

AUBERT&DUVAL



METALLURGICAL SOLUTIONS FOR THE DEFENSE INDUSTRY

**HIGH-PERFORMANCE
STEELS AND ALLOYS**



www.aubertduval.com

- + Referenced partner for co-engineering of dedicated grades and co-design of forging solutions.
- + Dedicated and patented steel grades developed for the defense market: ARMAD®, CLARM®HB7...
- + Meticulous management of a very high level of confidentiality, particular to defense applications



AUBERT & DUVAL

Committed to support the defense industry in the fields of land, air and sea

Established for 70 years in the defense market, Aubert & Duval is the metallurgical partner of reference for manufacturers in this sector.

Our expertise covers the most demanding materials: special steels, superalloys, titanium, aluminum and metal powders for additive manufacturing. We can design steel grades as well as design and manufacture open die forgings or closed-die forging parts. Along with supplying raw materials and semifinished products.

Our expertise is based on the skills and know-how of our teams, along with the mastery of a unique set of industrial tools: air and vacuum melting furnaces, ESR and VAR remelting furnaces, rolling mills, large open die forging and closed-die forging presses, heat treatment and special processes furnaces, as well as design and simulation capabilities.

A trusted, certified and accredited partner for the defense markets

Aubert & Duval has the necessary certifications to support its customers in the defense markets based on the extensive experience of its teams:

- ISO 9001, ISO 14001, OHSAS 18001
- NADCAP Heat Treatment
- AQAP2110
- Approved by major NATO gun manufacturers
- Fully Authorized Economic Operator (AEO)
- Strict compliance with confidentiality: our teams are authorized to deal with sensitive information and support you right from the early stages of your projects (design of steel grades, design of complex parts, etc.).
- A network of carefully selected, and regularly audited, contractors enabling an extremely wide range of tools to be used.
- Clearance : Aubert & Duval has highly specialists with secret clearance to deal with confidential projects.

The quality of your products at the heart of our requirements

The quality and conformity of the products we supply on demanding markets (aerospace, energy, defense, medical, etc.) are at the heart of our stringency and our commitment to all of our customers. Every day, our teams work to ensure your satisfaction and support over the long term, with the most reliable and most efficient metallurgical solutions.





Main materials

HPS High performance steels

A range of alloyed steels with tightly controlled characteristics offering optimum value for customers.

NiSA Nickel-based superalloys

A range of alloyed materials with specific resistance to very high temperatures and corrosion, the majority component being nickel.

Ti Titanium alloys

Pure or alloyed titanium, combining mechanical properties and corrosion-resistance with light weight.

Al Aluminum alloys

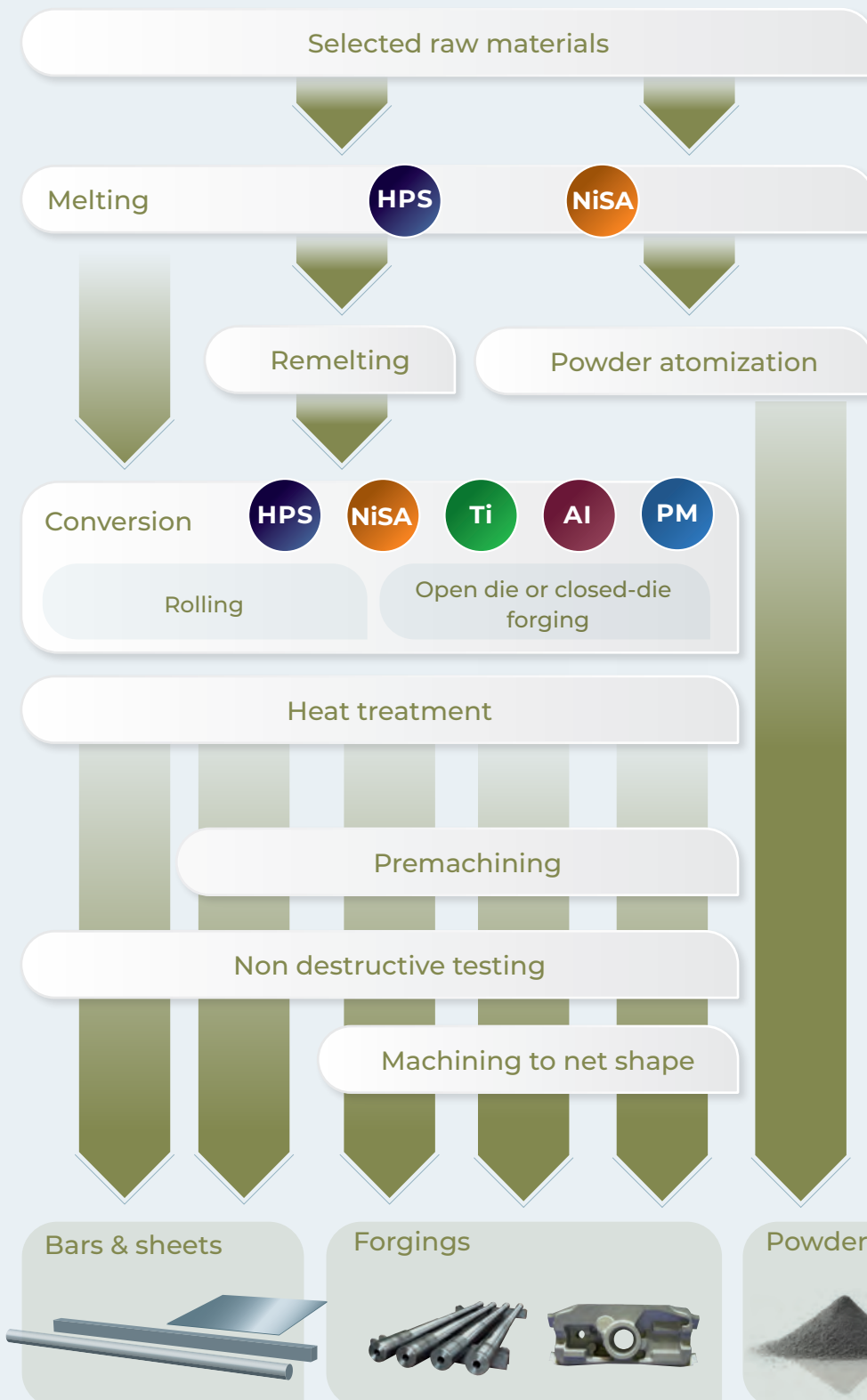
Slightly alloyed aluminum.

PM Metal powders

Superalloys for high temperatures and steel powders dedicated for Additive Manufacturing technologies.



Process flow





FORGINGS FOR LARGE CALIBER GUNS

Aubert & Duval has over 70 years of experience as a leading supplier of high performance steels for defense applications, including forgings for large caliber gun barrels and breech components.



CLARM® grades
*Blank barrels up to 10 meters
for enhanced action range*



Customer benefits

- + Combat proven
- + High endurance
- + Excellent behavior in any environmental conditions
- + Resistance to intensive fire rates
- + Extended munitions range
- + Long cycle life maintaining high accuracy
- + Optimized properties of dedicated alloys grades
- + Providing global solution for breech blocks, breech rings and barrels
- + Dedicated Technical Support and R&D Team

Increasing system life

Aubert & Duval CLARM® grades offer unique ability for:

- + Thickness Reduction due to high mechanical performances to decrease weight impact
- + Increasing systems service life and maximum range
- + Cost reduction (maintenance & logistics) to battlefield
- + Capable of withstanding higher pressures, resulting in greater maximum ranges than traditional materials.

Aubert & Duval has the capability to vertically heat treat barrels in order to minimize distortion and residual stresses in the product, avoiding barrel deformation during machining and firing.

LARGE CALIBERS

Why using CLARM[®] steel grades?

- + 3 different CLARM[®] Grades depending on final requirements
- + Optimized chemical analyses for the best YS/KV (-40°C) and YS/K1C compromise
- + High toughness at -40°C; Typical K1C in the 140/180 MPa.m^{1/2} range
- + Elevated temperature tensile strength up to 400°C
- + Allow homogeneous yield strength along the barrel for optimum autofrettage
- + Heat treated in vertical position for lower deformation and mechanical properties homogeneity

Choose the best grade for your application

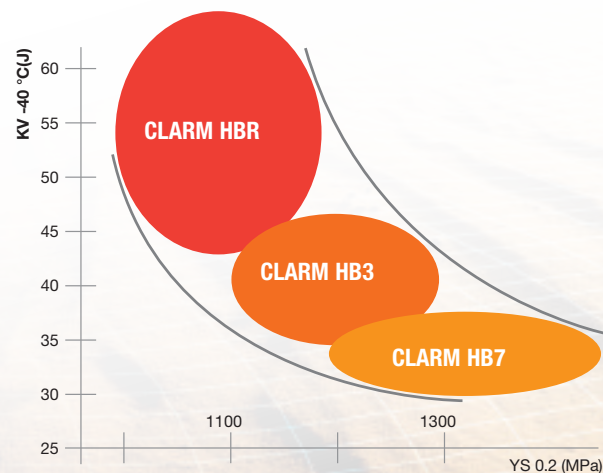
The choice of steel grade for gun barrel forgings is mainly governed by a compromise between yield strength (YS) and toughness at low temperatures (KV-40°C).

To define this compromise, the choice of optimum material for large gun barrels obviously leads to the Ni-Cr-Mo or Ni-Cr-Mo-V steels with a carbon content between 0.3 and 0.4% to guarantee the best strength and toughness balance. The chemical composition can be adjusted to achieve the desired, final mechanical properties.

Among all steel grades for artillery application available at Aubert & Duval, three of them are specifically designed for gun blanks and mortar barrel forgings.

• CLARM[®]HBR / CLARM[®]HB3 / CLARM[®]HB7

The CLARM[®] family is famous worldwide for its exceptional combination of tensile strength, ductility and toughness. The steel grade choice is mainly governed by the required compromise between yield strength (YS) and toughness at low temperature (KV-40°C). See drawing below.



Corresponding data sheets available on our website



Applications design

- + **Field towed guns:**
105 - 155 mm
- + **Tank guns:**
90 - 100 - 105 - 120 - 125 - 130 - 140 mm
- + **Self-propelled howitzers:**
155 mm
- + **Naval guns:**
40 - 57 - 76 - 127 mm
- + **Mortars:**
60 - 81 - 120 mm
- + Breech ring and breech block to complete any firing set

CLARM[®]HBR

The CLARM[®]HBR has an optimized chemical analysis for a high level of impact toughness and the best compromise between strength and toughness. The good hardenability provides homogenous mechanical properties in massive forgings parts after quench and tempering heat treatment.

Combining high quenching rates and elevated tempering temperatures results in a best toughness / ultimate strength compromise.

CLARM[®] HBR & CLARM[®]HB7

The search for even higher mechanical characteristics led to the development of the CLARM[®]HBR and CLARM[®]HB7 grades, the latter allowing yield strength of more than 1300MPa combined with exceptional K1c values.



STEEL BARS FOR MEDIUM CALIBER GUNS

Aubert & Duval is a leading supplier of high performance steels for defense applications, including medium caliber guns with over 70 years of experience supplying rolled and forged solutions to weapon manufacturers worldwide.



Customer benefits

- + Combat proven
- + High endurance
- + Excellent behavior in any environmental conditions
- + Resistance to intensive fire rates
- + Extended munitions range
- + Long cycle life maintaining high accuracy
- + Optimized properties of dedicated alloys grades
- + Dedicated Technical Support and R&D Team

Product range

Forged and rolled bars for diameters 20 - 25 - 30 - 35 - 40 mm

Provided for guns on:

- + Land armored vehicles
- + Battleships
- + Aircraft
- + Helicopters



MEDIUM CALIBERS



Choose the best grade for you application

Medium caliber guns can fire different types of ammunitions up to 3 km at a high firing rate (from 500 rounds/min up to 2500 rounds/min). Failure mode is usually wear due to high velocity ammunition and thermal fatigue.

The grades used for most of the barrels are chosen from the Cr-Mo-V family (high temperature strength, resistance to thermal fatigue) or the Ni-Cr-Mo-V family (when ductility and toughness at low temperature is required).

Material is mainly supplied in the form of rolled or forged bars manufactured from air melt ingot or VAR remelted ingots for the most stringent requirements.

Increasing system life

- + High temperature strength
- + Resistance to thermal fatigue
- + Ductility and toughness at low temperature



Courtesy CTA International

Supplied grades



	GKH®	ARMAD®	NC35M	CLARM®HB3W	GH4W	NC35M1W
C	0.28/0.34	0.30/0.35	0.35/0.40	0.30/0.35	0.35/0.42	0.37/0.42
Cr	2.8/3.2	2.8/3.2	0.9/1.3	1.2/1.7	3.0/3.5	1.2/1.7
Mo	0.8/1.2	0.7/1.2	0.3/0.6	0.3/0.6	0.8/1.2	0.7/1.2
Ni	-	≤ 0.30	3.0/3.6	3.0/4.0	-	3.3/3.9
V	0.25/0.35	0.15/0.35	0.15/0.25	0.15/0.25	0.15/0.25	0.2/0.3

MECHANICAL PROPERTIES:

	GKH®	ARMAD®	NC35M	CLARM®HB3W	GH4W	NC35M1W
Hardness (HRC)	32/39	35/41	38	38/42	39/44	44.5/47.5
UTS (MPa)	1000/1200	1100/1300	1200	1200/1350	1250/1400	1420/1550
YS (MPa)	≥ 800	≥ 900	≥ 1100	≥ 1180	≥ 1000	≥ 1300
EL (%)	≥ 10	≥ 16	≥ 16	≥ 14	≥ 12	≥ 12
KV J (RT)	≥ 130	≥ 140	-	≥ 60	≥ 50	≥ 45
KV J (-40°C)	≥ 110	≥ 120	≥ 70	≥ 35	≥ 30	≥ 28



STEEL BARS FOR FIREARMS

With over 70 years of experience serving the defense industry, Aubert & Duval is a leading supplier of high performance steels for defense applications, including firearms. It serves the firearm manufacturing sector for all types of small caliber barrel manufacturing, including cut rifling, button rifling, and hammer forging, as well as various grades suitable for other firearm components.

Gun barrels

Aubert & Duval offers martensitic steel grades achieving the best high strength / toughness compromise on the market:

- GKH® and ARMAD® (CrMoV martensitic steel grades)
- APX®4 (martensitic stainless-steel grade)

For barrels that withstand a transverse load during firing, specific care has been given to bars' transversal properties. GKH®, ARMAD® and APX®4 present an isotropic structure giving the material equivalent tensile, ductility and toughness properties, resulting from Aubert & Duval's high-tech production process.

These grades can be used with cut rifling, button rifling or cold hammer forging process.



credit photo ©H&K

Customer benefits

- + High endurance, even in extreme environmental conditions
- + Long cycle life & High accuracy
- + Weight optimization
- + Resistance to intensive fire rates
- + Compatible with new high pressure ammunition
- + Customized alloys grades
- + A global supplier of the weapon systems manufacturers
- + Technical Support
- + Dedicated R&D Team

Services

- + In-house fully integrated production process
- + Small MOQ possibility: 1500 kg
- + Distribution centers in Europe & USA.



Firearm metallurgical expertise

Benefits to firearm producers/designers

- Higher cold hammering rates, saving material compared with other grades
- Possibility of manufacturing the chamber during the cold hammering process
- GKH® and ARMAD®'s fatigue/strength upgrading gives opportunities to lighter barrel design with thinner wall sections
- Possibility with ARMAD® to achieve toughness and very good nitriding capability
- Ensuring stable process and limit disruptions at customer shop
- Ensuring perfect straightness and surface roughness during the cold hammering / button rifling operation

Steels for gun barrels

GKH®

Many years ago, Aubert & Duval developed the GKH® steel grade for gun barrels. GKH® steel (32CrMoV12) heat treated for 28-32 HRC which presents exceptional ductility and toughness including in transverse direction thanks to its homogeneous microstructure nearly free of banding.

APX®4

When corrosion resistance is needed or in the case where no corrosion protection is present (hard chromium plating of black chromium), manufacturers often used martensitic stainless steels. The most common grade is AISI 416 martensitic stainless steel. The steel contains high amount of sulfur favorable to boring and machining. Aubert & Duval has developed for these application APX®4 martensitic stainless steel.

	APX®4	GKH®	ARMAD®
Type	Martensitic stainless	Martensitic CrMoV	Martensitic CrMoV
EN designation	X4CrNiMo16-5-1	33CrMoV12-2	32CrMoV12-10
HRC as delivered	28/34	28/34	38/40.5
UTS (MPa)	900/1050	930/1080	1200/1280
YS 0,2 (MPa)	≥ 700	≥ 750	≥ 950
EL (%)	≥ 16	≥ 15	≥ 16
KV (RT)	≥ 120	≥ 140	≥ 160
KV (-40°C)	≥ 90	≥ 130	≥ 130

High Performance Steels for mechanism parts

For firing pins, extractors, ejectors, breeches (carburizing steels, nitriding steels and maraging steels).

FADH	14NiCrMo13-4
FDG®	20NiCrMo13-4
FND®	15NiMoSiCr10
FDMA	30NiCrMo16
819B	36NiCrMo16
NC310YW	40SiNiCrMoV10
819AW	E35NiCrMo16
MARVAL®18	X2NiCoMo18-8-5
MY19	X2NiCoMo18-9-5

ARMAD®

The development of new ammunitions with increased pressure and temperature in the chamber and barrel has been the driving force to improve mechanical properties at elevated temperature and resistance to wear during firing. ARMAD® steel grade has been developed for these purposes aiming at higher mechanical properties up to 650°C without impairing ductility and toughness.

FIRING TESTS RESULTS - BORE AFTER 15K ROUNDS





STRUCTURAL PARTS FOR ARM SYSTEMS AND PLATFORMS

Aubert & Duval meets the defense industry's material requirements for armored vehicles. By producing high performance materials for advanced structural parts. These parts are critical for the soldier's safety and product reliability in the battlefield.



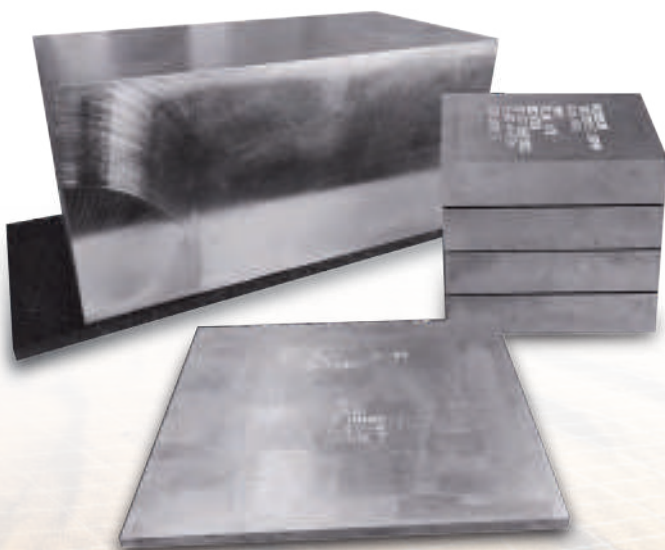
Customer benefits

- + Secure source for critical parts
- + Co-conception
- + Simulation of the manufacturing process
- + Patented alloys grades
- + High technical expertise
- + Dedicated Technical Support and R&D Team
- + Combat proven
- + Parts with high armored norms

Safety & reliability

Aubert & Duval offers solutions for critical parts:

- + Closed die-forgings needed to bring strength to critical areas, including armored vehicle parts such as wheels or hatches
- + Titanium armor plates and solutions
- + Bars & blocks in special steels, superalloys, aluminum alloys and titanium alloys



STRUCTURAL PARTS

Closed die forging

- + Die forging presses up to 65KT
- + Closed-die forging is the process of forming complex-shaped parts from a metal semi-product between two engraved tools (dies) by pressing with a closed-die forging press
- + Aubert & Duval is a world forgings supplier in aluminum, superalloy, steel and titanium materials made with closed die forging process for critical applications like aerospace, energy and defense

Supplied grades

High performance steels

819B (36NiMoCr16)
SCV®
APX®4 (X4CrNiMo16-5-1)

Maraging steels

MARVAL®X12
MARVAL®18 (Maraging 250)
MY19 (Maraging 300)
X17U4 (17-4PH)
X15U5W (15-5PH)

Aluminum

7010 and similar grades
2214 and similar grades

Superalloys

718, 625, Waspalloy

Titanium

TA6V
Grade 2
Grade 4

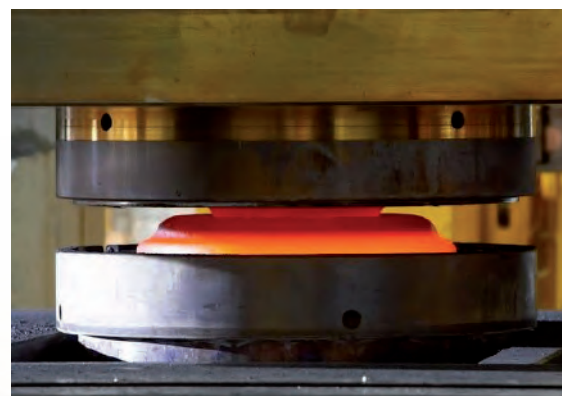
Standards

ASTM, AQAP2110, AMS, AIR, AFNOR, ASME, DFARS, MIL 1000-DTL, MIL standards



Large closed-die forgings

- + Max diameter for disks:
2 500 mm (79 in)
- + Max length for shafts: 4m (157 in)
- + From 20 kg / 44 lbs to 20 t





STEEL BARS FOR MISSILES

Aubert & Duval is a leading supplier of high performance steels for defense applications, including missile systems, with a long history of supplying material to missile manufacturers worldwide.

Choose the best grade for your application

Due to their expertise, Aubert & Duval develops and produces a range of precipitation hardening steels that meet missile producers'/designers' needs:

- + High UTS up to 2000 MPa
- + Simple heat treatment
- + Control of distortions during the process
- + Best compromise between UTS and toughness (at room and low temperatures)
- + Welding and flowforming ability
- + Corrosion and stress corrosion cracking resistance

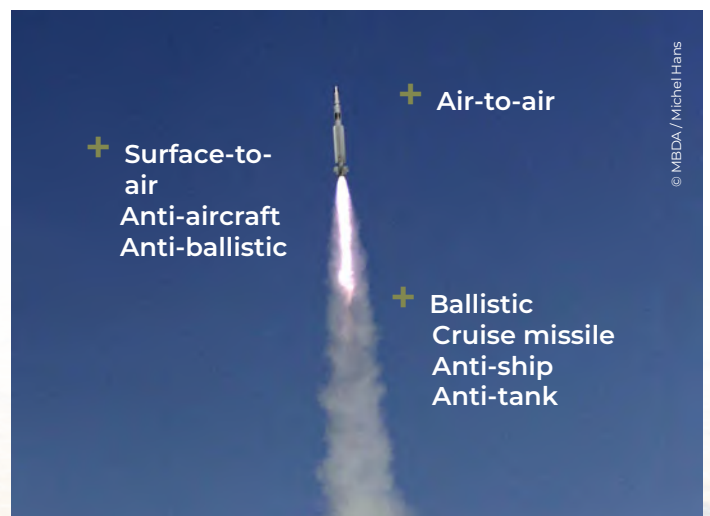


Customer benefits

- + Weight optimization
- + Customized alloys grades
- + A global supplier of the missiles systems manufacturers
- + Technical Support
- + Dedicated R&D Team

Product range

Forged and rolled bars for:



MISSILES

Metallurgical expertise

Precipitation hardening steels are key candidates to fulfill requirements for missiles structural parts such as body, frames and hangers:

- + High static and fatigue properties
- + Best combination of high strength and high toughness (even at low temperature)
- + High stress corrosion cracking performances
- + Suitable for welding and flowforming

Non stainless steels

High Performance Steels for missiles structural parts



	819B	819AW	MARVAL®18	MY19	ML340
Type	Martensitic steels		Precipitation hardening steels		
EN designation	36CrNiMo16	36CrNiMo16	Maraging 250	Maraging 300	X23NiCoCrMoAl13-6-3
UTS (MPa)	≥ 1230	≥ 1760	≥ 1720	≥ 1930	2220
YS 0.2% (MPa)	≥ 1030	≥ 1420	≥ 1600	≥ 1860	1900
EI (%)	≥ 8	≥ 6	≥ 6	≥ 5	10
KV (J)	≥ 25	≥ 17	≥ 15	≥ 12	≥ 20

Stainless steels

	APX®4	X17U4	X15U5W	MARVAL®X12	MARVAL®13X	MARVAL®X12H	MLX®17		
Type	Martensitic steel	Precipitation hardening steels							
EN designation	X4CrNiMo16-5-1	17-4PH	15-5PH	X1CrNiMoTiAl12-9	PH13-8Mo	X1CrNiMoTiAl12-10	X1CrNiMoTiAl12-11		
UTS (MPa)	≥ 950/1050	≥ 1150	≥ 1070	≥ 1070	≥ 1200	≥ 1200	≥ 1400	≥ 1520	≥ 1650
YS 0.2% (MPa)	≥ 700	≥ 900	≥ 1000	≥ 1000	≥ 1100	≥ 1140	≥ 1300	≥ 1380	≥ 1520
EI (%)	≥ 16	≥ 14	≥ 10	≥ 10	≥ 12	≥ 10	≥ 9	≥ 10	≥ 10
KV RT (J)	≥ 120	≥ 100	-	≥ 80	≥ 90	≥ 40	≥ 50	≥ 30	≥ 15
KV -40° (J)	≥ 70	≥ 60 (-30°C)	-	≥ 35(-30°C)	≥ 30	-	≥ 20	-	-

Ni-based alloys

Aubert & Duval provides Ni-based alloys for high temperature applications:

- AD730®
- PYRAD53NW (INCO718)

Titanium alloys

Aubert & Duval provides titanium alloy for missiles structural parts & systems:

- Ti6Al4V

equipment

melting

- Melting furnaces (EAF, AOD, Ladle refining process) up to 60 tons
- Vacuum Induction Melting (VIM) up to 20 tons
- Remelting furnaces (ESR, VAR) up to 30 tons

powder metallurgy

- Atomization VIGA (Ar and N)

forging

- Open-die forging presses from 1,500 to 10,000 tons
- Closed-die forging presses from 4,500 to 65,000 tons
- Forging machine

rolling mill

- 20 to 192 mm dia (depending on the grade laminability), peeled diameters

heat treatment

- Solution and ageing furnaces
- Horizontal and vertical quenching equipment

testing

- Immersion UT up to 13 tons (28,000 lbs)
- Automated contact UT up to 20 tons
- Material testing laboratories ISO 17025



AUBERT & DUVAL



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