
AUBERT&DUVAL
HIGH-PERFORMANCE STEELS AND ALLOYS
Metallurgical solutions
for the defense industry
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 andmetal 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
- TAA registered (US market)
- 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.

# 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.

# 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 (Air, VIM)

## 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

# Process flow

Selected raw materials

Melting — HPS — NiSA

Remelting

Powder atomization

Conversion — HPS — NiSA — Ti — Al — PM

Rolling

Open die or closed-die forging

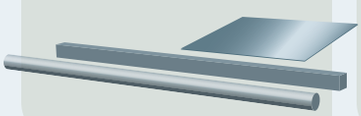
Heat treatment

Premachining

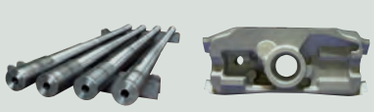
Non destructive testing

Machining to net shape

Bars & sheets



Forgings



Powders

## 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, titanium and steel Pearl Micro powders dedicated for Additive Manufacturing technologies.

PARTENAIRE de la RÉSERVE MILITAIRE DÉFENSE

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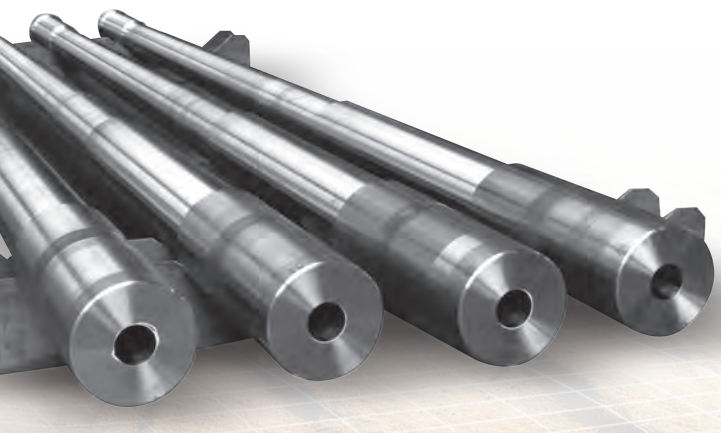
# FORGINGS FOR LARGE CALIBER GUNS

**As a leading supplier of defense high performance steels, Aubert & Duval has over 65 years' experience in providing forgings for gun barrels. Aubert & Duval supports worldwide weapon manufacturing sector delivering forgings solutions for large gun calibers.**



## 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 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
- Cost reduction (maintenance & logistics) to battlefield
- Acceptation of most demanding and powerful ammunitions

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.

# 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.m1/2 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

## Applications design

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

# Choose the best designed grade for your application

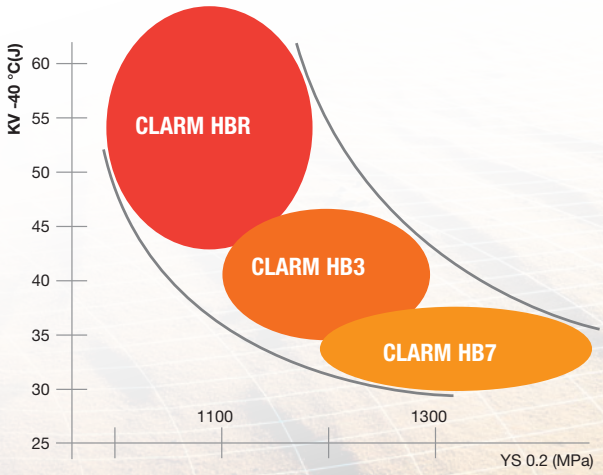
The choice of steel grade for gun barrel forgings is mainly governed by a compromise between yield strength (YS) and toughness at low temperatures (KV-40°C).

To guarantee these comprise the choice of optimum material for large gun barrels obviously fell on the Ni-Cr-Mo or Ni-Cr-Mo-V steels grades with a content of carbon between 0.3 et 0.4%. The chemical composition can be adjusted regarding the final mechanical properties.

Among the steel grades for artillery forgings available from Aubert & Duval, three are especially 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 are available on request.

## CLARM®HBR

The grade used for the 155mm caliber Howitzer and 120mm battle tank is the CLARM®HBR. This steel grade shows a high level of impact toughness thanks to an optimization of the chemical analysis which able to water quench the forgings after austenitizing heat treatment. Combining high quenching rates and elevated tempering temperatures bring a best toughness/ ultimate strength compromise.

## CLARM®HBR & CLARM®HB7

The search for ever higher mechanical characteristics led a few years ago 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.

COMBAT PROVEN

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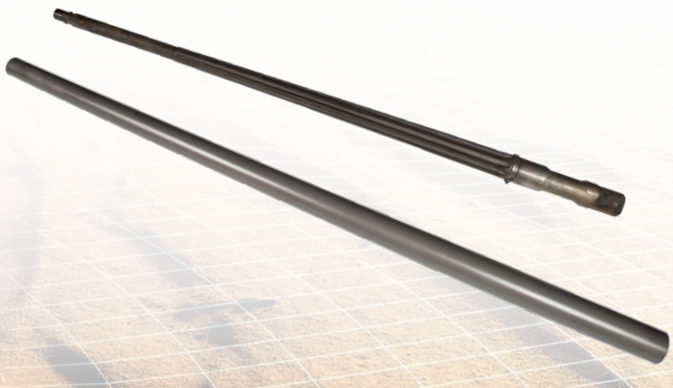
# STEEL BARS FOR MEDIUM CALIBER GUNS


**As a leading supplier of defense high performance steels, Aubert & Duval has over 65 years' experience in providing rolled and forged gun barrels. Aubert & Duval supports worldwide weapon manufacturing sector delivering rolling and forging solutions for medium caliber guns.**

## 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**

**20 - 25 - 30 - 35 - 40mm diameters**

**Provided for guns on:**

- + Land armoured vehicules
- + Battleships
- + Aircraft
- + Helicopters

# MEDIUM CALIBERS

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## Choose the best designed grade for you application

Medium caliber guns can fire different type 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 most stringent requirements.

## Increasing system life

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

## Supplied grades

| | GKH® | GH4W | NC35M | NC35M1 |
|---|---|---|---|---|
| C | 0.28/0.34 | 0.35/0.42 | 0.35/0.40 | 0.37/0.42 |
| Cr | 2.8/3.2 | 3.0/3.5 | 0.9/1.3 | 1.2/1.7 |
| Mo | 0.8/1.2 | 0.8/1.2 | 0.3/0.6 | 0.7/1.2 |
| Ni | - | - | 3.0/3.6 | 3.3/3.9 |
| V | 0.25/0.35 | 0.15/0.25 | 0.15/0.25 | 0.2/0.3 |

COMBAT PROVEN

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# STEEL BARS FOR FIREARMS


**As leading supplier of high quality steels for firearm industry, Aubert & Duval has over 65 years' experience in this defense market segment. It serves the weapon manufacturing sector for cut rifling, button rifling and hammer forging processes.**

## 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.

## Customer benefits

+ High endurance, even in extreme environmental conditions
+ Long cycle life & High accuracy
+ Weight optimization
+ Resistance to intensive fire rates
+ New powerful ammunitions
+ 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
+ Random lengths or customized blank lengths

# Firearm metallurgical expertise

**Benefits for 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.

## 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.

| | 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 | 38/42 |
| UTS (MPa) | 900/1050 | 930/1080 | 1200/1250 |
| 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 |
| 819AW | E35NiCrMo16 |
| MARVAL18 | X2NiCoMo18-8-5 |

## 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.

*Gun Barrel Shape Evolution during the Forming Process*

COMBAT PROVEN

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# STEEL BARS FOR MISSILES

**Aubert & Duval has a long history in supplying material to missiles systems manufacturers.**
**As a leading supplier of defense high performance steels, Aubert & Duval supports missiles manufacturing sector.**

## Choose the best designed grade for your application

Due to its expertise, Aubert & Duval develops and produces a range of precipitation hardening steels that quite meet the 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:

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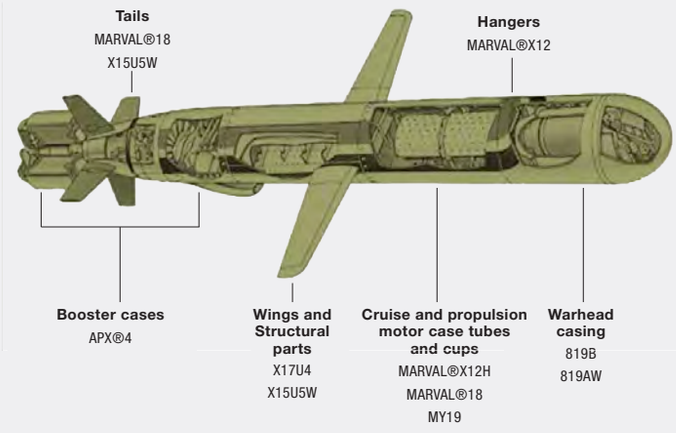
# Metallurgical expertise

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

## High Performance Steels for missiles structural parts




# Non stainless steels

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



# 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

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

AD730®

PYRAD53NW (INCO718)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