FA-TR-76022

AD

INTERDRAW ANNEALING
ON THE SCAMP CASE SUBMODULE

April 1976

Approved for public release; distribution unlimited.

Manufacturing Technology Directorate

FRANKFORD ARSENAL
U.S. ARMY

PHILADELPHIA, PENNSYLVANIA 19137

U.S. ARMY ARMAMENT COMMAND
FRANKFORD ARSENAL
PHILADELPHIA, PENNSYLVANIA 19137

DISPOSITION INSTRUCTIONS

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER FA-TR-76022	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INTERDRAW ANNEALING ON THE SCAMP CASE SUBMODULE.		5. TYPE OF REPORT & PERIOD COVERED Final Engineering Report. Nov 1975 - March 1976
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Dr. Martin M. Roffman		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Frankford Arsenal ATTN: SARFA-MTS-E Philadelphia, PA 19137		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DA- 4932 05 6200
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Armament Command		12. REPORT DATE 23 Apr 1976
		13. NUMBER OF PAGES 44
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Project Manager for Munitions Production Base Modernization and Expansion ATTN: DRCPM-PBM Dover, N. J. 07801		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

SCAMP	ANNEALING
CASE SUBMODULE	
CARTRIDGE CASE	
MANUFACTURING	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A decision risk analysis was performed to determine the optimal number of cup draws and interdraw anneals required during manufacture of 5.56mm brass cartridge cases on modernized, high speed production equipment. The recommended approach to satisfying the current 5.56mm TDP consists of a two draw process without an interdraw anneal. However, should a grain structure requirement be imposed on the existing TDP, then the optimal configuration would be two draws with an interdraw anneal.

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

142 720

20. ABSTRACT (Cont)

These recommendations are limited to 5.56 mm brass cases only and can not be extended to other calibers or case materials without reviewing and revising the input data.

ACCESSION for

NTIS   White Section ☑
DDC   Buff Section   ☐
UNANNOUNCED   ☐
JUSTIFICATION ....

BY
DISTRIBUTION / AVAILABILITY CODES
DIST.   AVAIL and/or SPECIAL

A

OCT 14 1976

D

TABLE OF CONTENTS

List of Tables

List of Illustrations

Figure

INTRODUCTION

On 20 November 1975, the Project Manager for Production Base Modernization, MG Malley, directed Frankford Arsenal to perform a decision risk analysis on a number of long range planning options related to the SCAMP 5.56mm follow-on cartridge case submodules. Principal process options specified for consideration included:

1. Two draws without an interdraw anneal;
2. Two draws with an interdraw anneal;
3. Three draws with two interdraw anneals.

Option one duplicates the modernized approach currently utilized in building 189 at Twin Cities. Option two has never previously been implemented or tested. Option three most closely simulates the existing batch process found in building 4 at Lake City. The principal objective of this analysis was to determine which option would produce an acceptable cartridge case satisfying all requirements of the present 5.56mm Technical Data Package (TDP) including hardness gradient, at minimum cost and risk to the Army. Procedures, findings, and recommendations of the analysis are presented in this document.

During the course of the investigation, however, it became apparent that the 5.56mm cartridge TDP might be modified to incorporate a grain structure requirement. Motivation for potentially revising the TDP arises from the Army's committment to insure cartridge compatibility with alternative U.S. rifles like the SAWS light machine gun and MICV system, as well as the successful candidate for future rifle system due to be selected after the April, 1977, NATO field tests. Follow-on SCAMP case submodules would, of course, have to be capable of producing ammunition compatible with those rifle systems. Therefore, the optimal case submodule alternative is specified for the conditions of compliance with both the present TDP and a TDP amended to reflect a grain structure requirement.

RECOMMENDATIONS

The following comments are offered regarding choice of the best case submodule alternative under the conditions of no TDP requirement on grain structure:

1. Substantial funding and extensive development time must be expended to perfect and integrate hardware for the interdraw anneal options;
2. The material cost savings and thruput gains expected from the incorporation of an interdraw anneal do not appear to be overly impressive.

Therefore, given no grain structure requirement to satisfy, it is recommended that no additional funding be committed to interdraw annealing for the 5.56mm system.

In contrast, the following comments apply when grain structure must be controlled:

1. Severe time and cost penalties will be encountered in assemblying hardware for the three draw, two anneal option at Lake City;

2. The two draw, one interdraw anneal option should be capable of controlling grain structure while maintaining reasonable thruput rates.

Therefore, given the necessity of meeting a grain structure requirement, it is recommended that the present case submodule be modified to incorporate an interdraw anneal.

The safest course of action would be to proceed with fabrication of the case submodule in its current configuration until positive indications were received that modification of the 5.56mm cartridge TDP to include a grain structure requirement is imminent. At that time, the investment in interdraw anneal hardware could more easily be justified on the basis of confirmed need rather than speculation.

Lastly, none of these conclusions apply to the manufacture of 7.62mm cases. While the NATO grain structure requirement for 7.62 makes it imperative to add at least one interdraw anneal to the process, 7.62 case manufacturing has not been addressed in this study and no claims in that area are implied or intended.

Table 1. Principal Findings and Recommendations

SUBJECT

PRINCIPAL FINDING AND RECOMMENDATION

Best Alternative:
    Without Including
    Grain Structure

Two Draw without Interdraw Anneal

    Including Grain
    Structure

Two Draw with Interdraw Anneal and
Pinch Trim

Blade and End Mill
Trim vs. Pinch Trim

Pinch Trim should work even for a system
containing one or more interdraw annealers

Induction Annealing

Convert voltage regulators to current
regulators; also environmental control
in the coil vicinity should be instituted.

Novel American and
Foreign Weapon Systems

Strong likelihood exists that novel American and Foreign weapons systems will
experience difficulty with cartridges
produced by Option 1., similar to
difficulties documented on the Israeli
Galil rifle with commercial ammunition.
Most probable estimate on time of greatest cartridge failure rate is April -
September, 1977, during NATO future
rifle tests in Europe.

METALLURGICAL EVALUATION

Option 1

Relevant operations performed by the G+W case submodule are now discussed to clarify their impact on cartridge case metallurgy. Specific process alterations appropriate to options two and three will then be evaluated in order to provide a feasible basis for predicting success probabilities and scrap rates.

Table 2 displays the metal forming operations designed into the case submodule. Two draws are performed sequentially without the inclusion of an interdraw anneal. The recommendation for removing the interdraw anneal originated with research findings reported by the case submodule vendor: "The purpose of the initial phase of the (case submodule feasibility) study was to optimize the present drawing process consisting of three draws, a trim, and intermediate cleaning and annealing operations, by eliminating as many steps as possible... A successful two draw operation was demonstrated; the need for an intermediate anneal was eliminated."[1] Further, a pinch trim operation was incorporated on the second draw, in contrast to the more conventional blade type trim found on established case manufacturing lines. Reasoning given for incorporating the pinch trim is found on page 25 of the same feasibility study: "Pinch trimming during the final draw eliminates not only the need of an additional piece of equipment (i.e., a blade trim), but also eliminates the need for an intermediate anneal". Independent government studies verified the conviction that removal of the interdraw anneal would not detrimentally affect the process: "The two step draw operation without an intermediate anneal developed by Gulf + Western Company has fully demonstrated the feasibility of this production method".[2]

---

[1]G.H. Reinemuth and M. J. Connor, Feasibility Study, High Speed Manufacture of 5.56mm Cartridge Cases, Gulf + Western Research and Development Division, Swarthmore, PA General Revision, 1969

[2]Capt. G.A. Gegel, Review of Status on New Generation Small Caliber Ammunition Production Equipment: Production Equipment Concept, USA Munitions Command, Dover, N. J. 1969

Table 2. Option 1 Process Definition

```
DRAW
DRAW AND PINCH TRIM
HEAD
HEAD TURN
PIERCE
BODY ANNEAL
1ST TAPER
2ND TAPER
TRIM
STRESS AND MOUTH ANNEAL
```

Pinch trimming is performed by the second draw tool primarily to increase submodule efficiency and reduce operating costs through removal of the blade trim press. However, several process difficulties arise with pinch trimming:

1. Small burrs can be observed on both the inner and outer case mouth surfaces, burrs that must be removed in later operations;

2. Case mouths demonstrate a tendency to tear and this defect cannot always be removed.

The next three sequential case forming operations are heading, head turn, and pierce. These operations have acted as the source of many RAM and process related problems in the past but that factor alone would not have warranted their inclusion in this analysis. However, the type of brass cup chosen for input material in each of the options can either aggravate or diminish the severity of such problems. Since throughput capability and scrap rate projections tangibly affect system economics, a description of the three operations is now presented.

In connection with heading, the following process problems have been observed:

1. Round heads
2. Rills in the primer pockets
3. Primer pocket diameter

Government process experts consider that each of these problems can be corrected by substituting a new cup for the one currently used in building 189, thicker in the base by approximately .004". However, a problem exists in connection with obtaining a supplier for these cups since only one United States' manufacturer supplies cups for SCAMP equipment. That manufacturer expressed reservations about producing the new cup and meeting the required dimensional tolerances. This information

is offered as background with further details of the projected economic trade-offs presented later in this study.

As indicated in Table 2, the cartridge cup is drawn, headed and head turned without relieving the accompanying internal stresses by means of annealing. The very next process operation, therefore, is an induction body anneal performed on cases held in a nonrotating, captive oriented manner. Much effort has been directed toward improving the body anneal system during the past year since its success strongly influences final cartridge case compliance with the 5.56mm TDP. A summary of recent annealing research is now presented along with suggested guidelines for further developmental effort. Doberstein and McElwee have asserted the need for current regulation as opposed to voltage regulation in the induction anneal system.[3] They contend that the voltage regulator is incapable of demonstrating rapid responsiveness to varying inductive loads caused by case feed line voids. This contention is based upon a thermodynamic equation (Eqn 1) relating incident electromagnetic energy to temperature changes in annealed cases.

$$\Delta T = \frac{R}{MC} \quad I^2 \, t \qquad\qquad (1)$$

Where ΔT = Temperature change over a localized area of the case.

I = Coil Current
R = Eddy Current resistance of brass cases
t = Time interval that the case is located within the flux field
M = Localized Mass of the case
C = Heat capacity of brass

Several important conclusions follow from equation 1:

1. Energy induced in cases depends upon coil current, not voltage. Therefore, a system designed to regulate voltage will demonstrate current fluctuations in response to changing inductive loads. Such fluctuations are observed daily on each anneal unit found on the case submodule in building 189.

2. Coil current fluctuations tend to increase the variance in localized hardness between adjoining cases by depositing either more or less energy than desired at a given point. Numerically, an 8.5% temperature fluctuation has been observed to result from varying coil current and at a nominal anneal temperature of 1100°F, that fluctuation amounts to 94°F. (Appendix A describes mathematical details of the relationship between fluctuations in coil current and anneal temperature). Doberstein and McElwee substantiated their theoretical approach with infrared heat measurements of sequential, annealed cases for which "fluctuations of 100°F to 160°F (were observed) when one void was introduced in the case flow".[3]

---

[3]C. Doberstein and C. McElwee, Anneal Problems: Case Submodule, Frankford Arsenal, Phila., Pa. 1975

Two other useful observations are now abstracted from that study because of their relevance to induction annealing on the case submodule and usefulness to system planners:

A. A change in machine speed of 1 RPM (out of 41 RPM) caused a 40°F temperature change;

B. A 60°F change in temperature can be induced by placing a fan that blows at 45° to the case plane, 20 feet away.

Each of the other anneal units in the case submodule react similarly to the body anneal although the criticality of their power settings are lower due to decreased energy requirements that must be deposited over the case. Coil current regulation is capable of reducing the magnitude of fluctuations due to the appearance of voids. This claim has been substantiated in tests conducted during January, 1976, with a current regulator that provides 1% temperature regulation in the presence of a single feedline void. At the nominal operating temperature of 1100°F, the fluctuation amounts to 11°F, quite an improvement over the 94°F figure listed for a voltage regulated system. (See Appendix A for details). Further benefit would derive from linking the desired current level with machine RPM so that moderate changes in speed could automatically be temperature compensated in the annealers. Finally, better environmental control over wind gusts and temperatures in the vicinity of the annealing coils is easily achieved by shielding the coils themselves. Such a procedure can provide immediate tangible rewards to attaining better uniformity in hardness gradient patterns at a relatively modest cost expenditure.

Doberstein, McElwee, and Roznowski have confirmed the fact that hardness gradients produced with a longer (47"), single turn anneal coil are well within the limits specified by the TDP.[4] This is a gratifying result and one that bears repeated demonstration in future production on the prototype submodule.

The importance of grain structure has basically been overlooked in previous 5.56mm production since that attribute is not presently specified in the TDP. Appendix B offers abstracts from a technical report published in Hebrew by the Israeli government in which several lots of 5.56mm ammunition were observed to possess a high incidence of case rupture when fired in the Galil rifle system.[5] (For more information on the Galil weapon, consult reference 6). The report concluded that even though the Winchester ammunition

[4]C. Doberstein, C. McElwee, and M. Roznowski, Case Submodule Anneal Testing and Evaluation, Frankford Arsenal, Phila., PA 1976

[5]K. Bar Avi, 5.56MM Brass Cased Ammunition- Metallurgical Research (Clarification of the Causes of Case Failure During Test Firing) Israel Military Industries, Technical Report #10404-12/2-C, Tel Aviv, Israel, 1975

[6]J. Weller, "The Galil Rifle - An Israeli Weapon System", National Defense Magazine, 1973

satisfied the TDP with respect to hardness gradient, it lacked strength to withstand ejection from the chamber while propellant gas levels were still relatively high. The principal cause of case rupture was traced to elongated grains. SCAMP ammunition demonstrates very similar elongated grain structure to the cartridge cases examined in this test. Since the M-16 weapon operates differently than the Galil, case rupture strictly attributable to grain structure has not yet been observed. The lesson, however, is clear: Compatibility problems may arise in future 5.56mm rifle systems attempting to fire SCAMP cartridges unless attention is paid to grain structure.

The remaining case manufacturing operations consist of tapers, finish trim, and mouth/stress anneals. These particular operations are not relevant to the risk analysis since no modification of them is contemplated between each of the three options being considered in this study.

Option 2

Table 3 displays the sequence of metal forming operations comprising Option Two. The essential differences between this approach and option one consist of an interdraw anneal and one set of respacers to allow components to enter and depart the new anneal system. Although the same cup can be used with this option as is currently fed into the case submodule, a thicker based cup is recommended to control scrap costs, especially those incurred during head forming. As reported previously, difficulties may arise in this connection because the sole source cup supplier for building 189 has not expressed eagerness to manufacture the thicker based cup.

The major process modification related to option two is insertion of an interdraw anneal unit between the first and second draws. Similar temperature fluctuation difficulties will occur due to variable anneal coil current unless a successful form of current regulation is perfected. However, the severity of these problems should be reduced over those presently encountered because hardening occurs more as a result of cold work in the draws. In this respect, cold work can more easily be controlled than can the annealing system so that less emphasis may be placed on the annealers themselves.

As mentioned in the introduction, there is a good possibility that some form of a grain structure requirement will be imposed on 5.56mm cartridges within the next few years by virtue of the NATO field test. Recent research indicates that an interdraw anneal coil whose dimensions allow at least six seconds for recrystallization and grain growth to occur in the case wall should provide the necessary flexibility to avoid grain structure problems of the type experienced with the Galil weapon.

In early February, Lake City AAP conducted an independent assessment of the need for an interdraw anneal. Several hundred first draw SCAMP cases were annealed in a gas-fired furnace and processed in the current generation production line at building #4 where they received all of the

10

Table 3.   Option 2 Process Definition

```
        DRAW
    *   ANNEAL
        DRAW
        TRIM
        HEAD
        HEAD TURN
        PIERCE
        BODY ANNEAL
        1ST TAPER
        2ND TAPER
        TRIM
        STRESS AND MOUTH ANNEAL


    *   ADDED OPERATION
```

remaining metal forming operations. These cases were compared functionally and metallurgically against a control lot of Lake City cases as well as SCAMP cases that lacked the interdraw anneal. The metallurgical examination revealed "evidence of severe stress lines in the cases which were not annealed before final draw" while "no significant grain structure difference was noted between the control cases and SCAMP cases which were subjected to an interdraw anneal".[7] Although these results strongly support the need for an interdraw anneal, the validity of that conclusion is questionable since it is founded upon data derived from conventional rather that modernized manufacturing equipment. The results, are, however, in step with current metallurgical knowledge of cartridge case manufacturing processes.

After interdraw anneal, cases proceed to second draw. Prior to performing this risk analysis, it was assumed that the interdraw anneal would soften the cup mouth to such a great extent that pinch trimming would no longer be feasible. The assumption of pinch trim failure due to softer case mouths was tested on 5 February at Twin Cities by selecting 70 first draw cases, annealing them in a conventional gas fired furnace and then passing them through the second draw/pinch trim simulator. No failures in trimming were found and no characteristics were observed to vary greatly from those typically observed without the interdraw anneal unit. While this is an encouraging result, certain limitations must qualify the applicability of this research finding. First, the simulator

[7]J. Covey, Evaluation of Cases Manufactured at Twin Cities Army Ammunition Plant on Gulf + Western Equipment, Remington Arms Company, Inc., Lake City Army Ammunition Plant, Independence, Missouri, 1976

FAILURE RATE OF VARIOUS TRIM
OPERATIONS VS. SUBMODULE RPM

FIGURE I
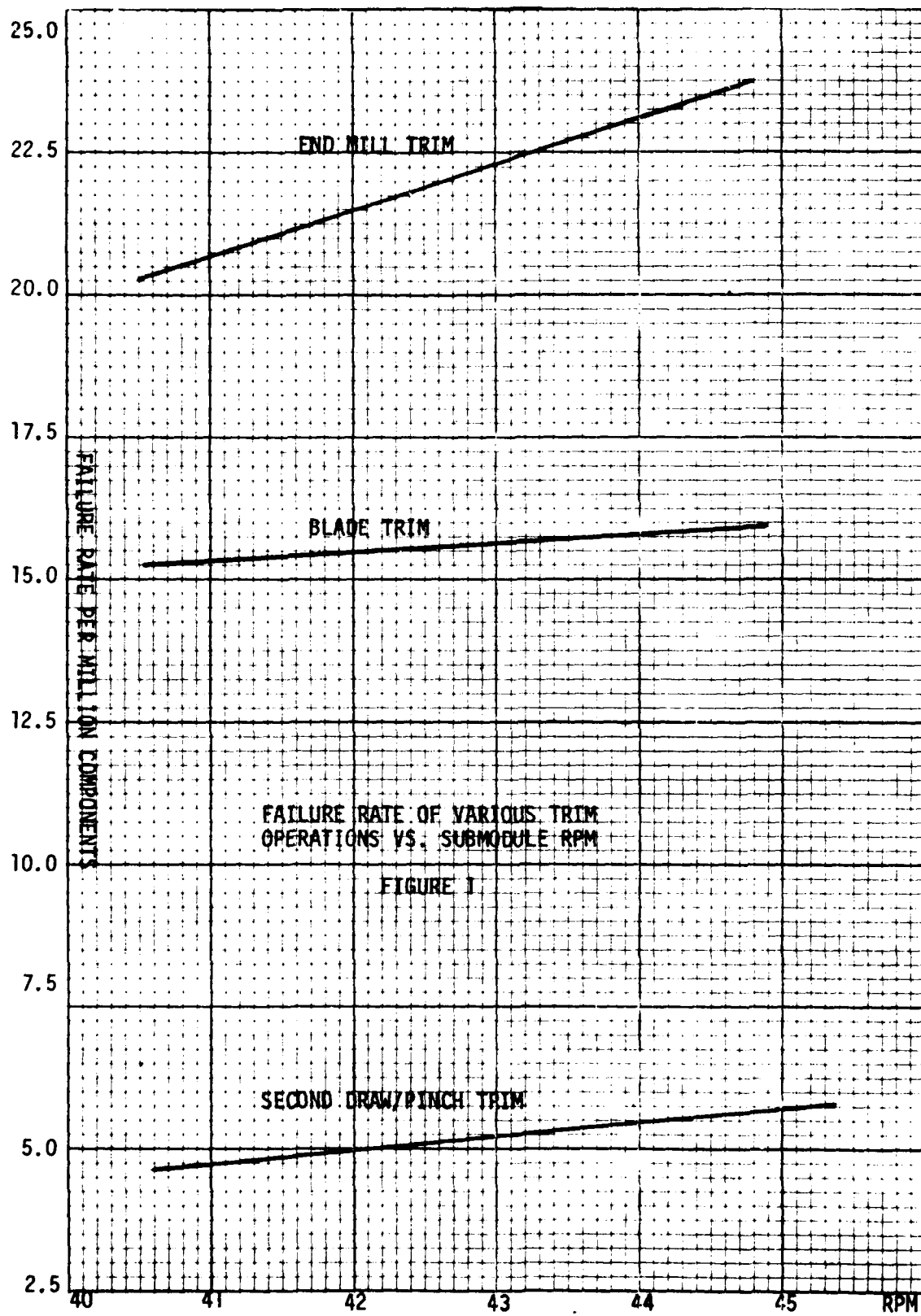
is a hydraulically operated device while the actual second draw press is mechanically operated. The simulator does not provide a completely accurate representation of the second draw press. Also, the experiment was limited to testing feasibility of the pinch trim operation itself and did not attempt to determine whether the scrap rate of these few tested pieces was equivalent, superior, or inferior to that observed on finished cases produced under option one.

Alternatives to pinch trimming include an end-mill operation similar to the case submodule final trim, and the bullet submodule blade trim. The SCAMP throughput and reliability data base was examined to reveal operating traits that might distinguish each alternative. Figure 1 illustrates the failure rates observed for each alternative between 1 October 1975 and 4 February 1976 at speeds of 41 and 44 RPM for the case submodule, 40 and 45 RPM for the bullet. It is immediately apparent that the pinch trim demonstrates superior reliability in contrast to either blade or end mill trimming. Consider also that the pinch trim data are biased since they include failures attributable to the second draw operation (no distinction was made between failures of the second draw tool and failures of the pinch trim while the data were being gathered). Thus, the actual pinch trim failure rate is lower than that presented in the graph. The repair time for replacing failed trim tools is approximately equal for each type, hence that characteristic is not useful for distinguishing among the alternatives.

Aside from scrap and tool reliability, economics must be considered in selecting the optimal trim alternative. Lengthy and costly development programs have been proposed to integrate the end-mill or blade trim presses into the follow-on Gulf + Western Case Submodule Systems. Therefore, based upon the best data currently available, it appears that the Government would incur lowest risk and derive maximum benefit by selecting the pinch trim option.

Option 3

Table 4 displays the sequence of operations employed to produce cartridge cases according to Option three. The principal differences between it and option one include two interdraw annealers, two sets of respacers and an additional draw press. Brass cups utilized by this alternative are standard three draw cups currently manufactured in mass quantities for use in Building #4 at Lake City. No procurement difficulties or cost premiums affect the supply of these cups since several manufacturers are capable and willing to produce them.

The process begins with three serial draws interspersed by two induction anneal units, in which pinch trimming now occurs on the third draw. If Option three is selected for implementation, it is recommended

that the pinch trim be maintained rather than resorting to an end-mill or blade trim by virtue of the arguments already presented in Option two.

The existing batch process for manufacturing 5.56mm ammunition is a three draw-two interdraw anneal process. Therefore, very few difficulties would be expected in achieving any present or anticpated hardness gradient and grain structure requirements. This option offers the maximum flexibility of any of the alternatives to control the process by apportioning cold work between the draws and reducing stress via two interdraw anneals as well as a body anneal. Severity of problems arising from coil current fluctuations is further reduced because lower power levels are demanded from each coil and deficiencies arising from surge currents on one of the anneal units has several possibilities for undergoing correction. As stated for Option two, physical dimensions for each anneal coil should be large enough to allow at least six seconds for cup wall grain recrystallization and grain growth to approximately .020 - .035mm.

All other process operations are equivalent to those described in the first option.

Table 4. Option 3 Process Definition

```
0   DRAW
0   ANNEAL
    DRAW
0   ANNEAL
    DRAW
    TRIM
    HEAD
    HEAD TURN
    PIERCE
    BODY ANNEAL
    1ST TAPER
    2ND TAPER
    TRIM
    STRESS AND MOUTH ANNEAL


0   ADDED OPERATIONS
```

14

RAM ANALYSIS

Reliability/Maintainability (RAM) and thruput predictions for the various options are now derived. Data for the analysis were obtained during the manufacture of 5.7 million cases at Twin Cities during October, 1975. Table 5 displays RAM data observed at the constant operating speed of 41 RPM. Caution should be observed in extending the RAM results beyond several RPM from that figure since failure rates are known to be speed dependent.[8] Failure models are sub-divided into the usual categories of serial and station events: Station failures affect production on only one particular station while serial failures cause the entire submodule to halt operation prior to performing repairs. In terms of failure rates alone, predominant difficulties are encountered in the head turn, final trim, and vent areas. These difficulties closely parallel the failure categories responsible for greatest machine downtime, i.e., head turn, trim, and heading.

Table 6 presents cumulative summaries of the various failure rates and chargeable downtimes, as well as run times, availability, parts produced, and thruput rate.

One very glaring aspect of Table 5 is the excessive downtime attributable to head turn tool failure. This problem is primarily aggravated by the high incidence of failure on that tool. If a major tool redesign were undertaken to reduce the incidence of failure from 81 to 20 failures per million cases produced, the long term average thruput rate would increase by 15.67% or 89 parts per minute without changing machine RPM, as illustrated in Table 7. Therefore, investments in improved head turn tooling should rank high on the list of management priorities for increasing case submodule productivity.

Numerical estimates of failure rate, chargeable downtime, and parts produced were suitably modified to accomodate the interdraw anneal option presented in Table 8. Essentially, the respacer failure rate should increase slightly while those for the second draw and all operations subsequent to the header should decrease. Chargeable downtime has accordingly been scaled by linking it to the predicted failure rate on a percentage basis. Table 9 presents cumulative RAM and thruput rate summaries analogous to those found in Table 6. It has been assumed that:

1. The sum of run plus downtime will be held to 10080 minutes so that an X minute decrease in the downtime results in an X minute increase in the run time

2. Submodule RPM rate is constant for each option

---

[8]M. M. Roffman, SCAMP Operating Strategies: Results of Speed Variation Tests, Frankford Arsenal, Phila., PA 1976

A comparison of Tables 6 and 9 reveals that the interdraw anneal would cause an increase in run time and availability, thereby resulting in the production of more parts at a higher thruput rate. Quantitatively, a long term average gain of 5.6% or 32 parts per minute thruput can be anticipated by incorporating the interdraw anneal and its peripheral equipment.

Additional equipment comprising option three should affect the RAM and thruput characteristics in a manner approximated by Tables 10 and 11. All of the numerical estimates presented here were derived in a manner similar to that applied in option two with the average long term thruput gain over that currently demonstrated by the Case Submodule being 5.3% or 30 parts per minute.

Table 5. Case Submodule Ram Data

SERIAL FAILURE MODES	FAILURE RATE PER MILLION	MEAN PARTS BETWEEN FAILURE	AVERAGE UNIT REPAIR TIME (MINUTES)	TOTAL CHARGEABLE DOWNTIME (MINUTES)
CHAINS	1.76	568182	2.93	30
RESPACERS	1.41	709220	14.90	121
OTHER	1.41	709220	29.90	242
STATION FAILURE MODES				
CUP FEEDER JAMS	10.36	96525	1.47	88
FIRST DRAW	1.41	709220	5.86	48
SECOND DRAW	3.16	316456	5.86	107
HEADING	17.92	55804	2.93	301
HEAD TURN	81.34	12294	2.93	1368
FIRST TAPER	5.97	167504	2.93	101
SECOND TAPER	15.64	63939	2.93	263
FINAL TRIM	20.91	47824	5.86	703
VENT	20.73	48239	1.47	175

Table 6. Case Submodule Cumulative Summary of RAM and Thruput Rates for October 1975

SERIAL FAILURE RATE PER MILLION	4.58
TOTAL SERIAL DOWNTIME	393 MINUTES
STATION FAILURE RATE PER MILLION	177.44
TOTAL STATION DOWNTIME	3154 MINUTES
RUN TIME	6533 MINUTES
DOWNTIME	3547 MINUTES
RUN + DOWNTIME	10080 MINUTES
AVAILABILITY	64.81%
PARTS PRODUCED	5731734
RUN RATE @ 41 RPM	876 PARTS/MINUTE
THROUGHPUT RATE @ 41 RPM	568 PARTS/MINUTE

Table 7. Case Submodule RAM and Thruput Summary Given A Head Turn Failure Rate of 20 Per Million

SERIAL FAILURE RATE PER MILLION	4.58	
TOTAL SERIAL DOWNTIME	393	MINUTES
STATION FAILURE RATE PER MILLION	116.1	
TOTAL STATION DOWNTIME	2122	MINUTES
RUN TIME	7565	MINUTES
DOWNTIME	2515	MINUTES
RUN AND DOWNTIME	10,080	MINUTES
AVAILABILITY	75.05%	
PARTS PRODUCED	6,626,940	
RUN RATE @ 41 RPM	876	PARTS/MINUTE
THRUPUT RATE @ 41 RPM	657	PARTS/MINUTE

19

Table 8.   Predicted Reliability and Maintenance Data for Option 2

SERIAL FAILURE MODES	FAILURE RATE PER MILLION	MEAN PARTS BETWEEN FAILURE	AVERAGE UNIT REPAIR TIME (MINUTES)	TOTAL CHARGEABLE DOWNTIME (MINUTES)
CHAINS	1.76	568,182	2.93	31
RESPACERS	2.50	400,000	14.90	225
OTHER	1.41	709,000	29.90	255
STATION FAILURE MODES				
CUP FEEDER JAMS	10.36	96,525	1.47	92
FIRST DRAW	1.41	709,220	5.86	50
SECOND DRAW	2.0	500,000	5.86	71
HEADING	12.00	83,333	2.93	212
HEAD TURN	70.00	14,286	2.93	1239
FIRST TAPER	5.50	181,818	2.93	97
SECOND TAPER	10.00	100,000	2.93	177
FINAL TRIM	17.00	58,823	5.86	602
VENT	15.00	66,667	1.47	133

Table 9. Predicted Cumulative Summary of RAM and Thruput Rates for Option 2

SERIAL FAILURE RATE PER MILLION	5.67	
TOTAL SERIAL DOWNTIME	511	MINUTES
STATION FAILURE RATE PER MILLION	143.27	
TOTAL STATION DOWNTIME	2673	MINUTES
RUN TIME	6896	MINUTES
DOWNTIME	3184	MINUTES
RUN AND DOWNTIME	10080	MINUTES
AVAILABILITY	68.41%	
PARTS PRODUCED	6,040,896	
RUN RATE @ 41 RPM	876	PARTS/MINUTE
THRUPUT RATE @ 41 RPM	599	PARTS/MINUTE

21

Table 10. Predicted Reliability and Maintenance Data for Option 3

	FAILURE RATE PER MILLION	MEAN PARTS BETWEEN FAILURE	AVERAGE UNIT REPAIR TIME (MINUTES)	TOTAL CHARGEABLE DOWNTIME (MINUTES)
SERIAL FAILURE MODES				
CHAINS	2.00	500,000	2.93	35
RESPACERS	3.50	285,714	14.90	314
OTHER	1.41	709,220	29.90	254
STATION FAILURE MODES				
CUP FEEDER JAMS	10.00	100,000	1.47	89
FIRST DRAW	.50	2,000,000	5.86	18
SECOND DRAW	1.0	1,000,000	5.86	36
THIRD DRAW	2.0	500,000	5.86	71
HEADING	8.00	125,000	2.93	141
HEAD TURN	70.00	14,286	2.93	1236
FIRST TAPER	5.50	181,818	2.93	97
SECOND TAPER	10.00	100,000	2.93	177
FINAL TRIM	17.00	58,823	5.86	600
VENT	15.00	66,667	1.47	132

Table 11. Predicted Cumulative Summary of RAM and Thruput Rates for Option 3

SERIAL FAILURE RATE PER MILLION	6.91
TOTAL SERIAL DOWNTIME	603 MINUTES
STATION FAILURE RATE PER MILLION	139.00
TOTAL STATION DOWNTIME	2597 MINUTES
RUN TIME	6880 MINUTES
DOWNTIME	3200 MINUTES
RUN AND DOWNTIME	10080 MINUTES
AVAILABILITY	68.25%
PARTS PRODUCED	6,026,880
RUN RATE @ 41 RPM	876 PARTS/MINUTE
THRUPUT RATE @ 41 RPM	598 PARTS/MINUTE

23

SCRAP ANALYSIS

Table 12 displays the percentages of scrap, by category, observed for option one during the last three weeks of January 1976. These data are the most recent and presumably, the best available at the time this study was performed. The figure of 4.19% for cup scrap includes components that are purged each time the submodule stops for repair work as well as parts that do not successfully transfer through each of the process operations. Thus, the more frequently the submodule is stopped, the greater is the percentage of cup scrap. Round heads and head stamp deficiencies are characteristics related to cup geometry while head burrs, head thickness, head diameter, and extractor groove defects arise in the heading and head turn operations. Buckles and mouth splits are attributable to pinch trim deficiencies while head to shoulder and overall length are problems that stem from deficiencies in the body anneal system. Finally, neck scratches are produced both by improper characteristics in the taper die lubrication and by metallic particles accumulating in the taper dies themselves.

Data for options two and three are categorical estimates of scrap assuming the use of a pinch time. The only categories that change as a result of the new interdraw anneal(s) and change in cup dimensions are neck wall variation and round heads. Therefore, the cumulative scrap totals for each option tend to remain relatively close together.

Table 12.   Scrap Analysis

SCRAP CATEGORY	OPTION 1	OPTION 2	OPTION 3
CUP	4.19%	4.19%	4.19%
VISUAL			
ROUND HEADS	2.18%	0.0%	0.0%
BUCKLES	.38%	.38%	.38%
MOUTH	.26%	.26%	.26%
HEAD BURRS	10.45%	10.45%	10.45%
HEAD STAMP	.84%	.84%	.84%
NECK SCRATCH	.98%	.98%	.98%
DIMENSIONAL			
HEAD THICKNESS	.78 %	.78%	.78%
HEAD DIAMETER	1.47%	1.47%	1.47%
EXTRACTOR GROOVE	1.39%	1.39%	1.39%
HEAD TO SHOULDER	.21%	.21%	.21%
LENGTH	1.29%	1.29%	1.29%
NECK WALL VARIATION	2.90%	2.90%	2.90%
TOTAL	27.32%	23.74%	23.74%

ECONOMIC ANALYSIS

The economics of Case Submodule operation are now investigated using data derived from Remington Arms Company, Federal Cartridge Corporation, and various Governmental sources. Table 13 summarizes the projected material costs incurred in manufacturing 7.62 million acceptable cases per month based upon recent vendor price quotations for procurement of a large quantity of cups.

Table 14 presents a summary of the factors used to derive monthly labor costs for each option. Assumptions implicity here are threefold, namely,

1. The number of supervisors, maintenance, and inspection personnel required to run the submodule equal fourteen.

2. The average hourly wage of employees is $6.60;

3. The monthly production quota of acceptable cartridge cases is 7.62 million.

Table 15 utilizes the labor and materials data just described to compute the payback period for the additional equipment required to support each option. Relevant assumptions for this table include the following:

1. The monthly production quota of acceptable case is 7.62 million;

2. A ten percent discount factor;

3. Payback of savings begins the first month after the investment of funds in new equipment.

Since it is unlikely that options two and three would generate cost savings immediately after the investment of funds, assumption three basically imposes a lower limit on the discounted payback period. To clarify, the actual payback period should be greater than the value of 8.31 and 8.81 listed in Table 15.

Certain factors influence the discounted payback period more than others. In order to shed more light on this aspect of the problem, a sensitivity analysis has been performed on the input parameters to determine which are critical and which are not. Table 16 displays the variation in discounted payback period for option two as each of five specific parameters are perturbed from their mean values. The most sensitive factors in the table are cup cost and the weight per thousand cups. If the long term average cost of cups is higher than $.95 per pound, then option two must be eliminated from consideration because payback would not occur until well after the required ten year period.

Sensitivity factors for option three are presented in Table 17 analogous to those just discussed for option two. In this situation, payback period is still highly sensitive to cup cost and weight per thousand cups but the degree of sensitivity is slightly lower than that derived for option two primarily because of reduced material costs. For example, cup cost per pound can be allowed to increase by, at most, .87% from its quoted value of $.86 before the payback period exceeds ten years.

Table 13. Material Cost Analysis

	CUPS/LB	COST/LB	LBS/1000 CUPS	SCRAP	CUP COST 1000 CASES	CUP COST/ 7.62M CASES
OPTION 1	64.22	$.95	15.57	27.32%	$20.35	$155,078.74
OPTION 2	61.95	$.95	16.14	23.74%	$20.11	$153,209.30
OPTION 3	62.769	$.86	15.93	23.74%	$17.96	$136,890.21

Table 14. Labor Cost Analysis

OPTION	AVERAGE THRUPUT (PPM)	SCRAP RATE	QUALITY THRUPUT (PPM)	HOURS REQUIRED	LABOR COST
1	568	27.32%	413	308	$28,425.78
2	600	23.74%	458	277	$25,646.47
3	598	23.74%	456	279	$25,732.25

Table 15. Payback Analysis

OPTION	MONTHLY MATERIAL AND LABOR	MONTHLY SAVINGS	ADDITIONAL EQUIPMENT COST	UNDISCOUNTED PAYBACK PERIOD (YRS)	DISCOUNTED PAYBACK PERIOD (YRS)
1	$183554.60	$ 0	$ 0	0	0
2	$178855.84	$4,648.60	$ 350,000	6.27	9.84
3	$162622.46	$20,882.07	$1,500,000	5.99	9.10

Table 16. Sensitivity Analysis of Option 2

SENSITIVITY FACTOR	PERCENT CHANGE	PAYBACK PERIOD (YEARS)
CUP COST	+ .02% -5.00%	10.00 2.70
WEIGHT/1000 CUPS	+ .02% -5.00%	10.00 2.70
RELEVANT SCRAP RATE	+ .08% -5.00%	10.00 5.01
THRUPUT RATE	+5.00% - .17%	6.80 10.00
EQUIPMENT COST	+ 1.43% - 5.00%	10.00 9.04

30

Table 17. Sensitivity Analysis of Option 3

SENSITIVITY FACTOR	PERCENT CHANGE	PAYBACK PERIOD (YEARS)
CUP COST	+ .87% -5.00%	10.00 5.98
WEIGHT/1000 CUPS	+ .87% -5.00%	10.00 5.98
RELEVANT SCRAP RATE	+2.36% -5.00%	10.00 7.63
THRUPUT RATE	+5.00% -4.35%	8.31 10.00
EQUIPMENT COST	+6.00% -5.00%	10.00 8.39

BIBLIOGRAPHY

1. Channon, S. and Walker, H., "Recrystallization and Grain Growth in Alpha Brass", Thirty Fourth Annual Convention of the America Society for Metals, October 1952

2. Darby, William, Trip Report, MT Directorate, Frankford Arsenal, Phila., PA November 1975.

3. Gustad, Duane, Metallurgical Examination of LC and TC 5.56mm Cartridge Cases to Compare Hardness and Grain Structure, MT Directorate, Frankford Arsenal, Phila., PA, November 1975

REFERENCES

1. G. H. Reinemuth and M. J. Connor, Feasibility Study, High Speed Manufacture of 5.56mm Cartridge Cases, Gulf + Western Research and Development Division, Swarthmore, PA General Revision, 1969

2. Capt. G. A. Gegel, Review of Status on New Generation Small Caliber Ammunition Production Equipment: Production Equipment Concept, USA Munitions Command, Dover, N. J. 1969

3. C. Doberstein and C. McElwee, Anneal Problems: Case Submodule Frankford Arsenal, Phila., PA 1975

4. C. Doberstein, C. McElwee, and M. Roznowski, Case Submodule Anneal Testing and Evaluation, Frankford Arsenal, Phila., PA 1976

5. K. Bar Avi, 5.56MM Brass Cased Ammunition - Metallurgical Research (Clarification of the Causes of Case Failure During Test Firing), Israel Military Industries, Technical Report #10404-12/2-C, Tel Aviv, Israel, 1975

6. J. Weller, "The Galil Rifle - An Israeli Weapon System", National Defense Magazine, 1973, pp 142-145

7. J. Covey, Evaluation of Cases Manufactured at Twin Cities Army Ammunition Plant on Gulf + Western Equipment, Remington Arms Company, Inc., Lake City Army Ammuniton Plant, Independence, Missouri, 1976

8. M. M. Roffman, SCAMP Operating Strategies: Results of Speed Variation Tests, Frankford Arsenal, Phila., PA 1976

APPENDIX A

Coil current fluctuations can be related to temperature variations between adjoining cases in the following manner. By definition, power = I^2R so that a difference equation relating changes in power, ΔPower, to changes in current, ΔI, is simply Power = $2I(\Delta I)R$. The percent change in power with fluctuation in anneal current is given by

$$\frac{\Delta \text{ Power}}{\text{Power}} = \frac{2I(\Delta I) R}{I^2 R} = \frac{2(\Delta I)}{I}$$

However, the percent change in power is also equivalent to the ratio of observed power fluctuations to useful anneal power. Under the voltage regulated system, the total input power fluctuations of 1KW out of 12KW of useful anneal power are common observed. Therefore,

$$\frac{2(\Delta I)}{I} = 1/12$$

so that

$$\frac{\Delta I}{I} = .0417$$

Since temperature fluctuation is proportional to the square of current fluctuation, the expected percentage change in temperature is

$$100 \left\{ \left(1 + \frac{\Delta I}{I}\right)^2 - 1 \right\} = 8.5\%$$

which at a nominal temperature of 1100°F amounts to 93.5°F. A novel, current regluated system has recently been tested which is capable of providing 1% regulation for a single void in the feedline. Using this value as a tentative planning figure, the expected percentage change in temperature is also 1% which at the nominal operating temperature of 1100°F amounts to a fluctuation of 11oF.

APPENDIX B

ABSTRACTS FROM

ISRAEL MILITARY INDUSTRIES

TECHNICAL REPORT   10404-12/2-C

30 JUNE 1975

SUBJECT: 5.56MM BRASS CASED AMMUNITION-METALLURGICAL RESEARCH

(CLARIFICATION OF THE CAUSES OF CASE FAILURE DURING TEST FIRING)

K. BAR AVI
DIRECTOR OF METALLURGICAL SERVICES

TECHNICAL TRANSLATION:
DR. MARTIN M. ROFFMAN
FRANKFORD ARSENAL

Microscopic Data

The failure of Winchester cases during test firings in the Galil rifle always occurred at the same location in the wall, namely, 14-15MM from the rim, extending horizontally and circumferentially. There were no noticeable longitudinal defects or signs that attracted attention. The most obvious defect of drawing in a number of instances was the separation of the case body into two different sections (Figure 1). In other instances, the responsibility for rupture can be attributed to localized stretching that arose from inadequate annealing during manufacture (Figure 2-3). The location of failures is always associated with a place at which the force profile abruptly changes, generally at the junction between more massive and thinner portions of the wall.

Metallurgical Investigation of the Longitudinal Section

It isn't possible to predict where a rupture is likely to occur merely from a knowledge of the alloy composition and hardness limits involved without resorting to optical means to distinguish between otherwise equivalent cases. Therefore, structure in the vicinity of 6mm (.25") from the rim has been reviewed in order to emphasize any potential differences between the types. Figures 4 through 6 display the results of investigations on three series of Winchester cases while figures 7 through 10 illustrate the remaining four types for comparison. (Note: these are 75 power enlargements) In each instance, the amount of structural deformation is known and the estimated grain size is as indicated below (according to ASTM, E-9):

Winchester (all three series)	70-90
TCAAP	25
LCAAP	25
Belgium (FN)	15
Israel (IMI)	10

Figures 11 and 12 display relevant hardness gradient data observed on the first series of Winchester cases. Case dimensional measurements are printed in inches at the top of Figure 11 and millimeters at the bottom.
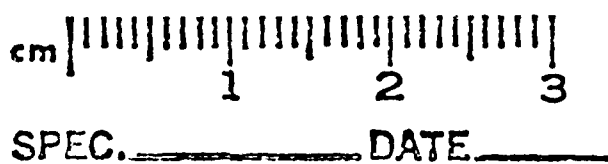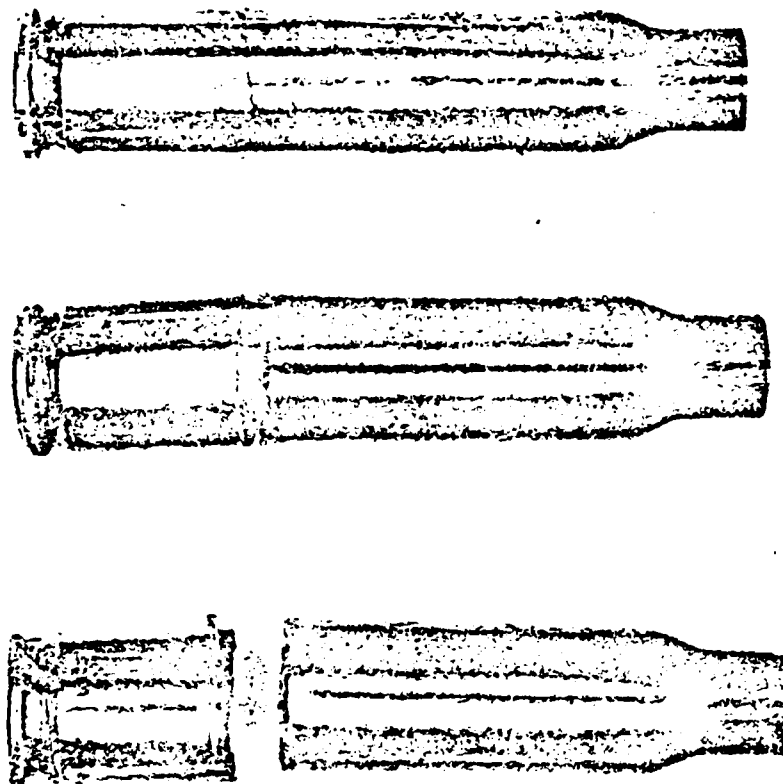
Figure 1. Winchester Cases That Split During Test Firings in the Galil Rifle. (The rupture is approximately 15mm (.65") from the case rim).

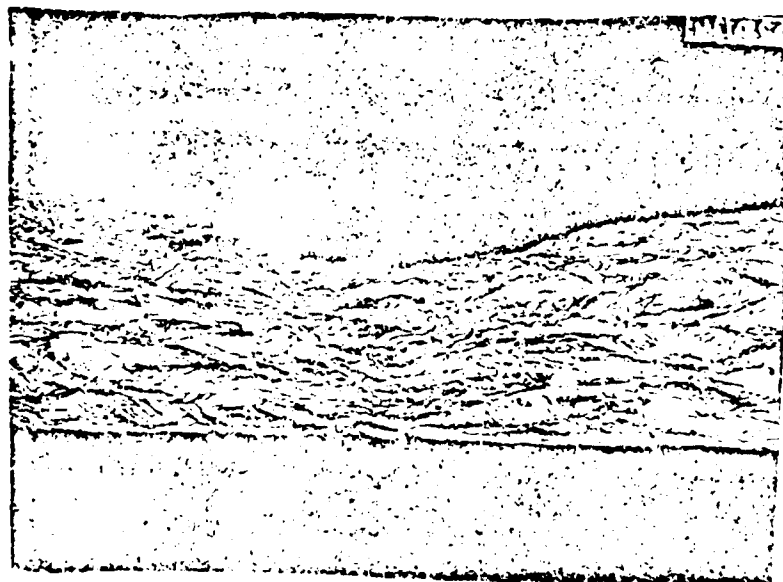Figure 2.   Winchester Case Fired from Galil Rifle.

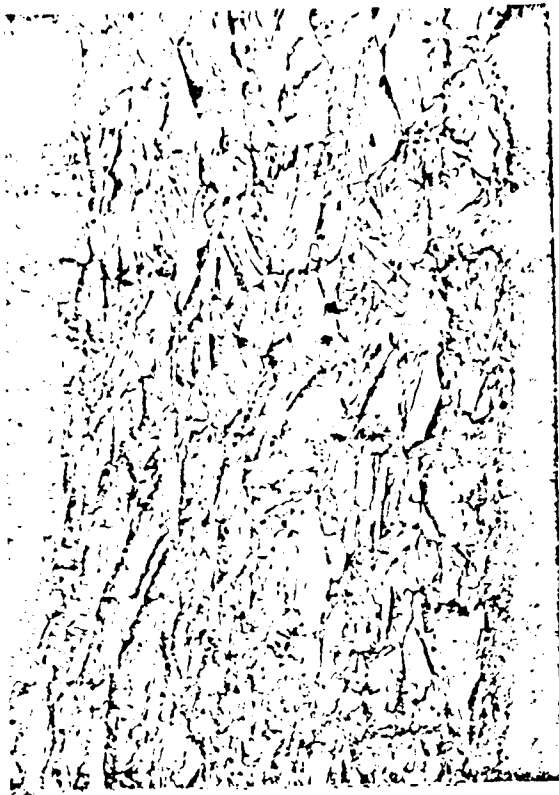Figure 3.   Formation of a Flaw in a Place Destined for Rupture

Figure 4

Figure 5

Figure 6

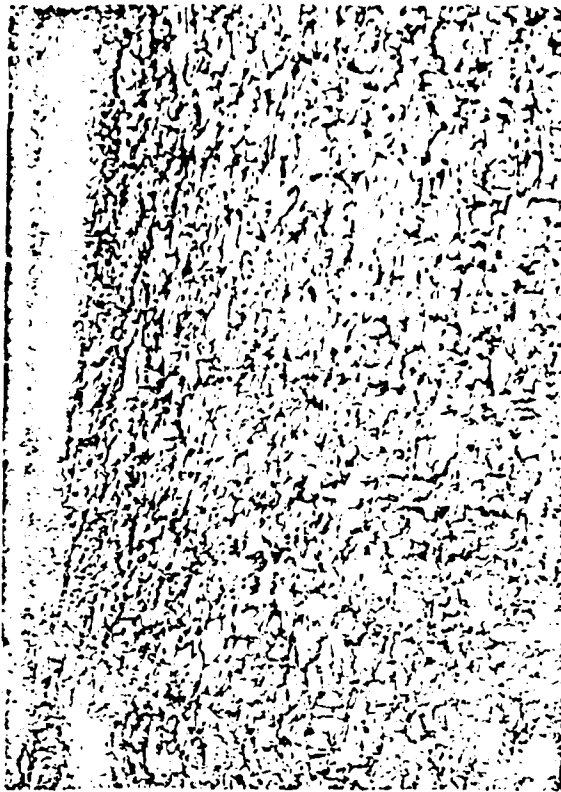Figures 4 - 6.   Cases Produced by Winchester

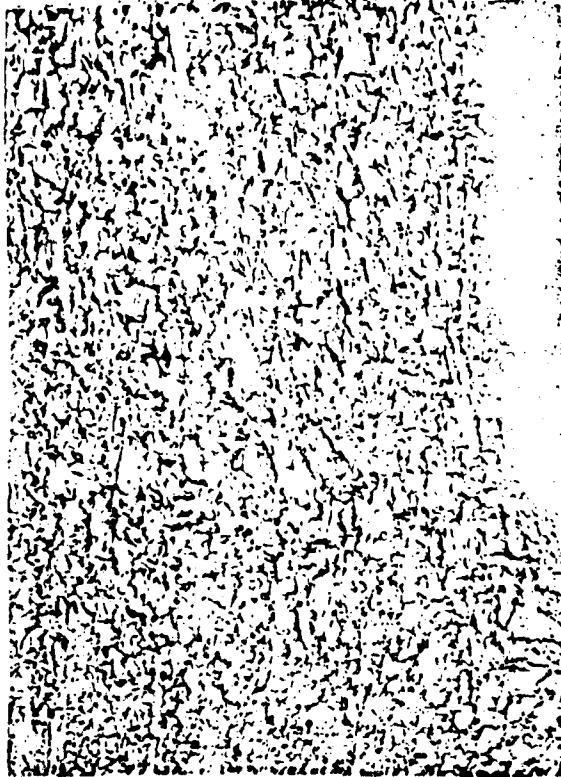Figure 7.   Cases Produced by Twin Cities.
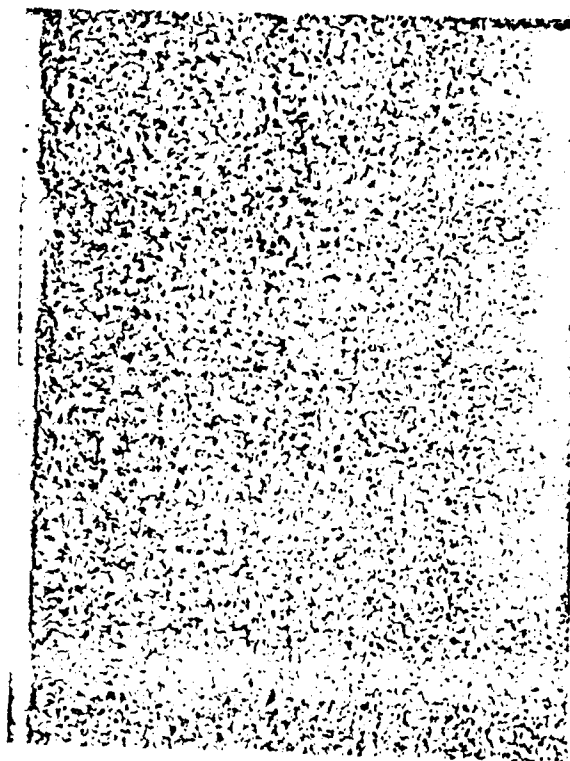

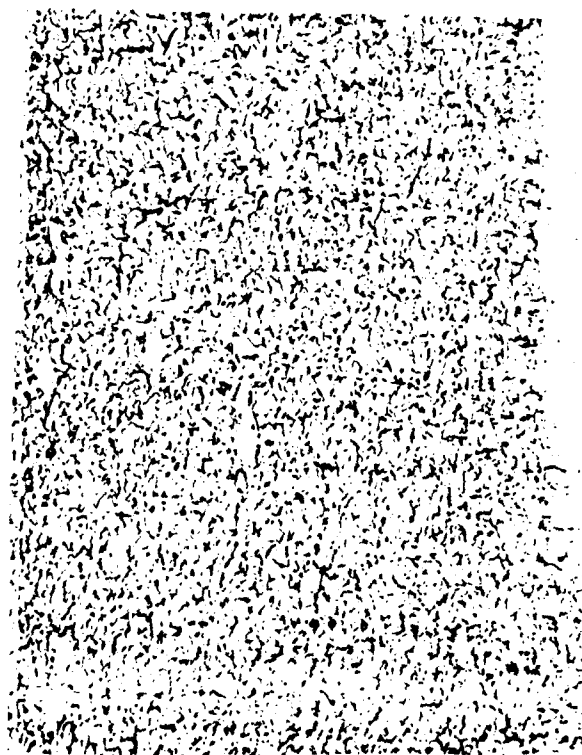Figure 8.   Cases Produced at Lake City.

Figure 9. Cases Produced in Israel.

Figure 10. Cases Produced in Belgium.

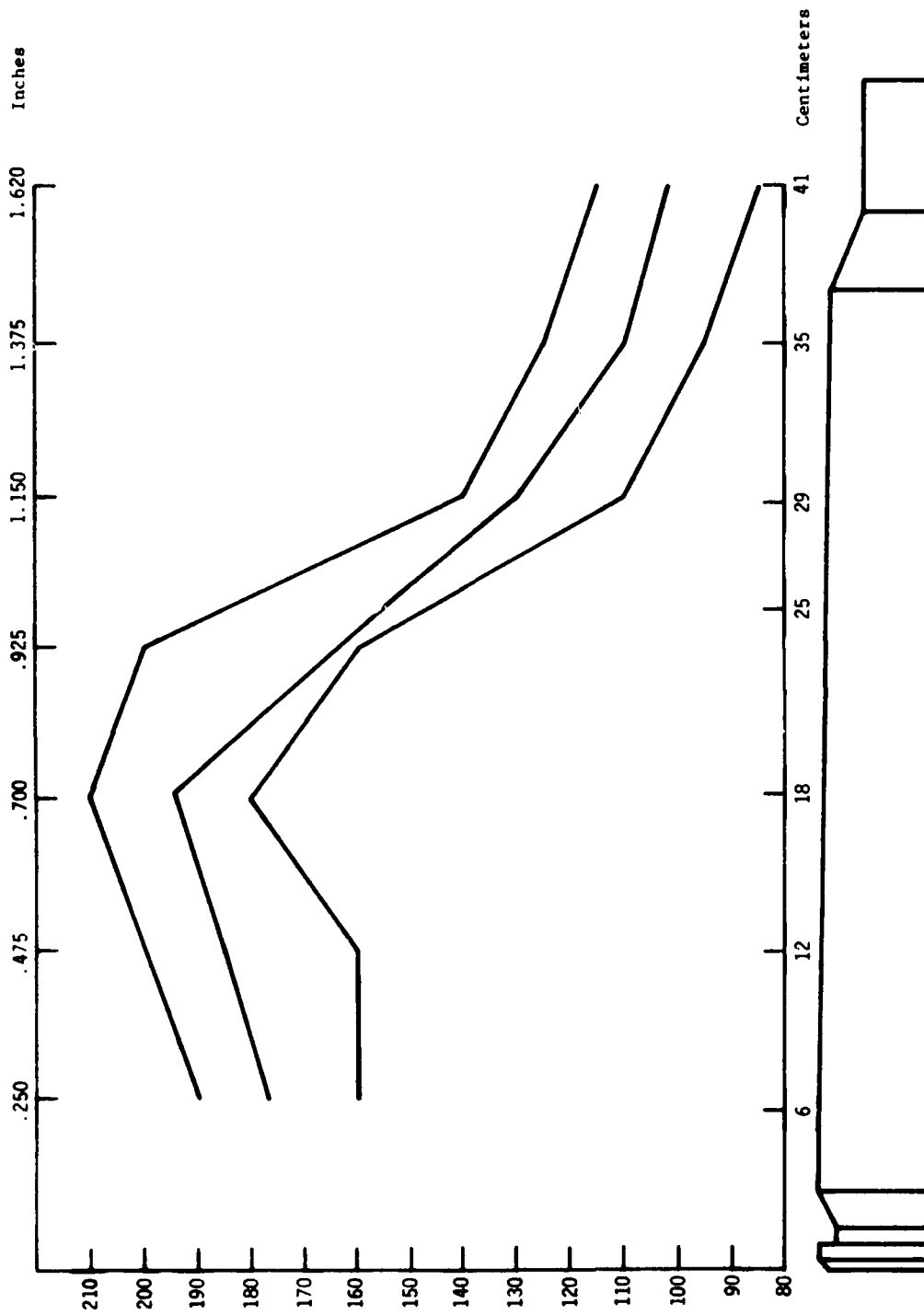Figure 11. Winchester Lot 1 (Average of 10 Readings)

41

6	12	18	25	29	35	41		
174	186	200	161	141	125	101		
174	165	186	151	135	114	101		
174	200	207	176	136	112	102		
169	184	194	143	117	108	97		
171	184	149	165	141	107	103		
176	169	194	152	128	101	110		
184	179	214	161	135	118	105		
174	187	191	152	128	102	97		
186	194	194	140	120	93	101		
179	204	207	152	129	121	102		
186	204	214	176	141	125	110	מכס.	max.
169	165	149	140	117	93	97	מינ.	min.
17	39	65	36	24	32	13	פיזור	spread
176	185	194	155	131	110	102	ממוצע	average
5.4	12.3	17.9	10.7	8.1	9.9	3.7	סטית הקן	std. dev.

Figure 12. Actual Readings

42

Conclusions

The goal of this research has been to clarify why, of all lots tested, only the combination of Winchester ammunition/Galil rifle produced misfires, ruptures and circumferential case wall stretching. Research findings point to the following chain of events:

Case wall rupture results from a coaxial shear stress that rips the wall asunder in a mechanism similar to static stretching of a tube under load. Our speculation is that the rupture occurs during retration of the bolt while propellant gas pressure in the bore is still relatively high.

The reduction in strength demonstrated by Winchester cases is not apparent from its hardness pattern. There is thus no possibility of predicting behavioral anomalies from a knowledge of hardness gradients alone.

As is well known, resistance of cartridge brass to drawing depends upon wall geometry (thickness). The reduction in strength is especially sensitive to profile or localized wall geometry variations. Of all the case lots surveyed, the Winchester lots were approximately 20% weaker when compared against cases derived from other sources. This variance is attributed mainly to differences in grain structure and size; the grain size found in Winchester case walls was much larger than that observed in all of the remaining lots sampled. Sources of (grain size) variance arise from the particular arrangement of process operations utilized in case manufacturing and these operations are not generally modified to satisfy individual customer's specifications. The Winchester cases are more likely to prove acceptable if the final annealing temperature is raised or its duration prolonged to levels comparable with those normally found at other manufacturing plants.

Therefore, in order to avoid the firing difficulties encountered in the Winchester/Galil case system, the following two courses of action may be taken, either separately or together:

a. Increase the resistance to wall rupture by modifying the ammunition production process.

b. Delay removal of the rifle bolt (change the rifle's timing) until propellant gas pressure inside the bore has diminished.

43

44