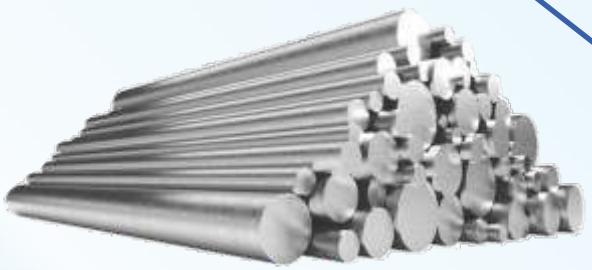


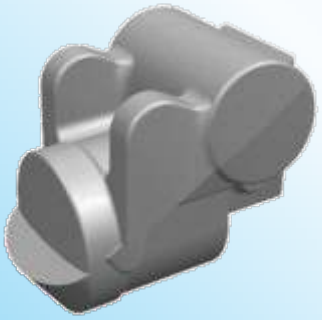
COMPENDIUM

ON

RATIONALISATION OF AVIATION METALLIC MATERIALS

VOLUME-I

FORGING STOCK



RCMA (F&F), CEMILAC
DRDO
Bengaluru

Foundry & Forge Division
Hindustan Aeronautics Ltd.
Bengaluru

COMPENDIUM

ON

RATIONALISATION OF AVIATION METALLIC MATERIALS

VOLUME - I

FORGING STOCK

MAY 2019

RCMA(F&F-FOL)
CEMILAC
Bengaluru

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FOREWORD

Materials, in specific Aviation Metallic Materials, take a huge share among different class of materials in the Military Aircraft, Aeroengines, Helicopters and Missiles. Over the century, Metallic Materials Development has evolved to the stage where we have plenty of Aerograde Alloys of Different country origins. Much time, with huge expenditure, has been devoted by many special alloy producers to the development of these alloys which provide higher mechanical properties and corrosion resistance often with low density for aircraft components. Most of the Aerograde Alloys of different country origins are essentially similar. These necessitate the best practices to be established in the materials rationalization.

There has been a remarkable growth, over the last decade, in the Civil and Defence Aerospace fields. Today, the Aerospace sector has become a major potential area for manufacturing activities in India. The Government's "Make in India" initiative has certainly gathered momentum with more and more Indian companies establishing themselves as trusted partners to global OEM's. The challenges that constrain the growth of Indian Aerospace industry include lack of indigenous raw material sources, which meet global Aerospace standards.

Hindustan Aeronautics Limited (HAL) is involved in developing various platforms of indigenous designs and also those manufactured through "Transfer of Technology (ToT)" involving both 'fixed wing' and 'rotary wing'. A large variety of Alloys in Aluminium, Steel, Titanium and Nickel are used in the manufacture, repair and overhaul of Helicopter, Aircraft and Aeroengines. Further, these material specifications originate from different countries and are in various shapes, forms and sizes.

In India, very few types of Aluminium alloys, Steel, Nickel and Titanium have been developed by DPSUs, Ordnance Factory and Private sectors with limited size, Mill forms and quantity. In spite of above, most of the materials required by HAL and other organisations are sourced from abroad. Whenever a material is imported from abroad to a particular specification, minimum order quantity, cost, obsolescence and superseded documents, delivery period are the key issues and at times this will delay the delivery of the end product which may further affect the programme.

With a view to break all the aforementioned barriers, it is thought appropriate, as a first step, to have a consolidation of the different material specifications with information on their chemistry, heat treatment and mechanical properties as a compilation of materials information of indigenous and imported materials in one place.

In this regard, Foundry & Forge Division with the support of various stakeholders like DGAQA, ADA, RCMAs and other HAL Divisions and approval of CEMILAC has brought out a Compendium of Forging Stock. This document acts as a ready-reckoner for all the Designers and Production assembly for the manufacturing of Forgings and Rolled rings towards the selection of Materials. Apart from aiding HAL in their indigenization mission, I foresee this book as an important information guide for the materials selection and usage at the Government and policy maker's level towards indigenization of materials.

I complement the entire team for their efforts in accomplishing this challenging and commendable task in a short notice.

P. Jayapal
OS & Chief Executive (Airworthiness)
CEMILAC
Bangalore

ABOUT THE BOOK

The Compendium on the Rationalization of Aviation Metallic Materials used in Aeronautical industry, initiated by Foundry & Forge Division, HAL(BC), in association with Regulatory Authorities is an important activity and a good step taken in the materials front. In the current scenario of HAL wherein HAL needs to support legacy products, extending support to these platforms is getting to be a challenge. In such a situation, material sourcing has become an uphill task because of the non-availability of older material specifications. This has a severe impact on the delivery schedules both in overhaul and during manufacturing of HAL products.

This compendium which is a compilation of equivalence of materials rationalized to known two to three specifications is expected to aid Designers, Methods Engineers and Materials Management Personnel in their struggle to look for alternate material specification. In this regard, I wish to thank CEMILAC for their active participation in reviewing the work done and approving the equivalence to enable effective usage of this compendium.

I foresee this compendium as an important source document to the Indian Defence and Aerospace Industries in their effort in indigenization of raw materials in the country apart from serving as an essential guide to all the stakeholders.

My hearty congratulations to the entire team.

Shekhar Shrivastava
CEO (BC)
HAL

PREFACE

Hindustan Aeronautics Limited (HAL) uses different Grades of Metallic Materials in Aircraft as well as Helicopter programme. These Materials are used in Aerostructures, Landing Gear, Power Plant etc. The Metallic Materials used are broadly classified as Aluminium / Magnesium and their Alloys, Steels, Titanium / Nickel and their Alloys and Copper and its Alloys. Further, these materials are also in various forms, such as Forgings, Bars, Rods, Extrusions, Sheets, Plates, Wires, etc.

HAL has been supporting India's Military Aerospace Programmes through indigenized development of Castings and Forgings of Western / Russian platform and also the Ab-initio projects. There are a number of Material Specifications for the same Grade of Material but of different Country origin /OEMs such as DIN (German), AIR (French), BS (British), AMS (American), MSRR (Rolls-Royce), GOST (Russian), EMS (Honeywell), CCT (Turbomeca), etc. These specifications do undergo periodic revisions and many have become obsolete over time, having been replaced with newer material specifications. The current aerospace raw material market is largely driven by AMS Specifications due to their versatility and adoption by leading global Aerospace majors.

Over the period, procuring of raw material of such diverse specifications is becoming difficult particularly when the quantities are not significant. Hence, the need was felt to bring out a Compendium of Rationalized Material Specification by grouping Materials based on their near equivalency with respect to chemistry and mechanical properties to facilitate steady flow of indigenization activity and also ensure effective supply chain management. The compilation will be useful to the Designers as well as Manufacturing Divisions as a ready-reckoner to select suitable equivalent specifications for overcoming material obsolescence and issues of small quantity requirements.

In this connection, a Task Force was constituted under the Chairmanship of Shri. P. Jayapal, CE-CEMILAC with Representatives of various Divisions of HAL, RCMA(F&F), RCMA(Materials), DGAQA(F&F) and M/s. ADA, Bangalore, as Members with a brief to take up the Grouping and Rationalization.

The consolidation effort has been divided into two categories.

Volume I: Forging Stock in Aluminium Alloys, Steels, Nickel and Titanium Alloys

Volume II: Other forms such as Bars, Rods, Extrusions, Sheets, Plates, Strips and Wires of Aluminium Alloys, Steels, Nickel, Titanium and Copper Alloys.

The scope of work involved:

a) Preparation of Consolidated List of Applicable Metallic Material Grades in the Form of Forging Stock, Forging, Bar, Rods, Extrusions, Sheets, Plates, Strips and wires.

b) Grouping material specifications based on their equivalence and compile chemical composition, heat treatment, hardness and mechanical properties.

c) Identify obsolete material specifications and indicate latest superseded material specification.

d) List out the Rationalized Material specifications for a particular material grade. The result of this effort has been this compendium, which would be used for determining near equivalent material specifications and substitute for obsolete raw material specifications.

Dr Shirish S Kale

RD, RCMA(F&F-FOL)

ACKNOWLEDGEMENTS

The task of preparation of Compendium on “Rationalization of Aviation Metallic Materials – Forging Stock” (Volume 1), in a short notice would not have been possible without active participation of the Members and encouragement from the Management of HAL and CEMILAC.

The team would like to express their sincere thanks to Mr. P. Jayapal, OS & Chief Executive (Airworthiness), CEMILAC, who has sown the seed and approved this source book.

I sincerely express my gratitude to Mr. Shekhar Shrivastava, Chief Executive Officer, HAL, Bangalore Complex, for motivating the team towards bringing out this publication. My wholehearted gratitude also goes to Mr. M.S. Venkatesh, General Manager (F&F), who was instrumental in driving the team and providing support and guidance for this vital compilation.

I express my profound thanks to Mr. Gantayata Gouda, OS & Associate Direction (Propulsion), CEMILAC, for his timely guidance during this period. My sincere thanks to Mr. B. Saha, RD, RCMA(Materials), Hyderabad and Dr Shirish S Kale, RD, RCMA(F&F-FOL), for their timely review of data and perusal of the manuscript for its authentication.

I also place on record my special thanks to Mr. V.P.Deepkumar, GD-Materials, ADA, Bangalore and Mr. P.V. Ananthanarayanan, PScO, ORDAQA, F&F Division, Bangalore.

I am thankful to Mr. V. N. Anil Kumar, AGM(F&F), Mr. V.Bhargava Reddy, DGM(D) and “Team Development” for their pains taking efforts in compiling the data to enable bringing out this edition of compendium.

At this juncture, I would also like to thank the contribution made by Authors from various organisations in a similar compilation earlier. This is incorporated as Addendum in this Compendium.

Last but not the least, I must place on record the efforts of our colleagues from various Divisions of HAL who worked as a team in bringing out this Source Book.

Dr R.Raghavendra Bhat

DGM(CMPL), F&F

RECOMMENDATION OF THE COMMITTEE

The committee constituted to bring out the Compendium on "Rationalization of Aviation Metallic Materials" used in various HAL programs has studied the various specifications. The committee comprised of all the stakeholders i.e., RCMA, DGAQA, ADA and Design and Manufacturing Centres of HAL. This compendium has been prepared based on the intense discussions with Regulatory Authorities, All the Work Centres and Design Liaison Groups, so as to ensure that no changes are made in the material that are already in use in legacy projects and content, but only identified near Equivalent Aeronautical grade materials that are currently available in market.

The compilation contains

a) Four alloy systems consisting of Aluminium alloys, Steels, Nickel alloys and Titanium alloys. Further these alloy systems are divided into Forging stock, bars, rods, extrusion, plates, wires etc.

b) All the materials under various forms and sizes are grouped into material grades with countries of different origin followed by comparison of Chemical Composition, Mechanical properties and Heat treatment condition.

c) A summary sheet that brings out the rationalization of the grade to one or more specifications which could be sourced easily in the industry.

d) Designers while selecting the material for designing of any items may consider this document so as to address any issues during the life cycle management of the project

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CATEGORISATION OF AVIATION METALLIC MATERIALS

Volume I : Forging stock in Aluminium Alloys, Steels, Nickel and Titanium Alloys

Volume II: Other forms such as Bars, Rods, Extrusions, Sheets, Plates, Strips and Wires of Aluminium Alloys, Steels, Nickel, Titanium and Copper Alloys.

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21	Mr. J. Rajeev	Asst. Sup. (Dev)-F&F	HAL	Co-opted Member
22	Mr. M. Veera Prasad	STA 'B‘	RCMA (F&F)	Co-opted Member

INDEX

1. INTRODUCTION

1.1 AIM OF RATIONALIZATION

Foundry And Forge Division, Hindustan Aeronautics Limited, manufactures Forgings in Aluminium, Iron, Nickel and Titanium base alloys for other HAL Divisions. F&F supports legacy projects such as Kiran, Jaguar, Dornier, Garrette, Adour, Dart, Avro, HS-748, etc., as also recent projects such as ALH, LCH, LUH, LCA, HTT-40 and IJT

As F&F Division is involved in supporting various platforms, it handles a variety of material specifications of different origins. Many of the specifications are similar in chemical composition and due to different origin, separate specification names are evolved. Also F&F Division due to variety of specifications and the requirement for quantum of parts being less in quantity, the Division faces the issue of substantially high MOQ while procuring the raw materials. Further, over the past years, some of the specifications have become obsolete and are no longer available in market.

Hence, the need for Rationalization of Metallic Materials has arisen. Rationalization of Metallic Materials will help to narrow down many different specifications to a few equivalent specifications and will help in easy procurability of materials.

1.2 APPROACH TO RATIONALISATION

The following approach has been adopted for rationalizing the material specifications:

- The list of material specifications used for manufacturing Forgings in Foundry and Forge Division has been taken from the current product range across all the projects.
- This List has been segregated into Four broad categories based on the Base Metal: Aluminium base, Iron base, Nickel base and Titanium base alloys.
- Further, these alloys have been arranged as per principal alloying elements and grouped under different sub-categories.
- AMS specifications and commonly available equivalent specifications are also added in the list to make it comprehensive.
- The Rationalized material has been chosen based on the near equivalent specification comparable with other grades in the same sub-group, ease of procurement and as far as possible avoiding the company specific specification (eg. MSRR-Rolls Royce, CCT-Turbomeca, etc) by rationalizing to AMS specifications, and including Indigenized materials wherever available.

- After grouping, rationalization data has been bifurcated into three headings / sections as shown below :

    1. First sheet is the summary sheet that contains the Identified specifications and rationalized specification

    2. Second sheet contains the Chemical composition

    3. Third sheet contains Heat treatment and Mechanical properties data

- Mechanical properties provided are as per material specification and wherever different values are specified against ranges of section thicknesses, properties pertaining to 50mm section thickness are mentioned in this book for reference

- Heat treatment cycle considered is for 50mm section thickness.

- Wherever, hardness values are specified in Material Specification as BHN, reported values shall be in HBW (Test to be done with Tungsten Carbide ball).

- Unless otherwise specified, Mechanical test properties are reported for Room Temperature.

1.3 CONDITIONS OF USAGE

The Rationalized material specifications provided in this compendium have to be used only if the following conditions are met :

- The forgings for which rationalized material specification to be used shall have respective Test Schedule.

- The properties of Forgings/Rings produced from Rationalized material shall meet the requirements specified in the respective Test Schedule.

- No separate Production Permit is required while using the Rationalized material specification provided in this book.

- Material specification other than specified in this book need to follow Production Permit route as per the prescribed procedure.

- Higher issues of the material specification issued at later stage are acceptable in lieu of previous / lower issues.

- **Heat treatment cycle and Mechanical properties are only for reference purpose**. Heat treatment to be followed and Mechanical properties are to be met as per respective Test Schedule.

- Incoming raw material shall be in wrought form only. If cast billets to be used, Test schedule made for such Forging / Ring shall specify the usage of cast billet as raw material.

- For Aluminium alloys, wrought forging stock upto ∅200mm shall have minimum working ratio of 4 and above ∅200mm working ratio shall not be less than 2.7.

- For cast forging stock, process sheet shall be prepared to obtain the required properties as per respective Test Schedule.

1.4 RATIONALISATION OF ALLOYS

1.4.1 Table 1 provides the Number of Alloys Identified and Number of Alloys Rationalized.

Table 1 : Summary of Alloys Rationalized

Sl. No.	Type of Base Alloy	No. of Alloys Identified	No. of Groups	No. of Rationalized Alloys
1	Aluminium Alloys	64	10	21
2	Ferrous Alloys	116	25	35
3	Nickel Alloys	61	10	17
4	Titanium Alloys	37	5	9
Total		**278**	**50**	**82**

1.4.2 Table 2 provides the Designation, Mill Form and Number of Rationalized Alloy Grades with respect to Identified Alloy Grades

Table 2 : Material Specifications and Their Rationalized Grades

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
ALUMINIUM ALLOYS						
2014						
1	ASTM B247/221	2014	BS L77/ AMS 4133/ HE 15A	2014/ 2014A	14	3
2	BS L77	-				
3	AMS 4133	2014				
4	AIR 3350	A-U4 SG				
5	AMS-QQ-A-367	2014				
6	AMS-QQA-200/2	2014				
7	BS EN 573-3	EN AW-2014				
8	BS EN 573-3	EN AW-2014A				
9	AIR 9051	A7-U4SG (2014F)				
10	IS: 734	24345 (HF15 Old)				
11	DIN 1747 3.1255	2014A				
12	MIL-A-22771 / AMS-A-22771	2014				
13	BS L 168	-				
14	HE15A (Indeginsed)	2014A				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
2618						
1	MSRR 8007	-	AMS 4132 / AIR 9051	2618 / AU2GN	10	2
2	AIR 9051	AU2GN				
3	MSRR 8018 (Superseded by RRMS 34001/2)	2618-F				
4	DTD-731 (Obsolete)	-				
5	BS EN 573-3	EN AW-2618A				
6	DTD-5014 (Obsolete)	-				
7	MIL-A-22771/ AMS-A-22771	2618				
8	ASTM -B-247/221	2618				
9	AMS 4132	2618				
10	AMS-QQ-A-367	2618				
2024						
1	AIR 9051	AU4G1	AMS 4152 / AMS-QQ-A-200/3	2024 / 2024	4	2
2	BS EN 573-3	EN AW-2024				
3	AMS 4152	2024				
4	AMS-QQ-A-200/3	2024				
2017						
1	AIR 9051	AU4G	AMS 4118 / AIR 9051	2017/ AU4G	3	2
2	BS EN 573-3	EN AW-2017A				
3	AMS 4118	2017				
2219						
1	AMS-QQ-A-367	2219	AMS-QQ-A-367/ AMS 4162	2219	5	2
2	ASTM B247/221	2219				
3	AMS 4162	2219				
4	AMS 4143	2219				
5	MIL-A-22771/ AMS-A-22771	2219				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
5083						
1	AIR 9051	AG4MC	AMS-QQ-A-367 / ASTM B247/221	5083 / 5083	4	2
2	AMS-QQ-A-367	5083				
3	BS EN 573-3	EN AW-5083				
4	ASTM B247/221	5083				
6061						
1	ASTM B247/221	6061	AMS 4127/ ASTM B247/ 221/ HE20A	6061/ 6061	7	3
2	AMS-QQ-A-367	6061				
3	BS EN 573-3	EN AW-6061				
4	IS 734	65032 (HF20 Old)				
5	MIL-A-22771/ AMS-A-22771	6061				
6	AMS 4127	6061				
7	HE20A (Indigenized)	6061				
7049						
1	ASTM B247/221	7049	AMS 4111/ AMS-QQ-A-367	7049	4	2
2	AMS-QQ-A-367	7049				
3	AMS 4111	7049				
4	MIL-A-22771/ AMS-A-22771	7049				
7050						
1	ASTM -B-247/221	7050	AMS 4333	7050	3	1
2	AMS 4333	7050				
3	MIL-A-22771/ AMS-A-22771	7050				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
7075						
1	ASTM B247/ 221	7075	AMS-QQ- A-367 / BS EN 573-3	7075/ EN AW-7075	10	2
2	AMS-QQ-A-367	7075				
3	BS EN 573-3	EN AW-7175				
4	MIL-A-22771/ AMS-A-22771	7075				
5	AMS -QQ-A-200/11	7075				
6	WL 3.4364	-				
7	AIR 9051	AZ5GU				
8	BS EN 573-3	EN AW-7075				
9	ASTM -B-247	7175				
10	MIL-A-22771/ AMS-A-22771	7175				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
STEEL						
SAE 9310						
1	AMS 6260	SAE 9310	AMS 6265	SAE 9310	3	1
2	AMS 6265	SAE 9310				
3	EMS 56280	SAE 9310				
JETHETE M152						
1	AIR 9160	Z12CNDV12	AMS 5719/ AIR 9160	Z12CN DV12	9	2
2	MSRR 6503 (Made from MSRR 6916)	-				
3	RRMS 32007/1 (Made from RRMS 32007)	-				
4	CCT-00115	Z12CNDV12				
5	BS S151	-				
6	AMS 5719	-				
7	MSRR 6509	-				
8	CCT-00321	EZ12CNDV12				
9	MSRR 6510	-				
FV 448						
1	MSRR 6596 (Made from 6919)	-	MSRR 6596 (MSRR 6919-Forging stock)	FV 448	2	1
2	BS S 150					
3	TU14-1-1161-75	15KH12N2MB-FAB-SH AP 517				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
12NC12						
1	MSRR 6004	-	BS S15	-	3	1
2	BS S15	-				
3	AIR 9160	12NC12				
16NCD13						
1	MSRR 6061	-	AMS 6549/ E16CD13 (Indigenised)	-	9	2
2	BSEM 545 (Replaced by MSRR 6051 and obsolete)	-				
3	AIR 9160	16NCD13				
4	MSRR 6051	-				
5	BS S157	-				
6	AMS 6549	-				
7	CCT-00264	16NCD13				
8	CCT-00140	E16NCD13				
9	E16NCD13 (Indigenised)	-				
15CDV6						
1	WL 1.7734	-	AIR-9160	E15CDV6	7	1
2	CCT-00067	15CDV6				
3	CCT LA 189	E15CDV6				
4	AIR-9160	15CDV6/ E15CDV6				
5	TU14-4-950-86	30KHGSA				
6	TU14-4-950-86	30KHGSA-SH				
7	TU14-1-1885-76	30KHGSA-VD				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
SAE 4340						
1	AMS 6414	SAE 4340	AMS 6414	SAE 4340	3	1
2	MIL S 5000	E4340				
3	AMS 6415	SAE 4340				
Maraging Steel 250						
1	MIL-S-46850	TY IV, Grade 250	AMS 6512/ MIL-S-46850 / MDN 250A	TY IV, GRADE 250	5	3
2	AMS 6512	-				
3	DTD 5212	-				
4	MLA 101	-				
5	MDN 250A (Indigenised)	-				
NCM Steel						
1	MSRR 6009	-	AMS 6264	-	5	1
2	MSRR 6010/ (MSRR 6010 SUPERSEDED TO RRMS 31014/1)	-				
3	RRMS 31014/ RRMS 31014/1	-				
4	MSRR 6094	-				
5	AMS 6264	-				
Z30C13 Steel						
1	MSRR 6602	-	AMS 5655	-	3	1
2	AIR 9160	Z30C13				
3	AMS 5655	-				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
	35CD4 Steel					
1	AIR-9160	35CD4	AMS 6348	Forging Stock	3	1
2	AMS 6348	-				
3	CCT-00308	35CD4				
	CMV Steel					
1	MSRR 6012 (Made from MSRR 6911)	-	BS S132/ MDN 132A (Indigenised)	-	5	2
2	MSRR 6011 (Made from MSRR 6910)	-				
3	MSRR 6100	-				
4	BS S 132	-				
5	MDN 132A (Indigenised)	-				
	Ni-Cr-Mo Steel					
1	BS S95	-	BS S95	-	3	1
2	MSRR 6017	-				
3	MSRR 6036 (Obselete) MSRR 6017 IS ALTERNATE TO MSRR 6036)	-				
	4130 Steel					
1	MIL-S-6758 (Obselete. Superceded by AMS-S-6758)	4130	AMS-S-6758/ MDN6758A	4130	6	2
2	AMS-S-6758	4130				
3	AIR-9160C	25CD4S				
4	BS S142	-				
5	AMS 6370	4130				
6	MDN6758A (Indigenised)	-				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
2.5%Ni-Cr-Mo Steel						
1	BS S99	-	BS S 99/ MDN 99A	-	6	2
2	BS S98	-				
3	BS S154	-				
4	BS S96 (Obselete. Replaced by S154)	-				
5	BS S97	-				
6	MDN 99A	-				
18/8 Steel						
1	AMS 5645	SAE 30321	AMS 5645/ MDN 347A	SAE 30321	8	2
2	DIN 17440	X10CrNiTi 189 1.4541				
3	BS S129	-				
4	BS 2S 130	-				
5	AIR 9160	Z10CNT18 -11				
6	MSRR 6522	18/8				
7	MDN 347A	-				
8	G-5632-72 G-5949-75 TU14-1-378-72 G-8060-78	12KH18N10T KH18N10T				
18/9 Steel						
1	MDN 321A	-	AMS 5646/MDN 321A	SAE 30347	2	1
2	AMS 5646	SAE 30347				
17-4 PH Steel						
1	AMS 5643	17-4 PH	AMS 5622/ MDN 174A	17-4 PH	3	2
2	AMS 5622	17-4 PH				
3	MDN 174A (Indigenised)	17-4 PH				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
SAE 51431 Steel						
1	BS S 80	-	AMS 5628/ MDN 431A	SAE 51431	8	2
2	MSRR 6573	-				
3	AIR 9160	Z15CN17-03				
4	AMS 5628	SAE 51431				
5	DIN 17440	X22CrNi17 1.4057				
6	MIL-S-18732	431				
7	MDN 431A	-				
8	CCT-00343	Z15CN17-03				
Nitriding Steel						
1	BS 4S 106	-	AIR 9160	30CD12	6	1
2	AIR 9160	30CD12				
3	MSRR 6001/ (MSRR 6001 SUPERSEDED TO RRMS 31018/1)	-				
4	CCT LA 239	30CD12				
5	MSRR 6002/ (MSRR 6002 SUPERSEDED TO RRMS 31018/2)	-				
6	RRMS 31018 (Forging stock specification)	RRMS 31018/1 RRMS 31018/2				
Case Hardening Steel						
1	AIR 9160	16NCD17	BS S82	-	3	1
2	BS S82	-				
3	MSRR 6009	-				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
15 Cr- 25 Ni Steel						
1	AMS 5731	-	AMS 5737	-	4	1
2	AMS 5732	-				
3	AMS 5734	-				
4	AMS 5737	-				
Cr-Mo Steel						
1	AIR 9160	Z12CN13	AMS 5613	SAE 51410	3	1
2	CCT-0037	Z12CN13				
3	AMS 5613	SAE 51410				
Cr-Mo Steel						
1	ZFNL 9201	-	MDN 9201A	-	2	1
2	MDN 9201A (Indigenised)	-				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
NICKEL ALLOYS						
NIMONIC 263						
1	MSRR 7035 [superseded by RRMS 33031, RRMS 33031/1, RRMS 33030/2, RRMS 33030/3, RRMS 33030/4]	-	AMS 5886 / BS 2HR10 / SUPERNI 263A	-	7	3
2	MSRR 7038 [superseded by RRMS 33045, RRMS 33045/1, RRMS 33045/2, RRMS 33045/3, RRMS 33045/4]	-				
3	BS HR 10	-				
4	AIR 9165	NCK20D				
5	AMS 5886	-				
6	GTM SU 263 (Indigenized)	-				
7	SUPERNI 263A (Indiginized)	-				
INCONEL 625						
1	AMS 5666	-	AMS 5666	-	4	1
2	CCT LA 398	NC22D Nb				
3	ASTM B 564	UNS N06625				
4	BS EN 10095	NiCr22Mo9Nb Alloy no. 2.4856				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
Inconel 718 (Special Grade)						
1	MSRR 7202	Special grade Inco 718	MSRR 7202	Special grade Inco 718	2	1
2	EMS 55476 (supersedes EMS 55458)	Delta Processed (DP) 718				
Inconel 718						
1	AMS 5662	-	AMS 5662 / SUPERNI 718A	-	8	2
2	AMS 5663	-				
3	AMS 5664	-				
4	AIR 9165	NC19FeNb				
5	MSRR 7115	-				
6	GTM Su-718 (Indigenized)	-				
7	SUPERNI 718A (Indigenized)	-				
8	TU14-1-3905-85	KHN45MV TYUBR EP718				
NIMONIC 75						
1	RRMS 33030 & RRMS 33030/1 [supersedes MSRR 7004]	-	BS 2HR 5 / SUPERNI 75A	-	6	2
2	MSRR 7008 [superseded by RRMS 33030 & RRMS 33030/2]	-				
3	BS HR 5	-				
4	BS HR 504	-				
5	AIR 9165	NC 20T				
6	SuperNi 75A / MDN 75 (Indigenized)	-				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
NIMONIC 80A						
1	MSRR 7009	-	BS HR1	-	7	1
2	MSRR 7010 (cancelled)	-				
3	MSRR 7011	-				
4	MSRR 7012	-				
5	BS HR1	-				
6	BS HR 601 (supersedes MSRR 7013)	-				
7	AIR 9165	NC 20 TA				
NIMONIC 90/93						
1	MSRR 7137	-	AIR 9165 / BS HR2	NCK20 TA	8	2
2	MSRR 7135	-				
3	MSRR 7129	-				
4	MSRR 7016	-				
5	BS HR 2	-				
6	AIR 9165	NCK 20 TA				
7	BSEM 561	-				
8	BACE 417 / BACE 423	-				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
NIMONIC 105						
1	MSRR 7017	-	BS HR 3	-	6	1
2	MSRR 7018	-				
3	MSRR 7134	-				
4	BS HR 3	-				
5	DTD 5007 (obsolete)	-				
6	AIR 9165	NK 20 CDA				
NIMONIC 115 [For Turbine Blade Blanks]						
1	MSRR 7023	-	BS HR4/ SuperNi115	-	5	2
2	MSRR 7022	-				
3	BS HR 4	-				
4	DTD 5017 (Obsolete)					
5	SuperNi115 (Indigenized)	-				
WASPALLOY						
1	MSRR 7192	-	AMS 5707/ EMS 55388	-	8	2
2	AIR 9165	NC20 K14				
3	AMS 5704	-				
4	AMS 5706	-				
5	AMS 5707	-				
6	AMS 5708	-				
7	AMS 5709	-				
8	EMS 55388	-				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
TITANIUM ALLOYS						
Ti64						
1	MSRR 8614	-	AMS 4928 / TITAN 31A	-	15	2
2	AMS 4928	-				
3	CCT 00166	TA6V.PQ				
4	GTM Ti-64 (Indigenized)	-				
5	AIR9183	TA6V				
6	CCT LA109	TA6V				
7	BS TA12 (Obsolete) - superseded by BS EN 3310	-				
8	BS TA13 (Obsolete) - superseded by BS EN 3312	-				
9	TITAN 31A (Indigenized)	-				
10	AMS-T-9047 / MIL-T-9047 6Al-4V (obsolete) - superseded by AMS 6931	-				
11	ASTM B 348	Grade 5, UNS R56400				
12	ASTM B 381	Grade F5, UNS R56400				
13	EMS 54930	-				
14	3.7164	-				
15	OST1 90013-81 / OST1 90173-75 / AMTY 451	BT6 / VT6				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
TA6ZrD						
1	CCT 00202	TA6ZrD	TITAN 26A	-	6	1
2	MSRR 8616	-				
3	BS TA 43 (withdrawn)	-				
4	BS TA 44 (withdrawn)	-				
5	GTM Ti-685 (Indigenized)	-				
6	TITAN 26A (Indigenized)	-				
TA8DV						
1	CCT LA 114	TA8DV	AMS 4972 / TITAN 22A	-	6	2
2	AMS 4972	-				
3	AMS 4933	-				
4	AMS-T-9047 / MIL-T-9047 (8Al-1Mo-1V) [obsolete] - superseded by AMS 6910	-				
5	AMS 4973					
6	TITAN 22A (Indigenized)	-				
Ti-6-2-4-2 / Ti6242S						
1	EMS 54929	-	AMS 4976 / EMS 54929	-	4	2
2	AMS 4976	-				
3	AMS 4975	-				
4	AMS-T-9047 / MIL-T-9047 [6Al-2Sn-4Zr-2Mo] (obsolete)- superseded by AMS 6905	-				

Sl. No.	Material Specification	Grade	Rationalized Material Specification	Grade	No. of Alloy Grades	
					Identified	Rationalized
Ti-6-6-2						
1	TA6V6E2	-	AMS 4979 / AMS 4971	-	6	2
2	AMS-T-9047 / MIL-T-9047 [6Al-6V-2Sn] (obsolete)- superseded by AMS 6935	-				
3	AMS 4971	-				
4	AMS 4979	-				
5	AMS-T-9047 / MIL-T-9047 [6Al-6V-2Sn] (obsolete)- superseded by AMS 6936	-				
6	AMS 4978	-				

2. LITERATURE

2.1 ALUMINIUM ALLOYS

Aluminum Alloys are used extensively because of the following benefits:

- Aluminum is a light metal, and is about one third of the density of Steel, Copper and Brass.
- Aluminum has good corrosion resistance to common atmospheric and marine atmospheres. It's corrosion resistance and scratch resistance can be enhanced by anodizing.
- Aluminum has high reflectivity and can be used for decorative applications.
- Some Aluminum Alloys can match or even exceed the strength of common construction steel.
- Aluminum retains its toughness at very low temperatures, without becoming brittle (like carbon steels).
- Aluminum is a good conductor of heat and electricity. When measured with using equal cross-sectional area, electrical grade aluminum has conductivity which is approximately 62% of electrical grade annealed copper. However, when compared using equal weight, the conductivity of aluminum is 204% of copper.
- Aluminum can be readily worked and formed using a wide variety of forming processes including deep- drawing and roll forming.
- Aluminum can be readily recycled.

2.1.1 Classification of Aluminum Alloys

Classification of Aluminium alloys is established by the International Alloy Designation System (IADS), based on the classification developed by Aluminum Association of the United States. Each wrought aluminum alloy is designated by a four digit number.

The first digit indicates the alloy group according to the major alloying element:

1xxx Aluminum 99.0% minimum
2xxx Copper (1.9%-.6.8%)
3xxx Manganese (0.3%-1.5%)
4xxx Silicon (3.6%-13.5%)
5xxx Magnesium (0.5%-5.5%)
6xxx Magnesium and Silicon (Mg 0.4%-1.5%, Si 0.2%-1.7%)
7xxx Zinc (1%-8.2%)
8xxx Others

The second digit indicates modification of the alloy or impurity limits.

- Original (basic) alloy is designated by “0” as the second digit. Numbers 1…9 indicate various alloy modifications with slight differences in the compositions.

- In the alloys of the 1xxx series the second digit indicates modifications in impurity limits: 0 means natural impurity limit, 1…9 indicate special control of one or more impurities or alloying element.

The last two digits identify aluminum alloy or indicate the alloy purity. In the alloys of the 1xxx series the last two digits indicate the level of purity of the alloy:

1070 or 1170 mean minimum 99.70% of aluminum in the alloys
1050 or 1250 mean 99.50% of aluminum in the alloys
1100 or 1200 mean minimum 99.00% of aluminum in the alloys.

In all other groups of aluminum alloys (2xxx through 8xxx) the last two digits signify different alloys in the group.

Foundry and Forge Division currently manufactures forgings in 2xxx, 6xxx, 5xxx and 7xxx series alloys and their properties are briefed below.

2.1.2 Heat-Treatable Alloys

Some alloys are strengthened by solution heat-treating and then quenching, or rapid cooling. Heat treating takes the solid, alloyed metal and heats it to a specific point. The alloy elements called solute, are homogeneously distributed with the aluminum putting them in a solid solution. The metal is subsequently quenched, or rapidly cooled, which freezes the solute atoms in place. The solute atoms consequently combine into a finely distributed precipitate. This occurs at room temperature which is called natural aging or in a low temperature furnace operation which is called Artificial aging.

2.1.2.1 2xxx Series

In the 2xxx series, copper is used as the principal alloying element and can be strengthened significantly through solution heat-treating. These alloys possess a good combination of high strength and toughness, but do not have the levels of atmospheric corrosion resistance as many other aluminum alloys. Therefore, these alloys are usually painted or clad for such exposures. They are generally clad with a high-purity alloy or a 6xxx series alloy to greatly resist corrosion. Alloy 2014 is perhaps the most widely known Aircraft Alloy.

2.1.2.2 6xxx Series

The 6xxx series are versatile, heat treatable, highly formable, weldable and have moderately high strength coupled with excellent corrosion resistance. Alloys in this series contain silicon and magnesium in order to form magnesium silicide within the alloy. Extrusion products from the 6xxx series are the first choice for architectural and structural applications. Alloy 6061 is the most widely used alloy in this series and is often used in truck and marine frames.

2.1.2.3 7xxx Series

Zinc is the primary alloying agent for this series, and when magnesium is added in a smaller amount, the result is a heat-treatable, very high strength alloy. Other elements such as copper and chromium may also be added in small quantities. The most commonly known alloys are 7050 and 7075, which are widely used in the aircraft industry.

2.1.3 Non Heat-Treatable Alloys

Non-heat treated alloys are strengthened through cold-working. Cold working occurs during rolling or forging methods and is the action of “working” the metal to make it stronger. For example, when rolling aluminum down to thinner gauges, it gets stronger. This is because cold working builds up dislocations and vacancies in the structure, which then inhibit the movement of atoms relative to each other. This increases the strength of the metal. Alloying elements like magnesium intensify this effect, resulting in even higher strength.

2.1.3.1 5xxx Series

Magnesium is one of the most effective and widely used alloying elements for Aluminum and is the primary alloying agent in the 5xxx series. Alloys in this series possess moderate to high strength characteristics, as well as good weldablility and resistance to corrosion in the marine environment. Because of this, Aluminum-Magnesium Alloys are widely used in building and construction, storage tanks, pressure vessels and marine applications. Examples of common alloy applications include: 5052 in Electronics, 5083 in Marine applications, Anodized 5005 sheet for Architectural applications and 5182 makes the Aluminum beverage can lid.

2.1.4 Effect of Alloying Elements

Alloying elements when added to Aluminum alloys produce effects such as precipitation hardening (age hardening), solid solution hardening, dispersion strengthening, grain refining, modifying metallic and intermetallic phases, suppression of grain growth at elevated temperatures (e.g. during annealing), wear resistance and other tribological properties. Following provides some of the effects of alloying elements to Aluminium Alloys.

2.1.4.1 **Silicon - Si** (up to 17%)

- Improves castability of Aluminum Alloys due to a better fluidity and lower shrinkage of molten Aluminum-Silicon Alloys.
- Increases strength of the Alloys.
- Improves resistance to abrasive wear.
- Silicon in combination with Magnesium allows to strengthen the alloys by precipitation hardening heat treatment (Wrought Aluminum-Magnesium-Silicon Alloys (6xxx)).

2.1.4.2 **Copper - Cu** (up to 6.5%)

- Increases tensile strength, fatigue strength and hardness of the alloys due to the effect of solid solution hardening.
- Allows to strengthen the alloys by precipitation hardening heat treatment (Wrought Aluminum-Copper Alloys (2xxx)).
- Decreases the ductility of the Alloys.
- Decreases corrosion resistance.

2.1.4.3 **Magnesium - Mg** (up to 10%)

- Strengthens and hardens the Alloys by Solid solution hardening mechanism without considerable decrease of ductility (Wrought Aluminum-Magnesium Alloys (5xxx))
- In combination with Silicon or Zinc allows to strengthen the alloys by precipitation hardening heat treatment (Wrought Aluminum-Magnesium-Silicon Alloys (6xxx), Wrought Aluminum-Zinc-Magnesium Alloys (7xxx).

2.1.4.4 **Manganese - Mn** (up to 1.5%)

- Strengthens and hardens the Alloys (Wrought Aluminum-Manganese Alloys (3xxx)) by Solid solution hardening and dispersion hardening mechanisms.

- Improves low cycle fatigue resistance.

- Increases corrosion resistance.

- Improves ductility of Aluminum Alloys containing Iron and Silicon due to modification of Al_5FeSi intermetallic inclusions from platelet to cubic form $Al_{15}(MnFe)_3Si_2$.

2.1.4.5 **Zinc - Zn** (up to 8%)

- In combination with Magnesium or Magnesium-Copper allows to strengthen the Alloys by precipitation hardening heat treatment (Wrought Aluminum-Zinc-Magnesium Alloys (7xxx)).

- Increases susceptibility of the Alloys to Stress corrosion cracking.

2.1.4.6 **Chromium - Cr** (up to 0.3%)

- Suppresses the grain growth at elevated temperatures (e.g. during heat treatment).

- Improves ductility and toughness of Aluminum Alloys containing Iron and Silicon due to modification of Al_5FeSi intermetallic inclusions from platelet to cubic form (similar to the effect of Manganese).

- Reduces susceptibility of the Alloys to Stress corrosion cracking.

2.1.4.7 **Nickel - Ni** (up to 2%)

- Increases hardness and strength of Aluminum-Copper (Wrought Aluminum-Copper Alloys (2xxx) and Aluminum-Silicon (Wrought Aluminum-Silicon Alloy 4032) at elevated temperatures.

- Reduces the Coefficient of Thermal Expansion.

2.1.4.8 **Lithium - Li** (up to 2.6%)

- Increases strength by the precipitation hardening heat treatment.
- Increases Modulus of Elasticity.
- Reduces density.

2.1.4.9 **Titanium - Ti** (up to 0.35%)

- Refines primary aluminum grains (grains formed during the Solidification) due to formation of fine nuclei of Al_3Ti. Titanium is commonly added to Aluminum Alloys together with Boron due to their synergistic grain refining effect.

2.1.4.10 **Boron - B** (up to 0.03%)

- Boron in combination with Titanium refines primary Aluminum grains (grains formed during the Solidification) due to formation of fine nuclei TiB_2.

2.1.4.11 **Zirconium - Zr** (up to 0.3%); **Vanadium - V** (up to 0.2%)

- Inhibit recovery and recrystallization
- Increase the recrystallization temperature.

2.1.4.12 **Iron - Fe** (up to 1.1%)

- Increases strength due to formation of Al-Fe intermetallics.
- Decreases ductility. In most Aluminum Alloys, Iron is undesirable impurity.

2.1.4.13 **Sodium - Na** (up to 0.015%); **Antimony - Sb** (up to 0.5%); **Calcium - Ca** (up to 0.015%), **Strontium - Sr** (up to 0.05%)

- Increase ductility of Hypoeutectic and Eutectic Aluminum-Silicon Alloys (Wrought Aluminum-Silicon Alloys (4xxx)) by a modification of the Silicon phase from coarse platelet like particles to fine fibrous structure.

2.1.4.14 **Tin - Sn** (up to 40%)

- Reduces co-efficient of friction of Aluminum Alloys (Aluminum based bearing materials).
- Increases compatibility of the Aluminum bearing Alloy.
- Improves conformability.
- Improves embedability.

2.2 Ferrous Alloys

Ferrous alloys are those in which Iron is the prime constituent. These are produced in larger quantities than any other metal type. Ferrous Alloys are broadly classified into two major categories.

- Steels
- Cast Irons

2.2.1 Steels

Steels are Iron–Carbon Alloys that may contain appreciable concentrations of other alloying elements; there are thousands of Alloys that have different compositions and/or heat treatments. The mechanical properties are sensitive to the content of Carbon, which is normally less than 1.0% by weight. Some of the more common Steels are classified according to Carbon concentration—namely, Low, Medium and High Carbon types. Sub-classes also exist within each group according to the concentration of other alloying elements.

Plain carbon steels contain only residual concentrations of impurities in addition to Carbon and a little Manganese. For Alloy Steels, more alloying elements are intentionally added in specific concentrations.

2.2.1.1 Low-Carbon Steels

Low Carbon Steels generally contain less than about 0.25 wt% C and are unresponsive to heat treatments intended to form martensite. Strengthening is accomplished by cold work. Microstructures consist of ferrite and pearlite constituents. As a consequence, these Alloys are relatively soft and weak

but have outstanding ductility and toughness. In addition, they are machinable as well as weldable and of all the Steels, are the least expensive to produce.

Typical applications include automobile body components, structural shapes (I-beams, channel and angle iron) and sheets that are used in pipelines, buildings, bridges and tin cans. Another group of Low-carbon Alloys are the high-strength, low-alloy (HSLA) steels. They contain other alloying elements such as Copper, Vanadium, Nickel and Molybdenum in combined concentrations as high as 10 wt% and possess higher strengths than the plain low-carbon steels. Most may be strengthened by heat treatment, giving tensile strengths in excess of 480 MPa. In addition, they are ductile, formable and machinable. In normal atmospheres, the HSLA steels are more resistant to corrosion than the plain carbon steels, which they have replaced in many applications where structural strength is critical (e.g., bridges, towers, support columns in high-rise buildings and pressure vessels).

2.2.1.2 Medium-Carbon Steels

The Medium-Carbon Steels have Carbon concentrations between about 0.25 and 0.60 wt%. These Alloys may be heat treated by austenitizing, quenching and then tempering to improve their mechanical properties. They are most often utilized in the tempered condition, having microstructures of tempered martensite. The medium-carbon steels have low hardenabilities and can be successfully heat treated only in very thin sections and with very rapid quenching rates. Additions of Chromium, Nickel and Molybdenum improve the capacity of these Alloys to be heat treated, giving rise to a variety of strength–ductility combinations. These heat-treated Alloys are stronger than the Low-carbon steels, but at the cost of ductility and toughness. Applications include railway wheels and tracks, gears, crankshafts and other machine parts and high-strength structural components calling for a combination of high strength, wear resistance and toughness.

2.2.1.3 High-Carbon Steels

The High-Carbon Steels, normally having Carbon contents between 0.60 and 1.4 wt%, are the hardest, strongest and yet least ductile of the carbon steels. They are almost always used in a hardened and tempered condition and as such, are especially wear resistant and capable of holding a sharp cutting edge. The tool and die steels are High-carbon alloys, usually containing Chromium, Vanadium, Tungsten and Molybdenum. These Alloying elements combine with Carbon to form very hard and wear-resistant carbide compounds (e.g.: $Cr_{23}C_6$, V_4C_3, and WC). These Steels are utilized as

cutting tools and dies for forming and shaping materials, as well as in knives, razors, hacksaw blades, springs and high-strength wire.

2.2.1.4 Stainless Steels

The Stainless Steels are highly resistant to corrosion (rusting) in a variety of environments, especially the ambient atmosphere. Their predominant alloying element is Chromium; a concentration of atleast 11 wt% Cr is required. Corrosion resistance may also be enhanced by Nickel and Molybdenum additions. Stainless Steels are divided into three classes on the basis of the predominant phase constituent of the Microstructure — Martensitic, Ferritic or Austenitic. A wide range of mechanical properties combined with excellent resistance to corrosion make stainless steels very versatile in their applicability.

Martensitic stainless steels are capable of being heat treated in such a way that martensite is the prime micro-constituent. Additions of alloying elements in significant concentrations produce dramatic alterations in the Iron–Iron carbide phase diagram.

For Austenitic stainless steels, the austenite (or γ) phase field is extended to room temperature. Ferritic stainless steels are composed of the Ferrite (BCC) phase. Austenitic and Ferritic stainless steels are hardened and strengthened by cold work because they are not heat treatable. The austenitic stainless steels are the most corrosion resistant because of the high Chromium contents and also the Nickel additions and they are produced in the largest quantities. Both Martensitic and Ferritic stainless steels are magnetic but the Austenitic stainless are not.

Some stainless steels are frequently used at elevated temperatures and in severe environments because they resist oxidation and maintain their mechanical integrity under such conditions. The upper temperature limit in oxidizing atmospheres is about 1000°C. Equipment employing these steels includes gas turbines, high-temperature steam boilers, heat-treating furnaces, aircraft, missiles and nuclear power generating units.

2.2.2 Effects of Alloying Elements

Specific effects of the addition of such elements are outlined below :

2.2.2.1 Carbon - C:

- The most important constituent of Steel.
- It raises tensile strength, hardness and resistance to wear and abrasion.
- It lowers ductility, toughness and machinability.

2.2.2.2 Chromium - Cr:

- Increases tensile strength, hardness, hardenability, toughness
- Increases resistance to wear and abrasion, resistance to corrosion and scaling at elevated temperatures.

2.2.2.3 Cobalt - Co:

- Increases strength and hardness
- permits higher quenching temperatures
- increases the red hardness of high speed steel.
- It also intensifies the individual effects of other major elements in more complex steels.

2.2.2.4 Columbium - Cb:

- Used as stabilizing elements in Stainless steels.
- high affinity for carbon and forms carbides, which are uniformly dispersed throughout the steel. Thus, localized precipitation of carbides at grain boundaries is prevented.

2.2.2.5 Copper - Cu:

- In significant amounts is detrimental to hot-working steels.
- Copper negatively affects forge welding, but does not seriously affect arc or oxyacetylene welding.
- Copper can be detrimental to surface quality.
- Copper is beneficial to atmospheric corrosion resistance when present in amounts exceeding 0.20%. Weathering steels are sold having greater than 0.20% Copper.

2.2.2.6 Manganese - Mn:

- A deoxidizer and degasifier and reacts with sulfur to improve forgeability.
- It increases tensile strength, hardness, hardenability and resistance to wear.
- It decreases tendency toward scaling and distortion.
- It increases the rate of carbon-penetration in carburizing.

2.2.2.7 Molybdenum - Mo:

- Increases strength, hardness, hardenability, and toughness, as well as creep resistance and strength at elevated temperatures.

- It improves machinability and resistance to corrosion and it intensifies the effects of other alloying elements.
- In hot-work steels and high speed steels, it increases red-hardness properties.

2.2.2.8 Nickel - Ni:

- Increases strength and hardness without sacrificing ductility and toughness.
- It also increases resistance to corrosion and scaling at elevated temperatures when introduced in suitable quantities in high-chromium (stainless) steels.

2.2.2.9 Phosphorus - P:

- Increases strength and hardness and improves machinability.
- Adds marked brittleness or cold-shortness to steel.

2.2.2.10 Silicon - Si:

- A deoxidizer and degasifier.
- It increases tensile and yield strength, hardness, forgeability and magnetic permeability.

2.2.2.11 Sulphur - S:

- Improves machinability in free-cutting steels, but without sufficient Manganese it produces brittleness at red heat.
- It decreases weldability, impact toughness and ductility.

2.2.2.12 Tantalum - Ta:

- Used as stabilizing elements in stainless steels.
- It has a high affinity for carbon and forms carbides, which are uniformly dispersed throughout the steel. Thus, localized precipitation of carbides at grain boundaries is prevented.

2.2.2.13 Titanium - Ti:

- Used as stabilizing elements in Stainless steels.
- It has a high affinity for carbon and forms carbides, which are uniformly dispersed throughout the steel. Thus, localized precipitation of carbides at grain boundaries is prevented.

2.2.2.14 Tungsten - W:

- Increases strength, wear resistance, hardness and toughness.
- Tungsten steels have superior hot-working and greater cutting efficiency at elevated temperatures.

2.2.2.15 Vanadium - V:

- Increases strength, hardness, wear resistance and resistance to shock impact.
- It retards grain growth, permitting higher quenching temperatures.
- It also enhances the red-hardness properties of high-speed metal cutting tools.

2.3 Nickel Alloys

Nickel is a versatile element and alloys well with most Metals. Complete solid solubility exists between Nickel and Copper. Wide solubility range of Iron, Chromium with Nickel can make many alloy combinations possible. The Face-centered cubic structure of the Nickel matrix (γ) can be strengthened by solid-solution hardening, carbide precipitation or precipitation hardening.

2.3.1 Solid-Solution Hardening

Cobalt, Iron, Chromium, Molybdenum, Tungsten, Vanadium, Titanium and Aluminum are all Solid-solution hardeners in Nickel. The elements differ with Nickel in atomic diameter from 1 to 13%. Lattice expansion related to atomic diameter oversize can be related to the hardening observed. Above 0.6 *T*m (melting temperature), which is the range of high-temperature creep, strengthening is diffusion dependent and large slow diffusing elements such as Molybdenum and Tungsten are the most effective hardeners.

2.3.2 Carbide Strengthening

Nickel is not a carbide former. Carbon reacts with other elements alloyed with Nickel to form carbides that can be either a bane or a blessing to the designer of alloys.

The carbides most frequently found in Nickel-base alloys are MC, M_6C, M_7C_3, and $M_{23}C_6$ (where M is the Metallic carbide-forming element or elements).

MC is usually a large blocky carbide, random in distribution and generally not desired.

M_6C carbides are also blocky; formed in grain boundaries. They can be used to control grain size, or precipitated in a Widmanstätten pattern throughout the grain. These carbides can impair ductility and rupture life.

M_7C_3 carbides (predominately Cr_7C_3) form intergranularly and are beneficial if precipitated as discrete particles. They can cause embrittlement if they agglomerate, forming continuous grain-boundary films. This condition will occur over an extended period of time at high temperatures.

$M_{23}C_6$ carbides show a propensity for grain-boundary precipitation.

The $M_{23}C_6$ carbides are influential in determining the mechanical properties of Nickel-base alloys. Discrete grain-boundary particles enhance rupture properties. Long time exposure at 760 to 980 °C (1400 to 1800 °F) will cause precipitation of angular intragranular carbides as well as particles along twin bands and twin ends.

2.3.3 Precipitation Hardening

The precipitation of γ', Ni3(Al,Ti) in a high-nickel matrix provides significant strengthening to the material. This unique intermetallic phase has a Face-centered cubic structure similar to that of the matrix and a lattice constant having 1% or less mismatch in the lattice constant with the γ matrix. This close matching allows low surface energy and long time stability. Precipitation of the γ' from the supersaturated matrix yields an increase in strength with increasing precipitation temperature, up to the overaging or coarsening temperature. Strengthening of alloys by γ' precipitation is a function of γ' particle size. The hardness of the alloy increases with particle size growth, which is a function of temperature and time. The volume percent of γ' precipitated is also important because high-temperature strength increases with amount of the phase present. The amount of gamma prime formed is a function of the hardener content of the Alloy. Aluminum, Titanium, Niobium and Tantalum are strong γ' formers. Effective strengthening by γ' decreases above about 0.6 *T*m as the particles coarsen. To retard coarsening, the alloy designer can add elements to increase the volume percent of γ' or add high-partitioning, slow-diffusing elements such as Niobium or Tantalum to form the desired precipitate.

2.3.4 Applications of Nickel Alloys

Nickel and Nickel Alloys are used for a wide variety of applications, the majority of which involve corrosion resistance and/or heat resistance. Some of these include:

- *Aircraft Gas Turbines* : Disks, combustion chambers, bolts, casings, shafts, exhaust systems, cases, blades, vanes, burner cans, afterburners, thrust reversers.

- *Steam Turbine Power Plants :* Bolts, blades, stack gas reheaters
- *Reciprocating Engines :* Turbochargers, exhaust valves, hot plugs, valve seat inserts
- *Metal Processing :* Hot-work tools and dies
- *Medical Applications :* Dentistry uses, prosthetic devices
- *Space Vehicles :* Aerodynamically heated skins, Rocket engine parts
- *Heat-treating Equipment :* Trays, fixtures, conveyor belts, baskets, fans, furnace mufflers
- *Nuclear Power Systems :* Control rod drive mechanisms, valve stems, springs, ducting
- *Chemical and Petrochemical Industries :* Bolts, fans, valves, reaction vessels, piping, pumps
- *Pollution Control Equipment* : Scrubbers, flue gas desulfurization equipment (liners, fans, stack gas reheaters, ducting)
- *Metals Processing Mills :* Ovens, afterburners, exhaust fans
- *Coal Gasification and Liquefaction Systems* : Heat exchangers, reheaters, piping
- *Pulp and Paper Mills* : Tubing, doctor blades, bleaching circuit equipment, scrubbers

2.4 Titanium Alloys

The rapid growth of the Titanium industry is testimony to the metal's high specific strength and corrosion resistance. With density about 55% that of Steel, Titanium Alloys are widely used for highly loaded aerospace components that operate at low to moderately elevated temperatures, including both Airframe and Jet-engine components. Inspite of high temperature reactivity, the corrosion resistance of Titanium Alloys at normal temperatures is unusually high. They are virtually immune to air, marine and a variety of industrial environments. They are commonly utilized in airplane structures, space vehicles, surgical implants and in the petroleum and chemical industries. At room temperature, Titanium has a Hexagonal

close-packed (hcp) crystal structure, which is referred to as “alpha” phase. This structure transforms to a body-centered cubic (bcc) crystal structure, called “beta” phase, at 888 °C (l621 °F). It is common to separate the alloys into three categories, referring to the phases normally present. The alloy categories generally are called:

- Alpha
- Alpha-beta (alpha-plus-beta)
- Beta

2.4.1 Alpha Alloys

Alpha Alloys contain elements such as Aluminum and Tin. These α-stabilizing elements work by either inhibiting change in the phase transformation temperature or by causing it to increase. Alpha Alloys generally have creep resistance superior to β Alloys, and are preferred for high-temperature applications. The absence of a ductile-to-brittle transition, a feature of β alloys, makes α Alloys suitable for cryogenic applications. Alpha Alloys are characterized by satisfactory strength, toughness, and weldability, but poorer forgeability than β Alloys. This latter characteristic results in a greater tendency for forging defects. Smaller reductions and frequent reheating can minimize these problems. Unlike β alloys, alpha alloys cannot be strengthened by heat treatment. Most often they are used in the annealed or recrystallized condition to eliminate residual stresses caused by working.

2.4.2 Alpha + beta alloys

Alpha plus beta Alloys have compositions that support a mixture of α and β phases and may contain between 10 and 50% β phase at room temperature. Alloys in alpha-beta systems contain one or more alpha stabilizers (e.g., Aluminum) or alpha-soluble elements plus one or more beta stabilizers (e.g. Vanadium, Molybdenum) in larger amounts than in near-alpha alloys. The most common α + β alloy is Ti-6Al-4V. This particular alloy is relatively difficult to form even in the annealed condition, whereas, α + β alloys generally have good formability. The properties of these Alloys can be controlled through heat treatment, which is used to adjust the amounts and types of β phase present. Solution treatment followed by aging at 480 to 650°C (900 to 1200°F) precipitates α, resulting in a fine mixture of α and β in a matrix of retained or transformed β phase.

2.4.3 Beta Alloys

Beta Alloys contain transition elements such as Vanadium, Niobium and Molybdenum, which tend to decrease the temperature of the α to β phase transition and thus promote development of the bcc β phase. They have excellent forgeability over a wider range of forging temperatures than α alloys, and β alloy sheet is cold formable in the solution treated condition. Beta Alloys have excellent hardenability and respond readily to heat treatment. A common thermal treatment involves solution treatment followed by aging at temperatures of 450 to 650°C (850 to 1200°F). This treatment results in formation of finely dispersed α particles in the retained β.

3. TERMINOLOGIES AND ABBREVIATIONS

The following are the notations used in this book:

O	:	Annealed
W	:	Solution treated and naturally aged
WP	:	Solution heat treated and Precipitation treated
T1	:	Cooled from an elevated temperature shaping process and naturally aged
T2	:	Cooled from an elevated temperature shaping process, cold worked and naturally aged
T3	:	Solution heat-treated, cold worked and naturally aged.
T4	:	Solution heat-treated and naturally aged to a substantially stable condition
T5	:	Cooled from an elevated temperature shaping process and then artificially aged
T6	:	Solution heat-treated and then artificially aged
T7	:	Solution heat-treated and overaged / stabilised
T61	:	Solution heat treated and then artificially aged in underaging conditions to improve formability
T651	:	Solution heat treated, stress relieved by controlled stretching and then artificially aged
T6510	:	Solution heat treated, stress relieved by controlled stretching and then artificially aged. The products receive no further straightening after stretching
T6511	:	Same as T6510, except minor straightening is allowed after stretching to comply with standard tolerances
T652	:	Solution heat treated, stress relieved by compressing to produce a permanent set of 1-5% and then artificially aged
T73	:	Solution heat treated and stabilized condition to develop required mechanical properties and high resistance to stress corrosion cracking
WQ	:	Water Quench
BWQ	:	Boiling Water Quench
HWQ	:	Hot Water Quench
A	:	Annealed
N	:	Normalized
T	:	Tempered
H	:	Hardened

H&T	:	Hardened and Tempered
N&T	:	Normalised and Tempered
Sol	:	Solutionised
Soln & Ppt	:	Solutionised and Precipitation Treated
Solutionise + Age	:	Solutionised and Aged
WQ	:	Water Quench
OQ	:	Oil Quench
AC	:	Air cool
FAC	:	Forced Air Cool
MPa	:	Mega Pascal
P.S.	:	Proof stress
UTS	:	Ultimate Tensile Strength
El	:	Elongation
RA	:	Reduction in Area
HB	:	Unit of hardness, Brinell Hardness Number
RC	:	Unit of hardness, Rockwell C scale
RB	:	Unit of hardness, Rockwell B scale
HV	:	Vickers hardness
VHN	:	Vickers Hardness Number
HBW	:	Brinell hardness, Tungsten Ball
J	:	Joules
Max	:	Maximum
Min	:	Minimum
Wt%	:	Weight in percentage
RT	:	Room Temperature
Ppm	:	Parts per million
BS	:	British Standard
AMS	:	Aerospace Material Specification
ASTM	:	American Society for Testing of Material
GTM	:	Gas Turbine Material Specification
MSRR	:	Material Specification Rolls Royce
RRMS	:	Rolls Royce Material Specification

- Chemical Elements as per Periodic Table as shown in Annexure-3

Forging Stock: Forging stock refers to the input material for forging. The following forms are considered as forging stock:

- Bar stock of any type of cross section such as cylindrical, rectangular, square, hexagonal, etc,
- Plate of minimum thickness 10mm, rectangular slabs, Tubes, wires where the material is meant for further forging operations.

Indigenized Materials: Materials developed and approved by CEMILAC.

Withdrawn Specifications: These specifications are made inactive by respective issuing agencies.

Superseded Specifications: These specifications are replaced by another specification by issuing agencies.

Obsolete specifications : These specifications are old and not used in current designs. Hence procurement of material to this specification is difficult.

PART-1
Aluminium Alloys

Data Sheet for Rationalization of Metallic Materials - Aluminium Alloys

General Grade of material	2014	Type of Material	Al -Cu-Si	Number of identified specifications	14
Rationalization for use	Forging Stock				

Identified specifications			Rationalized to		Material Type	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade				
Heat Treatment Condition : T6						14	3	1. OFA developed Material for this grade HE15A up to 240 Dia.
1	ASTM -B-247 / 221	2014	BS L77/ AMS 4133/ HE 15A	2014/ 2014A	Forging Stock			
2	BS L77	-						
3	AMS 4133	2014						
4	AIR 3350	A-U4 SG						
5	AMS-QQ-A-367	2014						
6	AMS-QQA-200/2	2014						
7	BS EN 573-3	EN AW-2014						
8	BS EN 573-3	EN AW-2014A						
9	AIR 9051	A7-U4SG (2014F)						
10	IS: 734	24345 (HF15 Old)						
11	DIN 1747 3.1255	2014A						
12	MIL-A-22771 / AMS-A-22771	2014						
Heat Treatment Condition : T61/ T6511								
13	BS L 168	-	BS L77/ AMS 4133/ BS EN 573-3/ HE 15A	2014/ EN AW-2014A/ 2014A	Forging Stock			
14	HE15A (Indigenised)	2014A						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)													
				Cu	Zn	Si	Mg	Fe	Mn	Cr	Ti	Ti+Zr	Ni	Pb	Others (Max)	Each (Max)	Al
1	ASTM -B-247 / 221	2014	American	3.9-5.0	0.25	0.5-1.2	0.2-0.8	0.7	0.40-1.2	0.1	0.15	-	-	-	0.15	0.05	Base
2	BS L77	-	British	3.9 - 5.0	0.2	0.5-0.9	0.2-0.8	0.5	0.4-1.2	0.1	0.05	0.2	0.2	0.05	Sn:0.05	-	Base
3	AMS 4133	2014	American	3.9 - 5.0	0.25	0.5-1.2	0.20-0.8	-	0.40-1.2	0.1	0.15	-	-	0.7	0.15	0.05	Base
4	AIR 3350	A-U4 SG	French	4.4	-	0.8	0.3	0.5	0.8	-	0.2	-	-	-	-	-	Base
5	AMS-QQ-A-367	2014	American	3.9-5.0	0.25	0.5-1.2	0.20-0.8	0.7	0.40-1.2	0.1	0.15	-	-	-	0.15	0.05	Base
6	AMS-QQA-200/2	2014	American	3.9-5.0	0.25	0.5-1.2	0.2-0.8	0.7	0.40-1.2	0.1	0.15	-	-	-	0.15	0.05	Base
7	BS EN 573-3	EN AW-2014	EU	3.9-5.0	0.25	0.5-1.2	0.2-0.8	0.7	0.40-1.2	0.1	0.15	-	-	-	0.15	0.05	Base
8	BS EN 573-3	EN AW-2014A	EU	3.9-5.0	0.25	0.5-0.9	0.20-0.8	0.5	0.40-1.2	0.1	0.15	-	0.1	-	0.15	0.05	Base
9	AIR 9051	A7-U4SG (2014F)	French	3.9-5.0	0.25	0.5-1.2	0.20-0.8	0.35	0.40-1.2	0.1	0.15	0.2	-	-	0.15	0.05	Base
10	IS: 734	24345 (HF15 Old)	Indian	3.8-2.0	0.2	0.5-1.2	0.20-0.8	0.7	0.3-1.2	0.3	0.3	-	-	-	-	-	Base
11	DIN 1747 3.1255	2014A	German	3.9 - 5.0	0.25	0.5-1.2	0.20-0.8	0.7	0.40-1.2	0.1	0.15	-	-	-	0.15	0.05	Base
12	MIL-A-22771 / AMS-A-22771	2014	American	3.9 - 5.0	0.25	0.5-1.2	0.20-0.8	0.7	0.40-1.2	0.1	0.15	-	-	-	0.15	0.05	Base
13	BS L 168	-	British	3.9 - 5.0	0.2	0.5-0.9	0.2-0.8	0.5	0.4-1.2	0.1	0.05	0.2	0.2	0.05	-	-	Base
14	HE15A (Indigenised)	2014A	Indian	3.9 - 5.0	0.25	0.5-0.9	0.2-0.8	0.5	0.40-1.2	0.1	0.15	0.2	0.1	-	0.15	0.05	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
Heat Treatment Condition : T6								
1	ASTM -B-247 / 221	2014	Sol : 502°C / HWQ Age : 177°C / 8-9Hr /AC (As per AMS 2770)	T6	450	385	6	125
2	BS L77	-	Sol : 500°C / 1 Hr / WQ Age : 175°C / 9-12Hr /AC	T6	450	395	6	134
3	AMS 4133	2014	Sol : 502°C / HWQ Age : 177°C / 9 Hr /AC (HT As per AMS 2772)	T6	448	386	8(4D)	125
4	AIR 3350	A-U4 SG	Sol : 505°C / WQ Age : 170°C / 10Hr /AC	T6	470	412	7	120
5	AMS-QQ-A-367	2014	Sol : 502°C / HWQ Age : 177°C / 8-9 Hr /AC (HT As per AMS 2772)	T6	448	385	6 (4D)	125
6	AMS-QQA-200/2	2014	Sol : 502°C /HWQ Age : 177°C / 9 Hr /AC (HT As per AMS 2772)	T6	468	400	6(4D)	Not specified
7	BS EN 573-3	EN AW-2014	Sol : 502°C /HWQ Age : 177°C / 9 Hr /AC (HT As per AMS 2772)	T6	460	415	7	140
8	BS EN 573-3	EN AW-2014A	Sol : 502°C /HWQ Age : 177°C / 9 Hr /AC (HT As per AMS 2772)	T6	460	415	7	140
9	AIR 9051	A7-U4SG (2014F)	Sol : 502°C / WQ Age : 160°C / 16Hr /AC	T6	450	380	8	Not specified
10	IS: 734	24345 (HF15 Old)	Sol : 502°C /HWQ Age : 177°C / 9 Hr /AC (HT As per AMS 2772)	WP/T6	445	385	6	Not specified
11	DIN 1747 3.1255	2014A	Sol : 500±5°C / WQ Age : 165-177°C / 10 Hr /AC	T6	430	385	6	155
12	MIL-A-22771 / AMS-A-22771	2014	Sol : 517°C / WQ Age : 171°C / 10 Hr /AC (As per MIL-H-6088)	T6	447	378	6	125
Heat Treatment Condition : T651/ T6511								
1	BS L 168	-	Sol : 505°C / WQ Age : 175°C / 5-12Hr /AC	T651	480	435	7	Not specified
2	HE15A (Indigenised)	2014A	As per TA No.724	T6511	465	420	7	134

Fatigue Data in T6 condition (Extracted from MMPDS, Minimum values assumed 10% less than mean value)	
Test Condition : R= -1, Wave form: Sine, Load Direction : Axial, Temperature : Room Temperature, Frequency: 1100 to 3600 cpm, Specimen type : Unnotched	
1. Stress: 278 MPa, No of cycles : 1,00,000 (min)	2. Stress: 173 MPa, No of cycles : 10,00,000 (min)

Data Sheet for Rationalization of Metallic Materials - Aluminium Alloys

General Grade of material :	2618	Type of Material:	Al -Cu-Mg	Number of identified specifications	10
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade				
Heat Treatment Condition : T6						10	2	-
1	MSRR 8007	-	AMS 4132 / AIR 9051/	2618 / AU2GN	Forging Stock			
2	AIR 9051	AU2GN						
3	MSRR 8018 (Superseded by RRMS 34001/2)	2618-F						
4	DTD-731 (Obsolete)	-						
5	BS EN 573-3	EN AW-2618A						
6	DTD-5014 (Obsolete)	-						
Heat Treatment Condition : T61								
7	MIL-A-22771/ AMS-A-22771	2618	AMS 4132 / AIR 9051	2618 / AU2GN	Forging Stock			
8	ASTM -B-247 / 221	2618						
9	AMS 4132	2618						
10	AMS-QQ-A-367	2618						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				Cu	Zn	Si	Mg	Ni	Fe	Ti	Mn	Pb	Ti+Zr	Others (Max)	Each (Max)	Al
1	MSRR 8007	-	British	2.1-2.7	0.1	0.25	1.35-1.65	1.0-1.4	0.9-1.2	0.1	0.2	0.05	-	-	-	Base
2	AIR 9051	AU2GN	French	1.8-2.7	0.15	0.25	1.2-1.8	0.8-1.4	0.9-1.4	0.2	0.2	-	0.25	0.15	0.05	Base
3	MSRR 8018 (Superseded by RRMS 34001/2)	2618-F	British	1.8-2.7	0.15	0.15-0.25	1.2-1.8	0.8-1.1	0.9-1.4	0.2	0.25	-	0.25	0.15	0.05	Base
4	DTD-731 (Obsolete)	-	British	1.8-2.7	0.1	0.25	1.2-1.8	0.8-1.4	0.9-1.4	-	0.2	0.05	0.2	-	-	Base
5	BS EN 573-3	EN AW-2618A	EU	1.8-2.7	0.15	0.15-0.25	0.2-0.8	0.8-1.4	0.9-1.4	0.2	0.25	-	1.2-1.8	0.15	0.05	Base
6	DTD-5014 (Obsolete)	-	British	1.8-2.7	0.1	0.25	1.2-1.8	0.8-1.4	0.9-1.4	0.2	0.2	0.05	1.2-1.8	Sn:0.05	-	Base
7	MIL-A-22771/ AMS-A-22771	2618	American	1.9-2.7	0.1	0.1-0.25	1.3-1.8	0.9-1.2	0.9-1.3	0.04-0.1	-	0.05	-	Sn:0.05	-	Base
8	ASTM -B-247 / 221	2618	American	1.9-2.7	0.1	0.1-0.25	1.3-1.8	0.9-1.2	0.9-1.3	0.04-0.1	-	-	-	0.15	0.05	Base
9	AMS 4132	2618	American	1.9-2.7	0.1	0.1-0.25	1.3-1.8	0.9-1.2	0.9-1.3	0.04-0.1	-	-	-	0.15	0.05	Base
10	AMS-QQ-A-367	2618	American	1.9-2.7	0.1	0.25	1.3-1.8	0.9-1.2	0.9-1.3	0.04-0.1	-	-	-	0.15	0.05	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
Heat Treatment Condition : T6								
1	MSRR 8007	-	Sol : 525°C / WQ Age : 195°C / 16-20Hr /AC	T6	400	330	6	125-150
2	AIR 9051	AU2GN	Sol : 530°C / WQ Age : 200°C / 22Hr /AC	T6	410	340	6	Not Specified
3	MSRR 8018 (Superseded by RRMS 34001/2)	2618-F	Sol : 530°C / BWQ Age : 200°C / 20 Hr /AC	T6	430	340	5	125-150
4	DTD-731 (Obsolete)	-	Sol : 530°C / BWQ Age : 200°C / 20-24 Hr /AC	T6	430	340	5	Not Specified
5	BS EN 573-3	EN AW-2618A	Sol : 530°C / BWQ Age : 200°C / 20 Hr /AC (HT As per MIL-H-6088)	T6	420	360	5	145
6	DTD-5014 (Obsolete)	-	Sol : 530°C / WQ Age : 200°C / 16-24Hr /AC	T6	430	310	6	130
Heat Treatment Condition : T61								
7	MIL-A-22771/ AMS-A-22771	2618	Sol : 530°C / BWQ Age : 200°C / 20 Hr /AC (HT As per MIL-H-6088)	T61	400	310	4 (4D)	115
8	ASTM -B-247 / 221	2618	Sol : 530°C / BWQ Age : 200°C / 20 Hr /AC (HT As per MIL-H-6088)	T61	400	310	4	115
9	AMS 4132	2618	Sol : 530°C / BWQ Age : 200°C / 20 Hr /AC (HT As per MIL-H-6088)	T61	448	368	8 (4D)	120
10	AMS-QQ-A-367	2618	Sol : 530°C / BWQ Age : 199°C / 20 Hr /AC (HT As per AMS 2772)	T61	400	310	4 (4D)	Not Specified

Data Sheet for Rationalization of Metallic Materials - Aluminium Alloys								
General Grade of material :			**2024**	**Type of Material:**	**Al -Cu-Mg-Mn**		**Number of identified specifications**	**4**
Rationalization for use:			**Forging Stock**					
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl No.	**Specification**	**Grade**	**Specification**	**Grade**				
1	AIR 9051	AU4G1	AMS 4152 / AMS-QQ-A-200/3	2024 / 2024	Forging Stock	**4**	**2**	-
2	BS EN 573-3	EN AW-2024						
3	AMS 4152	2024						
4	AMS-QQ-A-200/3	2024						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)											
				Cu	Zn	Si	Mg	Ti+Zr	Ti	Fe	Mn	Cr	Others (Max)	Each (Max)	Al
1	AIR 9051	AU4G1	French	3.8-4.9	0.25	0.5	1.2-1.8	0.25	-	0.5	0.3-0.9	0.1	0.15	0.05	Base
2	BS EN 573-3	EN AW-2024	EU	3.8-4.9	0.25	0.5	1.2-1.8	-	0.15	0.5	0.3-0.9	0.1	0.15	0.05	Base
3	AMS 4152	2024	American	3.8-4.9	0.25	0.5	1.2-1.8	0.2	0.15	0.5	0.3-0.9	0.1	0.15	0.05	Base
4	AMS-QQ-A-200/3	2024	American	3.8-4.9	0.25	0.5	1.2-1.8	-	0.15	0.5	0.3-0.9	0.1	0.15	0.05	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	AIR 9051	AU4G1	Sol : 495°C / WQ Natural Age : 4 Days (Min)	T4	450	290	9	Not specified
2	BS EN 573-3	EN AW-2024	Sol : 495°C / WQ Natural Age : 4 Days (Min)	T4	440	300	8	120
3	AMS 4152	2024	Sol : 493°C / HWQ (As per MIL-H-6088)	T3	450	315	10(4D)	100
4	AMS-QQ-A-200/3	2024	Sol : 493°C / HWQ (As per MIL-H-6088)	T3	468	330	8	Not specified
Fatigue Data in T4 condition (Extracted from MMPDS, Minimum values assumed 10% less than mean value)								
Test Condition : R= -1, Wave form: Sine, Load Direction : Axial, Temperature : Room Temperature, Frequency: 1800 to 3600 cpm, Specimen type : Unnotched								
1. Stress: 235 MPa, No of cycles : 1,00,000 (min)					2. Stress: 180 MPa, No of cycles : 10,00,000 (min)			

Data Sheet for Rationalization of Metallic Materials - Aluminium Alloys

General Grade of material :			2017	Type of Material:	Al -Cu-Mn-Mg-Si	Number of identified specifications		3
Rationalization for use:			Forging Stock					
Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade				
1	AIR 9051	AU4G	AMS 4118 / AIR 9051	2017/ AU4G	Forging Stock	3	2	-
2	BS EN 573-3	EN AW-2017A						
3	AMS 4118	2017						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)											
				Cu	Zn	Si	Mg	Ti+Zr	Ti	Fe	Mn	Cr	Others (Max)	Each (Max)	Al
1	AIR 9051	AU4G	French	3.5-4.5	0.25	0.25-0.8	0.5-1.0	0.25	0.2	0.5	0.3-0.8	-	0.15	0.05	Base
2	BS EN 573-3	EN AW-2017A	EU	3.5-4.5	0.25	0.2-0.8	0.4-1.0	0.25	-	0.7	0.4-1.0	0.1	0.15	0.05	Base
3	AMS 4118	2017	American	3.5-4.5	0.25	0.2-0.8	0.4-0.8	-	0.15	0.7	0.4-1.0	0.1	0.15	0.05	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	AIR 9051	AU4G	Sol : 500°C / WQ Natural Age : 4 Days (Min)	T4	400	260	13	Not specified
2	BS EN 573-3	EN AW-2017A	Sol : 502°C / WQ Natural Age : 4 Days (Min) (As per MIL-H-6088)	T4	400	270	10	105
3	AMS 4118	2017	Sol : 502°C / WQ Natural Age : 4 Days (Min) (As per MIL-H-6088)	T4	380	220	12(4D)	90

Data Sheet for Rationalization of Metallic Materials - Aluminium Alloys

General Grade of material :	2219	Type of Material:	Al -Cu	Number of identified specifications	5
Rationalization for use:	Forging Stock				

Rationalized specifications

Identified specifications			Rationalized to		Material Type	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade				
1	AMS-QQ-A-367	2219	AMS-QQ-A-367/ AMS 4162	2219	Forging Stock	5	2	-
2	ASTM B247	2219						
3	AMS 4143	2219						
4	MIL-A-22771/ AMS-A-22771	2219						
5	AMS 4162	2219						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)											
				Cu	Zn	Si	Mg	Zr	V	Fe	Mn	Ti	Others (Max)	Each (Max)	Al
1	AMS-QQ-A-367	2219	American	5.8-6.8	0.1	0.2	0.02	0.1-0.25	0.05-0.15	0.3	0.2-0.4	0.02-0.1	0.15	0.05	Base
2	ASTM B247	2219	American	5.8-6.8	0.1	0.2	0.02	0.1-0.25	-	0.3	0.2-0.4	0.02-0.1	0.15	0.05 Cr: 0.1	Base
3	AMS 4143	2219	American	5.8-6.8	0.1	0.2	0.02	0.1-0.25	0.05-0.15	0.3	0.2-0.4	0.02-0.1	0.15	0.05	Base
4	MIL-A-22771/ AMS-A-22771	2219	American	5.8-6.8	0.1	0.2	0.02	0.1-0.25	0.05-0.15	0.3	0.2-0.4	0.02-0.1	0.15	0.05	Base
5	AMS 4162	2219	American	5.8-6.8	0.1	0.2	0.02	0.1-0.25	0.05-0.15	0.3	0.2-0.4	0.02-0.1	0.15	0.05	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	AMS-QQ-A-367	2219	Sol : 535°C / WQ Age : 191°C / 26Hr /AC (As per AMS 2772)	T6	400	262	8 (4D)	Not specified
2	ASTM B247	2219	Sol : 535°C / HWQ Age : 191°C / 26Hr /AC (As per AMS 2772)	T6	400	260	8	100
3	AMS 4143	2219	Sol : 535°C / WQ Age : 190°C / 26Hr /AC (As per MIL-H-6088)	T6	400	260	7(4D)	115
4	MIL-A-22771/ AMS-A-22771	2219	Sol : 535°C / HWQ Age : 190°C / 26Hr /AC (As per MIL-H-6088)	T6	400	261	8	100
5	AMS 4162	2219	Sol : 535°C / HWQ Age : 190°C / 18Hr /AC (As per MIL-H-6088)	T8511	400	290	6(4D)	122

Fatigue Data in T851 condition
(Extracted from MMPDS, Minimum values assumed 10% less than mean value)

Test Condition : R= -1, Wave form: Sine, Load Direction : Axial, Temperature : Room Temperature, Frequency: 7000 to 8000 cpm, Specimen type: Notched (Kt=2.0)

1. Stress: 111 MPa, No of cycles : 1,00,000 (min)	2. Stress: 86 MPa, No of cycles : 10,00,000 (min)

Data Sheet for Rationalization of Metallic Materials - Aluminium Alloys

General Grade of material :	6061	Type of Material:	Al -Mg-Si-Cu	Number of identified specifications	7
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Material Type	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade				
1	ASTM B247	6061	AMS 4127/ AMS-QQ-A-367/ HE20A	6061/ 6061/ 6061	Forging Stock	7	3	-
2	AMS-QQ-A-367	6061						
3	BS EN 573-3	EN AW-6061						
4	IS 734	65032 (HF20 Old)						
5	MIL-A-22771/ AMS-A-22771	6061						
6	AMS 4127	6061						
7	HE20A (Indigenised)	6061						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)											
				Cu	Zn	Si	Mg	Fe	Mn	Cr	Ti	Ti+Zr	Others (Max)	Each (Max)	Al
1	ASTM B247	6061	American	0.15-0.4	0.25	0.4-0.8	0.8-1.2	0.7	0.15	0.04-0.35	0.15	-	0.15	0.05	Base
2	AMS-QQ-A-367	6061	American	0.15-0.4	0.25	0.4-0.8	0.8-1.2	0.7	0.15	0.04-0.35	0.15	-	0.15	0.05	Base
3	BS EN 573-3	EN AW-6061	EU	0.15-0.4	0.25	0.4-0.8	0.8-1.2	0.7	0.15	0.04-0.35	0.15	-	0.15	0.05	Base
4	IS 734	65032 (HF20 Old)	Indian	0.15-0.4	0.2	0.4-0.8	0.7-1.2	0.7	0.2-0.8	0.15-0.35	0.2	-	Either Mn or Cr shall be present		Base
5	MIL-A-22771/ AMS-A-22771	6061	American	0.15-0.4	0.25	0.4-0.8	0.8-1.2	0.7	0.15	0.04-0.35	0.15	-	0.15	0.05	Base
6	AMS 4127	6061	American	0.15-0.4	0.25	0.4-0.8	0.8-1.2	0.7	0.15	0.04-0.35	0.15	-	0.15	0.05	Base
7	HE20A (Indigenised)	6061	Indian	0.15-0.4	0.2	0.4-0.8	0.7-1.2	0.7	0.2-0.8	0.1-0.35	-	0.2	Ni: 0.1 Sn: 0.05	-	Rem

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	ASTM B247	6061	Sol : 529°C / HWQ Age : 177°C / 8-10Hr /AC (HT As per AMS-2770)	T6	260	240	7	80
2	AMS-QQ-A-367	6061	Sol : 529°C / WQ Age : 177°C / 8-10Hr /AC (HT As per AMS-2770)	T6	262	241	7 (4D)	Not specified
3	BS EN 573-3	EN AW-6061	Sol : 529°C / WQ Age : 177°C / 8-10Hr /AC (HT As per AMS-2770)	T6	260	240	6	95
4	IS 734	65032 (HF20 Old)	Sol : 529°C / WQ Age : 177°C / 8-10Hr /AC (HT As per AMS-2770)	T6	280	235	7	Not specified
5	MIL-A-22771/ AMS-A-22771	6061	Sol : 547°C / WQ Age : 177°C / 8Hr /AC (HT As per MIL-H-6088)	T61	262	241	7	80
6	AMS 4127	6061	Sol : 547°C / WQ Age : 176°C / 8Hr /AC (HT As per MIL-H-6088)	T6	260	240	9	80
7	HE20A (Indigenised)	6061	As per type record	T6	280	235	7	93-100

Fatigue Data in T6 condition (Extracted from MMPDS, Minimum values assumed 10% less than mean value)	
Test Condition : R= -1, Wave form: Sine, Load Direction : Axial, Temperature : Room Temperature, Frequency: 1100 to 3600 cpm, Specimen type: Unnotched	
1. Stress: 155 MPa, No of cycles : 1,00,000 (min)	2. Stress: 120 MPa, No of cycles : 10,00,000 (min)

Data Sheet for Rationalization of Metallic Materials - Aluminium Alloys

General Grade of material :			7075	Type of Material:	Al -Zn-Mg	Number of identified specifications	10
Rationalization for use:			Forging Stock				

Identified specifications			Rationalized to		Material Type	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade				
Heat Treatment Condition : T73 / T6						10	2	-
1	ASTM -B-247 / 221	7075	AMS-QQ- A-367 / ASTM-B-247/221	7075/ 7075	Forging Stock			
2	AMS-QQ-A-367	7075						
3	BS EN 573-3	EN AW-7175						
4	MIL-A-22771/ AMS-A-22771	7075						
5	AMS -QQ-A-200/11	7075						
6	WL 3.4364	-						
7	AIR 9051	AZ5GU						
8	BS EN 573-3	EN AW-7075						
Heat Treatment Condition : T74								
9	ASTM -B-247 / 221	7175	AMS-QQ- A-367 / ASTM-B-247 / 221	7075/ 7075	Forging Stock			
10	MIL-A-22771/ AMS-A-22771	7175						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)											
				Cu	Zn	Si	Mg	Ti	Fe	Mn	Cr	Ti+Zr	Others (Max)	Each (Max)	Al
1	ASTM -B-247 / 221	7075	American	1.2-2.0	5.1-6.1	0.4	2.1-2.9	0.2	0.5	0.3	0.18-0.28	-	0.15	0.05	Base
2	AMS-QQ-A-367	7075	American	1.2-2.0	5.1-6.1	0.4	2.1-2.9	0.2	0.5	0.3	0.18-0.28	-	0.15	0.05	Base
3	BS EN 573-3	EN AW-7175	EU	1.2-2.0	5.1-6.1	0.15	2.1-2.9	0.1	0.2	0.1	0.18-0.28	-	0.15	0.05	Base
4	MIL-A-22771/ AMS-A-22771	7075	American	1.2-2.0	5.1-6.1	0.4	2.1-2.9	0.2	0.5	0.1	0.18-0.28	-	0.15	0.05	Base
5	AMS -QQ-A-200/11	7075	American	1.2-2.0	5.1-6.1	0.4	2.1-2.9	0.2	0.5	0.3	0.18-0.28	-	0.15	0.05	Base
6	WL 3.4364	-	German	1.2-2.0	5.1-6.1	0.4	2.1-2.9	-	0.5	-	0.18-0.28	0.2	0.15	0.05	Base
7	AIR 9051	AZ5GU	French	1.2-2.0	5.1-6.1	0.4	2.1-2.9	0.2	0.5	0.3	0.18-0.35	-	0.15	0.05	Base
8	BS EN 573-3	EN AW-7075	EU	1.2-2.0	5.1-6.1	0.4	2.1-2.9	0.2	0.5	0.3	0.18-0.28	-	0.15	0.05	Base
9	ASTM -B-247 / 221	7175	American	1.2-2.0	5.1-6.1	0.15	2.1-2.9	0.1	0.2	0.1	0.18-0.28	-	0.15	0.05	Base
10	MIL-A-22771/ AMS-A-22771	7175	American	1.2-2.0	5.1-6.1	0.15	2.1-2.9	0.1	0.2	0.1	0.18-0.28	-	0.15	0.05	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
Heat Treatment Condition : T73								
1	ASTM -B-247 / 221	7075	Sol : 466°C / HWQ Age1 : 107°C / 6-7Hr /AC Age 2: 177°C /8-10Hr /AC (As per AMS 2770)	T73	455	385	7	125
2	AMS-QQ-A-367	7075	Sol : 466°C / HWQ Age1 : 107°C / 6-7Hr /AC Age 2: 177°C /8-10Hr /AC (As per AMS 2770)	T73	455	386	7(4D)	Not specified
3	BS EN 573-3	EN AW-7175	Sol : 466°C / HWQ Age1 : 107°C / 6-7Hr /AC Age 2: 177°C /8-10Hr /AC (As per AMS 2770)	T73	475	405	7	135
4	MIL-A-22771/ AMS-A-22771	7075	Sol : 465°C / HWQ Age1 : 107°C / 6-8Hr /AC Age 2: 177°C /8-10Hr /AC (As per MIL-H-6088)	T73	455	385	7	130
5	AMS -QQ-A-200/11	7075	Sol : 480°C / HWQ Age1 : 107°C / 6-8Hr /AC Age 2: 177°C /6-8Hr /AC (As per AMS 2772)	T73	379	448	7	Not specified
6	WL 3.4364-DIN 65033	7075	Sol : 470°C / WQ Age : 105°C / 6-8 Hr + 165°C / 24-30 Hr / AC	T73	455	385	7	135

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
Heat Treatment Condition : T6								
1	ASTM -B-247 / 221	7075	Sol : 466°C / HWQ Age : 120°C / 23-25Hr /AC (As per AMS 2770)	T6	510	435	7	135
7	AIR 9051	AZ5GU	Sol : 465°C / WQ Age : 120°C / 24Hr /AC	T6	530	450	8	Not specified
2	AMS-QQ-A-367	7075	Sol : 466°C / HWQ Age : 120°C / 23-25Hr /AC (As per AMS 2770)	T6	510	434	7(4D)	Not specified
3	BS EN 573-3	EN AW-7075	Sol : 466°C / HWQ Age : 120°C / 23-25Hr /AC (As per AMS 2770)	T6	560	500	7	150
4	MIL-A-22771/ AMS-A-22771	7075	Sol : 465°C / HWQ Age : 121°C / 24Hr /AC (As per MIL-H-6088)	T6	510	434	7	135
Sl No.	**Specification**	**Grade**	**Heat treatment**	**Condition**	**Mechanical properties (Minimum)**			
					UTS (MPa)	**0.2% P.S. (MPa)**	**% El (5D)**	**Hardness (HB)**
Heat Treatment Condition : T74								
9	ASTM -B-247 / 221	7175	Sol : 480°C / HWQ Age1 : 107°C / 6-8Hr /AC Age 2: 177°C /6-8Hr /AC (As per AMS 2772)	T74	525	455	7	Not specified
10	MIL-A-22771/ AMS-A-22771	7175	Sol : 480°C / HWQ Age1 : 107°C / 6-8Hr /AC Age 2: 177°C /6-8Hr /AC (As per AMS 2772)	T74	524	455	7	135
Fatigue Data in T6 condition (Extracted from MMPDS, Minimum values assumed 10% less than mean value)								
Test Condition : R= -1, Wave form: Sine, Load Direction : Axial, Temperature : Room Temperature, Frequency: 1100 to 3600 cpm, Specimen type: Unnotched								
1. Stress: 247 MPa, No of cycles : 1,00,000 (min)					2. Stress: 192 MPa, No of cycles : 10,00,000 (min)			

PART 2: STEEL

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material			**SAE 9310**	**Type of Material**	**Ni-Cr-Mo Steel**		**Number of identified specifications**	**3**
Rationalization for use			**Forging Stock**					
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl No.	**Specification**	**Grade**	**Specification**	**Grade**	**Form**			
1	AMS 6260	SAE 9310	AMS 6265	SAE 9310	Forging Stock	**3**	**1**	-
2	AMS 6265	SAE 9310						
3	EMS 56280	SAE 9310						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)										
				C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Others	Fe
1	AMS 6260	SAE 9310	AMERICAN	0.07-0.13	0.4-0.7	0.15-0.35	0.025	0.025	3.0-3.5	1.0-1.4	0.08-0.15	0.35	B: 0.001	Base
2	AMS 6265	SAE 9310	AMERICAN	0.07-0.13	0.4-0.7	0.15-0.35	0.015	0.015	3.0-3.5	1.0-1.4	0.08-0.15	0.35	B: 0.001	Base
3	EMS 56280	SAE 9310	EUROPEAN	0.07-0.13	0.4-0.7	0.15-0.35	0.015	0.015	3.0-3.5	1.0-1.4	0.08-0.15	0.35	Al:0.02-0.1	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S (MPa)	% El (5D)	Hardness (HRC)
1	AMS 6260	SAE 9310	Harden: 815□□C/WQ Temper to customer requirement (Mechanical values are for tempering at 150□C)	H&T	1030	-	-	33-43
2	AMS 6265	SAE 9310	Harden: 815□□C/WQ Temper to customer requirement (Mechanical values are for tempering at 150□C)	H&T	1030	-	-	33-43
3	EMS 56280	SAE 9310	Harden: 815□□C/WQ Temper to customer requirement (Mechanical values are for tempering at 150□C)	H&T	1030	-	-	33-43
Endurance Limit : 50% of UTS Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO								

Data Sheet for Rationalization of Metallic Materials - Steel

General Grade of material			JETHETE M152		Type of Material:	Ni-Cr-Mo Steel		Number of identified specifications	9
Rationalization for use:			FORGING STOCK						
Identified specifications			Rationalized to			Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade		Form			
1	AIR 9160	Z12CNDV12	AMS 5719/ AIR 9160	Z12CNDV12		Forging Stock	9	2	1. MSRR 6503 is superseded by RRMS 32007/1. Stock procured with MSRR 6503 can also be used. 2. MSRR 6503 (forging) is made from MSRR 6916 (forging stock). MSRR 6916 is superseded by RRMS 32007.
2	MSRR 6503 (Made from MSRR 6916)	-							
3	RRMS 32007/1 (Made from RRMS 32007)	-							
4	CCT-00115	Z12CNDV12							
5	BS S151	-							
6	AMS 5719	-							
7	MSRR 6509	-							
8	CCT-00321	EZ12CNDV12							
9	MSRR 6510	-							

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V	N	Others Each	Fe
1	AIR 9160	Z12CNDV12	FRENCH	0.08-0.12	0.5-0.9	0.35	0.025	0.035	2.0-3.0	11.0-12.5	1.5-2.0	-	0.25-0.4	0.02-0.04	-	Base
2	MSRR 6503 (Made from MSRR 6916)	-	BRITISH	0.08-0.13	0.5-0.9	0.35	0.025	0.03	2.0-3.0	11.0-12.5	1.5-2.0	-	-	-	0.35	Base
3	RRMS 32007/1 (Made from RRMS 32007)	-	BRITISH	0.08-0.13	0.5-0.9	0.35	0.025	0.03	2.0-3.0	11.0-12.5	1.5-2.0	-	-	-	0.35	Base
4	CCT-00115	Z12CNDV12	TURBOMECA	0.08-0.13	0.5-0.9	0.35	0.025	0.03	2.0-3.0	11.0-12.5	1.5-2.0	0.5	0.25-0.4	0.02-0.04	-	Base
5	BS S151	-	BRITISH	0.08-0.13	0.5-0.9	0.35	0.025	0.03	2.0-3.0	11.0-12.5	1.5-2.0	-	0.25-0.4	0.02-0.04	-	Base
6	AMS 5719	-	AMERICAN	0.08-0.15	0.5-0.9	0.35	0.025	0.025	2.0-3.0	11.0-12.5	1.5-2.0	0.5	0.25-0.4	0.01-0.05	-	Base
7	MSRR 6509	-	BRITISH	0.08-0.13	0.5-0.9	0.35	0.025	0.025	2.0-3.0	11.0-12.5	1.5-2.0	0.35	-	-	-	Base
8	CCT-00321	EZ12CNDV12	TURBOMECA	0.08-0.13	0.5-0.9	0.35	0.025	0.025	2.0-3.0	11.0-12.5	1.5-2.0	0.5	0.25-0.4	0.02-0.04	-	Base
9	MSRR 6510	-	BRITISH	0.08-0.13	0.5-0.9	0.35	0.025	0.025	2.0-3.0	11.0-12.5	1.5-2.0	-	0.25-0.4	0.015-0.04	-	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	AIR 9160	Z12CNDV12	HARDEN: 1050 ±C, OIL QUENCH TEMPER: >640°C, AIRCOOL	H&T	930-1130	780	6	60	286
2	MSRR 6503 (Made from MSRR 6916)	-	HARDEN AT 1050°C, AIR COOL / OIL QUENCH TEMPER-1: 650°C, AIR COOL TEMPER-2 : 630°C, AIR COOL	H&T	930-1130	760	14	60	286-331
3	RRMS 32007/1 (Made from RRMS 32007)	-	HARDEN AT 1050°C, AIR COOL / OIL QUENCH TEMPER-1: 650°C, AIR COOL TEMPER-2 : 630°C, AIR COOL	H&T	930-1130	760	14	60	286-331
4	CCT-00115	Z12CNDV12	HARDEN: 1020-1050 °C, AIRCOOL/ OIL QUENCH TEMPER: 650°C, AIRCOOL	H&T	930-1130	760	14	50	-
5	BS S151	-	HARDEN: 1050°C, AIRCOOL TEMPER: 650°C, AIRCOOL	H&T	930-1130	760	14	61 45 (ft lbf)	286-331
6	AMS 5719	-	HARDEN AT 1050°DEG C, QUENCH IN OIL TEMPER-1 AT 560 TO 580° C, AIR COOL TEMPER-2 AT 540-560° C, AIR COOL	H&T	1070	895	12	-	341 to 375
7	MSRR 6509	-	HARDEN: 1050°C, AIRCOOL/ OIL QUENCH TEMPER: 560-590°C, AIRCOOL	H&T	1080-1310	900	9	40	321-388
8	CCT-00321	EZ12CNDV12	HARDEN: 1020-1050°C, AIRCOOL/ OIL QUENCH TEMPER 1: 560°C, AIRCOOL TEMPER 2: 560°C, AIRCOOL	H&T	1080-1240	900	8	-	320-365
9	MSRR 6510	-	HARDEN: 1050°C, AIRCOOL/ OIL QUENCH TEMPER: 300-370°C, AIRCOOL	H&T	1206-1470	950	9	40	374-429

Endurance Limit : 50% of UTS

Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material :			**FV 448**	**Type of Material:**	**Ni-Cr-Mo Steel**		**Number of identified specifications**	**2**
Rationalization for use:			**FORGING STOCK**					
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl No.	**Specification**	**Grade**	**Specification**	**Grade**	**Form**			
1	MSRR 6596 (Made from 6919)	-	MSRR 6596 (MSRR 6919- Forging stock)	FV 448	Forging Stock	**3**	**1**	1. MSRR 6919 is forging stock for MSRR 6596. 2. MSRR 6503 and MSRR 6602 are alternate to MSRR 6596 as per MSRR 6596. 3. Sl. No. 3 is equivalent to grade FV 448 as per RCMA(Nsk)/07/01 dated 27.09.2007
2	BS S 150	-						
3	TU14-1-1161-75	15KH12N2MB-FAB-SH AP 517						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				C	Mn	Si	S	P	Ni	Cr	Mo	V	N	Nb	Others Each	Fe
1	MSRR 6596 (Made from 6919)	-	BRITISH	0.08-0.16	0.3-1.2	0.15-0.6	0.025	0.03	0.6-1.2	9.8-11.2	0.4-0.8	0.1-0.25	0.03-0.075	0.15-0.45	Co: 0.85	Base
2	BS S 150	-	BRITISH	0.08-0.16	0.3-1.2	0.15-0.6	0.025	0.03	0.6-1.2	9.8-11.2	0.4-0.8	0.1-0.25	0.03-0.075	0.15-0.45	-	Base
3	TU14-1-1161-75	15KH12N2MB-FAB-SH AP 517	RUSSIAN	0.13-0.18	0.5	0.5	0.015	0.03	1.7-2.1	11.0-12.5	1.35-1.65	0.16-0.32	0.02-0.08	0.2-0.35	W:0.65-1.05	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	MSRR 6596 (Made from 6919)	-	HARDEN: 1150°C, AIR COOL / OIL QUENCH TEMPER : 650 -720°C , AIR COOL	H & T	930-1080	800	10	286-321
2	BS S 150	-	HARDEN: 1150°C, AIR COOL / OIL QUENCH TEMPER : 650 -700°C , AIR COOL	H & T	930-1080	780	10	285-331
3	TU14-1-1161-75	15KH12N2MB-FAB-SH AP 517	HARDEN: 1120°C, OIL QUENCH TEMPER : 670 -720°C , AIR COOL	H & T	1030	934	-	-

Endurance Limit : 50% of UTS
Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material :			12NC12	Type of Material:	3% Ni Case carburising steel	Number of identified specifications		3
Rationalization for use:			FORGING STOCK					
Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	MSRR 6004	-	BS S15	-	Forging Stock	3	1	-
2	BS S15	-						
3	AIR 9160	12NC12						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)							
				C	Mn	Si	S	P	Ni	Cr	Fe
1	MSRR 6004	-	BRITISH	0.1-0.15	0.35-0.6	0.1-0.35	0.02	0.025	2.75-3.25	0.9	Base
2	BS S15	-	BRITISH	0.1-0.15	0.35-0.6	0.1-0.35	0.02	0.025	2.75-3.25	0.3	Base
3	AIR 9160	12NC12	French	0.1-0.16	0.35-0.65	0.1-0.4	0.02	0.025	2.75-3.25	0.6-0.9	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	MSRR 6004	-	HARDEN: 760-780° C, OIL QUENCH TEMPER 2 : 120-140° C, AIR COOL	H & T	770- 1235	400	12	47.5 35 (ft lbf)	225-365
2	BS S15	-	HARDEN: 760-780 ° C, WATER QUENCH TEMPER 2 : 120-140° C, AIR COOL	H & T	775	-	12	65 47.5 (ft lbf)	-
3	AIR 9160	12NC12	HARDEN: 810-830° C, OIL QUENCH TEMPER 2 : 140-190° C, AIR COOL	H & T	830	630	11	35 7 daJ/cm2	-

Fatigue Data in H&T condition (Extracted from Book: Aerospace Materials by Balram Gupta, Minimum values are taken for 12NC12)
Test Condition : R= -1, Wave form: Sine, Rotating beam bending, Temperature : Room Temperature, Specimen type : Unnotched
Stress: 432 MPa, No of cycles : 10 X 10^6 (min)

Data Sheet for Rationalization of Metallic Materials - Steel

General Grade of material :	16NCD13	Type of Material:	Ni-Cr-Mo Steel	Number of identified specifications	8
Rationalization for use:	FORGING STOCK				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	MSRR 6061	-	AMS 6549/ E16NCD13 (Indigenised)	-	Forging Stock	9	2	1. Other equivalent specifications for E16NCD13 are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	BSEM 545 (Replaced by MSRR 6051 and obsolete)	-						
3	AIR 9160	16NCD13						
4	MSRR 6051	-						
5	BS S157	-						
6	AMS 6549	-						
7	CCT-00264	16NCD13						
8	CCT-00140	E16NCD13						
9	E16NCD13 (Indigenised)	-						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)									
				C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Fe
1	MSRR 6061	-	BRITISH	0.12-0.17	0.3-0.6	0.15-0.4	0.02	0.02	3.0-3.5	0.8-1.1	0.2-0.3	-	Base
2	BSEM 545 (Replaced by MSRR 6051 and obsolete)	-	BRITISH	0.12-0.17	0.3-0.6	0.15-0.4	0.02	0.025	3.0-3.5	0.8-1.1	0.2-0.3	-	Base
3	AIR 9160	16NCD13	FRENCH	0.12-0.17	0.3-0.6	0.15-0.4	0.02	0.025	3.0-3.5	0.8-1.1	0.20-0.3	-	Base
4	MSRR 6051	-	BRITISH	0.12-0.17	0.3-0.6	0.15-0.4	0.02	0.02	3.0-3.5	0.8-1.1	0.2-0.3	-	Base
5	BS S157	-	BRITISH	0.12-0.17	0.3-0.6	0.15-0.4	0.02	0.025	3.0-3.5	0.8-1.1	0.2-0.3	-	Base
6	AMS 6549	-	AMERICAN	0.12-0.17	0.3-0.6	0.15-0.4	0.005	0.015	3.0-3.5	0.8-1.1	0.22-0.32	0.35	Base
7	CCT-00264	16NCD13	TURBOMECA	0.12-0.17	0.3-0.6	0.15-0.4	0.02	0.025	3.0-3.5	0.8-1.1	0.2-0.3	0.35	Base
8	CCT-00140	E16NCD13	TURBOMECA	0.12-0.17	0.3-0.6	0.15-0.4	0.01	0.015	3.0-3.5	0.8-1.1	0.2-0.3	0.35	Base
9	E16NCD13 (Indigenised)	-	Indian	0.16C-3.25Ni-1Cr-0.25Mo-Bal Fe as per CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)									

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	MSRR 6061	-	HARDEN : 750-780°C, OIL QUENCH TEMPER: 125° C, AIRCOOL	H & T	1080-1400	780	11	40	321-401
2	BSEM 545 (Replaced by MSRR 6051 and obsolete)	-	HARDEN: 825° C, OIL QUENCH TEMPER : 180° C, AIR COOL	H & T	1180-1380	930	8	34 25 (ft lbf)	345-420
3	AIR 9160	16NCD13	HARDEN: 825° C, OIL QUENCH TEMPER : 190° C, AIR COOL	H&T	1180-1380	980	8	30 6 (daj/cm2)	340-410
4	MSRR 6051	-	HARDEN: 825°C, OIL QUENCH TEMPER : 180° C, AIR COOL	H & T	1180-1380	930	8	34 25 (ft lbf)	345-420
5	BS S157	-	HARDEN: 825° C, OIL QUENCH (Tempering temperature can be varied as per requirement) TEMPER : 180° C, AIR COOL	H & T	1180-1380	930	8	34 25 (ft lbf)	-
6	AMS 6549	-	HARDEN: 825° C, OIL QUENCH TEMPER : 190° C, AIR COOL	H & T	1180-1430	980	8	40 8 (daj/cm2)	-
7	CCT-00264	16NCD13	HARDEN: 825° C, OIL QUENCH TEMPER : 190° C, AIR COOL	H & T	1180-1380	980	8	40 8 (daj/cm2)	-
8	CCT-00140	E16NCD13	HARDEN: 825° C, OIL QUENCH TEMPER : 190° C, AIR COOL	H & T	1180-1430	980	8	40 8 (daj/cm2)	-
9	E16NCD13 (Indigenised)	-	Refer CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)						
Endurance Limit : 50% of UTS Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO									

Data Sheet for Rationalization of Metallic Materials - Steel

General Grade of material :			15CDV6	Type of Material	Cr-Mo Steel		Number of identified specifications	7
Rationalization for use:			FORGING STOCK					
Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	WL 1.7734	-	AIR-9160	15CDV6	Forging Stock	7	1	1. Sl.No. 5, 6, and 7 are specified as Equivalent to 15CDV6 as per RCMA(Nsk)/07/01 dated 27.09.2007.
2	CCT-00067	15CDV6						
3	CCT LA 189	E15CDV6						
4	AIR-9160	15CDV6/ E15CDV6						
5	TU14-4-950-86	30KHGSA						
6	TU14-4-950-86	30KHGSA-SH						
7	TU14-1-1885-76	30KHGSA-VD						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)									
				C	Mn	Si	S	P	Cr	Mo	V	Others	Fe
1	WL 1.7734	-	GERMAN	0.12-0.18	0.8-1.1	0.2	0.015	0.02	1.25-1.5	0.8-1.0	0.20-.30	-	Base
2	CCT-00067	15CDV6	TURBOMECA	0.12-0.18	0.8-1.1	0.2	0.015	0.02	1.25-1.5	0.8-1.0	020-.30	-	Base
3	CCT LA 189	E15CDV6	TURBOMECA	0.12-0.18	0.8-1.1	0.2	0.01	0.015	1.25-1.5	0.8-1.0	020-.30	Cu:0.35 Sn: 0.03	Base
4	AIR-9160	15CDV6/ E15CDV6	FRENCH	0.12-0.18	0.8-1.1	0.2	0.015	0.02	1.25-1.5	0.8-1.0	0.20-.30	-	Base
5	TU14-4-950-86	30KHGSA	RUSSIAN	0.28-0.34	0.8-1.1	0.9-1.2	0.025	0.025	0.8-1.1	0.015-0.25	-	Cu: 0.25	Base
6	TU14-4-950-86	30KHGSA-SH	RUSSIAN	0.28-0.34	0.8-1.1	0.9-1.2	0.015	0.015	0.8-1.1	-	-	Cu: 0.25	Base
7	TU14-1-1885-76	30KHGSA-VD	RUSSIAN	0.28-0.34	0.8-1.1	0.8-1.1	0.015	0.015	0.8-1.1	-	-	Cu: 0.2	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	WL 1.7734	-	HEAT TO 960-990° C OIL QUENCH. TEMPER AT 720-740° C COOL IN AIR.	H&T	700	550	12	60	205 HV
2	CCT-00067	15CDV6	HEAT TO 975° C OIL QUENCH. TEMPER AT 650° C COOL IN AIR.	H&T	980-1180	780	12	60	33 (HRB)
3	CCT LA 189	E15CDV6	HEAT TO 975° C OIL QUENCH. TEMPER AT 650° C COOL IN AIR.	H&T	980-1180	780	12	60	287-342
4	AIR-9160	15CDV6/ E15CDV6	HEAT TO 975° C, AIR COOL TEMPER AT 620-650° C COOL IN AIR.	H&T	1080-1280	930	10	-	33 (HRB)
5	TU14-4-950-86	30KHGSA	HARDEN TO 880° C, OIL QUENCH TEMPER AT 510 -570° C, OIL QUENCH	H&T	1078	-	10	-	-
6	TU14-4-950-86	30KHGSA-SH	HARDEN TO 880° C, OIL QUENCH TEMPER AT 510 -570° C, AIR COOL	H&T	1078	833	10	-	311-363
7	TU14-1-1885-76	30KHGSA-VD	HARDEN TO 880° C, OIL QUENCH TEMPER AT 510 -570° C, OIL QUENCH	H&T	1078	882	10	-	-

Fatigue Data in H&T condition
(Extracted from Book: Aerospace Materials by Balram Gupta, Minimum values are taken for 15CDV6)

Test Condition : R= -1, Wave form: Sine, Rotating beam bending, Temperature : Room Temperature, Specimen type : Unnotched

Stress: 372 MPa, No of cycles : 10.3 X 10^6 (min)

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material :			SAE 4340	Type of Material:	Ni-Cr-Mo Steel		Number of identified specifications	3
Rationalization for use:			FORGING STOCK					
Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	AMS 6414	SAE 4340	AMS 6414	SAE 4340	Forging Stock	3	1	-
2	MIL S 5000	E4340						
3	AMS 6415	SAE 4340						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)									
				C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Fe
1	AMS 6414	SAE 4340	AMERICAN	0.38-0.43	0.6-0.9	0.15-0.35	0.01	0.01	1.65-2.0	0.7-0.9	0.2-0.3	0.35	Base
2	MIL S 5000	E4340	AMERICAN	0.38-0.43	0.65-0.85	0.15-0.35	0.025	0.025	1.65-2.0	0.7-0.9	0.2-0.3	0.35	Base
3	AMS 6415	SAE 4340	AMERICAN	0.38-0.43	0.6-0.9	0.15-0.35	0.01	0.01	1.65-2.0	0.7-0.9	0.2-0.3	0.35	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	AMS 6414	SAE 4340	NORMALISE: 899° C., AIR COOL. HARDEN : 816° C, OIL QUENCH TEMPER 1: 246° C,AIR COOL TEMPER 2: 246° C, AIR COOL	H&T	1793	1496	10	-
2	MIL S 5000	E4340	HARDEN: 795 -840° C, OIL QUENCH TEMPER ACCORDING TO ACHIEVE VALUES	H&T	1034	896	14	-
3	AMS 6415	SAE 4340	NORMALISE: 899° C., AIR COOL. HARDEN : 816° C, OIL QUENCH TEMPER 1: 246° C,AIR COOL TEMPER 2: 246° C, AIR COOL Heat treatment and mechanical properties are from established data	H&T	1793	1496	10	-

Fatigue Data in H&T condition (Extracted from MMPDS, Minimum values assumed 10% less than mean value)	
Test Condition : R= -1, Wave form: Sine, Load Direction : Axial, Temperature : Room Temperature, Frequency: 2000 to 2500 cpm, Specimen type : Unnotched	
1. Stress: 360 MPa, No of cycles : 1,00,000 (min)	2. Stress: 340 MPa, No of cycles : 10,00,000 (min)

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material :			**Maraging steel 250**	**Type of Material:**	**MARAGING STEEL**	**Number of identified specifications**		**5**
Rationalization for use:			**FORGING STOCK**					
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl No.	**Specification**	**Grade**	**Specification**	**Grade**	**Form**			
1	MIL-S-46850	TY IV, Grade 250	AMS 6512/ MIL-S-46850 / MDN 250A	TY IV, GRADE 250	Forging Stock	**5**	**3**	1. Other equivalent specifications for MDN 250A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalization of Metallic Materials)
2	AMS 6512	-						
3	DTD 5212	-						
4	MLA 101	-						
5	MDN 250A (Indigenised)	-						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				C	Mn	Si	S	P	Ni	Zr	Mo	Al	Co	Ti	Others Each max	Fe
1	MIL-S-46850	TY IV, Grade 250	American	0.03	0.1	0.1	0.01	0.01	17.0-19.0	0.02	4.6-5.2	0.05-0.15	7.0-8.5	0.3-0.5	B: 0.03 Ca: 0.05	Base
2	AMS 6512	-	American	0.03	0.1	0.1	0.01	0.01	17.0-19.0	0.02	4.6-5.2	0.05-0.15	7.0-8.5	0.3-0.5	B: 0.003 Cu: 0.5 Cr: 0.5 Ca: 0.05	Base
3	DTD 5212	-	British	0.015	0.1	0.1	0.01	0.01	17.0-19.0	0.25	4.6-5.2	0.05-0.15	7.0-8.5	0.3-0.6	Cr: 0.25	Base
4	MLA 101	-	European	0.02	0.1	0.1	0.01	0.01	17.0-19.0	0.25	4.6-5.2	0.05-0.15	7.0-8.5	0.3-0.6	Cr 0.25 B 0.03 Zr 0.02 Ca 0.05	Base
5	MDN 250A (Indigenised)	-	Indian	18Ni-8Co-5Mo-0.54Ti-0.1Al-Bal Fe as per CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)												

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	MIL-S-46850	TY IV, Grade 250	SOLUTIONISING : 815° C, AIR COOL AGING : 480°.C, 3-6 HRS AIR COOL	SOL & AGED	-	1654	3	48 HRC
2	AMS 6512	-	SOLUTIONISING : 815° C, AIR COOL AGING : 480°.C, 6 HRS AIR COOL	SOL & AGED	1760	1725	6	48 HRC
3	DTD 5212	-	SOLUTIONISING : 820° C, AIR COOL AGING : 485°.C, 3 HRS, AIR COOL	SOL & AGED	1800-2000	1700	8	520-620 HV
4	MLA 101	-	SOLUTIONISING : 820° C, AIR COOL AGING : 485°.C, 3 HRS, AIR COOL	SOL & AGED	1517	1448	8	520 HV
5	MDN 250A (Indigenised)	-	Refer CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)					
Fatigue Data in H&T condition (Extracted from Book: Aerospace Materials by Balram Gupta, Minimum values are taken for MDN 250A)								
Test Condition : R= -1, Wave form: Sine, Rotating beam bending, Temperature : Room Temperature, Specimen type : Unnotched								
Stress: 680 MPa, No of cycles : 10 X 10^6 (min)								

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material			**NCM Steel**	**Type of Material**	**Ni-Cr-Mo Steel**		**Number of identified specifications**	**5**
Rationalization for use			**FORGING STOCK**					
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl No.	**Specification**	**Grade**	**Specification**	**Grade**	**Form**			
1	MSRR 6009	-	RRMS 31014/ RRMS 31014/1	-	Forging Stock	**5**	**1**	1. MSRR 6010 is superseded by RRMS 31014/1. Stock procured with MSRR 6010 can also be used. 2. RRMS 31014 is forging stock and RRMS 31014/1 is forging specification
2	MSRR 6010/ (MSRR 6010 SUPERSEDED TO RRMS 31014/1)	-						
3	RRMS 31014/ RRMS 31014/1	-						
4	MSRR 6094	-						
5	AMS 6264	-						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)								
				C	Mn	Si	S	P	Ni	Cr	Mo	Fe
1	MSRR 6009	-	BRITISH	0.14-0.18	0.25-0.55	0.15-0.4	0.015	0.015	3.8-4.3	1.0-1.4	0.2-0.3	Base
2	MSRR 6010/ (MSRR 6010 SUPERSEDED TO RRMS 31014/1)	-	BRITISH	0.14-0.18	0.25-0.55	0.1-0.35	0.012	0.015	3.8-4.3	1.0-1.4	0.2-0.3	Base
3	RRMS 31014/ RRMS 31014/1	-	BRITISH	0.14-0.18	0.25-0.55	0.1-0.35	0.012	0.015	3.8-4.3	1.0-1.4	0.2-0.3	Base
4	MSRR 6094	-	BRITISH	0.14-0.18	0.25-0.55	0.1-0.35	0.012	0.015	3.8-4.3	1.0-1.4	0.2-0.3	Base
5	AMS 6264	-	AMERICAN	0.14-0.2	0.4-0.7	0.15-0.35	0.025	0.025 Cu: 0.35	3-3.5	1.0-1.4	0.08-0.15	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	MSRR 6009	-	HARDEN: 820° C, OIL QUENCH TEMPER : 190° C, AIR COOL	H&T	1320-1520	1030	8	33	388-444
2	MSRR 6010/ (MSRR 6010 SUPERSEDED TO RRMS 31014/1)	-	HARDEN: 820° C, OIL QUENCH TEMPER : 190° C, AIR COOL	H&T	1320-1520	1030	11	33	388-444
3	RRMS 31014/ RRMS 31014/1	-	HARDEN: 820-850° C, OIL QUENCH TEMPER : 190° C, AIR COOL	H&T	1320-1480	1030	11	40	388-444
4	MSRR 6094	-	HARDEN: 820° C, OIL QUENCH TEMPER : 190° C, AIR COOL	H&T	1320-1520	1030	11	33	388-444
5	AMS 6264	-	NORMALISE: 925° C, AIR COOL	N	862 (Max)	-	-	-	229 (Max)
Endurance Limit : 50% of UTS Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO									

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material :			Z30C13	Type of Material:	Ni-Cr-Mo Steel		Number of identified specifications	3
Rationalization for use:			FORGING STOCK					
Rationalized specifications								
Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	MSRR 6602	-	AMS 5655	-	Forging Stock	3	1	-
2	AIR 9160	Z30C13						
3	AMS 5655	-						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)										
				C	Mn	Si	S	P	Ni	Cr	Mo	V	Other	Fe
1	MSRR 6602	-	BRITISH	0.22-0.32	0.5	0.5	0.025	0.03	1.0	12.0-14.5	-	-	-	Base
2	AIR 9160	Z30C13	FRENCH	0.25-0.32	1.0	0.8	0.025	0.035	1.0	12.0-14.0	-	-	-	Base
3	AMS 5655	-	AMERICAN	0.2-0.25	1.0	0.2-0.6	0.03	0.04	0.5-1.0	11-13.5	0.75-1.25	0.17-0.3	Cu: 0.5 W: 0.75-1.25	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S (MPa)	% El (5D)	Hardness (HB)
1	MSRR 6602	-	HARDEN: 940- 980° C., QUENCH IN OIL TEMPER: 550-650° C , WATER QUENCH	H&T	930-1080	750	8	286-321
2	AIR 9160	Z30C13	HARDEN: 980-1000° C, OIL QUENCH/ AIR COOL TEMPER: >580° C, AIR COOL	H&T	880-1080	690	10	262-326
3	AMS 5655	-	HARDEN:1052° C, OIL QUENCH TEMPER: HEAT TO 593° C COOL TO 538DEG C THEN, AIR COOL	H&T	965	793	13	293-341

Endurance Limit : 50% of UTS

Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO

Data Sheet for Rationalization of Metallic Materials - Steel

General Grade of material :			35CD4	Type of Material:	Ni-Cr-Mo Steel		Number of identified specifications	3
Rationalization for use:			FORGING STOCK					
Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	AIR-9160	35CD4	AMS 6348	-	Forging Stock	3	1	-
2	AMS 6348	-						
3	CCT-00308	35CD4						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)									
				C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Fe
1	AIR-9160	35CD4	FRENCH	0.3-0.37	0.5-0.8	0.15-0.4	0.02	0.025	0.4	0.9-1.2	0.15-0.3	-	Base
2	AMS 6348	-	AMERICAN	0.28-0.33	0.4-0.6	0.15-0.35	0.025	0.025	0.25	0.8-1.1	0.15-0.25	0.35	Base
3	CCT-00308	35CD4	TURBOMECA	0.3-0.37	0.5-0.8	0.15-0.4	0.02	0.025	0.4	0.9-1.2	0.15-0.3	-	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% P.S.(MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	AIR-9160	35CD4	HARDEN: 840-860° C, OIL QUENCH TEMPER: 580° C, AIR COOL	H&T	880-1080	740	12	30 6 daj/cm^2	267-324
2	AMS 6348	-	HARDEN: 840-860° C, OIL QUENCH TEMPER: 580° C, AIR COOL Heat treatment and mechanical properties are from established data	H&T	880-1080	740	12	30 6 daj/cm^2	267-324
3	CCT-00308	35CD4	HARDEN: 850° C, OIL QUENCH TEMPER: 550° C, OIL QUENCH	H&T	1080-1280	930	10	25 5 daj/cm^2	-

Endurance Limit : 50% of UTS

Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO

Data Sheet for Rationalization of Metallic Materials - Steel

General Grade of material :	CMV STEEL	Type of Material:	Cr-Mo Steel	Number of identified specifications	4
Rationalization for use:	FORGING STOCK				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	MSRR 6012 (Made from MSRR 6911)	-	BS S132/ MDN 132A (Indigenised)	-	Forging Stock	5	2	1. MSRR 6911 is forging stock can be used to make forgings of MSRR 6012 and MSRR 6011 2. Other equivalent specifications for MDN 132A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	MSRR 6011 (Made from MSRR 6910)	-						
3	MSRR 6100	-						
4	BS S 132	-						
5	MDN 132A (Indigenised)	-						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)											
				C	Mn	Si	S	P	Ni	Cr	Mo	Sn	V	Others: Each	Fe
1	MSRR 6012 (Made from MSRR 6911)	-	BRITISH	0.35-0.43	0.4-0.7	0.1-0.35	0.01	0.015	0.3	3.0-3.5	0.8-1.1	0.025	0.15-0.25	P+Sn 0.025	Base
2	MSRR 6011 (Made from MSRR 6910)	-	BRITISH	0.35-0.43	0.4-0.7	0.1-0.35	0.02	0.02	0.3	3.0-3.5	0.8-1.1	0.025	0.15-0.25	P+Sn 0.025	Base
3	MSRR 6100	-	BRITISH	0.35-0.43	0.4-0.7	0.1-0.35	0.01	0.015	0.3	3.0-3.5	0.8-1.1	0.025	0.15-0.25	P+Sn 0.025	Base
4	BS S 132	-	BRITISH	0.35-0.43	0.4-0.7	0.1-0.35	0.02	0.02	0.3	3.0-3.5	0.8-1.1	0.03	0.15-0.25	-	Base
5	MDN 132A (Indigenised)	-	Indian	0.4C-0.5Mn-3Cr-0.9Mo-Bal Fe as per CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)											

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	MSRR 6012 (Made from MSRR 6911)	-	HARDEN AT 930-950° C, OIL QUENCH TEMPER AT 590-620° C., AIR COOL	H&T	1240-1390	1030	10	-	363-401
2	MSRR 6011 (Made from MSRR 6910)	-	HARDEN AT 930-950° C, OIL QUENCH TEMPER AT 580-610° C., AIR COOL	H&T	1320-1470	1130	8	-	388-429
3	MSRR 6100	-	HARDEN AT 930-950° C, OIL QUENCH TEMPER AT 580-610° C., AIR COOL	H&T	1320-1470	1130	8	-	388-429
4	BS S 132	-	HARDEN AT 950° C, OIL QUENCH TEMPER AT 600° C., AIR COOL	H&T	1320-1470	1130	8	27.1 20 ft lbf	388-429
5	MDN 132A (Indigenised)	-	Refer CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)						

Fatigue Data in H&T condition (Extracted from Book: Aerospace Materials by Balram Gupta, Minimum values are taken for MDN 132A)
Test Condition : R= -1, Wave form: Sine, Rotating beam bending, Temperature : Room Temperature, Specimen type : Unnotched
Stress: 552 MPa, No of cycles : 30 X 10^6 (min)

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material			**Ni-Cr-Mo Steel**	**Type of Material:**	**Ni-Cr-Mo Steel**		**Number of identified specifications**	**3**
Rationalization for use:			**FORGING STOCK**					
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl No.	**Specification**	**Grade**	**Specification**	**Grade**	**Form**			
1	BS S95	-	BS S95	-	Forging Stock	**3**	**1**	1. MSRR 6036 is Obsolete. MSRR 6017 is alternate to MSRR 6036 as per MSRR 6036.
2	MSRR 6017	-						
3	MSRR 6036 (Obsolete) MSRR 6017 IS ALTERNATE TO MSRR 6036)	-						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)								
				C	Mn	Si	S	P	Ni	Cr	Mo	Fe
1	BS S95	-	BRITISH	0.36-0.44	0.45-0.7	0.15-0.35	0.02	0.025	1.3-1.7	1.1-1.4	0.2-0.35	Base
2	MSRR 6017	-	BRITISH	0.36-0.44	0.45-0.7	0.15-0.35	0.02	0.025	1.3-1.7	1.1-1.4	0.2-0.35	Base
3	MSRR 6036 (Obsolete) MSRR 6017 IS ALTERNATE TO MSRR 6036)	-	BRITISH	0.36-0.44	0.45-0.7	0.15-0.35	0.02	0.025	1.3-1.7	1.1-1.4	0.2-0.35	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	BS S95	-	HARDEN: 830-850° C, OIL QUENCH TEMPER: 580 ° C., AIR COOL	H&T	786 -965	607	12	45 40 (ft lbf)	255-321
2	MSRR 6017	-	HARDEN: 830-850° C, OIL QUENCH TEMPER: 630-660 ° C., AIR COOL	H&T	850-930	700	16	54	248-286
3	MSRR 6036 (Obsolete) MSRR 6017 IS ALTERNATE TO MSRR 6036)	-	HARDEN: 830-850° C, OIL QUENCH TEMPER: 570- 610 ° C., AIR COOL	H&T	1000-1160	900	13	41	301-341
Endurance Limit : 50% of UTS Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO									

Data Sheet for Rationalization of Metallic Materials - Steel

General Grade of material			4130 STEEL	Type of Material:	Cr-Mo Steel		Number of identified specifications	6
Rationalization for use:			FORGING STOCK					
Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	MIL-S-6758 (Obsolete. Superseded by AMS-S-6758)	4130	AMS-S-6758/ MDN6758A	4130	Forging Stock	6	2	1. Other equivalent specifications for MDN 6758A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials) 2. Sl.No. 7 specified as Equivalent to MIL-S-6758 as per RCMA(Nsk)/07/01 dated 27.09.2007.
2	AMS-S-6758	4130						
3	AIR-9160C	25CD4S						
4	BS S142	-						
5	AMS 6370	4130						
6	MDN6758A (Indigenised)	-						
7	G-4543-71	30KHMA						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)									
				C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Fe
1	MIL-S-6758 (Obsolete. Superseded by AMS-S-6758)	4130	American	0.28-0.33	0.4-0.6	0.2-0.35	0.025	0.025	0.25	0.8-1.1	0.15-0.25	-	Base
2	AMS-S-6758	4130	American	0.28-0.33	0.4-0.6	0.15-0.35	0.025	0.025	0.25	0.8-1.1	0.15-0.25	0.35	Base
3	AIR-9160C	25CD4S	French	0.22-0.29	0.4-0.8	0.1-0.25	0.015	0.02	0.3	0.9-1.2	0.15-0.25	-	Base
4	BS S142	-	British	0.22-0.29	0.5-0.8	0.15-0.35	0.015	0.02	0.3	0.9-1.2	0.15-0.25	-	Base
5	AMS 6370	4130	American	0.28-0.33	0.4-0.6	0.15-0.35	0.025	0.025	0.25	0.8-1.1	0.15-0.25	0.35	Base
6	MDN6758A (Indigenised)	-	Indian	0.3C-1Cr-0.2Mo-Bal Fe as per CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)									
7	G-4543-71	30KHMA	RUSSIAN	0.26-0.33	0.4-0.7	0.17-0.37	0.025	0.025	0.3	0.8-1.1	-	0.3	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	MIL-S-6758 (Obsolete. Superseded by AMS-S-6758)	4130	Harden at 845-885°.C Quench in Oil/Water Temper to achieve the properties	HT	861	689	17	-
2	AMS-S-6758	4130	Harden at 845-885°.C Quench in Oil/Water Temper to achieve the properties	HT	861	689	17	-
3	AIR-9160C	25CD4S	HARDEN: 860-880° C, OIL QUENCH TEMPER : > 520° C, AIR COOL	H&T	880-1080	690	10	264-321
4	BS S142	-	HARDEN: 830-880° C, OIL QUENCH/ WATER QUENCH TEMPER : > 520° C, AIR COOL	H&T	900-1100	700	12	269-331
5	AMS 6370	4130	Harden at 845-885°.C Quench in Oil/Water Temper to achieve the properties Heat treatment and mechanical properties are from established data	HT	861	689	17	-
6	MDN6758A (Indigenised)	-	Refer CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)					
7	G-4543-71	30KHMA	HARDEN: 880° C, OIL QUENCH TEMPER : 540° C, OIL QUENCH / WATER QUENCH	H&T	837	736	12	-

Fatigue Data in H&T condition
(Extracted from Book: Aerospace Materials by Balram Gupta, Minimum values are taken for 25CD4S)

Test Condition : R= -1, Wave form: Sine, Rotating beam bending, Temperature : Room Temperature, Specimen type : Unnotched

Stress: 295 MPa, No of cycles : 10.2 X 10^6 (min)

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material :			**2.5%Ni-Cr-Mo STEEL**	**Type of Material:**	**Ni-Cr-Mo Steel**		**Number of identified specifications**	**6**
Rationalization for use:			**FORGING STOCK**					
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl No.	**Specification**	**Grade**	**Specification**	**Grade**	**Form**			
1	BS S99	-	BS S 99/ MDN 99A	-	Forging Stock	**6**	**2**	1. Other equivalent specifications for MDN 99A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	BS S98	-						
3	BS S154	-						
4	BS S96 (Obsolete. Replaced by S154)	-						
5	BS S97	-						
6	MDN 99A	-						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)										
				C	Mn	Si	S	P	Ni	Cr	Mo	Al	Others	Fe
1	BS S99	-	BRITISH	0.36-0.44	0.45-0.7	0.1-0.35	0.015	0.025	2.3-2.8	0.5-0.8	0.45-0.65	0.015-0.06	-	Base
2	BS S98	-	BRITISH	0.36-0.44	0.45-0.7	0.1-0.35	0.02	0.025	2.3-2.8	0.5-0.8	0.45-0.65	-	-	Base
3	BS S154	-	BRITISH	0.27-0.35	0.45-0.7	0.15-0.35	0.015	0.025	2.3-2.8	0.5-0.8	0.45-0.65	Al:0.015-0.05	-	Base
4	BS S96 (Obsolete. Replaced by S154)	-	BRITISH	0.27-0.35	0.45-0.7	0.1-0.35	0.02	0.025	2.3-2.8	0.5-0.8	0.45-0.65	-	-	Base
5	BS S97	-	BRITISH	0.27-0.35	0.45-0.7	0.1-.035	0.02	0.025	2.3-2.8	0.5-0.8	0.45-0.65	-	-	Base
6	MDN 99A	-	INDIAN	0.4C-0.7Cr-0.5Mo-2.5Ni-Bal Fe as per CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)										

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (Mpa)	0.2% Proof (Mpa)	% El (5D)	Impact (J)	Hardness (HB)
1	BS S99	-	Harden : 820-850°.C Quench in Oil Temper at 500-600°.C	H&T	1230-1420	1080	10	25	363-415
2	BS S98	-	Harden at 820-850°.C Quench in Oil Temper at 500-660°.C	H&T	1034-1172	896	10	25	341-388
3	BS S154	-	HARDEN: 850° C, OIL QUENCH TEMPER:600° C, AIR COOL	H&T	880-1080	690	12	40	255-321
4	BS S96 (Obsolete. Replaced by S154)	-	HARDEN: 850° C, OIL QUENCH TEMPER:600° C, AIR COOL	H&T	880-1080	690	12	40	255-321
5	BS S97	-	HEAT AT 820-850° C, OIL QUENCH TEMPER: 560-660° C, AIR COOL	H&T	896-1034	758	12	35	293-341
6	MDN 99A	-	Refer CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)						

Fatigue Data in H&T condition
(Extracted from Book: Aerospace Materials by Balram Gupta, Minimum values are taken for BS S154)

Test Condition : R= -1, Wave form: Sine, Rotating beam bending, Temperature : Room Temperature, Specimen type : Unnotched

Stress: 431 MPa, No of cycles : 10 X 10^6 (min)

Data Sheet for Rationalization of Metallic Materials - Steel

General Grade of material :	18/8 STEEL	Type of Material:	Stainless Steel	Number of identified specifications	8
Rationalization for use:	FORGING STOCK				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	AMS 5645	SAE 30321	AMS 5645/ MDN 347A	SAE 30321	Forging Stock	8	2	1. Other equivalent specifications for MDN 347A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	DIN 17440	X10CrNiTi189 1.4541						
3	BS S129	-						
4	BS 2S 130	-						
5	AIR 9160	Z10CNT18-11						
6	MSRR 6522	18/8						
7	MDN 347A	-						
8	G-5632-72 G-5949-75 TU14-1-378-72 G-8060-78	12KH18N10T KH18N10T						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)											
				C	Mn	Si	S	P	Ni	Cr	Mo	Ti	Cu	Others Each	Fe
1	AMS 5645	SAE 30321	American	0.08	2.0	1.0	0.03	0.04	8.0-12.0	17.0-19.0	0.75	5(C+N)-0.7	0.75	N: 0.1	Base
2	DIN 17440	X10CrNiTi189 1.4541	German	0.1	2.0	1.0	0.03	0.045	9.0-11.5	17.0-19.0	-	5C - 0.8	-	-	Base
3	BS S129	-	British	0.08	0.5-2.0	0.2-1.0	0.025	0.035	8.0-11.0	17.0-19.0	0.7	5C - 0.8	-	-	Base
4	BS 2S 130	-	British	0.08	0.5-2.0	0.2-1.0	0.025	0.035	8.0-11.0	17.0-19.0	1.0	-	-	Nb: 10xC - 1.1	Base
5	AIR 9160	Z10CNT18-11	French	0.12	2.0	1.0	0.025	0.035	10.0-13.0	17.0-19.0	-	5C - 0.8	-	-	Base
6	MSRR 6522	18/8	British	0.08	0.5-2.0	0.2-1.0	0.025	0.035	7.0-11.0	17.0-19.0	1.0	5C - 0.8	0.5	Al: 0.05 Nb:10C - 1.1	Base
7	MDN 347A	-	Indian	18Cr-8Ni-Nb(stab)-Bal Fe as per CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)											
8	G-5632-72 G-5949-75 TU14-1-378-72 G-8060-78	12KH18N10T KH18N10T	RUSSIAN	0.12	2	0.8	0.02	0.035	9.0-11.0	17.0-19.0	-	(C-0.02) - 0.7	-	-	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	AMS 5645	SAE 30321	1000-1100° C, OIL QUENCH / WATER QUENCH / AIR COOL	Solution Annealed	615 (Max)	-	-	-	187 (Max)
2	DIN 17440	X10CrNiTi189 1.4541	1020-1070° C, WATER QUENCH / AIR COOL	Solution Annealed	500-750	205	35	115 85 (ft lbf)	130-190
3	BS S129	-	1000-1100° C, OIL QUENCH / WATER QUENCH / AIR COOL	Solution Annealed	540	210	35	-	183 (Max)
4	BS 2S 130	-	1000-1100° C, OIL QUENCH / WATER QUENCH / AIR COOL	Solution Annealed	540	210	35	-	183 (Max)
5	AIR 9160	Z10CNT18-11	1050-1100° C,WATER QUENCH	Solution Annealed	490-690	210	37	50 10 (daJ/cm2)	-
6	MSRR 6522	18/8	1050-1080° C, OIL QUENCH / WATER QUENCH / AIR COOL	Solution Annealed	540	210	35	-	140-220
7	MDN 347A	-	Refer CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)						
8	G-5632-72 G-5949-75 TU14-1-378-72 G-8060-78	12KH18N10T KH18N10T	1050-1100° C, OIL QUENCH / WATER QUENCH / AIR COOL	Solution Annealed	510	196	40	-	-

Endurance Limit : 50% of UTS

Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO

Data Sheet for Rationalization of Metallic Materials - Steel

General Grade of material :			18/9 STEEL	Type of Material:	Stainless Steel		Number of identified specifications	2
Rationalization for use:			FORGING STOCK					
Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	MDN 321A	-	AMS 5646/MDN 321A	SAE 30347	Forging stock	2	1	1. Other equivalent specifications for MDN 321A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	AMS 5646	SAE 30347						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)								
				C	Mn	Si	S	P	Ni	Cr	Others Each	Fe
1	MDN 321A	-	Indian	18Cr-10Ni-Ti-Bal Fe as per CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)								
2	AMS 5646	SAE 30347	American	0.12	2.0	1.0	0.025	0.035	10.0-13.0	17.0-19.0	Ti: 5C - 0.8	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	MDN 321A	-	Refer CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)					
2	AMS 5646	SAE 30347	SOLUTION ANNEALING: 1000-1100° C, OIL QUENCH / WATER QUENCH / AIR COOL	Solution Annealed	490-690	210	37	-
Endurance Limit : 50% of UTS Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO								

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material :			**17-4 PH STEEL**	**Type of Material:**	**PH Steel**		**Number of identified specifications**	**3**
Rationalization for use:			**FORGING STOCK**	**Shape**			**FORGING STOCK**	
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl No.	**Specification**	**Grade**	**Specification**	**Grade**	**Form**			
1	AMS 5643	17-4 PH	AMS 5622/ MDN 174A	17-4 PH	Forging stock	**3**	**2**	1. Other equivalent specifications for MDN 174A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	AMS 5622	17-4 PH						
3	MDN 174A (Indigenised)	17-4 PH						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)										
				C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Others: Each	Fe
1	AMS 5643	17-4 PH	American	0.07	1.0	1.0	0.03	0.04	3.0-5.0	15.0-17.5	0.5	3.0-5.0	Cb: 5xC-0.45	Base
2	AMS 5622	17-4 PH	American	0.07	1.0	1.0	0.015	0.025	3.0-5.0	15.0-17.5	0.5	3.0-5.0	Cb: 5xC-0.45	Base
3	MDN 174A (Indigenised)	17-4 PH	Indian	0.07	1.0	1.0	0.025	0.025	3.0-5.0	15.0-17.0	0.5	3.0-5.0	Cb+Ta: 5xC-0.45	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	AMS 5643	17-4 PH	Solution Treat: 1038°.C, OIL QUENCH. PPT 1) 482±5°.C for 1hr 2) 496±5°.C for 4hr 3)552±5°.C for 4hr 4)578±5°.C for 4hr 5)593±5°.C for 4hr 6)621±5°.C for 4hr	 H900 H925 H1025 H1075 H1100 H1150	 1310 1172 1069 1000 965 931	 1172 1069 1000 862 793 724	 10 10 12 13 14 16	 388-441 375-429 331-409 311-275 302-363 277-365
2	AMS 5622	17-4 PH	Solution Treat: 1038°.C , OIL QUENCH PPT 1) 482±5°.C for 1hr 2) 496±5°.C for 4hr 3)552±5°.C for 4hr 4)579±5°.C for 4hr 5)593±5°.C for 4hr 6)621±5°.C for 4hr	 H900 H925 H1025 H1075 H1100 H1150	 1310 1172 1069 1000 965 931	 1172 1069 1000 862 793 724	 10 10 12 13 14 16	 388-444 375-429 331-401 311-375 302-363 277-352
3	MDN 174A (Indigenised)	17-4 PH	Solution Treat at 1040±15°.C for 30-60mts, Cool below 30°.C PPT 1) 550±5°.C for 4hr 2) 620±5°.C for 4hr	 H1025 H1150	 1069 931	 1000 724	 12 16	 -

Fatigue Data in H900 condition (Extracted from MMPDS, Minimum values assumed 10% less than mean value)	
Test Condition : R= -1, Wave form: Sine, Load Direction : Axial, Temperature : Room Temperature, Frequency: 1800 cpm, Specimen type : Unnotched	
1. Stress: 925 MPa, No of cycles : 1,00,000 (min)	2. Stress: 681 MPa, No of cycles : 10,00,000 (min)

Data Sheet for Rationalization of Metallic Materials - Steel

General Grade of material :	SAE 51431	Type of Material:	Stainless Steel	Number of identified specifications	8
Rationalization for use:	FORGING STOCK				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	BS S 80	-	AMS 5628/ MDN 431A	SAE 51431	Forging Stock	8	2	1. Other equivalent specifications for MDN 431A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	MSRR 6573	-						
3	AIR 9160	Z15CN17-03						
4	AMS 5628	SAE 51431						
5	DIN 17440	X22CrNi17 1.4057						
6	MIL-S-18732	431						
7	MDN 431A	-						
8	TU14-1-377-72	14KH17N2 1KH17N2						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)										
				C	Mn	Si	S	P	Ni	Cr	Mo	Cu	Others Each max	Fe
1	BS S 80	-	British	0.12-0.20	1.0	1.0	0.025	0.03	2.0-3.0	15.0-18.0	0.3	0.3	Sn 0.02 Co: 0.05 Nb:0.05 Sn: 0.02 Ti:0.05 V:0.2 W: 0.05	Base
2	MSRR 6573	-	British	0.12-0.2	1.0	1.0	0.025	0.03	2.0-3.0	15.0-18.0	0.3	0.3	Sn 0.02 Co: 0.05 Nb:0.05 Sn: 0.02 Ti:0.05 V:0.2 W: 0.05	Base
3	AIR 9160	Z15CN17-03	French	0.12-0.2	1.0	1.0	0.025	0.035	2.0-3.0	15.0-18.0	-	-	-	Base
4	AMS 5628	SAE 51431	American	0.12-0.17	0.3-0.8	0.2-0.6	0.03	0.04	2.0-3.0	15.5-16.5	0.25	0.5	N: 0.1	Base
5	DIN 17440	X22CrNi17 1.4057	German	0.15-0.23	1.0	1.0	0.03	0.045	1.5-2.5	16.0-18.0	-	-	-	Base
6	MIL-S-18732	431	American	0.12-0.17	0.3-0.8	0.2-0.6	0.03	0.04	1.5-2.5	15.5-17.0	-	-	-	Base
7	MDN 431A	-	Indian	0.16C-17Cr-2.5Ni-Bal Fe as per CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)										
8	TU14-1-377-72	14KH17N2 1KH17N2	RUSSIAN	0.11-0.17	0.3-0.8	0.8	0.025	0.025	1.5-2.5	16-18	-	-	-	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	BS S 80	-	Harden at 1000-1020°.C Quench in oil Temper at 640-660° C OQ/WQ Re-Temper at 620-640°.C	H&T	880-1080	690	12	255-321
2	MSRR 6573	-	HARDEN: 1000-1020°.C, OIL QUENCH TEMPER 1: 640-660°.C, OIL QUENCH/ WATER QUENCH TEMPER 2: 620-640°.C, OIL QUENCH/ WATER QUENCH	H&T	880-1080	690	12	255-321
3	AIR 9160	Z15CN17-03	HARDEN: 1000-1030° C, OIL QUENCH TEMPER : 300-380° C, AIR COOL	H&T	1350	1050	10	388
4	AMS 5628	SAE 51431	Harden at 1024°.C Quench in oil Temper at 288° C.	H&T	1379	1034	10	-
5	DIN 17440	X22CrNi17 1.4057	HARDEN: 1000-1050° C, OIL QUENCH TEMPER: 630 -720° C, AIR COOL	H&T	800-950	600	9	225-275
6	MIL-S-18732	431	HARDEN: 1000-1020°.C, OIL QUENCH TEMPER 1: 640-660°.C, OIL QUENCH/ WATER QUENCH TEMPER 2: 620-640°.C, OIL QUENCH/ WATER QUENCH	H&T	880-1080	690	12	255-321
7	MDN 431A	-	Refer CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)					
8	TU14-1-377-72	14KH17N2 1KH17N2	HARDEN: 1010-1030°.C, OIL QUENCH TEMPER : 670-690°.C, AIR COOL	H&T	834	687	16	269-302

Endurance Limit : 50% of UTS

Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO

Data Sheet for Rationalization of Metallic Materials - Steel

General Grade of material :	-	Type of Material:	Nitriding Steel	Number of identified specifications	7
Rationalization for use:	FORGING STOCK				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade				
1	BS 4S 106	-	AIR 9160	30CD12	Forging Stock	7	2	1. MSRR 6001 and MSRR 6002 superseded to RRMS 31018/1 and RRMS 31018/2. RRMS 31018 is forging stock. RRMS 31018/1 and RRMS 31018/2 is forging specification. Any stock with MSRR 6001 and MSRR 6002 can also be used.
2	AIR 9160	30CD12						
3	MSRR 6001/ (MSRR 6001 SUPERSEDED TO RRMS 31018/1)	-						
4	CCT LA 239	30CD12						
5	MSRR 6002/ (MSRR 6002 SUPERSEDED TO RRMS 31018/2)	-						
6	RRMS 31018 (Forging stock specification)	RRMS 31018/1 RRMS 31018/2						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)									
				C	Mn	Si	S	P	Ni	Cr	Mo	Others: Each	Fe
1	BS 4S 106	-	British	0.2-0.28	0.4-0.7	0.1-0.35	0.02	0.02	0.3	3.0-3.5	0.5-0.7	Sn: 0.03	Base
2	AIR 9160	30CD12	French	0.28-0.35	0.4-0.7	0.1-0.4	0.02	0.025	0.3	2.8-3.3	0.3-0.5	-	Base
3	MSRR 6001/ (MSRR 6001 SUPERSEDED TO RRMS 31018/1)	-	BRITISH	0.2-0.28	0.4-0.7	0.1-0.35	0.02	0.02	0.3	3.0-3.5	0.5-0.7	Sn: 0.03 P+S+Sn:0.04	Base
4	CCT LA 239	30CD12	TURBOMECA	0.28-0.35	0.4-0.7	0.1-0.4	0.02	0.025	0.3	2.8-3.3	0.3-0.5	-	Base
5	MSRR 6002/ (MSRR 6002 SUPERSEDED TO RRMS 31018/2)	-	BRITISH	0.2-0.28	0.4-0.7	0.1-0.35	0.02	0.02	0.3	3.0-3.5	0.5-0.7	Sn: 0.03 P+S+Sn:0.04	Base
6	RRMS 31018 (Forging stock specification)	RRMS 31018/1 RRMS 31018/2	BRITISH	0.2-0.28	0.4-0.7	0.1-0.35	0.02	0.02	0.3	3.0-3.5	0.5-0.7	Sn: 0.03 P+S+Sn:0.04	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	BS 4S 106	-	Harden at 890-910°.C Quench in oil Temper at 570°.C AC	H&T	930-1080	740	13	-
2	AIR 9160	30CD12	Harden at 890-910°.C Quench in oil Temper > 625°.C, Air cool	H&T	930-1080	780	14	-
3	MSRR 6001/ (MSRR 6001 SUPERSEDED TO RRMS 31018/1)	-	HARDEN : 900° C, OIL QUENCH TEMPER: 580- 630° C, AIR COOL/ WATER QUENCH	H&T	910-1130	760	13	269-341
4	CCT LA 239	30CD12	HARDEN : 900° C, OIL QUENCH TEMPER : 600° C, AIR COOL	H&T	930 - 1080	780	14	269-317
5	MSRR 6002/ (MSRR 6002 SUPERSEDED TO RRMS 31018/2)	-	HARDEN : 900° C, OIL QUENCH TEMPER: 550 - 600° C, AIR COOL/ WATER QUENCH	H&T	1090-1300	980	11	352-388
6	RRMS 31018 (Forging stock specification)	RRMS 31018/1 RRMS 31018/2	HARDEN : 900° C, OIL QUENCH RRMS 31018/1: TEMPER: 580 - 630° C, AIR COOL/ WATER QUENCH RRMS 31018/2 : TEMPER: 550 - 600° C, AIR COOL/ WATER QUENCH	H&T	910-1130 1090-1300	760 980	13 11	269-341 352-388
Fatigue Data in H&T condition (Extracted from Book: Aerospace Materials by Balram Gupta, Minimum values are taken for 30CD12)								
Test Condition : R= -1, Wave form: Sine, Rotating beam bending, Temperature : Room Temperature, Specimen type : Unnotched								
Stress: 440 MPa, No of cycles : 10.1 X 10^6 (min)								

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material :			**16NCD17**	**Type of Material:**	**Case Hardening Steel**	**Number of identified specifications**		**3**
Rationalization for use:			**FORGING STOCK**					
Rationalized specifications								
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl No.	**Specification**	**Grade**	**Specification**	**Grade**	**Form**			
1	AIR 9160	16NCD17	BS S82	-	Forging Stock	**3**	**1**	-
2	BS S82	-						
3	MSRR 6009	-						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)								
				C	Mn	Si	S	P	Ni	Cr	Mo	Fe
1	AIR 9160	16NCD17	French	0.14-0.18	0.35-0.45	0.1-0.3	0.02	0.025	4.0-4.5	1.0-1.3	0.15-0.35	Base
2	BS S82	-	British	0.14-0.18	0.25-0.55	0.15-0.40	0.02	0.025	3.8-4.3	1.0-1.4	0.2-0.3	Base
3	MSRR 6009	-	British	0.14-0.18	0.25-0.55	0.15-0.4	0.015	0.015	3.8-4.3	1.0-1.4	0.2-0.3	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	AIR 9160	16NCD17	Blank Carburize at 880-900°.C Cool in air/OQ Harden at 840°.C Quench in oil. Temper 1: 760° C, OIL QUENCH TEMPER 2: 190° C, AIR COOL	H&T	1180	830	8	30 6 daJ/cm2	388-429
2	BS S82	-	Blank Carburize at 888-930°.C Cool in air/OQ Harden at 815-835°.C Quench in oil. SUB ZERO TREATMENT AT -60 to -80°.C Temper at 190±5°.C Cool in air	H&T	1320-1520	1030	8	34 25 ft lbf	-
3	MSRR 6009	-	HARDEN: 820° C, OIL QUENCH TEMPER : 190° C, AIR COOL	H&T	1320-1520	1030	8	33	388-444
Endurance Limit : 50% of UTS Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO									

Data Sheet for Rationalization of Metallic Materials - Steel									
General Grade of material :			High Alloy Steel	Type of Material:	15 Cr- 25 Ni		Number of identified specifications		4
Rationalization for use:			FORGING STOCK						
Identified specifications			Rationalized to		Shape		Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form				
1	AMS 5731	-	AMS 5737	-	Forging Stock		4	1	-
2	AMS 5732	-							
3	AMS 5734	-							
4	AMS 5737	-							

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				C	Mn	Si	S	P	Ni	Cr	Mo	V	Co	Ti	Others Each	Fe
1	AMS 5731	-	American	0.08	2.0	1.0	0.025	0.025	24.0-27.0	13.5-16.0	1.0-1.5	0.1-0.5	1.0	1.9-2.35	B: 0.003-0.01 Cu: 0.5 Al: 0.35	Base
2	AMS 5732	-	American	0.08	2.0	1.0	0.025	0.025	24.0-27.0	13.5-16.0	1.0-1.5	0.1-0.5	1.0	1.9-2.35	B: 0.003-0.01 Cu: 0.5 Al: 0.35	Base
3	AMS 5734	-	American	0.08	2.0	1.0	0.025	0.025	24.0-27.0	13.5-16.0	1.0-1.5	0.1-0.5	1.0	1.9-2.35	B: 0.003-0.01 Cu: 0.5 Al: 0.35	Base
4	AMS 5737	-	American	0.08	2.0	1.0	0.025	0.025	24.0-27.0	13.5-16.0	1.0-1.5	0.1-0.5	1.0	1.9-2.35	B: 0.003-0.01 Cu: 0.5 Al: 0.35	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)			
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Hardness (HB)
1	AMS 5731	-	Solution Treat at 980°.C Water/Oil Quench Ppt at 720°.C for 16hrs min, Air cool	ST+PPT	895	585	15	248-341
2	AMS 5732	-	Solution Treat at 982±14°.C Water/Oil Quench Ppt at 704-760°.C for 16hrs min, Air cool	ST+PPT	896	586	15	248-341
3	AMS 5734	-	Solution Treat at 899±14°.C Water/Oil Quench Ppt at 718±8°.C for 16hrs min, Air cool	ST+PPT	965	655	12	277-363
4	AMS 5737	-	Solution Treat at 899°.C Water/Oil Quench Ppt at 704-760°.C for 16hrs min, Air cool	ST+PPT	965	655	12	277-363

Endurance Limit : 50% of UTS

Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material :			**SAE 51410**	**Type of Material:**	**Cr-Mo Steel**		**Number of identified specifications**	**3**
Rationalization for use:			**FORGING STOCK**					
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl No.	**Specification**	**Grade**	**Specification**	**Grade**	**Form**			
1	AIR 9160	Z12CN13	AMS 5613	SAE 51410	Forging Stock	**3**	**1**	-
2	CCT LA 37	EN Z12CN13						
3	AMS 5613	SAE 51410						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)									
				C	Mn	Si	S	P	Ni	Mo	Cr	Others	Fe
1	AIR 9160	Z12CN13	FRENCH	0.12-0.15	0.3-0.6	0.8	0.025	0.035	0.3-0.8	-	11.5-13.0	-	Base
2	CCT LA 37	EN Z12CN13	FRENCH	0.10-0.15	0.3-0.8	0.8	0.025	0.035	0.3-0.8	-	11.5-13.0	-	Base
3	AMS 5613	SAE 51410	AMERICAN	0.12-0.15	1.0	1.0	0.03	0.04	0.8	0.5	11.5-13.5	Al: 0.05 N:0.08 Cu: 0.5 Sn:0.05	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	AIR 9160	Z12CN13	HARDEN: 980 -1000° C, WATER QUENCH TEMPER: > 640° C, AIR COOL	H&T	590-790	410	-	40 8 daJ/cm2	174-235
2	CCT LA 37	EN Z12CN13	HARDEN: 980 -1000° C, WATER QUENCH TEMPER: > 640° C, AIR COOL Heat treatment and mechanical properties are from established data	H&T	590-790	410	-	40 8 daJ/cm2	174-235
3	AMS 5613	SAE 51410	ANNEAL : 954° C, AIR COOL	A	800 (Max)	-	-	-	241 (Max)
Endurance Limit : 50% of UTS Ref: Mechanical Properties of Engineering Materials by Wole Soboyeio and Machine Design Data by ADEKO									

Data Sheet for Rationalization of Metallic Materials - Steel								
General Grade of material			Cr-Mo Steel	Type of Material:	Cr-Mo Steel		Number of identified specifications	2
Rationalization for use:			FORGING STOCK					
Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl No.	Specification	Grade	Specification	Grade	Form			
1	ZFNL 9201	-	MDN 9201A	-	Forging Stock	2	1	-
2	MDN 9201A (Indigenised)	-						

Sl No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)									
				C	Mn	Si	S	P	Ni	Mo	Cr	Others	Fe
1	ZFNL 9201	-	GERMAN	0.15-0.19	0.4-0.6	0.35	0.015	0.015	1.4-1.7	0.1	1.4-1.7	Cu: 0.2 Al: 0.045	Base
2	MDN 9201A (Indigenised)	-	INDIAN	0.15-0.19	0.4-0.6	0.35	0.005	0.015	1.4-1.7	0.1	1.4-1.7	Cu: 0.2 Al: 0.045	Base

Sl No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)				
					UTS (MPa)	0.2% P.S. (MPa)	% El (5D)	Impact (J)	Hardness (HB)
1	ZFNL 9201	-	HARDEN: 840° C, OIL QUENCH TEMPER: 150° C, AIR COOL	H&T	1100-1500	750	7	9 1.8 daJ/cm2	320
2	MDN 9201A (Indigenised)	-	HARDEN: 840° C, OIL QUENCH TEMPER: 150° C, AIR COOL	H&T	1100-1500	750	7	41	327
Fatigue Data in H&T condition (Extracted from DTS- MDN 9201A, Minimum values are taken for MDN 9201A)									
Test Condition : R= -1, Wave form: Sine, Rotating beam bending, Temperature : Room Temperature, Specimen type : Unnotched									
Stress: 525 MPa, No of cycles : 1 X 10^7 (min)									

PART-3: Titanium Alloys

Data Sheet for Rationalization of Metallic Materials - Titanium Alloys

General Grade of material :	TA6ZrD	Type of Material:	Ti-Al-Zr-Mo-Si alloy	Number of identified specification:	6
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	CCT 00202	TA6ZrD	TITAN 26A	-	Forging Stock	6	1	-
2	MSRR 8616	-						
3	BS TA 43 (withdrawn)	-						
4	BS TA 44 (withdrawn)	-						
5	GTM Ti-685 (Indigenised)	-						
6	TITAN 26A (Indigenised)	-						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)													
				Fe	H	Al	Cu	Mn	Sn	Zr	Mo	Si	V	Others (each)		Others (total)	Ti
1	CCT 00202	TA6ZrD	French	0.05	60 ppm	5.7-6.3	-	-	-	4.5-6.0	0.25-0.75	0.15-0.35 (for ingots/ forging stock), 0.15-0.40 (for forgings)	-	O=009-0.19 N= 0.03 C= 0.08	Y=10 ppm B = 50 ppm, Others (each) = 0.1	0.2	Base
2	MSRR 8616	-	British	0.2	0.006 (for forging stock) 0.013 (for forgings)	5.7-6.3	-	-	-	4.5-6.0	0.25-0.75	0.10-0.40	-	O=0.19 N=0.05	C=0.08, Y=0.005	-	Base
3	BS TA 43 (withdrawn)	-	British	0.2	0.006	5.7-6.3	-	-	-	4.0-6.0	0.25-0.75	0.10-0.40	-	C=0.08 O=0.19	N=0.05	-	Base

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%)(wherever limit not mentioned consider as max)													
				Fe	H	Al	Cu	Mn	Sn	Zr	Mo	Si	V	Others (each)		Others (total)	Ti
4	BS TA 44 (withdrawn)	-	British	0.2	0.01	5.7-6.3	-	-	-	4.0-6.0	0.25-0.75	0.10-0.40	-	C=0.08 O=0.25	N=0.05	-	Base
5	GTM Ti-685 (Indigenised)	-	Indian	0.2	60 ppm for forging stock, 100 ppm for forging	5.7-6.3	-	-	-	4.5-6.0	0.25-0.75	0.1-0.4	-	C=0.08 O=0.09-0.19	N=0.05 , Others (each) = 0.1	0.4	Base
6	TITAN 26A (Indigenised)	-	Indian	0.05	60 ppm [100 ppm for forging]	5.7-6.3	-	-	-	4.5-6.0	0.25-0.75	0.15-0.35	-	C=0.08 O=0.09-0.19	N=0.03 Y = 0.001 Others (each) = 0.1	0.2	Base

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	OTHERS	Remarks
1	CCT 00202	TA6ZrD	Solution treat: 1050°C / ≥30 minutes / OQ or equivalent Ppt: 550°C / 24 hr / AC	Solutionize + Ppt	990 (at RT)	850 (at RT)	6 (at RT) [@ 50 mm]	15 [at RT]	Notched / Plain tensile strength≥ 1.3 (at RT)	-
					620 (at 520°C)	480 (at 520°C)	9 (at 520°C) [@ 50 mm]	20 [at 520°C]	Creep test: Temperature= 520°C, Stress= 300 MPa, Duration ≥ 100 hours, Plastic strain = 0.1% max. Low Cycle Fatigue (LCF) = 41.5 to 800 MPa / 2 Hz / Sinusoidal/ ≥16000 cycles (at RT)	
2	MSRR 8616	-	Solution treat: 1050°C / ≥30 minutes / OQ Age: 550°C / 24 hr / AC. Stress relieve: 950-1000°C / 3 hrs max. / AC	Solutionize + Age	990-1140 (at RT)	850 (at RT)	6 (at RT)	15 [at RT]	-	-
					620-780 (at 520°C)	480 (at 520°C)	9 (at 520°C)	20 [at 520°C]		
3	BS TA 43 (withdrawn)	-	Solution treat: 1050°C / 30 minutes per 25 mm / OQ Age: 550±5°C / 24 hr / AC. Stress relieve: 900-1000°C / 3 hrs max. / AC	Solutionize + Age	990-1140 (at RT)	850 (at RT)	6 (at RT)	15 [at RT]	Creep test: Temperature= 520°C, Stress= 300 MPa, Duration ≥ 100 hours, Plastic strain = 0.1% max.	-
					620-780 (at 520°C)	480 (at 520°C)	9 (at 520°C)	20 [at 520°C]		
4	BS TA 44 (withdrawn)	-	Solution treat: 1050°C / 30 minutes per 25 mm / OQ Age: 550±5°C / 24 hr / AC. Stress relieve: 900-1000°C / 3 hrs max. / AC	Solutionize + Age	990-1140 (at RT)	850 (at RT)	6 (at RT)	15 [at RT]	-	-
					620-780 (at 520°C)	480 (at 520°C)	9 (at 520°C)	20 [at 520°C]		

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	OTHERS	Remarks
5	GTM Ti-685 (Indigenised)	-	Solution treat: 1050°C / 30 minutes -1 hr / OQ Age: 550°C / 24 hr / AC.	Solutionize + Age	990 (at RT)	850 (at RT)	6% (at RT) [@5D]	15% [at RT]	Notched / Plain tensile strength≥ 1.35 (at RT)	Creep test (only for forgings): Temperature= 450°C, Stress= 450 MPa, Duration = 100 hours, Plastic strain = 0.1% max.
					620 (at 520°C)	480 (at 520°C)	9 (at 520°C) [@5D]	20 [at 520°C]	Creep test: Temperature= 520°C, Stress= 310 MPa, Duration = 100 hours, Plastic strain = 0.1% max.	
									Post Creep tensile test: UTS≥ 990 MPa 0.2% YS≥ 850 MPa % El(5D) ≥6 %RA ≥10	
6	TITAN 26A (Indigenised)	-	Solution treat: 1050 ±10°C / ≥30 per 25 mm ruling thickness / OQ Age: 550 ± 5°C / 24 hr	Solutionize + Age	990 (at RT)	850 (at RT)	6 (at RT) [@5D]	15 [at RT]	Notched / Plain tensile strength≥ 1.35 (at RT)	-
									Low Cycle Fatigue (LCF) = 0.1P-P (R=0.1; 0.2% PS =850 MPa) / Sinusoidal / ≥ 1 X 10^4 cycles (at RT)	
									Rotating beam fatigue testing (R=-1): 440 MPa, 1 X 10^7 cycles (at RT)	
					620 (at 520°C)	480 (at 520°C)	9 (at 520°C) [@5D]	20 [at 520°C]	Creep test: Temperature= 520°C Stress= 310 MPa Duration = 100 hours Plastic strain = 0.15% max.	
									Post Creep tensile test: UTS≥ 990 MPa 0.2% PS≥ 850 MPa % El(5D) ≥6 %RA ≥10	

Data Sheet for Rationalization of Metallic Materials - Titanium Alloys

General Grade of material :	TA8DV	Type of Material:	Ti-Al-Mo-V	Number of identified specifications	6
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	CCT LA 114	TA8DV	AMS 4972 / TITAN 22A	-	Forging Stock	6	2	1. Other equivalent specifications for TITAN 22A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	AMS 4972	-						
3	AMS 4933	-						
4	AMS-T-9047 / MIL-T-9047 (8Al-1Mo-1V) [obsolete] Superseded by AMS 6910	-						
5	AMS 4973							
6	TITAN 22A (Indigenised)	-						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)													
				Fe	H	Al	Cu	Mn	Sn	Zr	Mo	Si	V	Others (each)		Others (total)	Ti
1	CCT LA 114	TA8DV	French	0.3	0.015	7.35-8.35	0.1	-	0.2	-	0.75-1.25	0.1	0.75-1.25	O=0.20 N= 0.05 C= 0.08	Y=50 ppm B = 10 ppm Others (each) = 0.1	-	Base
2	AMS 4972	-	American	0.3	0.015	7.35-8.35	-	-	-	-	0.75-1.25	-	0.75-1.25	O=0.12 N= 0.05 C= 0.08	Y=50 ppm Others (each) = 0.1	0.4	Base
3	AMS 4933	-	American	0.3	0.015	7.35-8.35	-	-	-	-	0.75-1.25	-	0.75-1.25	O=0.12 N= 0.05 C= 0.08	Y=50 ppm Others (each) = 0.1	0.4	Base
4	AMS-T-9047 / MIL-T-9047 (8Al-1Mo-1V) [obsolete] Superseded by AMS 6910	-	American	0.3	0.015	7.35-8.35	-	-	-	-	0.75-1.25	-	0.75-1.25	O=0.15 N= 0.05 C= 0.08	Y=50 ppm Others (each) = 0.1	0.4	Base
5	AMS 4973	-	American	0.3	0.015	7.35-8.35	-	-	-	-	0.75-1.25	-	0.75-1.25	O=0.12 N= 0.05 C= 0.08	Y=50 ppm Others (each) = 0.1	0.4	Base
6	TITAN 22A (Indigenised)	-	Indian	0.3	0.015	7.35-8.35	-	-	-	-	0.75-1.25	-	0.75-1.25	O=0.20 N= 0.05 C= 0.08 Ni =0.08	Ni+Cu=0.10 Y=50 ppm Mn+Cr = 0.15 B= 0.005	0.3	Base

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
1	CCT LA 114	TA8DV	Solution anneal: 1000°C /1 hr / OQ Age: 580°C / 8 hrs / AC	Solution anneal + Age	900 (at RT)	820 (at RT)	10 (at RT) [@ 5D]	20 [at RT]	Notched / Plain tensile strength≥ 1.3 (at RT)	-
					620 (at 425°C)	480 (at 425°C)	10 (at 425°C) [@ 5D]	25 [at 425°C]	Creep test: Temperature= 455ºC, Stress= 275 MPa, Duration ≥23 hours, Plastic strain = 0.15% max.	
2	AMS 4972	-	Solution treat: 899-927°C (±14°C) OR 982-1010°C / 1 hr ± 5 minutes / AC or faster Stabilize: 566-593°C (± 8°C) / ≥ 8 hr / AC	Solution treat + Stabilize	896 (at RT)	827 (at RT)	10 (at RT) [@ 4D]	20 [at RT]	-	-
					621 (at 427°C)	483 (at 427°C)	10 (at 427°C) [@ 4D]	25 [at 427°C]		
3	AMS 4933	-	Solution treat: 982-1010°C / 1 hr ± 6 minutes / AC or faster Stabilize: 566-621°C (± 14°C) / ≥ 8 hr / AC	Solution treat + Stabilize	896 (at RT)	827 (at RT)	10 (at RT) [@ 4D]	20 [at RT]	-	-
					621 (at 427°C)	483 (at 427°C)	10% (at 427°C) [@ 4D]	25% [at 427°C]		
4	AMS-T-9047 / MIL-T-9047 (8Al-1Mo-1V) [obsolete] Superseded by AMS 6910	-	Solution treat: 899-1010°C (±14°C) / AC or faster Stabilize: 595°C (±10°C) / ≥ 8hr / AC	Duplex annealed	896	827	10 [@ 4D or 50.8 mm]	20	-	-
5	AMS 4973	-	Solution treat: 899-927°C or 982-1010°C (±10°C) / 1 hr / AC Stabilize: 566-593°C (± 10°C) / ≥8 hr / AC	Solution treat + Stabilize	896 (at RT)	827 (at RT)	10 (at RT) [@ 4D]	20 [at RT]	-	-
					621 (at 427°C)	483 (at 427°C)	10 (at 427°C) [@ 4D]	25 [at 427°C]	-	-
6	TITAN 22A (Indigenised)	-	Solution treat: 900-925°C or 980-1010°C (±10°C)/ 1 hr / AC Stabilize: 565-595°C (±10°C) / ≥8 hr / AC	Solution treat + Stabilize	896 (at RT)	827 (at RT)	10 (at RT)	20 [at RT]	Notched / Plain tensile strength≥ 1.3 (at RT)	-
					621 (at 425°C)	483 (at 425°C)	10 (at 425°C)	25 [at 425°C]	Notched Stress rupture (at RT): Stress= 1034 MPa, Time to rupture ≥5 hours	-

Data Sheet for Rationalization of Metallic Materials - Titanium Alloys

General Grade of material :			Ti-6-2-4-2/ Ti6242S	Type of Material:	Ti-Al-Sn-Zr-Mo-Si	Number of identified specifications		4
Rationalization for use:			Forging Stock					
Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	EMS 54929	-	AMS 4976/ EMS 54929	-	Forging Stock	4	2	-
2	AMS 4976	-						
3	AMS 4975	-						
4	AMS-T-9047 / MIL-T-9047 [6Al-2Sn-4Zr-2Mo] (Obsolete) Superseded by AMS 6905	-						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)													
				Fe	H	Al	Cu	Mn	Sn	Zr	Mo	Si	V	Others (each)		Others (total)	Ti
1	EMS 54929	-	American	0.08	0.0125 [0.015 for forgings]	5.7-6.3	0.02	-	1.75-2.25	3.5-4.5	1.85-2.15	0.07-0.14 Si/Fe ≥1.4	-	O=0.10-0.15 N= 0.02 C= 0.04 Ni=50 ppm Cr =0.01	Y=50 ppm B = 30 ppm Others (each) = 0.1	0.4	Base
2	AMS 4976	-	American	0.1	0.0125 [0.015 for forgings]	5.5-6.5	-	-	1.80-2.20	3.6-4.40	1.80-2.20	0.06-0.10	-	O=0.15 N= 0.05 C= 0.05	Y=50 ppm, Others (each) = 0.1	0.3	Base
3	AMS 4975	-	American	0.1	0.0125 [0.015 for rings]	5.5-6.5	-	-	1.80-2.20	3.6-4.40	1.80-2.20	0.06-0.10	-	O=0.15 N= 0.05 C= 0.05	Y=50 ppm, Others (each) = 0.1	0.3	Base
4	AMS-T-9047 / MIL-T-9047 [6Al-2Sn-4Zr-2Mo] (Obsolete) Superseded by AMS 6905	-	American	0.25	0.0125	5.5-6.5	-	-	1.80-2.20	3.6-4.40	1.80-2.20	0.13	-	O=0.15 N= 0.04 C= 0.05	Y=50 ppm, Others (each) = 0.1	0.3	Base

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	OTHERS	Remarks
1	EMS 54929	-	Solution treat: sufficiently close to β transus temp /1-2 hr / AC or faster Ppt: 593°C (±14°C) / 8 hrs / AC	Solution treat + Ppt	896 (at RT)	827 (at RT)	10 (at RT) [@ 4D]	25 [at RT]	<u>Creep test:</u> Temperature= 510°C, Stress= 448 MPa, Duration ≥ 100 hours, Plastic strain = 1.0% max.	-
					620 (at 482°C)	483 (at 482°C)	15 (at 482°C) [@ 4D]	30 [at 482°C]		
2	AMS 4976	-	Solution treat: 14-28°C (±8°C) below βtransus temp /1 hr ± 5 minutes / AC or faster Ppt: 593°C (±8°C) / 8 hr ±15 minutes / AC	Solution treat + Ppt	896 (at RT)	827 (at RT)	10 (at RT) [@ 4D]	25 [at RT]	<u>Creep test:</u> Temperature= 510°C, Stress= 241 MPa, Duration ≥ 35 hours, Plastic strain = 0.1% max.	-
					621 (at 482°C)	483 (at 482°C)	15 (at 482°C) [@ 4D]	30 [at 482°C]		
3	AMS 4975	-	Solution treat: 14-28°C (±8°C) below βtransus temp /1 hr ± 5 minutes / AC or faster Ppt: 593°C (±8°C) / 8 hr ±15 minutes / AC	Solution treat + Ppt	896 (at RT)	827 (at RT)	10 (at RT) [@ 4D]	25 [at RT]	<u>Creep test:</u> Temperature= 510°C, Stress= 241 MPa, Duration ≥ 35 hours, Plastic strain = 0.1% max.	-
					621 (at 482°C)	483 (at 482°C)	15 (at 482°C) [@ 4D]	35 [at 482°C]		
4	AMS-T-9047 / MIL-T-9047 [6Al-2Sn-4Zr-2Mo] (obsolete) Superseded by AMS 6905	-	Solution treat: 14-28°C (±8°C) below βtransus temp / AC or faster Stabliize: 595°C (±14°C) / 8 hrs min. / AC	Solution treat + Stabilize (Duplex anneal)	896	827	10 [@ 4D or 50.8 mm]	25	-	-

Data Sheet for Rationalization of Metallic Materials - Titanium Alloys

General Grade of material :	Ti64	Type of Material:	Ti-Al-V	Number of identified specifications	15
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	MSRR 8614	-	AMS 4928 / TITAN 31A	-	Forging Stock	15	2	1. Other equivalent specifications for TITAN 31A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	AMS 4928	-						
3	CCT 00166	TA6V.PQ						
4	GTM Ti-64 (Indigenised)	-						
5	AIR9183	TA6V						
6	CCT LA109	TA6V						
7	BS TA12 (Obsolete) - superseded by BS EN 3310	-						
8	BS TA13 (Obsolete) - superseded by BS EN 3312	-						
9	TITAN 31A (Indigenised)	-						
10	AMS-T-9047 / MIL-T-9047 6Al-4V (obsolete) - superseded by AMS 6931	-						
11	ASTM B 348	Grade 5, UNS R56400						
12	ASTM B 381	Grade F5, UNS R56400						
13	EMS 54930	-						
14	3.7164	-						
15	OST1 90013-81 / OST1 90173-75 / AMTY 451	BT6 / VT6						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)													
				Fe	H	Al	Cu	Mn	Sn	Zr	Mo	Si	V	Others (each)		Others (total)	Ti
1	MSRR 8614	-	British	0.3	125 ppm for bar and section for machining, 100 ppm for forging stock and 150 ppmfor forging	5.5-6.75	-	-	-	-	-	-	3.5-4.5	O=0.14-0.23 N= 0.03 C = 0.08	Y=50 ppm	-	Base
2	AMS 4928	-	American	0.3	125 ppm [150 ppmfor forgings]	5.5-6.75	-	-	-	-	-	-	3.5-4.5	O=0.20 N=0.05 C=0.08	Y=50 ppm, Others (each)= 0.10	0.4	Base
3	CCT 00166	TA6V.PQ	French	0.3	100 ppm [150 ppmfor forgings]	5.5-6.75	0.1	0.1	Sn: 0.1, Sn+Mo+Cu+ Mn+Zr=0.20%	0.1	0.1	-	3.5-4.5	O=0.22 N=0.05 C=0.08 B=10 ppm	Y=50 ppm, Others (each)= 0.10	0.2	Base

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%)(wherever limit not mentioned consider as max)												
				Fe	H	Al	Cu	Mn	Sn	Zr	Mo	Si	V	Others (each)		Others (total)	Ti
4	GTM Ti-64 (Indigenised)	-	Indian	0.3	100 ppm	6.2-6.75	0.1	0.1	0.1	0.1	0.1	-	3.5-4.5	N= 0.03 Y=0.001 O=0.16-0.20	C=0.08 B=10 ppm Others (each) = 0.1	0.2	Base
5	AIR9183	TA6V	French	0.25	125 ppm max	5.5-7.0	-	-	-	-	-	-	3.5-4.5	C=0.08 O=0.20	N=0.07	-	Base
6	CCT LA109	TA6V	French	0.3	0.010 [0.015 for forgings]	5.5-6.75	-	-	-	-	-	-	3.5-4.5	C=0.08 O=0.12-0.20	N=0.05 Y=0.005	-	Base
7	BS TA12 (Obsolete) Superseded by BS EN 3310	-	British	0.3	0.010 max	5.5-6.75	-	-	-	-	-	-	3.5-4.5	O + 2N =0.25 C=0.08	N=0.03 Y=0.005 Others (each) = 0.1	0.4	Base
8	BS TA13 (Obsolete) Superseded by BS EN 3312	-	British	0.3	0.0125 max	5.5-6.75	-	-	-	-	-	-	3.5-4.5	O + 2N =0.25 C=0.08	N=0.03 Y=0.005 Others (each) = 0.1	0.4	Base
9	TITAN 31A (Indigenised)	-	Indian	0.3	0.008	5.5-6.75	0.1	0.1	0.1	0.1	0.1	Sn + Mo + Cu + Mn + Zr = 0.2	3.5-4.5	C=0.08 O=0.15-0.20, B = 0.005	N=0.05 Y=0.005 Others (each) = 0.1	0.2	Base

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)													
				Fe	H	Al	Cu	Mn	Sn	Zr	Mo	Si	V	Others (each)		Others (total)	Ti
10	AMS-T-9047 / MIL-T-9047 6Al-4V (Obsolete) Superseded by AMS 6931	-	American	0.3	0.0125	5.5-6.75	-	-	-	-	-	-	3.5-4.5	C=0.08 , O=0.20	N=0.05 Y=0.005 Others (each) = 0.1	0.4	Base
11	ASTM B 348	Grade 5, UNS R56400	American	0.4	0.015	5.5-6.75	-	-	-	-	-	-	3.5-4.5	C=0.08 , O=0.20	N=0.05 Others (each) = 0.1	0.4	Base
12	ASTM B 381	Grade F5, UNS R56400	American	0.4	0.015	5.5-6.75	-	-	-	-	-	-	3.5-4.5	C=0.08 , O=0.20	N=0.05 Others (each) = 0.1	0.4	Base
13	EMS 54930	-	American	0.1-0.25	0.0125 [0.015 for forgings]	5.75-6.75	-	-	-	-	-	-	3.5-4.5	C=0.05 , O=0.14-0.20, O+2N=0.22	Y=50 ppm N=0.02 Others (each) = 0.1	0.4	Base
14	3.7164	-	German	0.3	0.015	5.5-6.5	-	-	-	-	-	-	3.5-4.5	O =0.20 , C=0.08	N=0.05	-	Base
15	OST1 90013-81	BT6 / VT6	Russian	0.3	0.015	5.5-6.8	-	-	-	0.3	-	0.1	3.5-5.3	O =0.20 , C=0.10	N=0.05	0.3	Base

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	OTHERS	Remarks
1	MSRR 8614	-	Anneal: 700-705°C / 1 hr min. / AC	Anneal	930-1160	830	8	25	-	For Large Forgings, a homogenization treatment of 960°C/ 1 hr min./WQ may be used prior to annealing
2	AMS 4928	-	Solutionize: 28-83°C below beta transus (±14°C)/AC or faster Anneal:704-788°C (±14°C) / 1 hr min. / cool suitably	Solutionize and anneal	931	862	10 [@4D]	25	-	
3	CCT 00166	TA6V.PQ,	For Bars & Forging Stock:- Homogenize: 955°C (±7°C) / 1 hr / WQ Anneal: 700°C (±10°C) / 2 hr / AC; For Forgings:- Homogenize: 950-970°C / WQ Anneal: 700°C (±10°C) / 2 hr / AC	Homogenize + Anneal	930 (at RT)	830 (at RT)	10 for bars and forging stock; 9 for forgings (at RT)	25 (at RT)	Notched / Plain tensile strength≥ 1.3 (at RT)	-
									Fracture toughness K_{IC}≥ 50 MPa√m (at RT)	
					650 (at 300°C)	530 (at 300°C)	9 (at 300°C)	35 (at 300°C)	Low Cycle Fatigue (LCF) = 41.5 to 830 MPa / 1-2 Hz / Sinusoidal/ ≥16000 cycles (at RT)	
4	GTM Ti-64 (Indigenised)	-	Solutionize: 950-975°C (±10°C) / 1-2 hrs / quench in agitated water. Anneal:700 (±5°C) / 30 minutes to 2 hours/AC. Stress relieve:700 (±5°C) / 30 minutes to 2 hours/AC	Solutionize + anneal + stress relief	930 (at RT)	830 (at RT)	10 (for 4D) ; 9 (for 5D) {at RT}	25 (at RT)	Hardness: 300-380 HB	-
									Notched / Plain tensile strength≥ 1.3 (at RT)	
									Fracture toughness K_{IC}≈K_Q≥ 50 MPa√m (at RT)	
					650 (at 300°C)	530 (at 300°C)	10 (for 4D) ; 9 (for 5D) {at 300°C}	35 (at 300°C)	Notched Stress rupture (at RT): Stress= 1172 MPa, Time to rupture ≥5 hours	
									Creep test: Temperature= 300°C, Stress= 500 MPa, Duration = 100 hours, Plastic strain = 0.1% max.	
									Low Cycle Fatigue (LCF) = 41.5 to 830 MPa / 1.5 Hz / Sinusoidal/ ≥10000 cycles (at RT)	

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	OTHERS	Remarks
5	AIR9183	TA6V	Anneal at 730°C (±10°C) / 1 hr / AC	Anneal	830-1130	820	10	25	Stress rupture test (at RT): Stress= 1160 MPa, Time to rupture ≥5 hours	-
6	CCT LA109	TA6V	Anneal at 730°C (±10°C) / 1 hr / AC	Anneal	880-1130 (at RT)	820 (at RT)	8 for bars, 10% for forgings {at RT} [@5D]	20 for bars, 25% for forgings (at RT)	Hardness: 300-380 HB	HT tensile is for bars only
					640 (at 300°C)	530 (at 300°C)	9 (for 5D) {at 300°C}	35 (at 300°C)	Notched / Plain tensile strength≥ 1.3 (at RT)	
7	BS TA12 (Obsolete) superseded by BS EN 3310	-	Anneal at 690-840°C / ≥30 minutes/AC or cool in inert atmosphere	Anneal	900-1160	830	10	25	-	-
8	BS TA13 (Obsolete) superseded by BS EN 3312	-	Anneal at 690-840°C / ≥30 minutes/AC or cool in inert atmosphere	Anneal	900-1160	830	10	25	-	-
9	TITAN 31A (Indigenised)	-	Solutionize: 950-970°C (±10°C) / 1-2 hrs / quench in agitated water Anneal:700°C (±10°C) / ≥2 hours / AC.	Solution + Anneal	930 (at RT)	830 (at RT)	9 (@ 5D) {at RT}	25 (at RT)	Notched / Plain tensile strength≥ 1.3 (at RT)	-
									Fracture toughness $K_{IC} \approx K_Q \geq 50$ MPa$\sqrt{m}$ (at RT)	
									Notched Stress rupture (at RT): Stress= 1276 MPa, Time to rupture ≥5 hours	Notched Stress rupture test and Creep test shall be performed in Solution and Precipitation treated condition [Solutionize: 950°C (±10°C) / 1-2 hrs / quench in agitated water + Ppt:530-540°C (±10°C) / 4-8 hours / AC]
					650 (at 300°C)	530 (at 300°C)	9 (for 5D) {at 300°C}	35 (at 300°C)	Stress rupture (at 300ºC): Stress= 700 MPa, Time to rupture ≥100 hours	
									Creep test: Temperature= 300ºC, Stress= 580 MPa, Duration = 100 hours, Plastic strain = 0.2% max.	
									Low Cycle Fatigue (LCF) = 41.5 to 830 MPa / 1-2 Hz / Sinusoidal/ ≥10000 cycles (at RT)	STA heat treatment and Mill Annealing heat treatment are two distinct operations. However, it is combined here since it is a forging stock.
									High Cycle Fatigue (HCF)- Rotating Beam = 430 MPa / R= -1 / $3x0^7$ cycles (at RT)	

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	OTHERS	Remarks
10	AMS-T-9047 / MIL-T-9047 6Al-4V (obsolete) superseded by AMS 6931	-	Anneal: 704-788°C (±14°C) / AC	Anneal	896	827	10[@4D]	25	-	-
11	ASTM B 348	Grade 5, UNS R56400	-	Anneal	895	828	10 (@ 4D)	25	-	-
12	ASTM B 381	Grade F5, UNS R56400	-	Anneal	895	828	10 (@ 4D)	25	-	-
13	EMS 54930	-	Mill Anneal as per AMS 4928	Anneal	896 (at RT)	827 (at RT)	10 (@ 4D) (at RT)	20 (at RT)	-	-
					724 (at 204°C)	593 (at 204°C)	15 (at 204°C) (@ 4D)	40 (at 204°C)		
14	3.7164	-	Anneal: 700-840°C / AC or FC	Anneal	900	830	8	20-25	Shear strength = 550-580 MPa	-
									Fracture toughness K_{IC}: LT = 1770 $Nmm^{-3/2}$, TL = 1892 $Nmm^{-3/2}$	
15	OST1 90013-81 / OST1 90173-75/ AMTY 451	BT6 / VT6	-	Anneal	902-1049	-	10	30	Stress rupture (at 400°C): Stress= 590 MPa Time to rupture ≥100 hours	-

Data Sheet for Rationalization of Metallic Materials - Titanium Alloys

General Grade of material :	Ti-6-6-2	Type of Material:	Ti-Al-V-Sn	Number of identified specifications	6
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	TA6V6E2	-	AMS 4979 / AMS 4971	-	Forging Stock	6	2	-
2	AMS-T-9047 / MIL-T-9047 [6Al-6V-2Sn] (obsolete) superseded by AMS 6935	-						
3	AMS 4971	-						
4	AMS 4979	-						
5	AMS-T-9047 / MIL-T-9047 [6Al-6V-2Sn] (obsolete) superseded by AMS 6936	-						
6	AMS 4978	-						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)													
				Fe	H	Al	Cu	Mn	Sn	Zr	Mo	Si	V	Others (each)		Others (total)	Ti
1	TA6V6E2	-	French	0.5	0.015	5.5	0.7		2.0	-	-	-	5.5	C=0.05 O =0.20	N=0.04	-	Base
2	AMS-T-9047 / MIL-T-9047 [6Al-6V-2Sn] (obsolete) superseded by AMS 6935	-	American	0.35-1.00	0.015	5.00-6.00	0.35-1.00	-	1.50-2.50	-	-	-	5.00-6.00	O=0.20 N=0.0 Y= 0.005	C=0.05 Others (each) = 0.10	0.30	Base
3	AMS 4971	-	American	0.35-1.00	0.015	5.00-6.00	0.35-1.00	-	1.50-2.50	-	-	-	5.00-6.00	O=0.20 N=0.04 Y= 0.005	C=0.05 Others (each) = 0.10	0.40	Base
4	AMS 4979	-	American	0.35-1.00	0.015	5.00-6.00	0.35-1.00	-	1.50-2.50	-	-	-	5.00-6.00	O=0.20 N=0.04 Y= 0.005	C=0.05 Others (each) = 0.10	0.40	Base
5	AMS-T-9047 / MIL-T-9047 [6Al-6V-2Sn] (obsolete) superseded by AMS 6936	-	American	0.35-1.00	0.015	5.00-6.00	0.35-1.00	-	1.50-2.50	-	-	-	5.00-6.00	O=0.20 N=0.04 Y= 0.005	C=0.05 Others (each) = 0.10	0.30	Base
6	AMS 4978	-	American	0.35-1.00	0.015	5.00-6.00	0.35-1.00	-	1.50-2.50	-	-	-	5.00-6.00	O=0.20 N=0.04 Y= 0.005	C=0.05 Others (each) = 0.10	0.40	Base

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Hardness	Remarks
1	TA6V6E2	-	-	HT	1120	1050	8	20	-	<50.0 mm size
					1070	1000	8	20	-	50-75 mm size
2	AMS-T-9047 / MIL-T-9047 [6Al-6V-2Sn] (obsolete) superseded by AMS 6935	-	Solution treat: 843-927°C (±14°C) / WQ (thin sections may be air-cooled) Age: 468-621°C (±8°C) / 2-10 hours	Solution + Age	1172	1068	8 [@4D or 50.8 mm]	20	-	25.4-50.8 mm size
					1068	999	8 [@4D or 50.8 mm]	20	-	50.8-76.2 mm size
3	AMS 4971	-	Anneal: 704 (±14°C) / 2 hrs ±15 minutes / Cool suitably. Solution treat: 899°C (±14°C) / 1 hr ± 5 minutes / Quench in agitated water Ppt: 538°C (±8°C) / 4 hrs ± 15 minutes / AC [Ppt temperature for fastener stock shall be ≥ 538°C]	Solution + Ppt	1172	1069	8 [@4D]	20	-	25.4-50.8 mm size
					1069	1000	8 [@4D]	20	-	50.8-76.2 mm size
4	AMS 4979	-	Solution treat: 857-899°C (±14°C) / 1 hr ± 5 minutes / Quench in agitated water Ppt: ≥538°C (±14°C) / ≥ 4 hours / AC	Solution + Ppt	1172	1069	8 [@4D]	20	-	25.4-50.8 mm size
					1069	1000	8 [@4D]	20	-	50.8-76.2 mm size
5	AMS-T-9047 / MIL-T-9047 [6Al-6V-2Sn] - (obsolete) superseded by AMS 6936	-	Anneal: 704-788°C (±14°C) / AC	Anneal	986	903	10 [@ 4D or 50.8 mm]	20	-	38.10-76.20 mm size
6	AMS 4978	-	Anneal: 704-788°C / 1-2 hr / Cool suitably	Anneal	1034	965-1138	10 [@ 4D or 50.8 mm]	20	-	< 50.80 mm diameter
					1000	931-1103	10 [@ 4D or 50.8 mm]	15		50.80-101.60 mm diameter

PART 4:Nickel Alloys

Data Sheet for Rationalization of Metallic Materials - Nickel Alloys

General Grade of material :	NIMONIC 263	Type of Material:	Ni-Cr-Co-Mo-Ti-Al	Number of identified specifications	7
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	MSRR 7035 [superseded by RRMS 33031, RRMS 33031/1, RRMS 33030/2, RRMS 33030/3, RRMS 33030/4]	-	AMS 5886 / BS HR10 / SUPERNI 263A	-	Forging Stock	7	3	1. Other equivalent specifications for SUPERNI 263A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	MSRR 7038 [superseded by RRMS 33045, RRMS 33045/1, RRMS 33045/2, RRMS 33045/3, RRMS 33045/4]	-						
3	BS HR 10	-						
4	AIR 9165	NCK20D						
5	AMS 5886	-						
6	GTM SU 263 (Indigenised)	-						
7	SUPERNI 263A (Indigenised)	-						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)											
				Co	Fe	C	Si	Mn	Mo	Ti	Cr	Al	Others (each)			Ni
1	MSRR 7035 [superseded by RRMS 33031, RRMS 33031/1, RRMS 33030/2, RRMS 33030/3, RRMS 33030/4]	-	British	18.5-21.0	0.8	0.04-0.08	0.4	0.6	5.6-6.1	1.9-2.4	19-21	0.3-0.6, Al+Ti = 2.4-2.9	S=0.007 Zr= 0.04 Bi= 0.0001	Cu=0.20 B = 0.005	Ag= 0.0005 Pb= 0.002	Base
2	MSRR 7038 [superseded by RRMS 33045, RRMS 33045/1, RRMS 33045/2, RRMS 33045/3, RRMS 33045/4]	-	British	18.5-21.0	0.8	0.04-0.08	0.4	0.6	5.6-6.1	1.9-2.4	19-21	0.3-0.6, Al+Ti = 2.4-2.9	S=0.007 Zr= 0.04 Bi= 0.0001	Cu=0.20 B = 0.005	Ag= 0.0005 Pb= 0.002	Base
3	BS 2HR 10	-	British	19.0-21.0	0.7	0.04-0.08	0.4	0.6	5.6-6.1	1.9-2.4	19-21	0.3-0.6, Al+Ti = 2.4-2.8	S=0.007 Zr= 0.04 Bi= 0.0001	Cu=0.20 B = 0.005	Ag= 0.0005 Pb= 0.002	Base
4	AIR 9165	NCK 20D	French	19.0-21.0	0.7	0.04-0.08	0.1-0.4	0.2-0.6	5.6-6.1	1.9-2.4	19-21	0.3-0.6, Al+Ti = 2.4-2.8	S=0.007 P= 0.015	Cu=0.20 Bi= 0.0001	Ag= 0.0005 Pb= 0.002	Base
5	AMS 5886	-	American	19.0-21.0	0.7	0.04-0.08	0.4	0.6	5.6-6.1	1.9-2.4	19-21	0.3-0.6	Al+Ti = 2.4-2.8	S=0.007 P= 0.015	Cu=0.20 B = 0.005	Base
6	GTM SU 263 (Indigenised)	-	Indian	19.0-21.0	0.7	0.04-0.08	0.4	0.6	5.6-6.1	1.9-2.4	19-21	0.3-0.6	Al+Ti = 2.4-2.8 Bi=1 ppm Ag = 5 ppm	S=0.007 Pb= 0.002	Cu=0.20 B = 0.005	Base
7	SUPERNI 263A (Indigenised)	-	Indian	18.5-21.0	0.8	0.04-0.08	0.4	0.6	5.6-6.1	1.9-2.4	19-21	0.3-0.6	Al+Ti = 2.4-2.9 Bi=1 ppm Ag = 5 ppm	S=0.007 Pb= 0.002	Cu=0.20 B = 0.005	Base

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
1	MSRR 7035 [superseded by RRMS 33031, RRMS 33031/1, RRMS 33030/2, RRMS 33030/3, RRMS 33030/4]	-	Solutionize: 1150 (±10)°C / 30 minutes for ±8 mm, 1.5-2.5 hours for >8 mm / AC or OQ or WQ Ppt: 800°C (±10°C) / 8 hrs / AC	Solutionize + Ppt	540 (at 780°C)	400 (at 780°C)	12 (at 780°C) or 13 (at 780°C for 4D)	-	Creep test: Temperature= 780°C, Stress= 120 MPa, Duration= 50 hours, Total Plastic Strain: ≤ 0.1%.	-
2	MSRR 7038 [superseded by RRMS 33045, RRMS 33045/1, RRMS 33045/2, RRMS 33045/3, RRMS 33045/4]	-	Solutionize: 1150 (±10)°C / 1 hour / AC or WQ Ppt: 800°C (±10°C) / 8 hrs / AC	Solutionize + Ppt	540 (at 780°C)	400 (at 780°C)	15 (at 780°C) or 16 (at 780°C for 4D) - for Bars/Section OR 12 (at 780°C) or 13 (at 780°C for 4D) - for Flash welded rings/finished parts	-	Creep test: Temperature= 780°C, Stress= 120 MPa, Duration=50 hours, Total Plastic Strain: ≤0.1%.	For Flash welded cold-rolled rings- Weld diffuse: 1150°C / 1 hour / AC or WQ before Solutionizing and Ppt.
3	BS HR 10	-	Solutionize: 1150 (±10)°C / 30 minutes for <8 mm, 1.5-2.5 hours for >8 mm / WQ Ppt: 800°C (±10°C) / 8 hrs / AC	Solutionize + Ppt	540 (at 780°C)	400 (at 780°C)	12 (at 780°C)	-	Creep test: Temperature= 780°C, Stress= 120 MPa, Duration= 50 hours, Total Plastic Strain: ≤0.1% [≤0.15% for cold drawn and finally heat-treated bar]	-

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
4	AIR 9165	NCK 20D	Solutionize: 1100-1150°C / WQ + Ppt: 790-810°C / 8 hrs / AC	Solutionize + Ppt	540 (at 780°C)	400 (at 780°C)	12 (at 780°C)	-	Hardness: 230 HB(min.), Creep test: Temperature= 780°C, Stress= 120 MPa, Duration= 50 hours, Total Plastic Strain: ≤0.1%	-
5	AMS 5886	-	Solutionize: 1038-1163°C (±14°C)/ AC or faster Ppt: 802°C (±8°C) / 8 hrs / AC	Solutionize + Ppt	541 (at 780°C)	403 (at 780°C)	12 [@4D] (at 780°C)	-	Creep test: Temperature= 779°C, Stress= 120 MPa, Duration= 50 hours, Total Plastic Strain: ≤0.1%	-
6	GTM SU 263 (Indigenised)	-	Solutionize: 1150°C (±10°C) / 1-2 hr / WQ or OQ Ppt: 800°C (±°C) / 8 hrs / AC	Solutionize + Ppt	540 (at 780°C)	400 (at 780°C)	12 (at 780°C) [@5D]	-	Hardness: 260 HB (min.) for bars; 235 HB (min.) for forgings & rings	-
									Creep test: Temperature= 780°C, Stress= 120 MPa, Duration= 50 hours, Total Plastic Strain: ≤0.1%	
									Stress rupture test: Temperature= 780°C, Stress= 120 MPa, Time to rupture ≥30 hours,	

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
7	SUPERNI 263A (Indiginized)	-	Solutionize: 1150°C (±10°C) / 0.5 hr for <8 mm OR 1.5-2.5 hrs for >8 mm / WQ or OQ or AC Ppt: 800°C (±10°C) / 8 hrs / AC	Solutionize + Ppt	1000 (±10%) [at RT]	580 (±10%) [at RT]	40 (±10%) [at RT]	-	Hardness: ≥ 275 HV	Creep and stress rupture test, samples shall be heat-treated as follows- Solutionize: 1150°C / 2 hr / WQ + Ppt: 800°C / 8 hrs / AC
									Creep test: Temperature= 780°C, Stress= 120 MPa, Duration= 50 hours, Total Plastic Strain: ≤0.1%	
									Creep test: Temperature= 700°C, Stress= 417 MPa, Duration= 100 hours, Total Plastic Strain: ≤0.2%	
					540 (at 780°C)	400 (at 780°C)	12 (at 780°C)	-	Stress rupture test: Temperature= 600°C, Stress= 618 MPa, Time to rupture ≥100 hours	
									Stress rupture test: Temperature= 700°C, Stress= 448 MPa, Time to rupture ≥100 hours	
									Stress rupture test: Temperature= 800°C, Stress= 216 MPa, Time to rupture ≥100 hours	

Data Sheet for Rationalization of Metallic Materials - Nickel Alloys

General Grade of material :	INCONEL 625	Type of Material:	Ni-Cr-Mo-Nb	Number of identified specifications	4
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	AMS 5666	-	AMS 5666	-	Forging Stock	4	1	-
2	CCT LA 398	NC22DNb						
3	ASTM B 564	UNS N06625						
4	BS EN 10095	NiCr22Mo9Nb Alloy no. 2.4856						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				Co	Fe	C	Si	Mn	Mo	Ti	Cr	Al	Others (each)			Ni
1	AMS 5666	-	American	1.0	5.0	0.1	0.5	0.5	8.0-10.0	0.4	20.0-23.0	0.4	S=0.015, P=0.015	Ta=0.05	s	Base
2	CCT LA 398	NC22DNb	French	1.0	5.0	0.1	0.5	0.5	8.0-10.0	0.4	20.0-23.0	0.4	S=0.015	P=0.015	Nb+Ta= 3.15-4.15	Base
3	ASTM B 564	UNS N06625	American	-	5.0	0.1	0.5	0.5	8.0-10.0	0.4	20.0-23.0	0.4	S=0.015	P=0.015	Nb+Ta= 3.15-4.15	58 min
4	BS EN 10095	NiCr22Mo9Nb Alloy no. 2.4856	British	1.0	5.0	0.03-0.10	0.5	0.5	8.0-10.0	0.4	20.0-23.0	0.4	S=0.015, Cu = 0.50	P=0.020	Nb+Ta= 3.15-4.15	58 min

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Hardness (HB)	Remarks
1	AMS 5666	-	-	Annealed	827	414	30 (@4D)	-	287 (max)	-
2	CCT LA 398	NC22DNb	Solution treat: 1160°C (±10°C) / WQ	Solution treat	700	280	40 (@5D / 50mm)	-	250 (max)	-
3	ASTM B 564	UNS N06625	-	Annealed	827	414	30 (@4D or 50 mm)	-	-	-
4	BS EN 10095	NiCr22Mo9Nb Alloy no. 2.4856	Anneal: 950-1000°C / WQ or AC rapidly	Annealed	820-1050	415	30	-	240 (max)	-

Data Sheet for Rationalization of Metallic Materials - Nickel Alloys								
General Grade of material :			**Inconel 718 (special grade)**	**Type of Material:**	**Ni-Fe-Cr-Nb/Nb+Ta-Mo-Ti-Al**	**Number of identified specifications**		**2**
Rationalization for use:			**Forging Stock**					
Identified specifications			**Rationalized to**		**Shape**	**Number of identified specifications**	**Number of Rationalized specifications**	**Remarks**
Sl. No.	**Specification**	**Grade**	**Specification**	**Grade**				
1	MSRR 7202	Special grade Inco 718	MSRR 7202	Special grade Inco 718	Forging Stock	**2**	**1**	-
2	EMS 55476 (supersedes EMS 55458)	Delta Processed (DP) 718						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)											
				Co	Fe	C	Si	Mn	Mo	Ti	Cr	Al	Others (each)			Ni
1	MSRR 7202	Special grade Inco 718	British	1.0	Bal.	0.020-0.045	0.2	0.2	2.8-3.3	0.75-1.10	17-21	0.3-0.7	S=80 ppm B=20-60 ppm Ta=0.5 Ca=0.01 Bi =1 ppm	P = 0.015 Cu=0.2 Pb= 10 ppm	Ag= 5 ppm, Mg = 100 ppm Nb+Ta = 5.1-6.5	50-55
2	EMS 55476 (supersedes EMS 55458)	Delta Processed (DP) 718	American	1.0	Bal.	0.03	0.35	0.35	2.8-3.3	0.65-1.15	17-21	0.2-0.8	S=0.015 B= 0.006 Mg=0.003 N=0.01	P = 0.015 Cu=0.3 Nb+Ta = 4.75-5.5	Others (each) = 0.1	50-55

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
1	MSRR 7202 (for turbine discs)	Special grade Inco 718	Solution treat: 950-980°C / 1 hr / WQ or OQ Ppt: 720°C / 8 hours / FC at the rate of 55(±10)°C per hour upto 620°C / hold at 620°C for 8 hours / AC	Solution treat + Ppt	1345 (at RT)	1100 (at RT)	12 [@4D] (at RT)	-	Axial Fatigue (LCF at 550°C)-for turbine discs::Frequency = 0.25 Hz, Stress = 1120 MPa (max.), Cycles ≥10000, Stress reversal Ratio (R) =0	During Ppt, alternatively cool from 720 to 620°C and adjust time at 620°C to give a total ppt HT time of 18 hours (min.)
					1100 (at 650°C)	900 (at 650°C)	12 [@4D] (at 650°C)	-	Stress rupture test-for forgings: Temperature= 650°C, Stress=760 MPa, Time to rupture ≥ 25 hours, % El ≥ 5	
2	EMS 55476 (supersedes EMS 55458)	Delta Processed (DP) 718	Heat treat in accordance with HT5071 except that solution temperature shall be in the range of 954-996°C	Solution treat + Ppt	1345 (at RT)	1103 (at RT)	12 [@4D] (at RT)	15 (at RT)	Stress rupture test: Temperature = 649°C, Stress= 758 MPa, Time to rupture ≥ 25 hours, % El (@4D) ≥ 5	-
					1083 (at 649°C)	931 (at 649°C)	12 [@4D] (at 649°C)	15 (at 649°C)		

Data Sheet for Rationalization of Metallic Materials - Nickel Alloys

General Grade of material :	Inconel 718	Type of Material:	Ni-Fe-Cr-Nb/Nb+Ta-Mo-Ti-Al	Number of identified specifications	7
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	AMS 5662	-	AMS 5662 / SUPERNI 718A	-	Forging Stock	8	2	1. Sl. No. 8 has equivalent specification AMS 5662 as per RCMA(Nsk)/07/01 dated 27.09.2007. 2. Other equivalent specifications for SUPERNI 718A are mentioned in CEMILAC/2011/GDP dated 01.08.2007 (Rationalisation of Metallic Materials)
2	AMS 5663	-						
3	AMS 5664	-						
4	AIR 9165	NC19FeNb						
5	MSRR 7115	-						
6	GTM Su-718 (Indigenised)	-						
7	SUPERNI 718A (Indigenised)	-						
8	TU14-1-3905-85	KHN45MVTYUBR EP718						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				Ni	Co	Fe	C	Si	Mn	Mo	Ti	Cr	Al	Others (each)			Others (total)
1	AMS 5662	-	American	50-55	1.0	Bal.	0.08	0.35	0.35	2.8-3.3	0.65-1.15	17-21	0.2-0.8	S=0.015 B= 0.006 Se=3 ppm Bi=0.3 ppm	P = 0.015 Cu=0.3 Ta = 0.05 Pb= 5ppm	Nb=4.75-5.5	-
2	AMS 5663	-	American	50-55	1.0	Bal.	0.08	0.35	0.35	2.8-3.3	0.65-1.15	17-21	0.2-0.8	S=0.015 B= 0.006 Se=3 ppm Bi=0.3 ppm	P = 0.015 Cu=0.3 Pb= 5 ppm	Nb=4.75-5.5	-
3	AMS 5664	-	American	50-55	1.0	Bal.	0.08	0.35	0.35	2.8-3.3	0.65-1.15	17-21	0.2-0.8	S=0.015 B= 0.006	P = 0.015 Cu=0.3	Nb=4.75-5.5	-
4	AIR 9165	NC19FeNb	French	Bal.	1	17-20	0.03-0.10	0.35	0.35	2.8-3.3	0.65-1.15	17-21	0.4-0.8	P = 0.015 S=0.015	Cu=0.1 B = 0.006	Nb+Ta = 5.00-5.50	-
5	MSRR 7115	-	British	Ni+Co =50-55	1	Bal.	0.02-0.08	0.35	0.35	2.8-3.3	0.7-1.15	17-21	0.3-0.7	P = 0.015 S=0.015 B= 20-60 ppm Bi =1 ppm	Cu=0.2 Pb= 10 ppm Ag= 5 ppm	Nb+Ta = 4.75-5.50	-
6	GTM Su-718 (Indigenised)	-	Indian	50-55	1	Bal.	0.015-0.04	0.35	0.35	2.8-3.3	0.75-1.15	17-21	0.3-0.7	P = 0.015 S=0.015 B= 60 ppm Bi = 0.3 ppm Mg= 0.01	Cu=0.3 Pb= 5 ppm Ag= 10 ppm , Se=3 ppm , Sn= 50 ppm	O=20 ppm , N= 80 ppm , Ca= 0.01 , Nb = 5.00-5.50, Ta=0.1	-
7	SuperNi 718A (Indigenised)	-	Indian	50-55	1	Bal.	0.02-0.08	0.35	0.35	2.8-3.3	0.75-1.15	17-21	0.3-0.7	P = 0.015 S=0.015 B= 60 ppm Bi = 0.5ppm Mg= 0.01 Sn= 50 ppm	Cu=0.3 Pb= 5 ppm Ag= 10 ppm H= 5 ppm	O=100 ppm , Nb / Nb+Ta = 4.75-5.50, N = 140 ppm , Ca=0.01	-
8	TU14-1-3905-85	KHN45MVTYUBR EP718	RUSSIAN	43-47	-	Bal.	0.1	0.3	0.6	4-5.2	1.9-2.4	14-16	0.9-1.4	Nb: 0.8-1.5 B:0.008 W:2.5-3.5 Ce:0.1 Zr:0.02	S: 0.01	P: 0.015	-

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
1	AMS 5662	-	Solution treat: 941-1010°C (±14°C) / AC or faster Ppt: 718°C (±8°C) / ≥ 8 hours / Cool at the rate of 56°C (±8°C) per hour upto 621°C (±8°C) / hold at 621°C (±8°C) for ≥ 8 hours / AC	Solution treat + Ppt	1276 (at RT)	1034 (at RT)	12 (@4D) (at RT)	15 (at RT)	Hardness 331 HB (min.)	During Ppt, instead of cooling at the rate of 56°C (±8°C) per hour, FC at any rate provided the time at 621°C (±8°C) is adjusted to give a total ppt time of 18 hours (min.)
					1000 (at 649°C)	862 (at 649°C)	12 (@4D) (at 649°C)	15 (at 649°C)	Stress rupture test: Temperature= 649°C, Stress ≥ 689 MPa, Time to rupture ≥ 23 hours, % El(@4D) ≥ 4	
2	AMS 5663	-	Solution treat: 941-1010°C (±14°C) / AC or faster Ppt: 718-760°C (±8°C) / 8 hours / Cool at the rate of 56°C (±8°C) per hour upto 621-649°C (±8°C) / hold at 621°C (±8°C) for 8 hours / AC	Solution treat + Ppt	1276 (at RT)	1034 (at RT)	12 (@4D) (at RT)	15 (at RT)	Hardness 331 HB (min.)	During Ppt, instead of cooling at the rate of 56°C (±8°C) per hour, FC at any rate provided the time at 621-649°C (±8°C) is adjusted to give a total ppt time of 18 hours (min.)
					1000 (at 649°C)	862 (at 649°C)	12 (@4D) (at 649°C)	15 (at 649°C)	Stress rupture test: Temperature = 649°C, Stress ≥ 689 MPa, Time to rupture ≥ 23 hours, % El(@4D) ≥ 4	
3	AMS 5664	-	Solution treat: 1066°C (±14°C) / AC or faster Ppt: 760°C (±8°C) / 10 hours ± 30 minutes / FC to 649°C (±8°C) / hold at 649°C (±8°C) until total ppt time of 20 hours / cool suitably	Solution treat + Ppt	1241	1034	10 -for bars, 12% - for forgings and flash welded rings (@4D)	12 -for bars, 15% - for forgings and flash welded rings	Hardness 341 HB (min.)	-
4	AIR 9165	NC19FeNb	Solution treat: 955°C / 1 hr / AC Ppt: 720°C / 8 hours / Slowly cool at the rate of 50°C per hour upto 620°C / hold at 620°C for 8 hours / AC	Solution treat + Ppt	1240 (at RT)	1030 (at RT)	12 (at RT)	15 (at RT)	Hardness 329 HB (min.)	-
					1000 (at 650°C)	860 (at 650°C)	12 (at 650°C)	15 (at 650°C)	Stress rupture test: Temperature= 650°C, Stress =680 MPa, Time to rupture ≥ 30 hours, % El ≥ 5	

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
5	MSRR 7115	-	Solution treat: 950-980°C / 1 hr / AC or WQ or OQ Ppt: 720°C / 8 hours / FC at the rate of 45-65°C per hour upto 620°C / hold at 620°C for 8 hours / AC	Solution treat + Ppt	1270 (at RT)	1030 (at RT)	10	15	Hardness 331 HB (min.) or 361 HV (min.)	During Ppt, instead of cooling at the rate of 45-65°C per hour, FC at any rate provided the time at 620°C is adjusted to give a total ppt time of 18 hours (min.)
					1000 (at 650°C)	860 (at 650°C)	10 (at 650°C)	15 (at 650°C)	Stress rupture test: Temperature= 650°C, Stress =695 MPa, Time to rupture ≥ 23 hours, % El ≥ 5	
6	GTM Su-718 (Indigenised)	-	Solution treat: 954-982°C (±10°C) / 1 hr / AC or WQ or OQ Ppt: 720°C(±5°C) / 8 hours / FC at the rate of 55°C per hour upto 620°C (±5°C) / hold at 620°C (±5°C) for 8 hours / AC	Solution treat + Ppt	1275 (at RT)	1035 (at RT)	10 (@ 5D) or 12 (@ 4D) [at RT]	15	Hardness 346 HB (min.)	-
					1000 (at 650°C)	860 (at 650°C)	10 (@ 5D) or 12 (@ 4D) [at 650°C]	15 (at 650°C)	Stress rupture test (combined smooth and notched): Temperature= 650°C, Stress = 690 MPa, Time to rupture ≥ 23 hours, % El ≥ 4	
									Creep test: Temperature= 650°C, Stress = 550 MPa, Duration = 15 hours, Plastic strain <0.1%	
7	SuperNi 718A (Indigenised)	-	Solution treat: 925-1010°C (±14°C) / 1 hr / AC or faster Ppt: 720-760°C(±8°C) / 8 hours / cool at the rate of 45-65°C per hour upto 620-650°C / hold at selected temperature (±8°C) for 8 hours / AC	Solution treat + Ppt	1275 (at RT)	1030 (at RT)	12 (@4D or 50 mm) [at RT]	15	Hardness 331 HB (min.)	-
					1000 (at 650°C)	860 (at 650°C)	12 (@ 4D or 50 mm) [at 650°C]	15 (at 650°C)	Stress rupture test (combined smooth and notched): Temperature= 650°C, Stress = 690 MPa, Time to rupture ≥ 23 hours	
									Creep test: Temperature= 650°C, Stress = 550 MPa, Duration = 100 hours, Plastic strain <0.1%	
8	TU14-1-3905-85	KHN45MVTYUBR EP718	Solution treat: 1000-1130°C (±14°C) / 2-3 hr / Oil Quench Age: 560 -730°C(±8°C) / 16 hours, Air cool	Solution treat + Age	1128 (at RT)	687 (at RT)	12 (@ 5D) [at RT]	14	Hardness 302- 363 HB	-
									Stress rupture test : Temperature= 600°C, Stress = 785 MPa, Time to rupture ≥ 60 hours	

Data Sheet for Rationalization of Metallic Materials - Nickel Alloys

General Grade of material :	NIMONIC 75	Type of Material:	Ni-Cr-Ti	Number of identified specifications	6
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	RRMS 33030 & RRMS 33030/1 [supersedes MSRR 7004]	-	BS HR 5 / SUPERNI 75A	-	Forging Stock	6	2	-
2	MSRR 7008 [superseded by RRMS 33030 & RRMS 33030/2]	-						
3	BS HR 5	-						
4	BS HR 504	-						
5	AIR 9165	NC 20T						
6	SuperNi 75A (Indigenised)	-						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				Co	Fe	C	Si	Mn	Mo	Ti	Cr	Al	Others (each)			Ni
1	RRMS 33030 & RRMS 33030/1 [supersedes MSRR 7004]	-	British	5.0	5.0	0.08-0.15	1.0	1.0	-	0.2-0.6	18-21	-	S=0.02	Cu=0.50	Pb= 0.0050	Base
2	MSRR 7008 [superseded by RRMS 33030 & RRMS 33030/2]	-	British	5.0	5.0	0.08-0.15	1.0	1.0	-	0.2-0.6	18-21	-	S=0.02	Cu=0.50	Pb= 0.0050	Base
3	BS HR 5	-	British	5.0	5.0	0.08-0.15	1.0	1.0	-	0.2-0.6	18-21	-	S=0.02	Cu=0.50	Pb= 0.0050	Base
4	BS HR 504	-	British	5.0	5.0	0.08-0.15	1.0	1.0	-	0.2-0.6	18-21	-	S=0.02	Cu=0.50	Pb= 0.0050	Base
5	AIR 9165	NC 20T	French	5.0	5.0	0.08-0.15	1.0	1.0	-	0.2-0.6	18-21	-	S=0.015 P=0.015	Cu=0.50	Pb= 0.02	Base
6	SuperNi 75A (Indigenised)	-	Indian	-	1.0	0.08-0.12	0.8	0.7	-	0.2-0.4	19-21	0.15	S=0.01 P=0.015	Cu=0.07	Pb= 0.005	Base

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
1	RRMS 33030 & RRMS 33030/1 [supersedes MSRR 7004]	-	Anneal: 1050°C / AC or WQ	Annealed	650	230	30 (@ 5D)	-	Hardness 230 HB (max)	-
2	MSRR 7008 [superseded by RRMS 33030 & RRMS 33030/2]	-	Solution treat: 1050°C / ≥30 minutes / AC or WQ	Solution treat	620	230	30 (27% for flash welded rings)	-	-	For Flash welded and cold rolled rings- Weld diffuse at 1050°C / ≥ 30 minutes / AC + Cold roll + Solution treat at 1050°C / 1 hr / AC
3	BS HR 5	-	Anneal: 1000-1100°C / AC	Annealed	650	230	30	-	Hardness 230 HB (max). or 235 HV (max)	-
4	BS HR 504	-	Anneal: 1050°C (±10°C) / AC or WQ or cool suitably in controlled atmosphere	Annealed	620	232	30	-	Hardness 230 HB (max) or 240 HV (max)	-
5	AIR 9165	NC 20T	Anneal: 1000-1050°C / AC	Annealed	640	240	30	-	Hardness 230 HB (max)	-
6	SuperNi 75A (Indigenised)	-	Anneal: 1000°C (±10oC) / 1-4 hours / AC	Annealed	637	216	35 (@5D)	50	Hardness 230 HB (max) or 235 HV (max) Stress rupture test: Temperature= 700°C Stress = 103 MPa, Time to rupture ≥ 100 hours Creep test: Temperature= 700°C Stress = 39 MPa, Duration = 100 hours Plastic strain 0.2% (max)	-

Data Sheet for Rationalization of Metallic Materials - Nickel Alloys

General Grade of material :	NIMONIC 80A	Type of Material:	Ni-Cr-Ti-Al	Number of identified specifications	7
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	MSRR 7009	-	BS HR1	-	Forging Stock	7	2	-
2	MSRR 7010 (cancelled)	-						
3	MSRR 7011	-						
4	MSRR 7012	-						
5	BS HR1	-						
6	BS HR 601 (supersedes MSRR 7013)	-						
7	AIR 9165	NC 20 TA						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				Co	Fe	C	Si	Mn	Mo	Ti	Cr	Al	Others (each)			Ni
1	MSRR 7009	-	British	2.0	1.5	0.04-0.10	0.8	0.40	-	1.8-2.7	18-21	1.0-1.8	S=0.015 Bi= 0.0001	Cu=0.20 B = 0.008	Ag= 0.0005 Pb= 0.001	Base
2	MSRR 7010 (Cancelled)	-	British	2.0	1.5	0.04-0.10	0.8	0.40	-	1.8-2.7	18-21	1.0-1.8	S=0.015 Bi= 0.0001	Cu=0.20	Ag= 0.0005	Base
3	MSRR 7011	-	British	2.0	1.5	0.04-0.10	0.8	0.40	-	1.8-2.7	18-21	1.0-1.8	S=0.015 Bi= 0.0001	Cu=0.20 B = 0.008	Ag= 0.0005 Pb= 0.002	Base
4	MSRR 7012	-	British	2.0	1.5	0.04-0.10	0.8	0.40	-	1.8-2.7	18-21	1.0-1.8	S=0.015 Bi= 0.0001	Cu=0.20 B = 0.008	Ag= 0.0005 Pb= 0.002	Base
5	BS HR1	-	British	2	1.5	0.04-0.10	1	1.0	-	1.8-2.7	18-21	1.0-1.8	S=0.015 Bi= 0.0001	Cu=0.20 B = 0.008	Ag= 0.0005 , Pb= 0.002	Base
6	BS HR 601 (supersedes MSRR 7013)	-	British	2	1.5	0.04-0.10	1	1.0	-	1.8-2.7	18-21	1.0-1.8	S=0.015 Bi= 0.0001	Cu=0.20 B = 0.008	Ag= 0.0005 , Pb= 0.002	Base
7	AIR 9165	NC20TA	French	2	1.5	0.04-0.10	1	1.0	-	1.8-2.7	18-21	1.0-1.8	S=0.015 Bi= 0.0001	Cu=0.20 B = 0.008	Ag= 0.0005 , Pb= 0.001 , P = 0.015	Base

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
1	MSRR 7009	-	Solutionize: 1080°C / ≥8 hrs / AC Ppt: 700°C / ≥ 16 hrs / AC	Solutionize + Ppt	-	-	-	-	Stress rupture test: Temperature= 750°C, Stress= 340 MPa, Time to rupture ≥23 hours	-
2	MSRR 7010 (cancelled)	-	Solutionize: 1080°C (±10°C) / 8 hrs / AC Ppt: 700°C (±5°C) / 16 hrs / AC	Solutionize + Ppt	-	-	-	-	Stress rupture test: Temperature= 750°C, Stress= 340 MPa, Time to rupture ≥30 hours	-
3	MSRR 7011	-	Solutionize: 1080°C (±10°C) / 8 hrs / AC or WQ [OQ for bars > 40 mm] Ppt: 700°C (±10°C) / 16 hrs / AC OR 750°C (±10°C) / 4 hrs / AC	Solutionize + Ppt	1000	600	20	-	Hardness = 265 HB (miin.) or 285 HV (min.). Stress rupture test: Temperature= 750°C, Stress= 340 MPa, Time to rupture ≥ 30 hours	During Solutionizing, soaking time for bars <3 mm is 1 hr; >3-6 mm is 2 hours; >6-12.5 mm is 4 hours; and >12.5 mm is 8 hours.
4	MSRR 7012	-	Soften: 1050-1080°C / WQ Solutionize: 1050-1080°C / 2 hrs / WQ Ppt: 750°C / 4 hrs / AC	Solutionize + Ppt	1000	620	20	-	Hardness = 265 HB (miin.) or 285 HV (min.). Stress rupture test: Temperature= 750°C, Stress= 340 MPa, Time to rupture ≥ 30 hours	For Flash welded cold-rolled rings, **Weld diffuse:** 1120°C / 1 hr / AC or WQ before Solution treatment and Ppt

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
5	BS 3HR1	-	Soften: 1080°C (±10°C) / 30 minutes / WQ, Solutionize: 1080°C (±10°C) / 8 hrs / AC or OQ or WQ Ppt: 700°C (±10°C) / 16 hrs / AC	Solutionize + Ppt	1000	600	20	-	Hardness = 285 HB (miin.) or 310 HV (min.). Stress rupture test: Temperature= 750°C, Stress= 340 MPa, Time to rupture ≥ 30 hours	During solutionizing, for Bars & extruded sections for machining (viz. HR1A) as well as for Forgings (HR1D), soaking time is ≥1 hour for ≤3 mm; ≥2 hours for >3-6 mm; and ≥ 4 hours for > 6-12.5 mm
6	BS HR 601 (supersedes MSRR 7013)	-	Solutionize: 1080°C (±10°C) / 15-30 minutes for <15 mm & 30-60 minutes for 15-30 mm / AC or faster Ppt: 750°C (±10°C) / 4 hrs / AC	Solutionize + Ppt	1000	620	20	-	Stress rupture test: Temperature= 750°C, Stress= 340 MPa, Time to rupture ≥ 30 hours	-
7	AIR 9165	NC 20 TA	Anneal: 1050-1080°C / AC Ppt: 700°C / 16 hrs / AC	Solutionize + Ppt	1000	620	20	-	Hardness = 280 HB (miin.), Stress rupture test: Temperature= 750°C, Stress= 305 MPa, Time to rupture ≥ 75 hours Stress rupture test: Temperature= 815°C, Stress= 240 MPa, Time to rupture ≥ 30 hours, % El ≥3.5	-

Data Sheet for Rationalization of Metallic Materials - Nickel Alloys

General Grade of material :	NIMONIC 90/93	Type of Material:	Ni-Cr-Co-Ti-Al	Number of identified specifications	8
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	MSRR 7137	-	AIR 9165 / BS HR2	NCK 20TA	Forging Stock	8	2	-
2	MSRR 7135	-						
3	MSRR 7129	-						
4	MSRR 7016	-						
5	BS HR 2	-						
6	AIR 9165	NCK 20 TA						
7	BSEM 561	-						
8	BACE 417 / BACE 423	-						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)											
				Co	Fe	C	Si	Mn	Ti	Cr	Al	Others (each)			Ni
1	MSRR 7137	-	British	15-21	1.5	0.13	1.0	1.0	2.0-3.0	18-21	1.0-2.0	S=0.015 Zr= 0.15 Bi= 0.0001	Cu=0.20 B = 0.02	Ag= 0.0005 Pb= 0.001	Base
2	MSRR 7135	-	British	15-21	1.5	0.13	0.8	0.4	2.0-3.0	18-21	1.0-2.0	S=0.015 Zr= 0.15 Bi= 0.0001	Cu=0.20 B = 0.02	Ag= 0.0005 Pb= 0.002	Base
3	MSRR 7129	-	British	15-21	1.5	0.13	0.8	0.4	2.0-3.0	18-21	1.0-2.0	S=0.015 Zr= 0.15 Bi= 0.0001	Cu=0.20 B = 0.02	Ag= 0.0005 Pb= 0.001	Base
4	MSRR 7016	-	British	15-21	1.5	0.13	0.8	0.4	2.0-3.0	18-21	1.0-2.0	S=0.015 Zr= 0.15 Bi= 0.0001	Cu=0.20 ,B = 0.02	Ag= 0.0005 Pb= 0.002	Base
5	BS HR 2	-	British	15-21	1.5	0.13	1	1.0	2.0-3.0	18-21	1.0-2.0	S=0.015 Zr= 0.15 Bi= 0.0001	Cu=0.20 B = 0.02	Ag= 0.0005 Pb= 0.002	Base
6	AIR 9165	NCK 20 TA	French	15-21	1	0.13	1	1.0	2.0-3.0	18-21	1.0-2.0	S=0.015 P= 0.015	Cu=0.20 B = 0.02	Pb= 0.02	Base
7	BSEM 561	-	British	15-21	1.5	0.1	1.0	1.0	2.0-3.0	18-21	1.0-2.0	S=0.015	Zr=0.15 , B = 0.03	Pb= 0.0025	Base
8	BACE 417 / BACE 423	-	British	15-21	2.0	0.1	1.5	1.0	2.0-2.7	18-21	1.0-1.65	-	-	Pb= 0.005	Base

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
1	MSRR 7137	-	Stress relieve: 1080°C (±10°C) / 30 minutes / AC (if required). Solutionize: 1080°C (±10°C) / 8 hrs / AC (for bars) and AC or OQ or WQ (for forgings) Ppt: 700°C (±10°C) for 16 hrs OR 750°C (±10°C) for 4 hrs / AC	Solutionize + Ppt	1080	695	20	-	Stress rupture test: Temperature= 870°C Stress= 140 MPa, Time to rupture ≥30 hours	During solutionizing, soaking time for bars <3 mm is 1 hr, >3-6 mm is 2 hours and >6-12.5 mm is 4 hours
2	MSRR 7135	-	Soften (anneal): 1050-1080°C / WQ. Solutionize: 1050-1080°C / 8 hrs / AC Ppt: 700°C for 16 hrs OR 750°C for 4 hrs / AC	Solutionize + Ppt	1080	620	18	-	Stress rupture test: Temperature= 870°C Stress= 140 MPa, Time to rupture ≥30 hours	-
3	MSRR 7129	-	Solutionize:1080°C / 8 hrs / AC Ppt: 700°C / ≥16 hrs / AC	Solutionize + Ppt	-	-	-	-	Stress rupture test: Temperature= 870°C Stress= 140 MPa, Time to rupture ≥56 hours	-
4	MSRR 7016	-	Solutionize: 1080°C / AC or WQ Ppt: 750°C / 4 hrs / AC	Solutionize + Ppt	820 (at 650°C)	590 (at 650°C)	8 (at 650°C)	-	Hardness: 295-370 HV (for forgings); 295-330 HV (for bars). Stress rupture test: Temperature= 870°C, Stress= 140 MPa, Time to rupture ≥30 hours	During solutionizing, soaking time for < 3 mm is 1 hr, >3-6 mm is 2 hours; >6-12.5 mm is 4 hours; and >12.5-25 mm is 8 hrs

Sl. No.	Specification	Grade	Section thickness 50mm Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
5	BS 3HR 2	-	Solutionize: 1080°C (±10°C) / 8 hrs / AC or OQ or WQ Ppt: 700°C (±10°C) / 16 hrs / AC	Solutionize + Ppt	1080	695	20	-	Hardness: 293 HB (min.) or 310 HV (min.). Stress rupture test: Temperature= 870°C, Stress= 140 MPa, Time to rupture ≥ 30 hours	During solutionizing, for Bars & extruded sections for machining (viz. HR2A) as well as for Forgings (HR2D), soaking time is 1 hour for 3 mm; 2 hours for >3-6 mm; and 4 hours for > 6-12.5 mm
6	AIR 9165	NCK 20 TA	Solutionize: 1050-1080°C / 8 hrs / AC Ppt: 710°C / 16 hrs / AC	Solutionize + Ppt	1080	690	20	-	Hardness: 290 HB (min.) Stress rupture test: Temperature= 700°C, Stress= 590 MPa, Time to rupture ≥ 30 hours, % El ≥ 5 [for forgings) Stress rupture test: Temperature= 815°C Stress= 290 MPa, Time to rupture ≥ 30 hours, % El ≥ 7	-
7	BSEM 561	-	Solution treat: 1080°C / 8 hrs / AC Ppt: 700°C / 16 hrs / AC	Solution treated + Ppt	-	-	-	-	Stress rupture test: Temperature= 870°C Stress= 135 MPa, Time to rupture ≥ 30 hours	-
8	BACE 417 / BACE 423	-	Anneal: 1110°C / 4 hr / WQ. Solution treat: 1080°C / 8 hrs / AC Ppt: 700°C / 16 hrs / AC	Solution treated + Ppt	1000	600 (0.1% PS)	16	-	Hardness: 254 HB (min.), Stress rupture test: Temperature= 870oC, Stress= 135 MPa, Time to rupture ≥ 30 hours	-

Data Sheet for Rationalization of Metallic Materials - Nickel Alloys

General Grade of material :	NIMONIC 105	Type of Material:	Ni-Co-Cr-Mo-Al-Ti-B	Number of identified specifications	6
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	MSRR 7017	-	BS 2HR 3	-	Forging Stock	6	1	-
2	MSRR 7018	-						
3	MSRR 7134	-						
4	BS 2HR 3	-						
5	DTD 5007 (Obsolete)	-						
6	AIR 9165	NK 20 CDA						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				Co	Fe	C	Si	Mn	Mo	Ti	Cr	Al	Others (each)			Ni
1	MSRR 7017	-	British	18-22	1.0	0.12-0.17	0.25	0.40	4.5-5.5	1.18-1.50	14.0-15.7	4.5-4.9	S=0.010 Bi= 0.0001 Zr=0.07-0.15	Cu=0.20 B = 0.003-0.010	Ag= 0.0005 Pb= 0.0005	Base
2	MSRR 7018	-	British	18-22	1.0	0.12-0.17	0.25	0.40	4.5-5.5	1.18-1.50	14.0-15.7	4.5-4.9	S=0.010 Bi= 0.0001 Zr=0.07-0.15	Cu=0.20 , B = 0.003-0.010	Ag= 0.0005 Pb= 0.0005	Base
3	MSRR 7134	-	British	18-22	1.0	0.12-0.17	0.25	0.40	4.5-5.5	1.18-1.50	14.0-15.7	4.5-4.9	S=0.010 Bi= 0.0001 Zr=0.07-0.15	Cu=0.20 , B = 0.003-0.010	Ag= 0.0005 Pb= 0.001	Base
4	BS 2HR 3	-	British	18-22	1.0	0.12-0.17	1	1.0	4.5-5.5	0.90-1.50	14.0-15.7	4.5-4.9	S=0.015 Bi= 0.0001 Zr=0.15	Cu=0.20 B = 0.003-0.010	Ag= 0.0005 Pb= 0.0015	Base
5	DTD 5007 (Obsolete)	-	British	18-22	2.0	0.2	1	1.0	4.5-5.5	0.90-1.50	14.0-15.75	4.5-4.9	S=0.015 Zr=0.15	Cu=0.20 B = 0.015	Pb= 0.005	Base
6	AIR 9165	NK 20 CDA	French	18-22	1.0	0.12-0.17	1	1.0	4.5-5.5	0.90-1.50	14.0-15.7	4.5-4.9	S=0.015 P=0.015	Cu=0.20 B = 0.003-0.010	Zr=0.15	Base

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
1	MSRR 7017	-	Solutionize: 1150°C / 4 hrs / AC Ppt: 1030°C / 16 hrs / AC + 700°C / ≥16 hrs / AC	Solutionize + Ppt	-	-	-	-	Stress rupture test: Temperature= 950°C, Stress= 110 MPa, Time to rupture ≥ 30 hours Stress rupture test: Temperature= 815°C, Stress= 360 MPa, Time to rupture ≥30 hours	-
2	MSRR 7018	-	Solutionize: 1150°C / 4 hrs / AC Ppt: 1030°C / 16 hrs / AC + 700°C / 16 hrs / AC	Solutionize + Ppt	-	-	-	-	Stress rupture test: Temperature= 815°C, Stress= 360 MPa, Time to rupture ≥30 hours	-
3	MSRR 7134	-	Soften: 1100°C / 30 minutes / Cool rapidly Weld diffuse: 1150°C / 4 hrs / AC Ppt: 1030°C / 16 hrs / AC Ppt: 700°C / 16 hrs / AC	Soften + Weld diffuse + Ppt	925 [at 700°C]	650 [at 700°C]	10 [at 700°C]	-	Stress rupture test: Temperature= 815°C, Stress= 330 MPa, Time to rupture ≥ 25 hours	-
4	BS 2HR 3	-	Solutionize: 1150°C (±10°C) / 4 hrs / AC Heat at 1050°C (±10°C) / 16 hrs / AC Ppt: 850°C (±10°C) / 16 hrs / AC	Solutionize + Ppt	-	-	-	-	Hardness 331 HB (miin.) Stress rupture test: Temperature= 815°C, Stress= 360 MPa, Time to rupture ≥30 hours Stress rupture test Temperature= 950°C, Stress= 108 MPa, Time to rupture ≥ 30 hours	-

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
5	DTD 5007 (Obsolete)		Stage 1: Heat to 1150°C (±10°C) / 2-4 hrs / AC + Stage 2: Heat to 1050-1100°C / 8-16 hrs / AC + Stage 3: Heat to 850°C (±10°C) / 8-16 hrs / AC	Heat-treated	-	-	-	-	Hardness 300 HB (min.) or 315 HV (min.) Stress rupture test: Temperature= 950°C Stress= 108 MPa Time to rupture ≥ 28 hours	-
6	AIR 9165	NK 20 CDA	Solutionize: 1150°C / 4 hrs / AC + Heat at 1030-1080°C / 8 hrs / AC + Ppt: 700-850°C / 16 hrs / AC	Solutionize + Ppt	-	-	-	-	Hardness 350 HB (min.) Stress rupture test: Temperature= 950°C Stress= 108 MPa Time to rupture ≥ 30 hours % El= ≥2 Stress rupture test: Temperature= 815°C Stress= 300 MPa Time to rupture ≥ 75 hours % El= ≥2	-

Data Sheet for Rationalization of Metallic Materials - Nickel Alloys

General Grade of material :	NIMONIC 115 [for turbine blade blanks]	Type of Material:	Ni-Co-Cr-Al-Mo-Ti-B	Number of identified specifications	5
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	MSRR 7023	-	BS HR4/ SuperNi115	-	Forging Stock	5	2	-
2	MSRR 7022	-						
3	BS 2HR 4	-						
4	DTD 5017 (Obsolete)							
5	SuperNi115 (Indigenised)	-						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)													
				Co	Fe	C	Si	Mn	Mo	Ti	Cr	Al	Others (each)			Others (total)	Ni
1	MSRR 7023	-	British	13-17	0.8	0.12-0.20	0.25	0.20	3.0-5.0	3.5-4.5	14.0-16.0	4.5-5.5	S=0.01 Bi= 0.0001 Zr=0.08	Cu=0.20 B = 0.010-0.025	Ag= 0.0005 Pb= 0.0005	Electron Vacany No. (Nv) ≤2.8 for remelting stock	Base
2	MSRR 7022	-	British	13-17	0.8	0.12-0.20	0.25	0.20	3.0-5.0	3.5-4.5	14.0-16.0	4.5-5.5	S=0.01 Bi= 0.0001 Zr=0.08	Cu=0.20 B = 0.010-0.025	Ag= 0.0005 Pb= 0.0005	Electron Vacany No. (Nv) ≤2.8	Base
3	BS HR 4	-	British	13-15.5	1.0	0.12-0.20	1.0	1.0	3.0-5.0	3.5-4.5	14.0-16.0	4.5-5.5	S=0.015 Bi= 0.0001 Zr=0.15	Cu=0.20 B = 0.010-0.025	Ag= 0.0005 Pb= 0.0015	Note 1	Base
4	DTD 5017 (Obsolete)	-	British	13-15.5	1.0	0.2	1.0	1.0	3.0-5.0	3.5-4.5	14.0-16.0	4.5-5.5	S=0.015 Zr=0.15	Cu=0.20 B = 0.010-0.025	Pb= 0.005	-	Base
5	SuperNi115 (Indigenised)	-	Indian	13-17	0.8	0.12-0.20	0.25	0.20	3.0-5.0	3.5-4.5	14.0-16.0	4.5-5.5	S=0.010 Bi= 0.0001 Zr=0.08	Cu=0.20 B = 0.010-0.025	Ag= 0.0005 Pb= 0.0005	Electron Vacany No. (Nv) ≤2.8	Base
Note 1: Electron vacancy no. (Nv) limits to be agreed between the manufacturer and purchaser so as to limit sigma phase formation																	

Sl. No.	Specification	Grade	Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
1	MSRR 7023	-	Solution treat: 1190°C / 1.5 hrs / FC to 1000°C at rate of 2-3°C per minute (limit 1-5°C per minute) / AC+ Stress relieve: 1030°C / 1.5 hrs in protective atmosphere	Solution treated + stress relieved	-	-	-	-	Stress rupture test: Temperature= 850°C, Stress= 350 MPa, Time to rupture ≥ 40 hours Stress rupture test: Temperature= 980°C, Stress= 115 MPa, Time to rupture ≥60 hours	-
2	MSRR 7022	-	Solution treat: 1190°C / 1.5 hrs / FC to 1000°C at rate of 2-3°C per minute (limit 1-5°C per minute)/ AC	Solution treated	-	-	-	-	Stress rupture test: Temperature= 850°C, Stress= 350 MPa, Time to rupture ≥ 40 hours Stress rupture test: Temperature= 980°C, Stress= 115 MPa, Time to rupture ≥60 hours	Stress relieve: 1030°C / 1.5 hrs in protective atmosphere for blade forgings or finished part.
3	BS 2HR 4	-	Solution treat: 1190°C (±10°C) / 1.5 hrs / FC to 1000°C at rate of 2-3°C per minute (limit 1-5°C per minute) / AC	Solution treated	-	-	-	-	Stress rupture test: Temperature= 980°C, Stress= 116 MPa, Time to rupture ≥60 hours	-
4	DTD 5017 (Obsolete)	-	-	-	-	-	-	-	Hardness: 320 HB (min.) or 335 HV (min.), Stress rupture test: Temperature= 980°C, Stress= 116 MPa, Time to rupture ≥ 50 hours	-
5	SuperNi115 (Indigenised)	-	Solution treat: 1190°C (±10°C) / 1.5-2.5 hrs / FC to 1000°C at rate of 2-3°C per minute (limit 1-5°C per minute) / AC	Solution treated	-	-	-	-	Stress rupture test: Temperature= 850°C, Stress= 350 MPa, Time to rupture ≥ 40 hours Stress rupture test: Temperature= 980°C, Stress= 115 MPa, Time to rupture ≥60 hours	-

Data Sheet for Rationalization of Metallic Materials - Nickel Alloys

General Grade of material :	WASPALOY	Type of Material:	Ni-Cr-Co-Mo-Ti-Al-Zr-B	Number of identified specifications	8
Rationalization for use:	Forging Stock				

Identified specifications			Rationalized to		Shape	Number of identified specifications	Number of Rationalized specifications	Remarks
Sl. No.	Specification	Grade	Specification	Grade				
1	MSRR 7192	-	AMS 5707/ EMS 55388	-	Forging Stock	8	2	-
2	AIR 9165	NC20 K14						
3	AMS 5704	-						
4	AMS 5706	-						
5	AMS 5707	-						
6	AMS 5708	-						
7	AMS 5709	-						
8	EMS 55388	-						

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%) (wherever limit not mentioned consider as max)												
				Co	Fe	C	Si	Mn	Mo	Ti	Cr	Al	Others (each)			Ni
1	MSRR 7192	-	British	12.0-15.0	2.0	0.02-0.10	0.15	0.10	3.5-5.0	2.8-3.3	18-21	1.2-1.6	S=80 ppm, Zr= 0.02-0.08 Bi= 1 ppm	Cu=0.1 B = 30-100 ppm	Ag= 5 ppm P= 0.015 Pb= 10 ppm	Base
2	AIR 9165	NC 20 K14	French	12.0-15.0	2.0	0.03-0.10	0.15	0.10	3.5-5.0	2.75-3.25	18-21	1.2-1.6	S=0.015 Zr= 0.02-0.08	Cu=0.1 B = 0.003-0.01	P= 0.015	Base
3	AMS 5704	-	American	12.0-15.0	2.0	0.02-0.10	0.15	0.10	3.5-5.0	2.75-3.25	18-21	1.2-1.6	S= 0.015 Zr= 0.02-0.08 Bi= 0.3 ppm	Cu=0.1 B = 0.003-0.010, Se= 3 ppm	Ag= 5 ppm P= 0.015 Pb= 5 ppm	Base
4	AMS 5706	-	American	12.0-15.0	2.0	0.02-0.10	0.15	0.10	3.5-5.0	2.75-3.25	18-21	1.2-1.6	S= 0.015 Zr= 0.02-0.08 Bi= 0.3 ppm	Cu=0.1 B = 0.003-0.010 Se= 3 ppm	P= 0.015 Pb= 5 ppm	Base

Sl. No.	Specification	Grade	Origin	Chemical composition (Wt%)(wherever limit not mentioned consider as max)											
				Co	Fe	C	Si	Mn	Mo	Ti	Cr	Al	Others (each)			Ni
5	AMS 5707	-	American	12.0-15.0	2.0	0.02-0.10	0.15	0.10	3.5-5.0	2.75-3.25	18-21	1.2-1.6	S= 0.015 Zr= 0.02-0.08 Bi= 0.3 ppm.	Cu=0.1 B = 0.003-0.010 Se= 3 ppm.	P= 0.015 Pb= 5 ppm	Base
6	AMS 5708	-	American	12.0-15.0	2.0	0.02-0.10	0.15	0.10	3.5-5.0	2.75-3.25	18-21	1.2-1.6	S= 0.015 Zr= 0.02-0.08 Bi= 0.3 ppm	Cu=0.1 B = 0.003-0.010 Se= 3 ppm	P= 0.015 Pb= 5 ppm .	Base
7	AMS 5709	-	American	12.0-15.0	2.0	0.02-0.10	0.15	0.10	3.5-5.0	2.75-3.25	18-21	1.2-1.6	S= 0.015 Zr= 0.02-0.08 Bi= 0.3 ppm	Cu=0.1 B = 0.003-0.010 Se= 3 ppm	P= 0.015 Pb= 5 ppm	Base
8	EMS 55388	-	American	12.0-15.0	2.0	0.02-0.08	0.15	0.10	3.5-5.0	2.75-3.25	18-21	1.2-1.6	S= 0.015 Zr= 0.02-0.08 Al +Ti= 4.1-4.45	Cu=0.1 B = 0.003-0.010, N=175 ppm	P= 0.015, Other (each) = 0.15	Base

Sl. No.	Specification	Grade	Section thickness 50mm Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
1	MSRR 7192	-	Solution treat: 995-1035°C / 4 hrs / OQ or WQ Ppt: 850°C / 4 hrs / AC + 760°C / 16 hrs / AC	Solution treat + Ppt	1080 (at 535°C)	770 (at 535°C)	12 (at 535°C)	18 (at 535°C)	Creep test: Temperature= 670°C, Stress= 555 MPa, Duration = 23 hours, Plastic strain = 0.2% max. Stress rupture test: Temperature= 730°C, Stress= 550 MPa, Time to rupture ≥23 hours. % El= ≥5% [@5D] or ≥6% [@4D]	Stress relieving (for bars and forgings after machining): 1000°C/ 2-4 hrs / OQ [Hardness <280 HB]
2	AIR 9165	NC 20 K14	Solution treat:1020°C / AC Ppt: 845°C / 4 hrs / AC + 760°C / 16 hrs / AC	Solution treat + Ppt	1080 (at 535°C)	770 (at 535°C)	12 (at 535°C)	18 (at 535°C)	Hardness: 321-403 HB Creep test: Temperature= 800°C, Stress= 100 MPa, Duration = 100 hours, Plastic strain = 0.2% max. Stress rupture test: Temperature= 730°C, Stress= 530 MPa, Time to rupture ≥30 hours. % El= ≥5%	-
3	AMS 5704	-	Solutionize: 996-1038°C (±14°C) / 4 hrs± 15 minutes / OQ or WQ + Stabilize: 843°C (±8°C) / 4 hrs ± 30 minutes / AC Ppt: 760°C (±8°C) / 16 ± 1 hr / AC	Solutionize + Stabilize + Ppt	1207 (at RT)	827 (at RT)	15 (at RT) [@4D]	18 (at RT)	Hardness:341-401 HB, Stress rupture test: Temperature= 732°C, Stress= ≥550 MPa, Time to rupture ≥ 23 hours, % El= ≥5% [@4D]	-
					1069 (at 538°C)	724 (at 538°C)	15 (at 538°C) [@4D]	18 (at 538°C)	Stress rupture test: Temperature= 816°C, Stress= ≥293 MPa, Time to rupture ≥23 hours, % El= ≥5% [@4D]	

Sl. No.	Specification	Grade	Section thickness 50mm Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
4	AMS 5706	-	Solutionize: 996-1038°C (±14°C) / AC or faster + Stabilize: 843°C (±8°C) / 4 hrs ± 15 minutes / AC Ppt: 760°C (±8°C) / 16 ± 1 hr / AC	Solutionize + Stabilize + Ppt	1103	758	15 [@4D]	18	Hardness:321-437 HB Stress rupture test: Temperature= 732°C, Stress= ≥517 MPa, Time to rupture ≥23 hours, % El= ≥8% [@4D]	-
5	AMS 5707	-	Solutionize: 996-1038°C (±14°C) / 4 hrs ± 30 minutes / AC + Stabilize: 843°C (±8°C) / 4 hrs ± 30 minutes / AC Ppt: 760°C (±8°C) / 16 ± 1 hr / AC	Solutionize + Stabilize + Ppt	1103	758	15 [@4D]	18	Hardness= 321-437 HB Stress rupture test: Temperature= 732°C, Stress= ≥517 MPa, Time to rupture ≥ 23 hours, % El ≥ 8 [@4D] Stress rupture test: Temperature= 816°C, Stress= ≥276 MPa, Time to rupture ≥ 23 hours, % El ≥ 5 [@4D]	-
6	AMS 5708	-	Solution treat: 1038-1079°C (±14°C) / 1-4 hours / AC or faster + Stabilize: 843°C (±8°C) / 4 hrs ± 15 minutes (24±1 hr for blade forgings)/ AC Ppt: 760°C (±8°C) / 16 ± 1 hr / AC	Solutionize + Stabilize + Ppt	-	-	-	-	Hardness= 32-42 HRC Stress rupture test: Temperature= 816°C, Stress= ≥328 MPa, Time to rupture ≥ 23 hours, % El ≥ 8 [@4D]	-

Sl. No.	Specification	Grade	Section thickness 50mm Heat treatment	Condition	Mechanical properties (Minimum)					
					UTS (MPa)	0.2% Proof (MPa)	% El (5D)	% RA	Others	Remarks
7	AMS 5709	-	Solutionize: 1079°C (±14°C) / 4 hrs± 30 minutes / AC or faster + Stabilize: 843°C (±8°C) / 4 hrs ± 30 minutes (24±1 hr for blade forgings) / AC Ppt: 760°C (±8°C) / 16 ± 1 hr / AC	Solutionize + Stabilize + Ppt	-	-	-	-	Hardness= 32-42 HRC Stress rupture test: Temperature= 816°C Stress= ≥328 MPa Time to rupture ≥ 23 hours % El ≥ 8 [@4D]	-
8	EMS 55388	-	Solution treat: 1024-1079°C (±14°C) {for Condition A} OR 996-1038°C (±14°C) {for Condition B} / 4 hr / OQ or WQ or Polymer quench Stabilize: 843°C (±8°C) / 4 hrs / AC Ppt: 760°C (±8°C) / 16 hr / AC [For more details on heat treatment, refer EMS 55388 and HT 5088]	Solutionize + Stabilize + Ppt	1103 [at RT] for Condition A	758 [at RT] for Condition A	12 [@4D] [at RT] for Condition A	15 [at RT] for Condition A	Stress rupture test (smooth) For Condition Temperature= 816°C Stress= ≥328 MPa Time to rupture ≥ 23 hours % El ≥ 5 [@4D]	Condition A: Material requiring max. Stresses rupture properties. Condition B: Material requiring max. tenslie properties.
					1207 [at RT] for Condition B	827 [at RT] for Condition B	12 [@4D] [at RT] for Condition B	15 [at RT] for Condition B	Stress rupture test (smooth & notched) For Condition A Temperature= 732°C Stress= 552 MPa, Time to rupture ≥ 23 hours % El ≥ 5 [@4D]	
					1103 [at 538°C] for Condition B	758 [at 538°C] for Condition B	12 [@4D] [at 538°C] for Condition B	15 [at 538°C] for Condition B	Stress rupture test (smooth & notched): For Condition B: Temperature= 732°C Stress= 517 MPa, Time to rupture ≥ 23 hours % El ≥ 5 [@4D]	

8. ADDENDUM

RATIONALISATION OF MIDHANI METALLIC MATERIALS

1. SUPERALLOYS

Sl. No	Grade / TA No.	Nominal Composition	Product		Equivalent Specifications
			Nomen-clature	Size (mm) Dia./ Thick.	
1.	Superni 263A TA No. 904	20Cr-20Co-5.9Mo-2.1Ti-0.5Al-Bal. Ni	F & HR Bars	75-180 (F) 10-70 (HR)	GTM-SU-263/FS-1 GTM-SU-263/M-HB-1 MSRR 7035 BS HR 10 CRE(M)/22 JSS-9630-09-2001-Bars GTM-SU-263 AMS 5886
2.	Superni 263A TA No. 929	20Cr-20Co-5.9Mo-2.1Ti-0.5Al-Bal. Ni	CR Sheets	0.5 – 6.0	GTM-SU-263/M-CS-1 MSRR 7036 BS HR 206:1973 (1993) AMS 5872 CRE(M)/20 JSS-9630-10-2001-CR Sheets
3.	Superni 718A TA No. 905	19Cr-18Fe-5Nb-3Mo-1Ti-0.5Al-52Ni	Feed Stock for Forgings	75-160	GTM-SU-718/FS-1 AMS 5663 CRE(M)/45 BS 2 HR 2 Nimonic 90 16-114.3
4.	Superni 718A TA No. 922	19Cr-18Fe-5Nb-3Mo-1Ti-0.5Al-52Ni	Feed Stock for Compressor Blades	10-70	GTM-SU-718/FS-2 GTM-SU-718-M-HB-1 AMS 5663 AMS 5662 CRE(M)/46 JSS-9630-26-2002
5.	Superni 718A PC No. RCMA(M) / PC/ 006/2003	19Cr-18Fe-5Nb-3Mo-1Ti-0.5Al-52Ni	CR Sheets	0.5-6.0	GTM-SU-718/M-CS-1 AMS 5596 CRE(M)/47 JSS-9630-23-2001-Plates , Sheets, Strips
6.	Superni 75A TA No. 546	20Cr-0.3Ti-Bal. Ni	Forged Bars	75-180	BS HR 5 NC 20T AE 435 CRE/REP/1068 MSRR 7007 MSRR 7004 JSS-9630-07-2001-Bars
7.	Superni 75A TA No. 495	20Cr-0.3Ti-Bal. Ni	HR Bars	10-70	BS HR 5 NC 20T AE 435 CRE/REP/1068 MSRR 7007 MSRR 7004 JSS-9630-07-2001-Bars

Ref. No: CEMILAC/2011/GDP dated 01.08.2007

RATIONALISATION OF MIDHANI METALLIC MATERIALS

2. TITANIUM ALLOYS

Sl. No	Grade / TA No.	Nominal Composition	Product		Equivalent Specifications
			Nomen-clature	Size (mm) Dia./ Thick.	
1.	Titan 22A	8Al-1V-1Mo-Bal. Ti	HR Bars	20-70	LA 114 CRE(M)/33 MIL-T-9047E AMS 4972E TA8DV
2.	Titan 23A TA No. 910	2Al-1.5Mn-Bal Ti	Forged & HR Bars	10-70(HR)	GTM-Ti-OT4-1/M/HS-1 OCT.1-90173-75 CRE(M)/14 JSS-9630-20-2001-HR Bars
3.	Titan 23A TA No. 906	2Al-1.5Mn-Bal Ti	CR Sheets	0.5-6.0	GTM-Ti-OT4-1/M/HS-1 OCT.1-90218-76 CRE(M)/16 JSS-9630-19-2001-CR Sheets
4.	Titan 31A (TM) TA No. 908	6Al-4V-Bal. Ti	Feed stock for Forgings	75-250	GTM-Ti-64/FS-1 CRE(M)/49 AMS 4928K AMS 4967E BS 2TA 12 GTM-Ti-64 AMS 4928P MIL-T-9047G
5.	Titan 31A (TM) TA No. 907	6Al-4V-Bal. Ti	Feed Stock for Blades	10-70	GTM-Ti-64/FS-1 CRE(M)/41 GTM-Ti-64/FS-2 MIL-T-9047 BS 2 TA 12 BS 2 TA 11 AMS 4967E AMS 4928K IMI 318 3.7164.1/ DIN 65040 GTM-Ti-64
6.	Titan 31A (DM) TA No. 909	6Al-4V-Bal.Ti	Feed stock for Forgings	10-250	GTM-Ti-64/FS-1 GTM-Ti-6-4/M-HB-1 CRE(M)/51 AMS 4967E AMS 4928K BS 2 TA 12 3.7164.1/DIN 65040 GTM-Ti-64

Ref. No: CEMILAC/2011/GDP dated 01.08.2007

RATIONALISATION OF MIDHANI METALLIC MATERIALS

2. TITANIUM ALLOYS

Sl. No	Grade / TA No.	Nominal Composition	Product		Equivalent Specifications
			Nomen-clature	Size (mm) Dia./ Thick.	
7.	Titan 35 A (GTM 900) TA No. 646	6.5Al-3.3Mo-1.4Zr-0.25Si-Bal. Ti	Forged & HR Bars	25x35 210x230 (Flats)	GTM 900/FS-2 OCT.1-90006-77 CRE(M)/36 OCT.1.90173-75 OCT.1.90266-78 OCT.1.90266-77 JSS-9630-18-2002-HR Bars
8.	Half Alloy	3Al-2.5V-Bal Ti	Forged Bars	75-150	MIL-T-9047 CRE(M)/38 JSS-9510-13-2003-F& Annealed Bars

RATIONALISATION OF MIDHANI METALLIC MATERIALS

3. STEELS

Sl. No	Grade / TA No.	Nominal Composition	Product		Equivalent Specifications
			Nomen-Cloture	Size (mm) Dia./ Thick.	
1.	MDN 431A TA No. 903	0.16C-17Cr-2.5Ni-Bal. Fe	Forged & Hot Rolled Bars	10-70 (HR) 75-180(F)	GTM-S-80/FS-1 (Rev2) GTM-S-80/M-HB-1 (Rev2) CRE (M)/18 BS 6S 80 MSRR 6573 JSS-9640-02-2002-Bars 23 DC 13
2.	MDN 431A TA No. 928	0.16C-17Cr-2.5Ni-Bal. Fe	Hot Rolled Flats	6-25	GTM-S-80/M-HB-1 (Rev2) CRE(M)/53 BS 6S 80 MSRR 6573 JSS-9640-03-2001-Flats
3.	MDN 321A TA No. 693	18Cr-10Ni-Ti-Bal. Fe	Cold Rolled Sheets	0:5-6.0	BS S 526 MSRR 6561 Z 10CNT18 CRE/REP/1081 JSS-9515-13-2000-CRSheets & Strips
4.	MDN 321A TA No. 322	18Cr-10Ni-Ti-Bal. Fe	Forged Bars	75-150	BS S 129 Z10CNT18 Z10CNT18-11 12X18H10T 12X18H9T CRE/REP/1062 JSS-9510-10-2000-F & HR Bars
5.	MDN 321A TA No. 732	18Cr-10Ni-Ti-Bal. Fe	HR Bars	10-70	BS S 129 Z10CNT18 MSRR 6562 CRE/REP/1062 JSS-9510-10-2000-F&HRBars
6.	MDN 321A TA No. 619	18Cr-10Ni-Ti-Bal. Fe	Cold Drawn & Annnealed Wires	0.5-8.0	S 129 Z10CNT18 12X18H10T 12X18H9T CRE/REP/1079

3. STEELS

Sl. No	Grade / TA No.	Nominal Composition	Product		Equivalent Specifications
			Nomen-Cloture	Size (mm) Dia./ Thick.	
7.	MDN 321A TA No. 991	18Cr-10Ni-Ti-Bal. Fe	Cold Drawn Wires	0.5-6.0	DTD 189A Z10CNT18 AIR 9160 12X18H10T 12X18H9T GOST 18143 TY-3-1002-77 GOST 18907 5548-80 CRE/REP/1079
8.	MDN 347A TA No. 556	18Cr-8Ni-Bal. Fe-Nb (Stab)	Forged & HR Bars	10-70 (HR) 75-150 (F)	BS S 130 MSRR 6522 KH18NHB CRE(M)/3 BS 2S 130 RTO/ENG/33-1(L-2) JSS-9630-03-2000-F&HR Bars MDN 321 BS 2S 130 AISI 316 BS 970 En 58M BS 970 Part-1 304 S16 AISI 3162 QQ-S-173 Type 304 & 321 Z10 CNT 18-11
9.	MDN 347A TA No. 713	18Cr-8Ni-Bal. Fe-Nb (Stab)	Cold Rolled Sheets	0.5-6.0	BS S 527 MSRR 6523 AMS 5512F CRE(M)/9 MSRR 6523 BS S 527 AMS 5512F MDN 321 A MIL-S-6721 BS S 526 BS S 521 BS 1449 P-II 304 S 16 AISI 304 AISI 316 BS S 524 JSS-9630-02-2000-Sheets & Strips

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RATIONALISATION OF MIDHANI METALLIC MATERIALS

3. STEELS

Sl. No	Grade / TA No.	Nominal Composition	Product		Equivalent Specifications
			Nomen-Cloture	Size (mm) Dia./ Thick.	
10.	MDN 15-5PH TA No. 1166	0.07C-15Cr-4.5Ni-0.3Nb-3.5Cu-Bal.Fe	Forged & Hot Rolled Bars	10-70(HR) 75-200(F)	AMS 5659K RCMA(M)/76 EZ6NCT25
11.	MDN 174A PC No. RCMA(M) /PC/010, 012/03 (Forged)	0.07C-16Cr-4Ni-0.3Nb-4Cu-Bal. Fe	Forged & HR Bars	10-70(HR) 75-200(F)	RCMA(M)/77 AMS 5622B AMS 5643L
12.	E16NCD13 PC No.: RCMA(M) /PC/011,1030 /03,05 (Forged) RCMA(M)/PC/27/05(F & HR Bars)	0.16C-3.25Ni-1Cr-0.25Mo-Bal. Fe	Forged Bars	75-200	RCMA(M)/93 AIR 9160C GTM-E-16-NCD-13/M-HB&FS 16NCD13
13.	E16NCD13 PC No. RCMA(M)/PC/011/03 (HR Bars) RCMA(M)/PC/27/05(F & HR Bars)	0.16C-3.25Ni-1Cr-0.25Mo-Bal. Fe	HR Bars	10-70	RCMA(M)/93 AIR 9160C GTM-E-16-NCD-13/M-HB&FS 16NCD13
14.	15CDV6	0.15C-1Mn-1.4Cr-0.9Mo-0.25V-Bal Fe	HR & CR Sheets	0.5 – 6.0 (CR) 7 – 12 (HR)	CRE(M)/58 AIR 9160 RCMA(M)/63 AIR 9160C (JSS-9510-11-2003-F & HR Bars) 15CDV6

Ref. No: CEMILAC/2011/GDP dated 01.08.2007

RATIONALISATION OF MIDHANI METALLIC MATERIALS

3. STEELS

Sl. No	Grade / TA No.	Nominal Composition	Product		Equivalent Specifications
			Nomen-Cloture	Size (mm) Dia./ Thick.	
15.	MDN6758A	0.3C-1Cr-0.2Mo-Bal. Fe	Forged Bars, Forged Flats & HR Bars	10-70 (HR) 75-200 (F)	RCMA(M)/80 MIL-S-6758B C 40 BS S 93
16.	MDN 99A	0.4C-0.7Cr-0.5Mo-2.5Ni-Bal Fe	Forged Bars, Forged Flats & HR Bars	10-70 (HR) 75-200 (F)	RCMA(M)/79 BS 5S 99 BS 2S 96 BS 2S 98 30KHGSA BS S 154 35NC6
17.	MDN 132A TA No. 927	0.4C-0.5Mn-3Cr-0.9Mo-Bal Fe	Forged Bars	75-180	GTM-S-132/FS-1 (Rev2) CRE(M)/40 BS 3S 132 MSRR 6011 MSRR 6012 30CD12 38KHMYuA JSS-9640-04-2001-Forged Bars
18.	MDN 132A PC No. RCMA(M)/PC/019,28/04,05 (HR bars)	0.4C-0.5Mn-3Cr-0.9Mo-Bal Fe	HR Bars	10-70	CRE(M)/40 BS 3S 132 MSRR 6011 MSRR 6012 JSS-9640-04-2001-Forged Bars
19.	MDN 440C PC No. RCMA(M)/PC/015/2003, Heat No. G2701	1.1C-17Cr-0.5Mo-Bal. Fe	HR Bars	10-70	RCMA(M)/78 AMS 5618D AMS 1518D SAE 52100 BS S135
20.	MDN 13-8Mo PH	0.05C-13Cr-8Ni-2.2Mo-1.1Al-Bal-Fe	Forged & HR Bars	10-70 (HR) 75-180 (F)	RCMA(M)/75 AMS 5629D
21.	MDN 127A PC No. RCMA(M)/PC/25/2005	0.031C-1.25Cr-0.05Mo-0.25V-Bal. Fe	HR & CR Flats	6-15 (HR), 3-6 (CR)	RCMA(M)/60 DMS 127 DMR MC 3S DMS 127E

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RATIONALISATION OF MIDHANI METALLIC MATERIALS

3. STEELS

Sl. No	Grade / TA No.	Nominal Composition	Product		Equivalent Specifications
			Nomen-Cloture	Size (mm) Dia./ Thick.	
22.	MDN 250A TA No. 694	18Ni-8Co-5Mo-0.54Ti-0.1Al-Bal. Fe	Forged Bars	70-200 (HR)	CRE(M)/25 AMS 6512 MIL-S-46850B MARBAL 18 E-Z2NKD 18 JSS-9630-14-2001-F Bars

ANNEXURE TO LETTER NO. CEMILAC/2011/GDP dt. 30.10.2006

AL. ALLOYS CHART OF EQUIVALENCE INTERNATIONAL STANDARDS WITH RE-DESIGNATED OFAJ MATERIAL

SL NO	TYPE APPROVAL NO.	TYPE APPROVED ALLOY	RE-DESIGNATED TYPE APPROVED ALLOY	GENERAL	BRITISH	AMERICAN	FRENCH	INDIAN	GERMAN
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1.	724	HE 15 AST	IOF 2014A-T651	2014	BBL 168	AMS-QQ-A-20072	-	-	-
2.	617	HE 15A	IOF 2014A-T5	2014	B S L 277	AMS-QQ-A-367H	AU4SG, AIR 9251	IS 733 24945	DIN 1747 3.1255
3.	738	HE 20 A	IOF 6061A-T6	6061	B S L 131	AMS-QQ-A-20072	-	IS 733-65082	-
4.	984	7010 AST	IOF 7010A-T7451	7010	DTD 5130	AMS-4235	-	-	DIN 1747 3.4384
5.	751	Al-Mg-Mn Alloy	IOF 5083A-'O'	5083	-	AMS-QQ-A-20072	AG5MC	IS 733 54300	DIN 1747 3.3547
6.	1330	5086 alloy	IOF 5086A-H111	5086	-	AMS-QQ-A-20072	A04MC, AIR 9050	-	-
7.	1327	AU4G1	IOF 2024A-T4	2024	-	AMS-QQ-A-20072	AU4G1 AIR 9050	-	DIN 1747 3.1355

APPROVED BY CEMILAC

Appendix-3

IUPAC Periodic Table of the Elements

Key:

atomic number **Symbol** name conventional atomic weight standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** hydrogen 1.008 [1.0078, 1.0082]																	2 **He** helium 4.0026
3 **Li** lithium 6.94 [6.938, 6.997]	4 **Be** beryllium 9.0122											5 **B** boron 10.81 [10.806, 10.821]	6 **C** carbon 12.011 [12.009, 12.012]	7 **N** nitrogen 14.007 [14.006, 14.008]	8 **O** oxygen 15.999 [15.999, 16.000]	9 **F** fluorine 18.998	10 **Ne** neon 20.180
11 **Na** sodium 22.990	12 **Mg** magnesium 24.305 [24.304, 24.307]											13 **Al** aluminium 26.982	14 **Si** silicon 28.085 [28.084, 28.086]	15 **P** phosphorus 30.974	16 **S** sulfur 32.06 [32.059, 32.076]	17 **Cl** chlorine 35.45 [35.446, 35.457]	18 **Ar** argon 39.948
19 **K** potassium 39.098	20 **Ca** calcium 40.078(4)	21 **Sc** scandium 44.956	22 **Ti** titanium 47.867	23 **V** vanadium 50.942	24 **Cr** chromium 51.996	25 **Mn** manganese 54.938	26 **Fe** iron 55.845(2)	27 **Co** cobalt 58.933	28 **Ni** nickel 58.693	29 **Cu** copper 63.546(3)	30 **Zn** zinc 65.38(2)	31 **Ga** gallium 69.723	32 **Ge** germanium 72.630(8)	33 **As** arsenic 74.922	34 **Se** selenium 78.971(8)	35 **Br** bromine 79.904 [79.901, 79.907]	36 **Kr** krypton 83.798(2)
37 **Rb** rubidium 85.468	38 **Sr** strontium 87.62	39 **Y** yttrium 88.906	40 **Zr** zirconium 91.224(2)	41 **Nb** niobium 92.906	42 **Mo** molybdenum 95.95	43 **Tc** technetium	44 **Ru** ruthenium 101.07(2)	45 **Rh** rhodium 102.91	46 **Pd** palladium 106.42	47 **Ag** silver 107.87	48 **Cd** cadmium 112.41	49 **In** indium 114.82	50 **Sn** tin 118.71	51 **Sb** antimony 121.76	52 **Te** tellurium 127.60(3)	53 **I** iodine 126.90	54 **Xe** xenon 131.29
55 **Cs** caesium 132.91	56 **Ba** barium 137.33	57-71 lanthanoids	72 **Hf** hafnium 178.49(2)	73 **Ta** tantalum 180.95	74 **W** tungsten 183.84	75 **Re** rhenium 186.21	76 **Os** osmium 190.23(3)	77 **Ir** iridium 192.22	78 **Pt** platinum 195.08	79 **Au** gold 196.97	80 **Hg** mercury 200.59	81 **Tl** thallium 204.38 [204.38, 204.39]	82 **Pb** lead 207.2	83 **Bi** bismuth 208.98	84 **Po** polonium	85 **At** astatine	86 **Rn** radon
87 **Fr** francium	88 **Ra** radium	89-103 actinoids	104 **Rf** rutherfordium	105 **Db** dubnium	106 **Sg** seaborgium	107 **Bh** bohrium	108 **Hs** hassium	109 **Mt** meitnerium	110 **Ds** darmstadtium	111 **Rg** roentgenium	112 **Cn** copernicium	113 **Nh** nihonium	114 **Fl** flerovium	115 **Mc** moscovium	116 **Lv** livermorium	117 **Ts** tennessine	118 **Og** oganesson

57 **La** lanthanum 138.91	58 **Ce** cerium 140.12	59 **Pr** praseodymium 140.91	60 **Nd** neodymium 144.24	61 **Pm** promethium	62 **Sm** samarium 150.36(2)	63 **Eu** europium 151.96	64 **Gd** gadolinium 157.25(3)	65 **Tb** terbium 158.93	66 **Dy** dysprosium 162.50	67 **Ho** holmium 164.93	68 **Er** erbium 167.26	69 **Tm** thulium 168.93	70 **Yb** ytterbium 173.05	71 **Lu** lutetium 174.97
89 **Ac** actinium	90 **Th** thorium 232.04	91 **Pa** protactinium 231.04	92 **U** uranium 238.03	93 **Np** neptunium	94 **Pu** plutonium	95 **Am** americium	96 **Cm** curium	97 **Bk** berkelium	98 **Cf** californium	99 **Es** einsteinium	100 **Fm** fermium	101 **Md** mendelevium	102 **No** nobelium	103 **Lr** lawrencium

Appendix-4

ENGLISH EQUIVALENT OF RUSSIAN LETTERS

U.S.S.R.	Pronounced as	ENGLISH	U.S.S.R.	Pronounced as	ENGLISH
A	a	A	0	o	0
Б	beh	B	П	peh	P
B	veh	V	P	err	R
Г	geh	G	C	ess	S
Д	day	D	T	teh	T
E	Ye	Ye	Y	OOO	U
Ё	Yo	Yo	Ф	ef	F
Ж	zheh	Jh	X	khah	Kh
З	zeh	Z	Ц	tsch	Tse
И	ee	Ee	Ч	cheh	ch
Й	y	Y	Щ	shah	Sh
K	kah	K	Ш	shchah	Sch
Л	eL	L	Э	e	E
M	em	M	Ю	u	Yu
H	en	N	Я	ya	Ya

9.0 References of previously rationalized materials

In the past, similar exercise has been taken up by various agencies along with RCMA / CEMILAC. Some of the known references of rationalization of materials are as follows :

1. Compendium of Alternate / Equivalent Material for Tejas Aircraft (LCA MK1 – Air Force Version Fighter & Trainer)" - Ref No.HAL/ARDC/LCA/MTL/005 Issue 'B' dated 05.12.2016.

2. Rationalization of Metallic Materials of Russian Military Aircraft and Aero-Engines - Ref No: RCMA(Nsk)/07/01 dated 27.09.2007.

3. Rationalization of MIDANI Metallic Materials - Annexure-1 Ref.No. : CEMILAC/2011/GDP dated 01.08.2007

4. Ordnance Factory, Ambajhari - Rationalization of Aluminium Alloys - Annexure-2. Ref. No. CEMILAC/2011/GDP dated 30.10.2006