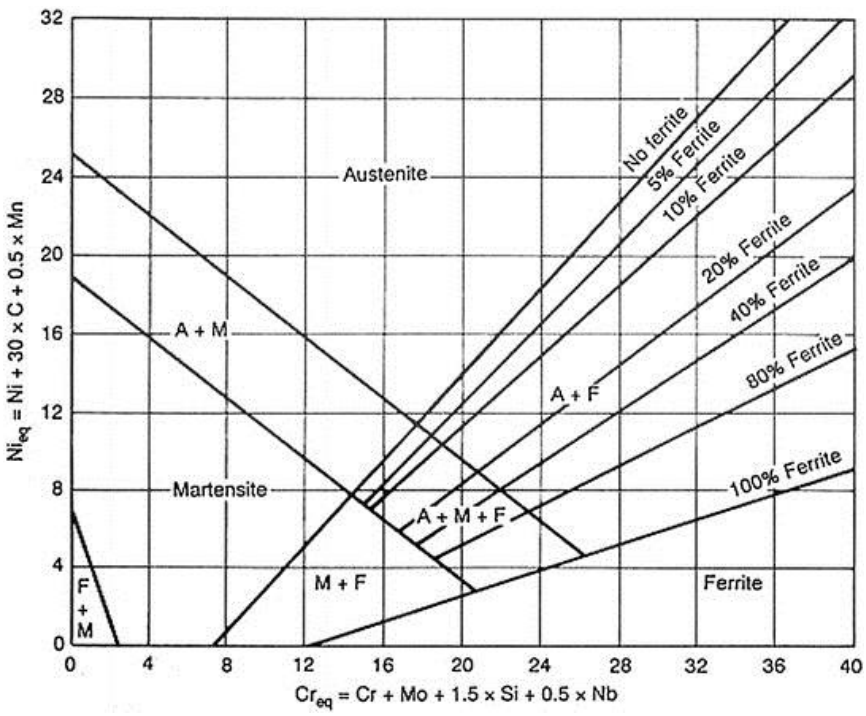

Figure 1. Shaeffler diagram: indicating metallurgical structure of stainless steel as function of nickel- and chromium equivalent composition [16].

The machinability of stainless steels varies with type and grade. Ferritic types with low carbon and chromium have good machinability, but higher carbon and chromium contents pose more difficulties. Especially martensitic types with high carbon contents prove difficult, due to the presence of carbides. These require much lower cutting speeds. Austenitic types also have limited machinability due to their high ductility, cold-reinforcement and low thermal conductivity. The precipitation hardening types are similar to the austenitic types. The machinability rating in the materials table is an index relative to free-cutting steel AISI B1112 (=100) [4].

Sulphur may be added to improve the machinability. The working principle behind this is that it reacts with molybdenum into MoS_2 which segregates, resulting in short chips during (automatic) machining. The same effect can be achieved using selenium, forming $MoSe_2$, however its use has mainly been discontinued (with the exception of 303Se) [14]. The downside of these grades is decreased corrosion resistance and weldability [4]. These are also some of the grades that have proven problematic with respect to passivation. This is further considered in section 4.2.

Passivation is a post-fabrication process that maximizes the corrosion resistance of the stainless steel. In principle, a thin chrome-oxide layer (around 15 nm) is formed when the surface is exposed to oxygen, protecting the material from corrosion. However in practice this layer never fully seals and shop dirt, iron particles (from tooling) and sulphides (from the alloy) may be present at the surface and become initiation sites for corrosion.

A two-step procedure can yield the best possible corrosion resistance: cleaning & degreasing, followed by a treatment in an acid bath [17] [18]. The cleaning step removes foreign particles, which can react with the acid bath and form gas bubbles, which interfere with passivation. The chemical passivation step increases the chromium content at the surface by dissolving some of the iron. Subsequent exposure to air activates and reinforces the chrome-oxide layer, resulting in a stronger and more protective layer. Failure to clean parts can also contaminate the acid bath. The main issue currently at hand with some alloys is best described as flash attack: a darkening, deterioration and roughening of the surface. The effects are shown in Figure 2.

Figure 2. Examples of flash attack on stainless steel parts, compared to an A2 (~304) stainless steel nut.

The corrosion resistance rating and application areas are determined from a salt spray- and temperature-humidity test. The conclusions are given in HSV-P-3048-280. The passivation process is described in HSV-P-3048-281.

3.3. Aluminium alloys

In general aluminium and its alloys have a low density, good corrosion resistance and high thermal and electrical conductivity. They also have a relatively low modulus of elasticity and melting point, therefore the typical maximum application temperature is around 200°C. It has no transition temperature with respect to brittle fracture, resulting in excellent low temperature performance [4] [9]. The most common alloying elements are magnesium, silicon, copper, manganese and zinc [19]. The naturally occurring oxide surface layer (≈0,01 µm thick) can also be created artificially (up to 50 µm) for better protection and high hardness, which is called anodizing. This makes it quite wear resistant, but also hard to solder. The mechanical properties can be improved through cold deformation (or cold work) and precipitation hardening, depending on the alloy. Aluminium exhibits poor fatigue performance, since it does not possess an 'endurance limit' like many other materials.

In 1954 the Aluminium Association (AA) created a designation system for wrought alloys that has since been adopted by ANSI, ISO and EN standards. While largely identical, some alloys are not standardised in one system or another. Designation differs slightly, with the AA requiring the prefix "AA" and EN requiring the prefix "AW" (Aluminium Wrought) [20]. It divides alloys in groups, based on the principal alloying element(s). An overview is given in Table 3.

Wrought series	**Principal alloying element(s)**	**Typical R_m [MPa]**	**Description**
1xxx	Minimum 99.000wt% aluminium	70-190	High purity, not precipitation hardenable, weldable. Excellent corrosion resistance and thermal/electrical conductivity, relatively poor mechanical properties.
2xxx	Copper	190-430	High strength, precipitation hardenable, mixed weldability. Excellent strength over wide temperature range, susceptible to stress corrosion cracking. Low corrosion resistance. 2024 is also known as duralumin.
3xxx	Manganese	110-280	Suited for use at elevated temperatures, not precipitation hardenable, weldable. Moderate strength, good corrosion resistance and formability.
4xxx	Silicon	170-380	Typically used as welding filler material, mixed precipitation hardenability, weldable.
5xxx	Magnesium	120-350	Highest not precipitation hardenable strength, mostly weldable. Excellent corrosion resistance.
6xxx	Magnesium and silicon	120-400	Good strength and formability, precipitation hardenable, weldable. Good corrosion resistance.
7xxx	Zinc	220-610	Highest strength, precipitation hardenable, mixed weldability. Used in aircraft & aerospace for high performance. Limited corrosion resistance.
8xxx	Other elements	n/a	Different alloys, e.g. Al-Li.

Table 3. Description of wrought aluminium series [19] [21] [22] [23].

Unlike the wrought alloys, EN has a separate system from AA for cast alloys. It has the form of A = aluminium, followed by B = ingot or C = cast part. Then a two digit code as described in Table 4. Followed by a digit that is free to choose (for an alloy modification), then a zero, then another zero (except for aerospace alloys) [20] [24]. For example, EN AC 43100 is an AlSi10Mg cast alloy.

First digit	Second digit
2 = Cu	1 = Cu
4 = Si	1 = SiMgTi 2 = Si7Mg 3 = Si10Mg 4 = Si 5 = Si5Cu 6 = Si9Cu 7 = Si(Cu) 8 = SiCuNiMg
5 = Mg	1 = Mg
7 = Zn	1 = ZnMg

Table 4. Description of cast alloy designation according to EN [24].

The casting process is indicated by a suffix, for which the following letters are used.

S sand casting.
K chill or permanent mould casting.
D pressure die-casting.
L investment casting.

The alloy can be work hardened or heat treated, which is indicated with an alfa-numerical temper designation after the alloy designation. Some common temper designations for aluminium alloys are given in Table 5.

Designation	Description
F	**As fabricated** / as cast
O	**Annealed**
W	**Solution annealed**
H	**Strain hardened**
H12	1/4 hard
H14	1/2 hard
H16	3/4 hard
H18	4/4 hard (fully hardened)
T	**Heat treated** (other than F, O, H)
T3	Solution heat-treated, cold worked and naturally aged
T4	Solution heat-treated and naturally aged
T6	Solution heat-treated and fully artificially aged
T651	Solution heat-treated, stress-relieved by stretching a controlled amount and then artificially aged; the products receive no further straightening after stretching

Table 5. Some temper designations for aluminium alloys, according to ISO 3522:2008, EN 485-2:2013 (E), [24].

3.4. Copper alloys

Copper typically has a high electrical and thermal conductivity, about half the worldwide production is used in applications where electrical conductivity is required [13]. It also has good corrosion resistance and is very suited for soldering, but less for machining. Due to its low hardness it tends to smear when machined, but the machinability can be improved by the addition of tellurium. Alloying can increase strength, machinability and/or corrosion resistance, but typically decreases the conductivity. Common alloying elements are zinc (brass), tin (tinbronze), aluminium (aluminiumbronze) and beryllium (berylliumcopper) [4].

The symbolic designation of unalloyed copper is done according to ISO 1190-1. This has the form Cu-XXXX, with XXXX being [24]:

ETP: Refined electrolytically, not deoxidized, with guaranteed conductivity.
FRHC/FRTP: Fire-refined, deoxidized, with guaranteed conductivity.
OF: Deoxidized.
DHC/HCP/DLP/DHP/DXP: Phosphorised coppers with increasing content of residual phosphor.

Phosphor is used for deoxidation of the copper, this may be required to prevent hydrogen (or steam) embrittlement. When exposed to hydrogen at elevated temperatures this may bond with residual Cu_2O inclusions to form water (or steam). This forms (pressurized) bubbles at the grain boundaries, embrittling the material. Deoxidation makes the material very suited for welding and brazing, but does result in a significant reduction in conductivity [9] [13] [25]. Cu-ETP has a conductivity of at least 58 $m/\Omega.mm^2$ while Cu-DHP has about 45 $m/\Omega.mm^2$. Most alloys have even lower conductivity, such as CuZn37 (brass) with about 15 $m/\Omega.mm^2$. Cold work typically decreases the conductivity further [13].

For alloyed coppers the symbolic designation has the form Cu [space], followed by the alloying elements of which more than 1wt% are present and their nominal (integer) amount in wt%. To identify cast alloys from wrought, a prefix is added identifying their casting process as follows [24].

GS: sand moulded product.
GM: chill (permanent) casting.
GZ: centrifugal casting.
GC: continuous casting.
GP: die casting.

The numerical classification is done according to EN 1412, it starts with a C (for Copper), then a letter, three digits and finally another letter. The second letter can be as follows [24].

B: Materials in the form of ingots for re-melting.
C: Materials in the form of moulded products.
F: Filler materials for brazing and welding.
M: Master alloys.
R: Unrefined and refined coppers.
S: Materials in the form of recyclable work materials.
W: Materials in the form of worked products.
X: Non standardized materials.

The three digits are only for differentiation between alloys. The final letter indicates a group of materials including unalloyed copper and which are described in Table 6.

Letter	Group	Description
A or B	Copper	High electrical and thermal conductivity. Good corrosion resistance but is susceptible to hydrogen embrittlement at elevated temperatures, unless deoxidized. Its limited hardness results in poor machinability.
C or D	Low alloy (<5wt% alloying elements)	The addition of 0,1wt% Ag, Cd or Cr increases the recrystallization temperature from ca. 200°C to ca. 350°C. Ag does not decrease the conductivity, while Cd increases the recrystallization temperature somewhat more and increases wear-resistance. With higher alloying contents CuCd and CuCr are precipitation hardenable. Beryllium-copper is also precipitation hardenable and possesses an unmatched (electrical) conductivity-to-strength ratio.
E or F	Various alloy (>5wt% alloying elements)	
G	Copper-aluminium alloys (aluminium-bronze)	Up to 7wt% Al only α-phase is present: this has good cold deformability. Alloys with higher Al contents[1] also have the harder β-phase, limiting cold deformability but possess good hot formability and are often cast. Cu-Al has good corrosion resistance, but may prove difficult during casting. Machinability is good with modified tooling. The addition of Fe reduces grain size, Ni improves corrosion resistance and Mn deoxidizes.
H	Copper-nickel alloys	Cu-Ni has good corrosion resistance (also in marine environments), high ductility, and high yield point. Good cold deformability, poor machinability in soft condition. Addition of Fe or Mn increases strength and erosion-resistance. Can be ferromagnetic.
J	Copper-nickel-zinc alloys	Good corrosion resistance, relatively low price. Silver-white appearance. Can be in cold deformable α- or hot deformable α+β'-phase.
K	Copper-tin alloys (tin-bronze)	Up to 8wt% Sn only α-phase is present, which has good cold deformability, but with higher reinforcement than α-brass. Higher Sn contents also lead to harder δ-phase, resulting in poor cold & hot deformability and is therefore typically cast. This α+δ structure makes it very suitable for bearing material. The addition of Pb improves dry-running of bearings and machinability. The addition of Zn can reduce price, while increasing mouldability and machinability somewhat. Phosphor bronzes have good spring qualities, fatigue resistance, formability, solderability and corrosion resistance.
L or M	Copper-zinc binary alloys (brass)	Up to 38wt% Zn only α-phase is present, which has good cold deformability. Above this value also the brittle β'-phase is present, making the alloy only suitable for hot deformability, with good machinability. The machinability can be further improved with the addition of Pb. It has excellent corrosion and erosion resistance, also in marine applications, for which special alloys with Al, Sn, Mn and Fe are developed.
N or P	Copper-zinc-lead alloys (machining brass)	
R or S	Copper-zinc complex alloys	

Table 6. Description of copper alloys [4] [9] [24] [26] [27].

[1] Up to 11wt% Al the κ-phase may absorb sufficient Al to prevent formation of the β-phase [37].

The final part of the material designation is to define the state, in accordance with EN 1173. This is done with a letter identifying the designated characteristic, followed by a three digit number to indicate the minimum value of that characteristic. The characteristic can be as follows [24].

A Elongation.
B Limit of elastic bending.
D* As drawn.
G** Grain size.
H Hardness (Brinell or Vickers).
M* As manufactured.
R Tensile strength.
Y Conventional limit of elasticity at 0,2% strain.

The designations marked with a * are not followed by digits and ** defines the average value. A fourth digit can be added, e.g. to identify a heat treatment. Finally, the letter S can be added as suffix to indicate a stress relief is required.

3.5. Other metals

In addition to the previous materials, there are two standardized metals that cannot be categorized among the rest: magnesium and lead. While the designation of magnesium starts with HSN-T- (just as the aluminium alloys) it is a significantly different material with different properties.

Magnesium

Magnesium has a low density, good machinability and provides high internal damping of vibrations. However it has a low modulus of elasticity, limited cold deformability and is susceptible to contact corrosion with most construction metals. Due to its limited cold deformability the main strengthening mechanism is alloying, which can be used for solution and precipitation hardening. The main alloying elements are aluminium which increases the yield point and strain at fracture, manganese which increases corrosion resistance and zinc which increases the strength. The combination of zinc and aluminium significantly improves the mouldability [4] [9].

Flammability of magnesium is a function of geometry and environment. It is hard to ignite in bulk, but can easily be ignited when in powder form. Once it burns, it is hard to extinguish since nitrogen, carbon dioxide and water can all sustain the fire. This flammability and its corrosive tendencies make it generally unwanted in naval equipment [28] [29].

Lead

Lead is a soft, malleable metal with a high density and low melting point. It is not suitable for structural applications due to its low strength. Its main use is for balancing and weighting. It is classified as a heavy metal and poses health and environmental risks due to its toxicity [30].

3.6. Plastics, composites and sandwich cores

Plastics and polymers

While sometimes used interchangeably, most plastics are a subset of the broader category of polymers. Polymers consist of a large number of monomers that are joined into extremely long chains. These chains typically have molar masses of 10^4-10^6 g/mol. Polymers can have three different origins: natural, semi-synthetic or fully synthetic. Natural polymers can be from plants (wood, cotton) or from animals (wool, silk). Semi-synthetic polymers can be from wood (cellulose), milk (casein), animal skins (leather) or latex (rubber). Fully synthetic polymers are created in chemical plants from monomers, which can be extracted from coal, oil or natural gas [31].

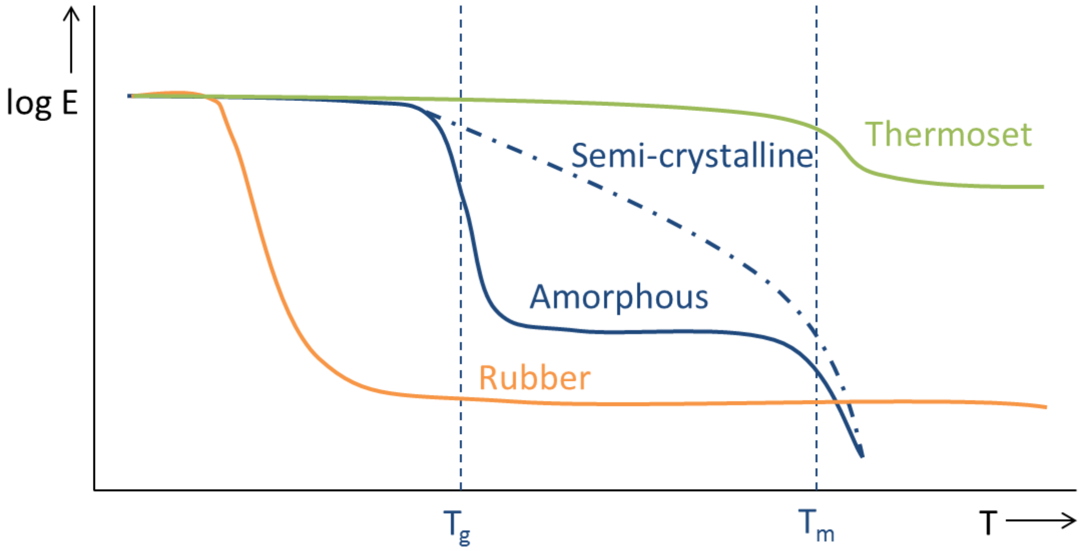

Figure 3. Qualitative plot of polymer stiffness E as a function of temperature T, with glass transition temperature T_g and melting temperature T_m of the thermoplastic indicated. Combined and redrawn from [3] and [31].

Plastics can be divided in three main groups: thermoplastics, (synthetic) rubbers and thermosets [3] [31].

Thermoplastics are polymer systems without crosslinks (inter-chain bonds). With an amorphous structure they behave ‘glassy’ below the glass transition temperature, ‘rubbery’ between the glass- and melting temperature and viscous (or liquid) above the melting temperature. A semi-crystalline thermoplastic behaves similar, only with higher stiffness between the glass- and melting temperature.

Uncured rubbers behave similar to amorphous thermoplastics, however when cured by a vulcanisation process they form crosslinks. This allows them to be subjected to large deformations (up to 600%) and return elastically to their original shape.

Thermosets also form crosslinks, usually at elevated temperatures. The crosslink density is much higher than for rubbers, resulting in a higher stiffness but lower deformability. At high temperatures they soften somewhat, but will not melt. Eventually they degrade at very high temperatures.

Composites

A composite is a material which is composed of two components: a matrix and a reinforcement. Typically the matrix is a resin (thermoplastic or thermoset) and the reinforcement a fibre. Although over-simplified, it can be stated the fibres carry the main loads and determine the tensile strength and stiffness, while the matrix keeps the fibres together and determines the shear and thermal properties [32].

The most common matrix materials are Epoxy (EP), Polyester (UP) and Vinylester (VE). Epoxy can be used for structural applications and radomes and has good reproducibility in prepreg form, but it is the most expensive of the three. Polyester can be processed quickly, resulting in low production costs, but results in a lower quality product and produces harmful gasses. Vinylester is quite similar to polyester, only with improved properties, but worse than epoxy. Fibres are produced from different materials and qualities. The most common materials are glass, carbon and aramid. These are available as prepregs, woven rovings or mats [4].

Thales Nederland primarily uses epoxy as matrix. Glass Epoxy (GEP) is the most widely used for radomes and other covers. Others include Aramide Epoxy (AREP) in the Squire and Carbon Epoxy (CEP) in the Mirador [33].

Sandwich core materials

A sandwich structure consists of skins that are adhesively bonded to a lightweight core. The concept is that the skins carry the bending loads while the core carries the shear load. This results in a structure with high strength and stiffness combined with a low weight. For this reason it is extensively used in the aerospace industry, among others. The core materials used by Thales Nederland are foam and honeycomb.

Foam has isotropic properties and can handle loads in all directions well, including sideways shear, but the acceptable temperature range differs quite a bit. Currently three foams are in use at Thales Nederland: Airex R82 (polyetherimide), Gurit Corecell T400 (styrene acronitrile) and Evonik Rohacell IG (polymethacrylimide) [32] [33]. Airex R82 is a fire resistant structural foam with high stiffness, a wide temperature range and good radar transparency, but also a high price. Corecell has slightly lesser mechanical properties than Airex R82 and not the radar transparency, however its price is around half that of Airex. Rohacell IG is used around the RF components of the radars. At the time of writing Airex T90 is being considered as an affordable foam for future use.

Honeycombs are available in different grades and materials. The mechanical properties are better than that of foam, but sideways shear loading of the cells should be avoided or the cells have to be stabilized using a potting compound. HSV-R-0094/006 indicates three materials and three forms: glassfibre reinforced phenolic resin (Hexcel HRP), aramide reinforced phenolic resin (Hexcel HRH[2]) and aluminium foil (Hexcel CR-III). These can be in hexagonal, overexpanded or flex-core cell form. In addition to this, another glassfibre grade (Euro-Composites ECG), aramide grade (Ten Cate ANA) and second aluminium grade (with different cell size), were found. This is further discussed in section 5.2.

[2] In the HSV-R "HRN" honeycomb is mentioned, which is most likely a typo since this is not a Hexcel product and the corresponding BSPs also indicate "HRH".

4. ELIMINATION CANDIDATES

An integral part of the assignment is the identification of elimination candidates. This is done in two steps: first based on usage and subsequently on properties. Rarely used or dated materials allow for a simple clean-up of the standardized materials, because most are not used in current systems. The following step, elimination based on properties, is more comprehensive, since all relevant data has to be evaluated and possible applications have to be considered.

4.1. Based on usage

Some materials have been introduced in the past and have never been applied or were only used in a single system. These should be excluded from the standardized materials stock since documentation maintenance is wasteful. Should the need for the material arise for a new design, sourcing a dated specification will probably be harder than introducing a new material.

Methodology

As part of the material overview the number of 12ncs per HSN have been determined. This is typically done three times since materials are designated in KIS by their HSN number, in-house name and/or old name. This can be interpreted as the number of sizes a material is available in. To determine the number of applications a Single Level Implosion (SLI) can be done per 12nc in KIS. Since this has to be done manually for each 12nc, it is assumed that if there are a lot of 12ncs per material (around 10 or more) it is commonly used and no SLIs are done.

This choice has been made from a practical perspective, but it is easy to see that the assumption is not correct. For example, two aluminium alloys, HSN-T-423 and HSN-T-880, both have nine 12ncs, but the first has a single SLI, while the latter has 142. Similarly, steel HSN-N-1269 has six 12ncs but not a single SLI. The scope of the project did not allow checking every 12nc or developing an automated system to do this, so the focus will be on the “low hanging fruit” for now.

While the number of SLIs is a measure for how much a material is applied, this does not say whether this is for an old (legacy) system or for currently marketed equipment. To determine this the 12ncs are brought up in Windchill, which has the “Where Used” function. This may result in hundreds (or sometimes thousands) of entries. When going through the expanded structure, often system names can be recognised, or projectnames. While often successful, not all projectnames (e.g. 191NE) can be back-traced to a (single) system.

For older systems, or when only a projectname could be found, the purchase specification or BSP of the material has been retrieved. While current products can still be ordered according to older specifications, it is a measure for when the material was introduced and therefore its age.

No substitution materials are suggested in this section since the materials described here are no longer used, in a new design the designer will select a suitable material. Also note that no cast materials are included since castings are not linked to their base material in KIS, so no 12ncs can be determined for these materials.

Candidates

Materials that are not or no longer used are given in the tables below, with their applications if found. These are preferably system names since these give a clear indication of the age. Alternatively product codes are given. Currently these are 12ncs, but for these materials only older codes[3] are found (such as VAG16A16). Additional information may be given in between brackets, such as the oldest and newest date of possible BSPs.

A number of steels have been identified for elimination. This is no surprise as stainless steel has become widely used. Two tool steels, two carbon steels and two special alloys are identified. 'Soft Magnetic Steel' is used for continuous current relays while 'Nickel Iron' is described as a thermostat alloy for its low coefficient of expansion.

HSN-N-297 spring steel has only been found in old applications, but due to the large structure not every application could be checked. Therefore it is incorporated in the next section based on properties.

HSN-N-	Old	#12nc	#SLI	Name	Application(s)
1019	-	0	0	Alloy cold work tool steel	-
1054	SNST	12	2	HSS tool steel	VAG16A16, VAG13/18 (BSP 1975-81)
1269	CRMST2	6	0	Steel	-
312	ST2	1	1	Steel	- (EBE55L32)
398 (HSV-N-9510)	MAGN.YZ	8	2+1	Soft Magnetic Steel	Flycatcher, WM22, Lirod, PRTL
005	NIKK.YZ	4	12	Nickel Iron	- (BSP 1975-83) (Thermostat alloy)

Table 7. Steel elimination candidates.

In addition to regular steel, also two stainless steel candidates are identified. The first is AISI 420, which has only one use. It is also considered in the next section, where AISI 431 is suggested for its replacement. The second candidate, AISI 416, also appears to have only one application in an old system. However it is also used in forgings, for which the products are not linked to their base material (just as with castings).

HSN-N-	Old	#12nc	#SLI	Description	Application(s)
1188	RVST15	1	1	AISI 420	Flycatcher
1272/01	RVST11	8	1	AISI 416	LW08 (amount for forgings unknown)

Table 8. Stainless steel elimination candidates.

Most aluminium (alloy) grades are either cast or have current applications. The only exception is HSN-T-423 which is a high purity grade containing at least 99.5wt% aluminium. Given its poor mechanical properties this is mainly used when high conductivity is required. Apparently for those applications HSN-T-136 is more often used, which is the same alloy only cold worked.

HSN-T-	Old	#12nc	#SLI	Description	Application(s)
423	ALK11	9	1	1050A (99.5%)	WM22

Table 9. Aluminium elimination candidate.

[3] These are estimated to be from before 1980.

Four copper alloys are identified for elimination. Sintered bronze is only used in the Flycatcher (Mk1). Unalloyed oxygen-free copper has no uses, while there are two alternatives which are deoxidized. HSN-R-1266/02 is one of three brasses and the other two are much more used. Finally HSN-R-2601 has no applications, but is a precipitation hardening alloy, introduced as a more affordable alternative to beryllium copper (HSN-R-716). A choice has to be made whether to start using this material or eliminate it again.

HSN-R-	Old	#12nc	#SLI	Name	Application(s)
1384/01	SBR1	2	3	Sintered Bronze	Flycatcher
1156/01	CU10	0	0	Copper Oxygen-free	-
1266/02	MS2	8	10	Copper alloy	WM22, DA05
2601	-	0	0	Copper alloy	-

Table 10. Copper alloy elimination candidates.

From the “other metals” only magnesium is not used. It is unwanted in naval applications for the fire-hazard it poses and has no current applications.

HSN-T-	Old	#12nc	#SLI	Description	Application(s)
1095	MG1	3	0	Magnesium	-

Table 11. Other metals elimination candidate.

The following plastic elimination candidates have been found. With the exception of PA11 all are barely used, or only in old systems. PA11 has a lot of SLI's, but can no longer be bought as semi-finished product, only as injection moulded part[4].

PA11 is a polyamide (or nylon) with good resistance against many substances. Its properties are between those of polyamides (with good resistance hydrocarbons) and polyolefin (which have good acid, alkali and salt resistance). In addition it is almost insensitive to humidity and is supple and impact resistant. It has good sealing properties, making it suitable for hoses. Its application temperature range is from –60°C to +150°C [34].

Knowledge of the applications of this material is required to find a suitable replacement, therefore no suggestion for replacement is presented here.

Standard	Abbreviation[5]	Description	#12nc	#SLI	Application(s)
HSN-K-332	PA11	Polyamide	36	?	?, also "PA". No longer available except for injection moulded parts
HSV-R-2012-002	CG	Koolstof-glas	0	0	-
HSV-R-2012-002	CGEP	Koolstof-glas-epoxy	1	0	- (BSP 1987)
HSV-R-2012-002	FOILBOARD	Foilboard	4	0	- (BSP 1974, 91)
HSV-R-2012-002	KARTON	Karton	2	0	- (BSP 1973)
HSV-R-2012-002	MAGN.BAND	Computer tape	2	0	- (BSP 1970)
HSV-R-2012-002	PES	Polyethersulfon	1	0	- (BSP 1988)
HSV-R-2012-002	RF.ABS	RF absorptie-materiaal	1	0	- (BSP 1970)
HSV-R-2012-002	PCFE	Polychloortrifluor-etheen	1	1	DA… 323DU, 191/200/250/254NE, 48/49BE, 18SI (BSP 1971)
HSV-R-2012-002	LINOLEUM	Linoleum	2	2	DA… 191/200/648NE, 323/444DU (BSP 1969, 79)
HSV-R-2012-002	POLAROID	Polarisatiefilter	2	12	4EQ, 30VE, 38PE, 8TU, 23CO (BSP 1972)
HSV-R-2012-002	PERGPAPIER	Pergamijnpapier	5	81	250/343/358/530NE, 38SG, 131AU (=CAS) (BSP 1971)
HSV-R-2012-002	MULTIPLEX	Multiplex	5	9	- (BSP 1976)
HSV-R-2012-002	ABS	Acrylonitril-butadieen-styreen	5	1	LW08 (BSP 1984)
HSV-R-2012-002	PP	Polypropeen	1	3	229GR (=CAS) (BSP 1971)

Table 12. Plastics & composites elimination candidates.

[4] Indicated by Charles ten Buuren.
[5] Per HSV-R-2012-002.

4.2. Based on properties

The cost of the (raw) material has only a limited contribution to the overall cost of the final part. Other processes such as machining, surface treatments, storage etc. also contribute, especially if they have to be fine-tuned to each material. Because of these additional steps, which need preparation, documentation and upkeep, it can be economical to reduce the material stock even further, accepting the fact that sometimes superior or “too expensive” grades are used for some applications. While cost analysis and overall cost optimization are outside the scope of this assignment, a cost indication may be given if available.

Suggestions are made for “old” and “new” materials. Both are currently standardized materials, but this indicates what material is an elimination candidate (old) and by which material it could be replaced (new).

Stainless steel

Five of the eight martensitic stainless steels have been problematic with respect to passivation and even the other three still have a low risk for flash attack (see section 3.2). All grades that require a treatment with sodium hydroxide (NaOH) have a high risk or have no solution. This step is indicated by the letter I in the material tables (appendix D.).

To avoid difficulties with passivation, and to further reduce the amount of standard materials, it is investigated whether these grades can be replaced by another grade that is already standardized which does not have passivation problems. For reference, two sources of hardness for a range of tempers are given in appendix C. , as well as indicative chemical compositions. Only the hardness range of Interlloy is presented here, since they are a bit higher than those of Atlas and Thales Nederland typically tempers the products even slightly harder. The machinability is an index rating from [4] relative to free-cutting steel AISI B1112 (=100).

Property	Old	New
HSN-N-	1188	1252/01
Designation	420	431
Form	Bar	Bar, profile, wire
Yield strength [MPa]	500-600	600-750
Tens. Strength [MPa]	700-850	850-950
Hardness standard [HB]	230 +A	295 +A
Hardness TNL [HB]	<262 +QT700	<270 +QT800
Hardness range [HB]	262-495	270-410
Machinability	45	45
Corrosion resistance Exposed + painted / Sheltered + air	No/Yes	Yes/Yes
Passivation status	No solution	Low risk

Table 13. Stainless steel AISI 420 and 431 properties.

AISI 420 and 431 have very similar carbon contents, 431 has higher chrome and nickel contents, but less silicon. Its strength is higher at the same machinability and with better corrosion resistance. While 420 can be hardened to a higher degree[6], it is bought in +QT700

[6] The HSN indicates it is hardenable, which is not the case since it is bought in +QT condition. This is incorporated in the proposed changes in section 5.3.

condition and 431 in +QT800. The numbers indicate the tensile strength, which typically scales with hardness. As described in the previous section, 420 is only used in the Flycatcher Mk1, which is an older system. Therefore the elimination is not expected to give any problems and 431 seems a superior material for new designs.

Property	**Old**	**New**
HSN-N-	1024	440/03
Designation	420C	440B
Form	Bar	Bar, section
Yield strength [MPa]	650-700	-
Hardness standard [HB]	245 +A	265 +A
Hardness TNL [HRC] (hardened)	52-57	57-59
Machinability	- (<45)	40
Corrosion resistance Exposed + painted / Sheltered + air	No/No	No/No
Passivation status	No solution	Low risk

Table 14. Stainless steel AISI 420C and 440B properties.

AISI 420C is a high-carbon modification of 420 and is primarily used when high hardness is required. At Thales Nederland it is hardened to 52-57 HRC, 440B is the only other stainless steel that can also be hardened to or above this level. It has a much higher carbon content, more chromium and also molybdenum and vanadium added. This allows it to be hardened to 57-59 HRC[7]. It is currently only used in one application, so an analysis of different tempers may allow a wider range of properties. I.e. a higher temper temperature will result in a lower hardness, closer to the current 420C specification. Its corrosion resistance is similar and machinability is not expected to be much worse, since 420C will be more difficult to machine than 420 (index 45) given its higher carbon content. The higher contents of alloying elements probably result in a higher price for 440B.

It can be investigated whether AISI 440C is also suitable as an alternative to both. It has even higher carbon content, but also better availability. It has a hardness typically 2 HRC above that of 440B [14], but may provide similar properties in a moderate temper.

Property	**Old**
HSN-N-	1176
Designation	410
Form	Bar
Yield strength [MPa]	450-550
Hardness standard [HB]	220 +A
Hardness TNL (hardened)	350-450 HB 38-47 HRC
Machinability	55
Corrosion resistance Exposed + painted / Sheltered + air	Yes/Yes
Passivation status	No solution

Table 15. Stainless steel AISI 410 properties.

[7] Not mentioned in HSN, there is no HSV-P for its heat treatment since there is currently only a single application with 12nc = 3522 346 0869.

The properties of AISI 410 in hardened state are between those of 431 and 440B. While 431 may be hardened to a similar level as 410, it is bought in +QT800 condition, therefore this is not an option. Buying 431 in +A condition and hardening it to a hard temper is an option which can be investigated. AISI 440B is much harder and has vastly inferior corrosion resistance. Also 17-4PH comes close, but does not have sufficient hardness in its hardest condition of 247-371 HB (= 22-40 HRC) [HSV-P-4270/002]. This may still be suitable for some applications, but it is rather more expensive.

The other problematic passivation AISI grades, 303, 416 and 430F, are all free machining grades and do not have clear solutions. AISI 303 could be replaced by 304(L) since the mechanical properties are similar, but 303 is especially selected for its machinability, therefore 304 is not expected to perform sufficiently. AISI 416 has such a unique combination of properties that no other grade gets close: 431 has much higher strength and 430 quite a bit less. Both have less than half the machinability rating. Mechanically and corrosion-wise 431 could also replace 430F, but again its machinability is expected to be significantly lower.

Steel

From the iron and steel group, alloy spring steel in strip form has been identified, which could be replaced by a stainless spring steel. The strength and hardness are vastly superior, but the elastic modulus is lower.

Property	Old	New
HSN	HSN-N-297	HSN-N-939
Name	Spring steel	Stainless spring steel
Form	Strip	Strip
Modulus [GPa]	≈ 205 [4]	185
Yield strength [MPa]	530	≈ 800 [4]
Hardness [HV]	205	250-600

Table 16. Steel and stainless steel spring steel properties.

The amount of spring energy an elastic spring can store is proportional to the elastic limit squared divided by the elastic modulus, or in equation form $E_{spring} \propto \sigma_p^2/E$ [4]. Thus the resulting ratio of stored energy for the two spring materials becomes

$$\frac{E_{stainless}}{E_{steel}} = \frac{\sigma^2{}_{p,stainless}/E_{stainless}}{\sigma^2{}_{p,steel}/E_{steel}} = 2{,}56$$

This means the stainless steel spring material can store over 2,5 times as much energy as the spring steel with the same dimensions, making it in principle a better spring material. However the elastic modulus is lower, therefore if the material is replaced in an existing design the spring rate will change. This may not be problematic if the spring just functions to make contact (e.g. for EMC applications) but it will be if the spring rate must be within a specific range. With replacement in a current design there is also the risk for (accelerated) galvanic corrosion of a (less-noble) contacting body.

Applications of the spring steel include: Flycatcher Mk1, ZW06, LW08, DA05 and WM22, all older systems. Its BSPs range from 1971 to 1982 indicating it is already in use for a long time. However not all applications could be determined due to the huge “where used” tree. Therefore it is suggested to exclude HSN-N-297 for new designs. Due to the large amount of applications there is a serious risk of malfunctioning systems if older parts are simply reproduced with the new material.

Aluminium

For wrought aluminium profiles Thales Nederland has 4 HSNs. Two are the same EN AW 6082 alloy, only with different heat treatment (T4 and T6). The other two, which are given in the table below, are especially good extrusion qualities.

Property	Old	New
HSN-T-	1051/80	1089/01
Designation	6060	6005
Form	Profile, tube	Profile
Yield strength [MPa]	150	200-225
Tensile strength [MPa]	190	250
Treatment	T6	T6
Extrusion speed	115	80
Extrusion tolerance	95	115
Price	100	90

Table 17. Wrought aluminium EN AW 6060 and 6005 properties.

The extrusion speed, extrusion tolerance and price are an index by Mifa [35], which is relative to EN AW 6063 (=100). 6005 has a lower extrusion speed, higher material price and lower tolerances, however with the higher strength less material may be required, reducing the increased cost of the material and processing.

Both might be replaceable for some applications by 6082 (HSN-T-633/80) which has higher strength, but this is a lesser extrusion quality. The two alloys in the table above have “maximal shape freedom” at Mifa, while 6082 has not. 6082 has an extrusion speed index of 40, tolerance index of 80 and price index of 160. In addition, 6060 is ‘feingerichtet’ while 6082 is ‘normalgerichtet’ (HSV-N-9540-001) in accordance with DIN 1748-4-1981[8].

[8] This standard is superseded by EN 755-9, which is not available at the time of writing.

Two cast aluminium alloys are quite similar, both can be sand- or permanent cast and are described in the following tables. HSN-T-1072/91 and /92 describe two alloy grades that meet the requirements, therefore both are considered. As already described in section 4.1, no application data is available for cast materials, so that information cannot be used during this evaluation. In addition to sand- and permanent casting, HSN-T-1072/93 describes the same alloy for investment casting.

Property	**Old**	**Old**	**New**
HSN-T-	1024/45	1024/92	1072/91
Designation	43100 AlSi10Mg(b)	43100 AlSi10Mg(b)	42000 & 42100 AlSi7Mg(0,3)
Form	As cast	Sand cast	Sand cast
Yield strength [MPa]	80	180	180
Tensile strength [MPa]	150	220	220
Treatment	F	T6	T6

Table 18. Sand cast aluminium EN AC 43100 and 42000/42100 properties.

Property	**Old**	**Old**	**New**
HSN-T-	1024/43	1024/93	1072/92
Designation	43100 AlSi10Mg(b)	43100 AlSi10Mg(b)	42000 & 42100 AlSi7Mg(0,3)
Form	As cast	Permanent cast	Permanent cast
Yield strength [MPa]	90	220	220
Tensile strength [MPa]	180	260	260
Treatment	F	T6	T6

Table 19. Permanent cast aluminium EN AC 43100 and 42000/42100 properties.

The strength of both alloys is the same in T6 condition, as is the magnesium content of EN AC 42100 and 43100. The referenced standard (EN 1706:2010) allows for more impurities in 42000, including a wider Mg range. For relevant differences one has to look further than just the strength or composition of the alloys.

The melting trajectory of AlSi10Mg is between 557-582°C and of AlSi7Mg between 500-610°C [4]. This can be explained since the latter is further away from the eutectic point of 12,7wt% Si in the Al-Si phase diagram[9] [36]. This also contributes to the decrease in fluidity described in the governing standard, which is reproduced in the table below. While the proposed change may limit the maximum complexity of castings somewhat, they will have better corrosion resistance and ductility. Here the increase in allowable impurities of 42000 compared to 42100 also shows its effect in inferior properties.

Property	**43100**	**42000 & 42100**
Fluidity	Excellent	Good
Corrosion resistance	Fair	Fair-good (42000) Good (42100)
Weldability	Excellent	Good
Ductility (shock resistance)	Fair	Fair (42000) Excellent (42100)

Table 20. Differing properties of the aluminium alloys, from EN 1706:2010.

[9] For these alloys it may be slightly different due to the addition of Mg, but still close to this value.

Copper

As described in section 3.4, unalloyed copper comes in different qualities. Thales Nederland has standardized two grades of Cu-ETP (refined electrolytically, not deoxidized, with guaranteed conductivity). Their properties are given in the following table.

Property	Old	New
HSN-R-	1170/65	132
Designation	CW004A	CW004A
Condition(s)	R240 – H065	R290 – H090
Form	Sheet, strip	Bar, tube, sheet, strip
Yield strength [MPa]	>180	>250
Tensile strength [MPa]	240-300	290-360
Strain A_{50} [%]	>8	>4
Hardness [HV]	65-95	90-110
Treatment	ETP	ETP

Table 21. High-purity Cu-ETP properties in two conditions.

These are different in their treatments, R290/H090 has been cold worked more than R240/H065 resulting in higher strength but lower strain at failure. Also conductivity tends to decrease when a material is worked more. However, since ETP has a guaranteed conductivity this is not expected to be problematic. Also HSN-R-132 is available in more product forms.

Aluminium bronze is typically used for its combination of high strength and excellent corrosion- and wear resistance. The microstructure consists of an α-phase in which Al is soluted in Cu and a Fe & Ni rich κ-phase. The κ-phase absorbs Al from the α-phase, preventing the formation of the brittle β-phase upon quenching. This only happens up to 11wt% Al, above which the β-phase will form, reducing the ductility of the alloy and/or requiring tempering. The addition of Fe and Ni also suppress the γ''-phase, which degrades the properties significantly [37].

The two alloys given below have a nominal Al content below 11wt%, therefore the formation of the β-phase will be limited in both. The replacement candidate has higher alloy contents of Al, Fe and Ni. This should suppress the γ''-phase more. Also since the strengthening of the alloy is a combination of solid solution hardening and precipitation hardening (and cold work), the increase in alloying elements will typically result in better properties, which also becomes clear in the table below. The only inferior property is the strain at fracture.

Property	Old	New
HSN-R-	1047	108/70
Designation	CW303G	CW307G
Form	Bar	Bar
Yield strength [MPa]	180	350
Tensile strength [MPa]	460	650
Strain A [%]	30	12
Composition	CuAl8Fe3	CuAl10Ni5Fe4

Table 22. Aluminium bronze CW303G and CW307G properties.

It is assumed that HSN-R-108/70 can replace HSN-R-1047 in nearly all applications. It is already included in HSV-N-9530 while HSN-R-1047 is not, probably resulting in limited application of the latter. The only concern is a possibly significant price difference due to the increase in alloying elements, especially Ni.

5. DOCUMENTATION UPDATE

5.1. External standard references

In the following (internal) HSN standards a reference is made to an external standard which is no longer up to date. If there are no relevant changes (with respect to the specified material) the reference in the HSN can be updated. If there are relevant changes they are briefly discussed below. These changes have to be evaluated thoroughly before the HSN can be updated.

HSN-	Referenced standard	Latest standard	Relevant changes
N-925	ISO 683-9:1988	ISO 683-4:2016	Yes: alloy removed
N-1272/01	ASTM A582/A582M-12 (ε1) ASTM A473-13	2017 2017	No No
T-668; T-669; T-633/80; T-633/01	EN 485-2:2013	2016	No No No No
T-1089/01; *T-1051/80; T-633/80	EN 755-2:2013	2016	No Yes: dimensions No
T-1086/01	EN 754-2:2013	2016	No
R-019; R-1161/65 *R-1266/02	EN 12449:2012	2016	No Yes: thickness & A% No
R-2601	EN 12163:1998 (FROZEN)	2016	Yes: alloy removed
R-1179/16 R-108/70	EN 12163:2011	2016	No No
R-108/70	EN 12420:2012	2014	No
R-1338-01	EN 12164:2011[10]	2016	No

*Table 23. Outdated references in HSN standards. Materials marked with an * have been identified as elimination candidates in the previous chapter.*

HSN-N-925 is affected by the updated standard since 11SMnPb28 has been removed. It can be investigated whether it can be replaced by 11SMnPb30, which is close in composition and is included in the updated standard.

HSN-T-1051/80 is affected since the dimensions of the profiles for which certain properties are indicated have changed, which can result in different properties for some profile sizes.

HSN-R-1161/65 is affected by the updated standard, since the thicknesses and corresponding stain at failure (A%) have been changed.

HSN-R-2601 refers to the frozen EN 12163:1998 standard, because in the 2011 version the material was excluded. It is not included in the 2016 update, therefore the reference should remain to the frozen standard from 1998.

HSN-R-108/70 has the product form ‘bar’, which is governed by EN 12163, however sizes larger than 120 mm are not included in the standard. Therefore EN 12420 is being referred to, which applies to forgings, but is apparently indicative for large sizes.

[10] The HSN indicates CW118C I.A.W. EN 12164:2011 meets the Thales composition requirements, however there is 0,001wt% difference in P content specification.

In HSN standards also similar materials, or materials that meet the specifications, are described. The standards referred to in this context are given in the following table.

HSN-	Referenced standard	Latest standard	Relevant changes
N-312	EN 10139:1997	2016	No
N-1269/01	ISO 683-2:2012 EN 10263-4:2001	2016 2017	No No
N-1131/01	ISO 683-9:1988	ISO 683-4:2016	Yes: composition
N-116; N-371; *N-1176; *N-1188; N-1252/01; N-440/03; N-2205	ASTM A276/A276M-15	2017	No No No No No No No & No[11]
N-371; N-2205	ASTM A240/A240M-15	2017	No No & No[11]
N-630	SAE AMS 5643S:2013	SAE AMS 5643V:2018	Yes: composition & hardness
N-1279/01; N-1279/02; N-1279/03	SAE AMS 5355J:2009	SAE AMS 5355J:2015	Yes: composition & mechanical properties
T-423	EN 485-2:2013	2016	No
T-136	EN 754-2:2013	2016	No
T-1019-91	ASTM B26/B26M-12	2014 (ε15)[12]	No

*Table 24. Outdated references for similar materials in HSNs. Materials marked with an * have been identified as elimination candidates in the previous chapter.*

HSN-N-1131/01 is affected by a minor difference in composition.

For HSN-N-630 there are slight differences in composition and hardness.

For HSN-N-1279/01, /02 and /03 there are differences in composition specified and very minor discrepancies in mechanical requirements.

HSN-T-1072/91, /92, /93 and HSN-T-1024/43, /45, /92, /93 all have “former similar material” descriptions in their document which refers to DIN 1725 teil 2 – 1986, which has been updated to DIN EN 1706:2013. This is only a German translation of EN 1706:2010, which is the governing standard of the main material. Therefore these sections can be removed from the HSN standards.

[11] HSN-N-2205 describes two similar grades.
[12] 2018 is the latest update, but was not available at the time of writing.

5.2. Honeycomb overview

HSV-R-0094-006 provides an overview of honeycomb materials, however it was noticed that this overview was neither complete, nor entirely correct. Matters got worse when it turned out that also (bought) parts and subassemblies were named “honeycomb” or “honingraat” in KIS/Windchill. Therefore the following overview of honeycomb materials has been composed. The subject has already been briefly covered in section 3.6. The mechanical properties have also been determined and are given in appendix D. The 12ncs of the honeycombs not currently included in HSV-R-0094-006 are given with footnotes. In addition sometimes the honeycomb is specified on drawings in text, primarily with HRP for ‘complex bought parts’.

Type	Cell shape	Material	Remarks
Hexcel HRH-10-3/16-3,0 (HRH-10-4,8-48)	Hexagonal	Aramidefibre reinforced phenolic resin (Nomex)	Average strength, low stiffness, good dielectric properties, low thermal conductivity, excellent environmental resistance, service temperature up to 175°C. Mostly applied in overexpanded form, which can be bent with a radius of 10 times its thickness.
Hexcel HRH-10/OX-3/16-3,0 (HRH-10/OX-4,8-48)	Overexpanded, rectangular		
Hexcel HRH-10-F35-2,5	Flex-Core		
Hexcel CR-III-1/4-5052-0,0015P-3,4	Hexagonal	Aluminium (foil)	High strength and stiffness, bad dielectric properties, high thermal conductivity, good environmental resistance, service temperature up to 175°C. Not suitable for radomes.
Hexcel CR-III-1/8-5052-0,002P-8,1	Hexagonal		
Hexcel HRP-3/16-4,0 (HRP-4,8-64)	Hexagonal	Glassfibre reinforced phenolic resin	High strength, average stiffness, excellent dielectric properties, low thermal conductivity, excellent environmental resistance, service temperature up to 175°C.
Ten Cate ANA-4,8-48 OX	Overexpanded, rectangular	Aramidefibre reinforced phenolic resin (Nomex)	Average strength, low stiffness, good dielectric properties, service temperature up to 180°C.
Euro-Composites ECG-4,8-64	Not indicated	Glassfibre reinforced resin	High strength, average modulus. Only mechanical properties available. Used in STIR (UC).

Table 25. Overview of honeycomb types in use by Thales Nederland [38] [39] [40] [41] [42] [43] [44].

Most honeycomb materials have the following designation: “*material – cell size – density*”, with the material a brand specific designation, cell size in inch or mm and density in lb/ft^3 or kg/m^3. Sometimes additional information is included, for example to indicate cell shape (OX or F) or additional material properties. The latter is done for aluminium honeycomb, indicating the alloy (here 5052), foil thickness (in inch) and foil state (P for perforated, N if not). Flex-core is an exception with respect to the cell size indication, since it is designated with the number of cells per lineal foot in W direction.

Hexagonal cells cannot be bend, but can be ordered as (3D) curved parts. Overexpanded cells can be bent in one direction, with a radius that is material dependent. Flex-core has triangular cells and can be bent in two directions, but is very expensive. Hexagonal cell honeycomb section can be combined by 'tapping' them together with an overlap of ca. 1 cm or by locally 'potting' the cells [32].

Hexcel HRH-10 (aramidefibre reinforced phenolic resin) appears to be the most widely used honeycomb, given its large number of 12ncs. However Ten Cate ANA-4,8-48 OX[13] has been introduced for the Squire (only one size), which is a very similar material. It is not clear why this has been done. No BSP is available, in Tidus it is stated that this is not required since it is a standard material for Ten Cate. It can be useful to evaluate why the Ten Cate honeycomb has been introduced and whether one of the two aramide-honeycombs can be replaced by the other to further reduce the material stock.

The aluminium honeycombs have a limited number of 12ncs and BSPs have been found for a grade that was not yet described in the HSV-R. Given the low amount of 12ncs, the applications have been determined as follows.

CR-III-1/8-5052-8.1 in SMART-S Mk2 and Mirador.
CR-III-1/4-5052-3.4[14] (T = 13mm) in Lirod.
CR-III-1/4-5052-3.4[15] (T = 52mm) in SMART-S Mk2, Variant, APAR, Mirador, MW08.

Since it is not indicated whether this concerns the Lirod Mk1 or Mk2 it cannot be concluded whether this is outdated. Besides this would only mean a single 12nc (or dimension) is eliminated and not the material itself. Therefore this would not be much use.

Finally Hexcel HRP[16] is a glassfibre reinforced phenolic resin with higher strength than HRH, with improved dielectrical properties making it even better suited for radomes. It is expected this is also the case for Euro-Composites ECG[17], since this has been used for the small cap on one of the STIR family radars, where the RF radiation energy is very high. ECG is used in the current (unified-casting) version. For the high powered variant this is made of quartz glass. The description in KIS is wrong, since this indicates it ECG is bought from Hexcel and should be changed. It would be interesting to trace back why the choice for ECG has been made and to determine whether both HRP and ECG should be used side by side, or whether one can replace the other.

[13] 12nc = 3208 006 00001.
[14] 12nc = 0422 028 98003.
[15] 12nc = 0422 028 98004.
[16] 12nc = 9556 005 06800.
[17] 12nc = 3522 500 49602.

5.3. Change proposals

This section provides a short overview of the change proposals considered during this assignment. Subjects that have already been covered are only briefly mentioned.

In the previous section an expanded overview of honeycomb materials is presented. Here it is suggested that it can be investigated whether some grades can be replaced by others made of similar materials. It is advised to do this first and subsequently update the governing HSV-R-0094-006. If this cannot be done the previous section can still provide a basis for an update of the HSV-R, which would provide designers with a more complete overview of available honeycombs.

One of the difficulties in making the overview was the fact that Euro-Composites ECG honeycomb[18] is described in KIS as a bought part from Hexcel, which is confusing and wrong. This should be changed in order to prevent future mistakes.

In HSV-R-0094/006 one of the composite resins is consequently called “Venylester”. This does not appear to be a common name in English or Dutch. It can be considered to change this into the more commonly used “Vinylester”.

HSV-R-0079 says HSN-N-1101/60 (AISI 430) is not applicable in marine environments, around chloride-ions or below 0°C. Most literature on this subject, including Handboek RVS [15], indicates that ferritic stainless steels are more resistant to stress corrosion cracking than austenitic types, especially in chloridic environments. Given the most common application area of Thales Nederland products (marine environments) it appears critical to the functioning of the radar systems to properly know the limitations of this material. Also, if its performance is superior to other grades, this could improve the durability and safety of future designs.

Aluminium alloy EN AW 6061 T6 is available in profile and sheet, but is only included in HSN-T-880 with the product form ‘waveguide’ (a specific profile). Its mechanical properties are close to those of 6005 but without the extrusion freedom. It is arguably the most widely used 6000-series alloy, which can result in a relatively low price, but this does not show in the price index found. It can be investigated whether the waveguides currently made of 6061 can be made from 6082 profiles, which would mean a further stock reduction. With respect to sheet alloys, there are already 5000 and 7000 series sheets in addition to 6082. Therefore it does not seem necessary to add that product form either.

HSN-T-	**EN AW**	**R_m** [MPa]	**R_p** [MPa]	**Price index**	**Profile freedom**	**Sheet**	**R_p/price**
1989/01	6005	270	225	115	Yes	No	1.956
*1051/80	6060	190	150	95	Yes	No	1.579
633/80	6082	310	260	160	No	Yes	1.625
880	6061	260	240	120	No	Yes	2.000

*Table 26. Aluminium profile alloy properties [35]. Material marked with an * indicates a current elimination candidate.*

[18] 12nc = 3522 500 49602.

In addition to the updated references to standards (which can be found in section 5.1) there were some minor aspects encountered in HSN standards that can be changed. These are as follows.

HSN-N-1113 does not specify a product form. Two BSPs were found: for bar[19] and strip[20]. These forms should be specified on the HSN.

In HSN-N-1188 “Bar hardenable” is stated in the header and document name, but is bought in quenched and tempered condition +QT700 and is thus no longer hardenable. This should be removed from the HSN.

HSN-T-1051/80 has a typo in the header, which states “HSN-N-T-1051/80” and can be changed.

HSN-R-160 has “Quality and finish” as regular text instead as the usual header. The formatting can be changed and numbering added.

HSN-R-1179/16 has the description “Bronze” which (while correct) can be further specified as “Phosphor bronze”. HSN-R-337 “Phosphor bronze” has the same phosphor contents and the material is already described as “Phosphor bronze” in HSV-R-2012-001.

HSN-R-1338/01 has the description “Copper alloy” which also can be further specified as “Tellurium copper”. This element is added for the machinability and HSV-R-2012-001 already describes the material as such.

HSN-R-001/01 has the description “Brass” which also can be further specified as “Free-machining brass”. Lead is added to improve the machinability and HSV-R-2012-001 already describes is as “Free-machining brass”.

HSN-R-2601 has both in the document name and header “Cu/r2601” with lower caps instead of the customary capital “CU/R2601”.

HSN-R-249/45, HSN-R-1292 and HSN-R-1051 have suffix “B” in the EN symbolic name, which is an indication for ingots instead of castings. The standard (EN 1982) describes two materials with equal composition and properties, only with different applications. For castings, which will be the form used by Thales Nederland, the suffix should be changed to “C”.

Finally it can be investigated whether the reference to ISO 209:2007 in the composition of wrought aluminium HSNs is relevant. The document primarily indicates equivalence between older ISO designations and current designations in line with AA, EN and JIS. For the composition specifications it refers to the Aluminum Association document[21] “*International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys*”.

[19] 12nc = 0122 199 00000.
[20] 12nc = 0122 199 01000.
[21] Available without charge at *http://www.aluminum.org/tealsheets*.

5.4. Material designation on drawings

Materials can be specified on drawings using multiple methods. When done incompletely only a grade is specified (e.g. AISI 304 or EN AW 6082) but, while widely used, these have no requirements regarding their composition and/or properties. To specify this a reference to a standard must be made.

Old abbreviated name

In the past materials used have simply been given a name. Throughout the report this is called the 'old' name. Typically these are abbreviations of the Dutch description, for example 'ST1' for general steel ("staal") or 'VEST1' for spring steel ("verenstaal"). While practical for a limited material stock, this does not provide any specification of the properties and is not a suitable designation method for a modern company designing high-tech equipment.

Basic name (in-house)

Since 1-6-1991 the old abbreviated names are no longer used and the basic name is used. This is also referred to as the in-house designation. This starts with an indication of the material group, followed by a designation based on the materials supply of Philips. In the past materials were obtained from "Magazijn 4500", but this was split off from Philips in 2004 and currently operates under the name MAG45. This will still be called the Philips designation and consists of a letter which also indicates the material group, followed by a number to specify the material. An example is 'ST/N297' which corresponds to the spring steel mentioned above. HSV-R-2012-001 identifies the following relevant material groups, with the corresponding basic designations and 'Philips letters'.

Material group	Basic designation	Philips letter
Aluminium alloys	AL	T
Copper alloys	CU	R
Stainless steels	RVS	N
Irons and steels	ST	N
Magnesium	MG	T
Lead	PB	W

Table 27. Material group designations according to the basic name and Philips method.

HSV-R-2012-005 describes the material designation for 'Signaal production parts'. This can be summarized as requiring the basic name with 12nc and if required additional information between brackets. Other production parts require the HSN and corresponding name. If there is no HSN for the material there should be a reference to an external standard.

Change proposal "fae10a" indicates that not all materials are coded with 12ncs and therefore not indicated as such on drawings. This means only the basic name can appear on the drawing, which is not unique. For example, 'AL/T633' may refer to HSN-T-633/01 or to HSN-T-633/80. These two HSNs describe the same alloy, but have different treatments resulting in significantly different properties.

The proposed solution indicates that materials should either be designated with reference to the HSN ("ALUMINIUM SHEET I.A.W. HSN-T-633/80") or to an external standard with possible additions for forms or sizes ("ALUMINIUM SHEET 6 mm EN AW-6082 T6 I.A.W. EN 485-2").

Material in accordance with external standard

Standardization bodies can define their own designation systems. For example, for aluminium alloys this is defined in EN 573-1 and 573-2. These can also cross-reference, e.g. ISO refers to EN, UNS and JIS designations for aluminium alloys in ISO 209. In this method a designation is given followed by “in accordance with” or “I.A.W.” and the standard that is being referred to.

The most prevalent standards referred to in the current stock of standardized materials are given in the following table, with the corresponding designations.

Material group	Prevalent standard(s)	Corresponding designations
Aluminium alloys	EN 573-3 EN 1706 (cast)	EN symbolic & EN numerical
Copper alloys	EN 1652 EN 1982 (cast)	EN symbolic & EN numerical
Stainless steels	EN 10088	EN symbolic & material number
Irons and steels	EN 10130 EN 10083	Short name & material number

Table 28. Common standards and designations per material group.

In general this indicates that EN numerical and symbolic designations are most common, since mostly EN standards are used. For steels this is not entirely clear since different designations are in use. Short names of steels are governed by EN 10020 and 10027-1, which both are not available at the time of writing. These are mostly used in conjunction with the material number, which is described in EN 10027-2. Tool steels have separate names in ISO 4957, which describes three forms: CxxxU with ‘xxx’ a value indicative of the carbon content (e.g. C70U with 0,65-0,75wt% carbon), a symbolic designation similar to EN (e.g. 95MnWCr5) and “HS” followed by the indicative “W-Mo-V-Co” contents (e.g. HS6-5-2). However, EN 10027-2 also has special material number groups (1.15XX-1.18XX) for tools steels. Cast irons are separately designated with a system described in ISO/TR 15931.

In addition a lot of institutions refer to stainless steel by their AISI designation. Non-European standards can also use different designations. Plastics are not considered since these are also commonly referred to by their tradenames.

The positive side of this designation method is that the alloy grade and corresponding properties are immediately clear for most people. This prevents the need of equivalence tables and may allow quicker processing by suppliers. New employees may already be familiar with common material designations, but rarely with the ‘Philips designation’ or Thales Nederland material standards. The inclusion of the (nominal) composition can provide better insight in some alloys and can be helpful for some surface treatments.

Downsides are that the reference to a standard may be forgotten, resulting in improper specification of the material. Also, if a reference to a standard is made on a large number of drawings, all drawings have to be updated when the standard is updated. This system is also not uniform, since each designation has to be done according to the standard that is being referred to. For example, chrome-machine steel would be designated ‘42CrMo4 (1.7225)’ while high-speed tool steel would be designated ‘HS6-5-2’.

HSN specification

A HSN is a company standard, which fully specifies the material. It typically has the following components:

- Description
    - "Name", in-house name, product form
- Composition
    - Designation I.A.W. "external standard"
    - Contents of the referenced standard
    - Thales specifications (if any)
- Mechanical properties
    - Designation I.A.W. "external standard"
    - Contents of the referenced standard
    - Thales specifications (if any)
- Quality and Finish
    - Mostly standardized text
- Materials that meet the requirements
- Similar materials

The designation of materials that meet the requirements and similar materials are typically as described on the previous page, which is also done in the composition and mechanical properties sections. It allows for referencing to multiple external standards and Thales Nederland specifications can be added. In these sections the relevant contents of the standards are repeated, such that the information is at hand. Requirements regarding the quality and finish of the products are given. Materials that meet the requirements or are similar can be given.

The upside of this method is that all relevant information is captured in a single document, often even fitting on a single page. This prevents the need for engineers or suppliers to look into (or even buy) the external standards that are being referred to. Also the incorporation of Thales specifications are clear and suitable materials can quickly be identified. If there are updates in the referenced standards only the HSN document has to be changes and all drawings can remain the same. Since multiple materials and standards can be described, HSNs can allow more freedom for suppliers resulting in more flexibility in sourcing materials.

The downside is that most HSNs are numbered according to the 'Philips method', making it unclear for new employees and people outside Thales. Since that method is no longer required, new materials have been added with numbering in line with more common designations, e.g. HSN-N-440/03 describes stainless steel AISI 440B.

6. CONCLUSION

The main objectives were to create a material overview with the relevant properties and to identify elimination candidates from the standardized material stock. The overview has been created by the material tables, which can be found in appendix D. Chapter 3 provides background information for these tables and can be used both as an introduction and a reference for the tables.

Based on this overview, which also included application data, elimination candidates have been identified both based on usage and overlapping properties in chapter 4. From a total of 83 metals 24 materials have been identified as elimination candidates, or 29%. From 114 plastics 15 elimination candidates have been identified based on usage alone, or 13%. Combined this results in a suggested stock reduction of 20%.

Halfway through the internship progress was going faster than expected and it was agreed to also include a documentation update into the assignment. This included updating of references to standards, making an overview of honeycomb materials and some minor change proposals for HSNs. Finally, arguments have been collected for different methods of material designation on drawings. This last part has not been done with the aim of making a recommendation for one system, but as a collection of arguments which can provide a basis for a future evaluation.

Finally, on a personal level I have had a great time during my internship at Thales Nederland. It has been a period of personal development and a great learning opportunity. It was interesting to function as an engineer in such an experienced company and I have gained a lot of knowledge, especially with respect to materials and their applications. Not least of all, I really enjoyed my time here and looked forward to each day as I went to the office.

Recommendations

The application of ferritic stainless steels in chloridic environments can be investigated. HSV-R-0079 indicates HSN-N-1101/60 (AISI 430) is not applicable in marine environments, around Cl-ions or below 0°C. However most literature indicates it very suitable for those environments. Among them Handboek RVS [15], which indicates “ferritic stainless steels are more resistant to stress corrosion cracking than austenitic types, especially in chloridic environments”. This can be relevant for the performance of Thales Nederland products and thorough understanding may influence the future material choice of designers for the better.

If castings and forgings could be linked to materials, the material reduction can possibly be expanded. Also there are most likely much more plastics that could be eliminated, with respect to properties or lack of current usage. Further evaluation of plastics will be a project in itself, because for this report the data has been obtained from several HSNs, HSV-Ns, HSV-Rs and KIS but still a lot of potential candidates are missed. The applications and specifications are very different from metals and would also require a suitable approach.

Ideally the documentation of castings and forgings would be structured similarly to the wrought materials, such that the products can be linked to their base material. Also restructuring of plastics and composites would make the available materials more clear and allow for easier access if information is required.

7. BIBLIOGRAPHY

[1] Rime, “Material numbers,” 23 03 2018. [Online]. Available: https://www.rime.de/en/101/material-numbers/. [Accessed 19 06 2018].

[2] MatWeb, “Overview of the UNS system,” [Online]. Available: http://www.matweb.com/search/SearchUNS.aspx. [Accessed 19 06 2018].

[3] W. D. Callister and D. Rethwisch, Materials Science and Engineering, 8th ed., John Wiley & Sons, Inc., 2011.

[4] M. ten Bouwhuijs, J. Godijk, C. Verbaak and P. Willemse, Materiaalkeuze in de werktuigbouwkunde, Enschede: Educaboek, 1986.

[5] Parker Steel Company, “Metric Metals Reference Guide,” 2018. [Online]. Available: http://www.metricmetal.com/wp-content/uploads/2017/10/2018MMRefGuide-w-Links.pdf. [Accessed 01 06 2018].

[6] Korea Aerospace University, “Classification of Steels, Welding of Mild Steels,” [Online]. Available: http://mercury.kau.ac.kr/welding/Welding%20Technology%20II%20-%20Welding%20Metallurgy/Chapter%204%20-%20Classification%20of%20Steels,%20Welding%20of%20Mild%20Steels.pdf. [Accessed 13 06 2018].

[7] Steel Construction, “Steel material properties,” [Online]. Available: https://www.steelconstruction.info/Steel_material_properties. [Accessed 14 06 2018].

[8] Metal Supermarket, “Four types of Steel - Part 1 - Classification & Carbon,” 23 03 2015. [Online]. Available: https://www.metalsupermarkets.com/types-of-steel/. [Accessed 01 05 2018].

[9] P. Willemse, Materiaalkunde 2, Enschede: Technische Hogeschool Twente, 1984.

[10] Metal Supermarket, “Four types of Steel - Part 2 - Alloy Steel,” 23 03 2015. [Online]. Available: https://www.metalsupermarkets.com/alloy-steel-types/. [Accessed 01 05 2018].

[11] Metal Supermarket, “5 Common Alloying Elements,” 09 08 2017. [Online]. Available: https://www.metalsupermarkets.com/5-common-alloying-elements/ . [Accessed 01 05 2018].

[12] Metal Supermarket, “5 (More) Common Alloying Elements,” 21 11 2018. [Online]. Available: https://www.metalsupermarkets.com/5-more-common-alloying-elements/. [Accessed 01 05 2018].

[13] MCB, Het MCB boek, Valkenswaard: MCB, 2016.

[14] Committe of Stainless Steel Producers, Stainless Steels for Machining, Washington, D.C., USA: American Iron and Steel Institute.

[15] J. Opstal and K. Buijs, Handboek Roestvast Staal, Leiden: C.M.A. Willenborg, 2017.

[16] W. Hoffelner, “Materials for Nuclear Plants - Figure 23: Schaeffler Diagram,” January 2013. [Online]. Available: https://www.researchgate.net/figure/23-Schaeffler-Diagram-replotted-from-23_fig2_278660466. [Accessed 30 4 2018].

[17] Carpenter Technology Corporation, “How to Passivate Stainless Steel Parts,” [Online]. Available: https://www.cartech.com/en/alloy-techzone/technical-information/manufacturing-guides/how-to-passivate-stainless-steel-parts. [Accessed 06 06 2018].

[18] L. Klein SA, “Passivation - Martensitic stainless steels,” 3 2014. [Online]. Available: http://www.kleinmetals.ch/about-us/images/passivation_e.pdf. [Accessed 6 6 2018].

[19] ALURVS, “Wat is aluminium? Deel 1,” *ALURVS,* pp. 22-29, 5 2017.

[20] European Aluminium Association, “The Aluminium Automotive Manual,” 2002. [Online]. Available: https://www.european-aluminium.eu/media/1533/aam-materials-3-designation-system.pdf. [Accessed 08 06 2018].

[21] ESAB, “Understanding the Aluminum Alloy Designation System,” [Online]. Available:

http://www.esabna.com/us/en/education/blog/understanding-the-aluminum-alloy-designation-system.cfm. [Accessed 07 05 2018].

[22] The Aluminum Association, “Aluminum Alloys 101,” [Online]. Available: http://www.aluminum.org/resources/industry-standards/aluminum-alloys-101. [Accessed 07 05 2018].

[23] Wikipedia, “Aluminium alloy,” [Online]. Available: https://en.wikipedia.org/wiki/Aluminium_alloy. [Accessed 07 05 2018].

[24] Renault, “Guide of the standardized designations of the aluminum alloys and of the copper alloy,” 01 2009. [Online]. Available: http://www.cnomo.com/fichiers/2/14047/Ge01020r_B_en.pdf . [Accessed 07 05 2018].

[25] Wikipedia, “Hydrogen embrittlement - Related phenomena,” [Online]. Available: https://en.wikipedia.org/wiki/Hydrogen_embrittlement#Related_phenomena. [Accessed 13 06 2018].

[26] NGK Berylco, “Beryllium Copper Alloys - Technical Guide,” 01 2014. [Online]. Available: http://www.ngk-alloys.com/NGK_Berylco_Design_Guide_En.pdf. [Accessed 08 05 2018].

[27] Copper Development Association Inc., “Phosphor Bronze,” [Online]. Available: https://www.copper.org/resources/properties/microstructure/phos_bronze.html. [Accessed 13 06 2018].

[28] CorrDefense Online Magazine, “For its Rotorcraft, Navy is Switching to Aluminum Gearboxes,” 2008. [Online]. Available: http://corrdefense.nace.org/CorrDefense_Summer_2008/pdf/feature.pdf. [Accessed 8 06 2018].

[29] Wikipedia, “Magnesium - Flammability,” [Online]. Available: https://en.wikipedia.org/wiki/Magnesium#Flammability. [Accessed 8 6 2018].

[30] Stichting VAM, Materialen, Voorschoten: VAM, 1983.

[31] A. v. d. Vegt and L. Govaert, Polymeren, van keten tot kunststof, Delft: VSSD, 2013.

[32] Thales Nederland, *Ontwerp & Constructierichtlijn HSV-R-0094-006: Kunststof Vezelversterkt Product,* Hengelo, 2011.

[33] E. Kappel, Interviewee, *Discussion on HSV-R-0094-006.* [Interview]. 28 05 2018.

[34] Resinex, “Rilsan PA11,” [Online]. Available: http://www.resinex.nl/producten/rilsan.html. [Accessed 27 06 2018].

[35] Mifa, “Whitepaper - Legeringen,” [Online]. Available: https://mifa.eu/nl/whitepapers/995-legeringen. [Accessed 14 06 2018].

[36] Aluminium Brazing, “Cladding Alloys,” [Online]. Available: https://www.aluminium-brazing.com/2010/09/29/cladding-alloys/. [Accessed 20 06 2018].

[37] Copper Development Association Inc., “Aluminum Bronzes,” [Online]. Available: https://www.copper.org/resources/properties/microstructure/al_bronzes.html. [Accessed 22 06 2018].

[38] Ten Kate Advanced Composites, “Datasheet - Nomex Honeycomb - Aerospace Grade,” 2014.

[39] Euro-Composites, “Mechanical Properties of ECG Honeycomb,” 2018.

[40] Hexcel, “HexWeb HRP - Product Data (EU),” 2007.

[41] Hexcel, “HexWeb CR III - Product Data Sheet,” 2017.

[42] Hexcel, “HexWeb HRH-10 - Product Data Sheet (EU),” 2017.

[43] Hexcel, “HexWeb Honeycomb Selector Guide,” 2016.

[44] Hexcel, “HexWeb Nonmetallic Flex-Core - Product Data,” 2014.

[45] Thales Group, “Corporate Presentation,” 10 2017. [Online]. Available: https://www.thalesgroup.com/sites/default/files/asset/document/thales-group-presentation_2017-10-05_en.pdf. [Accessed 18 05 2018].

[46] Thales, “Netherlands,” [Online]. Available: https://www.thalesgroup.com/en/countries/europe/netherlands. [Accessed 18 05 2018].

[47] Prof. ir. Piet van Genderen et. al., Radar Development in The Netherlands, Haaksbergen: Hassink, 2004.

[48] Jane's, Radar And Electronic Warfare Systems, Digital: IHS Global Inc., 2013.

[49] Thales, “Defence in Netherlands,” [Online]. Available: https://www.thalesgroup.com/en/countries/europe/netherlands/defence-netherlands. [Accessed 18 05 2018].

[50] J. Karremann, “Thales Goalkeeper CIWS,” 22 11 2016. [Online]. Available: https://marineschepen.nl/dossiers/goalkeeper.html. [Accessed 18 05 2018].

[51] Thales, “Integrated Mast,” [Online]. Available: https://www.thalesgroup.com/en/innovation/integrated-mast. [Accessed 18 05 2018].

[52] Thales, “Mirador - Electro-optical multi-sensor,” [Online]. Available: https://www.thalesgroup.com/en/mirador-electro-optical-multi-sensor. [Accessed 18 05 2018].

[53] Thales, “Gatekeeper,” [Online]. Available: https://www.thalesgroup.com/en/gatekeeper. [Accessed 18 05 2018].

[54] Interlloy, “Products/Datasheets - Stainless Steel,” [Online]. Available: http://www.interlloy.com.au/our-products/stainless-steel/. [Accessed 14 06 2018].

[55] Atlas Steels, “Stainless Steel Grade Datasheets,” [Online]. Available: http://www.atlassteels.com.au/site/pages/stainless-steel-datasheets.php . [Accessed 14 06 2018].

[56] Böhler, Special Steel Manual, Kapfenberg: Böhler Gesellschaft M.B.H., 1989.

A. EMPLOYER DESCRIPTION

Thales is a world-class technology company with 64.000 employees, operations in 56 countries and yearly revenues of 15 billion euros. The revenues are balanced 50%-50% between defence and civil. The markets Thales serves are Aerospace, Space, Ground Transportation, Defence and Security [45]. Thales has five locations in The Netherlands: Huizen, Den Haag, Delft, Eindhoven and Hengelo. In these locations there are 1.800 employees with 500 million euros of sales [46].

Thales Hengelo started as *Hazemeijer's Fabriek van Signaalapparaten* in 1922. Through a Dutch subsidiary (IPATH) of Siemens & Halske (which was not allowed to produce military equipment in Germany because of the treaty of Versailles) fire control equipment could be produced for the Dutch destroyers Hr.Ms. Sumatra and Java. Until WWII most directors and employees were German. At the end of the war most of the factory equipment and employees were evacuated, captured or bombed. After the war the Dutch government took control and mainly civil products were produced, but also some fire control equipment. In 1948 the name was changed into *Hollandse Signaalapparaten*, with the focus again on military radar equipment. In 1956 Philips bought the company and continued the production of radar systems. In 1990 *Signaal* (as it is commonly referred to) was sold to Thomson CSF, which changed its name to Thales in 2000 [47].

In Hengelo mainly (naval) radar systems are developed, but also the Tacticos combat management system. Surveillance, fire control, optronic and early warning ballistic missile detection systems can be provided. Some notable systems are as follows [47] [48] [49] [50] [51] [52] [53].

- Goalkeeper: a Close-In Weapons System (CIWS) which is a last ditch defence system for incoming missiles on naval ships. It was developed in conjunction with General Electric which provided the 30 mm Gatling gun. The system has both a search and a tracking radar and operates fully automatic using its own fire control computers. It is capable of combatting 8 incoming subsonic missiles simultaneously.
- SMART-S Mk2: a medium-to-long range surveillance & target acquisition radar intended for complex environments, which include small surface targets, helicopters and anti-ship missiles.
- SMART-L: a surveillance & target acquisition radar for medium-range detection of 'stealth' air targets and long-range detection of conventional aircraft. In 1997 it could detect a metallic tennis ball, which was towed by an aircraft, at more than 60 km.
- SMART-L EWC (Early Warning Capability): has a range up to 2000 km and in a 2015 test, proved capable of tracking a ballistic missile while engaging and tracking two anti-ship cruise missiles simultaneously.
- Integrated Mast (I-Mast): consists of a housing incorporating all major radars, sensors and antennas of a naval vessel. It contains no rotating radars resulting in higher time on target. All components are designed and tested as one system, resulting in quick installation and minimal interference between the components. The surface surveillance radar (Seastar) was developed especially for this system and is capable of detecting and tracking small objects between waves, such as a divers' head. Gatekeeper provides 360° IR & video view and surveillance.
- MIRADOR: an optronic sensor, providing surveillance, tracking and fire control capability in a stealthy design. It contains two daylight video cameras (for surveillance and tracking), an IR camera (tracking) and laser range finder & tracking unit.

B. PERSONAL REFLECTION

Just as with most new starts, the beginning of the internship was both exciting and confusing, but most of all a huge opportunity for learning and personal development. While I had already been to the company to discuss the assignment and meet my supervisor, the first moments were still somewhat confronting with respect to the security briefing at the new environment I was going into. However the atmosphere was very friendly and I quickly became accustomed to the security measures. Another company aspect took longer to get acquainted with: while co-workers used terms as HSV-P, 12nc and KIS (not to mention the radar system names) as everyday terms, this took me quite a while to internalize.

The first part of the assignment, making an overview of the materials, was very suited to get familiar with the nomenclature and structure of the company. Jan had some interesting books I could borrow to provide background information and when I could not find answers myself he could often help me along or refer me to someone who could. While the creation of the tables was quite a tedious work, it was nice to always have something that could be done. I also started directly with the documentation of my work, allowing me to directly convert the background information I had found into (the basis for) my report.

Meanwhile I had gotten a fixed place, which was nice since from then on I got to know the colleagues around me better. Everyone I asked for something was very helpful and if they could not help me themselves, they introduced me to someone who could. This was often necessary since materials are used in every aspect of the design, in both current and older systems. Therefore it was sometimes required to go round the whole office until an answer was found. The helpful attitude and casual atmosphere during coffee and lunch breaks made me feel welcome and quite at home. This also reflected positively on my energy levels during and after work, rarely feeling exhausted after a day's work. Even though I also had to finish two courses during the evenings and weekends, I never felt like I had to drag myself to the office.

My only reference for an individual 10 week project was my BSc thesis. During that project I found it quite frustrating that the time between really understanding the problem and thinking about the finalisation of the project was very short, maybe a couple of weeks. With that in mind I wanted to be as productive as possible in the first few weeks, to allow for sufficient time until the converging and finalisation phase of the project. I had no reference regarding my productivity and independence during this time, but at the self-initiated midway review it was satisfying to hear that I was doing well on these aspects. It was also agreed upon to look into the secondary objectives during this meeting.

During the final part of the internship the social contact was somewhat less since I had to focus on the report and had less interaction with others. However during coffee brakes many colleagues were interested in how I experienced my time at Thales, what my findings were and what my plans for the future are. This further confirmed my positive impressions of the organisational culture and its people.

I look back on the internship as period in which I have learned a lot. Not only how the theoretical knowledge obtained during my education can be applied, but also on how the company and its people function. Not least important, I also experienced it as a fun period and I could easily see myself staying here longer were it not for the end of my internship.

C. STAINLESS STEEL PROPERTIES

As a background reference two sources with a wide range of temper data are presented to get an idea of the hardness ranges that can be achieved with each grade. The non-free machining martensitic grades are presented, as well as a precipitation hardening and duplex grade. Some Thales Nederland tempers are slightly higher than the maximum values presented here.

Hardness range	Interlloy [54]	Atlas [55]
410	223-400 HB = 20-43 HRC	225-388 HB
420	262-495 HB = 27-52 HRC	262-444 HB
420C	"Developed to provide higher hardness after heat treatment" than 420	-
431	270-410 HB = 29-44 HRC	290-380 HB
440B	-	"Slightly softer and more corrosion resistant" than 440C
440C	56-60 HRC	56-59 HRC
17-4PH	295-420 HB = 31-44 HRC	277-388 HB = 28-40 HRC
Duplex 2205	up to 290 HB +A	Up to 293 HB = 31 HRC

Table 29. Hardness ranges (depending on temper) of various AISI grades.

To get an overview of the grades, the average composition of Böhler is given. While a producer will usually try to match most international standards, they are free to deviate if they wish to do so. Therefore a full reference to a standard needs to be made to agree on a specific material. Still, this overview gives a clearer overview, since the average composition is given instead of a range, as is usual in standards.

AISI	**Böhler**	**C**	**Si**	**Mn**	**Cr**	**Mo**	**Other**
410	N100	0.11	0.40	0.40	12.5	-	-
420	N320[22]	0.20	0.40	0.40	12.5	-	-
420C	N540	0.46	0.40	0.40	13.0	-	-
431	N350	0.19	0.25	0.40	15.9	-	Ni 1.60
440B	N685	0.90	0.45	0.40	17.5	1.10	V 0.10
440C	N695	1.05	0.40	0.40	17.0	0.50	-

Table 30. Average chemical composition in wt% of some stainless steel grades by Böhler [56].

[22] Böhler grade T651 is also indicated to be equivalent with AISI 420, but with slightly different composition for improved creep resistance.

D. MATERIAL TABLES

The tables presented in this appendix are the actual overview of the standardized materials and their properties. While these tables should be sufficiently clear, the best experience can be achieved by looking at the original Excel file. For ease of finding specific information the following table of contents has been composed.

Table 31. Contents of appendix D.

An overview of the found materials is given and relevant properties are included. Most groups are spit into multiple pages, this can be due to the amount of materials, the amount of properties, or both. For a description of the properties and classification chapter 3 can be read. Some cells that deserve extra attention have been shaded, for example to indicate a reference to an outdated standard or if the material has been identified as an elimination candidate based on its lack of current applications.

	Designations												Elim. candidate		Updated		Updated			Updated
	Thales NL	EN Name	HSV-N-	Name	In-house	Old	Material number	12nc HSN	12nc in-h	12nc oud	12nc total	#SLI	Applications	Composition norm	Latest norm	Properties norm	Latest norm	Thales spec	Similar	Latest norm
Carbon	HSN-N-1130/06	DC01	9515	Steel	ST/N1130	ST1	1.0330	0	0	18	18			EN 10130-2006	2006	EN 10130-2006	2006			
Carbon	HSN-N-312	DC04		Steel	ST/N312	ST2	1.0338	0	0	1	1	1	-	EN 10130-2006	2006	EN 10130-2006	2006		DC04 LC (1.0338), EN 10139-1997 meets req.	2016
Carbon	HSN-N-305	42CrMo4	9510/9515	Chrome-machine steel	ST/N305	CRMST1	1.7225	0	43	0	43			EN10083-3-2006	2006	EN10083-3-2006	2006	for 250<d<500 mm		
Carbon	HSN-N-1269	34CrMo4		Steel	ST/N1269	CRMST2	1.7220	0	0	6	6	0	-	EN10083-3-2006	2006	EN10083-3-2006	2006		34CrMo4, ISO 683-2:2012 meets req. ; 34CrMo4, EN 10263-4:2001	2016; 2017
Tool steel	HSN-N-094	115CrV3		Steel	ST/N094	ZIST	1.2210	0	0	50	50			DIN 17350-1980	FROZEN	DIN 17350-1980	FROZEN			
Tool steel	HSN-N-1113	95MnWCr5		Tool steel	ST/N1113	GERST1		0	114	32	146			ISO 4957-1999	1999	ISO 4957-1999	1999			
Tool steel	HSN-N1054	HS6-5-2		High-speed tool steel	ST/N1054	SNST		0	0	12	12	2	-	ISO 4957-1999	1999	ISO 4957-1999	1999			
Tool steel	HSN-N-1019	X153CrMoV12		Alloy cold work tool steel	ST/N1019	-		0	0	-	0	-	-	ISO 4957-1999	1999	ISO 4957-1999	1999			
Low alloy	HSN-N-285	S235JRC		Steel	ST/N285	VLST1	1.0122	0	2	424	426			EN10277-2 : 2008	2008	EN10277-2 : 2008	2008			
Low alloy	HSN-N-041	S235JR	9515	Mild steel	ST/N041	VLST3	1.0038	0	56	6	62			EN 10025-2:2004	2004	EN 10025-2:2004	2004		S235B, ISO 630-2:2011 ; Carbon structural steel, ASTM A36/A36M - 14	2011; 2014
Low alloy	HSN-N-1271/01	E355		Steel	ST/N1271	ST4	1.0580	0	0	5	5	13	Lirod, STIR (2400/240hp), Sting-EO, LW08, Flycatcher	EN 10305-1-2010	2016	EN 10305-1-2010	2016			
Free cutting	HSN-N-925	11SMnPb28	9510	Free-cutting steel	ST/N925	AUTST1		0	48	0	48			ISO 683-9 1988	ISO 683-4:2016	ISO 683-9 1988	ISO 683-4:2016	Structure	11SMnPb30 (1.0718), EN 10277-3 : 2008	2008
Free cutting	HSN-N-1131/01	44SMn28	9510	Free-cutting steel	ST/N1131	MAST2	1.0762	0	15	0	15			EN 10277-3 : 2008	2008	EN 10277-3 : 2008	2008		Steeltec ETG 100, manuf. Spec. meets req. ; 44 SMn 28, ISO 683-9:1988	- ; ISO 683-4:2016
Hardening	HSN-N-1032	16MnCr5	9510	Case-hardening steel	ST/N1032	CARST		0	32	0	32			ISO 683-11: 2012	ISO 683-3	ISO 683-11: 2012	ISO 683-3	Blind hardening <350HB for t=10mm	16MnCr5 condition +A or +TH, EN 10084 : 2008 (1.7131) meets req.	(1997)
Hardening	HSN-N579	34CrAlMo5-10		Nitriding steel	ST/N579	NIST	1.8507	0	0	23	23			EN 10085:2001	2001	EN 10085:2001	2001			
Cast	HSN-N1037	270-480		Cast steel	ST/N1037	GST50		0	0	0	0	-	(Cast)	ISO 3755-1991	ISO14737:2015	ISO 3755-1991	ISO14737:2015			
Cast	HSN-N-099/45	ISO 185/JL/250		Grey cast iron perlitic	ST/N099	PGY		0	0	29	29		(Cast)	ISO 185-2005	2005	ISO 185-2005	2005	Test piece acc. ISO 6892-1:2009	EN-GJL-250, EN 1561:2011	2011
Other	HSN-N-297	C67S		Spring steel	ST/N297	VEST1	1.1231	0	0	16	16		Flycatcher, ZW06, LW08, DA05, WM22, Stir, ... Goalkeeper, STIR (240hp/2400), Sting-EO, SMCS?	EN 10132-4-2000	2000	EN 10132-4-2000	2000			
Other	HSN-N-1030/01	NiCo29-18		Fernico	ST/N1030	FERN	1.3981	0	0	9	9			SEW 385- Edition 2 - 1991	1991	SEW 385- Edition 2 - 1991	1991		NiCo 29 18, DIN 17745-2002 (1.3981) meets req. ; UNS K94610 temper B, ASTM F15 - 04 (Reapproved 2013).	2002; 2004 (R2017)
Other	HSN-N-398	RFe100	9510	Soft magnetic steel	ST/N398	MAGN.YZ	1.1013	0	2	6	8	2	+ 1x12nc (HSV-N): Flycatcher, WM22, Lirod, PRTL	DIN 17405-1979 & Thales	1979	Thales		C<=0.10, Si<0.15		
Other	HSN-N-005	T-36		Nickel iron	ST/N005	NIKK.YZ		0	0	4	4	12	- (Thermostat alloy)	ASTM B753-2007(R2013)	2007 (R2013)	ASTM B753-2007(R2013)	2007 (R2013)		Carpenter Invar 36 Alloy (UNS K93601/K93603), manuf. Spec meets req. ; Carpenter free-cut Invar 36 Alloy (UNS K93602/K93050), manuf spec ; Ni 36 (1.3912), SEW 385- REV -1991.	- ; 1991

Figure 4. Irons and steels overview and properties (1 of 2).

Group	Thales NL	EN Name	Average composition: Carbon content (0.01wt%)	Average composition: Mn content (0.01wt%)	Average composition: Si content (0.01wt%)	Average composition: Alloy comp. (0.01wt%)	Small sizes: Rp (MPa)	Small sizes: Rm (MPa)	Small sizes: A (%)	Large sizes: Rp (MPa)	Large sizes: Rm (MPa)	Large sizes: A (%)	Hardness (HB)	Remarks	Condition	Form: Bar	Form: Profile	Form: Wire	Form: Section	Form: Tube	Form: Sheet	Form: Strip	Form: Forging	Form: Casting
Carbon	HSN-N-1130/06	DC01	12	60	0	81	140-320	270-410	24	140-280	270-410	28		Good weldability	Cold worked						x			
Carbon	HSN-N-312	DC04	8	40	0	54	140-250	270-350	34	140-210	270-350	38			Cold worked						x			
Carbon	HSN-N-305	42CrMo4	42	75	40	291	900	1100-1300	10	460	690-840	15		Hardenable, results in good strength and ductility, decent machinability, limited roughness	+QT	x								
Carbon	HSN-N-1269	34CrMo4	34	75	40	283	800	1000-1200	11	450	700-850	15			+QT	x								
Tool steel	HSN-N-094	115CrV3	115	30	23	256							223 HB +A, 60HRC +QT	Norm: EN 107CrV3 similar	+A	x								
Tool steel	HSN-N-1113	95MnWCr5	95	120	25	461							229HB, 60HRC hardened	Oil quenched, no form in HSN but probably bar & strip	+A	x						x		
Tool steel	HSN-N1054	HS6-5-2	84	0	45	2159							262HB, 64HRC hardened		+A	x								
Tool steel	HSN-N-1019	X153CrMoV12	153	40	35	1558							255HB, 61HRC hardened	Air quenched	+A	x								
Low alloy	HSN-N-285	S235JRC	18	140	0	167	355	470-840	8	215	360-640	11		Cold drawn	+C	x				x		x		
Low alloy	HSN-N-041	S235JR	17	140	0	220	235	360-510	17	225	260-510	26		Hot rolled, decent weldability			x				x			
Low alloy	HSN-N-1271/01	E355	22	160	55	242				355	640	4		for +C Rp => 0.8Rm	+C					x				
Free cutting	HSN-N-925	11SMnPb28	11	110	5	192	410	510-810	7	245	360-630	10		Good machinability, tolerances and price, limited roughness		x								
Free cutting	HSN-N-1131/01	44SMn28	44	150	40	269	595	850-1000	9	490	700-900	12			+QT+C	x								
Hardening	HSN-N-1032	16MnCr5	16	115	27	302							207 HB +A, 156-207HB +TH	For hard & wear resistant surface with tough core	+A or +TH	x								
Hardening	HSN-N579	34CrAlMo5-10	34	55	40	370				600	800-1000	14	950 HV (+/- 68 HRC)		+QT	x								
Cast	HSN-N1037	270-480					270	480-630	18	260	500-650	18												x
Cast	HSN-N-099/45	ISO 185/JL/250						250			160													x
Other	HSN-N-297	C67S								530	660	13	205HV	Spring steel	+A							x		
Other	HSN-N-1030/01	NiCo29-18									440-640	25		Similar expansion coeff. as glass, for seals etc		x						x		
Other	HSN-N-398	RFe100									300-450	15	80-150	For continuous current relays, unalloyed, "koerzitivfeldstärke" max 100 A/m		x								
Other	HSN-N-005	T-36	15	60	40	3795							72HRB	Thermostat alloy, low expansion (?)	+A	x						x		

Figure 5. Irons and steels overview and properties (2 of 2).

	Designations													Elim. candidate		Updated		Updated			Updated
	Thales NL	AISI / SAE	HSV-N-	In-house name	Old name	UNS	Mat. Nr.	ISO	12nc HSN	12nc in-h	12nc oud	12nc total	#SLI	Application	Composition norm	Latest norm	Properties norm	Latest norm	Thales spec	Similar	Latest norm
Austenitic	HSN-N-284	303	9510	RVS/N284	RVST1	S30300	1.4305	X8CrNiS18-9	0	108	1	109			EN 10088-1:2014	2014	EN 10088-3:2014; Thales	2014	for d<30 mm		2012
Austenitic	HSN-N-1170/60	304	9515	RVS/N1170	-	S30400	1.4301	X5CrNi18-10	0	38	0	38			EN 10088-1:2014	2014	EN 10088-2:2014; EN 10088-3:2014	2014; 2014			
Austenitic	HSN-N-116	316	9510	RVS/N116	RVST2	S31600	1.4401	X5CrNiMo17-12-2	0	0	54	54			EN 10088-1:2014	2014	EN 10088-3:2014	2014		UNS S31600 type 316, ASTM A276/A276M - 15	2017
Austenitic	HSN-N-371	316L	9510	RVS/N371	RVST4	S31603	1.4404	X2CrNiMo17-12-2	0	72	3	75			EN 10088-1:2014	2014	EN 10088-2:2014; EN 10088-3:2014	2014; 2014		UNS S31603 type 316L, ASTM A240/A240M - 15; UNS S31603 type 316L, ASTM A276/A276M - 15	2017; 2107
Austenitic	HSN-N-129	321		RVS/N129	RVST5	S32100	1.4541	X6CrNiTi18-10	0	1	7	8	12	MW08, STIR	EN 10088-1:2014	2014	EN 10088-3:2014	2014			
Martensitic/ferritic	HSN-N-1176	410	9510	RVS/N1176	RVST8	S41000	1.4006	X12Cr13	0	13	0	13		IR-Scan, S1850, ...	EN 10088-1:2014	2014	EN 10088-3:2014; Thales	2014	for d<35 mm	UNS S41000 type 410, ASTM A276/A276M - 15	2017
Martensitic/ferritic	HSN-N-1272/01	416		RVS/N1272	RVST11	S41600	1.4005	X12CrS13	0	0	8	8	1	LW08 (& forgings?)	ASTM A582/A582M-12 (ε1); ASTM A473 - 13	2017; 2017	ASTM A582/A582M-12 (ε1); ASTM A473 - 13	2017; 2017			
Martensitic/ferritic	HSN-N-1188	420		RVS/N1188	RVST15	S42000	1.4021	X20Cr13	0	0	1	1	1	Flycatcher	EN 10088-1:2014	2014	EN 10088-3:2014	2014		UNS S42000 type 420, ASTM A276/A276M - 15	2017
Martensitic/ferritic	HSN-N-1024	420C		RVS/N1024	RVST13	S42000	1.4034	X46Cr13	0	0	25	25			EN 10088-1:2014	2014	EN 10088-3:2014; Thales	2014	for d<35 mm		
Martensitic/ferritic	HSN-N-1101/60	430	9515	RVS/N1101	RVST22	S43000	1.4016	X6Cr17	0	7	0	7	33	Smart-S Mk2, Lirod Mk2, Flycatcher	EN 10088-1:2014	2014	EN 10088-2:2014	2014			
Martensitic/ferritic	HSN-N-219	430F	9510	RVS/N219	RVST21	S43020	1.4104	X14CrMoS17	0	24	1	25			EN 10088-1:2014	2014	EN 10088-3:2014	2014			
Martensitic/ferritic	HSN-N-1252/01	431	9510	RVS/N1252	RVST16	S43100	1.4057	X17CrNi16-2	0	11	3	14			EN 10088-1:2014	2014	EN 10088-3:2014	2014		UNS S43100 type 431, ASTM A276/A276M - 15	2017
Martensitic/ferritic	HSN-N-440/03	440B		RVS/N440	-	S44003	1.4112	X90CrMoV18	0	0	0	0		12nc=35223460869 = SMART-L	EN 10088-1:2014	2014	EN 10088-3:2014	2014		Bar: X89CrMoV18-1 (1.3549), cond. A, ISO 683-17 (2014); Bar, shape: UNS S44003, type 440B, cond. A, ASTM A276/A276M – 16a	

Figure 6. Stainless steels overview and properties (1 of 4)

			Designations											Elim. candidate		Updated		Updated			Updated
	Thales NL	AISI / SAE	HSV-N-	In-house name	Old name	UNS	Mat. Nr.	ISO	12nc HSN	12nc in-h	12nc oud	12nc total	#SLI	Application	Composition norm	Latest norm	Properties norm	Latest norm	Thales spec	Similar	Latest norm
Duplex	Cast duplex	329			-	S32900	1.4460	GX4CrNiMoN27-5-2	0	0	7	7	4	(Cast) Smart-L (ELR)							
	HSN-N-2205	2205		RVS/N2205	-	S31803 & S:	1.4462	X2CrNiMoN22-5-3	0	0	0	0		Duplex = used	EN 10088-1:2014	2014	EN 10088-2:2014; EN 10088-3:2014	2014; 2014		UNS S31803 and UNS S32205, ASTM A276/A276M – 16a	2017
Precipitation hardening	HSN-N-630	630		RVS/N630	-	S17400	1.4542	X5CrNiCuNb16-4	11	0	0	11		Sting-EO, Liod, Liod Mk2, APAR, 127DE: SMART-L, ...	ASTM A564/A564M - 13	2013e1	ASTM A564/A564M - 13	2013e1		UNS S17400, SAE AMS5622F:2013 (meets req.); UNS S17400, SAE AMS5643S:2013 (meets req.); X5CrNiCuNb16-4 (1.4542) cond. AT, EN 10088-3:2014 (meets req.)	
	HSN-N-1279/01			RVS/N1279	-		1.4549.4		0	0	0	0		(Cast) MW08	WL 1.4549 - 1982	1982	WL 1.4549 - 1982	1982		SAE AMS5355J 2009 condition H1100 (meets req.)	2015
	HSN-N-1279/02			RVS/N1279	-		1.4549.5		0	0	0	0		(Cast) MW08	WL 1.4549 - 1982	1982	WL 1.4549 - 1982	1982		SAE AMS5355J 2009 condition H1000 (meets req.)	2015
	HSN-N-1279/03			RVS/N1279	-		1.4549.6		0	0	0	0		(Cast) MW08	WL 1.4549 - 1982	1982	WL 1.4549 - 1982	1982		SAE AMS5355J 2009 condition H900 (meets req.)	2015
Spring	HSN-N-939			RVS/N939	VEST2/STR		1.4310	X10CrNi18-8	0	1	14	15		Spring steel	EN 10151- 2003	2002	EN 10151 - 2003	2002			
	HSN-N-940			RVS/N940	VEST2/RD		1.4310	X10CrNi18-8	0	0	15	15		Spring steel	EN 10151- 2003	2002	EN 10270-3:2001	2011			

Figure 7. Stainless steels overview and properties (2 of 4).

	Thales NL	AISI / SAE	Condition	Large size Rp (MPa)	Modulus (GPa)	Hardness (HV)	Machinability (index)	Structure	Remarks	Product form: Bar	Profile	Wire	Section	Tube	Sheet	Strip	Forging	Casting	Corrosion resistance: Exposed: Un-painted	Exposed: Painted	Sheltered: In air	Sheltered: Greased	Pass. Status	Passivation processes (HSV-P-3048/281): A	B	Problematic: IBI	Problematic: ICI	Problematic: IDI	E	F	G	H	H2-D.E.	Anodizing (HSV-P-3048/141)
Austenitic	HSN-N-284	303		190	200	230	65	Austenitic	Limited size-accuracy & surface roughness, good machinability	x									NO	YES	YES	YES	High risk			•				•				YES
Austenitic	HSN-N-1170/60	304		210	200	200	50	Austenitic	Heat resistant, low carbon, corrosion resistant after welding	x	x	x			x	x			NO	YES	YES	YES	Good	•	•					•				NO
Austenitic	HSN-N-116	316		200			50	Austenitic	Good corrosion & chemical resistance, creep strength up to 760'C	x									YES	YES	YES	YES	Good	•	•					•				YES
Austenitic	HSN-N-371	316L		200				Austenitic	Comparable to 316, better corrosion resistance after welding, applicable up to 425'C	x	x	x			x	x			YES	YES	YES	YES	Good	•	•					•				YES
Austenitic	HSN-N-129	321		190			55	Austenitic	Corrosion resistant after welding, applicable up to 425-900'C					x					YES	YES	YES	YES	Good	•	•					•				NO
Martensitic/ferritic	HSN-N-1176	410	+A, hardenable	450		222	55	Martensitic	Hardenable to 370-470 HV, good corrosion resistance, decent machinability	x									NO	YES	YES	YES	No sol.				•						•	NO
Martensitic/ferritic	HSN-N-1272/01	416	+A	275		223 (bar=262)	80	Martensitic	Excellent machinability, hardenable to 350 HB. Properties for forgings.	x							x		NO	NO	NO	YES	No sol.					•						NO
Martensitic/ferritic	HSN-N-1188	420	HT + QT700, Hardenable(?)	500			45	Martensitic	Better corrosion resistance if hardened and tempered than annealed	x									NO	NO	YES	YES	No sol.				•							NO
Martensitic/ferritic	HSN-N-1024	420C	+A, hardenable	650		252		Martensitic	High-carbon variant of 420	x									NO	NO	NO	YES	No sol.				•						•	NO
Martensitic/ferritic	HSN-N-1101/60	430		240	220	200		Ferritic	Not applicable in marine environment, around Cl-ions or below 0'C. Better corrosion resistance & heat resistance than 410						x	x			NO	YES	YES	YES	Low risk		•						•			NO
Martensitic/ferritic	HSN-N-219	430F	+QT650	500	215			Ferritic	Sulphur added for good machinability, size-accuracy and surface roughness	x									NO	NO	NO	YES	High risk						•					NO
Martensitic/ferritic	HSN-N-1252/01	431	+QT800	600	216		45	Martensitic	For high loading, no heat treatment required, better corrosion resistance than 410/420/440	x	x	x							NO	YES	YES	YES	Low risk								•		•	NO
Martensitic/ferritic	HSN-N-440/03	440B	+A, hardenable			292	40	Martensitic	Highly hardenable (to 57-59 HRC), high hardness, limited corrosion resistance	x			x						NO	NO	NO	YES	Low risk									•	•	NO

Figure 8. Stainless steels overview and properties (3 of 4).

	Thales NL	AISI / SAE	Condition	Large size Rp (MPa)	Modulus (GPa)	Hardness (HV)	Machinability (index)	Structure	Remarks	Product form: Bar	Profile	Wire	Section	Tube	Sheet	Strip	Forging	Casting	Corrosion resistance, Exposed: Un-painted	Painted	Sheltered: In air	Greased	Pass. Status	A	B	Problematic: IBI	ICI	IDI	E	F	G	H	H2-D.E.	Anodizing (HSV-P-3048/141)
Duplex	Cast duplex	329	Age-hardenable					Duplex	Corrosion resistance comparable to 316, better stress corrosion cracking resistance, brittle if completely aged									x	NO	YES	YES	YES	Good	•						•				NO
Duplex	HSN-N-2205	2205	Sol. Annealed +AT	450		271		Duplex	High strength and resistance to stress corrosion cracking	x			x		x	x			YES	YES	YES	YES	Good	•						•	•		•	YES
Precipitation hardening	HSN-N-630	630	Cond. A, req. HT	725-1170	197	271-406		Precipitation hardening	Also called 17-4PH (CrNi), corrosion resistance similar to 304	x									Greased	YES	YES	YES	Low risk		•								•	NO
Precipitation hardening	HSN-N-1279/01		Heat treated	830		285		Precipitation hardening										x	NO	YES	YES	YES	Good		•							•	•	NO
Precipitation hardening	HSN-N-1279/02		Heat treated	900		320		Precipitation hardening										x	NO	YES	YES	YES	Good		•							•	•	NO
Precipitation hardening	HSN-N-1279/03		Heat treated	1100		388		Precipitation hardening										x	NO	YES	YES	YES	Good		•							•	•	NO
Spring	HSN-N-939		Cond. +C1300		185	250-600		Austenitic spring steel	Slightly less corrosion resistant than 304, applicable up to 120-250'C, high cold deformability							x			NO	YES	YES	YES	Good	•	•					•				NO
Spring	HSN-N-940				185	250-600		Austenitic spring steel	Slightly less corrosion resistant than 304, applicable up to 120-250'C, high cold deformability			x							NO	YES	YES	YES	Good	•	•					•				NO

Passivation processes (HSV-P-3048/281)

Figure 9. Stainless steels overview and properties (4 of 4).

	Thales NL	EN prefix	EN Numerical	EN Symbols	HSV-N-	In-house	Old	12nc HSN	12nc in-h	12nc oud	12nc total	# SLI	Elim. candidate Application	Composition norm	Updated Latest norm	Properties norm	Updated Latest norm	Thales spec	Similar	Updated Latest norm
	HSN-T-423	AW	1050A	Al99.5		AL/T423	ALK11	0	0	9	9	1	WM22	EN 573-3:2013 & ISO 209:2007	2013; 2007	ISO 6361-2:2012	2014		EN AW-1050A H14, EN485-2:2013 meets req.	2016
	HSN-T-136	AW	1050A	Al99.5		AL/T136	ALK8	0	0	29	29			EN 573-3:2013 & ISO 209:2007	2013; 2007	ISO 6363-2:2012	2012		EN AW-1050A H14, EN754-2:2013 meets req.	2016
	HSN-T-668	AW	5754	AlMg3	9535	AL/T668	ALK17	0	6	2	8		Flycatcher, STIR, Goalkeeper, ...	EN 573-3:2013 & ISO 209:2007	2013; 2007	EN485-2:2013	2016	Bending test, surface composition	Al Mg3 temper O, ISO 6361-2:2014 meets req.	2014
	HSN-T-669	AW	5754	AlMg3	9535	AL/T669	ALK3	0	30	0	30			EN 573-3:2013 & ISO 209:2007	2013; 2007	EN485-2:2013	2016	Bending test, surface composition		
	HSN-T-1089/01	AW	6005	AlSiMg		AL/T1089	ALK18	0	4	2	6	12	Flycatcher, SMART-L (&APAR?)	EN 573-3:2013 & ISO 209:2007	2013; 2007	EN 755-2:2013	2016	Hardness & surface composition		
Wrought	HSN-T-1051/80	AW	6060	AlMgSi	9540	AL/T1051	ALK12	0	16	107	123			EN 573-3:2013 & ISO 209:2007	2013; 2007	EN 755-2:2013 & ISO 6362-2:2014	2016; 2014			
	HSN-T-880	AW	6061	AlMg1SiCu		AL/T880	ALK6	0	0	9	9	142	Goalkeeper	EN 573-3:2013 & ISO 209:2007	2013; 2007	Thales		Hardness > 50HV		
	HSN-T-633/80	AW	6082	AlSi1MgMn	9530/9535/9540	AL/T633	-	0	30	-	30			EN 573-3:2013 & ISO 209:2007	2013; 2007	EN 755-2:2013 & ISO 6362-2:2014 & EN 485-2:2013	2016; 2014; 2016	For d=>250 mm, surface composition		
	HSN-T-633/01	AW	6082	AlSi1MgMn		AL/T633	ALK13	0	328	22	350			EN 573-3:2013 & ISO 209:2007	2013; 2007	EN485-2:2013 (sheet); ISO6362-2:2014 (profile)	2016; 2014	Surface composition		
	HSN-T-7019	AW	7019	AlZn4Mg2	9535	AL/T7019	-	0	0	-	0		+ 2x12nc uit HSV-N: Variant, SMART-L-ELR	EN 573-3:2013	2013	Manufacturer spec (Unidal)			Unidal by Almet/Alusuisse meets req.	
	HSN-T-1086/01	AW	7022	AlZn5Mg3Cu	9530	AL/T1086	ALK16	0	18	0	18		Euro2000 (legacy), IR-Scan, STIR, SMART-S, ...	EN 573-3:2013 & ISO 209:2007	2013; 2007	EN 754-2:2013	2016	for d = 80-270 mm		

Figure 10. Aluminium alloys overview and properties (1 of 4).

														Elim. candidate		Updated		Updated			Updated
	Thales NL	EN prefix	EN Numerical	EN Symbols	HSV-N-	In-house	Old	*12nc HSN*	*12nc in-h*	*12nc oud*	12nc total	# SLI	Application	Composition norm	Latest norm	Properties norm	Latest norm	Thales spec	Similar	Latest norm
Cast	HSN-T-1072/91	AC	42000 & 42100	AlSi7Mg & AlSi7Mg0,3		AL/T1072	AL10	*0*	*0*	*0*	0		(Cast)	EN 1706:2010	2010	EN 1706:2010	2010		Al Si7Mg T6 & Al Si7Mg0,3 T6, ISO 3522:2007 meet req.; Former G-AlSi7Mg WA 3.2371.61, DIN 1725 teil 2-1986	2007; EN 1706:2010
	HSN-T-1072/92	AC	42000 & 42100	AlSi7Mg & AlSi7Mg0,3		AL/T1072	AL11	*0*	*0*	*0*	0		(Cast)	EN 1706:2010	2010	EN 1706:2010	2010		Al Si7Mg T6 & Al Si7Mg0,3 T6, ISO 3522:2007 meet req.; Former G-AlSi7Mg WA 3.2371.61, DIN 1725 teil 2-1986	2007; EN 1706:2010
	HSN-T-1072/93	AC	42000 & 42100	AlSi7Mg & AlSi7Mg0,3		AL/T1072	AL14	*0*	*0*	*0*	0		(Cast)	EN 1706:2010	2010	EN 1706:2010	2010		Al Si7Mg T6 & Al Si7Mg0,3 T6, ISO 3522:2007 meet req.; Former G-AlSi7Mg WA 3.2371.61, DIN 1725 teil 2-1986	2007; EN 1706:2010
	HSN-T-1024/45	AC	43100	AlSi10Mg(b)		AL/T1024	AL7	*0*	*0*	*0*	0		(Cast)	EN 1706:2010	2010	EN 1706:2010	2010		Al Si10Mg F, ISO 3522:2007 meets req; former GK-AlSi10Mg (3.2381.01), DIN 1725 teil 2 - 1986	2007; EN 1706:2010
	HSN-T-1024/92	AC	43100	AlSi10Mg(b)		AL/T1024	AL8	*0*	*0*	*0*	0		(Cast)	EN 1706:2010	2010	EN 1706:2010	2010		Al Si10Mg T6, ISO 3522:2007 meets req; former GK-AlSi10Mg WA (3.2381.62), DIN 1725 teil 2 - 1986	2007; EN 1706:2010
	HSN-T-1024/43	AC	43100	AlSi10Mg(b)		AL/T1024	AL6	*0*	*0*	*0*	0		(Cast)	EN 1706:2010	2010	EN 1706:2010	2010		Al Si10Mg F, ISO 3522:2007 meets req; former GK-AlSi10Mg (3.2381.02), DIN 1725 teil 2 - 1986	2007; EN 1706:2010
	HSN-T-1024/93	AC	43100	AlSi10Mg(b)		AL/T1024	AL9	*0*	*0*	*0*	0		(Cast)	EN 1706:2010	2010	EN 1706:2010	2010		Al Si10Mg T6, ISO 3522:2007 meets req; former GK-AlSi10Mg WA (3.2381.62), DIN 1725 teil 2 - 1986	2007; EN 1706:2010
	HSV-T-1019/91	AC	71000	ISO: Al Zn5Mg		AL/T1019	AL12	*0*	*0*	*0*	0		(Cast)	ISO 3522:2007	2007	ISO 3522:2007	2007		Alloy 712.0, ASTM B26/B26M-12	2018
	HSV-T-1019/92	AC	71000	ISO: Al Zn5Mg		AL/T1019	AL13	*0*	*0*	*0*	0		(Cast)	ISO 3522:2007	2007	ISO 3522:2007	2007			

Figure 11. Aluminium alloys overview and properties (2 of 4).

	Thales NL	EN prefix	EN Numerical	Condition	Small sizes Rp (MPa)	Small sizes Rm (MPa)	Small sizes A (%)	Large sizes Rp (MPa)	Large sizes Rm (MPa)	Large sizes A (%)	Hardness (HB)	Remarks	Bar	Profile	Wire	Section	Tube	Sheet	Strip	Plate	Waveguide	Sand cast.	Perm. Cast.	Invest. Cast
	HSN-T-423	AW	1050A	O	20	65-95	20	20	65-95	32		Good conductivity						x	x	x				
	HSN-T-136	AW	1050A	H14				70	100	6		Good conductivity					x							
	HSN-T-668	AW	5754	O	80	190-240	12	80	190-240	17		non heat treatable, good deformability and corrosion resistance, low strength and hardness						x						
	HSN-T-669	AW	5754	H12	170	220-270	4	170	220-270	9		non heat treatable, decent strength, good corrosion resistance						x						
	HSN-T-1089/01	AW	6005	T6	225	270	8	200	250	8	70-95 HB			x										
Wrought	HSN-T-1051/80	AW	6060	T6, profile: "feingerichtet"				150	190	6		Different specs for tube/prof & EN/ISO. Extrusion quality for special profiles. Good corrosion resistance and decent strength		x			x							
	HSN-T-880	AW	6061								50 HV	approx. 45 HB, only "waveguide"									x			
	HSN-T-633/80	AW	6082	T6, profile: "normalgerichtet"	260	310	6	190	240	4		Good strength, corrosion resistance, machinability and deformability. Bad re-formability	x	x			x	x						
	HSN-T-633/01	AW	6082	T4	110	205	12	110	205	12		Good strength, corrosion resistance, machinability and deformability. Bad re-formability		x				x						
	HSN-T-7019	AW	7019	T651	350	410	8	330	390	8								x						
	HSN-T-1086/01	AW	7022	T6				380	160	7		Good strength and machinability, bad corrosion resistance, hard to anodize	x											

Figure 12. Aluminium alloys overview and properties (3 of 4).

	Thales NL	EN prefix	EN Numerical	Condition	Small sizes Rp (MPa)	Small sizes Rm (MPa)	Small sizes A (%)	Large sizes Rp (MPa)	Large sizes Rm (MPa)	Large sizes A (%)	Hardness (HB)	Remarks	Bar	Profile	Wire	Section	Tube	Sheet	Strip	Plate	Waveguide	Sand cast	Perm. Cast	Invest. Cast
Cast	HSN-T-1072/91	AC	42000 & 42100	T6				180	220	1	75 HB	AC42100 slightly higher properties										x		
	HSN-T-1072/92	AC	42000 & 42100	T6				220	260	1	90 HB	AC42100 slightly different properties											x	
	HSN-T-1072/93	AC	42000 & 42100	T6				190	240	1	75 HB	AC42100 slightly higher properties												x
	HSN-T-1024/45	AC	43100	F				80	150	2	50 HB	as cast										x		
	HSN-T-1024/92	AC	43100	T6				180	220	1	75 HB	Heat treated										x		
	HSN-T-1024/43	AC	43100	F				90	180	2.5	55 HB												x	
	HSN-T-1024/93	AC	43100	T6				220	260	1	90 HB												x	
	HSV-T-1019/91	AC	71000					120	190	4	60 HB											x		
	HSV-T-1019/92	AC	71000					130	210	4	65 HB												x	

Figure 13. Aluminium alloys overview and properties (4 of 4).

													Elim. candidate		Updated		Updated	
	Thales NL	EN Numerical	EN Symbols	HSV-N-	Name	In-house	Old	12nc HSN	12nc in-h	12nc oud	12nc total	#SLI	Application	Composition norm	Latest	Properties norm	Latest	Thales spec
Unalloyed	HSN-R-132	CW004A	Cu-ETP	9530	Copper alloy	CU/R132	CU1	0	107	3	110			EN 1652:1997/AC:2003; EN 13599:2014; EN 13600:2013; EN 13601:2013	1997; 2014; 2013; 2013	EN 1652:1997/AC:2003; EN 13599:2014; EN 13600:2013; EN 13601:2013	1997; 2014; 2013; 2013	
Unalloyed	HSN-R-1170/65	CW004A	Cu-ETP		Copper alloy	CU/R1170	CU8	0	2	4	6	81	LW08, SMART-L, ...	EN 1652:1997/AC:2003; EN 13599:2014	1997; 2014	EN 1652:1997/AC:2003; EN 13599:2014	1997; 2014	
Unalloyed	HSN-R-1161/65	CW024A	Cu-DHP	9535	Copper	CU/R1161	CU9	0	22	3	25			EN 1652:1997/AC:2003; EN 12449:2012	1997; 2016	EN 1652:1997/AC:2003; EN 12449:2012	1997; 2016	
Unalloyed	HSN-R-1156/01	CW008A	CU-OF		Copper oxygen-free	CU/R1156	CU10	0	0	0	0		-	EN 1652:1997/AC:2003; EN 13600:2013	1997; 2013	EN 13600:2013	2013	
Unalloyed	HSN-R-160	CW005A	Cu-FRHC		Copper alloy	CU/R160	CU5	0	2		2	428	SMART-S, Goalkeeper, MW08, ...	EN 13599:2014	2014	EN 13599:2014	2014	
Brass	HSN-R-019	CW507L & CW508L	CUZn36 & CuZn37	9535	Brass	CU/R019	MS1	0	63	3	66			EN 1652:1997/AC:2003; EN 12449:2012	1997; 2016	EN 1652:1997/AC:2003; EN 12449:2012	1997; 2016	
Brass	HSN-R-001/01	CW614N & CW617N	CuZn39Pb3 & CuZn40Pb2	9530/9535	Brass	CU/R001	AUTMS	0	205	2	207			EN 12164:2011	2016	EN 12164:2011; EN 12168:2011 (tube)	2016; 2016	for bar d = 80-300 mm; sheet; strip
Brass	HSN-R-1266/02	CW505L	CuZn30		Copper alloy	CU/1266	MS2	0	0	8	8	10	WM22(?), DA05	EN 12449:2012	2016	Thales		Rm, A, HV
Bronze	HSN-R-1179/16	CW453K	CuSn8		Bronze	CU/R1179	-	0	0	23	23		DA05, DA08, LW08, PRTL, (CAS), WM22, Flycatcher, STIR, ...	EN 12163:2011	2016	EN 12163:2011	2016	for d>50 mm
Bronze	HSN-R-337	CW452K	CuSn6	9535	Phosphor bronze	CU/R337	PHBR	0	50	5	55			EN 1652:1997	1997	EN 1652:1997	1997	
Bronze	HSN-R-1047	CW303G	CuAl8Fe3		Copper alloy	CU/R1047	ALBRK	0	0	31	31			EN 12420:2014	2014	EN 12420:2014	2014	
Bronze	HSN-R-108/70	CW307G	CuAl10Ni5Fe4	9530	Aluminium bronze	CU/R108	ALBRK2	0	21	3	24			EN 12163:2011; EN 12420:2012	2016; 2014	EN 12163:2011; EN 12420:2012	2016; 2014	
Cast	HSN-R-249/45	CB491K	CuSn5Zn5Pb5-B		Cast bronze	CU/R249	GBR6	0	6	0	6	9	(Cast) STIR, Flycatcher Mk2, Kasturi(?)	EN 1982:2008	2017	EN 1982:2008	2017	
Cast	HSN-R-1292	CB333G	CuAl10Fe5Ni5-B		Aluminium bronze	CU/R1292	ALBR2	0	0	13	13		(Cast) LW08, DA08, Goalkeeper, Flycatcher, ...	EN 1982:2008	2017	EN 1982:2008	2017	
Cast	HSN-R-1051	CB480K	CuSn10-B		Bronze	CU/R1051	GBR3	0	0	17	17		(Cast)	EN 1982:2008	2017	EN 1982:2008	2017	
Other	HSN-R-1384/01	C-T10G-K90			Sintered bronze	CU/R1384	SBR1	0	0	2	2	3	Flycatcher	ISO 5755-2012	2012	ISO 5755-2012 & Thales	2012	A, HB
Other	HSV-R-1338/01	CW118C	CuTeP	9530	Copper alloy	CU/R1338	TELL.CU2	0	17	0	17		STIR 2.4 (hp), Goalkeeper, ...	Thales (EN 12164:2011)	(2016)	Thales		Conductivity
Other	HSN-R-716	UNS C17200			Beryllium copper	CU/R716	BECU	0	0	35	35			ASTM-B194-08	2015	ASTM-B194-08	2015	
Other	HSN-R-2601	CW112C	CuNi3Si1		Copper alloy	CU/R2601	-	0	0	-	0		-	EN 12163-1998	FROZEN (2016)	EN 12163-1998	FROZEN (2016)	

Figure 14. Copper alloys overview and properties (1 of 2).

Group	Thales NL	EN Numerical	EN Symbols	Condition	Small sizes Rp (MPa)	Small sizes Rm (MPa)	Small sizes A (%)	Large sizes Rp (MPa)	Large sizes Rm (MPa)	Large sizes A (%)	Hardness (HV/HB)	Treatment	Remarks	Bar	Tube	Sheet	Strip	Sand cast.
Unalloyed	HSN-R-132	CW004A	Cu-ETP	R290, H090	250	290-360	6	220	260	12	80-105 HV	ETP = Refined electrolytically, not deoxidized, with guaranteed conductivity	Due to oxygen not for brazing	x	x	x	x	
	HSN-R-1170/65	CW004A	Cu-ETP	R240, H065				180	240-300	8	65-95 HV	ETP = Refined electrolytically, not deoxidized, with guaranteed conductivity				x	x	
	HSN-R-1161/65	CW024A	Cu-DHP	R240, R250, H065, H070				150	250	30	70-100 HV	DHP = Phosporized copper; 0.015-0.04% phosphor	Deoxidized, suitable for brazing and electrical conductivity		x	x		
	HSN-R-1156/01	CW008A	CU-OF	R240, H065				150	250-300	15	65-95 HV	OF = Deoxidized	Deoxidized (against steam embrittlement?)		x			
	HSN-R-160	CW005A	Cu-FRHC	R360, H110				320	360	2	110 HV	FRHC = Fire-refined, deoxidized, with guaranteed conductivity	Deoxidized (against steam embrittlement?)			x	x	
Brass	HSN-R-019	CW507L & CW508L	CUZn36 & CuZn37	R290, R300, R350	170	350-440	28	180	290	50			Good (cold) deformability, less accurate machinining than HSN-R-001		x	x		
	HSN-R-001/01	CW614N & CW617N	CuZn39Pb3 & CuZn40Pb2	R360, R430, R500	390	500	8	150	360	20	90 HV		Pb for good machinability	x	x	x	x	
	HSN-R-1266/02	CW505L	CuZn30						440	20	90 HV	M = as manufactured			x			
Bronze	HSN-R-1179/16	CW453K	CuSn8	R450	280	450	18	290	390-450	60	90 HB		0.01-0.4% phosphor	x				
	HSN-R-337	CW452K	CuSn6						560-650	5			0.01-0.4% phosphor, suitable for springs			x		
	HSN-R-1047	CW303G	CuAl8Fe3	H090				180	460	30	90 HB			x				
	HSN-R-108/70	CW307G	CuAl10Ni5Fe4	R680, H170	320	680	10	350	650	12	170 HB		For bushings, axles, and gears	x				
Cast	HSN-R-249/45	CB491K	CuSn5Zn5Pb5-B					90	200	13	60 HB		GS = sand cast, Pb for lubrication (bearings) and machinability, Zn for price, mouldability & machinability					x
	HSN-R-1292	CB333G	CuAl10Fe5Ni5-B					250	600	13	140 HB		Prefered in HSV-R-0043					x
	HSN-R-1051	CB480K	CuSn10-B					130	250	18	70 HB		Cast & bar & tube	x	x			x
Other	HSN-R-1384/01	C-T10G-K90							90	1	23-30HB		Alloy nr. 9603 from Essem Oljebrons meets req.	x	x			
	HSV-R-1338/01	CW118C	CuTeP					50	200	30	50 HB		Telerium added for good machinability, electrical conductivy and/or soldering	x				
	HSN-R-716	UNS C17200		TB00					410-540	35	45-78 HRB						x	
	HSN-R-2601	CW112C	CuNi3Si1	R800, H200 (ST, CW, PH)				780	800	8	200 HB		Precipitaion hardening, introduced as alternative for Be-Cu (HSN-R-716)	x				

Figure 15. Copper alloys overview and properties (2 of 2).

Thales NL	In-house	Old	Normative name	12nc HSN	12nc in-h	12nc oud	12nc total	# SLI	Elim. candidate Application	Condition	Remarks	Composition norm	Latest norm	Properties norm	Latest norm	Thales spec	Similar	Latest norm	Bar	Section	Tube	Sheet
HSN-T-1095/01	MG/T1095	MG1	MgAl3Zn1(A)	0	0	3	3	0	-	F	Magnesium	ISO 3116:2007	2007	ISO 3116:2007	2007		AZ31B temper F, ASTM B107/107M-13	2013	x	x	x	
HSN-W-006	PB/W006	PB, PB1, PB12, PB2, PB3, LOOD	PB 990R	0	0	45	45	48	Euro2000, SMART-S, MW08 PO, Lirod, Flycatcher		Lead	EN 12659:1999		-					x			x

Figure 16. Other metals overview and properties.

Material (HSV-R-2012-002)	HSN-K-	HSV-N-	HSV-R-	In-house	Old	Name	Trade name	Grade	12nc HSN	12nc in-h	12nc oud	12nc HSV-N	12nc total	12nc group	#SLI	Application	Remarks
ABS			2012-002	ABS					0	5			5	5	1	LW08 (BSP 1984)	
ARMAFLEX			2012-002	ARMAFLEX	ARMAFL				0	6	15		21	21			
ASBEST			2012-002	ASBEST					0	17			17	17			
CA			2012-002	CA					0	?			0	?			
CAB			2012-002	CAB					0	?			0	?			
CR	1801			CR/K1801	RUB3	Chloroprene		Grade C60	0		15		15	97			60 Shore A
CR	1800			CR/K1800	RUB1	Chloroprene		Grade C40	0		24		24	97			40 Shore A
CR		9320-001				Rubber plaat		HSN-K-1799/1800/1801	0			24	24	97			
CR	1799			CR/K1799	RUB2	Chloroprene		20 Shore	0		34		34	97			20 Shore A
DEKORIT			2012-002	DEKORIT					0	5			5	5	13	Flycatcher, Stir, Liod mk2, Lirod	
ECCOSH			2012-002	ECCOSH					0	4			4	4	50		
ECCOSORP			2012-002	ECCOSORP	ECCOSOR, S-ECCOS				0	0	16		16	16			
EP	1153			EP/K1153	EPOXYHARS	Epoxy resin		Kufalit BZH	0				0	173			
EP		9330-001				Kunststof staf rond		HSN-K-1153	0			22	22	173			
EP			2012-002	EP	EPOXYHARS, FILMCARD				0	55	96		151	173			
FERODO			2012-002	FERODO					0	23			23	23			
FILTERMAT			2012-002	FILTERMAT	NYLONWOL				0	13	1		14	14			
FOILBOARD			2012-002	FOILBOARD					0	4			4	4	0	- (BSP 1974, 91)	
JACONET			2012-002	JACONET					0	1			1	1	4	Lirod, Stir, Sting-EO, Flycatcher, Goalkeeper, MOC-mk2, Variant	
KARTON			2012-002	KARTON					0	2			2	2	0	- (BSP 1973)	
KER			2012-002	KER	KER.WOL				0	14	2		16	16			
LINOLEUM			2012-002	LINOLEUM					0	2			2	2	2		
MAGN.BAND			2012-002	MAGN.BAND					0	2			2	2	0	- (BSP 1970)	
MF			2012-002	MF	RESOPAL				0	?	7		7	7	38		
MICA			2012-002	MICA	MICALEX				0	6	7		13	13			
MULTIPLEX			2012-002	MULTIPLEX					0	5			5	5	9	- (BSP 1976)	
PA		9330-001				Kunststof staf rond		HSN-K-1883	0			9	9	9			
PA			2012-002	PA	NYLONDRAAD, PA6, PA6,6, PA11, ROPE				0	31	54		85	88			
PA11	332			PA/K332	NYLONDRAAD, PA6, PA6,6, PA11	Polyamide 11		PA 0312, Group 03 (PA11), Class 1 (GP), Grade 2	0		36		36	88			Niet meer leverbaar in staf, enkel spuitgiet (Charles)
PA12	1883			PA/K1883	PA12	Polyamide 12		PA 12	0				0	9			
PAP			2012-002	PAP	PAPIER, (PAPER)				0	0	6		6	6	4146		
PBT		9330-001				Kunststof staf rond		-	0			6	6	22			
PBT			2012-002	PBT	PBTP				0	0	16		16	22			

Figure 17. Plastics overview (1 of 3).

Material (HSV-R-2012-002)	HSN-K-	HSV-N-	HSV-R-	In-house	Old	Name	Trade name	Grade	12nc HSN	12nc in-h	12nc oud	12nc HSV-N	12nc total	12nc group	#SLI	Application	Remarks
PC		9330-001				Kunststof staf rond		HSN-K-486	0			8	8	60			
PC		9330-002				Kunststof plaat		HSN-K-486	0			8	8	60			
PC	486			PC/K486	PC	Polycarbonate	Makrofol N	PC	0		44		44	60			
PCFE			2012-002	PCFE	PCTFE				0	0	1		1	1	1	323DU, 191/200/250/254NE, 48/49BE, 18SI (BSP 1971)	
PE			2012-002	PE	PE1, PE2				0	10	18		28	28			
PERGPAPIER			2012-002	PERGPAPIER					0	5			5	5	81	250/343/358/530NE, 38SG, 131AU (BSP 1971)	
PES			2012-002	PES					0	1			1	1	0	- (BSP 1988)	
PET		9330-001				Kunststof staf rond		-	0			4	4	36			
PET		9320-003				Kunststof schuim plaat	Draka 9030	-	0			11	11	36			
PET			2012-002	PET	PET.SCH				0	3	18		21	36			
PF			2012-002	PF					0	10			10	10			
PFKW	209			PFKW/K209	PFKW1,2,3,4	Phenolic cotton fabric		PF-CC 202 (coarse weave)	0				0	94			
PFKW		9330-002				Kunststof plaat		HSN-K-209	0			15	15	94			
PFKW/K			2012-002	PFKW/K	PFKW, PFKW1,2,3,4				0	0	79		79	94			
PFPA		9330-002				Kunststof plaat		HSN-K-905	0			12	12	98			
PFPA			2012-002	PFPA	PFPAP/BS/PL, WEERST				0	0	86		86	98			
PFPAP	905			PFPAP/K905	PFPAP1/BS/PL	Phenolic cellulose paper		PF-CP206	0	0	86		86	98			
PI			2012-002	PI	PICU, PI-ADH				0	0	54		54	54			
PLAST			2012-002	PLAST	PLAST3				0	0	2		2	2	424		
PMMA	977			PMMA/K977	-	Polymehylmethacrylaat	Perspex	Unfilled PMMA	0				0	138			ISO 7823-1 for cast, ISO 7823-3 is leading due to tolerances
PMMA		9330-002				Kunststof plaat	Niet voor nieuwe ontw.	HSN-K-977	0			1	1	138			
PMMA		4710-002				Pijp rond PMMA		HSN-K-977	0			5	5	138			
PMMA		9330-001				Kunststof staf rond		HSN-K-977	0			5	5	138			
PMMA		9330-002				Kunststof plaat		HSN-K-977	0			18	18	138			
PMMA			2012-002	PMMA					0	109			109	138			
POLAROID			2012-002	POLAROID					0	2			2	2	12	4EQ, 30VE, 38PE, 8TU, 23CO (BSP 1972)	
POM	1160			POM/K1160	POM	Polyoxymethylene	Delrin 550	POM C	0				0	17			
POM		9330-002				Kunststof plaat		HSN-K-1160	0			7	7	17			
POM		9330-001				Kunststof staf rond		HSN-K-1160	0			10	10	17			
PP			2012-002	PP					0	1			1	1	3	229GR=CAS (BSP 1971)	
PPO			2012-002	PPO					0	15			15	15			

Figure 18. Plastics overview (2 of 3).

Material (HSV-R-2012-002)	HSN-K-	HSV-N-	HSV-R-	In-house	Old	Name	Trade name	Grade	12nc HSN	12nc in-h	12nc oud	12nc HSV-N	12nc total	12nc group	#SLI	Application	Remarks
PS	1422			PS/K1422	REXOLIT, S-REXOL	Crosslinked polysyreen		L-P-516, type E2	0				0	28			
PS		9330-001				Kunststof staf rond		HSN-K-1422	0			9	9	28			
PS			2012-002	PS	REXOLIT, S-REXOL				0	3	16		19	28			
PSP		9330-002				Kunststof plaat		HSN-K-124	0			7	7	20			
PSP	124			PSP/K124	PSP	Press board	Prespaan	P.2.1 (paper); B.0.1 (board)	0		13		13	20			
PTFE		9330-001				Kunststof staf rond		HSN-K-315	0			10	10	217			
PTFE	315			PTFE/K315	PTFE-C	Polytetrafluoroethylene	Teflon	Type P (as processed), Grade 2 & E3	0	203	4		207	217			
PTFE			2012-002	PTFE	PTFE-C				0	203	4		207	217			
PTFG			2012-002	PTFG	PTFEG, PTFEGCU				0		4		4	4	27		
PUR		9320-003				Kunststof schuim plaat			0			9	9	63			
PUR			2012-002	PUR	GAM				0	49	5		54	63			
PVC			2012-002	PVC	PVC1,2,3,4,5,6 + SCH, PVC.SCH				0	31	50		81	81			
PVF			2012-002	PVF					0	4			4	4	59		
RF.ABS			2012-002	RF.ABS					0	1			1	1	0	- (BSP 1970)	
RUB			2012-002	RUB	RUB4,5,6 SCH, RUBBER, RUBSCH, RUB.SCH, SYNTH.RUBB (RUB1,2,3=CR)				0	60	123		183	183			
SIR		4720-003				Siliconrubberslang			0			4	4	57			
SIR			2012-002	SIR	SIL.RUB, SIL.RUBBER				0	0	53		53	57			
UP			2012-002	UP	P.EST, UP-PE, UP.HARS				0	15	7		22	22			
VF			2012-002	VF	FIBER				0	0	6		6	6	12	LW08, DA..., SMART-S, TDS	
VILT			2012-002	VILT	(VILTMAT)				0	4			4	4	14	SMART-S, DA-08, Flycatcher	

Figure 19. Plastics overview (3 of 3).

	Material (HSV-R-2012-002)	HSN-K-	HSV-N-	HSV-R-	In-house	Old	Name	Trade name	Grade	12nc HSN	12nc in-h	12nc oud	12nc HSV-N	12nc total	12nc group	#SLI	Application	Remarks
Honeycomb	HONINGR			0094/006			Honeycomb GF hexagonal	Hexcel HRP-10-3/16-4,0						10				
Honeycomb	HONINGR			0094/006			Honeycomb GF overexpanded	Hexcel HRP-10-3/16-4,0-OX										Does not exist
Honeycomb	HONINGR			0094/006			Honeycomb Nomex hexagonal	Hexcel HRH-10-3/16-3,0					1	1	84	1	323DU (=CAS?)	Typo on HSV-R (says "HRN")
Honeycomb	HONINGR			0094/006			Honeycomb Nomex overexpanded	Hexcel HRH-10/OX-3/16-3,0					14	14	84	81		Typo on HSV-R (says "HRN")
Honeycomb	HONINGR			Not incl.			Honeycomb Nomex Flex Core	Hexcel HRH-10-F35-2,5						1				Typo on HSV-R (says "HRN")
Honeycomb	HONINGR			Not incl.			Honeycomb aluminium	Hexcel CR-III-1/4-5052-0,0015P-3,4						2			Lirod, SMART-S Mk2, Variant, APAR, Mirador, MW08	
Honeycomb	HONINGR			0094/006			Honeycomb aluminium	Hexcel CR-III-1/8-5052-0,002P-8,1					1	1	84	25	SMART-S Mk2, Mirador	
Honeycomb	HONINGR			Not incl.			Honeycomb Nomex overexpanded	Ten Cate ANA-4,8-48 OX						1				
Honeycomb	HONINGR			Not incl.			Honeycomb GF (hexagonal?)	Euro-Composites ECG-4,8-64						1	84	1	Stir kapje	
Honeycomb	HONINGR			2012-002	HONINGR	HONEYCOMB, HONINGRAAT				0	1	83		84	84			
Foam	-		9330-007				Styrene acronitrile foam	Corecell	T400	0			2	2	2	26		
Foam	-		9330-006				Polyetherimide foam	Airex	82.60 & 82.110	0			14	14	14			
Foam	PMI		9330-005				Polymethacylimide foam	Rohacell	IG 31/51/71	0			21	21	87			
Foam	PMI			2012-002	PMI	SCHUIM, SCUIM				0	0	66		66	87			
Fibre (reinforced)	AR			2012-002	AR					0	3			3	3	11	SMART-S, DA-08, MW-08	
Fibre (reinforced)	AREP			2012-002	AREP	AREP-PREP				0	0	5		5	5	61	Squire	
Fibre (reinforced)	ARGEP			2012-002	ARGEP					0	1			1	1	3	MW08 (PO), SMART-S	
Fibre (reinforced)	C			2012-002	C	(KOOL/WFS				0	?			0	?			
Fibre (reinforced)	CEP			2012-002	CEP	CEP-PREP				0	7	7		14	14		Mirador, also EMC uses	
Fibre (reinforced)	CG			2012-002	CG					0				0	0	0	-	
Fibre (reinforced)	CGEP			2012-002	CGEP	CGEP-PREP				0	0	1		1	1	0	- (BSP 1987)	
Fibre (reinforced)	EPG			2012-002	EPG	EPGCU, S-EPG				0	116	413		529	529			
Fibre (reinforced)	G			2012-002	G	FIBG, GLAS, GLASPARELS, GLASS, GL.WFS, LOSS.WFS, ROV.BINDER				0	?	92		92	92?			
Fibre (reinforced)	GEP			2012-002	GEP	PREPREG				0	10	200		210	210		Widely used (first choice)	
Fibre (reinforced)	GPI			2012-002	GPI	PIPREPR, PLLYM				0	0	1		1	1	1	Lirod, Goalkeeper	
Fibre (reinforced)	PIG			2012-002	PIG	PIGCU				0	1	108		109	109			
Fibre (reinforced)	SIG	311			SIG/K311	-	Silicone glass fibre		SI GC 202	0				0	29			
Fibre (reinforced)	SIG		9330-002				Kunststof plaat		HSN-K-311	0			10	10	29			
Fibre (reinforced)	SIG			2012-002	SIG					0	19			19	29			
Fibre (reinforced)	UPG			2012-002	UPG					0	6			6	6	12	DA08, S1850, (570/577/671NE), (323/444DU, 191/200/250/254NE)	

Figure 20. Composites & sandwich cores overview.

Minimal properties [MPa]	**HRH-10-3/16-3.0**	**HRH-10/OX-3/16-3.0**	**HRH-10-F35-2.5**	**CR-III-1/4-5052-3.4**	**CR-III-1/8-5052-8.1**	**HRP-3/16-4.0**	**ANA-4.8-48 OX**	**ECG-4.8-64**
Compressive "bare" strength	1.62	1.79	0.62	1.65	6.89	2.76	-	3.32
Stabilized strength	1.86	1.96	0.72	1.72	7.58	3.31	-	0.00
Shear L strength	0.96	0.65	0.50	1.24	4.62	1.45	-	1.45
Shear W strength	0.59	0.76	0.28	0.72	2.76	0.90	-	0.88

Typical properties [MPa]	**HRH-10-3/16-3.0**	**HRH-10/OX-3/16-3.0**	**HRH-10-F35-2.5**	**CR-III-1/4-5052-3.4**	**CR-III-1/8-5052-8.1**	**HRP-3/16-4.0**	**ANA-4.8-48 OX**	**ECG-4.8-64**
Compressive "bare" strength	2.07	2.20	0.83	2.34	10.34	3.31	-	4.15
Compressive stabilized strength	2.24	2.41	0.96	2.55	10.75	4.07	2.90	-
Compressive stabilized modulus	138	117	-	620	2412	393	120	315*
Shear L strength	1.21	0.79	0.59	1.58	5.51	2.14	0.80	1.80
Shear L modulus	45	21	66	345	930	90	20	100
Shear W strength	0.69	0.93	0.31	0.96	3.24	1.10	0.85	1.10
Shear W modulus	23	41	21	165	372	45	35	50

* "bare" modulus

Figure 21. Honeycombs mechanical properties [38] [39] [40] [41] [42] [43] [44].