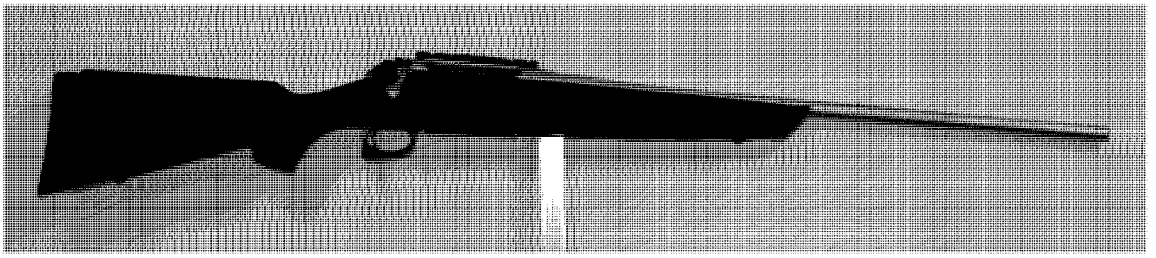
TRIAL AND PILOT TEST REPORT

Model 770 Stainless Steel
Bolt Action Rifle

TLW 2305
300 Win Mag
30-06 Sprg
243 Win Youth

TLW 2359
7mm Rem Mag
270 Win



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INTRODUCTION

The testing for this Trial and Pilot (T&P) test was selected to evaluate the changes made to the M/770 to create the stainless steel version. The T&P test was conducted in two rounds, an initial thorough investigation of three calibers and a follow up confirmation of two additional calibers. TLW 2305 covers the initial testing of the M770 SS. It consisted of A series (300 Win Mag), B series (30-06 Sprg), and C series (243 Win Youth) rifles. TLW 2359 covers the follow up testing and consisted of on the D series (7mm Rem Mag) and E Series (270 Win).

RESULTS SUMMARY

The M770 Stainless Steel bolt action rifle tested in this Trial and Pilot (T&P) test represents a line extension to the current M770 rifle. The M770 rifle is an established tested current product. The stainless steel version of the M770 test replaces the standard carbon steel barrel with a stainless steel barrel. The barrel on the M770 contains the locking lugs which engage the bolt head. The barrel end containing these locking lugs is induction hardened. This stainless steel barrel requires a different set of parameters to induction harden the locking lugs in the barrel. Additionally, the receiver and bolt body were plated with Electroless Nickel for cosmetic reasons. In all other aspects the stainless steel version in the same as the standard carbon steel rifle. Table 1 summarizes the test matrix performed in this T&P test along with the results, which supports the conclusion that all M770 SS variants passed and are recommended for full scale production.

Model 770 Stainless Steel Trial and Pilot Testing Summary

	TLW 2305																			
Caliber	300 Win Mag										30-06									
Serial #	71378664	71378765	71378946	71378961	71378967	71378751	71378790	71378795	71378962	71378963	71378563	71378643	71378645	71378789	71378951	71378741	71378763	71378768	71378856	71378960
Test Discription \ Gun ID #	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
Visual Inspection	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
Trigger Pull	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
Safety Function	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
Front take down screw hole depth	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
Chamber and Bore Dimensions	◍	◍	◍								◍	◍	◍							
HS - Proof - HS	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
Extended Proof							◍													
Accuracy	◍	◍	◍	◍	◍	◍					◍	◍	◍	◍	◍	◍				
Endurance to 100 RL	◍	◍	◍	◍	◍	◍					◍	◍	◍	◍	◍	◍				
Endurance to 500 RL	◍	◍	◍	◍	◍	◍					◍	◍	◍	◍	◍	◍				
Endurance to 1000 RL	◍	◍	◍	◍							◍	◍	◍	◍						
Endurance to 2000 RL	◍	◍									◍	◍								
Hot Function																		◍		
Cold Function																		◍		
Thremal Cycle																		⊗		
Metallurgical Evaulation of Barrel	◍										◍									
Dry Cycle																	◍			
High Pressure Abuse									◍											
Final Round Level	2021	2021	1021	1021	521	521	101	1	1 +	1	2021	2021	1021	1021	521	521	1 +	201	1	1

	TLW 2305								TLW 2359									
Caliber	243 Youth								7mm Rem Mag					270 Win				
Serial #	71378661	71378750	71378778	71378875	71378965	71378780	71378796	71378878	71380501	71384667	71384729	71385284	71385225	71390508	71384790	71384941	71385409	71386441
Test Discription \ Gun ID #	C1	C2	C3	C4	C5	C6	C7	C8	D1	D2	D3	D4	D5	E1	E2	E3	E4	E5
Visual Inspection	◍	◍	◍	◍	◍	◍	●	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
Trigger Pull	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
Safety Function	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
Front take down screw hole depth	◍	◍	◍	◍	◍	◍	◍	◍										
Chamber and Bore Dimensions	◍	◍	◍															
HS - Proof - HS	◍	◍	◍	◍	◍	◍	⊗	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
Extended Proof																		
Accuracy	◍	◍	◍	◍	◍	◍					◍	◍	◍			◍	◍	◍
Endurance to 100 RL	◍	◍	◍	◍	◍	◍			◍	◍	◍	◍	◍	◍	◍	◍	◍	◍
Endurance to 500 RL	◍	◍	◍	◍	◍	◍			◍	◍				◍	◍			
Endurance to 1000 RL	◍	◍	◍	◍					◍					◍				
Endurance to 2000 RL	◍	◍																
Hot Function								◍										
Cold Function								◍										
Thremal Cycle								⊗										
Metallurgical Evaulation of Barrel	◍								◍					◍				
Dry Cycle																		
High Pressure Abuse																		
Final Round Level	2021	2021	1021	1021	521	521	0	201	1001	501	120	120	121	1001	501	119	122	122

LEGEND ○ = Planned ○ = In-Progress ◍ = Completed & Passed ● = Completed Failed ⊗ = Cancelled (shaded) = Not Planned

Table 1: M770 SS Test Matrix

CONCLUSIONS & RECOMMENDATIONS

No major issues were discovered in this T&P test of the M770 stainless steel rifle. Visual inspection did not reveal any major anomalies. Trigger pull was with in specification and the safeties functioned properly. Headspace growth during Proof and Extended Proof testing was acceptable with the maximum head space growth during proof being 0.002". The accuracy as measured was deemed acceptable. The average 3-shot group size measured at 1.47". Endurance testing consisted of shooting 24,600 rounds in 28 guns. Only three malfunctions were recorded. Hardness inspection on five of the rifle barrels were found to be within specification and

metallurgical evaluation of the barrel showed no sign of stress induced cracking. Dry cycle testing and environmental testing also passed. Finally, high pressure abuse testing in which one rifle was subjected to a 120,000 psi abuse load was successfully passed. The barrel did take a permanent deformation set, but gun remained intact and did not come apart. In conclusion, all of the rifles functioned well and no safety issues were discovered. The Test and Measurement organization within the Elizabethtown Research and Development facility formally supports exit from Trial and Pilot testing of the M770 stainless steel rifle.

PROCEDURE & DETAILED RESULTS

Visual Inspection

Upon receipt, all of the rifles were given a thorough visual inspection. In general, the rifles looked very good. No visible mars were seen on any of the rifles. The electroless nickel plating on the receiver and bolt body looked good with no flaws observed. All of the rifles were hand cycled and most of the rifles cycled as expected for M770 actions. However, rifles, B10, C7, and D1 were more difficult to close. Upon closer inspection of gun C7 it was discovered that the firing pin assembly had an old vintage firing pin head. The shorter camming tab on the firing pin head did not allow the bolt head to travel far enough forward upon initial close up to engage the camming cuts in the barrel extension. This required a significant amount of forward force to be applied to the bolt handle compressing the main spring before the bolt could be cammed closed. Guns B10 and D1 were also difficult to close compared to the rest of the guns; however, they did have all of the correct components. Although not as difficult as C7 to close, they also required forward force to close the bolt. It was determined that the most likely reason for this issue was tolerance stack up that did not allow the bolt to come far enough forward during initial close up.

Trigger Pull

The trigger pull was measured on all of the rifles. The fire control on the M770 SS was not changed from that as found on the standard M770. This test was conducted as a standard safety check. The trigger pull is specified at 4.5 – 6.0 pound as found on the drawing Receiver Insert Assembly Complete (D-301412). During the initial test, TLW 2305, the trigger pull was measured using the Dvorak trigger scan device. Five scans were performed for each rifle. The average trigger pull for the A, B, and C series guns was 5.67 pounds with a standard deviation of 0.39 pounds. During the follow up test, TLW 2359, the trigger pull was measured using a Chatillon spring scale as a quick check. Five measurements were taken for each rifle. The average trigger pull for the D and E series guns was 4.54 pounds with a standard deviation of 0.27 pounds. It should be noted that previous testing comparing the Dvorak to the Chatillon spring scale showed a similar disparity when measuring the same sample of guns where the spring scale measured a lower trigger pull. These trigger pull tests showed that these M770 SS rifles had safe properly set triggers that were in spec.

Safety Function Check

As a standard safety check, the proper function of the safety was checked on all of the rifles. After checking to ensure that the rifle was unloaded, the bolt was closed and the trigger was pulled with the safety in the safe position. In all case the firing pin did not fall, indicating that the safety functioned as intended on all of the rifles.

Front take down screw hole depth

The front take down screw hole on the M770 is threaded directly in the barrel at the six o'clock position in roughly the middle of the chamber. In the development of the M710 Magnum it was determined that the depth of this hole needed to be shallower for magnum caliber rifles. Consequently, the maximum depth of this hole was changed from 0.227" for standard caliber rifles to 0.145" for magnum caliber rifles. These dimensions were not changed for the stainless steel version of the M770. However, as this hole is in the new stainless steel barrel, it

was determined prudent to measure this hole depth on the initial series of guns to verify process capability. The average depth of this hole on the A series (300 Win Mag) guns was 0.138" with a maximum individual depth of 0.142. The average depth for the B (30-06 sprg) and C (243 Win) series guns was 0.220" with a maximum individual depth of 0.227". The front take down screw hole depth was not measured on the D and E series guns. This indicates that the process is capable of meeting specification requirements.

Chamber and Bore Dimensions

It was decided to inspect the chamber and bore on a sample of rifles during the initial T&P test to verify the chambering process in the stainless steel material. Chamber casts were made for rifles A1 – A3, B1 – B3, and C1 – C3 using 170 F Cerrosafe. These chamber casts were inspected along with a visual inspection of the chamber and bore. The chambers inspected were to found to be within specification. No abnormalities or irregularities were observed.

Proof

Proof testing consists of measuring the head space of the rifle before and after firing one standard SAAMI proof cartridge in each rifle. Head space was measured using graduated head space gages incremented in 0.001" steps. Typical acceptable head space growth through proof is 0.002". Additionally, the proof case is inspected for any sign of damage, specifically case bulging or stretching, and loose, bulged, or dropped primers. Gun C7 was not proof tested as it had an incorrect firing pin assembly and was not slated for any additional testing. All of the proof tested rifles passed without any signs of excessive head space growth or proof case damage. The maximum head space growth through proof testing was 0.002" and the maximum measured head space after proof was min + 0.006".

Extended Proof

One rifle, A7, was selected to go through extended proof testing. Extended proof testing is an internal Remington abuse test designed to test the robustness of the firearms lockup. The test consists of firing 100 proof cartridges through the rifle and measuring headspace to monitor headspace growth. Figure 1 shows a graph of the measured headspace growth of gun A7 as a function of proof rounds fired. Total heat space growth during extended proof testing was 0.001". This is considered acceptable head space grown for extended proof testing. Additionally, none of the fired proof cases showed any sign of damage.

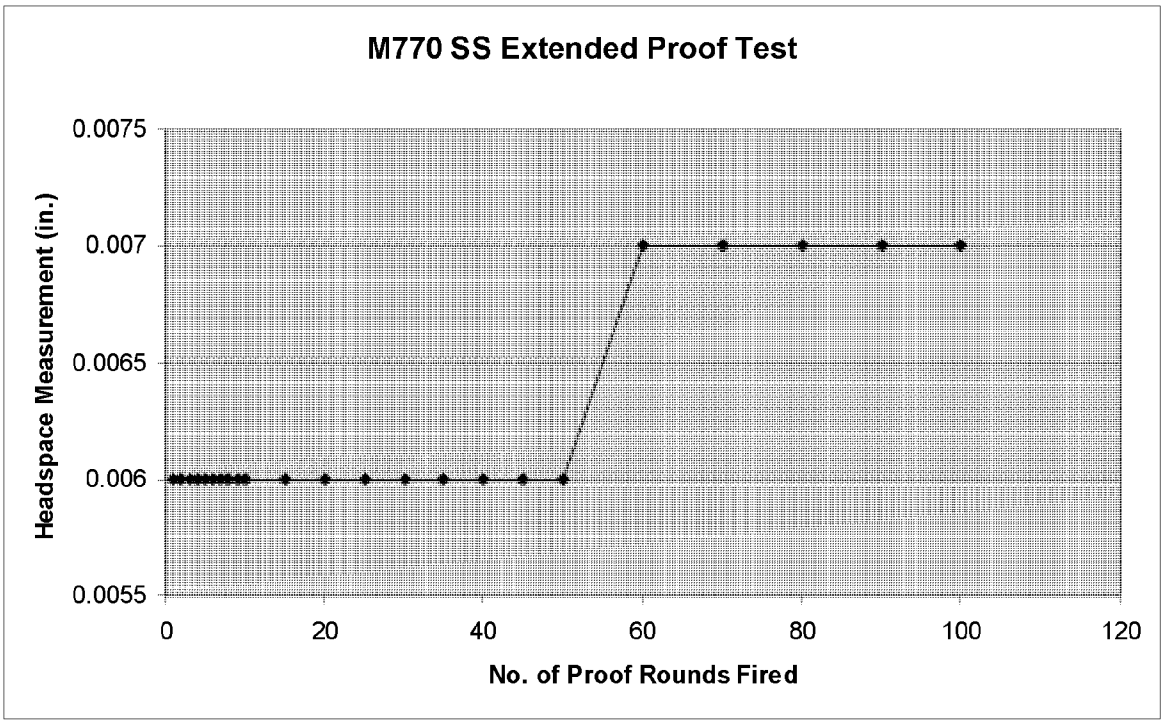

Figure 1: Headspace growth during Extended Proof of gun A7.

Accuracy

The accuracy of the M770 SS was evaluated via firing a sample of rifles from each of the five calibers tested. The rifles were fired from the bench using the lead sled with the standard Bushnell 3 x 9 scope supplied with the rifle. Three 5 shot groups were fired for each rifle at 100 yards. The order of the shots was recorded for each group. This was done so that the first three shots could be measured as a three shot group. This allowed us to compare the data to Mayfield's historical data. For the A, B, and C series rifles the Oehler acoustic target was used to capture the shot order and group size. Paper targets were used to confirm the Oehler data. For the D and E series rifles the amount of shooting did not justify setting up the Oehler acoustic target. So the groups were shot directly on paper targets to be measured manually using the range camera to track the shot order. Graphs of the 3 shot and 5 shot group sizes are shown in figures 2 and 3, respectively. The overall accuracy summary is shown in table 2. This table also contains a summary of the accuracy data provided by Mayfield prior to delivery of these test guns for comparison. The overall average Elizabethtown 3-shot groups size was 1.47 inches. This compares to the Mayfield Historical 3-shot average group size of 1.31 inches. A statistical comparison can not be made between the Elizabethtown and Mayfield data, because the conditions under which the data was collected differed significantly. However, this testing did show that the accuracy of the M/770 SS was comparable to that as measured in Mayfield.

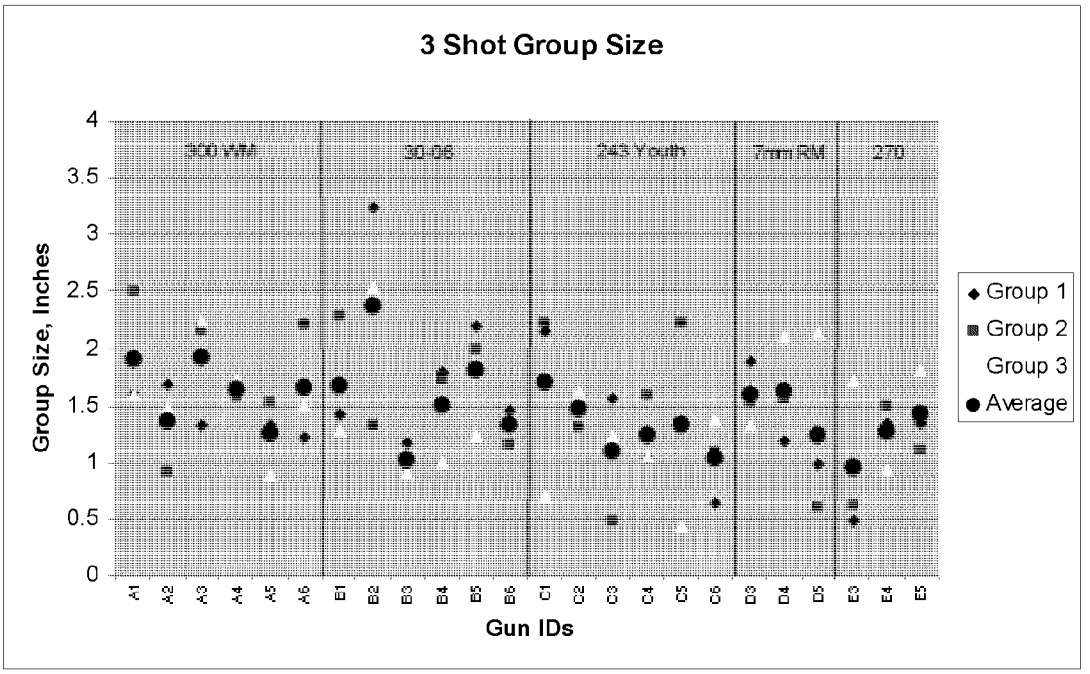

Figure 2: M770 SS 3 shot group accuracy graph.

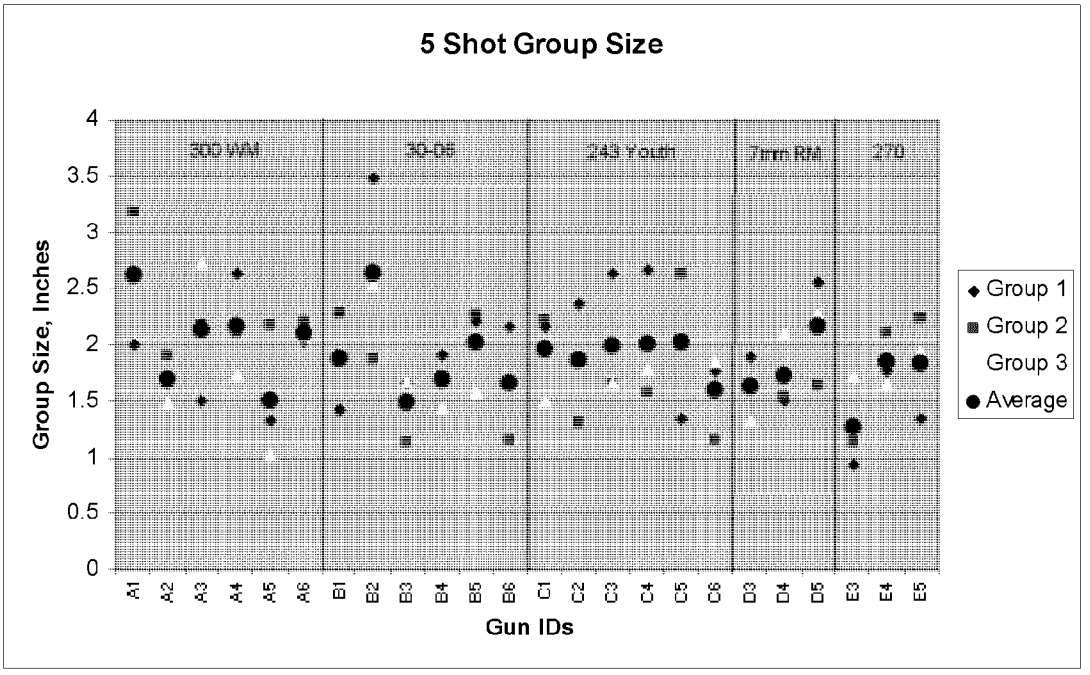

Figure 3: M770 SS 5 shot group accuracy graph.

Overall Accuracy Summary						
Series	A	B	C	D	E	All Calibers
Caliber	300 Win Mag	30-06 Sprg	243 Win Youth	7mm Rem Mag	270 Win	Combined
Elizabethtown Accuracy Data						
3 Shot Group Average	**1.62**	**1.61**	**1.31**	**1.48**	**1.20**	**1.47**
3 Shot Group Standard Deviation	0.44	0.63	0.55	0.51	0.46	0.54
5 Shot Group Average	**2.03**	**1.89**	**1.90**	**1.83**	**1.64**	**1.89**
5 Shot Group Standard Deviation	0.54	0.56	0.47	0.40	0.44	0.50
# of guns fired	6	6	6	3	3	24
# of groups per gun	3	3	3	3	3	3
Mayfield Accuracy Data						
3 Shot Group Average	**1.40**	**1.20**	**1.03**	**1.29**	**1.31**	**1.31**
3 Shot Group Standard Deviation	0.31	0.30	0.24	0.31	0.27	0.31
# of guns fired	101	80	8	3	23	215
# of groups per gun	1	1	1	1	1	1

Table 2: M770 SS accuracy summary.

Endurance

A tiered endurance regime was conducted on the M770 SS rifles as outlined in the summary in table 1. The malfunction summary is shown in table 3. Overall, the rifles functioned well with minimal malfunctions. Gun A3 experienced two instances where the firing pin bound at round levels 638 and 697. The trigger would get heavy the few rounds prior to the malfunction. In both cases the condition cleared up on its own. At the end of the endurance segment the firing pin assembly was disassembled and inspected. The firing pin was found to be gouged, shown in figure 4. It was determined that a piece of debris, most likely a metal chip, must have been lodged between the firing pin, bolt plug, and main spring, and must have restricted movement of the firing pin during live fire testing. No burr was found that could have caused the gouge. During the second round of the test, when the D and E series rifles were tested, the lower locking lug on the bolt intermittently hit the magazine follower when the bolt was pulled back. This was not observed during the initial test with the A, B, and C series rifles. This observation and condition has nothing to do with the stainless or plated parts, the focus of this test. A very slight chamfer was sanded on the front of magazine follower on guns D1, D2, E1, and E2.

Malfunction Summary																											
	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D1	D2	D3	D4	D5	E1	E2	E3	E4	E5
100 RL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 [c]	0 [c]	0 [c]	0 [c]	0 [c]	0 [c]	0 [c]	0 [c]	0 [c]	0 [c]
500 RL	0	1 [a]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 [c]	0 [c]				0 [c]	0 [c]			
1000 RL	0	0	2 [b]	0			0	0	0	0			0	0	0	0			0 [c]					0 [c]				
1500 RL	0	0					0	0					0	0														
2000 RL	0	0					0	0					0	0														

[a] Fail to Eject on round 315
[b] A3 Firing pin bound on rounds 638,697. Trigger got heavy few rounds prior to malfunction, then no fire.
[c] Bolt locking lug intermittenly hit front of magazine follower.

Table 3: M770 endurance malfunction summary.

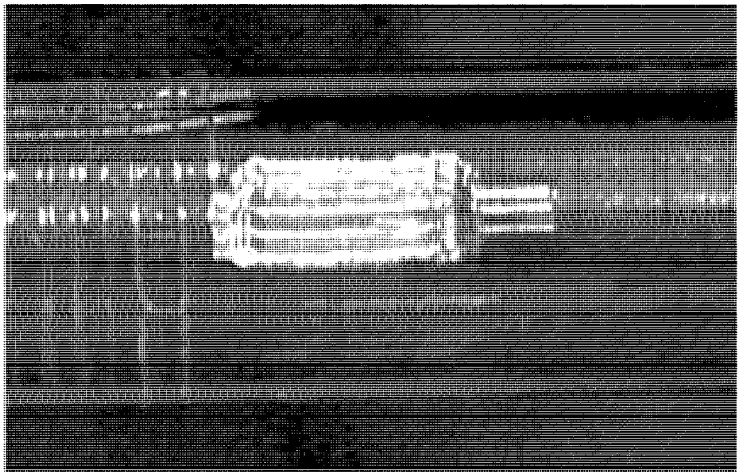

Figure 4: Gouged firing pin from gun A3.

Environmental Testing

Two rifles, B8 and C8, were environmentally tested via standard Remington hot and cold test procedure. Thermal cycle testing was initially planned; however, it was not performed due to equipment availability and a discussion as to the merits of conducting. The hot test consisted of placing the rifles in the Tenney environmental chamber set at 120F for 24 hours and then firing 20 rounds through each rifle at 2 hour intervals for a total of 100 rounds each. The cold test was conducted in a similar manner with the Tenney set -20F. No malfunctions were recorded during the hot test. One misfire was recorded during the cold test on gun B8 at round 22. The indent was good and appeared to be an ammunition malfunction.

Metallurgical Evaluation

Following endurance the barrels from rifles A1, B1, C1, D1, and E1 were removed from their receivers for metallurgical evaluation. The barrel of the M/770 rifle is manufactured with the locking lug machined integerally in to the barrel. The breech end of the barrel with these locking lugs is then induction hardened and tempered. The hardness specification for the barrel is HRc 37 – 45 as measured on the outside diameter of the hardened lug area. The hardness was inspected on the five barrels being evaluated in two locations; over one of the locking lugs and between two lugs. This data is show in figure 5.

Gun ID		A1	B1	C1	D1	E1
Location	Over Lug	43.0	44.4	41.4	39.4	42.9
	Between Lug	41.5	39.0	39.0	42.6	44.1

Figure 5: Hardness Inspection Data.

Each barrel was sectioned in four locations. Three of these sections were through the bore and the fourth section was cut through the center of the locking lugs, as seen in figure 6. Microhardness measurements were taken on each of the three lugs in each section to compare to the OD hardness data. These measurements were from the ID to the OD. The microhardness was preformed using the 500g Vickers scale. This data was then converted to HRc and is show graphically in figure 7. The specification states that the OD hardness should be between HRc 37 – 45, which they were. The microhardness data collected showed that the lugs were through hardened. Two locations at the ID of lug 3 on the barrel from gun E1 did show lower hardness. This most likely indicates that the ID of this particular lug got warmer then the rest during the temper cycle.

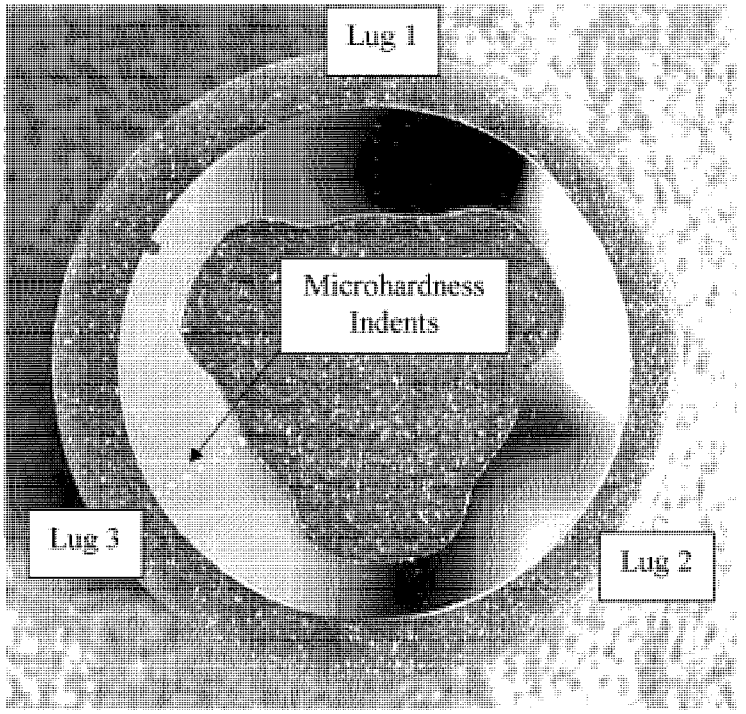

Figure 6: Representative lug section mount.

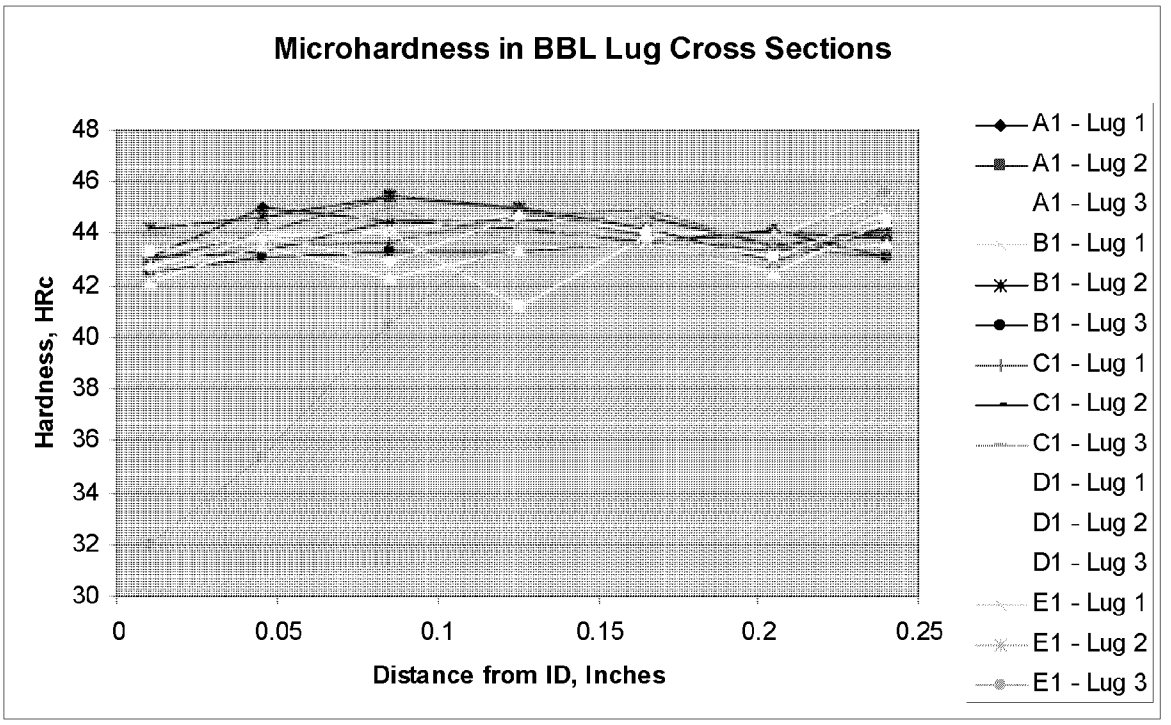

Figure 7: Locking Lug Microhardness Data.

The barrel sections were cut at the throat of the chamber, one inch down bore from the throat, and two inches down bore from the throat. These sections were mounted, polished, and inspected using the Nikon stereoscope. Representative pictures of these bore sections are shown in figures 8 - 10. A moderate about of heat checking was seen as would be expected in rifles with 1000 to 2000 rounds on them. No evidence of stress induced cracking was seen. The maximum measured crack length was 0.011" with the average measured crack length being 0.0064".

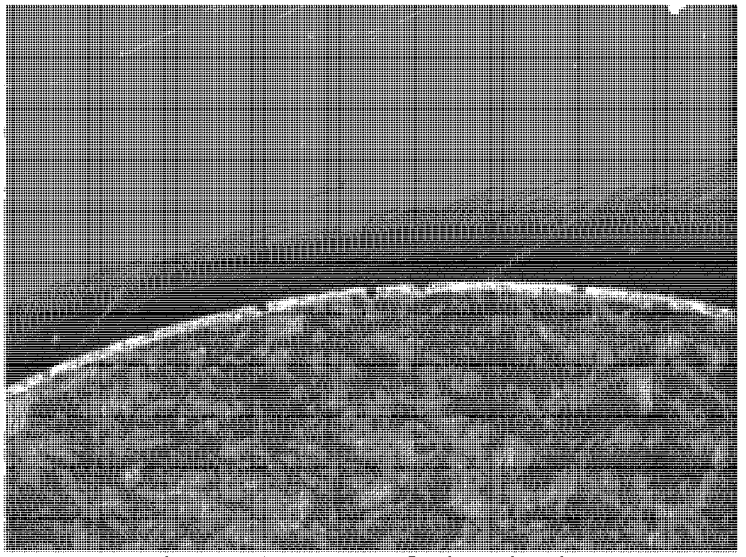

Figure 8: A1 (300 WM) @ Throat location.

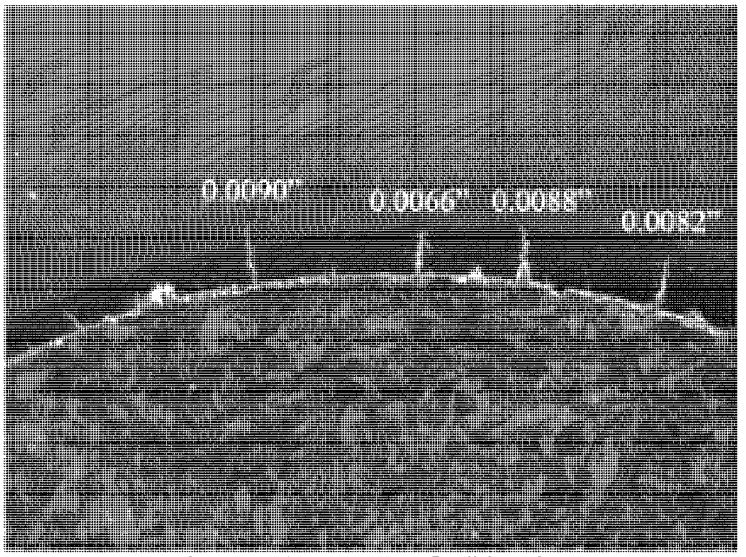

Figure 9: A1 (300 WM) @ 1" location.

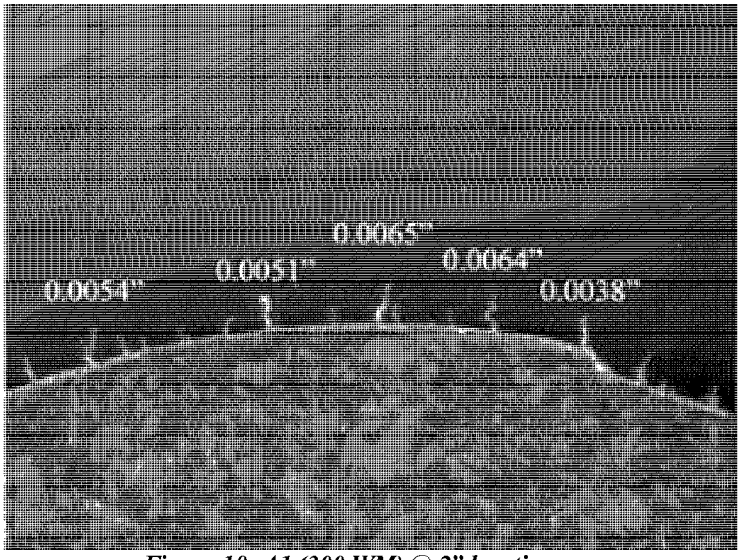

Figure 10: A1 (300 WM) @ 2" location.

Dry Cycle

One rifle, B7, was dry cycled using the pneumatic centerfire dry cycle machine. The action was cycled to 10,000 cycles stopping to lubricate every 500 round. No problems were discovered with the plating on the bolt or receiver. No appreciable wear was seen on the bolt.

High Pressure Abuse

High pressure abusive testing was performed on one rifle, A9, using SAAMI and Remington test procedures. The rifle selected for this test, A9, was chambered for the 300 Win Mag cartridge, representing the most sever scenario. The rifle had a strain gage place over the chamber portion of the barrel in the hoop direction. Three SAAMI reference rounds were fired through the rifle followed by three SAAMI Proof rounds. The rifle was then subjected to a 120,000 psi abuse round. The load for the abuse round was 71.5 grains of IMR 3031 Lot # E97AU19L1500. The result of this test were consistent with previously tested carbon steel product. The rifle remained intact; however, the strain data captured, seen in figure 11, shows that the barrel did take a permanent deformation set of approximately 300 μ" / ". The bolt required the use of a hammer to be opened. Figures 12 – 14 documents the condition of the rifle post test.

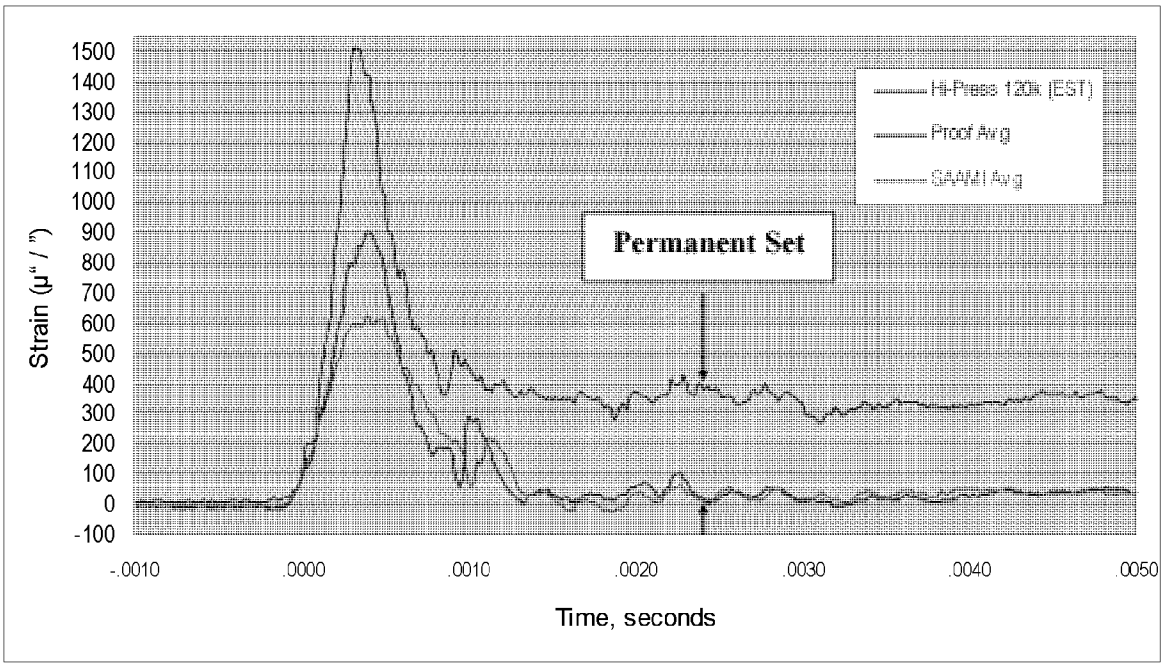

Figure 11: Strain Data for Abusive testing of gun A9.

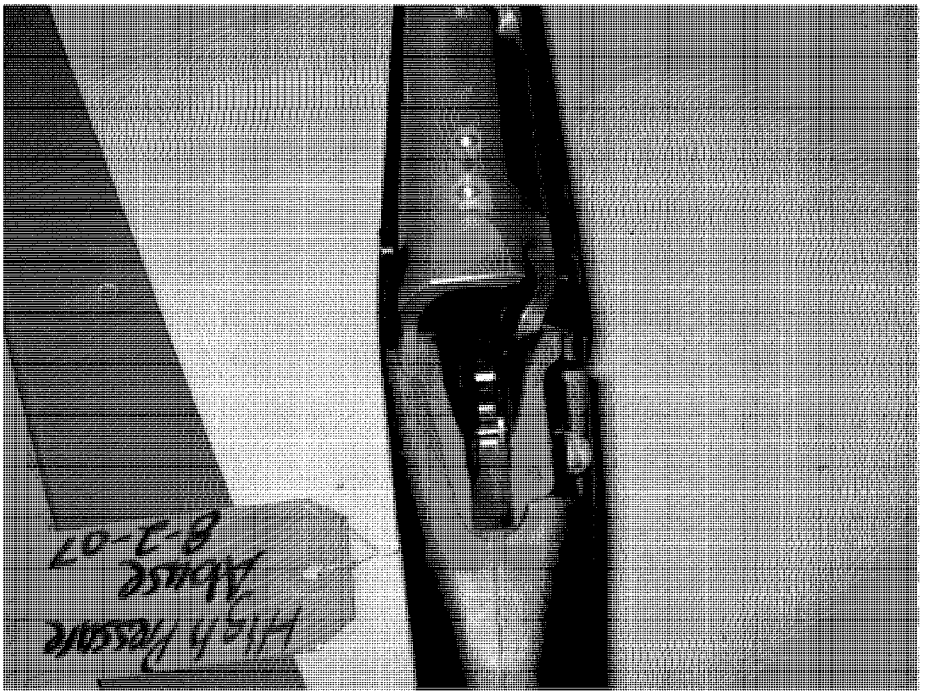

Figure 12: Gun A9 post abusive testing.

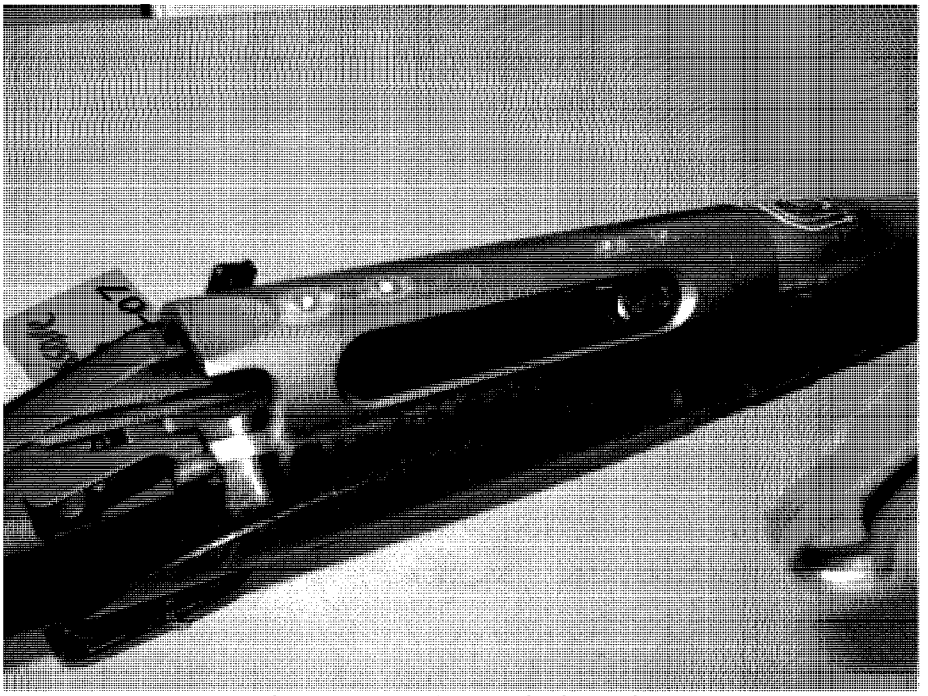

Figure 13: Gun A9 post abusive testing.

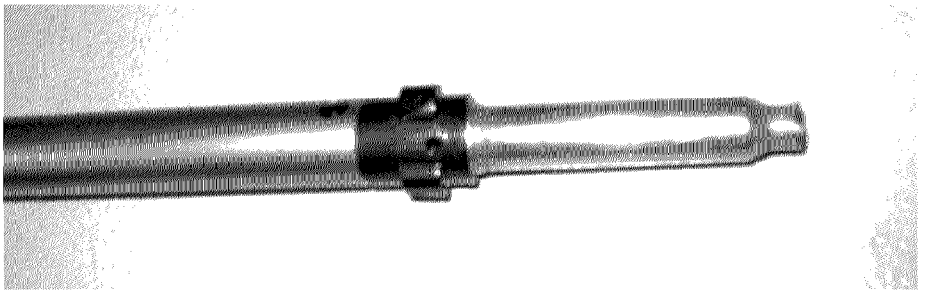

Figure 14: Gun A9 post abusive testing.