TRIGGER PULL STUDY
M/597 WIN. MAG.

June 25, 1998

Remington Arms Co., Inc.
Research and Development Center
Elizabethtown, KY

Requested By:
Matt Golemboski
Engineering Manager
Mayfield Plant

Prepared By:
Scott R. Franz
Staff Engineer

BARBER - RE 0002447

CONFIDENTIAL

TRIGGER PULL STUDY
MODEL 597 WIN. MAG.

PURPOSE:

To determine if differences in trigger pull measured at Mayfield and E-town during recent development and T & P testing is attributable to gage hardware, technique or whether they are in fact statistically different at all. This work is not meant to resolve the issue of trigger pull relative to specification. It will however help us better understand the main sources of error so that we can better resolve trigger pull issues in the future.

SUMMARY:

Of the three gages considered, the two spring type (1 E-town, 1 Mayfield) were not found to be statistically different at the 95 % Confidence Level when measuring trigger pull. The electronic type gage was statistically different from both of the other gages, also using a 95 % C.I.. The difference was on the order of .26 lbs. higher. This difference was found after all three gages were statistically calibrated with NRA approved dead weights. During static calibration all three gages yielded almost identical results with the dead weights at all levels between 1.0 and 9.0 lbs.. We can conclude then that either the electronic gage is more accurate than the spring gages and therefore able to resolve finer differences or that the technique used when measuring trigger pull with this gage resulted in the mean shift. I believe that the later is true. This is explained in detail under the Results section of this report. Bottom line here is that the two spring type gages used by E-town and Mayfield were not different.

Results from the Gage Repeatability & Reproducibility study indicate that the spring type gages are capable of determining differences no finer than .15 lbs. This resolution was achieved with 30 readings/test. As the number of readings per sample decreases the resolution gets courser. If we continue with the present practice of three readings/gun then the expected accuracy climbs into the .4 lb. range. In other words, we cannot say that two guns have different trigger pulls if the difference (avg. of 3 readings) is less than .4 lbs. The gages are not accurate enough to discern this difference with such small sample sizes.

Trigger pull measurements over the last three months on T & P samples at Mayfield and E-town are different by .56 lbs. There must be an identifiable cause for this difference given the large sample size and the fact that both groups are representative of the same population of guns. The most probable cause for the mean shift is a difference in gage calibration and/or differences in measuring technique. Given the large sample of guns measured, the spring gages should be capable of measuring within .15 lbs.. We therefore cannot blame the difference in trigger pull on the accuracy of the measurement system.

One final comment should be made concerning the range of trigger pulls expected given the data generated to date. With a combined (pooled) std. dev. of .374 lbs., the expected +/- Three Sigma range is 2.24 lbs.. In other words we should expect trigger pulls from 3.88 to 6.12 lbs. assuming we have a design/process centered at 5.0 lbs.. This range can be reduced by greater manufacturing control of part dimensions that effect trigger pull, an improvement in part finishes to reduce friction or by screening product to tighter limits. This is presently what the design/process is yielding.

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RECOMMENDATIONS:

SHORT TERM - A gage calibration frequency and procedure should be put in place at both E-town and Mayfield. I would also recommend that a procedure be established and documented for measuring trigger pull and that this should be reviewed with both site personnel. Both sites need to be doing exactly the same thing if we are going to reduce the error relative to trigger pull.

LONG TERM - I suggest additional data be collected for a short time once production is fully underway. This should determine the design/process capability. At that time Design, Manufacturing and Marketing should review these results to determine if they are acceptable as is or whether a shift needs to be made. At present there is no absolute specification that everyone agrees to. If the specification is 4.5 - 5.5 lbs. as Marketing understands it, then this data shows that we do not have a capable design/process that can meet this consistently.

TEST DESCRIPTION:

This work was broken up into two main categories. A more complete description of these tests along with a discussion of results can be found under the Test Procedure and Discussion of Results sections of this report.

- Experimental - Tests were designed and run to compare gage hardware under controlled conditions. Three gages were used for this phase. One spring type gage from Mayfield, one spring type gage from E-town and an electronic force gage from E-town. Three tests were run.

    1. Calibration of each gage using static weights (NRA approved).
    2. A Random Multiple Gage-Gun test with replication to reduce the effect of test sequence and operator influence on results.
    3. A Gage Reproducibility & Repeatability Test to determine the statistical capability of gages used.

- Statistical Analysis of Historical Data - Data obtained from Mayfield was compared to E-town data compiled over the past 3 months (3 T & P tests). This data was put through more extensive statistical tests to better compare the two data sets.

TEST PROCEDURE:

The three gages used are shown in Fig. 1. They are all Manufactured by the CHATILLON company of N.Y. but are all of different model types. The Mayfield gage is identical to what is used in production, while the E-town gage is the actual one used for all T & P measurements. The electronic gage was used more or less as a control and for information purposes only. The table below compares gage type, model designation and minimum resolution for all three gages.

MODEL **SERIAL NO.** **MIN.**

INCREMENT

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E-town Spring Gage	IN-10	---------	1/4 lb.
Mayfield Spring Gage	IN-12	---------	1/8 lb.
E-town Electronic Force gage	DFGS10	25298	.005 lb.

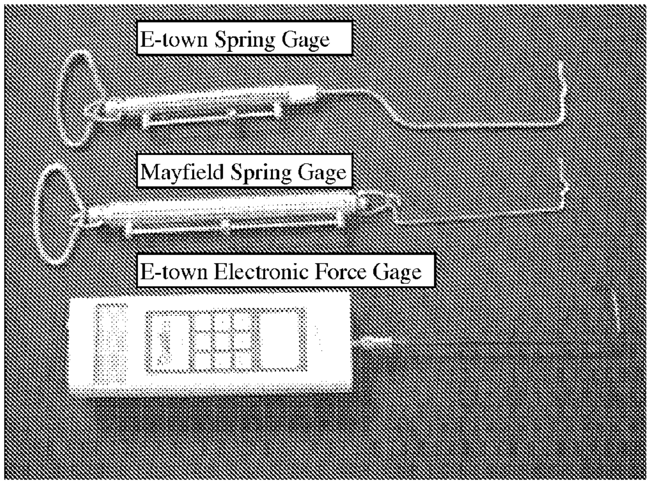

Figure 1.

The number in the model designation also indicates the maximum capability of the gage. The two E-town gages are good to 10 lbs. while the Mayfield gage measures up to 12 lbs.. See Figure 1. All three gages were initially inspected for correct operation. The Mayfield gage was not operating properly. The sliding indicator was dragging on the guide rod and the rod was crooked. This could of added additional force to our readings, therefore the gage was repaired prior to continuing. This damage could of happened in shipping from Mayfield to E-town. The gages were then checked for "Zero" in a vertical orientation and adjusted if needed. Weights in increments from 1.0 to 9.0 lbs. were hung from each gage and the reading on the gage was recorded. Three calibration runs per gage were done. Next was a random gun/gage test. Five M/597 Magnum rifles were chosen at random. Trigger pulls were measured on all five guns with all three gages. Three iterations were run per Gun/Gage combination. The sequence was randomized to eliminate any test sequence or operator influence on results. The final test was a Gage Repeatability and Reproducibility test. A single M/597 was selected from the five used for the last test. 30 consecutive trigger pulls were recorded with each gage. All trigger pulls recorded during this study was done with the action assembled in the stock, gun secured in a vise and direction parallel to the bore. A single operator was used for all this testing to eliminate operator variability. A copy of the Test Request can be found in the Appendix along with the results from all three tests.

DISCUSSION of RESULTS:

The three calibration runs per gage were averaged for each weight increment and then a regression line was fit for each gage relative to the dead weight values. The three regression lines were plotted and are shown in Figure 2. below. The actual regression data is summarized below.

	EQUATION
E-town Spring Gage	F=1.000W
Mayfield Spring Gage	F=1.012W-.074
E-town Electronic Force Gage	F=0.998W+.017

The slope of the line indicates the linearity of the gage whereas the intercept indicates the amount of offset. This data indicates the three gages are virtually identical for all practical purposes. It clearly shows that if gages are calibrated the same that they will yield the same result given an identical force input.

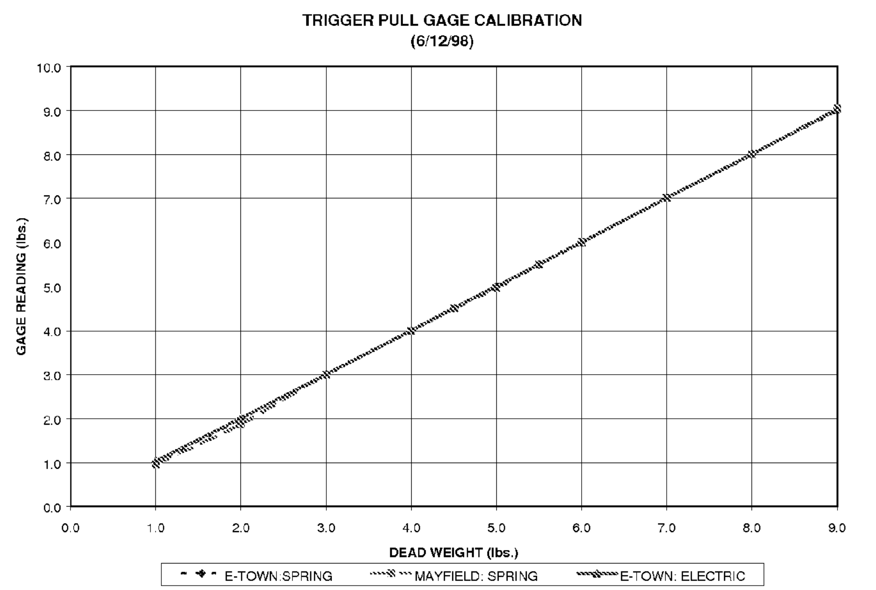

Figure 2.

Results for the "Five Gun-Three Gage" random test were compiled and a Oneway Analysis of Variance run to determine if these gages were statistically different at the 95 % level. The following table and graph summarizes results from the ANOVA.

One-Way Analysis of Variance

```
Analysis of Variance on FORCE:lb
Source     DF        SS        MS        F        p
TP GAGE     2     0.808     0.404     3.39    0.043
Error      42     5.003     0.119
Total      44     5.811
                                       Individual 95% CIs For Mean
                                       Based on Pooled StDev
   Gage         N      Mean     StDev  -------+---------+---------+---------
 E-TOWN SPG    15    5.2500    0.2362    (--------*-------)
 MAYFIELD "   15    5.3333    0.4787         (--------*--------)
 ELECTRONIC    15    5.5667    0.2690                    (--------*--------)
                                       -------+---------+---------+---------
Pooled StDev =    0.3451                      5.20      5.40      5.60
```

To interpret this data one merely needs to look at the location of the confidence intervals on the graph and look for overlap. Overlap indicates that the data sets and therefore the gages are not statistically different at the 95 % level. This test was not powerful enough to discern a difference between gages at the 95 % level. More readings taken per test condition would increased the detecting power. The last test clearly shows this to be the case. This is where only one gun was measured and that 30 readings per gage were recorded in succession. A similar ANOVA analysis showed the following:

<u>One-Way Analysis of Variance</u>

```
Analysis of Variance
Source     DF        SS         MS        F        p
Factor      2    1.4973     0.7487    18.71    0.000
Error      87    3.4804     0.0400
Total      89    4.9778
                                           Individual 95% CIs For Mean
                                           Based on Pooled StDev
    Gage        N      Mean      StDev     -+---------+---------+---------+-----
E-TOWN SPG     30    5.1667     0.1808      (---*----)
MAYFIELD "     30    5.2542     0.2445           (----*----)
ELECTRONIC     30    5.4733     0.1660                            (----*----)
                                           -+---------+---------+---------+-----
Pooled StDev =    0.2000                   5.10      5.25      5.40      5.55
```

In this case there is a statistical difference between the two spring type gages and the electronic force gage, even at the 95 % confidence level. This shows the correlation between the number of readings versus error, or the ability to detect differences between data sets. There are a number of possible explanations why the electronic gage reads higher than the spring type gages by about .26 lbs.. (The two spring gage means were averaged and compared to the electronic mean of 5.4733 lbs. to get a .26 lb. difference.)

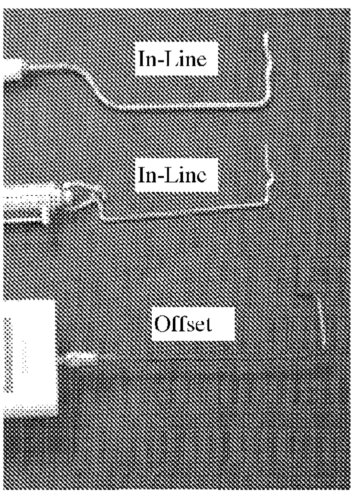

Figure 3.

The first has to do with the configuration of the "hook" on the end of the gage that contacts the trigger. See Figure 3. The spring type gages are bent so that the force is in-line with the actual force sensing element of the gage. The electronic gage is offset so that the trigger contact point is not in-line. This may effect the force reading since a bending moment in the hook is set-up. An offset type hook would also be more sensitive to operator technique. Another explanation has to do with the actual operation of the gage. The length of a spring type gage varies as a function of load, the electronic gage does not. As a result the electronic gage may be more susceptible to "trigger slapping" when the trigger breaks free after firing. Because of this "trigger slapping" at hammer release the electronic gage was not run in peak mode. The operator watched the digital readout and noted the highest force when this occurred. Again, this is open to operator judgment and error. This trigge[illegible]g would not occur when measuring dead weights and therefore would not be a factor. This is the most probable cause for this gage reading higher.

On April 6, 1998 Mayfield was in the process of preparing a 200 gun lot for R & D to select a 35 gun sample. During this build they had measured and recorded trigger pull on all 200 guns. This data was entered into the computer and compared to the trigger pulls taken by E-town during the three 35 gun M/597 Win. Mag. tests run over the last three months. (105 guns, 3 readings/gun) Results from this data comparison is shown below.

One-Way Analysis of Variance

```
Analysis of Variance
Source     DF        SS        MS        F        p
Factor      1    38.052    38.052   272.08    0.000
Error     513    71.748     0.140
Total     514   109.800
                                    Individual 95% CIs For Mean
                                    Based on Pooled StDev
 Level      N      Mean     StDev   --+---------+---------+---------+----
Mayfield  200    5.0300    0.3283    (--*-)
E-town    315    5.5877    0.4002                                (-*-)
                                    --+---------+---------+---------+----
Pooled StDev =   0.3740               5.00      5.20      5.40      5.60
```

The ANOVA clearly shows a difference in trigger pulls between these two data sets. It should be mentioned that most if not all of the 105 guns that were measured in E-town were drawn from Mayfield's 200 gun lot. The difference in average trigger pull is .56 lbs.. This difference is large enough to be measured by the spring gages and therefore cannot be explained by measurement error. Since the guns are sampled from the same lot, there must be another reason. I feel that the most probable cause is a slight difference in gage calibration and/or a difference in technique. The data sets were plotted in histogram form and are shown in Figure 4.

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```
Each dot represents 3 points

                 .
                 :    .
                 :    :
            .    :    :
            :    :    :    .
            :    :    :    :
            :    :    :    :
       :    :    :    :    :
       :    :    :    :    :
  :    :    :    :    :    :
-------+---------+---------+---------+---------+---------Mayfield
    4.50      5.00      5.50      6.00      6.50      7.00
```

```
Each dot represents 6 points

                           :
                           :
                      .    :    :    :
                      :    :    :    :
                 :    :    :    :    :
                 :    :    :    :    :         .
            .    :  . :    :    :    :    :    :    .
-------+---------+---------+---------+---------+---------E-town
    4.50      5.00      5.50      6.00      6.50      7.00
```

Figure 4.

Note the difference in mean value for the two populations and the variability as indicated by the width of the plots. Both distributions show enough variability that a specification range of 1 lb. cannot be held. One last thing to note is the truncated distribution in the Mayfield data. This resembles a distribution resulting from a screen operation which essentially they have since guns are inspected 100 % and are screened to a 5.5 lb. upper limit. If this were the case then we would expect the E-town data to also resemble a truncated distribution. The E-town data does not show this. A truncated distribution can also be the result of operator “Flinching”. “Flinching” means that if an operator is faced with a reading that’s close to a limit, they opt to call something just in specification as opposed to just out of specification. In either case, the best course of action to improve trigger pull agreement between E-town and Mayfield is to institute more stringent calibration procedures as well as general trigger pull procedures. We both need to be using the same calibration weights and the same technique if we are going to obtain closer agreement. It doesn’t make sense to address trigger pull relative to specification until this is done.

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APPENDICES

1. Test Request Form
2. Calibration Data
3. Five Gun-Three gage Test Data
4. Gage R & R Data

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Test Lab Request Form

Date Submitted: 5/6/98	Tracking #:
Project #: 241005	Engineer: FRANZ

Test Objective:

To compare E-town and Mayfield's trigger pull gages. Mayfield consistently measures approximately 1/2 lb. lower forces than E-town. This test will compare one spring type gage from each site along with a digital force gage(0-10 lb.) to determine if differences are attributed to technique or gages.

Test Description:

- Zero all three(3) gages with a 5 lb. dead wt..
  DO NOT RE-ZERO ANY GAGE AFTER THIS!!!!!!
- Perform dead wt. calibration on each gage.
  - from 1 - 9 lbs. in 1 lb. intervals (1/2 lb. interval between 4-6 lb. range)
  - 3 Calibration runs/gage
- Measure 5 guns with each gage. Do this 3 times. Follow the test order supplied by Scott Franz. This will result in 3 readings/gun/gage in random order.
- Select one gun and measure it 30 times with each of the three gages.
-

Resource Usage: Manpower Requirements - 1 technician • Facility Requirements - Metrology Lab	Test Results Required: Formal Report: Data Only: X REQUESTED Completion Date: 6/1/98

Required Materials/Parts/Equipment (include quantities):

5 - M/597 Magnum rifles (Select any 5 T & P guns)

3 - Trigger pull gages (E-town gage used for T&P testing , Mayfield gage, E-town 0-10 lb. electronic force gage)
See S. Franz for Mayfield Gage.

1 - NRA Dead Wt. Set

Test Parts: Available now

Start Date: 6/1/98 Completion Date: 6/2/98 Report Date:	Test Assigned To: J. Carson

☐ INDEXED ☐ ASSIGNED ☐ SCHEDULED

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DEAD WEIGHT CALIBRATION

GAGE NO.	DESCRIPTION
1	E-TOWN SPRING GAGE
2	MAYFIELD SPRING GAGE
3	E-TOWN ELECTRONIC GAGE

NRA WEIGHT (lbs.)	GAGE NO. 1 (lbs.) RUN 1	RUN 2	RUN 3	AVG.	GAGE NO. 2 (lbs.) RUN 1	RUN 2	RUN 3	AVG.
1.0	1.0	1.0	1.0	1.0	1.000	0.875	1.000	0.958
2.0	2.0	2.0	2.0	2.0	1.875	1.875	1.875	1.875
3.0	3.0	3.0	3.0	3.0	3.000	3.000	3.000	3.000
4.0	4.0	4.0	4.0	4.0	4.000	4.000	4.000	4.000
4.5	4.5	4.5	4.5	4.5	4.500	4.500	4.500	4.500
5.0	5.0	5.0	5.0	5.0	5.000	4.875	5.000	4.958
5.5	5.5	5.5	5.5	5.5	5.500	5.500	5.500	5.500
6.0	6.0	6.0	6.0	6.0	6.000	6.000	6.000	6.000
7.0	7.0	7.0	7.0	7.0	7.000	7.000	7.000	7.000
8.0	8.0	8.0	8.0	8.0	8.000	8.000	8.000	8.000
9.0	9.0	9.0	9.0	9.0	9.000	9.125	9.000	9.042

NRA WEIGHT (lbs.)	GAGE NO. 3 (lbs.) RUN 1	RUN 2	RUN 3	AVG.
1.0	1.085	1.015	1.005	1.035
2.0	2.005	2.005	2.025	2.012
3.0	3.005	3.020	2.995	3.007
4.0	4.000	3.995	4.005	4.000
4.5	4.520	4.495	4.510	4.508
5.0	5.005	4.990	5.010	5.002
5.5	5.500	5.500	5.515	5.505
6.0	6.010	5.995	5.995	6.000
7.0	7.035	7.005	7.000	7.013
8.0	8.025	7.990	7.995	8.003
9.0	9.015	9.000	9.025	9.013

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FIVE GUN-THREE GAGE RANDOM TEST

TP GAGE	GUN NO.	FORCE READING (lbs.)
2	5	6.500
2	2	6.250
1	3	5.500
3	3	5.500
3	5	6.000
1	4	5.000
1	5	5.250
2	3	5.000
3	5	5.800
3	3	5.700
3	2	5.800
1	1	5.750
3	4	5.200
1	2	5.125
2	4	5.000
2	1	5.500
1	2	5.500
2	5	5.500
3	4	5.100
1	2	5.000
1	3	5.250
1	4	5.000
3	3	5.600
2	1	5.250
2	4	5.125
2	3	5.000
1	5	5.375
3	2	5.300
1	1	5.250
1	1	5.250
2	1	5.000
1	5	5.500
1	3	5.000
2	2	5.125
2	5	5.625
3	1	5.300
2	4	4.875
3	1	5.600
3	4	5.500
1	4	5.000
3	1	5.800
2	2	5.000
3	2	5.400
2	3	5.250
3	5	5.900

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ONE GUN TEST: 30 CONSECUTIVE READINGS per GAGE

READING	GAGE NO. 1 FORCE READING (lbs.)	GAGE NO. 2 FORCE READING (lbs.)	GAGE NO. 3 FORCE READING (lbs.)
1	5.000	5.000	5.700
2	5.250	4.875	5.400
3	5.125	4.875	5.500
4	5.500	4.875	5.400
5	5.125	5.000	5.600
6	5.000	5.000	5.900
7	5.500	5.000	5.500
8	5.125	5.250	5.400
9	5.000	5.000	5.600
10	5.500	5.125	5.500
11	5.000	5.125	5.600
12	5.000	5.000	5.500
13	5.125	5.250	5.500
14	5.250	5.000	5.800
15	5.250	5.500	5.400
16	5.250	5.250	5.400
17	5.500	5.250	5.000
18	5.250	5.375	5.300
19	5.000	5.500	5.500
20	5.500	5.500	5.300
21	5.000	5.500	5.500
22	5.000	5.500	5.500
23	5.000	5.500	5.500
24	5.000	5.500	5.400
25	5.125	5.500	5.300
26	5.125	5.500	5.400
27	5.000	5.250	5.500
28	5.250	5.500	5.300
29	5.000	5.625	5.600
30	5.250	5.500	5.400
AVG.	5.167	5.254	5.473
ST.DEV.	0.181	0.245	0.166

GAGE	DESCRIPTION
1	E-town Spring Gage
2	Mayfield Spring Gage
3	E-town Electronic Gage

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