M/710 MAGNUM D.A.T.

BORE OBSTRUCTION TEST
ORIGIN OF FAILURE REPORT

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Prepared by:
Marlin R. Jiranek
Senior Research Engineer
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HISTORY

A Model 710 magnum rifle was subjected to a standard bore obstruction test as a function of the Design Acceptance Test protocol. The rifle failed during the test in a catastrophic manner that resulted in the rifle fracturing into many pieces.

The objective of this report is to identify the origin of the failure, determine the probable cause for the failure, and identify any possible actions that may be taken to prevent this type of failure in the future. Figure 1 presents an image of one half of the barrel fracture surface after the failure.

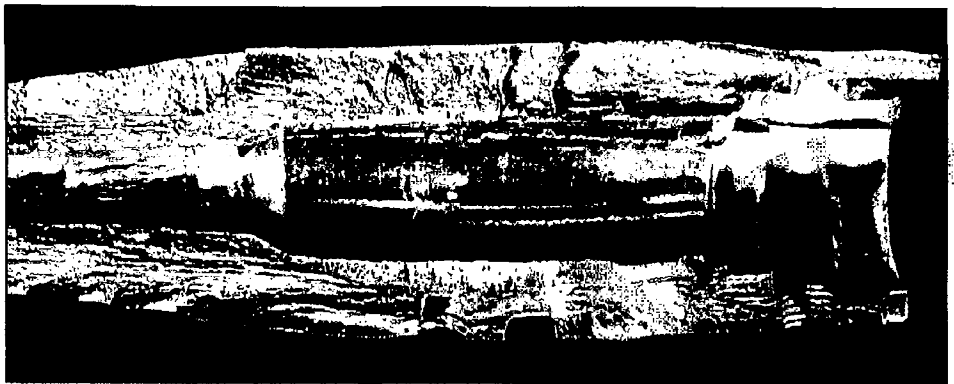

Figure 1. An image of one half of the barrel split fracture surface.

The test rifle was chambered for .300 Winchester Magnum. The test consisted of ramming a projectile (bullet) just far enough ahead of the chamber so that a standard factory round could be loaded in normal fashion. The rifle was then fired remotely and documented via high-speed video. A more thorough explanation of the testing protocol is presented in the D.A.T. report for the M/710 Magnum rifle product.

The initial failure and location of the various pieces of the rifle was documented using high-speed video and pictures taken by J. Snedeker after the event. The video documentation indicated that the failure occurred by fracture of the barrel, which then caused all of the other collateral damage to the firearm. Based on this evidence, the failure origin investigation was focused on the barrel of the rifle.

SUMMARY

The failure of the M/710 Magnum rifle originated at the bottom of the front takedown screw hole in the barrel. The material at this location was consistent with the design intentions and specifications and the failure occurred as a result of stress overload during the burst testing.

An FEA analysis was performed on the M/710 Magnum rifle system, simulating the type of loading that would take place during this testing scenario. The result of this analysis confirmed the failure origin location by indicating that the point of highest stress during the pressurization of the chamber would be the bottom of the front takedown screw hole. The results of the FEA analysis are presented at the end of this report.

If this failure is deemed to be a problem for the production product, it is recommended that the depth of the front takedown screw hole be reduced and controlled. It is suggested, based on the FEA analysis results, that the depth be reduced by at least 0.069" from nominal. It is recommended that the depth of the front takedown screw hole be reduced by approximately 0.100" to guarantee that enough material thickness is present to achieve the desired result. This change will move the point of highest stress during high pressure chamber overloading from the bottom of the front takedown screw hole to the inside chamber wall. This will most likely result in the system staying intact during extreme pressure overloads, similar to the pressures experienced in this test.

PROCEDURE

After being documented by J. Snedeker, the barrel was obtained for analysis. The barrel fracture surfaces were separated for evaluation using a band saw. A visual examination of the macro-characteristics of the fracture surfaces was performed utilizing a Nikon SMZ-2T stereoscope. Further examinations of the micro-characteristics of the fracture origin were completed utilizing a LEO s440σ scanning electron microscope (SEM). During the SEM examination, a qualitative chemical analysis of the material both on the fracture surface and of the clean substrate barrel material was performed using the energy dispursive x-ray (EDX) detector to identify contaminants on the surface of the fracture.

After the visual examination was completed, one half of the fractured barrel was sectioned to provide samples for determination the hardness profile of the barrel material and the hardness of the material at the failure origin location. This data was necessary to verify that the barrel was manufactured within the design specification parameters.

Microhardness testing was performed to determine the whether the barrel hardness profile conformed to the design specifications. The Vicker's hardness scale was used with a 500g major load and the results converted to Rockwell C-Scale values (HRc). The hardness profile was determined by taking hardness readings at locations running along the length of the barrel starting from the breach end. Additional micro-hardness measurements were performed around the fracture initiation site to verify that the material hardness in this location was consistent with the material hardness of the bulk barrel material.

The hardness results and EDX data, when taken together, indicate that the barrel material was most likely resulfurized AISI 4137 steel. For this reason, no quantitative chemical analysis was performed.

RESULTS

Visual Examination Results

Based on the fracture morphology on the barrel, it is clear that the fracture originated at the base of the front takedown screw hole. This position is shown in Figure 1 in the center of the image at the bottom of the barrel fracture (to the left of the notch). The location of the origin is evident by the presence of chevrons on the fracture surface that always point back to the origin of the fracture. Figures 2 and 3 present the left and right side of the fracture initiation site respectively. The direction of the fracture propagation and the fracture origin is indicated in each image.

The chevrons are angled orientations on the fracture surface, which visibly appear to be "flow lines". These lines point to the fracture origin and are caused by the propagation of the fracture from its origin.

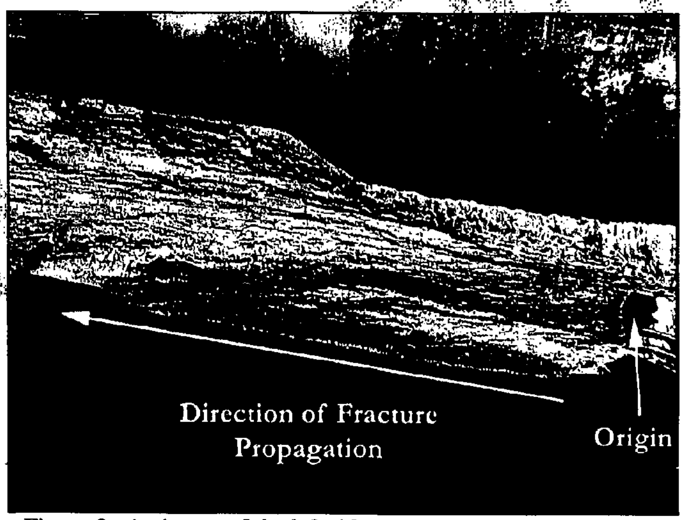

Figure 2. An image of the left side of the fracture initiation site.

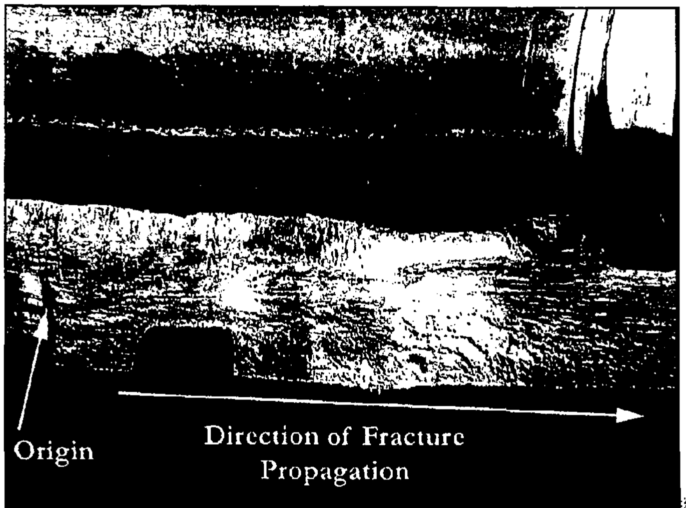

Figure 3. An image of the right side of the fracture initiation site.

The bore of the failed barrel, ahead of the chamber, exhibited a large amount of cracking. This cracking is typically known as heat checking or crazing. These cracks are typical of high pressure and high use firearms after significant firing. This particular rifle had an excess of 1,700 rounds fired through it prior to the burst testing. The heat-check cracks were likely present prior to the failure had no impact on the failure of the barrel. This conclusion is made based on the macro-characteristics of the fracture surface, as described in this section. Figure 4 presents an image of the heat-checked region of the barrel.

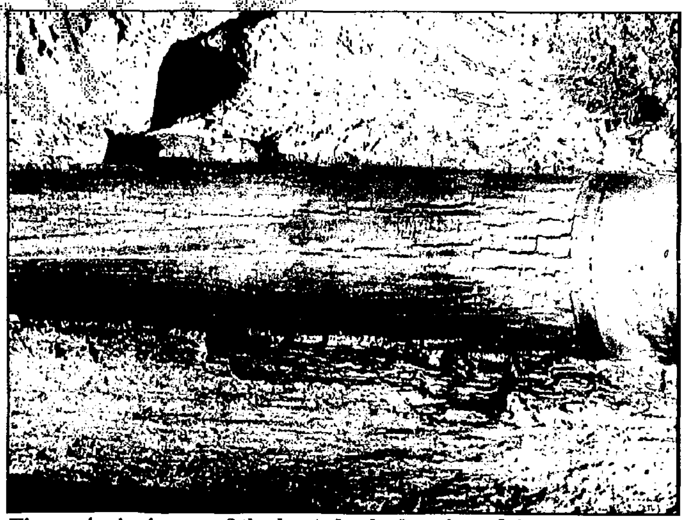

Figure 4. An image of the heat checked region of the failed barrel.

A sample cross section was taken from this region to determine the extent (depth) of the heat-check cracks. Figure 5 presents an image of the cross section of this heat-checked region and clearly depicts the crack depth. The deepest crack measured is approximately 0.027". The effect on these cracks on the safety of the barrel is a function of crack propagation. This issue is addressed in the endurance portion of the D.A.T. testing and not of issue in this report because it did not have a role in the failure of this barrel.

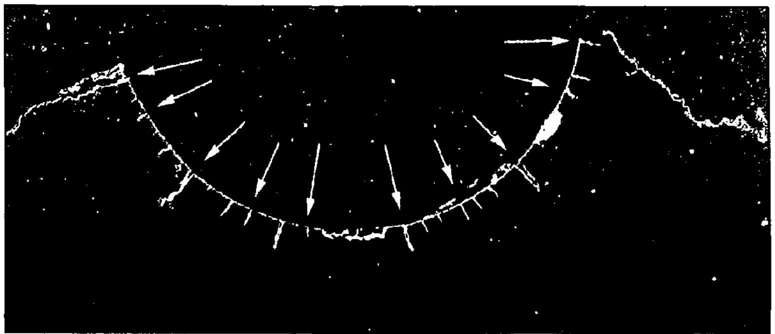

Figure 5. An image of the cross section of the heat-checked region of the failed M/710 Magnum barrel.

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Hardness Examination Results

Barrel Hardness Profile

Figure 6 presents a graph of the barrel material hardness versus distance from the breech end of the barrel. The actual data points are plotted along with the design specification as indicated on the barrel print for the magnum barrel.

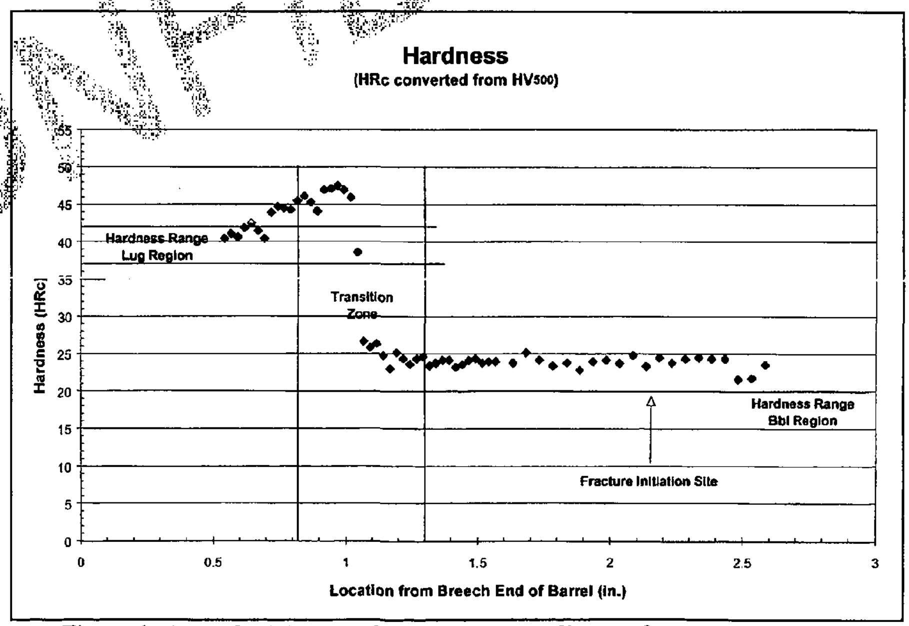

Figure 6. A graph of the barrel hardness versus distance from the breech end.

The hardness results indicate that the barrel was within the print specifications at the location of the failure. The hardness at the beginning of the transition zone is higher than the design specification hardness. This deviation had no impact on the failure of the barrel, based on the fracture origination location. This higher hardness is an indication that the tempering operation during manufacturing is not heating the barrel far enough into the breech end to fully temper back the quenched region. This issue, by itself, does not affect the destructive burst testing characteristics of the system.

Initiation Site Characterization

Figure 7 presents an image of the hardness indents that were performed around the fracture initiation site with each group of indents labeled. The hardness indents were performed utilizing the Vicker's scale with a 500g major load and then converted to HRc scale. The hardness specification in this location is a range of HRc 20-25. The material around the fracture origin was found to be within the design specification limits. Table 1 presents the hardness data.

The last several hardness points taken at the bottom of the takedown screw hole had slightly increased hardness values. This is most likely due to the deformation of the material at this location. The top of the image presented in Figure 7 is the chamber of the rifle.

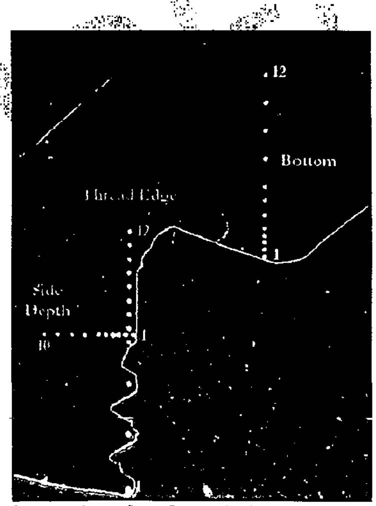

Figure 7. An image of the micro-hardness indent locations around the fracture origin location. Each group of indents and the first and last indent number are labeled.

FRACTURE ORIGIN MATERIAL HARDNESS			
Specification = 20 - 25 HRc			
	Hardness (HRc)		
Indent No.	Thread Edge	Bottom	Side Depth
1	24.0	22.5	22.4
2	23.1	23.3	24.4
3	23.1	24.2	24.4
4	23.1	24.0	24.0
5	24.5	25.0	22.6
6	24.4	25.6	22.4
7	24.4	24.9	21.3
8	25.7	25.7	21.6
9	25.8	25.4	20.6
10	25.2	27.7	20.6
11	25.4	27.7	
12	23.3	27.9	
High	25.8	27.9	24.4
Low	23.1	22.5	20.6

Table 1. The hardness results from the fracture origin micro-hardness measurements. The design specification is HRc 20-25.

SEM Examination Results

An SEM examination of the fracture origin was completed to determine the type of fracture that occurred. Based on the material and heat treatment, it was expected that a ductile overload fracture occurred which would result in the presence of ductile dimples at the fracture origin. Figure 8 presents a high magnification (1,540X) SEM image of the material at the fracture origination site. This image clearly shows the presence of ductile dimples in the material.

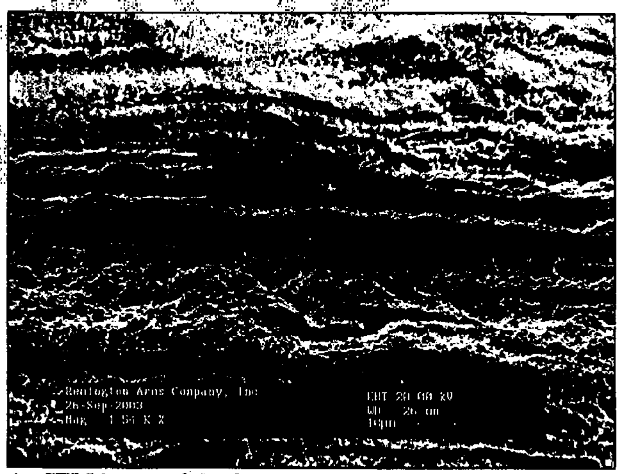

Figure 8. An SEM image of the fracture origination site showing the presence of ductile dimples. Magnification approximately 1,540X.

The fracture surface of the sample seemed to be covered with a light coating of material, evident by the soft edges of the ductile dimples. A qualitative EDX analysis was performed of this fracture surface and compared to a qualitative EDX analysis performed on the clean base material of this barrel. Figure 9 presents an image of the compared EDX spectrum obtained from each analysis.

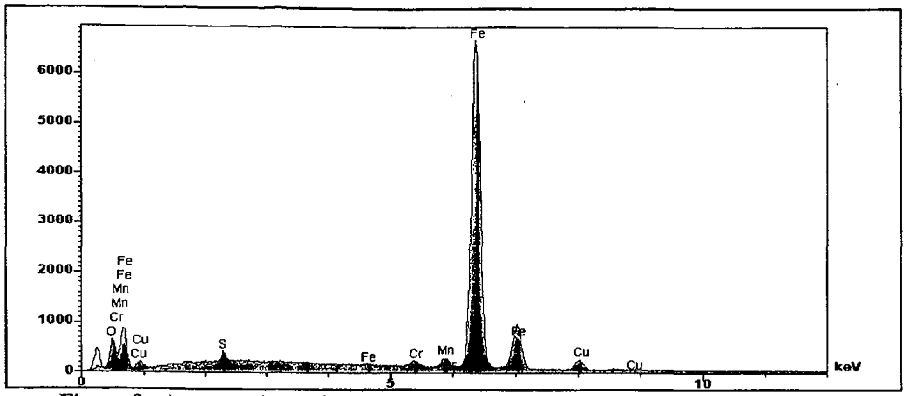

Figure 9. A comparison of two EDX spectra. The red spectrum represents the fracture surface and the blue spectrum is the compared base material spectrum. The spectra have been normalized to the main Fe peak in the center of the graph.

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The spectral comparison indicates that both materials have identical ratios of Fe, Mn, and Cr present. These materials are consistent with the AISI 4137 material used to fabricate the barrel. The fracture surface spectrum contains additions of Cu, O, and S. These are all combustion products and deposited material from the rifle shell case that was destroyed in the chamber during the test and accounts for the light coating of material on the fracture surface.

To: Marlin Jiranek

From: Harold Davidson

Date: 09-26-03

A M710 300 WinMag barrel chamber stress analysis was performed to determine stress patterns and relative stress magnitudes. This analysis was performed using ANSYS DesignSpace 7.0. All loading conditions were static.

Modeling and Constraints:

The barrel lugs were modeled using tetrahedral solid elements as shown in **IMAGE 1**. A chamber pressure of 100,000 psi was applied to the green surfaces highlighted in **IMAGE 2**. The barrel was fixed from any movement at the surface labeled "Fixed Support 4" shown on **IMAGE 2**.

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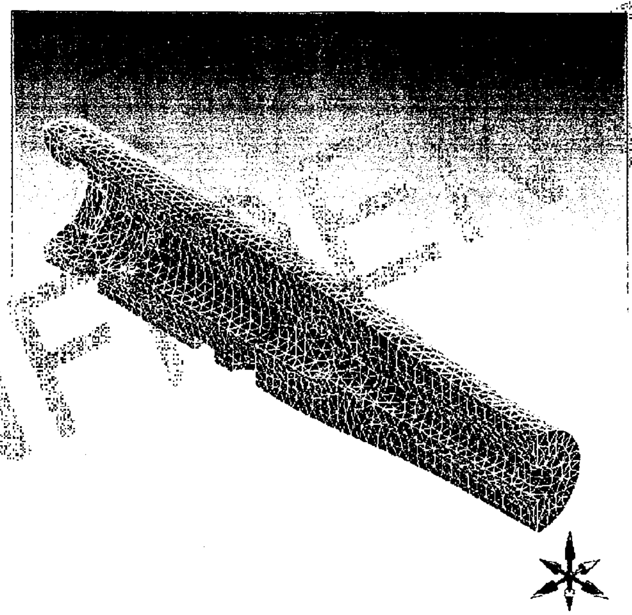


IMAGE 1. Tetrahedral mesh for M710 300 WinMag chamber.

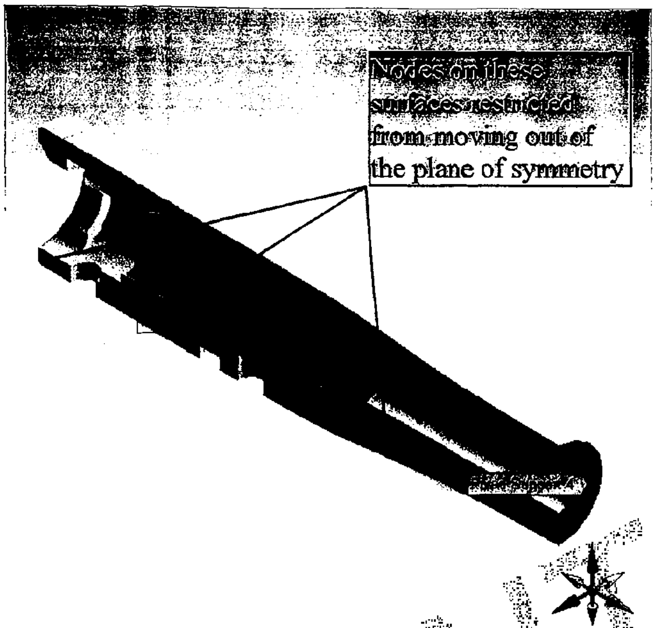
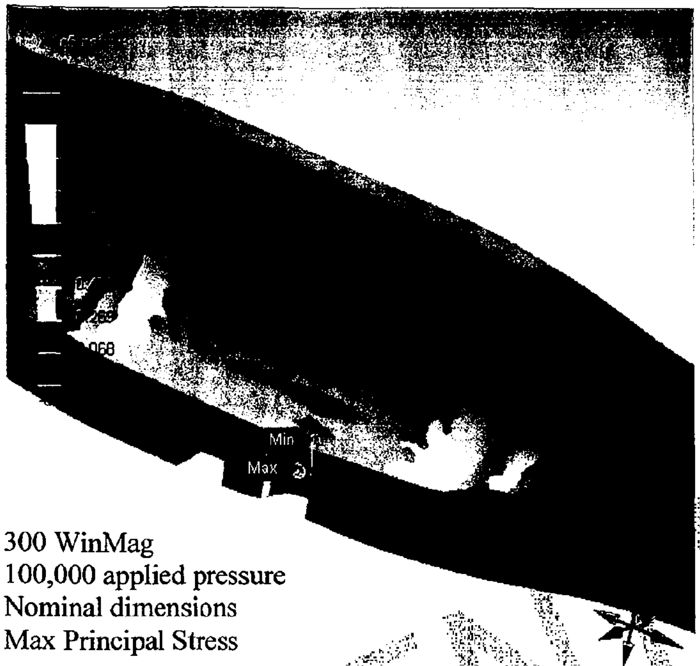


IMAGE 2. Loads and constraints for all geometry configurations.

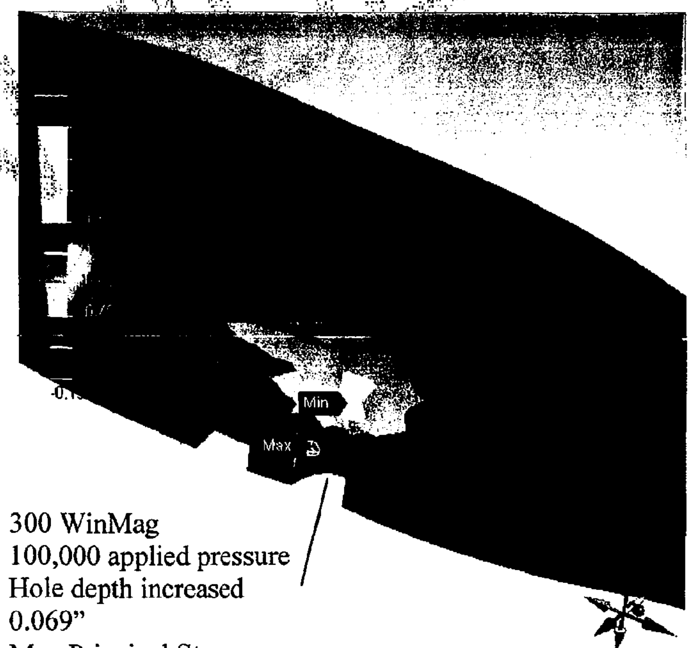
Results:

The first principal stress for each configuration analyzed is shown belowThe ANSYS DesignSpace databases were saved in K:\Research\Hed\M710\710 Magnum Barrel FEA\.



300 WinMag
100,000 applied pressure
Nominal dimensions
Max Principal Stress

IMAGE 3. M710 magnum barrel first prinipal stress.



300 WinMag
100,000 applied pressure
Hole depth increased
0.069"
Max Principal Stress

IMAGE 4. M710 300 WinMag chamber max principal stress with increased hole depth.

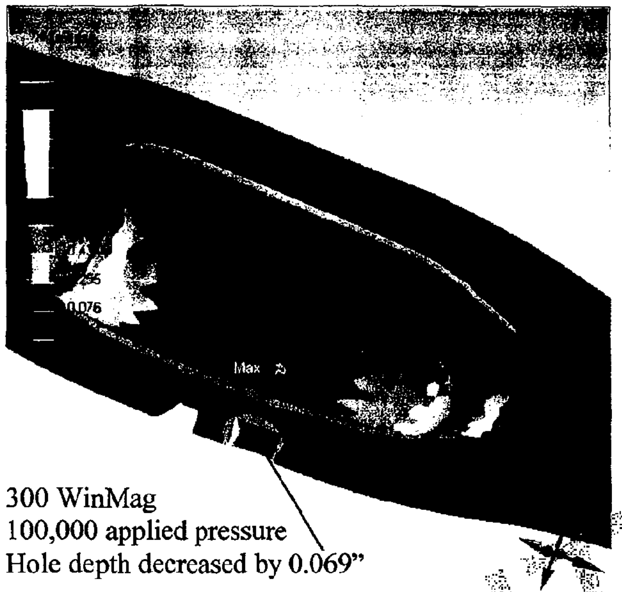


IMAGE 5. M710 300 WinMag chamber max principal stress with decreased hole depth.

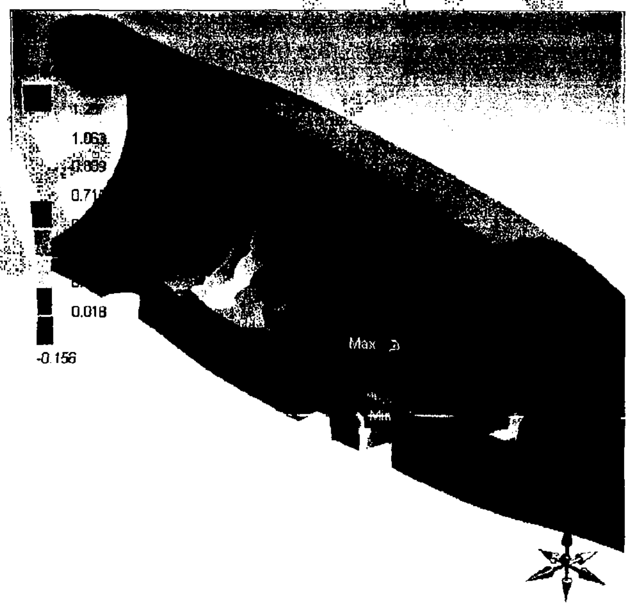


IMAGE 6. M710 30.06 chamber max principal stress.