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MATERIAL PROPERTIES HANDBOOK, VOLUME III. MAGNESIUM NICKEL AND TITANIUM ALLOYS

Advisory Group for Aeronautical Research and Development
Paris, France

1967

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NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AERONAUTICAL RESEARCH AND DEVELOPMENT

MATERIAL PROPERTIES HANDBOOK

VOLUME III

MAGNESIUM NICKEL AND TITANIUM ALLOYS

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THE ROYAL AERONAUTICAL SOCIETY
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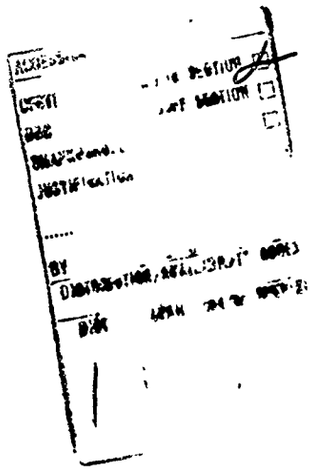

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PREFACE

The charts in this Handbook have been prepared from basic data supplied by representatives appointed in each country, thus assuring that the information is the best available at the present time. These representatives are also responsible for the approval of their National Section, and the preparation of the Handbook has been possible only with their enthusiastic co-operation.

The representatives who assisted in the preparation of Volume III are:-

Belgium	- Lt. Col. A. Parot, Belgian Air Force
Canada	- H.V. Kinsey, Department of Mines & Technical Surveys
France	- J. Faguet, Service Technique Aeronautique
Germany	- Dr. Ing. K. Reichel, Stuttgart-Zuffenhausen
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United Kingdom	- F. Clifton, Royal Aircraft Establishment
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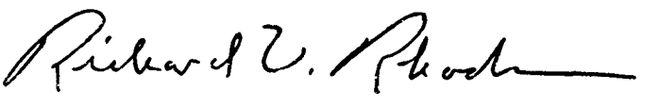
The charts will be reissued from time to time as additional or improved data become available, and it is envisaged that the Handbook may be extended at a later date to include other materials, in particular refractory metals.

Users of the Handbook are invited to comment to the Panel on the data or on the form of presentation, and consideration will be given to these comments in the preparation of further issues.



Richard V. Rhode,

Chairman
Structures and Materials Panel

February 1963

Volume III
Magnesium,
Nickel &
Titanium Alloys

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INTRODUCTION TO VOLUME III

PURPOSES AND USES OF THE HANDBOOK

A thorough knowledge of relevant material properties is a fundamental requirement of efficient aircraft design. Furthermore, a careful comparison of different materials. and particularly materials produced by different countries, is often of great value when considering manufacture under licence, modification or repair. Much of the basic information necessary for such a comparison is already available, although it is often widely scattered. The purpose of this Handbook therefore, is to collect the available information on aircraft materials produced by the nations of the NATO alliance, and to present this information in a consistent and systematic form.

In addition to its uses as a standard reference book, this Handbook could be used as an aid in the comparison of test results and in the comparison of the engineering practices of the various NATO nations. It could also be used to give an indication of some unknown property of a material by comparison with other similar materials whose relevant properties are known.

It is hoped that an outcome of the establishment of a standard format will be to encourage producers and others in all the NATO nations to record material properties in this form.

SCOPE OF VOLUME III OF THE HANDBOOK

This third volume of the Handbook deals with those magnesium, nickel and titanium alloys which are of most interest for structural use in aircraft of the NATO nations. Nickel and titanium alloys which are used only for castings or for rivets have not been included. However, a large proportion of magnesium alloy is used in the cast form and magnesium casting alloys have been included in this volume. This has necessitated the introduction of a classification of three types of test for use in the *Static Properties* charts. The classification is explained on p.3 of this Introduction.

The nations for which data are included in this first issue are Canada, France, Germany, Italy, the Netherlands, the United Kingdom and the United States. It has been established that none of the other NATO nations produce magnesium, nickel or titanium alloys which are used structurally in aircraft.

GENERAL LAYOUT

The data are divided into *National Sections*, each section dealing with the alloys produced by one country.

In each *National Section* there is, for each distinct alloy, or group of alloys, a set of sheets which give data on the physical and mechanical properties, both at room and elevated temperatures. Preceding these sheets are *Introductory Notes* which give general information and amplify such points as the designations and specifications of the alloys, heat treatment, testing procedures and other information which it is not practicable to include on the charts. It is advisable that these Notes should be read carefully before using any of the charts.

To facilitate the addition of information a loose leaf format has been adopted.

PRESENTATION OF DATA

The data are presented in tabular rather than graphical form. This presentation has the merit of simplicity, the data take up less space and modifications or alterations are simple to carry out. Where variation of properties with respect to two or more variables is involved, the choice of the most suitable variable as the abcissa will depend on the use to which the data are to be put; the tabular presentation leaves the user free in this choice. Also, when plotting curves for a specific purpose it is a simple matter to convert the units when working from tabulated values.

The wording on the charts is kept to a minimum, symbols replacing words wherever possible. The presentation is such that little, if any, translation will be required.

Any information which is non-standard, or any points which need stressing are dealt with by footnotes, references to which are displayed around the edges of the charts and apply to rows or columns.

NOTATION AND UNITS

The *Notation* chart given at the end of this Introduction shows the symbols used for the various properties. In each *National Section* a notation acceptable by that nation is used, and the chart enables comparison of the various notations used.

The units, which are quoted on every chart, are those used by the country of origin of the alloy. A chart giving *Conversion Scales* enables easy and rapid conversion from one system of units to another. This chart follows the *Notation* chart at the end of this Introduction.

DATA BASIS

On all the sheets giving mechanical properties, there is a statement on the statistical basis of the information. This is given as Data Basis 'A', 'B' or 'C' at the top of each sheet. The coding for each statistical basis is:-

A - minimum guaranteed values, i.e. the values listed are the minimum to be expected.

B - 90% probability values, i.e. the values listed will be met or exceeded by 90% of the material supplied.

C - Typical (basis for typicality not specified).

The preferred basis is 'B', 90% probability values, but if these values are not available the order of preference is first Data Basis 'A' and then 'C'.

TYPES OF TEST FOR CASTINGS

In the *Static Properties* charts for magnesium castings the properties are given for three types of test which are distinguished by the letters 'a', 'b' and 'c' on the charts. The significance of these is as follows.

a - Tests on special separately cast test specimens.

b - Tests to find the minimum properties of castings using specimens cut from various locations in production castings.

c - Tests to find the average properties throughout castings using specimens cut from various locations in production castings.

The results of each type of test may be given to 'Data Basis A, B or C' as defined under 'Data Basis' in this *Introduction*.

The manner in which these properties are applied for design purposes varies considerably. In general the castings are designed and accepted on the basis of one or more of the following procedures, depending on the importance or degree of complication of the component.

1) Acceptance by calculation

2) Acceptance by tests on complete production castings loaded in a manner representative of working conditions

3) Acceptance by tests on specimens cut from castings

4) Acceptance by radiological or other defect detention methods.

The properties used when designing by procedure (1) are either those from 'Type of Test: a' with a reduction factor, or those from 'Type of Test: b'. When procedures (2) and (3) are followed, the properties from 'Types of Test: b and c' are required. Procedure (4) is used alone only for lightly stressed parts, but great importance is attached to this when used in conjunction with the other procedures, particularly in the case of complicated castings. 'Type of Test: a' properties are also of value in the comparison of the properties of alloys from different countries.

DATA PRESENTED

For each distinct alloy or group of alloys a set of charts is given which include, for various forms and conditions of the alloy, information on the chemical composition and physical and mechanical properties at room and at elevated temperatures. A complete list of the properties covered is given at the end of these notes. For some of the alloys dealt with, the complete range of data is not yet available.

The *General Properties* chart gives the chemical composition of the alloy by quoting the limits of each alloying element as a percentage by weight of the total, with either upper and lower limits or an upper limit only.

The *General Properties* chart also gives selected physical properties of the alloy at room temperature and at elevated temperatures.

The *Static Properties* charts state the relevant official specifications and group the properties at room temperature according to form, heat treatment condition and thickness of the material. Two or three rows are included for some of the properties so that variation with grain direction or other parameters may be noted.

For a number of applications the shape of the compression stress-strain curve, up to about the 0.5 per cent offset yield stress, is of interest. Thus rather than present a large number of typical curves, values of the 0.1, 0.2 and 0.5 per cent offset yield stresses in compression are quoted. These values, together with the value of the Modulus of Elasticity in compression, may be used, in a method such as that given in the Royal Aeronautical Society Structures Data Sheets 00.02.00, 00.02.04 and 00.02.05, to provide information relevant to the shape of the stress-strain curve.

For the *Fatigue Properties* chart, reliable results have been selected from tests on specimens subject to various loading conditions. Brief descriptions of the test specimens are given on each chart, and further information is given in the *Introductory Notes* to the relevant *National Section*.

On the *Short Time Properties at Elevated Temperature* chart and the *Recovered Properties after Exposure to Elevated Temperature* chart, the mechanical properties after various times of exposure are expressed as percentages of their values at room temperature. The room temperature property on which these percentages are based and the temperature at which it applies are quoted when known at the head of the column. In general, data are included for temperatures up to the maximum working temperature.

The charts which give data on creep are headed *Properties under Load and Elevated Temperature*. The first sheet gives, as percentages of the ultimate tensile stress, the stresses required to produce specified total deformations after various times at elevated temperatures. A second sheet gives, as percentages of the ultimate tensile stress, the stresses required to produce specified minimum creep rates at various temperatures, and also the stresses required to cause tensile failure in a specified time at various temperatures. As for the other elevated temperature charts, the room temperature reference properties are given on the charts when known.

LIST OF PROPERTIES

The properties included on the charts are listed below. The properties are listed in the order in which they appear for each alloy and are grouped under the title of the relevant chart.

GENERAL PROPERTIES

Chemical composition

Physical properties

Density
Specific heat
Thermal conductivity
Coefficient of thermal expansion
Emissivity

STATIC PROPERTIES

Ultimate stress in tension
Offset yield stress in tension
0.1 per cent offset yield stress in compression
0.2 per cent offset yield stress in compression
0.5 per cent offset yield stress in compression
Ultimate shear stress
Ultimate bearing stress
Yield stress in bearing
Modulus of elasticity in tension
Modulus of elasticity in compression
Shear modulus
Ultimate elongation

FATIGUE PROPERTIES

Rotating bending test
Reversed flexure test
Repeated axial load test
Alternating torsion test

SHORT TIME PROPERTIES AT ELEVATED TEMPERATURES

Ultimate tensile stress
Offset yield stress in tension
0.2 per cent offset yield stress in compression
Ultimate shear stress
Yield stress in bearing
Elastic modulus

RECOVERED PROPERTIES AFTER EXPOSURE TO ELEVATED TEMPERATURE

Ultimate tensile stress
Offset yield stress in tension
0.2 per cent offset yield stress in compression
Ultimate shear stress

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

Time to creep to various deformations
Minimum creep rate
Time to tensile failure

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NOTATION

PROPERTY	CANADA	FRANCE	GERMANY	ITALY	NORWAY	UNITED KINGDOM	UNITED STATES OF AMERICA		
Ultimate Stress in Tension	F_{tu}	R	σ_B	R	σ_B	f_t	F_{tu}		
0·1 per cent. {Proof Stress / Offset Yield Stress} in Tension						t_1			
0·2 per cent. " " "	F_{ty}	$E_{0,2}$	$\sigma_{0,2}$	$S_{0,2}$	$\sigma_{0,2}$	t_2	F_{ty}		
0·1 per cent. " in Compression	F_{c1}	$E_{c0,1}$		$S_{c(0,1)}$		c_1	F_{c1}		
0·2 per cent. " " "	F_{cy}	$E_{c0,2}$	$\sigma_{dF0,2}$	$S_{c(0,2)}$		c_2	F_{cy}		
0·5 per cent. " " "	F_{c5}	$E_{c0,5}$	$\sigma_{dF0,5}$	$S_{c(0,5)}$		c_5	F_{c5}		
Ultimate Shear Stress	F_{su}	R_c	τ	τ_R	τ	f_q	F_{su}		
Ultimate Bearing Stress	F_{bru}		σ_L	σ_s		f_b	F_{bru}		
Yield Stress in Bearing	F_{bry}			S_s		b_{10}	F_{bry}		
Modulus of Elasticity in Tension	E	M	E	E	E	E	E		
" " " " Compression	E_c	M_c	E_d	E_c		E_c	E_c		
Shear Modulus or Modulus of Rigidity	G	G	G	G	G	G	G		
Ultimate Elongation	e	A	δ	A	δ	e	e		
Specific Weight	ω	δ	γ	γ	γ	ω	ω		
Specific Heat	c	c	c	c	c	c	c		
Thermal Conductivity	K	K	λ	K	λ	k	K		
Coefficient of Thermal Expansion	α	α	α	α	α	α	α		
Temperature	T	θ	T	T	T	T	T		
Time at Temperature	t	t	t	t	t	t	t		
Emissivity	ϵ	ϵ	ϵ	ϵ	ϵ	ϵ	ϵ		

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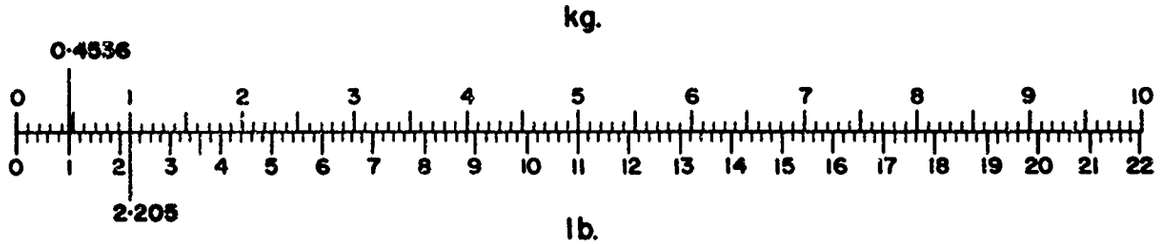

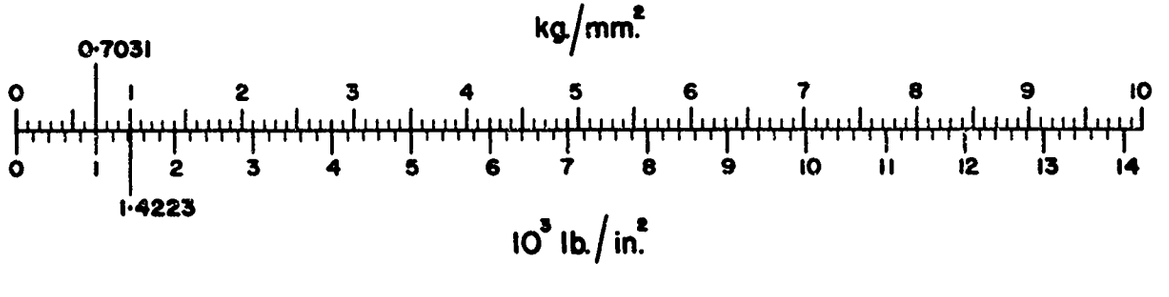

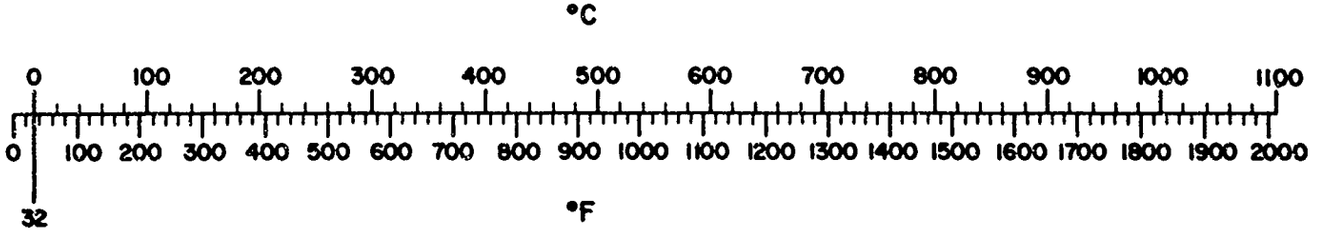

CANADIAN SECTION

Volume III
Magnesium,
Nickel &
Titanium Alloys

CANADIAN SECTION

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1. **Introductory Notes.**
2. **Charts as given in the table below.**

Magnesium Alloys	*Title of Chart*	*Issue No.*	*Date*
AZ 91	General Properties	1	Feb. 1962
	Static Properties	1	"
EZ 33	General Properties	1	"
	Static Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
HZ 32	General Properties	1	"
	Static Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
ZK 61	General Properties	1	"
	Static Properties	1	"

March 1962

CANADIAN SECTION

INTRODUCTORY NOTES

The *Introduction to Volume III* of this Handbook explains the general layout adopted for the presentation of the data, together with details of properties considered and the explanation of various terms. The purpose of the following notes is to amplify these points, where necessary, in relation to those Canadian alloys which are included.

DESIGNATION

The designations of the Canadian magnesium alloys are descriptive of the composition of the material. The designation consists of an initial group of letters indicating the main alloying elements followed by numbers which signify the approximate average percentage content of each of these elements.

The letters used to indicate elements are as follows:-

A - Aluminium	K - Zirconium
E - Rare Earth Metals	Z - Zinc
H - Thorium	

Thus EZ33 is a magnesium alloy containing 3 per cent rare earth metals and 3 per cent zinc.

SPECIFICATIONS

As for all the National Sections, the specifications appropriate to the various forms and conditions of the alloys are indicated on the *Static Properties* charts wherever possible.

CSA specifications are issued by:-

Canadian Standards Association,
235 Montreal Road,
Ottawa 2,
Ontario, Canada.

There is at present no CSA specification for HZ32 alloy, and the properties quoted are appropriate to the commercial specifications B50 T16B - S4 (aged) issued by the General Electric Company and GT - M - 4 (stabilised) issued by Orenda Engines, Ltd.

MATERIALS COVERED

This Section of the Handbook lists the available established data on those magnesium casting alloys produced in Canada which are most widely used in aircraft construction.

CHEMICAL COMPOSITION

The General Properties charts give the chemical composition by quoting the limits of the alloying elements as a percentage by weight of the total.

CONDITION

The 'Condition' row on the charts refers to the type of heat treatment and conditioning. The conditions of the various alloys are indicated on the charts by symbols which have the same meaning as those used in the United States section. The symbols used in the Canadian section are as follows:-

T5 - Artificially aged only.
T6 - Solution heat treated and then artificially aged.
T7 - Solution heat treated and then stabilised.

NOTATION

The notation used in this Section of the Handbook for the various physical and mechanical properties of Canadian alloys is defined in the *Notation Chart* in the *Introduction to Volume III*. This chart also compares the notations used for the other National Sections. Points where any amplification is needed are dealt with under the appropriate headings below.

UNITS

The units used for the various parameters and properties are indicated on each of the charts. For mechanical properties the stresses and moduli are given in units of $10^3 lb/in^2$, whilst temperature is quoted in degrees Centigrade. For conversion to other units see the *Conversion Scales* chart given in the *Introduction to Volume III*.

DATA BASIS

The *Introduction to Volume III* of this Handbook describes the use of the symbols 'A', 'B' and 'C' denoting the data basis of the values for the various properties given on the charts. Special aspects of this in relation to the values quoted for the Canadian alloys are outlined below.

A - This indicates that the values listed are minimum guaranteed properties, i.e. specification properties.

B - Insufficient data are available to quote Data Basis 'B' values for any of the Canadian alloys.

C - This indicates that the values listed are typical for the material, there being insufficient data to determine values for basis 'A' or 'B'.

In general the data basis used on any chart is shown at the top of the chart, but special attention must be paid to footnotes which sometimes indicate a different basis for some particular part of the chart.

STATIC PROPERTIES CHARTS

Tensile strength properties are given for three types of test distinguished by the letters 'a' 'b' or 'c' in the row labelled 'Type of Test'. The significance of these symbols is explained below.

TYPE OF TEST

a - This indicates that the values listed are for separately cast test specimens.

b - This indicates that the values listed are the minimum for any single specimen cut from a critical area of an actual casting.

c - This indicates that the values listed are the average of at least four test bars cut from any area of an actual casting.

ELEVATED TEMPERATURE DATA

On these charts the data are presented as percentages of the appropriate room temperature values, which are indicated when known in brackets at the head of the column. The initials R.T. signify that the data were obtained from tests conducted at an unspecified room temperature.

GENERAL PROPERTIES

CANADA
AZ 91
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn									Mg
Sand Casting	8·3 – 9·3	0·4 – 1·0	0·13 Min.									Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			R.T.				
ω	$gm./cm.^3$		1·81				
c	$cal./(gm.°C)$						
K	$cal.cm./(cm.^2\ sec.\ °C)$						
α	$per\ °C \times 10^{-6}$						
ϵ							

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STATIC PROPERTIES (SHEET)

CANADA AZ 91 Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis: A**

Footnotes	Form	Sand Casting																
	Specification	CSA-HG.9																
	Condition	T6																
	Thickness (in.)																	
	Cross-Sectional Area (or weight)																	
	Type of Test	a	b	c														
	F_{tu}	34																
	F_{ty}	16																
	F_{cl}																	
	F_{cy}																	
	F_{c5}																	
	F_{su}																	
	F_{bru}																	
	F_{bry}																	
	E																	
	E_c																	
	G																	
	e %	3																
	Footnotes																	

GENERAL PROPERTIES

CANADA
EZ 33
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Zr	Rare Earths										Mg
Sand Casting	2·5 – 4·0	0·5 – 1·0	2·5 – 4·0										Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			R.T.				
ω	$gm./cm.^3$		1·83				
c	$cal./(gm.°C)$						
K	$cal.cm./(cm.^2\ sec.\ °C)$						
α	$per\ °C \times 10^{-6}$						
ϵ							

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STATIC PROPERTIES (SHEET)

CANADA EZ33 Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis: A**

Footnotes																		
	Form	Sand Casting																
	Specification	CSA-HG.9																
	Condition	T 5																
	Thickness (in.)																	
	Cross-Sectional Area (or weight)																	
	Type of Test	a	b	c														
	F_{tu}	20	18															
	F_{ty}	13	11.5															
	F_{cl}																	
	F_{cy}																	
	F_{c5}																	
	F_{su}																	
	F_{bru}																	
	F_{bry}																	
	E																	
	E_c																	
	G																	
	e %	2	2															
	Footnotes																	

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

CANADA EZ 33 Magnesium Alloy

Units: hours, °C., 10^3 lb./in.^{2}

Data Basis: C

Form	Machined Sand Cast Bar						Test Bar Cut From Sand Casting						
Condition	T 5						T 5						
t →		1·0			1·0			1·0			1·0		
T ↓	Per Cent F_{tu} (24·2 at R.T.)			Per Cent F_{ty} (16·7 at R.T.)			Per Cent F_{tu} (25·0 at R.T.)			Per Cent F_{ty} (17·8 at R.T.)			
200		87			65								
250		72			62			64			59		
300		50			50								

GENERAL PROPERTIES

CANADA
HZ 32
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Th	Zr	Zn									Mg
Sand Casting Specification BSOTI6B-54	2·5 — 4·0	0·5 — 1·0	1·7 — 2·5									Remainder
Sand Casting Specification GT-M-4	2·7 — 3·3	0·6 — 1·0	2·1 — 2·6									Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			R.T.				
ω	$gm./cm.^3$		1·83				
c	$cal./(gm.°C)$						
K	$cal.cm./(cm.^2 sec. °C)$						
α	$per °C \times 10^{-6}$						
ϵ							

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STATIC PROPERTIES (SHEET)

CANADA
HZ 32
Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes	Form	Sand Casting																	
	Specification	B50T16B-S4			GT-M-4														
	Condition	T5			T7														
	Thickness (in.)																		
	Cross-Sectional Area(or weight)																		
	Type of Test	a	b	c	a	b	c												
	F_{tu}	27	20		27	24·3													
	F_{ty}	13	10		12	10·8													
	F_{cl}																		
	F_{cy}																		
	F_{cs}																		
	F_{su}																		
	F_{bru}																		
	F_{bry}																		
	E																		
	E_c																		
	G																		
	e %	4	3		5	4·5													
	Footnotes																		

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

CANADA
HZ 32
Magnesium Alloy

Units: hours, °C., 10^3lb./in.^{2} **Data Basis:** C

Form	Machined sand cast bar						Test bar cut from sand casting					
Condition	T5						T5					
t →		0.1			0.1			0.1			0.1	
T ↓	Per Cent F_{tu} (30.3 at R.T.)			Per Cent F_{ty} (13.1 at R.T.)			Per Cent F_{tu} (30.5 at R.T.)			Per Cent F_{ty}		
200		60			74							
250		49			63							
260		44			62			49			(1)	
300		39			57							
350		35			53							

(1) F_{ty} = 8.8 x 10^3lb./in.^{2}

GENERAL PROPERTIES

CANADA
ZK61
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Zr										Mg
Sand Casting	5·5 – 6·5	0·6 Min.										Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			R.T.				
ω	$gm./cm.^3$		1·83				
c	$cal./(gm.°C)$						
K	$cal.cm./(cm.^2\ sec.\ °C)$						
α	$per\ °C \times 10^{-6}$						
ϵ							

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STATIC PROPERTIES (SHEET)

CANADA
ZK61
Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis:** A

Footnotes																		
	Form	Sand Casting																
	Specification	CSA-HG.9																
	Condition	T6																
	Thickness (in.)																	
	Cross-Sectional Area (or weight)																	
	Type of Test	a	b	c														
	F_{tu}	42	40	34														
	F_{ty}	26	26	24														
	F_{cl}																	
	F_{cy}																	
	F_{cs}																	
	F_{su}																	
	F_{bru}																	
	F_{bry}																	
	E																	
	E_c																	
	G																	
	e %	5	5	3														
	Footnotes		(1)	(1)														

(1) Data Basis: C

Volume III
Magnesium,
Nickel &
Titanium
Alloy

FRENCH SECTION

CONTENTS

1. Introductory Notes.
2. Charts as given in the table below.

Magnesium Alloys	*Title of Chart*	*Issue No.*	*Date*
G-A9	General Properties Static Properties	1 1	June 1961 "
G-Z4Tr	General Properties Static Properties	1 1	" "
G-Z5Zr	General Properties Static Properties	1 1	" "
G-Tr3Z	General Properties Static Properties	1 1	" "
G-Z6H	General Properties Static Properties	1 1	" "
G-H3Z	General Properties Static Properties	1 1	" "
G-A7Z1	General Properties Static Properties	1 1	" "
G-A3Z1	General Properties Static Properties	1 1	" "

Cont...

CONTENTS *Continued*

Nickel Alloys	*Title of Chart*	*Issue No.*	*Date*
N-K20CDAT	General Properties	1	June 1961
	Static Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature, Sheet 1	1	"
	Properties under Load and Elevated Temperature, Sheet 2	1	"
N-C20KTA	General Properties	1	"
	Static Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature, Sheet 1	1	"
	Properties under Load and Elevated Temperature, Sheet 2	1	"
Titanium Alloys			
T-A4M	General Properties	1	"
	Static Properties	1	"
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature, Sheet 1	1	"
	Properties under Load and Elevated Temperature, Sheet 2	1	"
T-A6V	General Properties	1	"
	Static Properties	1	"
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature	1	"

FRENCH SECTION

INTRODUCTORY NOTES

The *Introduction to Volume III* of this Handbook explains the general layout adopted for the presentation of data, together with details of the properties considered and the explanation of various terms. The purpose of the following notes is to amplify these points, where necessary, in relation to those French alloys which are included.

DESIGNATION OF ALLOYS

In general the designation of the alloys is based on their mean chemical composition. The designation consists of a series of letters and numbers.

The first letter indicates the basic element (G : magnesium, N: nickel, T: titanium).

The group of letters and numbers which follows is separated from the first letter by a hyphen. The letters indicate the most important alloying elements, arranged in order of decreasing percentage content. The average percentage content by weight of a principal alloying element is indicated by a number following the symbol for that element.

The symbols used are as follows:

A - aluminium	N - nickel
C - chromium	S - silicon
D - molybdenum	T - titanium
Fe - iron	Tr - rare earths
G - magnesium	U - copper
H - thorium	V - vanadium
K - cobalt	Z - zinc
M - manganese	

As a rule, only the percentage of the first of the principal elements is mentioned, the percentage of the others only being added to resolve any ambiguity with a similar alloy.

e.g. T - A6V is titanium alloy containing about 6% of aluminium with some vanadium.

SPECIFICATIONS

The specifications appropriate to the various alloys are indicated on the *Static Properties* charts except where the mechanical properties requirements are based on time to tensile failure at elevated temperature, when the specifications are given in a footnote to the appropriate *Properties under Load and Elevated Temperature* chart.

The AIR specifications are issued by:

Ministère de la Défense Nationale et des Forces Armées,
Secrétariat d'Etat aux Forces Armées (AIR)

and copies can be obtained from:

Service de Documentation et d'Information Technique,
Bureau des Ventes,
2 Avenue de la Porte d'Issy,
Paris XVe.

AICMA specifications are issued by:

Association Internationale des Constructeurs de Matérial Aéronautique,
6 Rue Galilée,
Paris XVIe.

However not all the alloys are covered by AIR or AICMA specifications. Others which are not yet standardised are included in the Handbook since they are used widely for aircraft construction in France.

ALLOYS COVERED

This Section of the Handbook lists the available established data on eight magnesium alloys, two nickel alloys, and two titanium alloys which are widely used in aircraft construction in France. The materials covered, together with the forms in which they are produced are listed below. The designations in brackets are also in common use.

MAGNESIUM ALLOYS

G-A9	-	sand castings
G-Z4Tr (R-Z5)	-	sand castings
G-Z5Zr (Z-5Z)	-	sand castings
G-Tr3Z (ZRE1)	-	sand castings
G-Z6H (T-Z6)	-	sand castings
G-H3Z (ZTI)	-	sand castings
G-A7Z1	-	tubes, extrusions
G-A3Z1	-	Sheet, plate, tubes, extrusions

NICKEL ALLOYS

N-K20CDAT	-	bars, forgings
N-C20KTA	-	bars, forgings

TITANIUM ALLOYS

T-A4M	-	bars, forgings
T-A6V	-	bars, forgings, sheet

CHEMICAL COMPOSITION

The chemical composition of alloys covered by an AIR Specification is given in the *General Properties* charts by quoting the limits of the alloying elements as a percentage by weight of the total. In those cases where an alloy has not been standardised, the upper and lower limits in common use have been quoted. In other cases, the analysed composition of the material used in the mechanical properties tests has been given.

CONDITION

The 'Condition' row on the charts refers to the type of heat treatment and conditioning. The conditions are given in the French form on the charts in order to avoid slight changes in meaning that might occur with translation.

An indication of the meaning of the terms used is given below, and details of the temperatures and times of the various treatments for particular alloys are given in the table.

Brut de filage dressé - As extruded, straightened
Dur - Hard
Homogénéisé - Homogenised
Hypertrempé - Quenched or Solution Treated at high temperature
Recuit - Annealed
Revenu - Tempered or Aged
Traité - Heat Treated
Trempé - Quenched or Solution Treated
Vieilli - Aged

	Alloy	*Condition*	*Heating*	*Cooling*
Magnesium Alloys	G-A9	Homogénéisé	24 hrs. at 400°C	Air quench
	G-Z4Tr	Vieilli artificiellement	2 hrs. at 330°C followed by 16 hrs. at 175°C	Air cooled
	G-Z5Zr	Vieilli artificiellement	12 hrs. at 175°C	Air cooled
	G-Tr3Z	Vieilli artificiellement	16 hrs. at 175°C	Air cooled
	G-Z6H	Vieilli artificiellement	2 hrs. at 330°C followed by 16 hrs. at 200°C	Air cooled
	G-H3Z	Vieilli artificiellement	16 hrs. at 330°C	Air cooled

Table continued

	Alloy	Condition	Heating	Cooling
Nickel Alloys	N-C20KTA	Hypertrempé, Revenu	4 hrs. at 1150°C Followed by 8 hrs. at 1080°C 16 hrs. at 700°C	In Air In still air
	N-K20 CDAT	Hypertrempé, Revenu	1½ hrs. at 1200°C 16 hrs. at 850°C	In Air In still Air
Titanium Alloys	T-A6V	Recuit	1 hr. at 700°C	
		Trempé, Revenu	at 850°C 2 hrs. at 480°C	Water quench In still air
	T-A4M	Recuit	1 hr. at 700°C	

NOTATION

The notation used in this Section of the Handbook for the various physical and mechanical properties of the French alloys is defined in the *Notation* chart in the *Introdution to Volume III*. This chart also compares the notations used for the other National Sections. Points where any amplification is needed are dealt with under the appropriate headings below.

UNITS

The units used for the various parameters and properties are indicated on each of the charts. For mechanical properties, the stresses and moduli are given in kg./mm^2., whilst temperature is quoted in degrees Celsius. For conversion to other units see the *Conversion Scales* chart given in the *Introduction to Volume III*.

DATA BASIS

The symbols 'A' and 'C' denoting the data basis of the values for the various properties given on the charts of the French Section are explained below.

A - This indicates that the values listed are the minimum to be expected for the given material.

C - This indicates that the values listed are typical for the material, there being insufficient data to determine values for basis 'A' or 'B'.

As explained in the *Introduction to Volume III* the preferred basis is 'B', i.e. values which will be met or exceeded by 90% of the material supplied. This data basis is not used on the French charts.

In general the data basis used on any chart is shown at the top of the chart, but special attention must be paid to the footnotes which sometimes indicate a different data basis for some particular part of the chart.

TENSILE STRENGTH

The 0.2 per cent offset yield stress in tension is given and is denoted by the symbol $E_{0,2}$.

The sub-headings 'L' and 'LT' used on the *Static Properties* charts refer to the longitudinal and long-transverse directions respectively.

The tensile properties ($R, E_{0,2}, A\%$) are obtained from test pieces selected and prefered in accordance with the appropriate clauses of 'La Norme NF A 03-1011, obtainable from

L'Association Français de Normalisation (AFNOR),
23, Rue Notre Dame des Victoires,
PARIS 2e.

ELONGATION

The values of elongation given on the charts are quoted as the percentage elongation, at fracture, of the gauge length. For each alloy the values are given from measurements using a gauge length of $8.16\sqrt{S_0}$ where S_0 is the initial cross-sectional area of the test specimen. For details of this test, reference should be made to 'La Norme NFA 03-101'.

However for some alloys a gauge length of $5,65\sqrt{S_0}$ was used and this is indicated by a footnote on the appropriate chart.

FORGINGS

The Strength properties of forgings can vary markedly, but the values quoted give an indication of the level of strength that might be expected in a simple forging. The properties given for the nickel alloy forgings refer particularly to turbine blades. For details of testing and inspection of forgings, reference should be made to the specification AIR 3385.

CASTINGS

The *Static Properties* charts give data for castings for two types of test specimen. These are distinguished by the letters 'a' and 'b' in the row designated 'Type of Test'. The significance of these values is indicated below.

'a' - This indicates that the values given are the properties for separately cast test specimens.

'b' - This indicates that the values given are the properties for specimens cut from castings in an area specified by the designer.

The properties of separately cast test specimens are not used for design purposes, being normally used only for foundry control. However they are of interest for the comparison of the properties of alloys, particularly between those of countries which have different methods of arriving at design values for specimens cut from castings.

It should be noted that there is often a considerable variation in mechanical properties between different areas of a casting. This variation depends largely on the local rate of cooling, which is influenced by such factors as the local thickness, the pouring temperature, the method of feeding, etc. However, it has been found that by careful design and control of foundry technique it is possible to obtain consistently the properties quoted under 'Type of Test : b' in a specified area of the casting.

In other areas of the casting, over which no special precautions have been taken, the properties may not reach these values. For this reason, and also because many castings are very complicated and not amenable to accurate calculation of the stresses, great emphasis is placed on the examination of the castings by radiographic means and on break-up tests of sample castings.

Full information on the French requirements and procedure for the manufacture and testing of castings for aeronautical applications may be found in the publication AIR 3380 entitled 'Instruction relative aux Pièces de Fonderie Destinées aux Constructions Aeronautiques'.

Copies may be obtained from:

Service de Documentation et d' Information Technique,
Bureau des Ventes,
2, Avenue de la Porte d' Issy,
PARIS XVe.

FATIGUE PROPERTIES

The *Fatigue Properties* charts give data from rotating bending and repeated axial loading tests. The type of specimen is indicated briefly on the charts, and details of the geometry and the elastic concentration factors K_t, for the notches are given below.

The rotating bending tests were carried out on smooth round specimens of two shapes.

1) Smooth specimen TGM (torique grand modèle) - large toroidal pattern

Minimum diameter of specimen = 6.5 mm.
Radius of generating circle = 105 mm.

2) Smooth specimen CPM (conique petit modèle) - small conical pattern.

Diameter of section of maximum stress = 4.66 mm.
Semi-angle at apex of cone = $2^{\circ}30'$.

The repeated axial loading tests were performed on smooth and notched flat plate specimens.

1) Smooth waisted Schenk specimen ($K_t = 1.05$)

Width = 10 mm.
Radius at root of waist = 62.5 mm.

2) Notched Schenk specimen. (K_t = 2)

Width outside notch = 14 mm.
Width at root of notch = 10 mm.
Radius at root of notch = 2 mm.

3) Notched Schenk specimen, (K_t = 2)

Width outside notch = 14 mm.
Width at root of notch = 10 mm.
Radius at root of notch = 0.62 mm.

In all cases, the Nominal Maximum Stress' quoted on the charts is the maximum stress across the critical section of the specimen, determined at the maximum load of the fatigue cycle, without correction for stress concentration effects. The 'Stress Ratio' quoted on the charts is the ratio of minimum to maximum stress during the fatigue cycle with compressive stress being taken negative, and tensile stress positive.

It should be noted that there is always a wide scatter of results with tests of this type, and the values given on the charts represent mean lines through the scatter bands.

ELEVATED TEMPERATURE DATA

On these charts the data are presented as percentages of the appropriate room temperature values. The room temperature value is given in kg./mm^2., together with the value of 'room temperature' in ^{o}C, in brackets at the head of each column.

The elevated temperature tensile test pieces and those used for the room temperature tests are identical, conforming to 'La Norme NF A 03-101' with a gauge length $l_o = 8.16\sqrt{S_o}$ except for the titanium alloys when the AICMA specimens are used with a gauge length of $5.65\sqrt{S_o}$. In all cases the tests were conducted with a strain rate of between 0.001 and 0.002 mm. per mm. per minute.

For the *Properties under Load and Elevated Temperature* charts, the data were obtained from test pieces in accordance with the specification AIR 0820. The creep data presented on these charts give the stresses (expressed as percentages of the room temperature values of R) which, at a given temperature, will lead

1) to a permanent deformation of 0.2%
and 2) to rupture
at the end of the period of time indicated.

It should be noted that the creep deformation quoted is the permanent deformation, and does not include elastic extension or thermal expansion.

Some specifications, for alloys for high temperature service, base the strength requirements on time to tensile failure at given temperatures and stresses, rather than on the room temperature tensile properties. In such cases the actual stresses, instead of percentages of the room temperature values, are quoted on the *Time to Tensile Failure* charts. The Data Basis is 'A', and the specific number is quoted in a footnote.

GENERAL PROPERTIES

FRANCE
G-A9
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni						Mg
Casting	0·2 Max.	7·5 – 9·0	0·15 – 0·6	0·2 – 1·0	0·3 Max.	0·05 Max.	0·01 Max.						Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	$gm./cm.^3$	All Conditions	1·8				
C	$cal./(gm.°C)$	All Conditions	0·24	0·24			
K	$cal.cm./(cm.^2 sec. °C)$	Homogénéisé	0·12				
α	$per °C \times 10^{-6}$	Homogénéisé	27·2	27·2	27·2		

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STATIC PROPERTIES (SHEET)

FRANCE
G-A9
Magnesium Alloy

Units: kg./mm.² **Data Basis: A**

| Footnotes | | |

GENERAL PROPERTIES

FRANCE
G-Z4Tr
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni	Zr	Rare Earths				Mg
Casting	0·03 Max.	0·02 Max.	0·15 Max.	3·5 – 5·0	0·01 Max.	0·01 Max.	0·005 Max.	0·4 – 1·0	0·75 – 1·75				Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	$gm./cm.^3$	All Conditions	1·84				
C	$cal./(gm.°C)$	All Conditions	0·23	0·23			
K	$cal.cm./(cm.^2 sec. °C)$	Vieilli	0·27				
α	$per °C \times 10^{-6}$	Vieilli	27·1	27·1	27·1		

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STATIC PROPERTIES (SHEET)

FRANCE
G-Z4Tr
Magnesium Alloy

Units: kg./mm.² **Data Basis: A**

| Footnotes | | |

GENERAL PROPERTIES

FRANCE
G-Z5Zr
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni	Zr					Mg
Casting.	0·03 Max.	0·02 Max.	0·15 Max.	3·5 5·5	0·01 Max.	0·01 Max.	0·005 Max.	0·4 1·0					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	$gm./cm.^3$	All Conditions	1·81				
C	$cal./(gm.°C)$	All Conditions	0·23	0·23			
K	$cal.cm./(cm.^2\ sec.\ °C)$	vieilli	0·20				
α	$per\ °C \times 10^{-6}$	vieilli	27·3	27·3	27·3		

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STATIC PROPERTIES (SHEET)

FRANCE G-Z5Zr Magnesium Alloy

Units: kg./mm.²

Data Basis: A

Footnotes			
	Form	Sand Castings	
	Specification	AIR3380 – AICMA	
	Condition	Vieilli artificiellement	
	Thickness		
	Cross-Sectional Area		

	Type of Test	a	b
	R	24	22
	$E_{0.2}$	15	14
	M	4400	
	M_c		
	G	1650	
	A %	5	4
	Footnotes		

GENERAL PROPERTIES

FRANCE
G-Tr 3Z
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni	Zr	Rare Earths				Mg
Casting	0·03 Max.	0·02 Max.	0·15 Max.	0·8 – 3·0	0·01 Max.	0·01 Max.	0·005 Max.	0·4 – 1·0	2·5 – 4·0				Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	$gm./cm.^3$	All Conditions	1·80				
C	$cal./(gm.°C)$	All Conditions	0·25	0·25			
K	$cal.cm./(cm.^2\ sec.\ °C)$	Vieilli	0·24				
α	$per\ °C \times 10^{-6}$	Vieilli	26·3	26·8	26·8		

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STATIC PROPERTIES (SHEET)

FRANCE
G-T3Z
Magnesium Alloy

Units: kg./mm.² **Data Basis: A**

| Footnotes | | |

GENERAL PROPERTIES

FRANCE
G-Z6H
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni	Zr	Th	Rare Earths			Mg
Sand Casting	0·03 Max.	0·02 Max.	0·15 Max.	5·0 – 6·0	0·01 Max.	0·01 Max.	0·005 Max.	0·4 – 1·0	1·5 – 2·3	0·2 Max.			Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	$gm./cm.^3$	All Conditions	1·87				
C	$cal./(gm.°C)$	All Conditions	0·23	0·23			
K	$cal.cm./(cm.^2 sec. °C)$	Vieilli	0·26				
α	$per °C \times 10^{-6}$	Vieilli	27·1	27·1	27·1		

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STATIC PROPERTIES (SHEET)

FRANCE
G-Z6H
Magnesium Alloy

Units: kg./mm.² **Data Basis: A**

| Footnotes | | |

GENERAL PROPERTIES

FRANCE
G-H3Z
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Al	Mn	Zn	Si	Fe	Ni	Zr	Th	Rare Earths			Mg
Casting	0·03 Max.	0·02 Max.	0·15 Max.	1·7 ± 2·5	0·01 Max.	0·01 Max.	0·005 Max.	0·4 ± 1·0	2·5 ± 4·0	0·1 Max.			Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	$gm./cm.^3$	All Conditions	1·83				
C	$cal./(gm.°C)$	All Conditions	0·23	0·23			
K	$cal.cm./(cm.^2 sec. °C)$	Vieiili	0·25				
α	$per °C \times 10^{-6}$	Vieilli	26·7	26·7	26·7		

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Units: kg./mm² **Data Basis: A**

| Footnotes | | |

GENERAL PROPERTIES

FRANCE
G-A7Z1
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Ni	Cu	Fe				Others		Mg
											Each	Total	
All Forms	6·5 / 8·5	0·5 / 1·5	0·12 Min.	0·3 Max.	0·005 Max.	0·05 Max.	0·007 Max.				0·3 Max.	— / —	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	$gm./cm.^3$	All Conditions	1·8				
C	$cal./(gm.°C)$	All Conditions	0·24	0·24			
K	$cal.cm./(cm.^2\ sec.\ °C)$	Annealed	0·12				
α	$per\ °C \times 10^{-6}$	Annealed	27·3	27·3	27·3		

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STATIC PROPERTIES (SHEET)

FRANCE
G-A7Z1
Magnesium Alloy

Units: kg./mm.^{2}

Data Basis: A

Footnotes	Form		Extruded shapes and tubes				Extruded bars				
	Specification		AIR 9052				AIR 9052				
	Condition		Brut de filage dressé				Brut de filage dressé				
	Thickness										
	Cross-Sectional Area		≤ 2000				≤2000		>2000 ≤8000		
	R	L	28				30		30		
		LT									
	$E_{0,2}$	L	16				20		20		
		LT									
	M		4500								
	M_c										
	G		1700								
	A	%	6				8		7		
	Footnotes										

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GENERAL PROPERTIES

FRANCE
G-A3Z1
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni	Fe				Others		Mg
											Each	Total	
All Forms	2·5 – 3·5	0·5 – 1·5	0·2 Min.	0·3 Max.	0·05 Max.	0·005 Max.	0·007 Max.				0·3 Max.	— —	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
δ	$gm./cm.^3$	All Conditions	1·77				
C	$cal./(gm.°C)$	All Conditions	0·25	0·25			
K	$cal.cm./(cm.^2 sec. °C)$	Annealed	0·18				
α	$per °C \times 10^{-6}$	Annealed	26	26	26		

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STATIC PROPERTIES (SHEET)

FRANCE
G-A3Z1
Magnesium Alloy

Units: kg./mm.² **Data Basis: A**

Footnotes	Form	Sheet and plate				Extruded shapes and tubes				Extruded bars							
	Specification	AIR 9052															
	Condition	Recuit		Dur		Brut de filage dressé				Brut de filage dressé							
	Thickness (mm.)	< 6															
	Cross-Sectional Area (mm.²)					< 2000				< 2000		> 2000					
	R L					24				24		24					
	R LT	23		27													
	$E_{0,2}$ L					16				18		18					
	$E_{0,2}$ LT	13		20													
	M	4300															
	M_c																
	G	1600															
	A %	12		4		6				10		8					
	Footnotes																

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GENERAL PROPERTIES

FRANCE
N-K20CDAT
Nickel Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Mn	Cr	Mo	Al	Ti	Co						Ni
All Forms	0·22	0·06	11·14	4·10	3·9	1·38	20·06						Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
	$gm./cm^3$						
	$cal./(gm.°C)$						
	$cal.cm./cm^2\ sec.\ °C)$						
	$per\ °C \times 10^{-6}$						

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STATIC PROPERTIES (SHEET)

FRANCE
N-K20CDAT
Nickel Alloy

Units: kg./mm.^{2} **Data Basis:** C

Footnotes			
	Form	Bars and Forgings	
	Specification		
	Condition	Hypertrempé, revenu.	
	Thickness		
	Cross-Sectional Area		
	R	122·7	
	$E_{0,2}$	89·4	
	$E_{CO,2}$		
	$E_{CO,2}$		
	$E_{CO,5}$		
	R_C		
	M		
	M_C		
	G		
	A %	22·4	
	Footnotes		

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SHORT TIME PROPERTIES
AT ELEVATED TEMPERATURE
(SHEET)

FRANCE
N-K20CDAT
Nickel Alloy

Units: hrs., °C., kg./mm².

Data Basis: C

Form	Bars and Forgings.																										
Condition	Hypertrempé, revenu.																										
t →		7			7																						
θ ↓	Per Cent R (122·7 at 20°C)			Per Cent $E_{0,2}$ (89·4 at 20°C)																							
800		65			73																						
850		57			59																						
900		47			45																						
950		36			29																						
1000		25			17																						
1050		13			5·6																						

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET 1)

FRANCE
N-K20CDAT
Nickel Alloy

Units: hrs., °C., kg./mm²

Data Basis: C

CREEP DATA

Form		Bars and Forgings.															
Condition		Hypertrempé, revenu.															
t →			15		300												
θ ↓	Permanent Deformation Per Cent	Per Cent R (122·7 at 20°C)															
800	0·2		33		24												
850	0·2		21		15												
900	0·2		12		8·6												
950	0·2		6·5		4·3												
1000	0·2		3·4		1·7												
1050	0·2		1·1														

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PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE
(SHEET 2)

FRANCE
N-K20CDAT
Nickel Alloy

Units: hours, °C., kg./mm² Data Basis: C

MINIMUM CREEP RATE

Form														
Condition														
Creep Rate														
↓														

TIME TO TENSILE FAILURE

Form	Bars and Forgings.													
Condition	Hypertrempé, revenu.													
t →		15		300										
T ↓	Per Cent R (122·7 at 20°C)													
800		41		30										
850		29		19										
900		19		11										
950		11		5·9										
1000		6·1		2·9										
1050		2·4		1·1										

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GENERAL PROPERTIES

FRANCE
N-C20KTA
Nickel Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Si	Mn	Cr	Al	Ti	Co	Cu	Fe				
All Forms	0·12 Max.	1·5 Max.	1 Max.	18 $\overline{21}$	0·7 $\overline{1·8}$	1·8 $\overline{3}$	15 $\overline{21}$	0·1 Max.	2 Max.				

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
	$gm./cm.^3$						
	$cal./(gm.°C)$						
	$cal.cm./(cm.^2 sec. °C)$						
	$per °C \times 10^{-6}$						

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STATIC PROPERTIES (SHEET)

FRANCE
N-C20KTA
Nickel Alloy

Units: kg./mm². **Data Basis: C**

Footnotes																	
	Form	Bars and Forgings.															
	Specification																
	Condition	Hypertrempé, revenu.															
	Thickness																
	Cross-Sectional Area																
	R	100															
	$E_{0,2}$	70															
	$E_{co,1}$																
	$E_{co,2}$																
	$E_{co,3}$																
	R_c																
	M																
	M_c																
	G																
	A%																
	Footnotes																

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

FRANCE
N-C20KTA
Nickel Alloy

Units: hrs., °C., kg./mm². **Data Basis: C**

Form	Bars and Forgings.					
Condition	Hypertrempé, revenu.					
t →		7			7	
θ ↓	Per Cent R (100 at 20°C)			Per Cent $E_{0,2}$ (70 at 20°C)		
750		64			63	
800		55			54	
850		42			43	
900		32			31	
950		24			21	
1000		17			12	
1050		12			5·4	

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET 1)

FRANCE
N-C20KTA
Nickel Alloy

Units: hrs., °C., kg./mm^2.

Data Basis: C

CREEP DATA

Form		Bars and Forgings.																
Condition		Hypertrempé, revenu.																
→			15			300												
↓	Permanent Deformation Per Cent	Per cent R (100 at 20°C)																
750	0·2		38			25												
800	0·2		27			16												
850	0·2		16			8												
900	0·2		9			3·5												
950	0·2		4·6			1												
1000	0·2																	
1050	0 2																	

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PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE
(SHEET 2)

FRANCE
N-C20KTA
Nickel Alloy

Units: hrs., °C., kg/mm² Data Basis: C

MINIMUM CREEP RATE

Form														
Condition														
Creep Rate														
θ ↓														

TIME TO TENSILE FAILURE

Form	Bars, Forgings.							All Forms						
Condition	Hypertrempé, revenu.							Hypertrempé, revenu.						
t →			15		300				5		30			
θ ↓	Per Cent R (100 at 20°C)							Stress (kg./mm.²)(1)						
750			42		30									
800			32		21						27(2)			
850			21		13									
900			13·5		9									
950			8		3·5				8					
1000			4·4		1·6									
1050			2·1											

(1) N.B Data Basis: A, Specification AIR 9170. (2) At 815°C

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GENERAL PROPERTIES

FRANCE
T-A4M
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Si	Mn	Al	Fe								Ti
All Forms	0·08 Max.	0·04 Max.	3·5 5·0	3·5 5·0	0·15 Max.								Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
	$gm./cm.^3$						
	$cal./(gm.°C)$						
	$cal.cm./(cm.^2 sec. °C)$						
	$per °C \times 10^{-6}$						

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STATIC PROPERTIES

(SHEET)

FRANCE
T-A4M
Titanium Alloy

Units: kg./mm²

Data Basis: A

Footnotes	Form	Bars, Forgings, Sheet.
	Specification	AICMA
	Condition	Recuit
	Thickness	
	Cross-Sectional Area	
	R	95–115
	$E_{0,2}$	85
	$E_{co,1}$	
	$E_{co,2}$	
	$E_{co,5}$	
	R_c	
	M	
	M_c	
	G	
(1)	A %	10
	Footnotes	

(1) Gauge length = $5.65\sqrt{So}$

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FATIGUE PROPERTIES

FRANCE
T-A4M
Titanium Alloy

Units: kg./mm.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
					10^5	10^6	10^5	10^6	10^7	3×10^7
					Nominal Maximum Stress					
	Rotating	Smooth C P M	Recuit	-1·0		78	53	49·5	49·5	49·5
	Bending	Smooth T G M		-1·0		80	48	41	40	40
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

FRANCE T-A4M Titanium Alloy

Units: hrs., °C., kg./mm.²

Data Basis: C

Form	Bars, Forgings, Sheet.																								
Condition	Recuit																								
t →		7			7																				
θ ↓	Per Cent R (94·6 at 20°C)			Per Cent $E_{0,2}$ (87·3 at 20°C)																					
300		74			64																				
400		67			57																				
500		59			49																				
600		43			27																				

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET 1)

FRANCE
T-A4M
Titanium Alloy

Units: hrs., kg./mm.^{2}, °C.

Data Basis: C

CREEP DATA

Form		Bars, Forgings, Sheet.																
Condition		Recuit																
t →				10		300												
θ ↓	Permanent Deformation Per Cent	Per cent R (94·6 at 20°C)																
400	0·2			44		25												
450	0·2			19		11												
500	0·2			6·4		3·4												
550	0·2			1·6														
600	0·2																	

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PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE
(SHEET 2)

FRANCE
T-A4M
Titanium Alloy

Units: hrs., °C., kg./mm² Data Basis: C

MINIMUM CREEP RATE

Form														
Condition														
Creep Rate														
θ ↓														

TIME TO TENSILE FAILURE

Form	Bars, Forgings, Sheet.													
Condition	Recuit													
t →		15		300										
θ ↓	Per Cent R (94·6 at 20°C)													
400		63		59										
450		51		34										
500		32		17										
550		16		6·3										
600		8·5		3·2										

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GENERAL PROPERTIES

FRANCE
T-A6V
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	V	Al	Fe									Ti
All Forms	0·08 Max.	3·5 – 4·5	5·5 – 7·0	0·25 Max.									Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
	$gm./cm.^3$						
	$cal./(gm.^\circ C)$						
	$cal.cm./(cm.^2\ sec.\ ^\circ C)$						
	$per\ ^\circ C \times 10^{-6}$						

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STATIC PROPERTIES (SHEET)

FRANCE T-A6V Titanium Alloy

Units: kg./mm.^{2} **Data Basis:** A

Footnotes		
	Form	Bars, Forgings and Sheet.
	Specification	AICMA
	Condition	Recuit
	Thickness	
	Cross-Sectional Area	
	R	90 - 110
	$E_{0,2}$	82
	$E_{co,1}$	
	$E_{co,2}$	
	$E_{co,5}$	
	R_c	
	M	
	M_c	
	G	
(1)	A %	10
	Footnotes	

(1) Gauge length = 5·65 $\sqrt{So}$

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FATIGUE PROPERTIES

FRANCE T-A6V

Titanium Alloy

Units: kg./mm.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
					10^3	10^4	10^5	10^6	10^7	3×10^7
					Nominal Maximum Stress					
	Repeated Axial Loading	Smooth Schenk	Recuit	0·10			47	32	30	30
		Notched Schenk $K_t = 2$		0·10		63	40	30	28·5	28·5
		Notched Schenk $K_t = 3·25$		0·10		49	33	28	27·5	27·5
		Smooth Schenk	Trempé, revenu.	0·10			33·5	27·5	27·5	27·5
		Notched Schenk $K_t = 2$		0·10		56·5	30	26·5	26·5	26·5
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

FRANCE
T-A6V
Titanium Alloy

Units: hrs., °C., kg./mm.²

Data Basis: C

Form	Bars, Forgings and Sheet.																							
Condition	Recuit									Trempé, revenu.														
t →		↓			↓						↓			↓										
θ ↓	Per Cent R (103·5 at 20°C)			Per Cent $E_{0,2}$ (97·5 at 20°C)						Per Cent R (115 at 20°C)			Per Cent $E_{0,2}$ (102 at 20°C)										
200		77			71						81			74										
400		61			54						65			56										
550											52			43										
600		48			36																			

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET)

FRANCE
T-A6V
Titanium Alloy

Units: hrs., °C., kg./mm².

Data Basis: C

CREEP DATA

Form		Bars, Forgings and Sheet.			
Condition		Recuit			
t →		–	10	50	
θ ↓	Permanent Deformation Per Cent	Per Cent R (103·5 at 20°C)			
350	0·2		63	61	59
400	0·2		58	52	47
450	0·2		47	37	29

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GERMAN SECTION

GERMAN SECTION

INTRODUCTORY NOTES

The *Introduction to Volume III* of this Handbook explains the general layout adopted for the presentation of the data, together with details of the properties considered and the explanation of various terms. The purpose of the following notes is to amplify these points, where necessary, in relation to those German alloys which included.

MAGNESIUM ALLOY SPECIFICATION AND DESIGNATION

In Germany, for the wrought magnesium alloys, the specification and designation given to a material consist of the letter W followed by a Group of four figures, e.g. W3504.

For the cast magnesium alloys the specification and designation given to a material consists of a group of five figures, e.g. 3.5194. The first figure '3' indicates that the material is a light alloy. The group of four figures, separated from the first figure by a dot, is the designation of each particular alloy. For materials for aeronautical use, the last figure of the five figure designation is always '4'.

MATERIALS COVERED

MAGNESIUM ALLOYS

This Section of the Handbook lists the available established data on four wrought magnesium alloys and six cast magnesium alloys. These magnesium alloys are the ten most widely used structurally in aircraft.

The designations of the magnesium alloys covered, together with the forms in which they are produced are listed below:

W3501	- Sheet; tubes; extruded shapes	Gas weldable corrosion resistant magnesium alloy with very good machining and good hot-forming characteristics.
W3504	- Sheet	Argonarc weldable magnesium alloy with very good machining and good hot-forming characteristics.
W3510	- Tubes; extruded shapes	Hot-formable magnesium alloy with very good machining characteristics.
W3515	- Drawn and extruded rods; die forgings	Magnesium alloy with very good machining characteristics.

3.5104 - Sand castings	Casting magnesium alloy specially suitable for compact castings e.g. undercarriage struts. For temperatures up to 100°C. Not weldable.
3.5114 - Sand castings	High strength magnesium casting alloy suitable for bulky structural parts and hydraulic pressure vessels. Argonarc weldable.
3.5194 - Sand castings; permanent mould castings; pressure die castings	High Strength magnesium casting alloy for temperatures up to 100°C. Argonarc weldable.
3.6104 - Sand castings	Magnesium casting alloy suitable for bulky structural parts and pressure vessels at temperatures up to 150°C. Argonarc weldable.
3.6204 - Sand castings	Creep-resistant Mg. alloy suitable for gas turbine housings and structural parts where strength at temperatures up to 250°C is required. Argonarc weldable.
3.6254 - Sand castings	Creep-resistant Mg. alloy suitable for gas turbine housing and parts where high strength at temperatures in the region of 250-320°C is required. Argonarc weldable.

NICKEL AND TITANIUM

A range of nickel and titanium alloys is produced in Germany for use in aircraft construction and charts giving the properties of these materials will be issued when the necessary data are available. The following nickel and titanium alloys used in German aircraft construction are similar to the U.K. and U.S. alloys shown. The user is referred to the data presented in the U.K. and U.S. Sections.

	German Designation	*Form*	*Similar to:*	*Specification*
Nickel Alloy	2.4630	Sheet; strip; bars; tubing	D.T.D. 703B (U.K.)	D.T.D. 703B
Titanium Alloy	3.7164	Bars; forgings; shapes	6Al-4V (U.S.)	Mil-T-9047 Cl. 5

CHEMICAL COMPOSITION

The *General Properties* charts give the chemical composition by quoting the limits of the alloying elements as a percentage by weight of the total.

It should be noted that for the alloys containing zirconium the limits quoted are for 'available' zirconium, i.e. that quantity of zirconium which is soluble in dilute hydrochloric acid.

CONDITION

The 'Condition' row on the charts refers to the type of heat treatment and condition. The designation used with German magnesium alloys is a numerical system. The number follows the alloy specification number and is separated from it by a dot, e.g. 3.5194.8. The numbers designating the condition have the following meanings:

WROUGHT MAGNESIUM ALLOYS

0 - as fabricated

1 - soft (0)

2 - half hard

3 - hard

4 - solution heat treatment followed by natural ageing at room temperature to a substantially stable condition (T4)

5 - solution heat treatment followed by strain hardening (T3)

6 - solution heat treatment followed by stretch relieving

7 - solution heat treatment followed by artificial ageing (T6)

8 - hard drawn

9 - special treatment

For reference purposes the equivalent U.S. designation is included in brackets.

CAST MAGNESIUM ALLOYS

The condition designations for casting alloys have recently been revised but the new system is so far only in use for the alloys 3.5104 and 3.5114. The following table gives the meanings of the condition number for the two systems.

Condition Number	*For alloys* 3.5104 *and* 3.5114	*For Alloys* 3.5194, 3.6104, 3.6204 and 3.6254
0	As cast	Sand castings
1	Soft	
2		
3		
4	Naturally aged, or quenched or homogenized	Permanent mould castings
5		
6	Artificially aged	
7		Pressure die castings
8	Stress relieved	
9	Special treatment, e.g. Stabilized	

NOTATION

The notation used in this Section of the Handbook for the various physical and mechanical properties of the German alloys is defined on the *Notation* chart in the *Introduction to Volume III*. This chart also compares the notations used for the other National Sections. Points where any amplification is needed are dealt with under the appropriate headings below.

UNITS

The units used for the various parameters and properties are indicated on each of the charts. For mechanical properties the stresses and the moduli are given in kg./mm^2., whilst temperatures are quoted in degrees centigrade. For conversion to other units see the *Conversion Scales* chart given in the *Introduction to Volume III*.

DATA BASIS

The symbols 'A' and 'C' denoting the data basis of the values for the various properties given on the charts of the German Section are explained below:

A - This indicates that the values listed are the minimum to be expected for the given material.

C - This indicates the values listed are typical for the material, there being insufficient data to determine values for basis A.

No data to basis B are available for the German alloys.

In general the data basis used on any chart is shown at the top of the chart, but special attention must be paid to the footnotes which sometimes indicate a different basis for some particular part of the chart.

TENSILE STRENGTH

The tensile properties are obtained from test pieces selected and prepared in accordance with DIN50125 for material in bar form and with DIN 50114 for material in sheet form. DIN specifications are issued by Deutscher Normenausschuss (DNA), Berlin W15, and may be obtained from:

Beuth-Vertrieb,
Köln, Friesenplatz 16.

The sub-headings 'L', 'LT' and 'ST' used on the *Static Properties* charts refer to the longitudinal, long transverse and short transverse directions respectively.

ELONGATION

The values of elongation given on the charts are quoted as the percentage elongation, at fracture, of the gauge length. For circular specimens, the gauge length is 5 d_o, where d_o is the diameter of the test piece measured in the gauge length. For rectangular specimens the gauge length is $5.65\sqrt{F}$, where F is the cross-sectional area of the test piece measured in the gauge length.

Details of the test pieces and method of test are described in DIN 50125.

The elongation values are measured in the longitudinal direction unless otherwise stated in the footnotes.

CASTINGS

The *Static Properties* charts give data on castings for three types of test. These are distinguished by the letters 'a', 'b' and 'c' in the row designated 'Type of Test'. The significance of these letters is indicated below.

TYPE OF TEST

'a' - This indicates that the values given are for tests on separately cast test specimens.

'b' - This indicates that the values given are the minimum properties obtained for specimens cut from production castings in areas specified by the designer.

'c' - This indicates that the values given are the average values of at least 4 specimens cut from the same casting, at thin, medium and thick sections, in areas specified by the designer.

The properties of separately cast test specimens are not normally used for design purposes, being used mainly in foundry control. However they are of interest for the

comparison of the properties of alloys, particularly between those of countries which have different methods of arriving at design values for specimens cut from castings.

It should be noted that there is often a considerable variation in mechanical properties between different areas of a casting. The properties given under 'Type of Test: b and c' are for locations specified by the designer, where particular care is taken that the feeding, rate of cooling, etc., is favourable to good properties. In other areas, over which no special precautions have been taken, the properties may not reach these values.

The separately sand cast test specimens are made and tested to the British Standard specification B.S. 2L.101. Copies of this may be obtained from:

British Standards Institution
2, Park Street,
London, W.1.
England.

The permanent mould separately cast test specimens are made and tested to the specification LN 29531. Copies may be obtained from:

Beuth-Vertrieb,
Köln,
Friesenplatz 16,
Germany.

For specimens cut from castings the specification used is either DIN 50125, obtainable from the above address or the French specification NF - A03 - 101, which may be obtained from:

l'Association Français de Normalisation (AFNOR),
23, Rue Notre Dame,
Victoires, Paris, 2^{e}.

FATIGUE PROPERTIES

The data given on the *Fatigue Properties* chart are based on tests made in rotating bending. A brief description of the specimens is given on the charts, and a description of the method of testing is given in DIN 50113.

The 'Nominal Maximum Stress' quoted on the charts is the stress calculated by dividing the bending moment by the section modulus. In the case of notched test bars, the section modulus is based on the core or minimum cross-section.

ELEVATED TEMPERATURE DATA

On these charts the data are presented as percentages of the appropriate values at room temperature..

Room temperature is taken to be 20°C except where otherwise stated, and the value in kg./mm^{2}., at this temperature, on which the percentages were based, is quoted in brackets at the top of each column.

For the short time tensile tests at elevated temperatures the test pieces and methods of test are specified in DIN 50112.

For the *Properties under Load and Elevated Temperature* charts, the data are obtained from test pieces in accordance with the specifications DIN 50118 and DIN 50119.

June 1961

GENERAL PROPERTIES

GERMANY
W 3501
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Mn	Si	Zn	Fe	Al					Others	Mg
All Forms	0·05 max.	1·2 ± 2·0	0·10 max.	0·03 max.	0·005 max.	0·05 max.					0·1 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	$gm./cm.^3$	0,1	1·8				
c (1)	$cal/(gm.°C)$	0,1		0·25			
λ	$cal.cm./(cm.^2\ sec.\ °C)$		0·34				
α (1)	$per\ °C \times 10^{-6}$	0,1		26·1	26·9	27·7	
ϵ							

(1) Value between 20°C and temperature indicated

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STATIC PROPERTIES (SHEET 1)

GERMANY W3501 Magnesium Alloy

Units: kg./mm.^{2} Data Basis: A

Footnotes				
	Form		Sheet	
	Specification		W3501	
	Condition		I	
	Thickness (mm.)		0·5 ≤1·0	>1·0 ≤6·0
	σ_B	L	20	20
		LT		
		ST		
	$\sigma_{0,2}$	L	10	10
		LT		
		ST		
(1)	$\sigma_{dF0,2}$	L		8
		LT		
		ST		
	$\sigma_{dF0,8}$			
	τ			
	σ_L			
(1)	E		4000	
(1)	E_d		5000	
	δ_5	%	12	10
	Footnotes			

(1) Data Basis: C

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STATIC PROPERTIES (SHEET 2)

GERMANY
W3501
Magnesium Alloy

Units: kg./mm.^{2} **Data Basis:** A

Footnotes	Form		Extrusion and Tubing																
	Specification		W3501																
	Condition		0																
	Thickness (mm.)		≤2	>2 ≤6															
	Cross-Sectional Area																		
	σ_s	L	23	21															
		LT																	
	$\sigma_{0,2}$	L	17	15															
		LT																	
(1)	$\sigma_{dF0,2}$	L		10															
		LT																	
	$\sigma_{dF0,5}$																		
	τ																		
(1)	σ_L																		
(1)	E		4000																
(1)	E_d		5000																
	G																		
	δ_5		2	1·5															
	Footnotes		(2)	(3)															

(1) Data Basis: C

(2) For tubing, outside diameter ≤50mm.

(3) For tubing, outside diameter ≤125mm.

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE

GERMANY
W 3501
Magnesium Alloy

Units: hrs, °C, kg./mm.²

Data Basis: C

Form	Sheet (1)				Tubing and Extrusions (1)			
Condition	I				O			
t →	0·4		0·4		0·4		0·4	
T ↓	Per Cent σ_B (27·5 at R.T.)		Per Cent $\sigma_{0.2}$ (16·5 at R.T.)		Per Cent σ_B (27·5 at R.T.)		Per Cent $\sigma_{0.2}$ (16·5 at R.T.)	
50	87		91		87		91	
100	65		68		65		68	
150	47		48		47		48	
200	32		31		32		31	
250	22		23		22		23	
300	15		15		15		15	
350	11		12		11		12	

(1) Thickness ≥1mm.

GENERAL PROPERTIES

GERMANY
W 3504
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Mn	Si	Zn	Al						Others	Mg
Sheet	0·05 max.	0·05 – 0·40	0·20 max.	0·5 – 1·5	2·5 – 3·5						0·1 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	$gm./cm.^3$	1, 3	1·8				
c (1)	$cal./(gm.^\circ C)$	1, 3		0 25			
λ	$cal.cm./(cm.^2 sec.^\circ C)$		0·25				
α (1)	$per^\circ C \times 10^{-6}$	1, 3		26·1	27·1	27·9	
ϵ							

(1) Between 20°C and temperature indicated

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Units: kg./mm.^{2}

Data Basis: A

| Footnotes | | |

GENERAL PROPERTIES

GERMANY
W 3510
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Mn	Si	Zn	Al						Others	Mg
Tubing and extrusions	0·1 max.	0·05 0·4	0·2 max.	0·5 1·5	5·5 6·5						0·1 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
γ	$gm./cm.^3$	0	1·8				
c (1)	$cal./(gm.^\circ C)$			0·24			
λ	$cal.cm./(cm.^2 sec.^\circ C)$		0·195				
α (1)	$per^\circ C \times 10^{-6}$	0		26·0	27·3	28·0	
ϵ							

(1) Between 20°C and temperature indicated

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STATIC PROPERTIES

(SHEET 1)

GERMANY
W3510
Magnesium Alloy

Units: kg./mm.^{2}

Data Basis: A

Footnotes	Form		Tubing		Extruded shapes	
	Specification		W3510			
	Condition		0			
	Thickness (mm.)		≤2	>2 ≤6	≤2	>2 ≤6
	Cross-Sectional Area					
	σ_B	L	28	28	28	28
		T				
	$\sigma_{0,2}$	L	18	18	18	18
		T				
(1)	$\sigma_{dF0,2}$	L				13
		T				
	$\sigma_{dF0,3}$					
	τ					
	σ_L					
(1)	E		4200			
(1)	E_d		5200			
	G					
	δ_s		11	10	11	10
	Footnotes		(2)	(3)		

(1) Data Basis: C

(2) Outside diameter ≤50mm.

(3) Outside diameter ≤125mm.

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE

GERMANY
W 35IO
Magnesium Alloy

Units: hrs,. °C, kg./mm²

Data Basis: C

Form	Tubing and Extrusions	
Condition	O	
t →	0·4	0·4
T ↓	Per Cent σ_B (31 at R.T.)	Per Cent $\sigma_{0·2}$ (22 at R.T.)
50	98	94
100	94	83
150	73	64
200	52	41
250	33	23
300	22	8
350	10	

GENERAL PROPERTIES

GERMANY
W3515
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Cu	Mn	Si	Zn	Al					Others	Mg
All Forms	0·1 max.	0·05 ± 0·40	0·2 max.	0·5 ± 2·0	6·5 ± 8·0					0·1 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	$gm./cm.^3$	0, 7	1·8				
c (1)	$cal./(gm.°C)$	0, 7		0·24			
λ	$cal.cm./(cm.^2 sec. °C)$		0·9				
α (1)	$per °C \times 10^{-6}$	0, 7		26·3	27·1	27·6	
ϵ							

(1) Values between 20°C and temperature indicated

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STATIC PROPERTIES (SHEET)

GERMANY
W3515
Magnesium Alloy

Units: kg./mm.²

Data Basis: A

Footnotes	Form		Drawn Bar	Extruded Bar			Die Forgings	
	Specification		W3515					
	Condition		0				7	
	Thickness							
	Cross-Sectional Area (mm.²)		≤1000	>1000 ≤5000	>5000 ≤12,300	>5000		
	σ_B	L	28	30	28	32	32	
		T		22	20	24	28	
	$\sigma_{0,2}$	L	20	21	20	23	23	
(1)		T		12	10	14	16	
(1)	$\sigma_{dF0,2}$	L	14	14	12	15	15	
		T						
	$\sigma_{dF0,5}$							
	τ							
	σ_L							
(1)	E		4,500					
(1)	E		5,500					
	G							
(2)	δ_5		10 –	10 3	8 3	6 3	6 3	
	Footnotes							

(1) Data Basis: C

(2) The two values refer to longitudinal and transverse directions of testing respectively

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE

GERMANY
W3515
Magnesium Alloy

Units: hrs, °C, kg./mm²

Data Basis: C

Form	Bar, Rod and Die Forging						
Condition	7						
t →		0·4			0·4		
T ↓	Per Cent σ_B (36 at R.T.)			Per Cent $\sigma_{0.2}$ (26 at R.T.)			
50		98			98		
100		91			88		
150		71			63		
200		48			42		
250		32			23		
300		22			8		
350		11					

GENERAL PROPERTIES

GERMANY
3·5104
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Mn	Si	Fe	Ni	Cr	Zr	Cl				Mg
Casting	3·6 ± 5·5	0·15 max.	0·01 max.	0·01 max.	0·005 max.	0·03 max.	0·4 ± 1·0	0·01 max.				Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200		
γ	$gm./cm.^3$		1·81				
c (1)	$cal./(gm.°C)$			0·23			
λ	$cal.cm./(cm.^2 sec.°C)$		0·27				
α (1)	$per °C \times 10^{-6}$				27·3		

(1) Between 20°C and temperature indicated.

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STATIC PROPERTIES (SHEET)

GERMANY 3.5104 Magnesium Alloy

Units: kg./mm.² **Data Basis: A**

Footnotes					
	Form	Sand Casting			
	Specification	3.5104			
	Condition	9			
	Thickness				
	Cross-Sectional Area				
	Type of Test	a	b	c	
	σ_B	24	17	20	
	$\sigma_{0,2}$	15	10	12	
(1)	$\sigma_{dF0,2}$	14	12	13	
	$\sigma_{dF0,5}$				
(1)	τ	15	15	15	
	σ_L				
(1)	E	4,400			
(1)	E_d	4,400			
(1)	G				
	δ_5	5		2	
	Footnotes				

(1) Data Basis: C

GENERAL PROPERTIES

CHEMICAL COMPOSITION (per cent)

Form	Zn	Mn	Si	Fe	Ni	Cr	Zr	Th	Cl			Mg
Casting	4·8 ± 6·3	0·15 max.	0·01 max.	0·01 max.	0·003 max.	0·03 max.	0·4 ± 1·0	1·5 ± 2·0	0·01 max.			Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200		
γ	$gm./cm.^3$		1·87				
c (1)	$cal./(gm.°C)$			0·23			
λ	$cal.cm./(cm.^2 sec. °C)$		0·27				
α (1)	$per °C \times 10^{-6}$				27·1		

(1) Between 20°C and temperature indicated.

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STATIC PROPERTIES (SHEET)

GERMANY
3.5114
Magnesium Alloy

Units: kg./mm.^{2}

Data Basis: A

Footnotes					
	Form	Sand Casting			
	Specification	3·5114			
	Condition	9			
	Thickness				
	Cross-Sectional Area				
	Type of Test	a	b	c	
	σ_B	25	19	22	
	$\sigma_{0,2}$	15	11	12	
(1)	$\sigma_{dF0,2}$	12	10	11	
	$\sigma_{dF0,5}$				
(1)	τ	14	14	14	
	σ_L				
(1)	E	4,400			
(1)	E_d	4,400			
	G				
	δ_5	4	2	3	
	Footnotes				

(1) Data Basis: C

GENERAL PROPERTIES

GERMANY
3·5194
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu						Others	Mg
Casting	8·3 ± 10·0	0·3 ± 1·0	0·15 ± 0·3	0·3 max.	0·2 max.						0·2 max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	$gm./cm^3$	2 , 6 , 8	1·8				
c (1)	$cal./(gm.°C)$			0·24			
λ	$cal.cm./(cm^2.sec.°C)$	2 , 6 , 8	0·19				
α (1)	$per °C \times 10^{-6}$	2		26·0	27·0	27·8	
ϵ							

(1) Between 20°C and temperature indicated

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STATIC PROPERTIES (SHEET)

GERMANY
3.5194
Magnesium Alloy

Units: kg./mm.^{2} Data Basis: A

Footnotes	Form	Sand Casting			Permanent Mould Casting			Pressure Die Casting										
	Specification	3.5194																
	Condition	2			6			8										
	Thickness																	
	Cross-Sectional Area																	
	Type of Test	a	b		a	b		a										
	σ_B	24	17		24	17		22										
	$\sigma_{0,2}$	11	9		11	9		15										
(1)	$\sigma_{dF0,2}$	10	8		10	8		10										
	$\sigma_{dF0,5}$																	
(1)	τ	12	10		12	10												
	σ_L																	
(1)	E	4,400																
(1)	E_d	4,400																
(1)	G	1,760																
	δ_5	6	3		6	3		0.5										
	Footnotes																	

(1) Data Basis: C

Iss. No.	1		
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Units: kg./mm.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
							5x10^7			
					Nominal		Maximum		Stress	
	Rotating Bending	Separately sandcast specimens Unnotched	2, 6	−1·0			8·0			
		Separately sandcast specimens. Notched, radius=1·20mm K≐2·0	2, 6	−1·0			7·0			
	Footnotes									

FATIGUE PROPERTIES

GERMANY
3·5194
Magnesium Alloy

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE

GERMANY
3.5194
Magnesium Alloy

Units: kg./mm.^{2}

Data Basis: C

Form	Separately Cast Permanent Mould Test Specimens		
Condition	6		
t →	0.4	0.4	0.4
T ↓	Per Cent σ_B (26 at R.T.)	Per Cent $\sigma_{0,2}$ (13 at R.T.)	Per Cent E (4,400 at R.T.)
50	100	100	100
100	92	91	95
150	75	77	93
200	54	64	91
250			
300			

GENERAL PROPERTIES

GERMANY
3·6104
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Mn	Si	Fe	Ni	Cu	Zr	Rare Earths	Cl				Mg
Casting	3·5 — 5·0	0·15 max.	0·01 max.	0·01 max.	0·005 max.	0·03 max.	0·4 — 1·0	0·75 — 1·75	0·01 max.				Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	$gm./cm.^3$	1	1·8				
c (1)	$cal./(gm.°C)$			0·23			
λ	$cal.cm./(cm.^2\ sec.\ °C)$		0·27				
α (1)	$per\ °C \times 10^{-6}$	1		26·0	27·0	27·8	
ϵ							

(1) Between 20°C and temperature indicated

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STATIC PROPERTIES (SHEET)

GERMANY
3·6104
Magnesium Alloy

Units: kg./mm.^{2} **Data Basis:** A

Footnotes																		
	Form	Sand Casting																
	Specification	3·6104																
	Condition	1																
	Thickness																	
	Cross-Sectional Area																	
	Type of Test	a	b	c														
	σ_B	21	19															
	$\sigma_{0,2}$	15	14															
(1)	$\sigma_{dF0,2}$	14	13															
	$\sigma_{dF0,5}$																	
(1)	τ	10	9															
	σ_L																	
(1)	E	4400																
(1)	E_d	5500																
	G																	
	δ_5	3	2·0															
	Footnotes																	

(1) Data Basis: C

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FATIGUE PROPERTIES

GERMANY
3·6104
Magnesium Alloy

Units: kg./mm.²

Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
							5×10^7			
					Nominal		Maximum		Stress	
	Rotating Bending	Separately sandcast specimens Unnotched	1	−1·0			8·6			
		Separately sandcast specimens. Notched, radius=1·20mm K≐2·0	1	−1·0			7·0			
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE

GERMANY
3.6104
Magnesium Alloy

Units: hrs, °C, kg./mm.²

Data Basis: C

Form	Separately cast test specimens		
Condition	I		
t →	4·0	4·0	4·0
T ↓	Per Cent σ_B (21 at R.T.)	Per Cent $\sigma_{0\cdot2}$ (15 at R.T.)	Per Cent E (22 at R.T.)
50	95	97	100
100	93	93	95
150	83	83	93
200	67	73	93
250			
300			

GENERAL PROPERTIES

GERMANY
3·6204
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Mn	Si	Fe	Ni	Cu	Zr	Rare Earths					Mg
Casting	0·8 — 3·0	0·15 max.	0·01 max.	0·01 max.	0·005 max.	0·03 max.	0·4 — 1·0	2·5 — 4 0					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	$gm./cm.^3$	1	1·8				
c (1)	$cal./(gm.°C)$			0·25			
λ	$cal.cm./(cm.^2\ sec.\ °C)$		0·24				
α (1)	$per\ °C \times 10^{-6}$	1			27·8		
ϵ							

(1) Between 20°C and temperature indicated

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STATIC PROPERTIES (SHEET)

GERMANY
3.6204
Magnesium Alloy

Units: kg./mm.^{2}

Data Basis: A

Footnotes	Form	Sand Casting			
	Specification	3.6204			
	Condition	1			
	Thickness				
	Cross-Sectional Area				
	Type of Test	a	b	c	
	σ_B	14	12		
	$\sigma_{0,2}$	10	9		
	$\sigma_{dF0,2}$	9	8		
	$\sigma_{dF0,5}$				
	τ				
	σ_L				
(1)	E	4400			
(1)	E_d	5500			
	G				
	δ_5	3	2		
	Footnotes				

(1) Data Basis: C

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FATIGUE PROPERTIES

GERMANY
3·6204
Magnesium Alloy

Units: kg./mm.²

Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
							5 x 10⁷			
					Nominal		Maximum		Stress	
	Rotating Bending	Separately sandcast specimens Unnotched	1	−1·0			6·7			
		Separately sandcast specimens. Notch radius 1·20mm. K≐2·0	1	−1·0			5·1			
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

GERMANY
3·6204
Magnesium Alloy

Units: hrs., °C., kg./mm. **Data Basis:** C

| Form | Separately Sand Cast Test Specimens | | |

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET)

GERMANY
3·6204
Magnesium Alloy

Units: hrs, °C

Data Basis: A

CREEP DATA

Form		Separately Sand Cast Test Specimens															
Condition		I															
t →		10	30	100	250	300	500	800	1000								
T ↓	Total Strain Per Cent	Per Cent σ_B (σ_B = 14 Kg/mm^2 [1] at room temperature)															
200	0·05	40		31			26		25								
	0·10	51		44			33		31								
	0·20					46			38								
250	0·05	23		16													
	0·10	23		17			15										
	0·20		23	21		18		14	13								
	0·50			23			21		19								
	0·75				23			21	20								
	1·00					23		21	21								

(1) Data Basis A

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GENERAL PROPERTIES

GERMANY
3·6254
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Mn	Si	Fe	Ni	Cu	Cl	Zr	Th			Mg
Casting	1·7 – 2·7	0·15 max.	0·01 max.	0·01 max.	0·005 max.	0·03 max.	0·01 max.	0·4 – 1·0	2·7 – 3·3			Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	
γ	$gm./cm.^3$	1	1·8				
c (1)	$cal./(gm.°C)$	1		0·23			
λ	$cal.cm./(cm.^2 sec. °C)$	1	0·25				
α (1)	$per °C \times 10^{-6}$	1		26·0	27·0	27·8	
ϵ							

(1) Between 20°C and temperature indicated

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STATIC PROPERTIES (SHEET)

GERMANY
3.6254
Magnesium Alloy

Units: kg./mm.^{2} **Data Basis:** A

Footnotes					
	Form	Sand Casting			
	Specification	3·6254			
	Condition	1			
	Thickness				
	Cross-Sectional Area				
	Type of Test	a	b	c	
	σ_B	19	18		
	$\sigma_{0,2}$	9	8		
	$\sigma_{dF0,2}$	9	8		
	$\sigma_{dF0,5}$				
(1)	τ	9	8		
	σ_L				
(1)	$\bar{E}$	4400			
(1)	$\bar{E}_d$	5500			
	$\bar{G}$				
	δ_5	5	4		
	Footnotes				

(1) Data Basis: C

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FATIGUE PROPERTIES

GERMANY
3.6254
Magnesium Alloy

Units: kg./mm.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
							5×10^7			
					Nominal		Maximum		Stress	
	Rotating Bending	Separately sandcast specimens Unnotched	1	−1·0			6·7			
		Separately sandcast specimens. Notch radius 1·20mm. K≙2·0	1	−1·0			6·7			
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

GERMANY
3.6254
Magnesium Alloy

Units: hrs., °C., kg./mm.

Data Basis: C

Form	Separately Sand Cast Test Specimens		
Condition	I		
t →	4·0	4·0	4·0
T ↓	Per Cent (19 at 0° C)	Per Cent (9 at 0° C)	Per Cent E (4400 at 0°C)
50	100	100	100
100	95	100	95
150	68	89	93
200	58	78	91
250	53	67	
300	42	56	
325	32	50	
350 (1)	32	53	

(1) Data Basis: A. For specimens cut from castings, Per Cent σ_B=22, Per Cent $\sigma_{0,2}$= 42

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET)

GERMANY
3·6254
Magnesium Alloy

Units: hrs, °C

Data Basis: A

CREEP DATA

Form	Separately Sand Cast Test Specimens																
Condition	I																
t →	1	2	3	8	10	30	55	100	1000								
T ↓	Total Strain Per Cent	Per Cent σ_s (σ_s = 19 Kg/mm^2 [1] at room temperature)															
300	0·05		21		17												
	0·1					22			14								
	0·2					25			18								
	0·5					29			24	18							
	0·75						28		26	19							
	1·0							29	27	20							
350	0·05		11		9·5	8·4			5·8								
	0·1	17				12			8·4								
	0·2			17		15			8·4	6·8							
	0·5					17			11	7·4							
	0·75						17		12	7·9							
	1·0						15		13	9·0							

(1) Data Basis A

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ITALIAN SECTION

ITALIAN SECTION

A range of magnesium alloys is produced in Italy for use in aircraft construction. For the most part these alloys are ordered to United Kingdom or United States specifications, and the Italian alloys are, for practical purposes, identical with the equivalent United Kingdom or U.S. alloys.

For this reason it is not proposed in this Handbook to present separate charts giving the properties of the Italian alloys, but instead the user is referred to the data presented in the United Kingdom and United States sections.

The table below gives the designations of the Italian magnesium alloys used structurally in aircraft and the corresponding United Kingdom or United States designation.

AZ 31 B	U.S. specification	Wrought Alloy
AZ 80 A	U.S. specification	Wrought Alloy
ZK 60 A	U.S. specification	Wrought Alloy
El A 9	to U.K. specification 2L.121	Casting Alloy
El A 9V	to U.K. specification 2L.122	Casting Alloy
Z5Z	to U.K. specification L.127	Casting Alloy

NICKEL AND TITANIUM

No nickel or titanium alloys are produced in Italy for aeronautical applications.

NETHERLANDS SECTION

In the Netherlands a number of magnesium alloys is produced for use in aircraft construction. These are all casting alloys. They are produced in close agreement with United States or United Kingdom Specifications.

As typical examples, the following designations can be mentioned.

UNITED KINGDOM DESIGNATIONS

2L. 121,	2L. 122
L. 127,	DTD 711A
L. 128,	DTD 748

UNITED STATES DESIGNATIONS

AZ 63 A
AZ 91 C
AZ 92 A

Reference should be made to the appropriate charts in the United Kingdom and United States sections for the properties of these alloys.

Volume III
Magnesium
Nickel and
Titanium Alloys

UNITED KINGDOM SECTION

CONTENTS

1. **Introductory Notes**
2. **Charts as given in the table below.**

Magnesium Alloy	*Title of Chart*	*Issue No.*	*Date*
D.T.D. 118A	General Properties	1	Feb.1962
D.T.D. 142A	Static Properties, Sheet 1	1	"
	Static Properties, Sheet 2	1	"
D.T.D. 259A	General Properties	1	"
	Static Properties	1	Aug.1962
D.T.D. 742	General Properties	1	Feb.1962
	Static Properties	1	"
D.T.D. 622A	General Properties	1	"
D.T.D. 626A	Static Properties, Sheet 1	1	"
	Static Properties, Sheet 2	1	"
2L. 121	General Properties	2	Jan.1963
2L. 122	Static Properties	1	Aug.1962
	Fatigue Properties	1	Feb.1963
	Short Time Properties at Elevated Temperature	1	"
L. 127	General Properties	2	Jan.1963
D.T.D. 711A	Static Properties	2	"
	Fatigue Properties	1	Feb.1963
	Short Time Properties at Elevated Temperature	1	"
L. 128	General Properties	1	"
D.T.D. 748	Static Properties	1	Aug.1962
Nickel Alloy			
D.T.D. 108	General Properties	1	Feb.1963
D.T.D. 192	Static Properties, Sheet 1	1	"
D.T.D. 196	Static Properties, Sheet 2	2	"
D.T.D. 200A	Short Time Properties at Elevated Temperature	1	Aug.1962
	Properties under Load and Elevated Temperature	1	"

Nickel Alloy	*Title of Chart*	*Issue No.*	*Date*
D.T.D. 703B	General Properties	2	Jan.1963
	Static Properties, Sheet 1	2	"
	Static Properties, Sheet 2	1	Aug.1962
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	2	Jan.1963
	Properties under Load and Elevated Temperature	1	Feb.1963
Titanium Alloy			
D.T.D. 5003A	General Properties	1	Feb.1962
D.T.D. 5013A	Static Properties, Sheet 1	1	"
D.T.D. 5023A	Static Properties, Sheet 2	1	"
D.T.D. 5033A	Fatigue Properties	1	Feb.1963
D.T.D. 5063			
D.T.D. 5073			
D.T.D. 5053	General Properties	1	"
D.T.D. 5143	Static Properties	1	"
	Short Time Properties at Elevated Temperature	1	Aug.1962
	Properties under Load and Elevated Temperature	1	Feb.1963
D.T.D. 5083	General Properties	1	"
D.T.D. 5093	Static Properties, Sheet 1	1	"
	Static Properties, Sheet 2	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature Sheet 1	1	"
	Properties under Load and Elevated Temperature Sheet 2	1	"

UNITED KINGDOM SECTION

INTRODUCTORY NOTES

The *Introduction to Volume III* of this Handbook explains the general layout adopted for the presentation of the data, together with details of the properties considered and the explanation of various terms. The purpose of the following notes is to amplify these points, where necessary, in relation to those United Kingdom alloys which are included.

DESIGNATIONS AND SPECIFICATIONS

In the United Kingdom, magnesium, nickel and titanium alloys for aircraft use are supplied either to British Standard specifications (in which case the number is prefixed by the letter 'L'), or to D.T.D. specifications which are issued by the Directorate of Materials Research and Development of the Ministry of Aviation.

'D.T.D.' specifications are issued either to meet a limited requirement not covered by any existing British Standard Specification or to serve as a basis for inspection of materials the properties and uses of which are not sufficiently developed to warrant submission to the British Standards Institution for standardisation. 'D.T.D.' specifications may later be replaced by British Standard Specifications.

Copies of British Standard Specification may be obtained from:

British Standards Institution,
2, Park Street,
London, W.1.

'D.T.D.' specifications are published by Her Majesty's Staticnery Office and copies may be obtained from:

H.M. Stationery Office,
York House,
Kingsway, London, W.C.2.

ALLOYS COVERED

This Section of the Handbook lists the available established data on seven groups of magnesium alloys, three groups of titanium alloys and two groups of nickel alloys. Each group consists of alloys having basically the same chemical composition, and each specification within a group refers to a particular form and condition of the material.

These alloys are those most widely used structurally in aircraft, neglecting nickel and titanium alloys used solely for castings or for rivets. A large proportion of magnesium is used in the cast form and for this reason magnesium casting alloys have been included.

The designations of the materials covered, together with the forms in which they are produced are listed below:

MAGNESIUM ALLOYS

D.T.D. 118A - Sheet and strip
D.T.D. 142A - Bar and extrusions

D.T.D. 259A - Bar and extrusions

D.T.D. 622A - Bar and extrusions
D.T.D. 626A - Sheet and strip

D.T.D. 742 - Sheet and strip

2L. 121, 2L. 122 - Sand and chill castings

L. 127, D.T.D. 711A - Sand and chill castings

NICKEL ALLOYS

D.T.D. 10B - Sheet
D.T.D. 192 - Bar, stampings and forgings
D.T.D. 196 - Bar - suitable for cold bending
D.T.D. 200A - Bar

D.T.D. 703B - Sheet and strip
- Bar

TITANIUM ALLOYS

D.T.D. 5003A, 5013A - Bar and billet - suitable for welding
D.T.D. 5023A, 5033A
D.T.D. 5063 - Sheet and strip - suitable for welding
D.T.D. 5073 - Tubes - suitable for pipe tubes and high pressure hydraulic systems where flaring is required

D.T.D. 5053 - Bar and billets
D.T.D. 5143 - Forgings

D.T.D. 5083 - Bar and billets
D.T.D. 5093 - Sheet

Although there is no official specification for bar material of the composition of D.T.D. 703B, the properties are given in this section as the material is widely used.

CHEMICAL COMPOSITION

The *General Properties* charts give the chemical composition by quoting the limits of the alloying elements as a percentage by weight of the total. In the case of magnesium alloys containing zirconium the percentage of 'available' zirconium is given, i.e. that portion of the zirconium which is soluble in dilute hydrochloric acid.

CONDITION

The 'Condition' row on the charts refers to the type of heat treatment and conditioning. Although there are no officially recognised symbols to describe the various conditions, for simplicity the following designations are used in this Section:

MAGNESIUM ALLOYS

M - As manufactured, i.e. as rolled, extruded or cast. This may also include annealing or stress relieving by the supplier

O - Softened

½H - ½ Hard, cold rolled

P - Precipitation treated

W - Solution treated

NICKEL ALLOYS

A - Annealed

C.D.A. - Cold drawn and annealed or cold rolled and annealed

H.D. - Hard drawn (rolled and tempered, or rolled, drawn and tempered)

H.R. - Hot rolled or hot forged

TITANIUM ALLOYS

A - Annealed

H.T. - Heat treated

For details of the times and temperatures of heat treatments reference should be made to the relevant material specification.

NOTATION

The notation used in this Section of the Handbook for the various physical and mechanical properties of the United Kingdom alloys is defined on the *Notation* chart in the *Introduction to Volume III*. This chart also compares the notation used for other National Sections. Points where any amplification is needed are dealt with under the appropriate headings below.

UNITS

The units used for the various parameters and properties are indicated on each of the charts. For mechanical properties the stresses and moduli are given in units of 10^3 lb/in.^{2} whilst temperature is quoted in degrees Centigrade. For conversion to metric units see the *Conversion Scales* chart given in the *Introduction to Volume III*.

DATA BASIS

The *Introduction to Volume III* of this Handbook describes the use of symbols 'A', 'B' and 'C' denoting the data basis of the values for the various properties given on the charts. Special aspects of this in relation to the values quoted for the United Kingdom alloys are outlined below:

A - This indicates that the values listed are the minimum to be expected for the given material. The only values considered 'guaranteed minimum' are those for f_t and in most cases t_1 and e, which are marked as Data Basis 'A' and which are quoted for the grain directions stated in the relevant specification. The remaining values marked as data basis 'A' are 'derived' values; that is, tests indicate that a material just meeting the specification requirements for f_t, t_1 and e would have compressive, shear and bearing strength equal to the values quoted. Both minimum and maximum values of f_t are specified for commercially pure titanium which is available in different grades to comply with forming requirements.

B - This data basis is not used in the United Kingdom charts.

C - This indicates that the values listed are typical for the material, there being insufficient data to determine values for basis 'A' or 'B'.

In general the data basis used on any chart is shown at the top of the chart but special attention must be paid to the footnotes which sometimes indicate a different data basis for some particular part of the chart.

STATIC PROPERTIES CHART

Tensile and Compressive Strengths

In the United Kingdom, official specifications generally quote the 0.1 per cent proof stress in tension, t_1 and thus this value is given on the charts. It should be noted that in other National Sections the 0.2 per cent proof stress (or offset yield stress) in tension is given.

The sub-headings 'L' , 'LT' and 'ST' used with the tensile and compressive strengths on the *Static Properties* Charts refer to the longitudinal, long transverse and short transverse directions respectively.

The tensile properties are obtained from test pieces selected in accordance with the appropriate clauses of the relevant material specifications.

STRAIN RATE

The tensile strength of titanium is dependent to a marked extent on the strain rate. The values of f_t and t_1 given on the *Static Properties* charts apply to a strain rate of 0.002 to 0.005 in./in./min. up to the 0.5 per cent proof stress, with stops for readings not longer than 1 second and a total stopped time not greater than 20 seconds. Beyond the 0.5 per cent proof stress the strain rate is between 0.15 and 0.3 in./in./min. Fuller details of the testing procedure to achieve these strain rates are given in Appendices to the relevant material specifications.

SHEAR STRENGTH

The torsional ultimate stress f_q , is defined as the stress corresponding to the maximum torque that the member will sustain, irrespective of whether failure is by plastic shear, buckling of the wall, or a combination of both. The values given on the charts were obtained from torsion tests on tubes and solid section bars, and were determined on the assumption that the stress at any section was directly proportional to the distance from the axis of the tube or bar. Where values of f_q are given for material in forms other than tube, the tests were carried out on tubes or solid circular bars machined from the form in question. The tests were made on specimens with a length/diameter ratio of about 15 for tube materials and 8 for bar materials.

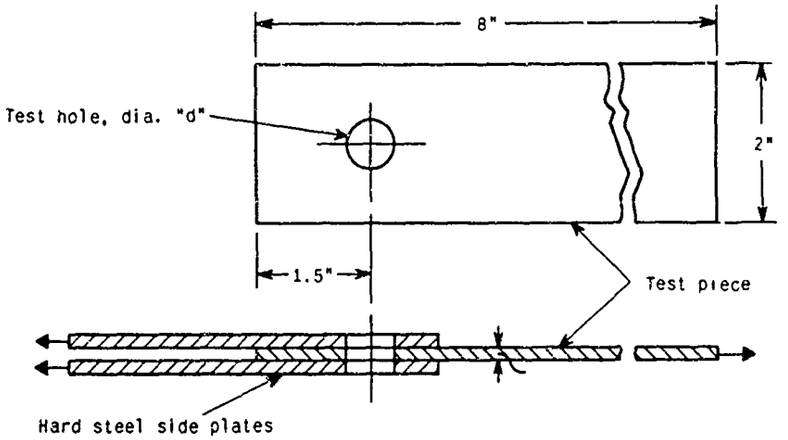
Values of f_q are given for a range of values of the ratio D/t , where D and t are the external diameter and the wall thickness respectively of the torsion member. Values of D/t of 2, 5 and 10 have been taken for wrought alloys and 11 for cast alloys.

The parameter D/t is included on the appropriate *Static Properties* Charts in the United Kingdom section by the alteration of the row used for 'Cross-sectional Area' in the other National Sections.

BEARING STRENGTH

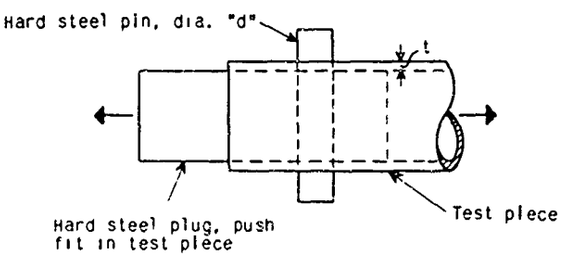
The symbol b_{10} denotes the 1.0 per cent proof stress in bearing. The values are derived from a series of tests of single bolt joints in plates and tubes, covering the effects of clearances, lateral support (such as that given by bolt heads or adjacent plates), curvature of the bearing surfaces and ratio of pin-diameter to plate thickness. b_{10} is defined as that stress which will produce a permanent deformation of the hole equal to 1.0 per cent of its original diameter.

The dimensions of the test specimens are indicated in Figures 1 and 2.



Note:- d/t in tests on wrought alloys was between 3.3 and 4.5. For cast magnesium alloys d/t was between 0.74 and 1.25 and the specimens were 5" diameter flanges machines from flanged cylinders of 1.85" internal dia. with test holes reamed to size on a 3.4" concentric circle, loaded diametrically

Fig.1 Lug Type Tests for Sheet and Plate Materials



Note:- d/t in tests was approximately constant at 5.0

Fig.2 Plug Type Tests for Bar and Tube Materials

ELASTIC AND SHEAR MODULI

The sub-headings 'L' and 'T' used with the elastic moduli on the *Static Properties* charts refer to the longitudinal and transverse directions respectively. Throughout the charts the values quoted for moduli should be regarded as typical, that is, data basis 'C'. This has been emphasised where the data are from unofficial sources by a footnote on the chart.

ELONGATION

The values of elongation given on the charts are quoted as the percentage elongation after failure for specimens as defined in the appropriate clause of the material specification. The specimens have a gauge length of four times the square root of the cross-sectional area or in some instances 2 inches.

FORGINGS

The strength properties of forgings can vary markedly, but the values quoted give an indication of the level of strength that might be expected in a simple forging. For more complex forgings the strength may be less. Due consideration should also be given to the effects of grain direction. For more precise strength values, tests should be made on the complete forging.

STATIC PROPERTIES CHARTS: CAST MAGNESIUM ALLOYS

Strength properties of magnesium castings are given for two Types of Test as explained below.

TYPE OF TEST: a

The strength properties of aeroplane casting materials are controlled by specifying a minimum strength that must be attained by test bars cast from the same batch of material and under the same conditions as the actual castings. These test bars are made and tested in accordance with British Standard 2L.101. The minimum strength values for such test bars are quoted on the *Static Properties* charts in the columns headed 'Type of Test: a'. The data basis is 'A', i.e. the minimum to be expected for the given material.

TYPE OF TEST: c

In general the strength properties in various parts of castings and in different castings differ from those of the standard test bars. To avoid excess weight incurred in allowing a sufficient margin of safety when designing by calculation based on 'Type of Test: a' strength values it is usual to base the acceptance of important castings on strength tests made on the actual castings. The strength values given on the *Static Properties* charts under 'Type of Test: c' are used as a guide in designing castings for approval by test. The 'Type of Test: c' values are estimates of the mean strength of all material made to the given specification, and have been obtained from cut-up tests on specimens taken from test castings of a standardised design, cast by two or three founders. It should be noted that the geometries of the specimens used to determine the static properties are not of the same form as those used for wrought alloys. The values indicate the general level of strength that can be obtained in castings of this type, but higher or lower mean strengths may occur in individual batches and other designs of castings. The data basis is 'C'.

FATIGUE PROPERTIES

The data, given on the *Fatigue Properties* charts cover tests in rotating bending and reversed flexural and repeated axial loading. A brief description of the various specimens tested is given on the charts.

Rotating bending tests were in general carried out on a Wohler type machine. The smooth specimens were round bars 0.30 - 0.40 inches diameter. The values of the elastic stress concentrations factor K_t for the notched specimens varied from 2.0 to 4.0

The reversed flexural tests were made on N.P.L./Bristol combined stress machines with a stress ratio of -1.0 using standard hollow specimens both smooth and with 0.04 inch radius fillet.

In all cases the 'Nominal Maximum Stress' quoted on the charts is the maximum stress across the critical section of the specimen determined at the maximum load of the fatigue cycle, without correction for stress concentration effects. The 'Stress Ratio' quoted on the charts is the ratio of minimum to maximum stress during the fatigue cycle with compressive stress being taken negative and tensile stress positive.

It should be noted that there is always a wide scatter of results with tests of this type and the values given on the charts represent mean lines through the scatter bands.

On the United Kingdom *Fatigue Properties* charts, the column headed 'Form and Condition' gives the appropriate specification number since this defines both the form and the condition of the material. In other National Sections this column is headed simply 'Condition'.

ELEVATED TEMPERATURE DATA

On these charts the data are presented as percentages of the appropriate room temperature value. The appropriate room temperature value of the specimens tested is indicated when known at the head of the column. It is not possible to give precise details of the test specimens used in determining the elevated temperature properties, since the test method has not been standardised.

No data are available for the Recovered Properties after Exposure to Elevated Temperature but it is known that for the Nickel and Titanium alloys included the room temperature properties are not greatly affected by exposure to temperature in the normal working range.

On the *Properties under Load and Elevated Temperature* charts, creep data are presented which give the stress (expressed as a percentage of the room temperature value of f_t) which, for a given time and at a given temperature, will produce given values of total deformation or failure. It should be noted that the 'total deformation' is the total plastic strain and includes neither the initial (or elastic) strain not the thermal expansion.

February 1963.

GENERAL PROPERTIES

U.K.
D.T.D.118A, 142A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Cu	Si	Fe	Ni	Ca	Mn					Mg
All Forms	0·05 Max.	0·03 Max.	0·02 Max.	0·02 Max.	0·03 Max.	0·005 Max.	0·02 Max.	1·0 – 2·0					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·74				
c (1)	$cal./(gm.°C)$			0·24			
k	$cal.cm./(cm.^2\ sec.\ °C)$			0·34			
α (1)	$per\ °C \times 10^{-6}$				27		
ϵ							

(1) Between 20°C and temperature indicated.

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STATIC PROPERTIES (SHEET 1)

U.K. D.T.D.118A, 142A Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis:** A

Footnotes	Form		Sheet
	Specification		D.T.D. 118 A
	Condition		M, O
	Thickness (in.)		
	f_t	L	29·1
		LT	
		ST	
	t_1	L	8·9
		LT	
		ST	
	C_1	L	
	C_2	L	
		LT	
		ST	
	C_5	L	
	f_q		
	f_b		
	b_{10}		
	E		6,500
	E_c		
	G		
(1)	e	%	5
	Footnotes		

(1) Thickness >0·104 in

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STATIC PROPERTIES (SHEET 2)

U.K. D.T.D. 118A, 142A
Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes																					
	Form		Bars and Extrusions																		
	Specification		D.T.D. 142 A																		
	Condition		M																		
	Thickness (in.)																				
	Cross-Sectional Area (in.^{2})																				
	f_t	L	33·6																		
		T																			
	t_1	L	17·9																		
		T																			
	C_1	L																			
	C_2	L																			
		T																			
	C_5																				
	f_s																				
	f_b																				
	b_{10}																				
	E		6,450																		
	E_c																				
	G																				
	e	%	4																		
	Footnotes																				

GENERAL PROPERTIES

U.K.
D.T.D. 259A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Cu	Si	Fe	Ni						Mg
Bars and Extrusions	5·5 – 8·5	1·5 Max.	0·20 – 0·40	0·1 Max.	0·1 Max.	0·03 Max.	0·005 Max.						Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·80				
c (1)	$cal./(gm.°C)$			0·24			
k	$cal.cm./(cm.^2 sec. °C)$			0·20			
α (1)	$per °C \times 10^{-6}$				27		
ϵ							

(1) Between 20°C. and temperature indicated.

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STATIC PROPERTIES (SHEET)

U.K. D.T.D. 259A Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis:** A

Footnotes	Form		Bars and Extrusions		
	Specification		D.T.D. 259A		
	Condition		M		
	Thickness (in.)				
	D / t		2	5	10
	f_t	L	38·1	38·1	38·1
		T			
	t_1	L	24·6	24·6	24·6
		T			
	C_1	L			
	C_2	L			
		T			
	C_5	L			
	f_q		27·6	24·8	21·6
	f_b				
	b_{10}		32·5	32·5	32·5
	E		6,500		
	E_c				
	G		2,400		
	e	%	10	10	10
	Footnotes				

GENERAL PROPERTIES

U.K.
D.T.D. 742
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Ca	Si	Cu	Ni	Fe					Mg
Sheet	2·5 – 3·5	0·6 – 1·4	0·15 – 0·7	0·3 Max.	0·3 Max.	0·05 Max.	0·005 Max.	0·005 Max.					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·77				
c (1)	$cal./(gm.°C)$			0·24			
k	$cal.cm./(cm.^2\ sec.\ °C)$			0·23			
α (1)	$per\ °C \times 10^{-6}$				26		
ϵ							

(1) Between 20°C and temperature indicated.

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Date	FEB '62		
App'd by	A.T.		

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App'd by	A.T.		

STATIC PROPERTIES (SHEET)

U.K. D.T.D. 742 Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis:** A

Footnotes																					
	Form		Sheet and Strip																		
	Specification		D.T.D. 742																		
	Condition		½ H																		
	Thickness (in.)																				
	f_t	L	35·8																		
		LT																			
		ST																			
	t_1	L	22·4																		
		LT																			
		ST																			
	C_1	L																			
	C_2	L																			
		LT																			
		ST																			
	C_5	L																			
	f_a																				
	f_b																				
	b_{10}																				
	E																				
	E_c																				
	G																				
	e	%	8																		
	Footnotes																				

GENERAL PROPERTIES

U.K.
D.T.D.622A, 626A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Zr	Mn	Cu	Al	Si	Fe	Ni					Mg
All Forms	2·5 – 4·0	0·5 – 1·0	0·15 Max.	0·03 Max.	0·02 Max.	0·01 Max.	0·01 Max.	0·005 Max.					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·80				
c (1)	$cal./(gm.°C)$			0·24			
k	$cal.cm./(cm.^2\ sec.\ °C)$			0·30			
α (1)	$per\ °C \times 10^{-6}$				27		
ϵ							

(1) Between 20°C. and temperature indicated.

Iss. No.	1	
Date	Feb '62	
App'd by	A.T	

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App'd by	A.T.		

STATIC PROPERTIES (SHEET 1)

U.K. D.T.D. 622A, 626A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes	Form		Sheet and Strip																			
	Specification		D.T.D. 626A																			
	Condition		M																			
	Thickness (in.)		< 0·048	0·048 0·104	> 0·104																	
	f_t	L	35·8	38·1	38·1																	
		LT																				
		ST																				
	t_1	L	22·4	24·6	24·6																	
		LT																				
		ST																				
	C_1	L																				
	C_2	L																				
		LT																				
		ST																				
	C_5	L																				
	f_c																					
	f_b																					
	b_{10}			42·5	42·5																	
	E		6,500																			
	E_c																					
	G																					
	e %		6	7	8																	
	Footnotes																					

Iss. No.	1		
Date	FEB '62		
App'd by	A.T.		

STATIC PROPERTIES (SHEET 2)

U.K. D.T.D. 622A, 626A Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis:** A

Footnotes	Form		Bars and Extrusions	
	Specification		D.T.D. 622 A	
	Condition		M	
	Thickness (in.)		>0·375 ≤ 4·0	≤ 0·375
	Cross-Sectional Area (in.^{2})			
	f_t	L	44·8	40·3
		T		
	t_1	L	31·4	26·9
		T		
	C_1	L		
	C_2	L		
		T		
	C_5			
	f_q			
	f_b			
	b_{10}			
	E		6,450	
	E_c			
	G			
	e	%	10	10
	Footnotes			

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Cu	Si	Fe	Ni	Sn			Total of Cu,Si,Fe and Ni.	Mg
Castings	7·5 – 9·0	0·3 – 1·0	0·15 – 0·4	0·15 Max.	0·3 Max.	0·05 Max.	0·01 Max.	0·1 Max			0·40 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·80				
c	$cal./(gm.°C)$						
k	$cal.cm./(cm.^2\ sec.\ °C)$	2L.121		0·21 (2)	0·23 (3)		
		2L.122		0·17 (2)	0·21 (3)		
α (1)	$per\ °C \times 10^{-6}$	2L.121		24·9	26·5	27·6	
		2L.122		25·3	26·7	27·9	
ϵ							

(1) Between 20°C and temperature indicated.
(2) Between 70°C and 180°C
(3) Between 180°C and 300°C

2	JAN '63	A.T.
1	FEB '62	AT
Iss. No.	Date	App'd by

Iss. No.	1		
Date	AUG '62		
App'd by	A.T.		

Units: 10^3 lb./in.^{2} **Data Basis: A**

Footnotes	Form	Sand Castings						Chill Castings									
	Specification	2L.121			2L.122			2L.121			2L.122						
	Condition	M			W			M			W						
	Thickness (in.)																
	Cross-Sectional Area (or weight)																
	Type of Test	a	b	c	a	b	c(2)	a	b	c	a	b	c				
	f_t	20·2			29·1		30·0	26 9			33·6						
	t_1	11·2			10·1		10·1	11·2			10·1						
	c_1																
	c_2																
	c_5																
(1)	f_q						19·3										
	f_b																
	b_{10}						27·3										
	E	6,300															
	E_c																
	G	2,200															
	e %	2			6			4			10						
	Footnotes																

(1) D/t = 11 (2) Data Basis: C. Specimens cut from castings

STATIC PROPERTIES (SHEET)

U.K. 2L.121, 2L.122 Magnesium Alloy

Iss. No.	1		
Date	FEB'63		
App'd by	AT		

FATIGUE PROPERTIES

U.K. 2L.121, 2L.122 Magnesium Alloy

Units: 10^3 lb/in.^{2} Data Basis: C

Footnotes	Test	Specimen	Form and Condition	Stress Ratio	Cycles					
					10^7	3×10^7	6×10^7	9×10^7	10^8	$1{\cdot}2\times10^8$
					Nominal Maximum Stress					
	Rotating Bending	0·3 and 0·4 inch diameter. Sand cast.	2L.121	−1·0	12·1	11·8	11·6	11·5	11·4	11·3
			2L.122	−1·0	12·7	12·1	11·6	11·4	11·2	11·2
	Reversed Flexure	Sand cast Plain	2L.121	−1·0	12·2	11·7	11·4			
			2L.122	−1·0	11·5	11·3				
		Fillet (R=0·04in) Sand cast	2L.121	−1·0	7·0	6·6				
			2L.122	−1·0	7·6	7·4				
	Footnotes									

Iss. No.	1		
Date	FEB '63		
App'd by	A T.		

SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.K. 2L.121, 2L.122 Magnesium Alloy

Units: Hours, °C, 10^3 lb./in.^{2} **Data Basis:** C

Form	Sand Casting																							
Condition	2L.121									2L.122														
t →		1			1			1			1			1			1							
T ↓	Per Cent f_t (24·6 at 20°C)			Per Cent t_1 (13·3 at 20°C)			Per Cent E (6,000 at 20°C)			Per Cent f_t (39·4 at 20°C)			Per Cent t_1 (12·0 at 20°C)			Per Cent E (5,900 at 20°C)								
100		96			89			96			92			90			91							
150		89			76			91			75			83			87							
200		80			70			76			53			77			79							

GENERAL PROPERTIES

U.K.
L127, D.T.D. 711A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Zr	Mn	Cu	Si	Fe	Ni						Mg
Castings	3·5 — 5·5	0·4 — 1·0	0·15 Max.	0·03 Max.	0·01 Max.	0·01 Max.	0·005 Max.						Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·80				
c (1)	$cal./(gm.^\circ C)$			0·24			
k	$cal.cm./(cm.^2\ sec.\ ^\circ C)$	L 127		0·322 (2)	0·324 (3)	0·324 (3)	
α (1)	$per\ ^\circ C \times 10^{-6}$	L 127		25·6	27·3	28·1	
ϵ							

(1) Between 20°C and temperature indicated.
(2) Between 86 and 199° C
(3) Between 199 and 311° C

Iss. No.	1	2	
Date	FEB '62	JAN '63	
App'd by	AT.	AT	

Iss. No.	1	2	
Date	AUG '62	JAN 63	
App'd by	AT	AT	

STATIC PROPERTIES (SHEET)

U.K. L.127, D.T.D. 711A Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis: A**

Footnotes	Form	Sand Castings						Chill Castings									
	Specification	D.T.D.711A			L.127			D.T.D.711A			L.127						
	Condition	M			P			M			P						
	Thickness (in.)																
	Cross-Sectional Area (or weight)																
	Type of Test	a	b	c(1)	a	b	c(1)	a	b	c(1)	a	b	c(1)				
	f_t	29·1			33·6		34·0	33·6			35·8						
	t_t	15·7			19·0		21·2	15·7			19·0						
	C_t																
	C_2																
	C_5																
(2)	f_q						24·2										
	f_b																
	b_{10}						39·4										
	E						5900										
	E_c																
	G						2400										
	e %	7			5			10			7						
	Footnotes																

(1) Data Basis: C. Specimens cut from castings.
(2) D/T = 11

Iss. No.	1		
Date	FEB '65		
App'd by	A.T.		

FATIGUE PROPERTIES

U.K. L127, D.T.D. 711A
Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Form and Condition	Stress Ratio	Cycles					
						10^7	3×10^7	6×10^7		
					Nominal		Maximum		Stress	
	Rotating Bending	Sand cast 0·3 inch Diameter	L127	−1·0		9·6	9·4	9·4		
	Reversed Flexure	Sand cast Plain		−1·0		9·2	9·0			
		Sand cast Fillet (R=0·04 in.)		−1·0		5·6	5·1			
	Footnotes									

Iss No	1		
Date	FEB 65		
App'd by	A T		

SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE

U.K. L.127, D.T.D.711A Magnesium Alloy

Units: Hours, °C, 10^3 lb./in.^{2}

Data Basis: C

| Form | Sand Casting | | |

GENERAL PROPERTIES

U.K.
L.128,D.T.D.748
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Rare Earth Metals	Zr	Mn	Cu	Si	Fe	Ni					Mg
Castings	3·5 – 5·0	0·75 – 1·75	0·4 – 1·0	0·15 Max.	0·03 Max.	0·01 Max.	0·01 Max.	0·005 Max.					Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·83				
c (1)	$cal./(gm.^\circ C)$			0·24			
k	$cal.cm./(cm.^2 sec.^\circ C)$			0·28			
α (1)	$per^\circ C \times 10^{-6}$					27	
ϵ							

(1) Between 20°C and temperature indicated.

Iss. No. 1	FEB '62	AT
Date		
App'd by		

Iss. No.	1		
Date	AUG '62		
App'd by	AT		

STATIC PROPERTIES

U.K. L.128, D.T.D.748 Magnesium Alloy

(SHEET)

Units: 10^3 lb./in.^{2} **Data Basis: A**

Footnotes	Form	Sand Casting			Chill Casting		
	Specification	L.128, D.T.D.748					
	Condition	P					
	Thickness (in.)						
	Cross-Sectional Area (or weight)						
	Type of Test	a	b	c	a	b	c
	f_t	29·1		30·5	31·4		
	t_1	17·9		18·6	17·9		
	c_1						
	c_2						
	c_5						
(1)	f_q			20·6			
	f_b						
	b_{10}			36·5			
	E	6,500		5,900	6,500		
	E_c						
	G			2,500			
	e %	3			4		
	Footnotes			(2)			

(1) D/t = 11

(2) Data Basis: C. Specimens cut from castings

GENERAL PROPERTIES

U.K.
D.T.D.108,192,196,200A
Nickel Alloy

CHEMICAL COMPOSITION (per cent)

Form	Mn	Fe	Ni								Total Impurities		Cu
All Forms	0·3 – 2·0	2·5 Max.	64·0 – 70·0								0·3 Max.		Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	$gm./cm.^3$	A	8·83				
c	$cal./(gm.°C)$	A	0·127				
k	$cal.cm./(cm^2 sec.°C)$	A	0·062	0·065	0·074	0·084	0·094
α (1)	$per °C \times 10^{-6}$	A		14·2	15·4		
ϵ							

(1) Between 20°C and temperature indicated.

Iss. No.	1		
Date	FEB 62		
App'd by	AT		

Iss. No.	1	2	
Date	FEB '62	JAN'63	
App'd by	AT	A T	

STATIC PROPERTIES (SHEET 1)

U.K. D.T.D.108,192,196,200A Nickel Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes	Form		Sheet				Strip																		
	Specification		D.T.D. 108				D.T.D200A																		
	Condition		A				H.D.																		
	Thickness (in.)		>0·02				>0·02																		
	f_t	L	67·2				101																		
		LT	67·2																						
		ST																							
	f_1	L	15·7				67·2																		
		LT	15·7																						
		ST																							
	C_1	L																							
	C_2	L																							
		LT																							
		ST																							
	C_5	L																							
	f_a																								
	f_b																								
	b_{10}																								
	E																								
	E_c																								
	G																								
(1)	e	%	40				14																		
	Footnotes																								

(1) Data Basis: C

Iss. No.	2		
Date	FEB 63		
App'd by	A.T.		

STATIC PROPERTIES (SHEET 2)

U.K. DTD.108,192,196,200A

Nickel Alloy

Units: 10^3 lb./in.^{2}

Data Basis: A

Footnotes	Form		Bars, Stampings and Forgings			Bars														
	Specification		D.T.D. 192			D.T.D.196		D.T.D. 200A												
	Condition		H.R.			C.D.A.		H.D.												
	Thickness																			
	Cross-Sectional Area																			
	f_1	L	76·1			67·2		101												
		T																		
	t_1	L						67·2												
		T																		
	c_1	L																		
(1)	c_2	L	38			26·9														
		T																		
	c_5																			
	f_a																			
	f_b																			
	b_{10}																			
(1)	E		26,800																	
	E_c																			
	G																			
	e	%	30			35		14												
	Footnotes																			

(1) Data Basis: C

Iss. No.	1		
Date	AUG '62		
App'd by	AT		

SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.K.
D.T.D.10B,192,196,200A
Nickel Alloy

Units: hours, °C., 10^3 lb./in.^{2}

Data Basis: C

Form	Bars								
Condition	H.R. (D.T.D. 192)								
t →		0·5			0·5			0·5	
T ↓	Per Cent f_1 (79 at R.T.)			Per Cent t_2 (30 at R.T.)			Per Cent E (26,800 at R.T.)		
316		95			72			96	
427		80			70			93	
538		58			67			88	
649		34			48			84	
760		22			37			79	
871		11			22			68	

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET)

U.K.
D.T.D. 108, 192, 196, 200A
Nickel Alloy

Units: hours, °C

Data Basis: C

CREEP DATA

Form		Bars															
Condition		H.R. (D.T.D. 192)						C.D.A. (D.T.D. 196)									
t →			10^5						10^5								
T ↓	Total Deformation Per Cent	Per Cent f_1 (79 x 10^3 lb./in.^{2} at R.T.)						Per Cent f_1 (84 x 10^3 lb./in.^{2} at R.T.)									
399	0·1		26						24								
	1·0		40						35								
427	0·1		20						19								
	1·0		29						29								
482	0·1								9·3								
	1·0		17						19								
538	0·1								4								
	1·0								11								

Iss. No.	1	
Date	AUG '62	
App'd by	A.T.	

CHEMICAL COMPOSITION (per cent)

Form	C	Ti	Cr	Si	Mn	Cu	Fe						Ni (plus Co)
Sheet and Strip	0·08 – 0·15	0·2 – 0·6	18·0 – 21·0	1·0 Max.	1·0 Max.	0·5 Max.	5·0 Max.						Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	$gm./cm.^3$	A	8·36				
$c^{(1)}$	$cal./gm.^{\circ}C$	A	0·110				
k	$cal.cm./(cm.^2\ sec.\ ^{\circ}C)$	A		0·038	0·046	0·054	0·062
$\alpha^{(1)}$	$per\ ^{\circ}C \times 10^{-6}$	A		13·0	13·8	14·7	15·5
ϵ	per cent	Shot blasted and oxidised at 1200 °C			86	92	100

(1) Between 20°C and temperature indicated.

Iss. No.	1	2	
Date	FEB '62	JAN 63	
App'd by	AT	A.T.	

Iss. No.	1	2	
Date	AUG '62	JAN '63	
App'd by	A.T	A.T.	

STATIC PROPERTIES
(SHEET 1)

U.K.
D.T.D.703B
Nickel Alloy

Units: 10^3lb./in.^{2}

Data Basis:C

Footnotes			
	Form		Sheet
	Specification		D.T.D 703B
	Condition		A
	Thickness (in.)		0·104
	f_t	L	116
		LT	
		ST	
	t_1	L	58·2
		LT	
		ST	
	C_1		
	C_2	L	
		LT	
		ST	
	C_5		
	f_q		
	f_b		
	b_{10}		
	E		
	E_c		
	G		
	e	%	33
	Footnotes		

Iss. No.	1		
Date	AUG '62		
App'd by	A.T.		

STATIC PROPERTIES (SHEET 2)

U.K. D.T.D. 703B Nickel Alloy

Units: 10^3 lb./in.^{2}

Data Basis: C

Footnotes																					
	Form		Bar																		
	Specification																				
	Condition		A																		
	Thickness (in.)																				
	Cross-Sectional Area (in.^{2})																				
	f_t	L	116·5																		
		T																			
	t_1	L	49·3																		
		T																			
	C_1	L																			
	C_2	L																			
		T																			
	C_5	L																			
	f_q																				
	f_b																				
	b_{10}																				
	E		32,400																		
	E_c																				
	G																				
	e	%	44																		
	Footnotes																				

Iss. No.	1		
Date	AUG '62		
App'd by	AT		

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
						10×10^6				
					Nominal		Maximum		Stress	
	Rotating Bending.	Smooth bar	H.R.A.	-1·0		37·6				
	Footnotes									

FATIGUE PROPERTIES

U.K.
D.T.D. 703B
Nickel Alloy

Iss. No.	1	2	
Date	AUG '62	JAN '63	
App'd by	AT	A.T.	

SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.K. D.T.D. 703B Nickel Alloy

Units: hours, °C., 10^3 lb./in.^{2} Data Basis: C

Form	Bar																										
Condition	A																										
t →																											
T ↓	Per Cent f_1 (1.6 at 68°F.)			Per Cent t_1 (49 at 68°F.)			Per Cent E (32,400 at 68°F.)																				
200		91			86			95																			
300		94			86			92																			
400		92			86			89																			
500		87			82			86																			
600		71			77			82																			
700		44			59			79																			
800		25			30			74																			
900		14			16																						
1000		10			11																						

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET)

U.K.
D.T.D. 703B
Nickel Alloy

Units: hours, °C

Data Basis: C

CREEP DATA

Form		Bar																
Condition		A																
t →		10^2	3×10^2	10^3	3×10^3	10^4												
T ↓	Total Deformation Per Cent	Per Cent f_t (116×10^3 lb./in.^{2})																
600	0·1	12·5	10·5	8·8	7·7	6·3												
	0·5	16	14	12·5	10·5	8·7												
	1·0	18	17	14	12·5	10·5												
	3·0		19	17	15	13·5												
650	0·1	8·1	6·4	5·0	4·2													
	0·5	11	9·4	7·9	6·3													
	1·0	12·5	11	9·0	7·3													
	3·0			11	9·2	7·7												
700	0·1	5·4	4·2	3·5	3·1													
	0·5	7·7	6·2	5·0	4·0													
	1·0	8·5	7·1	6·0	4·8													
	3·0			7·3														
750	0·1	3·7	3·1	2·7	2·5													
	0·5	5·2	4·2	3·7	3·3	2·7												
	1·0	6·2	5·2	4·0	3·5													
	3·0			5·4	4·6	3·8												

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GENERAL PROPERTIES

U.K.
D.T.D. 5003A, 5013A, 5023A
5033A, 5063, 5073
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Fe	H									Ti
Bars & Billets	0·10 Max.	0·20 Max.	0·013 Max.									Remainder
Sheet, Strip, Tubing.	0·10 Max.	0·20 Max.	0·015 Max.									Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		4·51				
c	$cal./(gm.^\circ C)$		0·123	0·130	0·139	0·143	0·145
k	$cal.cm./(cm.^2 sec.^\circ C)$		0·040	0·038	0·036	0·035	0·036
$\alpha^{(1)}$	$per^\circ C \times 10^{-6}$			9·0	9·1	9·2	9·4
ϵ							

(1) Between 20°C. and temperature indicated.

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STATIC PROPERTIES (SHEET 1)

U.K. D.T.D. 5003A, 5013A, 5023A 5033A, 5063, 5073 Titanium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes	Form		Sheet and Strip										Tubes		
	Specification		D.T.D. 5023 A			D.T.D.5033A			D.T.D. 5063				D.T.D. 5073		
	Condition		A												
	Thickness (in.)		All Thicknesses	> 0·0148	> 0·104	≤ 0·104	> 0·104		All Thicknesses	> 0·0148	> 0·104				
(1)	f_t	L	62·7-89·6	62·7-89·6	62·7-89·6	<67·2	<67·2		89·6-116·5	89·6-116·5	89·6-116·5		56		
(2)	f_t	LT	62·7-89·6	62·7-89·6	62·7-89·6	<67·2	<67·2		89·6-116·5	89·6-116·5	89·6-116·5				
	f_t	ST													
(1)	t_1	L		40·3	40·3	29·1	29·1			67·2	67·2		40·3		
(2)	t_1	LT		40·3	40·3	29·1	29·1			67·2	67·2				
	t_1	ST													
	C_1	L													
	C_2	L													
	C_2	LT													
	C_2	ST													
	C_5	L													
	f_q														
	f_b														
	b_{10}														
(3)	E		15,000-17,000						15,000 – 18,000						
	E_c														
	G														
	e	%			18		20				12				
	Footnotes														

(1) Width of sheet or strip <9 in (2) Width of sheet or strip >9 in (3) Data Basis C

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STATIC PROPERTIES (SHEET 2)

U.K.
D.T.D. 5003A, 5013A, 5023A
5033A, 5063, 5073
Titanium Alloy

Units: 10^3 lb./in.^{2} **Data Basis: A**

Footnotes	Form		Bars and Billets																	
	Specification		D.T.D. 5003A			D.T.D. 5013A														
	Condition		A			A														
	Thickness (in.)																			
	Cross-Sectional Area (in.^{2})																			
	f_1	L	62·7 – 89·6			<67·2														
		T																		
	t_1	L	40·3			29·1														
		T																		
	C_1	L																		
	C_2	L																		
		T																		
	C_5	L																		
	f_q																			
	f_b																			
	b_{10}																			
(1)	E		15,000 – 17,000																	
	E_c																			
	G																			
	e	%	18			20														
	Footnotes																			

(1) Data Basis: C

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FATIGUE PROPERTIES

U.K.
D.T.D. 5003A, 5013A, 5023A
5033A, 5063, 5073
Titanium

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Form and Condition	Stress Ratio	Cycles: Nominal Maximum Stress					
						10^5	10^6	10^7	10^8	
(1)	Rotating Bending	Plain	D.T.D.5003A	−1·0		45	41	39	39	
(1)		Notched K_t = 2·0		−1·0		33	22	21	21	
(1)		Notched K_t = 3·0		−1·0			21	18	18	
(1)		Notched K_t = 4·0		−1·0			19	16	16	
(2)	Repeated Axial Load	Plain	D.T.D5003A	−1·0				38	38	
(2)		Notched K_t = 2·0		−1·0				25	25	
(2)		Notched K_t = 3·3		−1·0				17	17	
	Footnotes									

(1) Static properties of material: f_t=85,000 lb/in.^{2}, t_t=58,000 lb/in.^{2}, e=30%
(2) Static properties of material: f_t=80,000 lb/in.^{2}, t_t=57,000 lb/in.^{2}, e=30%

GENERAL PROPERTIES

U.K.
D.T.D.5053,5143
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Mn	H	Fe								Ti
Bars & Billets	3·0 – 5·0	3·0 – 5·0	0·013 Max.	0·20 Max.								Remainder
Forgings	3·0 – 5·0	3·0 – 5·0	0·015 Max.	0·20 Max.								Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		4·51				
c	$cal./(gm.^\circ C)$			0·129	0·134	0·141	0·148
k	$cal.cm./(cm.^2 sec.^\circ C)$		0·017	0·020	0·024	0·025	0·027
$\alpha^{(1)}$	$per^\circ C \times 10^{-6}$			8·4	9·2	9·3	9·7
ϵ							

(1) Between 20°C and temperature indicated.

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App'd by	A.T	A.T	

STATIC PROPERTIES

(SHEET)

U.K.
D.T.D.5053,5143
Titanium Alloy

Units: 10^3 lb./in.^{2} **Data Basis:** A

Footnotes	Form		Bars and Billets			Forgings													
	Specification		D.T.D. 5053			D.T.D. 5143													
	Condition		H.T.			H.T.													
	Thickness (in.)																		
	Cross-Sectional Area (in.^{2})																		
	f_t	L	139			139													
		T																	
	f_l	L	128			128													
		T																	
	C_1																		
	C_2	L																	
		T																	
	C_5																		
(1)	f_c																		
	f_b																		
	b_{10}																		
(1)	E		16,000 – 19,000																
	E_c																		
	G																		
	e	%	12			12													
	Footnotes																		

(1) Data Basis: C

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.K. D.T.D.5053,5143 Titanium Alloy

Units: hours, °C., 10^3 lb./in.^{2} **Data Basis:** C

Form	Bar																										
Condition	Heat Treated																										
t →		0·5			0·5			0·5																			
T ↓	Per Cent f_1 (147 at 20°C.)			Per Cent f_1 (137 at 20°C.)			Per Cent E 16,800 at 20°C.																				
		(1)			(1)																						
100		89			85			97																			
200		80			75			93																			
300		78			70			87																			
400		63			51			80																			
500								70																			
600								59																			

(1) These are mean values for material from different manufactures, and with heat treatments varying between the wide limits specified in D.T.D. 5053. Typical properties may vary by as much as ±15% at high temperatures.

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET)

U.K.
D.T.D.5053, 5143
Titanium Alloy

Units: Hours, °C

Data Basis: C

CREEP DATA

Form		Bar																
Condition		H.T.																
t →			10	100	300	1000	2000											
T ↓	Total Deformation Per Cent	Per Cent f_t (f_t = 149,000 lb./in.^{2} at 22°C)																
22	0·05		80	76	74	73	73											
	0·1		83	80	78	77	76											
	0·2		84	81	80	79	78											
	0·5		85	82	81	80	79											
	1·0		86	84	83													
100	0·05		67	65	64	63	63											
	0·1		69	66	65	64	64											
	0·2		70	67	66	65	65											
	0·5		72	69	68	67	67											
	1·0			72	71	70	70											
200	0·05		56	55	55	55	55											
	0·1		58	57	57	57	57											
	0·2		60	59	59	59	59											
	0·5		63	63	63	62	62											
	1·0																	

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GENERAL PROPERTIES

U.K.
D.T.D. 5083, 5093
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Sn	Fe	H									Ti
Sheet	4·5 – 5·5	2·0 – 3·0	0·20 max.	0·015 max.									Remainder
Bars & Billets	4·5 – 5·5	2·0 – 3·0	0·20 max	0·013 max									Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		4·46				
c	$cal./(gm.°C)$		(1) 0·113	0·122	0·132	0·139	0·147
k	$cal.cm./(cm.^2 sec. °C)$		(1) 0·015	0·019	0·028	0·035	0·042
α	$per °C \times 10^{-6}$		(1) 7·8	8·7	10·3	10·9	10·3

(1) At 50°C

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STATIC PROPERTIES (SHEET 1)

U.K. D.T.D.5083, 5093 Titanium Alloy

Units: 10^3 lb./in.^{2}

Data Basis: A

| Footnotes | | |

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STATIC PROPERTIES (SHEET 2)

U.K. D.T.D.5083, 5093 Titanium Alloy

Units: 10^3 lb/in.^{2} Data Basis: A

Footnotes																				
	Form		Bars and Billets																	
	Specification		D.T.D. 5083																	
	Condition		H.T.																	
	Thickness																			
	Cross-Sectional Area																			
	f_t	L	112																	
		T	112																	
	f_l	L	101																	
		T	101																	
	C_1	L																		
	C_2	L																		
		T																		
	C_5	L																		
	f_a																			
	f_b																			
	b_{10}																			
(1)	E		15,000–18,000																	
	E_c																			
	G																			
	e	%	12																	
	Footnotes																			

(1) Data Basis: C

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.K. D.T.D.5083, 5093 Titanium Alloy

Units: Hours, °C, 10^3 lb./in.^{2} **Data Basis:** C

Form	Rod																											
Condition	H.T.																											
t →	0·5			0·5			0·5																					
T ↓	Per Cent f_t (134 at 20°C)			Per Cent f_1 (118 at 20°C)			Per Cent E (17,200 at 20°C)																					
100	84			83			91																					
200	69			65			83																					
300	60			52			76																					
400	56			46			71																					
500	53			42			69																					

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET 1)

U.K.
D.T.D. 5083, 5093
Titanium Alloy

Units: Hours, °C.

Data Basis: C

CREEP DATA

Form		Bar																	
Condition		H.T.																	
t →				100	300	1000	3000												
T ↓	Total Deformation Per Cent	Per Cent f_1 (f_1 = 134,000 lb./in.^{2} at 20°C																	
20	0·1			68	66	63	62												
	0·5			71	69	67	66												
100	0·1			51	50	49													
	0·5			54	53	52	52												
	1·0			58	57	56	55												
200	0·1			40	40	40	40												
	0·5			45	45	45	45												
	1·0			50	50	50	50												
300	0·1			38	38	38	38												
	0·5			41	41	41	41												
	1·0			44	44	44	44												
400	0·1			36	36	36	36												
	0·5			38	38	38	38												
	1·0			39	39	39	39												
500	0·1			17	13	9													
	0·5			23	19	16													

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PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE
(SHEET 2)

U.K.
D.T.D.5083,5093
Titanium Alloy

Units: Hours, °C.

Data Basis: C

MINIMUM CREEP RATE

Form														
Condition														
Creep Rate														
↓														

TIME TO TENSILE FAILURE

Form	Bar												
Condition	H.T.												
t →		0·1	0·3	1·0	3·0	10	30	100	300	1000	3000		
T ↓	Per Cent f_t (f_t = 134,000 lb/in² at 20°C)												
20		99	99	97	95	92	89	87	85	84	83		
100		84	81	79	78	76	75	74	73	72	72		
200		69	68	67	65	64	64	63	63	63	63		
300		60	58	58	58	58	57	57	57	57	57		
400		56	55	55	55	55	54	54	54	54			
500		53	51	50	48	45	40	33	29	26			

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UNITED STATES SECTION

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1. Introductory Notes
2. Charts as given in the table below

Magnesium Alloy	*Title of Chart*	*Issue No.*	*Date*
AZ31B	General Properties	1	July 1961
	Static Properties, Sheet 1	1	"
	Static Properties, Sheet 2	2	April 1962
	Fatigue Properties	1	July 1961
	Short Time Properties at Elevated Temperature	1	"
	Recovered Properties after Exposure to Elevated Temperature	1	August 1962
	Properties under Load and Elevated Temperature	1	"
AZ61A	General Properties	1	August 1962
	Static Properties	2	"
	Fatigue Properties	1	"
AZ63A	General Properties	1	July 1961
	Static Properties	2	April 1962
	Fatigue Properties	1	July 1961
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AZ80A	General Properties	1	July 1961
	Static Properties	1	"
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	Short Time Properties at Elevated Temperature	1	"
	Recovered Properties after Exposure to Elevated Temperature	1	August 1962
	Properties under Load and Elevated Temperature Sheet 1	1	"
	Properties under Load and Elevated Temperature Sheet 2	1	"
AZ91C	General Properties	1	July 1961
	Static Properties	2	April 1962
	Fatigue Properties	1	July 1961
	Short Time Properties at Elevated Temperature	1	"

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CONTENTS *Continued*

Magnesium Alloy	*Title of Chart*	*Issue No.*	*Date*
AZ92A	General Properties	1	July 1961
	Static Properties	2	April 1962
	Fatigue Properties	1	July 1961
	Short Time Properties at Elevated Temperature	1	"
	Recovered Properties after Exposure to Elevated Temperature	1	August 1962
HK31A	General Properties	1	July 1961
	Static Properties, Sheet 1	2	April 1962
	Static Properties, Sheet 2	2	"
	Fatigue Properties	1	July 1961
	Short Time Properties at Elevated Temperature	1	August 1962
	Recovered Properties after Exposure at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature	1	"
M1A	General Properties	1	July 1961
	Static Properties, Sheet 1	1	August 1962
	Static Properties, Sheet 2	2	"
	Fatigue Properties	1	"
ZK60A	General Properties	1	July 1961
	Static Properties	1	"
	Fatigue Properties	1	"
AM100A	General Properties	1	July 1961
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Nickel Alloy			
Inconel X	General Properties	1	July 1961
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	Properties under Load and Elevated Temperature, Sheet 2	1	"
Titanium Alloy			
Commercially pure titanium	General Properties	1	July 1961
	Static Properties, Sheet 1	1	August 1962
	Static Properties, Sheet 2	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature	1	"

Cont....

CONTENTS *Continued*

Titanium Alloy	*Title of Chart*	*Issue No.*	*Date*
8Mn	General Properties	1	July 1961
	Static Properties	1	August 1962
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
4Al-4Mn	General Properties	1	July 1961
	Static Properties	2	August 1962
	Fatigue Properties	1	"
	Short Time Properties at Elevated Temperature	1	"
	Properties under Load and Elevated Temperature	1	"
6Al-4V	General Properties	1	July 1961
	Static Properties, Sheet 1	1	"
	Static Properties, Sheet 2	1	"
	Short Time Properties at Elevated Temperature	1	August 1962
	Recovered Properties after Exposure at Elevated Temperature	1	"

August 1962

UNITED STATES SECTION

INTRODUCTORY NOTES

The *Introduction to Volume III* of this handbook explains the general layout adopted for the presentation of the data, together with details of the properties considered and the explanation of various terms. The purpose of the following notes is to amplify these points, where necessary, in relation to those United States materials which are included.

MAGNESIUM ALLOY DESIGNATIONS

The designations of the United States magnesium alloys are descriptive of the composition of the material. The designation consists of an initial group of letters indicating the main alloying elements, followed by numbers which signify the approximate average percentage content of each of these elements. A final letter is added to indicate any modification of the basic composition.

The elements indicated by the initial letters are as follows:

A - Aluminium	M - Manganese
H - Thorium	Z - Zinc
K - Zirconium	

Thus AZ91C is the third modification of a magnesium alloy containing 9 per cent aluminium and 1 per cent zinc, and AM100A is a magnesium alloy containing 10 per cent aluminium and less than 0.5 per cent manganese.

NICKEL ALLOY DESIGNATIONS

The commercial designations are used for the United States nickel alloys.

TITANIUM DESIGNATIONS

The designations used for the United States titanium alloys are simple descriptions of the approximate average percentages of the main alloying elements. E.g. 6Al-4V is a titanium alloy containing 6 per cent aluminium and 4 per cent vanadium.

The various grades of commercially pure titanium are designated in accordance with the percentage purity of the titanium e.g. 99Ti or 99+Ti, or alternatively in accordance with F_{ty} of the material in 10^3lb./in.^{2} e.g. Ti-70 has a yield strength of 70×10^3lb./in.^{2}

SPECIFICATIONS

As for all the National Sections, the specifications appropriate to the various forms and conditions of the alloys are indicated on the *Static Properties* charts wherever possible. The sources of these specifications are indicated below:-

MIL-M, MIL-N, MIL-T — These are Military Specifications approved by the Department of Defense for use by the Department of the Army, the Navy and the Airforce. Copies may be obtained from Commander, Wright-Patterson AFB, Ohio, Attn. EWBFE.

QQ-M, WW-T — These are Federal Government Specifications and copies may be obtained from the General Services Administration, Washington D.C.

AMS — These specifications are non-Government Specifications issued by S.A.E. and may be obtained from the Society of Automotive Engineers, 485 Lexington Avenue, New York 17, New York.

MATERIALS COVERED

This Section of the Handbook lists the available established data on several magnesium, nickel and titanium alloys produced in the United States. These alloys are those most widely used structurally in aircraft, neglecting as explained in the *Introduction to Volume III*, those alloys used solely for castings or for rivets, with the exception of magnesium castings.

Different forms of a particular alloy are usually covered by a different specification for each form. For this reason the alloys are listed below together with the more usual forms in which they are produced, and the specifications relevant to those forms.

MAGNESIUM ALLOYS

Designation	*Specifications*	*Form*
AZ31B	QQ-M-44; AMS4375; AMS4376; AMS4377	Sheet and plate[1]
	QQ-M-31	Extruded bars; rods; solid shapes & hollow shapes
	WW-T-825	Tubing
AZ61A	QQ-M-31; AMS4350	Extruded bars; rods; solid shapes & hollow shapes
	WW-T-825	Tubing
	QQ-M-40; AMS4358	Forgings

Cont....

Designation	*Specifications*	*Form*
AZ63A	QQ-M-56; AMS4420, AMS4422; AMS4424	Sand castings
	QQ-M-55; AMS4420; AMS4422; AMS4424	Permanent mold castings
AZ80A	QQ-M-31	Extruded bars; rods and solid shapes
	QQ-M-40	Forgings
	AMS4360	Die-forgings and hand forgings
AZ91C	QQ-M-56; AMS4437	Sand castings
	QQ-M-55; AMS4437	Permanent mold castings
AZ92A	QQ-M-56; AMS4434	Sand castings
	QQ-M-55; AMS4434	Permanent mold castings
HK31A	Mil-M-26075; AMS4384; AMS4385	Sheet and plate
	QQ-M-56; AMS4445	Sand castings
M1A	AMS4370	Sheet
	QQ-M-31	Extruded bars; rods; solid & hollow shapes
	WW-T-825	Tubing
	QQ-M-40	Forgings
ZK60A	QQ-M-31; AMS4352	Extruded bars; rods; solid & hollow shapes
	WW-T-825; AMS4352	Tubes
	QQ-M-40; AMS4362	Die forgings
	AMS4362	Hand forgings
AM100A	QQ-M-55; AMS4483	Permanent mold castings

Cont....

NICKEL ALLOY

Designation	*Specifications*	*Form*
Inconel X	MIL-N-7786; AMS5542	Sheet and strip
	AMS5667	Bars; forgings

TITANIUM ALLOYS

Commercially Pure	MIL-T-7993; AMS4900; AMS4901; AMS4902	Sheet; strip & plate
	MIL-T-9047 Class I; AMS4921	Bars; forgings & forging stock
	AMS4941	Welded tubing
8Mn	MIL-T-009046 Class I; AMS4908	Sheet and strip
4Al-4Mn	MIL-T-9047 Class 6; AMS4925	Bars; forgings & forging stock
6Al-4V	MIL-T-009046 Class 2; AMS4911 MIL-T-9047 Class 5; AMS4928	Sheet & strip Bars; forgings & forging stock

CHEMICAL COMPOSITION

The *General Properties* charts give the chemical composition by quoting the limits of the alloying elements as a percentage by weight of the total.

CONDITION

The 'Condition' row on the charts refers to the type of heat treatment and conditioning. The conditions of the various alloys are indicated on the charts by symbols which are defined briefly as follows:-

MAGNESIUM

F - As fabricated.

O - Annealed, recrystallized (wrought products only).

H - Strain hardened.

H1 plus one or more digits - Strain hardened only.

H2 plus one or more digits - Strain hardened and then partially annealed.

H3 plus one or more digits - Strain hardened and then stabilized.

W - Solution heat treated, unstable temper.

T - Treated to produce stable tempers other than F, O or H.

T2 - Annealed (cast products only).

T3 - Solution heat treated and then cold worked.

T4 - Solution heat treated.

T5 - Artificially aged only.

T6 - Solution heat treated and then artificially aged.

T7 - Solution heat treated and then stabilized.

T8 - Solution heat treated, cold worked and then artificially aged.

T9 - Solution heat treated, artificially aged and then cold worked.

T10 - Artificially aged and then cold worked.

NICKEL

Details of the heat treatments for Inconel X are given in the following table:

Condition / *Treatment*	*Fully heat treated (Full HT)*	*Precipitation heat treated*
Heated at:- for:-	2100 to 2125°F 2 to 4 hours	1900 to 2000°F 15 to 30 min.
Cooling:-	in air	oil or water quench
Heated at:- for:-	1525 to 1575°F 24 hours	1275 to 1325°F 20 to 30 hours
Cooling:-	rapidly in air to 1300°F maximum	
Heated at:- for:-	1275 to 1325°F 20 hours	
Cooling:-	in air	

TITANIUM

Annealing and heat treating temperatures and times for titanium and titanium alloys are given in the following table.

Material	*Commercially Pure*	*3Mn*	*4Al-4Mn*		*6Al-4V*	
Condition / *Treatment*	*Annealed (Ann.)*	*Annealed (Ann.)*	*Annealed (Ann.)*	*Aged*	*Annealed Sheet*	*Annealed Bar & Forgings*
Heated at:-	1000-1300°F	1300°F	1300°F	1440 to 1460°F	1300-1350°F	1275-1325°F
for:-	1 to 2 hours	1 hour	2 hours	1 to 2 hours	1 hour	2 hours
Cooling:-	in air	at 300°F per hour max.to 1050°F	at 300°F per hour max.	water quench	at 50°F per hour max.to 800°F	in air
Heated at:- for:-				900°F 8 hours		

NOTATION

The notation used in this Section of the Handbook for the various physical and mechanical properties of the U.S. alloys is defined in the *Notation* chart in the *Introduction to Volume III*. This chart also compares the notations used for the other National Sections. Points where any amplification is needed are dealt with under the appropriate headings below.

UNITS

The units used for the various parameters and properties are indicated on each of the charts. For mechanical properties the stresses and moduli are given in units of 10^3lb./in.^{2}, whilst temperature is quoted in degrees Fahrenheit. For conversion to other units see the *Conversion Scales* chart given in the *Introduction to Volume III*.

DATA BASIS

The *Introduction to Volume III* of this Handbook describes the use of the symbols 'A', 'B' and 'C' denoting the data basis of the values for the various properties given on the charts. Special aspects of this in relation to the values quoted for the U.S. alloys are outlined below.

A - This indicates that the values listed are the minimum to be expected for the given material. The only values considered 'guaranteed minimum' are those for F_{tu} and F_{ty} which are marked as data basis 'A' and which have been published by the material producer for the grain direction accepted for commercial guarantees. The remaining values marked as data basis 'A' are 'derived' values; that is, sufficient tests have been made to ascertain that if the material meets the 'A' value for F_{tu}, that material will have compressive, shear and bearing strengths equal to or exceeding the values listed.

B - Insufficient data are available on the U.S. magnesium, nickel and titanium alloys to quote any values to Data Basis 'B'.

C - This indicates that the values listed are typical for the material, there being insufficient data to determine values for Basis 'A' or 'B'.

In general the data basis used on any chart is shown at the top of the chart, but special attention must be paid to footnotes which sometimes indicate a different data basis for some particular part of the chart.

STATIC PROPERTIES CHARTS: WROUGHT ALLOYS

TENSILE AND COMPRESSIVE STRENGTHS

The symbol F_{ty} denotes the 0.2 per cent off-set yield stress in tension. In the United States this is generally termed the 'yield stress in tension'. Similarly, F_{cy} is the 0.2 per cent yield stress in compression or the 'yield stress in compression'.

The sub-headings 'L', 'LT' and 'ST' used with the tensile and compressive strengths on the *Static Properties* charts refer to the longitudinal, long transverse and short transverse directions respectively.

The form and dimensions of the specimens used to determine the tensile and compressive strengths are in accordance with the requirements of Federal Test Specification QQ-M-151a which may be obtained from the General Services Administration, Washington D.C. The yield strength is determined by the off-set or extension-under-load methods.

STRAIN RATES

Data on the Static Properties charts are based on strain rates of 0.003 to 0.007 inches per inch per minute where possible. Where data are used which were obtained at other strain rates it has been ascertained that the rate is sufficiently close to the 0.003 to 0.007 range for strain rate effects to be insignificant.

ELASTIC AND SHEAR MODULI

The sub-headings 'L' and 'T' used with the elastic moduli on the *Static Properties* charts refer to the longitudinal and transverse directions respectively: Although the values quoted for moduli are not strictly minimum values they may be regarded as Data Basis 'A' values unless otherwise indicated because they are very carefully chosen.

ELONGATION

The values of elongation given on the charts are quoted as the percentage elongation, at fracture, over a gauge length of 2 inches. The tests are made on the standard tension test specimen appropriate to the form and thickness of the material being tested as indicated in the Federal Specification QQ-M-151a. In general the elongation values are measured in the longitudinal direction. The values for the transverse direction may be appreciably less. Where values in both directions are known this is given on the charts.

The elongation values quoted on the *Static Properties* charts are all to Data Basis 'A'.

STATIC PROPERTIES CHARTS: CAST MAGNESIUM ALLOYS

Static properties are given for separately cast test specimens (Type of Test 'a'). The mechanical properties of production castings may be as low as 75 per cent of the tabulated values. Non-destructive and proof testing requirements for the acceptance of castings used in primary, secondary or non-structural applications are given in the specification Mil-C-6021D obtainable from:

Commander,
Wright Patterson A.F.B.,
Ohio,
Attn: EWBFE.

The allowable stresses used in design are left to the discretion of the designer.

Minimum and average tensile properties for specimens cut from castings are given in the appropriate material specifications.

The form and dimensions of the specimens used to determine the tensile strengths are in accordance with the requirements of Federal Test Specification QQ-M-151a.

FATIGUE PROPERTIES

The data given on the *Fatigue Properties* Charts cover tests in rotating bending, reversed flexure and repeated axial loading. A brief description of the various specimens tested together with the theoretical stress concentration factor in the case of notched specimens is given on the charts.

For rotating bending, the tests were carried out on R.R.Moore rotating-beam fatigue machines, using 0.30 inch diameter machined and polished specimens. Die-cast specimens were cast to shape.

For reversed flexure, the tests were carried out in Krouse constant-deflection type fatigue testing machines on 0.25 inch thick cast and forged specimens and 0.064 inch thick sheet specimens. Sand-cast specimens were machined; all other specimens received no special surface treatment.

The repeated axial load tests were made in Krouse direct tension-compression fatigue machines on 0.064 inch by 1 inch sheet specimens and 0.3 inch diameter machined and polished sand cast and extruded sections.

In all cases the 'Nominal Maximum Stress' quoted on the charts is the maximum stress across the critical section of the specimen determined at the maximum load of the fatigue cycle, without correction for stress concentration effects. The Stress Ratio quoted on the charts is the ratio minimum to maximum stress during the fatigue cycle with compressive stress being taken negative and tensile stress positive. It should be noted that there is always a wide scatter of results with tests of this type, and the values given on the charts represent mean lines through the scatter bands except for magnesium alloys where the upper and lower limits of scatter are given.

ELEVATED TEMPERATURE DATA

On these charts the data are presented as percentages of the appropriate room temperature values, which are indicated when known in brackets at the head of the column. The data have been obtained from uncoated specimens heated in air.

Except for details of the gripped portion, specimens used for the elevated temperature tests are similar in dimensions to those used for the corresponding room temperature tests.

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE: CREEP DATA

On these charts the data are presented in the form of the stress required, as a percentage of room temperature F_{tu}, to produce a given total deformation at a given temperature in a given time.

Total deformation is defined as the total strain at any given time, including initial strain but not including thermal expansion. This may be used to estimate the deformation or deflection of structural parts.

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GENERAL PROPERTIES

U.S.
AZ 31B
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Ca	Cu	Ni	Fe			Others	Mg
All Forms	2·5 – 3·5	0·7 – 1·3	0·20 Min	0·10 Max	0·04 Max	0·05 Max	0·005 Max	0·005 Max			0·30 Max	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition		Temperature °C 20	100	200	300	400
ω	$gm./cm.^3$	O		1·78	1·77	1·75	1·74	
c	$cal./(gm.°C)$	O		0·233	0·25	0·27	0·285	
K	$cal.cm./(cm^2\ sec.\ °C)$	O	(2)	0·19	0·21	0·24	0·26	
			(4)	0·20	0·22	0·25	0·26	
α (1)	$per\ °C \times 10^{-6}$	O	(2)	25·8	26·4	26·6	27·1	
			(3)	23·7	24·2	25·3	25·8	
			(4)	26·4	26·4	26·7	27·4	
ϵ (5)				0·12	0·13	0·15	0·16	

(1) Value between 20°C and temperature indicated. (2) Longitudinal direction
(3) Long transverse direction. (4) Short transverse direction.
(5) Polished surface.

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Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes	Form		Sheet and plate.																			
	Specification		QQ-M-44																			
			AMS 4375				AMS 4377					AMS 4376										
	Condition		O				H 24					H 26										
	Thickness (in.)		0.016 to 0.060	0.061 to 0.249	0.250 to 0.500	0.501 to 2.000	0.016 to 0.249	0.250 to 0.374	0.375 to 0.500	0.501 to 1.000	1.001 to 2.000	0.250 to 0.374	0.375 to 0.438	0.439 to 0.500	0.501 to 0.750	0.751 to 1.000	1.001 to 1.500	1.501 to 2.000				
	F_{tu}	L	32	32	32	30	39	38	37	36	34	39	38	38	37	37	35	35				
		LT					40	39	38	37	35	40	39	39	38	38	36	36				
		ST																				
	F_{ty}	L	18	15	15	15	29	26	24	22	20	27	26	26	25	23	22	21				
		LT					32	29	27	25	23	30	29	29	28	26	25	24				
		ST																				
	F_{cl}																					
(1)	F_{by}	L	12	12	10	10	24	20	16	13	10	22	21	18	17	16	15	14				
		LT																				
		ST																				
	F_{cs}																					
	F_{su}		17	17	17		18	18	18			18	18	18								
	F_{bru}	$e/D = 1.5$	50	50	50		58	56	54			58	56	56								
		$e/D = 2.0$	60	60	60		68	65	63			68	65	65								
	F_{bry}	$e/D = 1.5$	29	29	27		43	38	34			40	39	36								
		$e/D = 2.0$	29	29	27		43	38	34			40	39	36								
	E		6,500																			
	E_c		6,500																			
	G		2,400																			
(2)	e	%	12	12	12	10	6 8	8 10	8 10	8 10	8 10	6 8	6 8	6 8	6 8	6 8	6 8	6 8				
	Footnotes																					

(1) Long transverse F_{cy} allowables are equal to or greater than the longitudinal F_{cy} allowables.
(2) Where two figures are quoted, they refer to the Longitudinal and Long Transverse directions respectively

STATIC PROPERTIES (SHEET 1)

U.S. AZ 31B Magnesium Alloy

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STATIC PROPERTIES (SHEET 2)

U.S. AZ 31B Magnesium Alloy

Units: 10^3 lb./in.^{2}

Data Basis: A

Footnotes	Form		Extruded bars, Rod and Solid Shapes			Extruded Hollow Shapes		Extruded Tubes		
	Specification		QQ-M-31					WW-T-825		
	Condition		F							
	Thickness (in.)		≤0.249	0.250 to 1.499	1.500 to 2.499			0.028 to 0.250	0.251 to 0.750	
	Cross-Sectional Area (in.^{2})									
	F_{tu}	L	35	35	34	32		32	32	
		T								
	F_{ty}	L	21	22	22	16		16	16	
		T								
	F_{cu}									
	F_{cy}	L	12	12	10	10		10		
		T								
	F_{cs}									
	F_{su}		18	18	18					
	F_{bru}	(e/D=1.5)	36	36	36					
		(e/D=2.0)	45	45	45					
	F_{bry}	(e/D=1.5)	23	23	23					
		(e/D=2.0)	23	23	23					
	E		6,500							
	E_c		6,500							
	G		2,400							
	e	%	7	7	7	8		8	4	
	Footnotes									

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FATIGUE PROPERTIES

U.S. AZ 31B Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
						10^6	10^6	10^7	10^8	
					Nominal Maximum Stress					
	Rotating Bending	0·3ins. diameter. Machined and polished from extrusion.	F	-1·0		23 29	21 26	19 23	17 21	
	Reversed Flexure	As rolled sheet. 0·064ins. thick.	O	-1·0		18 22	15 17	14 16		
			H-24	-1·0		19 25	16 20	14 17		
	Repeated Axial Load	0·3ins. diameter. Machined and polished from extrusion.	F	0·25		23 28	22 25	20 24		
		As rolled sheet. 0·064ins. x 1·0ins.	O	0·25		20 24	19 22	18 21		
			H-24	0·25		22 27	20 24	19 23		
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.S. AZ 31 B Magnesium Alloy

Units: hrs., °F., 10^3 lb./in.^{2} Data Basis: C

Form	All Forms																					
Condition	H 24												O									
t →	0.5 1000		0.5 1000		≤1000		≤1000		≤1000				0.5 1000		0.5 1000		≤1000		0.5 1000		0.5 1000			
T ↓	Per Cent F_{tu}		Per Cent F_{ty}		Per Cent F_{cy}		Per Cent F_{su}		Per Cent F_{bry}		Per Cent E		Per Cent F_{tu} (38 at 78°F)		Per Cent F_{ty} (23 at 78°F)		Per Cent F_{cy} (17 at 78°F)		Per Cent F_{su} (17 at 78°F)		Per Cent F_{bry} [1] (31 at 78°F)		Per Cent E (6,600 at 78°F)	
100	98		96		98		98		99		98		97		96		100		99		97		98	
200	82		75		87		90		92		95		84		83		95		97		89		95	
300	54		44		72		76		73		81		58		59		82		91		71		91	
400	30		23		44		47		32		68		36		39		61		63		52		76	
500	19		13		23		31		22		53		22		22		39		38		33		64	
600	13		7		14		20		16		39		16		9		24		25		23		50	

(1) e/D = 1.5

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RECOVERED PROPERTIES AFTER EXPOSURE TO ELEVATED TEMPERATURE

U.S. AZ 31 B Magnesium Alloy

Units: hrs., °F., 10^3 lb./in.^{2} Data Basis: C

Form	Sheet					
Condition	H 24					
t →	16	1000	16	1000	16	1000
T ↓	Per Cent F_{tu} (41 at 78°F)		Per Cent F_{ty} (32 at 78°F)		Per Cent F_{cy} (24 at 78°F)	
100	100	100	100	100	100	100
200	100	100	101	101	100	100
300	98	98	98	95	97	88
400	91	91	84	81	79	75
500	90	90	76	76	73	72
600	88	88	73	73	71	71

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PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET 1)

U.S.
AZ 31B
Magnesium Alloy

Units: hrs., °F

Data Basis: C

CREEP DATA

Form	Sheet																
Condition	H 24																
t →	0.1	0.2	0.5	1.0	2.0	5.0	10	20	50	100	200	500	1000				
T ↓ / Total Deformation Per Cent	Per Cent F_{tu}																
300 / 2				45	38	31	27	25	24								
3					43	34	30	27	25								
4					46	36	32										
5					47	38	33	30									
400 / 2		29	25	23	20	16											
3		29	26	24	22	19	15										
4		29	27	25	23	20	17	13									
5		29	27	25	23	21	19	16									
500 / 2		18	16	14	12	8											
3			17	15	14	10	7										
4			18	16	15	12	9	6									
5				17	15	13	10	7									
600 / 2			7	6	5	3	2										
3			9	8	7	5	3	1									
4				9	7	6	4	2									
5				10	8	6	5	3	1								

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GENERAL PROPERTIES

U.S.
AZ 61 A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni	Fe				Others	Mg
Extrusions, Forgings	5·8 – 7·2	0·40 – 1·5	0·15 Min.	0·30 Max.	0·05 Max.	0·005 Max.	0·005 Max.				030 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·79				
c (1)	$cal./(gm.°C)$		0·25				
K	$cal.cm./(cm.^2\ sec.\ °C)$			0·19	0·19	0·19	
α (2)	$per\ °C \times 10^{-6}$			25			
ϵ							

(1) At 25°C
(2) Between 18°C and temperature indicated

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Iss. No	Date	App'd by

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STATIC PROPERTIES

(SHEET)

U.S. AZ61A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes	Form		Extruded bar, rod and solid shapes			Extruded hollowshapes		Extruded tubes		Forgings	
	Specification		QQ-M-31, AMS 4350					WW-T-825		QQ-M-40 AMS4358	
	Condition		F								
	Thickness (ins.)		≤ 0·249	0·250 2·499	2·500 4·499			0·028 0·750		< 6 (4)	
	Cross-Sectional Area ($in.^2$)				≤25						
	F_{tu}	L	38	39	3	36		36		38	
		T									
	F_{ty}	L	21	24	2	16		16		22	
		T									
	F_{cl}										
	F_{cy}	L	14	14		11		11		14	
	F_{c5}										
	F_{su}		19	19						19	
	F_{bru}	e/D = 1·5	45	45						50	
		e/D = 2·0	55	55						60	
	F_{bry}	e/D = 1·5	28	28						28	
		e/D = 2·0	32	32						32	
	E		6,300								
	E_c		6,300								
	G		2,400								
	e	%	8	9	5	7		7		5	
	Footnotes		(1)	(2)	(3)						

(1) AMS 4350 gives F_{ty} = 2
(2) AMS 4350 gives F_{tu} = 4
(3) AMS 4350 only.
(4) For hand forgings

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FATIGUE PROPERTIES

U.S. AZ61A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
						10^5	10^6	10^7	10^8	
					Nominal Maximum Stress					
	Rotating Bending	0.3 in. diameter machined from extrusions.	F	−1.0		24 – 30	22 – 27	20 – 25	18 – 23	
		0.3 in. diameter machined from forgings.		−1.0		24 – 28	21 – 25	19 – 23	17 – 22	
	Reversed Flexure	0.25 in. thick from extrusions	F	−1.0		17 – 19	12 – 15	11 – 14		
		0.25 in. thick from forgings Surface as forged.		−1.0		15 – 18	11 – 13	10 – 12		
	Repeated Axial Load	0.3 in diameter machined from extrusions.	F	0.25		23 – 26	19 – 22	18 – 20		
	Footnotes									

GENERAL PROPERTIES

U.S.
AZ63A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni					Others		Mg
Sand Castings	5·3 – 6·7	2·5 – 3·5	0·15 Min.	0·30 Max.	0·10 Max.	0·01 Max.					0·30 Max.		Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·82				
c	$cal./(gm.°C)$		0·25				
K	$cal.cm./(cm.^2\ sec.\ °C)$	F	0·141				
		T4	0·156				
		T5	0·125				
		T6	0·145				
α (1)	$per\ °C \times 10^{-6}$			25			
ϵ							

(1) Between 18°C and temperature indicated.

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App'd by	A.T	A.T	

STATIC PROPERTIES (SHEET)

U.S. AZ63A Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis: A**

Footnotes	Form	Sand and Permanent Mould Castings																
	Specification	QQ-M-55, QQ-M-56																
		AMS 4420			AMS 4422						AMS 4424							
	Condition	F			T4			T5			T6							
	Thickness (in.)																	
	Cross-Sectional Area																	
(1)	Type of Test	a			a			a			a							
	F_{tu}	24			34			24			34							
	F_{ty}	10			10			11			16							
	F_{cl}																	
	F_{cy}	10			10			11			16							
	F_{c5}																	
	F_{su}	16			17						19							
	F_{bru} $e/D=1.5$	36			36						50							
	F_{bru} $e/D=2.0$	50			50						65							
	F_{bry} $e/D=1.5$	28			32						36							
	F_{bry} $e/D=2.0$	30			36						45							
	E	6,500																
	E_c	6,500																
	G	2,400																
	e %	4			7			2			3							
	Footnotes																	

(1) Mechanical Properties are based the minimum guaranteed tensile properties from separately cast test bars. The Mechanical Properties of production castings may be as low as 75% of the tabulated values

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FATIGUE PROPERTIES

U.S. AZ63A Magnesium Alloy

Units: 10^3 lb/in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
						10^5	10^6	10^7	10^8	
					Nominal Maximum Stress					
	Rotating Bending	0·3 in. diameter sand cast specimens.	F	−1·0		15 – 18	12 – 15	10 – 13	9·5 – 12	
			T4	−1·0		18 – 23	16 – 21	14 – 19	13 – 17	
			T6	−1·0		17 – 20	15 – 18	12 – 16	11 – 15	
	Reversed Flexure	0·25 in. thick cast specimens	T4	−1·0		13 – 16	11 – 14	10 – 12		
	Repeated Axial Load	0·3 in diameter machined and polished from castings.	F	0·25		22 – 25	20 – 23	18 – 21		
			T4	0·25		23 – 27	21 – 24	18 – 21		
			T6	0·25		25 – 30	23 – 26	22 – 25		
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.S. AZ63A Magnesium Alloy

Units: hours, °F.

Data Basis: C

Form	Sand Casting									
Condition	T6									
t →	0.1	0.1	0.1	0.0	0.00	0.1	0.1	0.1	0.0	0.00
T ↓	Per Cent F_{tu}					Per Cent F_{ty}				
200	96	97	98	98	99	91	92	93	94	96
300	72	71	70	69	68	76	82	85	85	85
400	48	47	46	45	44	64	63	62	60	58

GENERAL PROPERTIES

U. S.
AZ 80 A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni	Fe				Others		Mg
All Forms	7·8 – 9·2	0·20 – 0·8	0·12 min.	0·30 max.	0·05 max.	0·005 max.	0·005 max.				0·30 max.		Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·80				
c	$cal./(gm.°C)$		0·25				
K	$cal.cm./(cm.^2\ sec.\ °C)$			0·182	0·182	0·182	
α (1)	$per\ °C \times 10^{-6}$			25·2			
ϵ							

(1) Between 18° and temperature indicated.

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STATIC PROPERTIES (SHEET)

U.S. AZ80A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes	Form		Extruded bars, rods and solid shapes.						Forgings		Die Forgings			Hand Forgings				
	Specification		QQ-M-31						QQ-M-40		AMS 4360							
	Condition		F			T5			F	T5	T5			T5				
	Thickness (in)		≤0.249	0.250 – 1.499	1.500 – 2.499	≤0.249	0.250 – 1.499	1.500 – 2.499			<2 OR <50	>2 <50	>2 >50	≤6				
	Weight of Forging lbs.																	
	F_{tu}	L	43	43	43	47	48	48	42	42	42	34	40	42				
		T										34						
	F_{ty}	L	28	28	28	30	33	33	26	28	30	22	26	28				
		T										22						
	F_{cl}																	
	F_{cy}			17	17		28	27	18	25								
	F_{cs}																	
	F_{su}		19	19	19	20	20	20	20	20								
	F_{bru}	e/D =1.5	48	48	48					50								
		e/D =2.0	56	56	56					70								
	F_{bry}	e/D =1.5	36	36	36					42								
		e/D =2.0	40	40	40													
	E		6,500															
	E_c		6,500															
	G		2,400															
	e	%	9	8	6	4	4	4	5	2	2	2	3	2				
	Footnotes											(1)	(2)					

(1) Minimum values of not less than 8 specimens cut from thick and thin sections, equal numbers of specimens to be tested in the longitudal and transverse directions.

(2) Average values of not less than 8 specimens, as in footnote (1)

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FATIGUE PROPERTIES

U.S. AZ80A

Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
					10^4	10^5	10^6	10^7	10^8	10^9
					Nominal Maximum Stress					
	Rotating Bending	0·3in. diameter specimen machined and polished from extrusion.	F	−1·0		25 – 30	23 – 28	21 – 26	20 – 24	
		0·3in. diameter specimens, machined and polished from forging.	F	−1·0		28 – 30	24 – 26	20 – 22	18 – 20	
			T4	−1·0			21 – 24	18 – 21	16 – 18	
			T5	−1·0		26 – 30	22 – 25	19 – 21	16 – 19	
			T6	−1·0		23 – 27	19 – 22	16 – 19	14 – 16	
	Reversed Flexure.	0·25in. thick from extrusion.	F	−1·0		19 – 21	13 – 16	12 – 14		
		0·25in. thick as forged.	T6	−1·0		16 – 20	13 – 16	12 – 15		
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.S. AZ 80 A Magnesium Alloy

Units: hours, °F.

Data Basis: C

Form	Forgings					
Condition	T 5					
t →	0.1	10	1000	0.1	10	1000
T ↓	per cent F_{tu}			per cent F_{ty}		
200	87	86	86	81	81	81
300	65	62	60	68	68	66
400	45	42	39	46	43	40

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App'd by	A.T.		

RECOVERED PROPERTIES AFTER EXPOSURE TO ELEVATED TEMPERATURE

U.S. AZ 80 A Magnesium Alloy

Units: hours, °F., 10^3 lb./in.^{2} Data Basis: C

Form	Extrusions					
Condition	T5					
t →	0.5	100	1000	0.5	100	1000
T ↓	per cent F_{tu} 57 at 78°F			per cent F_{ty} 40 at 78°F		
200	100	100	100	102	102	102
300	100	104	108	103	105	105
400	100	100	93	103	99	91
500	100	92	84	100	86	82
600	93	84	78	90	83	80
700	88	74	73	87	83	80

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET 1)

U.S. AZ 80 A Magnesium Alloy

Units: hours, °F.

Data Basis: C

CREEP DATA

Form		Forgings															
Condition		T 5															
t →		0·1	0·2	0·5	1·0	2·0	5·0	10	20	50	100	200	500	1000	2000	5000	10000
T ↓	Total Deformation Per Cent	per cent F_{tu}															
200	0·2	24	24	24	24	24	24	23	22	21	20	19	18	17			
	0·5	51	49	47	45	44	42	40	38	36	34	33	31	29			
	1·0										47	45	42	40			
300	0·2	22	22	21	20	19	17	15	13	10	8	5	2	1			
	0·5	42	40	36	34	30	27	24	21	18	15	12	9	6			
	1·0												14	12			

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PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE
(SHEET 2)

U. S.
AZ 80 A
Magnesium Alloy

Units: hours, °F. Data Basis: C

MINIMUM CREEP RATE

Form	Forgings													
Condition	T5													
Creep Rate			5×10^{-7}	10^{-6}	2×10^{-6}	5×10^{-6}	10^{-5}	2×10^{-5}						
T ↓	per cent F_{tu}													
200			24	28	33	38	42	46						
300				3	5	10	16							

TIME TO TENSILE FAILURE

Form	Forgings													
Condition	T5													
t →		100	200	500	1000	2000								
T ↓	per cent F_{tu}													
200				50	48	46								
300		24	23	22	21	20								

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App'd by		

GENERAL PROPERTIES

U.S.
AZ 91C
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni					Others		Mg
Sand Castings	8·1 – 9·3	0·4 – 1·0	0·13 Min.	0·30 Max.	0·10 Max.	0·01 Max.					0·30 Max.		Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·81				
c	$cal./(gm.°C)$		0·25				
K	$cal.cm./(cm.^2 sec. °C)$	F	0·129				
		T4	0·109				
		T6	0·134				
α (1)	$per °C \times 10^{-6}$			25			
ϵ							

(1) Value between 20 and 100°C.

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Iss. No	1	2	
Date	JULY '61	APRIL '62	
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STATIC PROPERTIES (SHEET)

U.S. AZ 91C Magnesium Alloy

Units: 10^3 lb/in.^{2}

Data Basis: A

Footnotes	Form	Sand and Permanent Mould Castings.																			
	Specification	QQ-M-55 QQ-M-56			AMS 4437																
	Condition	F	T4	T5	T6																
	Thickness (in.)																				
(1)	Type of Test	a	a	a	a																
	F_{tu}	18	34	20	34																
	F_{ty}	10	10	11	16																
	F_{cl}																				
	F_{cy}	10	10	11	16																
	F_{cs}																				
	F_{su}		17		19																
	F_{bru} $\%D=1.5$		36		50																
	F_{bru} $\%D=2.0$		50		65																
	F_{bry} $\%D=1.5$		32		36																
	F_{bry} $\%D=2.0$		36		45																
	E	6,500																			
	E_c	6,500																			
	G	2,400																			
	e %		7	2	3																
	Footnotes																				

(1) Mechanical Properties are based the minimum guaranteed tensile properties from separately cast test bars. The Mechanical Properties of production castings may be as low as 75% of the tabulated values

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Date	JULY '61		
App'd by	A.T		

FATIGUE PROPERTIES

U.S. AZ 91C Magnesium Alloy

Units: 10^3 lb/in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
						10^5	10^6	10^7	10^8	
					Nominal Maximum Stress					
	Rotating Bending	0·3in. diameter specimens, machined and polished from casting.	T 4	−1·0		17 – 22	15 – 19	13 – 17	12 – 15	
			T 6	−1·0		17 – 20	14 – 17	11 – 14	9·3 – 12	
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.S. AZ91C Magnesium Alloy

Units: hours, °F., 10^3 lb./in.^{2}

Data Basis: C

Form	Sand Castings																							
Condition	T4										T6													
t →	0·2		0·2								0·2		0·2											
T ↓	Per Cent F_{tu} 40 at 78°F		Per Cent F_{ty} 15 at 78°F		Per Cent F_{su} 22 at 78°F		Per Cent F_{bry} 37 at 78°F		Per Cent E and E_c		Per Cent F_{tu} 40 at 78°F		Per Cent F_{ty} 21 at 78°F		Per Cent F_{su} 235 at 78°F		Per Cent F_{bry} 52 at 78°F		Per Cent E and E_c					
100																			99					
200	85		93		102		103				92		91		105		92		94					
300	67		90								67		80						85					
400	50		85		70		86				50		68		67		65		70					
500																			55					
600											27		33						46					

GENERAL PROPERTIES

U.S.
AZ 92A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Mn	Si	Cu	Ni					Others		Mg
Castings	8·3 – 9·7	1·6 – 2·4	0·10 Min.	0·30 Max.	0·10 Max.	0·01 Max.					0·30 Max.		Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·82				
c (1)	$cal./(gm.°C)$		0·25				
K	$cal.cm./(cm.^2 sec. °C)$			0·161	0·161	0·161	
α (2)	$per °C \times 10^{-6}$			25			
ϵ							

(1) At 25°C. (2) Between 18°C and temperature indicated.

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Iss. No.	Date	App'd by

Iss. No	1	2	
Date	JULY '61	APRIL '62	
App'd by	AT	AT	

STATIC PROPERTIES (SHEET)

U.S. AZ92A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes																			
	Form	Sand and permanent mould castings																	
	Specification	QQ-M-56 QQ-M-55			AMS 4434														
	Condition	F	T4	T5	T6														
	Thickness (in.)																		
(1)	Type of Test	a	a	a	a														
	F_{tu}	20	34	20	34														
	F_{ty}	10	10	11	18														
	F_{cl}																		
	F_{cy}	10	10	11	18														
	F_{c5}																		
	F_{su}	16	17		20														
	F_{bru} $\%D=1.5$	32	48		52														
	F_{bru} $\%D=2.0$	42	58		70														
	F_{biy} $\%D=1.5$	30	32		45														
	F_{biy} $\%D=2.0$	40	40		55														
	E	6,500																	
	E_c	6,500																	
	G	2,400																	
	e %		6		1														
	Footnotes																		

(1) Mechanical Properties are based the minimum guaranteed tensile properties from separately cast test bars The Mechanical Properties of production castings may be as low as 75% of the tabulated values

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Date	JULY '61.		
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FATIGUE PROPERTIES

U.S. AZ92A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles: Nominal Maximum Stress					
						10^5	10^6	10^7	10^8	
	Rotating Bending	0·3in. diameter machined and polished from casting.	F	-1·0		16 – 18	14 – 16	13 – 15	12 – 14	
			T4	-1·0		16 – 20	14 – 18	13 – 17	12 – 15	
			T6	-1·0		16 – 21	14 – 19	12 – 17	11 – 15	
			T7	-1·0		18 – 20	16 – 17	14 – 15	13 – 14	
	Reversed Flexure.	0·25in. thick cast specimens.	T4	-1·0		13 – 17	10 – 13	8 – 10		
	Repeated Axial Load	0·3in. diameter machined and polished from casting.	F	0·25		23 – 25	22 – 24	21 – 23		
			T4	0·25			29 – 33	28 – 32		
			T6	0·25		29 – 32	27 – 30	26 – 29		
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET 1)

U.S. AZ92A Magnesium Alloy

Units: hours, °F.

Data Basis: C

Form	Castings					
Condition	T6					
t →	0.5	1000	0.5	1000		
T ↓	Per Cent F_{tu}		Per Cent F_{ty}		Per Cent E and E_c	
100	100	100	99	97	99	
200	98	97	91	78	94	
300	71	68	74	69	87	
400	46	41	52	47	72	
500	29		34		55	
600	20		22		46	

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RECOVERED PROPERTIES AFTER EXPOSURE TO ELEVATED TEMPERATURE

U.S. AZ92A Magnesium Alloy

Units: hours, °F.

Data Basis: C

Form	Castings																									
Condition	T6																									
t →	1000 VI		1000 VI																							
T ↓	Per Cent F_{tu}		Per Cent F_{ty}																							
100	100		98																							
200	100		95																							
300	98		94																							
400	97		92																							

GENERAL PROPERTIES

U.S.
HK31A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Th	Zr	Zn	Cu	Ni				Other Elements		Other Impurities Total	Mg
									Each	Total		
Sheet Plate	2·5 – 4·0	0·45 – 1·0							0·15 Max.	0·30 Max.		Remainder
Castings	2·5 – 4·0	0·5 – 1·0	0·30 Max.	0·10 Max.	0·01 Max.						0·20 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition		Temperature °C				
				20	100	200	300	400
ω	$gm./cm.^3$			1·79				
c	$cal./(gm.°C)$			0·25	0·25	0·26	0·28	0·30
K	$cal.cm./(cm.^2\ sec.\ °C)$	Sheet	0	0·252	0·265	0·283		
			H24	0·270	0·281	0·296		
		Casting	T6	0·219	0·240	0·260		
α (1)	$per\ °C \times 10^{-6}$					27		
ϵ								

(1) Value between 20 and 200°C.

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Iss. No.	1	2	
Date	JULY '61	APRIL '62	
App'd by	A.T.	A.T.	

STATIC PROPERTIES (SHEET 1)

U.S. HK31A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes	Form		Sheet and Plate																	
	Specification		Mil-M-26075 AMS 4384				AMS 4385 Mil-M-26075													
	Condition		O				H24													
	Thickness (in.)		0.016 0.250	0.251 0.500	0.501 1.000	1.001 3.000	0.016 0.125	0.126 0.250	0.251 0.500	0.501 1.000	1.001 2.000	2.001 3.000								
	F_{tu}	L	30	30	30	29	34	34	34	34	33	33								
(1)		LT																		
		ST																		
	F_{ty}	L	18	16	15	14	26	23	21	18	15	15								
(1)		LT																		
		ST																		
	F_{cl}																			
(1)	F_{cy}	LT	12	10	10	10	20	19	18	13	11	11								
		ST																		
	F_{cs}																			
	F_{su}		22	22	22		23	23	23	23										
	F_{bru}	$e/D=1.5$	43	43			49	49	49											
		$e/D=2.0$	51	51			57	57	57											
	F_{bry}	$e/D=1.5$	24	21			34	33	31											
		$e/D=2.0$	24	21			34	33	31											
	E		6,500																	
	E_c		6,500																	
	G		2,400																	
	e	%	12	12	12	12	4	4	4	10	10	8								
	Footnotes																			

(1) Transverse properties are equal to or greater than the longitudinal properties.

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App'd by	A.T	A.T	

STATIC PROPERTIES

(SHEET 2)

U.S. HK31A Magnesium Alloy

Units: 10^3 lb./in.^{2}

Data Basis: A

Footnotes																				
	Form	Sand Castings																		
	Specification	AMS4445 QQ-M-56																		
	Condition	T6																		
	Thickness (in)																			
	Cross-Sectional Area (in^2)																			
(1)	Type of Test	a																		
	F_{tu}	27																		
	F_{ty}	13																		
	F_{cl}																			
	F_{cy}	13																		
	F_{c5}																			
	F_{su}																			
	F_{bru} $\%D=1.5$																			
	F_{bru} $\%D=2.0$																			
	F_{bry} $\%D=1.5$																			
	F_{bry} $\%D=2.0$																			
	E	6,500																		
	E_c	6,500																		
	G	2,400																		
	e %	4																		
	Footnotes																			

(1) Mechanical Properties are based the minimum guaranteed tensile properties from separately cast test bars. The Mechanical Properties of production castings may be as low as 75% of the tabulated values

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App'd by	AT		

FATIGUE PROPERTIES

U.S. HK31A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
						10^5	10^6	10^7	10^8	
					Nominal Maximum Stress					
	Rotating, Bending.	0·3" dia. Machined and polished from sand casting.	T6	−1·0		15 – 18	12 – 14	10 – 12	9 – 11	
	Reversed Flexure	0·25in. thick, machined from casting.	T6	−1·0		16 – 20	10 – 12	8 – 10		
	Repeated Axial Load	0·064 in. thick by 1·0 in. sheet specimens.	H24	0·25		22 – 25	19 – 22	18 – 20		
	Footnotes									

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Date	AUG 62		
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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.S. HK31A Magnesium Alloy

Units: hours, °F. **Data Basis:** C

Form	Sheet and Plate												Sand Casting											
Condition	H24												T6											
t →	0.5	1000	0.5	1000	0.5								0.5	1000	0.5	1000								
T ↓	Per Cent F_{tu}		Per Cent F_{ty}		Per Cent F_{cy}		Per Cent F_{su}		Per Cent F_{bry} (1)		Per Cent E and E_c		Per Cent F_{tu}		Per Cent F_{ty}		Per Cent F_{cy}		Per Cent F_{su}		Per Cent F_{bry}		Per Cent E and E_c	
100	94	94	97	97	99		91		98		100		98	98	98	98							99	
200	76	76	86	86	96		79		88		98		92	92	94	94							97	
300	66	66	75	74	93		67		80		95		86	86	89	89							94	
400	61	52	69	59	88		50		71		89		81	81	83	83							92	
500	50	36	55	37	78		42		63		76		74	64	76	59							89	
600	32	26	25	22	41		35		49		58		63	32	66	16							85	

(1) $\%_D = 2.0$

Iss. No.	1		
Date	AUG '62		
App'd by	A.T.		

RECOVERED PROPERTIES AFTER EXPOSURE TO ELEVATED TEMPERATURE

U.S.
HK31A
Magnesium Alloy

Units: hours, °F

Data Basis: C

Form	All Forms								Sand Casting															
Condition	H24								T6															
t →	100		100	500	1000	100	500	1000	≤ 1000		≤ 1000													
T ↓	Per Cent F_{tu}		Per Cent F_{ty}			Per Cent F_{cy}			Per Cent F_{tu}		Per Cent F_{ty}													
300	100		100	100	100	100	100	100	100		100													
400	100		100	100	100	100	100	99	100		100													
500	94		100	100	99	97	91	85	99		99													
600	86		88	86	83	74	70	66	89		68													

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET)

U.S.
HK31A
Magnesium Alloy

Units: hours, °F

Data Basis: C

CREEP DATA

Form		Sand Casting															
Condition		T6															
t →		0·1	0·2	0·5	1	2	5	10	20	50	100	200	500	1000			
T ↓	Total Deformation Per Cent	Per Cent F_{tu} (F_{tu} = 33 x 10^3 lb./in.^{2} at 78°F)															
400	0·2	33	32	32	32	31	30	30	29	29	28	28	27	27			
	0·5	46	46	45	45	45	45	45	45	45	45	44	43	42			
	1·0	50	50	49	49	49	49	49	48	48	48	48	48	48			
500	0·2	32	32	31	30	29	27	26	24	22	19	18	15	13			
	0·5	44	44	43	42	41	39	37	35	32	29	27	23	20			
	1·0	49	49	48	48	47	45	44	42	39	36	35	29	22			
550	0·2	28	27	25	24	23	21	19	18	15	14	12	9·4	7·6			
	0·5	41	41	39	38	35	31	29	26	22	19	16	12	9·7			
	1·0																
600	0·2	22	21	20	19	17	15	14	12	10	8·5						
	0·5	37	36	34	31	29	25	21	19	14	10						
	1·0	45	43	40	38	34	29	26	22	17	13						
660	0·2	21	18	15	13	11	8·9	7·1	5·7	3·8	3·0						
	0·5	29	25	21	18	15	12	9·4	7·6	5·3	4·1						
	1·0																

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GENERAL PROPERTIES

U.S.
M1A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Mn	Si	Ca	Cu	Ni						Others Total		Mg
All Forms	1·2 Min.	0·30 Max.	0·14 Max.	0·05 Max.	0·01 Max.						0·30 Max.		Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·75				
c	$cal./(gm.°C)$		0·25				
K	$cal.cm./(cm.\ sec.\ °C)$			0·302	0·302	0·302	
α (1)	$per\ °C \times 10^{-6}$			25			
ϵ							

(1) Between 18°C and temperature indicated.

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STATIC PROPERTIES (SHEET 1)

U.S. M1A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

| Footnotes | | |

Iss. No.	1	2	
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App'd by	A.T	A.T.	

STATIC PROPERTIES (SHEET 2)

U.S. M1A Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis: A**

Footnotes	Form	Extruded bars, rod and solid shapes.			Extruded hollow shapes		Extruded tubes		Forgings										
	Specification	QQ-M-31					WW-T-825		QQ-M-40										
	Condition	F																	
	Thickness (in)	≤ 0·249	0·250 1·499	1·500 2·499			0·028 0·750												
	Cross-Sectional Area (in^2)																		
	F_{tu} L	30	32	32	28		28		30										
	F_{tu} T																		
	F_{ty} L	17	17	17			16		18										
	F_{ty} T																		
	F_{cl}																		
	F_{cy} L	8	8	8															
	F_{cy} T																		
	F_{c5}																		
	F_{su}	14	14	14					14										
	F_{bru} e/D=1·5	36	36	36					45										
	F_{bru} e/D=2·0	45	45	45					50										
	F_{bry} e/D=1·5	23	23	23					23										
	F_{bry} e/D	23	23	23					23										
	E	6,500																	
	E_c	6,500																	
	G	2,400																	
	e %	2	3	2	2		2		3										
	Footnotes																		

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FATIGUE PROPERTIES

U.S. M1A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
						10^5	10^6	10^7	10^8	
					Nominal Maximum Stress					
	Rotating Bending	0·3 in. dia. machined and polished from extrusion.	F	−1·0		15 – 18	12 – 16	11 – 14	10 – 13	
	Reversed Flexure	0·25 in. thick, surface as forged.	F	−1·0		12 – 14	8 – 10	5 – 7		
	Footnotes									

GENERAL PROPERTIES

U.S.
ZK60A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Zn	Zr	Mn						Other Elements Total	Other Impurities		Mg
										Each	Total	
Extrusions	4·8 – 6·2	0·45 Min.	0·15 Max.							0·05 Max.	0·20 Max.	Remainder
Forgings	4·8 – 6·2	0·45 Min.							0·30 Max			Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$		1·82				
c	$cal./(gm.°C)$		0·25				
K	$cal.cm./(cm.^2 sec. °C)$	F	0·281				
		T5	0·289				
α	$per °C \times 10^{-6}$		25 (1)				
ϵ							

(1) at 40°C.

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STATIC PROPERTIES (SHEET)

U.S. ZK60A Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis:** A

Footnotes	Form		Extruded rods, bars and solid shapes						Extruded hollow shapes		Extruded tubes		Die Forgings		Hand Forgings			
	Specification		QQ-M-31, AMS 4352								WW-T-825 AMS 4352		AMS 4362 QQ-M-40		AMS 4362			
	Condition		F			T5			F	T5	F	T5	T5		T5			
	Thickness (in.)										0.028 0.25		≤3.00		≤6			
	Cross-Sectional Area (in^2)		< 2.000	2.000 2.99	3.00 4.99	< 2.00	2.00 2.99	3.00 4.99	≤5									
	F_{tu}	L	43	43	43	45	45	45	40	46	40	46	42		38			
(2)		T																
	F_{ty}	L	31	31	31	36	36	36	28	38	28	38	26		20			
(2)		T																
	F_{cl}																	
	F_{cy}	L	27	26	25	30	28	25	20	26	20	26						
(1)		L				27	25.2	22.5										
	F_{c5}																	
	F_{su}		22	22	22	22	22	22										
	F_{bru}	$e/D=1.5$																
		$e/D=2.0$	70	70	70	71	71	71										
	F_{bry}	$e/D=1.5$																
		$e/D=2.0$	45	45	45	47	47	47										
	E		6,500															
	E_c		6,500															
	G		2,400															
	e	%	5	5	5	4	4	4	5	4	5	4	7		7			
	Footnotes																	

(1) For web sections of I beams and other extruded sections having width to thickness ratio of 20 to 1 or greater.

(2) The transverse properties for extruded ZK60A are lower than the longitudinal properties

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FATIGUE PROPERTIES

U.S. ZK60A Magnesium Alloy

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
						10^5	10^6	10^7	10^8	
					Nominal Maximum Stress					
	Rotating Bending	0·3 in. diameter, machined and polished from extrusion.	F	-1·0		29 – 32	26 – 29	23 – 26	20 – 23	
			T5	-1·0		26 – 35	21 – 29	18 – 26	17 – 23	
		0·3 in. dia., machined and polished from forging.		-1·0		22 – 25	18 – 21	17 – 20	16 – 18	
	Reversed Flexure	0·25 in. thick specimen from forging. (surface machined)	T5	-1·0		17 – 21	13 – 16	11 – 14		
	Repeated Axial Load	0·3 in. diameter, machined and polished from extrusion.	F	0·25		41 – 45	38 – 42	38 – 42		
			T5	0·25		42 – 48	41 – 45	40 – 44		
	Footnotes									

GENERAL PROPERTIES

U.S.
AM 100A
Magnesium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Zn	Si	Mn	Cu	Ni					Others	Mg
Castings	9·3 10·7	0·30 Max.	0·30 Max.	0·10 Min.	0·10 Max.	0·01 Max.					0·30 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100			
ω	$gm./cm.^3$		1·80				
c	$cal./(gm.°C)$						
K	$cal.cm./(cm.^2\ sec.\ °C)$						
α	$per\ °C \times 10^{-6}$						
ϵ							

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STATIC PROPERTIES (SHEET)

U.S. AM100A Magnesium Alloy

Units: 10^3 lb./in.^{2} **Data Basis:** A

Footnotes	Form	Permanent Mould Castings						
	Specification	QQ-M-55, AMS 4483						
	Condition	F	T4	T6			T6i	
	Thickness (in.)							
	Cross-Sectional Area (or weight)							
(1)	Type of Test	a	a	a			a	
	F_{tu}	20	32	34			34	
	F_{ty}	10	10	15			17	
	F_{cl}							
	F_{cy}	10	10	15			17	
	F_{c5}							
	F_{su}							
	F_{bru}							
	F_{bry}							
	E	6,500						
	E_c	6,500						
	G	2,400						
	e %		6	2				
	Footnotes							

(1) Mechanical Properties are based the minimum guaranteed tensile properties from separately cast test bars. The Mechanical Properties of production castings may be as low as 75% of the tabulated values.

GENERAL PROPERTIES

U.S.
Inconel X.
Nickel Alloy

CHEMICAL COMPOSITION (per cent)

Form	C	Mn	Si	S	Cr	Co	Ti	Cu	Al	Fe	Cb (Nb)		Ni and Co
All Forms	0·08 Max.	1·00 Max.	0·50 Max.	0·01 Max.	14·0 – 17·0	1·0 Max.	2·25 – 2·75	0·50 Max.	0·40 – 1·00	5·00 – 9·00	0·70 – 1·20		70·0 Min.

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	$gm./cm.^3$	Fully HT	8·25	8·20	8·11	8·04	7·94
c	$cal./(gm.^\circ C)$	Fully HT	0·103	0·116	0·124	0·133	0·157
K	$cal.cm./(cm.^2 sec.^\circ C)$	Fully HT	0·028	0·034	0·040	0·047	0·054
α	$per^\circ C \times 10^{-6}$	Fully HT	12·4	12·9	13·8	14·9	16·2
ϵ	per cent	Oxydised Surface	12	13	15	18	26
		As Received, Cleaned	9	11·5	14·5	18	22
		Polished.	6	8	11·5	16	19
		Total Hemispherical after 30min. Oxydisation at 2000°F			9	9	9

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STATIC PROPERTIES

(SHEET 1)

U.S. Inconel X Nickel Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes	Form		Sheet				Strip																		
	Specification		Mil-N-7786, AMS 5542				AMS 5542																		
	Condition		Precipitation heat treated.																						
	Thickness (in.)						< 0.010	0.010 0.024																	
	F_{tu}	L	155				150	155																	
		LT	155																						
		ST																							
	F_{ty}	L	100																						
		LT	100																						
		ST																							
	F_{cl}	L																							
	F_{cy}	L	105																						
		LT	105																						
		ST																							
	F_{c5}	L																							
	F_{su}		108																						
	F_{bru}	e/D=1.5																							
		e/D=2.0	286																						
	F_{bry}	e/D=1.5																							
		e/D=2.0	186																						
	E		31,000																						
	E_c																								
(1)	G		11,000																						
	e	%	20					15																	
	Footnotes																								

(1) Dynamic modulus. Data Basis: C

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STATIC PROPERTIES (SHEET 2)

U.S. Inconel X Nickel Alloy

Units: 10^3 lb./in.^{2} **Data Basis: A**

Footnotes	Form	Bar, Forgings		
	Specification	AMS 5667		
	Condition	Precipitation heat treated		
	Thickness (in.)	<4·0	≥4·0	
	Cross-Sectional Area (in.^{2})			
	F_{tu} L	165	165	
	F_{tu} T			
	F_{ty} L	105	100	
	F_{ty} T			
	F_{cl}			
	F_{cy} L			
	F_{cy} T			
	F_{c5}			
	F_{su}			
	F_{bru}			
	F_{bry}			
	E			
	E_c			
	G			
	e %	20	15	
	Footnotes	(1)	(1)	

(1) Gauge length = 4D. For specimens cut from near the centre of large disc forgings 'e' may be as low as 10%

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.S. Inconel X Nickel Alloy

Units: hours, °F., 10^3 lb./in.^{2} **Data Basis:** C

Form	Sheet																					
Condition	Precipitation heat treated												Fully heat treated						Hot rolled and aged					
t →	0.5 VI		0.5 VI		0.5 VI		0.5 VI		0.5 VI		0.5 VI		0.5 VI		0.5 VI				0.5 VI		0.5 VI			
T ↓	Per Cent F_{tu}		Per Cent F_{ty}		Per Cent F_{cy}		Per Cent F_{su}		Per Cent F_{bry}		Per Cent E and E_c		Per Cent F_{tu} 162 80°F		Per Cent F_{ty} 92 80°F				Per Cent F_{tu} 184 80°F		Per Cent F_{ty} 132 80°F			
600	96		93		88		90		97		89		95		96				96		95			
800	91		90		86		81		94		85		91		93				91		91			
1000	83		84		83		67		88		81		86		91				86		85			
1200	67		73		79		49		77		74		74		89				77		76			
1350	52		60						60		68		57		80									
1500	34		41								60		32		48									
1600	21		25										21		26									
1700													9		10									
1800													6		6									

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET)

U.S. Inconel X Nickel Alloy

Units: hours, °F

Data Basis: C

CREEP DATA

Form		Bar								Sheet							
Condition		Fully heat treated															
t →			–	10	100	1000					–	10	100	1000			
T ↓	Total Deformation Per Cent	Per cent F_{tu} (F_{tu} at R.T. = 162 x 10^3 lb./in.^{2})								Per cent F_{tu} (F_{tu} at R.T. = 160x10^3 lb./in.^{2})							
1200	0·2																
	0·5			49	44	40											
	1·0			51	46	41											
1350	0·2		27	26	23	20					24	19					
	0·5		33	32	28	22					33	27	19				
	1·0		38	34	29	23						29	21				
1500	0·2			17	14	9					16	11					
	0·5				16	10					18	14	7				
	1·0										19	16	9				
1600	0·2			8	6												
	0·5			8	6												
	1·0			9	6												

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PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE
(SHEET 2)

U.S.
Inconel X
Nickel Alloy

Units: hours, °F

Data Basis: C

MINIMUM CREEP RATE

Form														
Condition														
Creep Rate														
↓														

TIME TO TENSILE FAILURE

Form	Bar													
Condition	Fully heat treated													
t →	10^{-1}	1	10	10^2	10^3	10^4								
T ↓	Per Cent F_{tu} (F_{tu} at 80°F = 162 x 10^3 lb./in.^{2})													
1000			75	72	67	62								
1100			68	61	55	49								
1200			52	49	42	35								
1350		47	37	31	25	18								
1500	32	26	22	16	11	5								
1600		14	11	7	4	1								

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CHEMICAL COMPOSITION (per cent)

Form	C	N	O	H							Others Total	Ti
Sheet, Strip, Plate, Tubing.	0·20 Max.	0·07 (1) Max.		0·015 Max.							0·60 (2) Max.	Remainder
Bars, Forgings.	0·20 Max.	0·07 Max.	0·40 Max.	0·0125 Max.							0·80 Max.	Remainder

(1) Tubing only. (2) For AMS 4901 and Mil-T-7993 Cl. 1, 0·80 Max.

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	100	200	300	400
ω	$gm./cm.^3$	Ann.	4·54				
c	$cal./(gm.°C)$	Ann.	0·125	0·130	0·135	0·143	0·152
K	$cal.cm./(cm.^2 sec. °C)$	99+Ti Ann.	0·047	0·044	0·043	0·043	0·043
		99 Ti Ann.	0·041	0·041	0·041	0·041	0·041
α	$per °C \times 10^{-6}$	Ann.		8·73	9·36	9·54	9·72
ϵ							

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STATIC PROPERTIES (SHEET 1)

U.S. COMMERCIALLY PURE TITANIUM

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes	Form		Sheet, strip, plate.										Welded tubing								
	Specification		Mil-T-7993 (99+Ti)		Mil-T-7993 (99Ti)		AMS 4902 (Ti-40)		AMS 4900 (Ti-55)		AMS 4901 (Ti-70)		AMS 4941 (Ti-40)								
	Condition		Ann.																		
	Thickness (in.)																				
	F_{tu}	L	60		80		50		65		80		50								
		LT	60		80																
		ST																			
	F_{ty}	L	50		70		40		55		70		40								
		LT	50		70																
		ST																			
	F_{cl}																				
	F_{cy}	L	50		70																
		LT																			
		ST																			
	F_{cs}																				
	F_{su}		36		42																
	F_{bru}	e/D=1.5	99		120																
		e/D=2.0																			
	F_{bry}	e/D=1.5	82		101																
		e/D=2.0																			
	E		15,500																		
	E_c		16,000																		
	G																				
	e	%					20		18		15		20								
	Footnotes						(1)		(2)		(3)		(1)								

(1) F_{ty} max. = 65 (2) F_{ty} max. = 80 (3) F_{ty} max. = 95

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STATIC PROPERTIES (SHEET 2)

U.S. COMMERCIALLY PURE TITANIUM

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes																				
	Form		Bar, Forgings																	
	Specification		Mil-T-9047 Cl.1; AMS 4921 99 Ti; Ti-70																	
	Condition		Ann.																	
	Thickness (in.)		≤3																	
	Cross-Sectional Area (in.^{2})																			
	F_{tu}	L	80																	
		T	80																	
	F_{ty}	L	70																	
		T	70																	
	F_{cl}																			
	F_{cy}																			
	F_{c5}																			
	F_{su}																			
	F_{bru}																			
	F_{bry}																			
	E		15,500																	
	E_c																			
	G																			
	e	%	15																	
	Footnotes																			

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.S. Commercially Pure Titanium

Units: hours, °F, 10^3 lb./in.^{2} **Data Basis:** C

Form																								
Condition	Ann.												Cold Rolled											
t →	0.5	100	0.5	100	0.5	100	0.5	100	0.5	100			0.5	100	0.5	100	0.5	100	0.5	100	0.5	100		
T ↓	Per Cent F_{tu}		Per Cent F_{ty}		Per Cent F_{cy}		Per Cent F_{su}		Per Cent F_{bry}		Per Cent E (15400 at 60°F)		Per Cent F_{tu}		Per Cent F_{ty}		Per Cent F_{cy}		Per Cent F_{su}		Per Cent F_{bry}			
200	79	79	76	76	69	69	84	84	81	81	97		84	84	89	89	87	87	91	91	85	85		
300	66	66	59	59	54	54	73	73	67	67	93		73	73	81	81	78	78	84	84	75	75		
400	57	56	46	46	45	45	63	63	56	56	90		65	65	74	74	71	70	77	77	67	67		
500	50	48	37	37	45	45	56	56	48	48	85		59	59	67	67	66	62	71	71	60	60		
600	45	42	32	31	45	44	50	50	43	43	81		56	53	61	59	63	53	64	64	55	55		
700	40	37	28	26	44	40	46	45	40	40	77		52	43	54	45	59	39	55	55	52	40		
800	36	33	26	22	41	35	42	40	39	35	72		45	28	43	21	50	24	48	45	46	25		
900	33	29	23	19	36	32	37	34	34	30	68		34	18	30	15	36	19	41	37	39	18		
1000	30	26	20	16	30	29	31	27	26	25	64		16	12	15	12	20	17	36	33	24	16		

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE

(SHEET)

U.S. Commercially Pure Titanium

Units: hours, °F, 10^3 lb./in.^{2}

Data Basis: C

CREEP DATA

Form	Ti-70 Sheet
Condition	Ann.

T ↓	Total (1) Deformation Per Cent	t → 0.001	0.002	0.005	0.01	0.02	0.05	0.1	0.2	0.5	1	2	5	10
		Per Cent F_{tu} (90 at Room Temperature)												
600	2			35	34	33	33	33	33	33	33	33	32	
	3			42	36	35	34	34	34	34	34	34	33	
	5				38	36	36	35	35	35	34	34	34	
	7				42	39	37	36	36	36	36	36	35	
800	2				31	29	28	28	27	27	27	27	27	
	3									31	30	29	28	
	5										33	31	29	
	7													
1000	2				20	19	19	17	14	13	12	12	11	
	3				20	20	20	18	16	14	13	12	12	
	5				20	20	20	19	18	16	14	13	12	
	7					21	20	20	19	17	14	13	13	12
1200	2				9·7	8·5	7·2	5·2	4·3	3·9	3·6	3·4		
	3				10	9·3	8·5	7·0	5·6	4·6	3·9	3·6	3·4	
	5				10	9·9	9·4	8·3	6·5	5·3	4·2	3·8	3·5	
	7					10	9·8	8·9	7·6	6·0	4·7	4·0	3·7	3·4

(1) Including thermal expansion and elastic extension.

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App'd by	A.T.		

GENERAL PROPERTIES

U. S.
8 Mn
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Mn	C	O	N	H						Others		Ti
Sheet, Strip and Plate.	6·50 – 9·00	0·20 Max.	0·20 Max.	0·07 Max.	0·015 Max.						0·60 Max.		Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	$gm./cm.^3$		4·74				
c	$cal./(gm.°C)$		0·118	0·14	0·155	0·18	0·21
K	$cal.cm./(cm.^2 sec. °C)$		0·026	0·031	0·036	0·042	
α (1)	$per °C \times 10^{-6}$			9·1	10·1	11·2	12·4
ϵ							

(1) Between room temperature and temperature indicated.

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STATIC PROPERTIES (SHEET)

U.S. 8Mn Titanium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes																					
	Form		Sheet, Strip and Plate.																		
	Specification		Mil-T-009046 Cl.I, AMS 4908																		
	Condition		Ann																		
	Thickness (in.)																				
	F_{tu}	L	120																		
		LT	120																		
		ST																			
	F_{ty}	L	110																		
		LT	110																		
		ST																			
	F_{cl}																				
	F_{cy}	L	110																		
		LT	110																		
		ST																			
	F_{c5}																				
	F_{su}		84																		
	F_{bru}	$e/D=1.5$	170																		
		$e/D=2.0$																			
	F_{bry}	$e/D=1.5$	130																		
		$e/D=2.0$																			
	E		15,500																		
	E_c		16,000																		
	G																				
	e	%	10																		
	Footnotes																				

Iss. No.	1		
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FATIGUE PROPERTIES

U.S. 8Mn Titanium Alloy

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
						10^5	10^6	10^7		
					Nominal Maximum Stress					
	Repeated Axial Load	Smooth sheet	Ann.	0·25		85	85	85		
	Footnotes									

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.S. 8Mn Titanium Alloy

Units: hours, °F.

Data Basis: C

Form	Sheet, Strip, Plate.																							
Condition	Ann.																							
t →		1000 VI		1000 VI		1000 VI		1000 VI	0.5 VI	1000		1000 VI												
T ↓	Per Cent F_{tu}		Per Cent F_{ty}		Per Cent F_{cy}		Per Cent F_{su}		Per Cent F_{bry}		Per Cent E and E_c													
200		93		83		84		93	89			95												
300		87		73		74		88	81			91												
400		83		66		66		84	75			87												
500		79		62		62		79	71			84												
600		76		60		60		75	68			80												
700		71		56		56		71	64			76												
800		63		48		49		68	59			71												
900		50		36		38			50			60												
1000		30		22		22			33			38												

GENERAL PROPERTIES

U.S.
4Al-4Mn
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	Mn	Fe	O	C	N	H				Others		Ti
Bars and Forgings	3·0 – 5·0	3·0 – 5·0	0·5 Max.	0·20 Max.	0·15 Max.	0·07 Max.	0·0125 Max.				0·40 Max.		Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	$gm./cm.^3$		4·51				
c	$cal./(gm.°C)$		0·13	0·14	0·155	0·175	0·195
K	$cal.cm./(cm.^2\ sec.\ °C)$		0·0165	0·022	0·029	0·036	0·045
α (1)	$per\ °C \times 10^{-6}$			8·9	9·3	9·9	10·4
ϵ							

(1) Between room temperature and temperature indicated.

Iss. No.	1	A.T.
Date	JULY '61	
App'd by		

Iss. No.	1	2	
Date	JULY 61	AUG 62	
App'd by	AT	AT	

STATIC PROPERTIES (SHEET)

U.S. 4Al-4Mn Titanium Alloy

Units: 10^3 lb./in.^{2}

Data Basis: A

Footnotes		
	Form	Bar
	Specification	Mil-T-9047 Cl.6; AMS 4925
	Condition	Ann.
	Thickness (in.)	
	Diameter (in.)	≤3
	F_{tu} L	140
	F_{tu} T	
	F_{ty} L	130
	F_{ty} T	
	F_{cl}	
	F_{cy}	
	F_{c5}	
	F_{su}	
	F_{bru}	
	F_{bry}	
	E	15,500
	E_c	16,000
(1)	G	7,400
(2)	e %	12
	Footnotes	

(1) Data Basis: C (2) AMS 4925 gives e = 10%

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FATIGUE PROPERTIES

U.S. 4Al-4Mn Titanium Alloy.

Units: 10^3 lb./in.^{2} Data Basis: C

Footnotes	Test	Specimen	Condition	Stress Ratio	Cycles					
						10^5	10^6	10^7		
					Nominal		Maximum		Stress	
	Rotating Bending	Smooth Bar	Ann. (F_{tu}=158)	-1·0		108	101	101		
		Notched Bar K_t=3·9		-1·0		40	36	36		
		Smooth Bar	Aged (F_{tu}=172)	-1·0		112	108	108		
		Notched Bar K_t=3·9		-1·0		51	45	45		
	Reversed Flexure	Smooth Bar	Ann.	-1·0			86	86		
	Footnotes									

Iss. No.	1		
Date	AUG '62		
App'd by	A.T		

SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.S. 4Al-4Mn Titanium Alloy

Units: hours, °F., 10^3 lb./in.^{2} **Data Basis:** C

Form	Bar																															
Condition	Ann.																															
t →	0·5		0·5		0·5		0·5				0·5																					
T ↓	Per Cent F_{tu} (155 at R.T.)		Per Cent F_{ty} (144 at R.T.)		Per Cent F_{cy} (130 at R.T.)		Per Cent F_{su} (84 at R.T.)		Per Cent F_{bry}		Per Cent E (16,400 at R.T.)																					
200	90		88								96																					
300	86		81								93																					
400	81		75								90																					
500	77		71		74		80				87																					
600	74		67		72		76				83																					
700	71		63								80																					
800	66		57								77																					
900	57		47								74																					
1000	47		33								70																					

PROPERTIES UNDER LOAD AND ELEVATED TEMPERATURE
(SHEET)

U.S.
4Al–4Mn
Titanium Alloy

Units: hours, °F, 10^3 lb./in.^{2} Data Basis: C

MINIMUM CREEP RATE

Form														
Condition														
Creep Rate														
↓														

TIME TO TENSILE FAILURE

Form	Bar												
Condition	Ann.												
t →	0·1	1	10	100	1000								
T ↓	Per Cent F_{tu} (140 at R.T.)												
80	97		91	88·5	84								
200	86		84	81·5	73·6								
400	77·5		75	73·5	71								
600	71		68	66	61								
800	64·5		56·5	48·5	30								

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GENERAL PROPERTIES

U.S.
6Al – 4V
Titanium Alloy

CHEMICAL COMPOSITION (per cent)

Form	Al	V	Fe	O	C	N	H				Others	Ti
Sheet, Strip and Plate.	5·50 – 6·75	3·50 – 4·50	0·30 Max.	0·15 Max.	0·10 Max.	0·05 Max.	0·015 Max.				0·40 Max.	Remainder
Bars and Forgings.	5·50 – 6·75	3·50 – 4·50	0·30 Max.	0·15 Max.	0·10 Max.	0·05 Max.	0·0125 Max.				0·40 Max.	Remainder

PHYSICAL PROPERTIES

Property	Units	Condition	Temperature °C				
			20	200	400	600	800
ω	$gm./cm.^3$		4·43				
c	$cal./(gm.°C)$		0·135	0·135	0·138	0·143	0·153
K	$cal.cm./(cm.^2 sec. °C)$		0·0157	0·0165	0·0214	0·0248	0·0278
α (1)	$per °C \times 10^{-6}$			8·4	8·6	8·8	9·1
ϵ							

(1) Between room temperature and temperature indicated

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Iss. No.	1		
Date	JULY '61		
App'd by	AT		

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes			
	Form		Sheet, strip.
	Specification		AMS 4911, Mil-T-009046 Cl.2
	Condition		Ann.
	Thickness (in.)		≤ 0·187
	F_{tu}	L	130
		LT	130
		ST	
	F_{ty}	L	120
		LT	120
		ST	
	F_{cl}		
	F_{cy}	L	126
		LT	126
		ST	
	F_{c5}		
	F_{su}		76
	F_{bru}	(e/D=1·5)	191
		(e/D=2·0)	244
	F_{bry}	(e/D=1·5)	163
		(e/D=2·0)	198
	E	L	15,400
		T	16,400
	E_c	L	16,000
		T	16,900
	G		
	e	%	10
	Footnotes		

STATIC PROPERTIES

(SHEET 1)

U.S.
6Al-4V
Titanium Alloy

Iss. No	1		
Date	JULY '61		
App'd by	AT		

STATIC PROPERTIES (SHEET 2)

U.S. GAl-4V Titanium Alloy

Units: 10^3 lb./in.^{2} Data Basis: A

Footnotes			
	Form		Bar
	Specification		Mil-T-9047 Class 5, AMS 4928
	Condition		Ann.
	Thickness (in.)		≤ 1·5
	Cross-Sectional Area (in.^{2})		
	F_{tu}	L	130
		T	
	F_{ty}	L	120
		T	
	F_{cl}		
	F_{cy}	L	126
		T	
	F_{c5}		
	F_{su}		80
	F_{bru}	(e/D=1·5)	196
		(e/D=2·0)	248
	F_{bry}	(e/D=1·5)	174
		(e/D=2·0)	205
	E		16,000
	E_c		16,400
	G		6,200
	e %		10
	Footnotes		

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SHORT TIME PROPERTIES AT ELEVATED TEMPERATURE (SHEET)

U.S. 6Al-4V Titanium Alloy

Units: hours, °F

Data Basis: C

| Form | Sheet and Bar | | |

Iss. No.	1		
Date	AUG '62		
App'd by	AT		

RECOVERED PROPERTIES AFTER EXPOSURE TO ELEVATED TEMPERATURE

U.S. 6 Al - 4V Titanium Alloy

Units: hours, °F., 10^3 lb./in.^{2} Data Basis: C

Form	Sheet																											
Condition	Ann.																											
t →	100		100																									
T ↓	Per Cent F_{tu} 134 at R.T.		Per Cent F_{ty} 128 at R.T.																									
600	104		102																									
800	105		104																									
1000	104		105																									