AUBERT&DUVAL

ARMAD®

32CrMoV12-10

New

High Performance Steel Grade for Defense and high demanding Applications

CONTINUOUS
METALLURGICAL
INNOVATION

SPECIAL STEELS

DEVELOPMENT

RESEARCH

SERVICE

Enhancing your performance

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THE INDUSTRIAL ENVIRONMENT

Aubert & Duval designs cutting-edge metallurgical solutions in the form of parts or long products for the projects of the most demanding industries (aerospace, energy, defense, industrial tooling, motor racing, medical, etc.).

For 70 years, Aubert & Duval has been serving defense industries, mainly by producing:

- Gun barrel blanks for small, medium and large calibers
- Missile casings,
- Critical parts for submarines, military aircraft engines, launchers and satellites.

DEVELOPMENT OF A NEW STEEL GRADE: ARMAD®

ARMAD® is the new steel grade developed in the defense market for small caliber gun barrels.
This high-performance grade offers excellent toughness, thanks to optimized chemical composition and control of the key parameters for melting and processing. This allows an increase of tensile strength values giving to designers the opportunity of weight saving while safety in extreme conditions is maintained.

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APPLICATIONS

Military

Law enforcement

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CHEMICAL COMPOSITION (weight %)

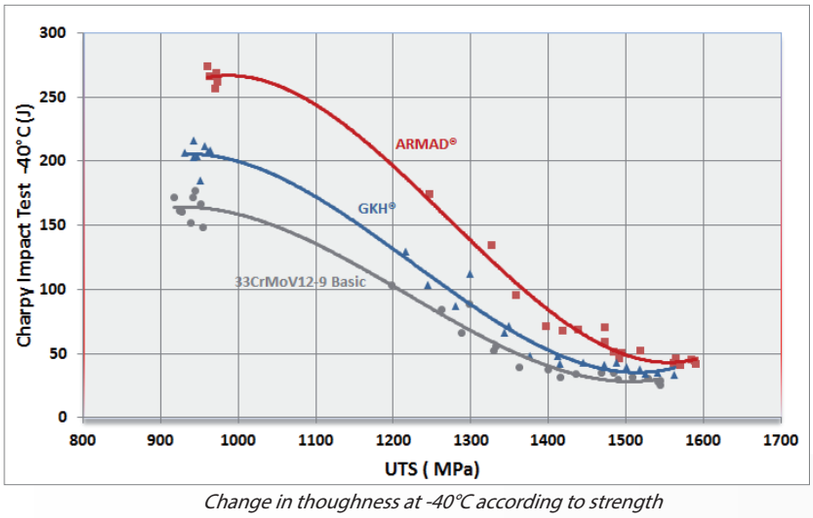
	C	Si	Mn	S	P	Ni	Cr	Mo	V
Mini	0.30	≤	≤	≤	≤	≤	2.80	0.70	0.15
Maxi	0.35	0.20	0.25	0.001	0.005	0.30	3.20	1.20	0.35

- ARMAD®'s chemical composition remains based on a 3% Cr, GKH® steel*.
- Very high purity, due to furnace loading quality control
- Very low phosphorous and sulfur content, due to melting process
- Higher molybdenum content
- Lower silicon and manganese

ALLOY DESIGN

ARMAD® is a new steel grade with an alloy design based on Aubert & Duval GKH® steel grade. ARMAD® contains a very low residual elements due to the accurate steel making process control. Optimized molybdenum content around 1 % improves mechanical properties after quenching and tempering heat treatment and increases the steel's hardenability. ARMAD®'s lower silicon and manganese content than standard for alloyed steels improves also the balance between strength and toughness.

Charpy Impact Toughness Test



Change in thoughness at -40°C according to strength

3%Cr grades Kv -40°C (l) for ARMAD®, GKH® and Standard 33CrMoV12-9

ARMAD® is a registered trademark of Aubert & Duval

* GKH®: steel developed by Aubert & Duval and used for the FAMAS assault rifle barrel

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PHYSICAL PROPERTIES

Density at 20°C (68°F)

- 7.84

Mean coefficient of thermal expansion (α)

Temperature range	10^{-6}.m /m.°C	10^{-6}.in / in.°F
20°C-100°C, 68°F-212°F	11.8	6.55
20°C-300°C, 68°F-572°F	12.7	7.05
20°C-500°C, 68°F-932°F	13.6	7.55
20°C-700°C, 68°F-1292°F	14.2	7.88

Thermal conductivity (K)

Temperature	W/mK	Btu.in/hr.ft².°F
20°C, 68°F	35.5	248
200°C, 392°F	38.2	267
500°C, 932°F	38.9	272
600°C, 1112°F	41.2	288

Specific heat (C)

Temperature	J/kg.°C	Btu/lb.°F
20°C, 68°F	460	0.110
100°C, 212°F	500	0.119
200°C, 392°F	540	0.129

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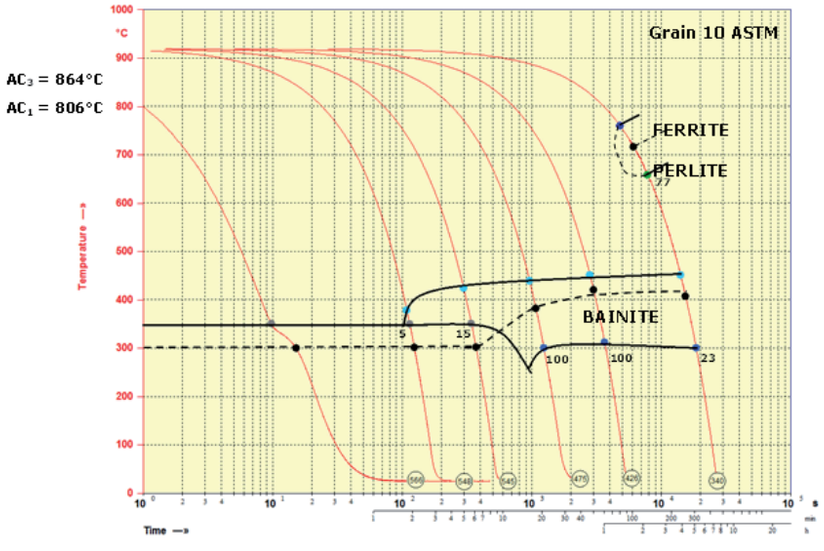
TRANSFORMATION POINTS

Ac1	806°C, 1483°F
Ac3	864°C, 1587°F
Ms	375°C, 707°F

CCT DIAGRAM



CCT Diagram _ austenitization 920°C, 1688°F

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MACROSTRUCTURE

The segregation, as measured on the ingots, complies with the tightest requirements.
Below, are examples for air melted products.

	Severity for ARMAD®
Subsurface conditions	S2
Random conditions	R1
Center segregation	C2

Macrostructure according to ASTM E381

CLEANLINESS

Micro-cleanliness complies with the tightest requirements.
Below, are examples of specifications met by ARMAD®.
Inclusion rating in accordance with ASTM E45 Meth A

I

Type	A		B		C		D	
	Thin	Heavy	Thin	Heavy	Thin	Heavy	Thin	Heavy
ARMAD®	0.5	0.5	1.5	1.0	1.0	1.0	1.5	1.0

Beyond the specifications, Aubert & Duval's optimized melting practices makes ARMAD®'s micro-cleanliness value far better than standard 33CrMoV12-9 and usual engineering grades using same melting processes.

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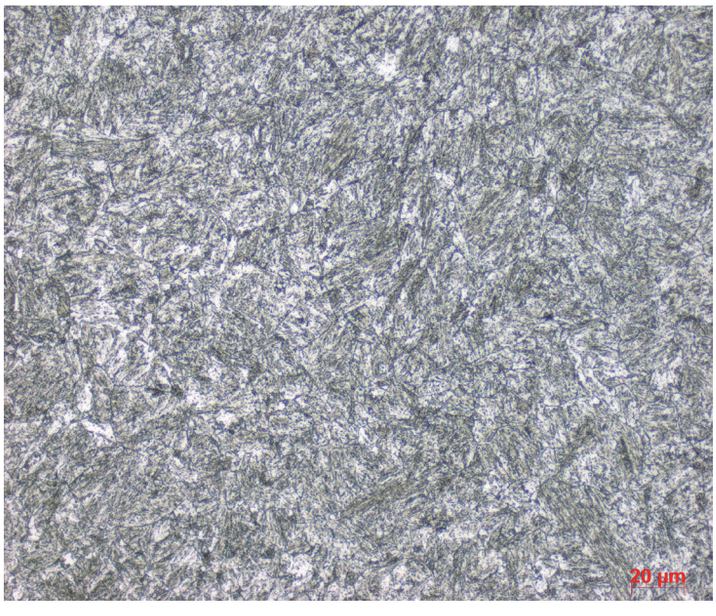
MICROGRAPHIC CHARACTERIZATION

Quenched and Tempered material
Grade: ARMAD®
Austenitizing: 920°C, 1688°F
Oil quenching
Tempering: 625°C, 1157°F
Mean grain size ≥ 7 ASTM



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MECHANICAL PROPERTIES

- In the delivery conditions

Guaranteed longitudinal mechanical properties:

Rm TS (N/mm^2)	Rp 0.2 YS (N/mm^2)	A5d Elongation (%)	KV (J) ambient (at room temperature)	KV - 40 °C (J)	Hardness (HB)
930 1080	≥ 750	≥ 15	≥ 170	≥ 150	280 325

- After quenching and tempering

Guaranteed longitudinal mechanical properties:

	ARMAD®	
Type	Martensitic CrMoV	
Symbol	32CrMoV12-10	
HRC as delivered	28/34	
HRC after final hardening	38/46	
UTS, MPa (ksi)	1200/1250, (174/181)	1500/1550 (218/225)
YS0.2 MPa (ksi)	> 950 (138)	> 1250 (181)
E5d (%)	> 16	> 14
KV(RT) J, (ft-lb)	> 160 (118)	> 50 (37)
KV (-40°C) J, -40°F (ft-lb)	> 130 (96)	> 40 (29)

APPLICATION IN DEFENSE / FIREARMS
ARMAD® FOR GUN BARRELS

Functions for gun barrels

Gun barrels are designed to withstand the high pressures and temperatures generated during firing. Basically, high yield strength levels (both at room and elevated temperature) combined with good ductility and toughness are required.

Problems on barrels	Barrels degradation modes	Material properties
Permanent bore expansion	Maximum pressure developed in combustion chamber	0.2% Proof strength at room and elevated temperature
Barrel rupture under extreme testing	Extreme gas pressure	No brittleness but plastic ductility at RT and low temperature High Charpy-V energy and low transition temperature
	Obstruction tests	
	Torture tests at low temperatures	
Unacceptable loss of material resulting in bore ovalization, lack of muzzle velocity, lack of accuracy	After thousands firing cycles, growth and coalescence of micro-cracks	Good resistance to thermal fatigue
	Action of hot gases at high velocity	Resistance to erosion wear due to gas (combination of thermal, mechanical and chemical causes)
	Interaction of projectile with barrels wall when moving through the bore	Resistance to abrasive Wear (mechanical degradation) - High surface hardness

For this application, air melted ARMAD® offers the best high strength / toughness compromise on the market. The specification we usually deliver for a cold hammering / Gun drilling and rifling processes are given above. Other Ultimate Tensile Strength levels can be achieved and released depending on customer need and forming capacity (cold hammering or rifling).

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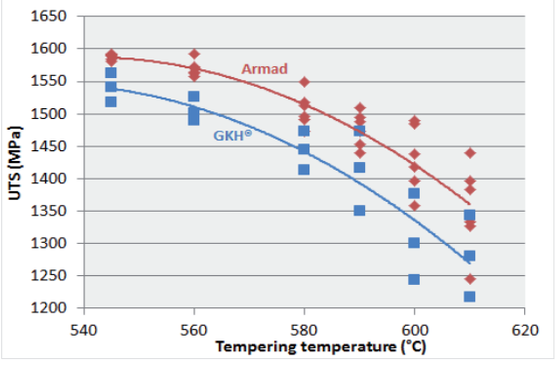
It has been especially demonstrated that ARMAD® brings additional value compared with standard CrMoV grades:

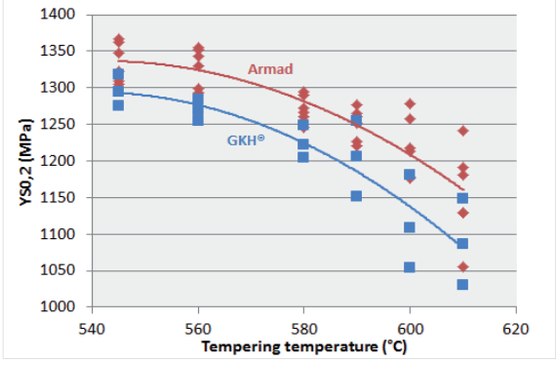
Benefits for firearm producer/designer:

- ARMAD has been designed to maintain ductility at cold forging percentage reduction beyond 30%
- Hammer forging the chamber and the bore in the same operation results in more cold working and higher hardness in the chamber
- Use fatigue/strength upgrading opportunities of ARMAD® to design lighter barrels with thinner wall sections
- During hammer forging, ARMAD's homogenous microstructure insures consistency in the formation of rifling and chamber
- Better tempering resistance for ARMAD compared to former 3%Cr steel grades:
  - Increases softening temperature thereby improving resistance to high bore temperatures
  - Improving resistance to higher temperature propellant

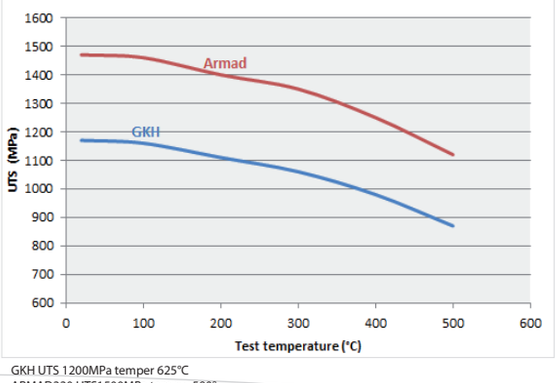
UTS vs Tempering Temperature



YS0,2 vs Tempering Temperature



Hot properties



GKH UTS 1200MPa temper 625°C
ARMAD220 UTS1500MPa temper 590°

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Benefits for firearm user:

- The increased hardness and higher tempering temperature improves barrel life because:
  - Wear is reduced in the critical areas of the barrel.
  - Thermal fatigue cracks initiation is delayed.
  - Higher tempering temperature results in delayed bore softening for improved resistance to heating and wear
- Higher strength material allows barrel size to be reduced in order to minimize weapon weight

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Design:

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