COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF AIRCRAFT PRODUCTION

SUBJECT

APPENDICES TO

A SERIES OF REPORTS, PREPARED BY A MEMBER OF THE DEPARTMENT OF AIRCRAFT PRODUCTION DEALING PRIMARILY WITH THE STANDARD OF AIRCRAFT DESIGN AND DEVELOPMENT ACHIEVED BY THE JAPANESE AIRCRAFT INDUSTRY.

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(JAPAN)

COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF AIRCRAFT PRODUCTION

JAPANESE

AIRCRAFT MATERIALS.

December, 1946.

INTRODUCTION.

This report, which has been prepared by engineers of the Beaufort Division, Department of Aircraft Production, compares Japanese materials with those in use in America and Britain, assuming that the data sheets given in the Appendices to Reports 4 and 6 are representative of the materials used throughout the Japanese aircraft industry.

1. JAPANESE STANDARDS POLICY.

Prior to entering hostilities Japan had not paid attention to the drawing up of standards covering aircraft materials in particular. It was the practice to adapt general engineering standards by including in orders for material any particular requirements above those already laid down in the commerical specification.

However, at the end of 1940, a technical committee was formed, composed of members of the Japanese Aeronautical Society and acting under the aegis of the Japanese Standards Bureau, to draw up standards covering aircraft materials. These were issued in July, 1941, and the majority of them were revised in 1944 as a result of raw material shortages.

On checking the lists obtained from the Yokosuka Naval Arsenal and the Tachikawa Company it was found that the Tachikawa Company adhered closely to standards policy, whereas the Naval Arsenal used materials which varied considerably from the standard specifications. The variations were found to occur more in the casting alloys where the manufacturer could actually carry out the alloying process. In the case of wrought aluminium alloys and steels, which had to be obtained from outside sources, a closer adherence to Standards was noted.

A complete set of Japanese Aircraft Specifications is not yet available in Australia, only the index having been translated to date. The translation of the Specifications is still in progress in Japan, and when complete will be forwarded to the Division of Aeronautics, C.S.I.R.

However it is considered that it may be of interest to review the information at present available, both from the point of view of adherence to the Japanese Standards, and comparison with British and American practice.

2. MATERIALS USED BY THE NAVAL ARSENAL, YOKOSUKA.

The materials listed in the Appendix to Report No. 4 have been consolidated to show the Japanese Aircraft Standard to which the individual materials correspond and where applicable the equivalent British or American Specification, and this consolidation has been included in this Report as Appendix 1. Apparently Commander Otsuki was not very familiar with the procurement of raw materials, knowing only the types of material available and not the individual specifications. It is quite possible, in view of the fact that large scale production was not undertaken, the Naval Arsenal being primarily a research station, that the materials in use had been in store for a considerable period and therefore of greater variety than would be available to the aircraft industry.

It is considered that the lists supplied by the Tachikawa Company are more representative of the materials used by the industry, where greater difficulties would be encountered in the procurement of raw materials.

Materials have been considered to be chemically equivalent where the variations in composition are such that the processing of the material or the physical properties are not affected in any unusual manner, and physically equivalent when the variations are within approximately 2.1/2% of the normal physical properties of the English or American specification.

Carbon Steels.

The properties of the carbon steels in general are listed in Table 1; specific properties relating to sheets and tubes set out in Tables 2 and 3. The chemical compositions in Table 1 is limited to the carbon content no mention being made to the allowable amounts of the usual impurities such as sulphur and phosphorous or to increased sulphur content for free cutting properties.

Of the five types of steels listed only the high carbon type has no equivalent British or American specification due to the fact that British and American practise favours the use of low alloy steels because of their superior physical properties coupled with the additional advantage of weldability.

Special Steels (1).

Of these six types of nickel-chromium steels for bar or forging stock, the first five have equivalent British Specifications; No. 6 is a replacement steel, the manganese content of which has been increased to conserve nickel which was in short supply in Japan after 1942, and this steel is used in three conditions of heat treatment. It is doubtful whether this steel should be used in the condition indicated by the first set of physical properties as brittleness would be a serious disadvantage. This would also limit its use in the second condition of heat treatment, although it might be a satisfactory replacement for steel No. 5. In its third condition it would be suitable as a replacement for Steel No. 4.

Special Steels (2).

These are nickel-free steels for bar or forging stock and Nos. 2, 3, 4 and 6 have equivalent British or American Specifications. No. 1 may be a chromium alloy replacement and No. 5 a reversion to the older silicon-manganese type alloy as a replacement for the 3% nickel-chromium steel listed as No. 1 in the nickel steels.

Surface Cementation Steel.

Of the eight types of steel for case-hardening, Nos. 1, 3, 4, 5 and 6 have equivalent British Specifications. No. 2 is identified as S.A.E. Type 5120, a 1% chromium deep-hardening steel, which may be a specific-purpose material or a replacement for the nickel and nickel-chromium types of case-hardening steels, but lacking the tough fibrous core of the latter. Nos. 7 and 8 are identified as S.A.E. Type 4115, 1% chromium-molybdenum steels and would most likely be replacement steels for the nickel and nickel-chromium steels.

Case-Hardening Steel (Nitriding).

Of the four types of steel for Nitriding, only No. 4 has no equivalent British or American Specification. Its composition suggests an attempt to produce a thin case with extreme hardness, at the expense of the danger of spalling (i.e. flaking) of the case.

Stainless Steel.

All stainless steels for bar or forging stock have equivalent British or American Specifications.

Special Steel Tube.

Of the special steels for tube, Nos. 3 and 4 have equivalent British and American Specifications. Number 2 is a 25% nickel stainless and non-magnetic steel of little interest as its corrosion properties are inferior to those of the better known high chromium nickel steel; the reference to hardening and tempering is erroneous, as the alloy is austenitic in structure and its strength is improved by work hardening only. Number 1 is the normal high chromium-nickel, 18-8 Type, Stainless Steel, and has chemically equivalent British and American Specifications; the erroneous reference to heat treatment as indicated above is repeated for this alloy and it is doubtful whether the mechanical properties quoted could be obtained by work-hardening.

Steel Wire.

Of the three types of steel for wire, No. 1 is the well-known chromium vanadium type and has equivalent British Specifications. Number 2 appears to be for hard-drawing purposes with British Specification D.T.D. 215 as a physical equivalent. Number 3 is a silicon-manganese steel, with small additions of chromium and tungsten, to effect a substitute for No. 1.

Steel Sheet for Springs.

Of the five types of spring steel for sheets and strips, the first three have equivalent British and American specifications, whilst No. 4 suggests a low carbon cold rolling material with spring characteristics; No. 5 is identified as S.A.E. Type 1350, and oil-hardening manganese steel, which has a near equivalent in B.S.S. 970 EN 43, where the manganese content has been reduced to allow water-hardening.

Steels for Ball and Roller Bearing.

The steels listed have equivalent British Specifications.

Magnet Steels.

These are all permanent magnet materials, and, although no standard specifications are available they are all equivalent to the following well-known commerical types in use in British and American practice:-

1% .... Carbon
6% .... Tungsten
2.1/2% .... Chromium
6% .... Cobalt
5% .... Chromium
11% .... Cobalt
9% .... Chromium
16% .... Cobalt
9% .... Chromium
16% .... Cobalt
9% .... Chromium, Cobalt-Chromium-Tungsten (KS Magnet) and Alnico III respectively.

Forged High-Strength Aluminium Alloys.

Of the four types of aluminium alloy for bars or forging stock, No. 3 is the only one which has no equivalent British or American Specification. It is chemically equivalent to British Specification D.T.D. 364, but the physical properties are much lower, especially the proof stress. This may be due to the fact that the Japanese desired to relax on these properties in order to reduce the effect of material rejection or to remove production difficulties, in the form of heat treatment control or forging practice.

High-Strength Aluminium Alloy Sheets (Unclad).

Of the three types of aluminium alloy for sheets and strips, No. 3 is the only one which has no equivalent British or American Specification, but is well-known as Alcoa Alloy C17S, a high silicon modified duralumin and has physical equivalents as for No. 2 (Condition SDH). A disadvantage with this alloy is that it requires artificial ageing to produce physical properties equivalent to those of No. 2 (Condition SDH).

High Strength Aluminium Alloy Sheets (Clad).

The first alloy quoted appears to constitute the cladding alloy for the second alloy. The former is identified as Alcoa Alloy 4S and its use as a cladding alloy as against pure aluminium is an attempt to obtain higher physical properties in the cladding with equivalent corrosion resistance. The physical properties quoted for the two conditions of the second alloy apparently apply to the finished clad material and to the centre of the sandwich. In each case there are equivalent American Specifications.

Forged Heat-Resisting Aluminium Alloy.

All of these alloys have chemically equivalent British or American Specifications. It is worthy of note that, where the physical properties of the first three alloys are approximately 10% lower than the relevant British and American

Specifications, those of the fourth alloy, are 10% higher. The only reason for this would appear to be that the Japanese had experienced production difficulties with the first three alloys and were forced to accept lower physical properties, whereas satisfactory production has been achieved with the higher physical properties in the case of the fourth alloy.

Aluminium Alloy Rivet Wire.

Of the four types of aluminium alloy for rivet wire, only No. 1 has no equivalent British or American Spcification. The physical properties of this aluminium wire for rivets suggest that it is more severely drawn than its British or American counterpart, since they are 30% higher.

Miscellaneous Aluminium Alloys.

Of the two alloys listed in connection with which only the chemical composition is quoted, the first is equivalent to British Specification D.T.D. 363, the other to D.T.D. 683. It is interesting to note that the Japanese claim an extrusion speed five to ten times that for Alcoa Alloy 24S.

Aluminium Alloy Casting.

The first type of alloy for casting has an equivalent American Specification, both in the as sand cast and heat treated conditions.

The second type has a chemical equivalent in British Specification L8 but has 60% higher physical properties which could be due to a number of factors; it may be a chill casting (the condition of casting is not quoted or different types and methods of casting test pieces may be employed).

The third type has a chemical equivalent in British Specification L.11, but has 20% higher physical properties in the sand cast condition of this specification; it has, however, equivalent physical properties in the chill cast condition. The remarks above for the second type in regard to factors influencing the physical properties also apply to this type.

The fourth type of casting alloy is identified as the German Alloy Lautal, which, in the as cast condition, has an equivalent in British Specification D.T.D. 424, and, in the heat treated condition, has a physical equivalent in British Specification D.T.D. 304.

The fifth type has chemically equivalent British and American specifications, but, in the as cast condition, the physical properties are 10% higher and, in the heat treated condition, 25% higher. The previous remarks for the second type in respect to factors influencing the physical properties also apply to this type.

The sixth type has a chemical equivalent in British Specification D.T.D. 133, but has no physical equivalent as apparently, it was used in the heat treated condition; the physical properties are 20% higher than those of D.T.D. 133.

The seventh type has a chemically equivalent British Specification, but, in the "as cast" condition, the physical properties are 30% higher than those of D.T.D. 238; in the heat treated condition, D.T.D. 131 is completely equivalent.

The eighth type has a complete equivalent in British Specification L.33.

The ninth and tenth types of alloys are identified as modifications of the German Alloy Silumin. They have no chemical equivalents in the British or American Specifications. The addition of zinc in the tenth type produces age-hardening properties and may produce greater fluidity for casting, but will markedly decrease the corrosion resistance.

The eleventh and twelfth types are identified as modifications of the Swiss Alloy Anticorodal. They have no chemical equivalents in the British or American Specifications, and as the type name for the alloy implies, are used principally for resistance to corrosion. They are an aluminium-magnesium silicide alloy, which is age-hardening and normally encountered as wrought alloys.

The thirteenth alloy is identified as the German Alloy K.S. Seewasser, for which there are no chemically equivalent British or American Specifications. Again, as the alloy type name implies, it is employed for its resistance to corrosion.

Cast Magnesium Alloys.

Of the three types of magnesium alloy for castings only the second type, in the as cast condition, has no equivalent British or American Specification. British Specification D.T.D. 136 is chemically equivalent, but the physical properties are 15% higher than those of this Specification. The previous remarks made for aluminium alloys in regard to the factors influencing physical properties also applies here.

Wrought Magnesium Alloys.

Of the two types of magnesium alloy for rolling, forging or extrusion the first type has chemically equivalent American specifications for each of the three forms; however in these specifications the physical properties of the rolled and extruded material are approximately 12% higher and of the forged material 5% higher. The second type of alloy has chemically equivalent British and American Specifications and similar discrepancies in physical properties again occur except that in this case where American requirements are 12% higher, British requirements are 12% lower to the Japanese.

Special Brass.

No information is possessed concerning the form of this material but it is considered reasonable to presume that the physical properties quoted cover bar and forging stock. Of the three alloys, only the second is at variance with British or American practice; this bronze, with the higher manganese content, has an 8% lower copper content and consequently an equally higher zinc content.

Phosphor Bronze.

Of the four phosphor bronzes, only the second type covering extrusions and the third type covering rolled sheet are of interest, the other alloys having equivalent British or American Specifications. These two alloys gain their physical properties by work hardening; it also appears that the second type has a higher tin content compared to the first type in order to produce physical properties equivalent to those of the first type with less severe cold working; the third alloy is of interest only for the reason that it is more severely cold rolled than its chemically equivalent British Specification to produce a spring temper.

Bearing Metals.

These are all Babbit Metals with varying compositions and are well-known commerically. The first two alloys have chemically equivalent British and American Specifications. These Babbit Metals are usually considered for their anti-friction properties only and normal physical properties are not specified

3. MATERIALS USED BY THE KAWASAKI AIRCRAFT COMPANY, TACHIKAWA.

As stated previously the materials in use by the Kawasaki Company are considered to be more representative of the materials in general use by the industry, the materials being purchased to Japanese Aeronautical material specifications.

Two lists were obtained from the Kawasaki Company and these are included as Appendix 2 to Report No. 6. The first, Data Sheets TS1404 to TS.1406, prepared in 1941 subsequent to the introduction of Japanese Aircraft Specifications, covers materials available to design draftsmen. The second, Data Sheets Ki 74 Pages 1 to 7, including Charts I to V, prepared in 1944, covers wartime emergency materials employed in the manufacture of the Ki 74 aircraft. The materials listed in the above mentioned data sheets have been consolidated to show the Japanese aircraft specification to which the individual materials correspond and, where applicable, the equivalent British or American Specification, and this consolidation has been included in this report as Appendices 2 and 3 respectively.

The Ki 74 list is much less comprehensive than the 1941 general list; this is to be expected in view of the fact that in any particular aircraft the number of different types of materials employed is kept to a minimum; nevertheless the effect of shortages can be seen.

It is noteworthy that practically all the materials have British or American equivalents. Set out hereunder are detailed comments on those specifications deviating from British and American practice.

Steel Bar - Data Sheets TS.1402 and Ki 74 Page 3 Chart 1.

The second and third types of steel for bar listed with Data Sheet TS.1402 appeared in the previous discussion on the material listed for the Naval Arsenal, Yokosuka, and were discussed as the fourth type of Plain Carbon Steel and the second type of Surface Cementation Steel respectively. The fifth type appears to be required for general use with the first set of physical properties quoted, but the data sheet also indicated that the designer may, on occasion, specify the second condition of physical properties. The latter physical properties are not required of this chromium-molybdenum steel in British and American practice. In the case of the data sheet for the Ki 74 Aircraft, the chrome-molybdenum steels have been replaced by the silicon-manganese chromium steels, and the stainless steel has been omitted entirely, both due to the shortage of alloying elements.

Copper Alloy Bar - Data Sheets TS 1402 and Ki 74 Page 5 Chart III.

Although the introduction to the data sheets for the Ki 74 indicated that there was a shortage of copper in Japan in 1944, there was no reduction in the alloy selection. The sole notable change was the introduction of a higher strength aluminium Bronze, which would have an overall equivalent in D.T.D. 197 but for the fact that manganese has been substituted for nickel.

Aluminium Alloy Bar or Forging - Data Sheets TS 1402 and Ki 74 Page 4 Chart II Parts 1 and 2.

The second and fourth types of alloys listed in data sheet TS 1402 have lower physical properties than the corresponding British specification in nominal sizes of bar from 1.9/16" to 3" and in nominal sizes of forging from 1.9/16" to 8".

Magnesium Alloy Bar - Data Sheets TS 1402 and Ki 74 Page 6 Chart IV.

The magnesium alloys listed in Data Sheet TS 1402 have higher physical properties than those employed in British and American practice. Unfortunately the data sheet for the Ki 74 dealing with magnesium alloy bar was not obtained, and consequently the selection of wartime emergency alloys cannot be discussed. However, the introduction to the Ki 74 Data Sheets indicated that the position of magnesium alloy was hopeless and that it was not to be employed.

Steel Sheet or Strip - Data Sheets TS 1403 and Ki 74 Page 3 Chart 1.

Comparing these Data Sheets it is evident that the number of types of steel for sheet was curtailed even more severely than for the bar form. Here, again the stainless steel has been excluded entirely and the chromium-molybdenum alloys replaced by a single silicon-manganese-chromium alloy.

Copper Alloy Sheet or Strip - Data Sheets TS 1403 and Ki 74 Page 5 Chart III.

Although, as instanced previously, copper was in short supply, the same selection of alloys existed for both of the above Data Sheets. As in the discussion on the material listed by the Naval Arsenal, Yokosuka, the phosphor bronze sheet was apparently severely cold rolled to produce a spring temper, and thus developed greater strength than the chemically equivalent type in British and American practice.

Aluminium Alloy Sheet or Strip - Data Sheets TS 1403 and Ki 74 Page 4 Chart II Parts 1 and 2.

All types have equivalents in British and/or American Specifications, and the sole notable difference between these Data Sheets is the reduction in the number of types.

Magnesium Alloy Sheet or Strip - Data Sheets TS 1403 and Ki 74 Page 6 Chart IV.

It is unfortunate that the Data Sheet for the Ki 74 is not available, as this prevents a comparison of the two sets of Data Sheets in respect to alloy selection.

Steel Tube - Data Sheets TS 1404 and Ki 74 Page 3 Chart 1.

The second type listed in Data Sheet TS 1404 employs a slightly higher carbon content to produce physical properties equivalent to British Specification D.T.D. 563. In the case of the third type, which is a chromium-molybdenum alloy, and for a wall thickness greater than 14 S.W.G., the physical properties demanded are lower than those for its comparable American specification. The selection of alloys listed in the Data Sheet for the Ki 74 evidenced a severe curtailment and chromium-molybdenum steel was replaced by silicon-manganese-chromium.

Copper Alloy Tube - Data Sheets TS 1404 and Ki 74 Page 5 Chart III.

All types are covered by British Specifications and the only variation between the two Data Sheets is that the selection of alloys has been curtailed in the case of the Ki 74.

Aluminium Alloy Tube - Data Sheets TS 1404 and Ki 74 Page 4 Chart II Parts 1 and 2.

The remarks above for the copper alloy tube also apply in this case.

Magnesium Alloy Tube - Data Sheets TS 1404 and Ki 74 Page 6 Chart IV.

The situation for magnesium alloy in tube form is akin to that for the sheet and strip form.

Copper Alloy Casting - Data Sheets TS 1405 and Ki 74 Page 5 Chart III.

The third type of alloy, a silicon bronze has a physical equivalent in British Specifications B.S.S. 208 Class 2, a manganese bronze. In British and American practice, the silicon bronzes employed have higher copper content with consequent lower physical properties. Where higher strength is sought, the aluminium or manganese bronze are employed.

Aluminium Alloy Casting - Data Sheets TS 1405 and Ki 74 Page 4 Chart II Parts 1 and 2.

Deviation from British and American practice occurs only in the case of the emergency materials for the Ki 74. The first type for casting listed in Page 1 has a chemical equivalent in the British first grade scrap alloy, D.T.D. 424, which has higher physical properties in both the sand and chill cast conditions; the Japanese sought to improve its physical properties by heat treatment, which is not done in Britain and America as heat treatable alloys capable of producing superior strength in the heat treated condition are available. The second type listed in Page 2 has no comparable alloy, as it was employed specifically as a substitute material for phosphor bronze in bearings, as stated in the Data Sheet. Apparently, the supply position of aluminium was more satisfactory than that of copper in Japan in 1944.

Magnesium Alloy Casting - Data Sheets TS 1405 and Ki 74 page 6 Chart IV.

The materials listed in Data Sheet TS 1405 have equivalent British Specifications. The unavailability of the emergency Data Sheet for the Ki 74 prevents a comparison being made of the selection of materials under normal and emergency conditions.

Miscellaneous Forms of Steel - Data Sheets TS 1405 and Ki 74 Page 3 Chart I.

The iron and steel casting alloys listed in the Ki 74 Data Sheet are of little interest in that this material is very rarely employed in aircraft construction, in view of its poor specific strength. It appears that the Japanese standardised on a silicon-manganese-chromium alloy to be used in the case or wrought, heat treated condition. This steel alloy for use on the cast heat treated condition is a lower carbon version of a general engineering alloy for cast crankshafts and similar applications where high stresses and severe conditions of service are encountered.

Aluminium Alloy Wire - Data Sheets TS 1405 and Ki 74 Page 4 Chart II Parts 1 and 2.

These materials are identical with those used at the Naval Arsenal, Yokosuka. The physical properties of the aluminium wire suggest that, after cold working, it is not softened to the extent that is required in the specification for its British or American counterpart.

Copper Alloy Wire - Data Sheets TS 1405 and Ki 74 Page 5 Chart III.

The materials listed have British equivalents.

Aluminium Alloy Sections Rolled from Sheet or Strip or Extruded - Data Sheets TS 1406 and Ki 74 Page 4 Chart II Parts 1 and 2.

All of these materials has British or American equivalents.

Magnesium Alloy Sections Rolled from Sheet or Strip or Extruded - Data Sheets TS 1406 and Page 6 Chart IV.

All of those listed in Data Sheet TS 1406 have equivalents in Britain or America. The unavailability of the emergency Data Sheet for the Ki 74 prevents a comparison being made between materials used under normal and emergency conditions.

Timber, Densified Wood, Plywood and Adhesives - Data Sheet Ki 74 Page 7 Chart V Parts 1 and 2.

It is difficult to select equivalents for these in view of the fact that the various forms of wood employed in any country depend to a great extent on the raw materials grown. Density has been selected as one of the important physical properties in this discussion and, in the main, the Japanese materials have either overall or physical equivalent - British or Australian Specifications, insufficient data being available in respect to American Specifications.

4. CONCLUSIONS.

It is worthy of note that, where similar materials are listed in the data supplied by Commander Otsuki (Ref. Appendix to Report No. 4) and in that supplied by Mr. Nakagawa (Ref. Appendix 2 to Report No. 6), close agreement occurs in respect to physical properties.

With few exceptions, as discussed in the body of this report, the Japanese aircraft materials coincide with those employed in British and American practice. The unavailability of alloying elements for steel, particularly nickel and molybdenum, during the war from the beginning of 1944, caused the Japanese to employ a silicon-manganese-chromium alloy steel. This latter type superseded alloys containing elements such as nickel, chormium, molybdenum and vanadium, individually or combined as principal constituents. It is interesting to note that the Japanese employed a very high strength aluminium alloy extrusions prior to 1941, since it was included in the Data Sheets issued early in that year. This alloy has its counterpart in Alcoa alloy 75S, which was not employed in Britain and America until late in 1943.

The general impression gained from the data available is that the Japanese were content to accept the practices of other countries in order to set up a basic series of aircraft materials, but were actively engaged in determining the optimum properties of them and in evolving more efficient types.

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