SMALL ARMS DEFENSE JOURNAL
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State of the Art

ACCURACY INTERNATIONAL TAKES PRECISION TO THE NEXT LEVEL

SLOVENIA'S MODULAR RIFLE
TINCK ARMS PERUN X SERIES

DON'T WASTE YOUR RANGE TIME
TODD HODNETT TALKS PRECISION TRAINING

M240 test gun with 250 round compliments ready for testing.

Top Gun?

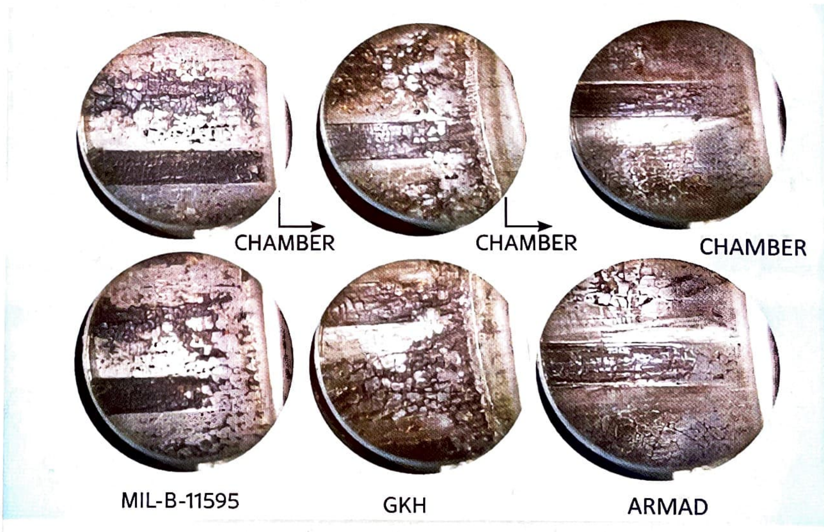
French Material Tops U.S. in Gun Barrel Life Test

By George Kontis
Photography by Aubert and Duval

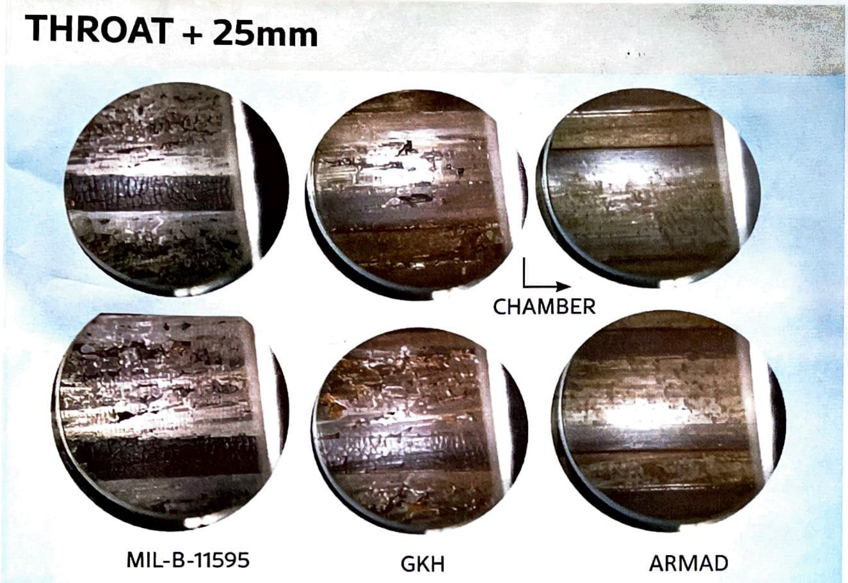
In the early 2010s, two French metallurgists at Aubert & Duval (A&D) steel company proposed a study to develop a new steel alloy for gun barrels. Their goal was to develop a new high strength steel which would allow barrel designers to reduce barrel weight and extended barrel life — especially for high rate of fire applications.

It was a gutsy undertaking because their idea was to use different amounts of the exact same elements found in almost all current gun barrels. Alloys with these elements have demonstrated little advancement since World War II. They had no plans to incorporate any of the refractory elements like cobalt, tungsten, and tantalum, even though studies have shown these elements can be useful in extending barrel life. Rather, they planned to improve on an existing

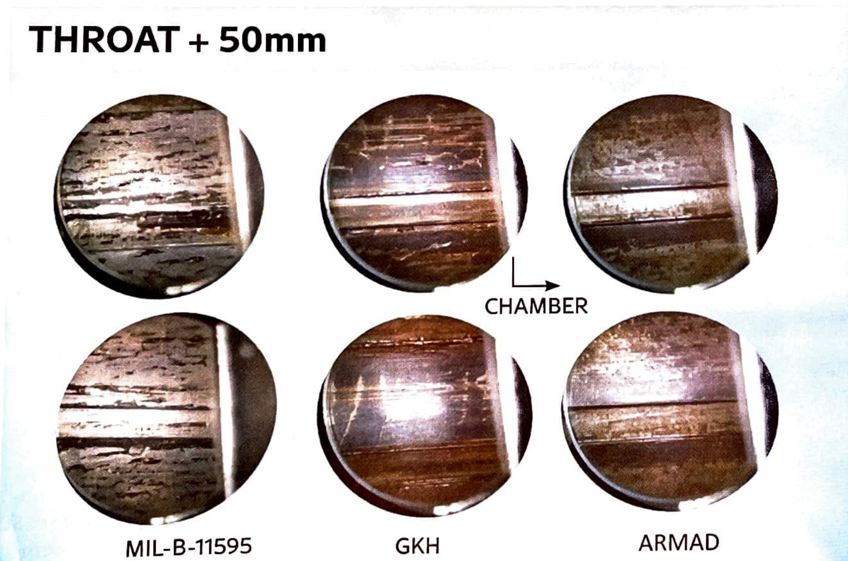
THROAT after 20 thousand rounds



Comparative bore damage at throat shows minimum wear for ARMAD after 20 thousand rounds.



ARMAD exhibits less bore damage than GKH or Mil-B-11595 after 20 thousand rounds.



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hammer forge grade gun barrel steel, GKH. The development of GKH having been undertaken by A&D in cooperation with the Austrian hammer forge manufacturer, GFM.

With high levels of chromium and molybdenum, GKH demonstrated its ability to maintain high strength at elevated temperatures. GKH had become a combat proven barrel material and a preferred alloy for high rate-of-fire applications. The two metallurgists convinced A&D management they could make an even better steel and received financial backing for the development.

ARMAD and GKH

After a seven-year effort, the typical time required for the development of any new alloy, ARMAD was introduced. The two metallurgists received U.S. and foreign patents on its formulation and production process. While the chemical makeup of ARMAD is almost identical to GKH, ARMAD's chemistry was tailored to have a 77° F higher tempering temperature. This would allow the barrel to reach higher temperature levels before hitting the tempering temperature—a critical point where a steel will not return to its original hardness after cooling. All steels simultaneously lose strength and hardness as temperature increases so this relationship, called "hot hardness", is recorded. A higher hot hardness means the barrel will retain strength at high temperature and gives barrel designers the opportunity to make lighter barrels for severe firing schedules. By fine tuning the chemistry of ARMAD, they were able to achieve a 27% improvement over GKH.

From a metallurgical standpoint, the properties of ARMAD promised to be superior to any barrel steel used by U.S. manufacturers, or those from anywhere else, for that matter. Yet there was one concern. To achieve these improved properties, barrels would need to be fabricated at a higher hardness level than barrels currently produced today. Before the drilling operation, barrel stock is held within a prescribed Rockwell C (Rc) hardness range, which is generally between Rc 28-Rc 32. (As points of reference, the hardness of a hand file is Rc 60 and steel is considered "dead soft" at Rc 20 and below.) The improved properties of ARMAD could only be achieved if the finished barrel was nominally at Rc 41. Machining at the preferred lower hardness level and hardening afterwards is possible but distortion would be inevitable. Who would want a machine gun with a crooked barrel?

Barrel Maker Challenge

When A&D announced their new steel had to be machined at Rockwell C 41, comments from barrel manufacturers were not encouraging. While some claimed gun drilling the bore would not be possible, others were convinced the rifling button would break free from its attachment rod and become stuck in the bore. Those who rifled by cutting a single groove at a time were worried the higher hardness material would be too hard to cut. Hammer forge barrel makers feared they would break expensive hammers, even though these forges are designed to cease operation if hammering loads are too high.

While these were all very legitimate concerns, ARMAD's impressive mechanical properties at the higher hardness enticed a few to make investigative trials. Some were motivated by funding from A&D. In the end, they found they could drill and ream with only minor machine adjustments. Button rifled and cut rifled barrels were produced and hammer forgers reported success, as well.

With manufacturing methodology proven, it was time for comparative trials. A&D decided they would pit ARMAD and GKH against the U.S. government's best gun barrel steel, CrMoV, from the governing specification Mil-B-11595. CrMoV is available commercially as 41V45 and is highly regarded in the sporting industry. Aubert & Duval has facilities for manufacturing huge cannon barrel tubes but no capability at all in building small arms barrels. A&D needed to find a reliable company who could produce machine gun barrels and conduct an independent test to evaluate barrel life.

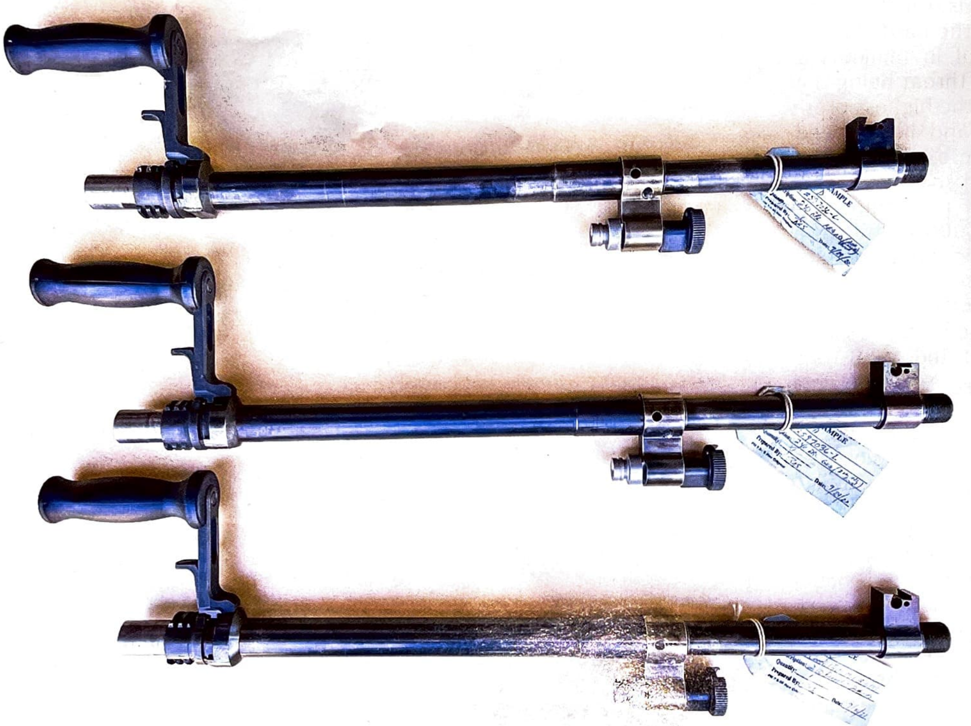
Ohio Ordnance Works Selected for Trials

A well-respected manufacturer, Ohio Ordnance Works of Chardon, Ohio, agreed to the undertaking. Besides .50 caliber and 5.56mm machine guns, Ohio Ordnance Works builds the 7.26mm M240 (Mag-58) machine gun and has a solid reputation worldwide for quality and performance. They agreed to produce and test M240 barrels from ARMAD, GKH, and Mil-B-11595. Given the manufacturing unknowns in producing the harder ARMAD barrels, it would be a "best effort" project to provide either cut rifled or button rifled barrels, whichever rifling technology worked best.

After making minor machining adjustments for the harder ARMAD material, Ohio Ordnance delivered barrels by both button and cut rifling. Four barrels with hard chrome plated bores were presented for the 60,000-round test: ARMAD barrels at Rc 40 and Rc 45, a GKH barrel at Rc 28 and a Mil-B-11595 barrel at Rc 30. To test 20,000 rounds per barrel, one of the four had to be saved for another day, and the Rc 40 ARMAD barrel was selected over the harder RC 45 barrel. The reasoning was simple. The softer of these would be easier to manufacture and thus more

Barrels readied for testing.

A&D Sales Manager, John Tracy, links ammunition for 250 round compliments.



Test barrels at completion of 60,000 round test.

Muzzle velocity measured every 250 rounds.

attractive to a wider range of manufacturers. Additionally, testing at the lower hardness level would validate any life improvement with expectations of equal or better performance at higher hardness levels.

Testing

In order to compare barrel life between different materials, it is of paramount importance to subject barrels to the same exact test. The endurance test schedule from the M240 prescribed in the governing military specification was selected as it is considered a gold standard test for barrel life evaluation. It is a test Ohio Ordnance Works has conducted numerous times.

Each barrel would be subjected to the same firing schedule for 20,000 rounds with periodic targeting, and muzzle velocity recordings. Each barrel was to be fired 250 rounds in 10-12 round bursts followed by a few seconds cooling. When 250 rounds were reached, the barrel would be removed and cooled to ambient temperature before continuing the test.

Per the specification, a barrel is considered to have failed when it reaches one of three criteria: One, if the average muzzle velocity drops more than 200 feet/sec (61 m/s) below the average of the first ten rounds fired through the barrel. Two, if 20% of the rounds exhibit yaw of 15° or more, and three, If the extreme spread of impacted rounds measured on a 100 meter target exceed specification.

While these three failure criteria are used by the government and manufacturers, in the field this level of testing is impractical. Armorers are supplied with two simple plug type gages for insertion into either end of the barrel. One gage measures wear at the throat and muzzle and the other is for wear at the bore. The gages are marked with lines for "Warning" and "Reject" so the armorer can determine barrel failure or can estimate remaining barrel life. The test protocol used by Ohio Ordnance Works requires these field gages be used at the firing range to gauge wear throughout the test. Every 1250 rounds the distance from the end of the barrel to the "Reject" mark was recorded.

Results

The Armorer gages did prove useful for most of the testing. After 20,000 rounds, none of the barrels showed any signs of muzzle wear. Wear at the throat, where the projectile is first launched, is usually a very high-wear area but the hard chrome plate was successful in minimizing wear, in spite of the throat being the region subjected to the highest pressure, temperature, and high speed gas. Over the course of testing, the throat region of GKH and Mil-B-11595 steel wore at about the same rate, while even after 20,000 rounds, the ARMAD barrel was only beginning to show signs of wear.

Bore wear measurements on the ARMAD again showed very minimal wear while the GKH and Mil-B-11595 wore at about the same rate up until 15,000 rounds. Here is where the Mil-B-11595 barrel took a turn for the worse. The bore gage could not be fully inserted to the maximum wear point due to bore damage and the pieces of chrome plating which had lifted but were still attached to the bore. Even after a thorough cleaning of the bore the debris could not be cleared for a good measurement. While muzzle velocity did not decrease in this barrel, some projectiles were unable to achieve gyroscopic stability, indicated by holes in the target which were no longer round. The Mil-B-11595 barrel was failing.

Coming back to the governing specification for failure, velocity, yaw, and accuracy, all of the barrels remained within specification for the three failure criteria at 15,000 rounds. The Mil-B-11595 barrel was failing but had not yet reached the yaw failure point. At 20,000 rounds, the GKH and, in particular, the ARMAD barrel were still going strong while the Mil-B-1595 barrel had finally failed due to excessive yaw.

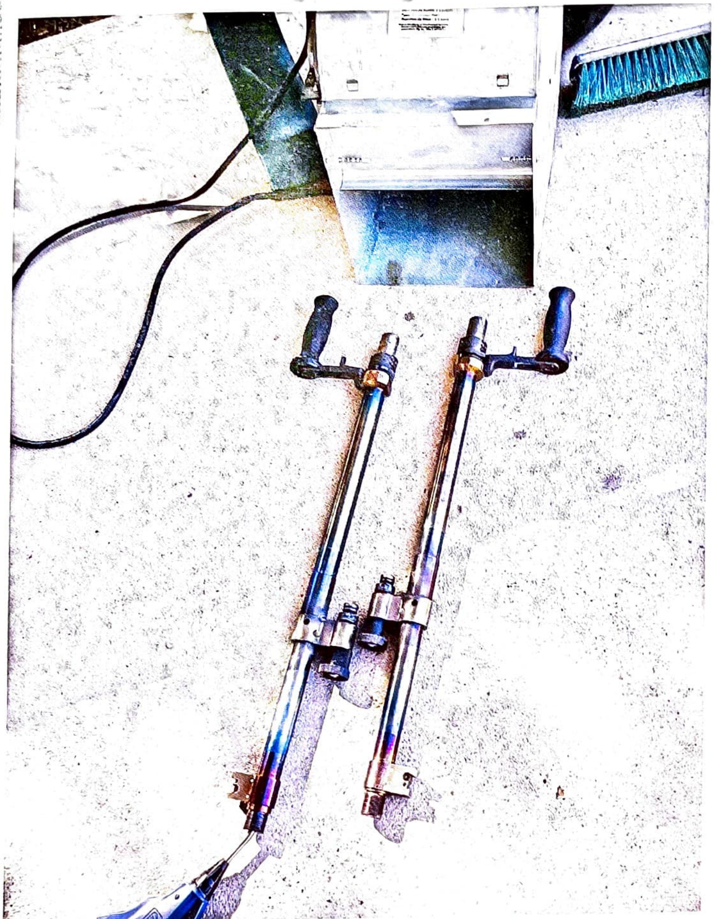
Conclusions

The ARMAD barrel demonstrated superior performance over its predecessor, GKH, and bested Mil-B-11595 by a significant margin. How much longer could either of the two surviving barrels last? It's a good question, and A&D is seeking additional support to fund further testing to determine this. If bore measurements are any indication, three or more times longer seem totally within the realm of possibility.

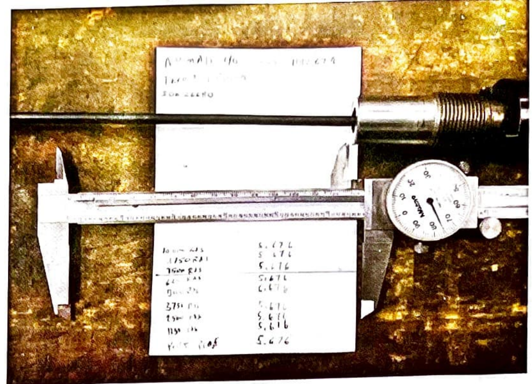
Barrel producers were surprised at their ability to work with the harder ARMAD material and are now working with firearms manufacturers who have requested this harder material. Others, who want to avoid the environmental concerns of hard chrome plating, want to experiment with

Test set-up at 100 meter range with chronograph.

Barrels readied for testing.



Barrels cooled to ambient after every 250 round compliment.



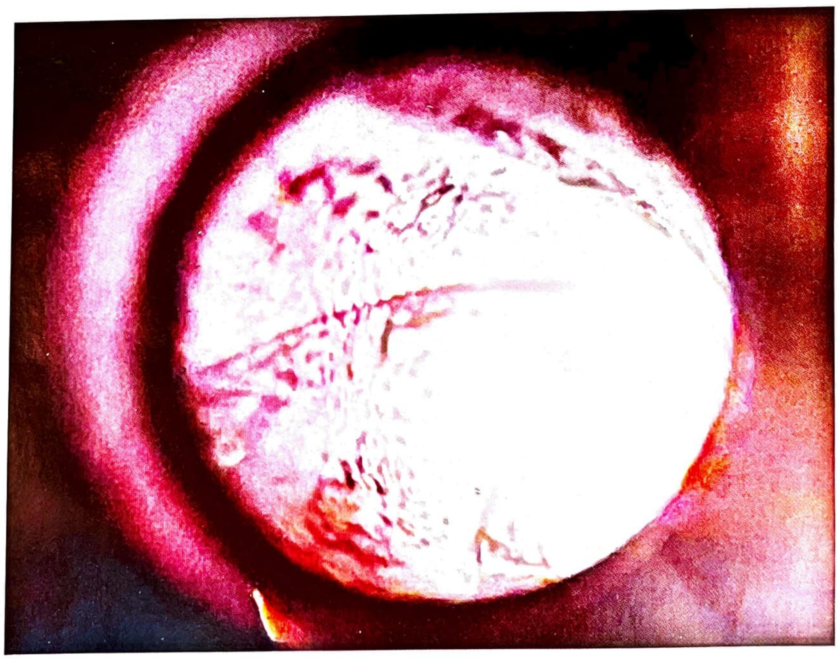
Throat erosion guaging.

Plug guages used to observe wear progression in throat, bore, and muzzle.

nitriding the bore, as both GKH and ARMAD are nitriding grade steels.

The list of projects undertaken over the last 75 years with the objective of developing better gun barrels include refractory metal liners, heat resistant materials flow formed over mandrels, promising new bore coatings, powder metal barrels, and even barrels with ceramic liners. None have been able to displace 1940's steel alloys either because they are too expensive or simply didn't work.

And yet, along came a team of metallurgists from Aubert & Duval, using the same exact elements as in the old 20th century steel to develop a stronger and longer lasting gun barrel alloy. How was it possible? It came about through the use of 21st century metallurgy and processing technology. When I asked the A&D team what new development they were working on now, the answer came back: "Well, the next generation steel after ARMAD, of course." SADJ



Extensive bore wear observed in Mil-B-11595 barrel after 20k rounds.