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SURVEY OF TECHNIQUES AND EQUIPMENT FOR HIGH-VOLUME, AUTOMATIC PRODUCTION OF NON-ELECTRIC DETONATORS

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13. ABSTRACT

As part of the overall program to modernize the government owned, company operated army ammunition loading and assembly plants, it is planned to develop fully automatic equipment to manufacture non-electric detonators at the rate of 1200 per minute. This survey of literature sources and industry was undertaken to discover techniques and equipment that may be applicable. Current production rate in the loading plants using semi-automatic equipment is about 32 per minute with one system used at Lake City AAP capable of about 300 per minute. Methodology and equipment is available to achieve the 1200 per minute rate after some development work in the areas of conditioning raw explosives, accurate metering of explosive charges, safe consolidation rates, automatic inspection for flaws in cups, automatic functioning tests (on-line), barricades to protect equipment and personnel and to avoid propagation of an explosion, and remotely controlled trouble shooting devices.

Specific recommendations include: (1) use design concepts based on continuous motion of individual, captive, oriented workpieces with endless, rigid transfer system and multiple tool modules (quick-change) on rotary turrets processing numerous workpieces simultaneously; (2) use mechanical presses with toggle or BLISS "Powerbar" linkage for consolidation, cup

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drawing, closure disc blanking and crimping; (3) use present gravity-fed, volumetric metering devices with improved accuracy, precision and safety; (4) develop optimum anti-propagation barricades for each operation, including dust control and reject disposal; (5) develop automatic flaw inspection, leakage and functioning test techniques and equipment; (6) develop remotely controlled binocular video equipped highly mobile devices for maintenance, repair and trouble shooting; (7) automate the "back-line" to meet high rate demands of the "front-line" safely; (8) start work on advancing technology immediately.

152

FOREWORD

The project was carried out under the direction of Mr. Stanley Adelman of Picatinny Arsenal's Manufacturing Technology Directorate. Mr. Hal Wanger actively participated as Technical Project Supervisor and his contributions to the final report are gratefully acknowledged.

The Gulf + Western Advanced Development and Engineering Center's Light Automated Manufacturing Systems Group managed by Mr. Mark J. Connor performed the work with Martin Friedland, J.C. Davis, and E.E. Hannum making the major contributions

SUMMARY

A survey of six months duration was made to find techniques and equipment for fully automatic, production, 100% inspection and packaging of non-electric detonators at a rate in excess of 1200 per minute.

The detonators must comply with the current drawings, specifications and functioning requirements.

It was found that the characteristics of the various priming mixes and high explosives used in detonators constitute the dominant constraints on choice of process techniques and manufacturing equipment. These characteristics include:

(1) sensitivity to initiating stimuli.

(2) Explosive power (output).

(3) Handling characteristics such as flow properties, dusting tendency, particle size, bulk density, uniformity, hygroscopicity, etc.

Because of the extreme sensitivity and tremendous destructive power of the detonator explosives, safety is the major consideration in all of the manufacturing processes. Detonation pressures are of the order of millions of pounds per square inch which no known structural material can withstand without damage. Thus, every conceivable precaution must be taken to avoid accidental detonations in the manufacturing processes and to minimize the extent of damage if a "blow" should occur.

The survey disclosed that techniques and equipment are available within the state-of-the-art to construct a fully automatic 1200 ppm detonator line except for several possible problem areas that will require some development work.

The major operations in detonator manufacture are listed in Part 4.5, pages 51-53, and the problem areas in Part 4.6, pages 54-55. These are discussed briefly in Part 3, Conclusions and Recommendations, and in more detail throughout the report.

Specific recommendations are as follows (justification arguments will be found in the text and supporting documents):

1. Use individual workpiece holders and move them continuously through the process line in captive, oriented manner using rigid continuous transfer devices. Mount multiple work stations (tool modules) on rotary turrets to simultaneously process numerous workpieces at one time. (See Appendix 2.)
2. Use mechanical presses with toggle linkage or Bliss "Powerbar" for consolidation stations for best control of ram speed. Also, satisfactory for cup drawing and blanking closure discs and crimping.
3. Automate the "back line" to meet the demands of the "front line" safely.
4. Use present gravity fed volumetric metering devices; Cargil scooper, Iowa dispenser, Chamlee dispenser, etc., but try to improve accuracy and precision and reduce cost and frequency of "blows".

5. Undertake a study to determine optimum consolidation rate, pressure, dwell, and tool clearances for each type of detonator explosive.

6. Develop optimum barricades for each type of tool module, process operation and inspection function; include dust control and reject disposal.

7. Completely automatic, on-line, 100% inspection is probably the most expensive feature of the envisioned modern production line and will require the most development effort. Automatic on-line functioning testers, leakage testers and flaw detectors must be developed although equipment for dimensional inspection is within the present state-of-the-art.

   "Flaws" include cracks, splits, thin spots, dents, perforations, burrs, scratches, exposed explosive, missing closure discs, missing lacquer seals, foreign materials, improper crimp, etc.

8. Remotely controlled maintenance, repair and trouble shooting equipment with binocular video and great mobility should be developed.

9. The efforts to advance technology in these problem areas should begin at once.

TABLE OF CONTENTS

TABLE OF CONTENTS

TITLE **PAGE**

TABLE OF CONTENTS

TABLE OF CONTENTS

1. ABSTRACT

As part of the overall program to modernize the government-owned, company-operated (GO-CO) Army Ammunition Loading and Assembly Plants, it is planned to develop fully automatic equipment to manufacture non-electric detonators at rates in excess of 1200 per minute. This search of literature sources and industry was undertaken to discover techniques and equipment that may be applicable. Current production rate in the loading plants is about 32 per minute with one system at Lake City AAP capable of about 300 per minute. Methodology and equipment is available to achieve high volume, automatic production after some development work in the areas of safely conditioning raw explosives, accurate metering of explosive charges, safe consolidation rates, inspection for flaws in metal parts, "on-line functioning tests, barricades to protect equipment and personnel and to avoid propagation of an explosion, remotely controlled trouble shooting devices, and improved leakage testing.

Specific recommendations include: (1) use design concepts based on continuous motion of individual, captive, oriented workpieces with endless, rigid transfer system and multiple tool modules (quick-change) on rotary turrets processing numerous workpieces simultaneously; (2) use mechanical presses with toggle or BLISS "Powerbar" linkage for consolidation, cup drawing, closure disc blanking and crimping; (3) use present

gravity-fed, volumetric metering devices with improved accuracy, precision and safety; (4) develop optimum anti-propagation barricades for each operation, including dust control and reject disposal; (5) develop automatic flaw inspection, leakage and functioning test techniques and equipment; (6) develop remotely controlled binocular video equipped highly mobile devices for maintenance, repair and trouble shooting; (7) automate the "back-line" to meet high rate demands of the "front-line" safely; (8) start work on advancing technology immediately.

2. INTRODUCTION

2.1 Historical Background

This survey is part of the Army's long range program to modernize the GO-CO Plants and the manufacture of munitions in general. Major objectives include modernization of methods and equipment with increased production capacity and quality while reducing cost through automation.

(See "Automation Concept" following.)

Because the desired production rate for detonators is orders of magnitude greater than present rates (1200 ppm vs. ~30), it was deemed wise to search for new techniques and equipment that might be adapted to the job.

Accordingly, a contract was let with the following Scope of Work and instructions for procedure:

THE AUTOMATION CONCEPT

1. Cuts Cost
   a) Reduced Labor Cost
   b) Reduced Material Cost via Fewer Rejects
2. Improves Quality
   a) Better Uniformity
   b) Reduces Human Error
3. Less Floor Space Required
4. Reduces Inventory Requirements
5. Higher Production Capacity
6. Saves Time ("Time is Money")
7. Avoids many Personnel Problems and Resulting Costs

2.2 Scope of Work (Extract)

2.2.1 Objective

The contractor shall devote his efforts and facilities to conducting a survey of modern high-volume, high-rate equipment and technology which may be applicable to the production of military detonators. This survey shall include equipment and technology currently used in the explosives industry and equipment and technology currently used in other industries requiring high-volume, high-rate production.

It is not intended to limit this study to the explosives and peripheral industries. At the conclusion of this survey, the contractor shall recommend which (if any) of the equipment and techniques surveyed are worthy of further consideration and may be adaptable to the production of detonators.

2.2.2 Procedure

To attain the objective, the contractor shall:

a. Make a thorough literature search of high-volume, high-rate equipment and technology.

b. Cull this listing to the extent of eliminating: (1) obvious duplications and (2) equipment and technology which is totally non-applicable to the production of military detonators. Since new methodology is being sought, extreme care should be exercised in the culling process to insure not losing a potentially valuable possibility.

c. The remaining equipment and technology shall be investigated thoroughly and a complete report submitted to MTD at Picatinny Arsenal. The report will include complete descriptive material, drawings, sketches, photographs, trip reports, cost estimates for material, equipment, labor, or implementation of technology and possible proprietary and/or other forseeable problem areas.

d. As noted in the objective, the contractor, in addition will submit a final report listing recommendations and techniques which appear to be most profitable in adaption to detonator production.

- END -
EXTRACT

2.3 Approach

The survey began by following the procedure outlined in the Scope of Work, but was modified as it progressed. In order to determine what to look for and how to evaluate potential applicability to high-volume detonator production, it was first necessary to have a detailed knowledge of how to make detonators. The various steps, procedures and processes were determined (Para. 4.5) and then the search was concentrated in these areas.

As the survey progressed, the most important problem areaswere identified (Para. 4.6) and the search concentrated on finding techniques and equipment to resolve them.

This had the effect of changing the nature of the end product originally envisioned.

The most potent approach is to determine the characteristics of the materials to be processed and then evolve techniques and equipment suitable to do the job safely and efficiently. Because of the nature of the explosive materials used in detonators, it was found that very definite limitations are imposed on processing rates and safety precautions.

A typical detonator contains three explosive charges; a priming mix, an intermediate charge, and an output charge. The priming mix is purposely made very sensitive to facilitate reliable initiation. The intermediate charge (usually lead azide) effects transition from burning (of the priming mix) to detonation which shocks the output charge into strong detonation. To accomplish this within very small confines of the detonator, it is necessary to consolidate the dry granular explosive charges under great pressure to achieve high density. Probably the most hazardous operation in the manufacture of detonators is that of consolidating the charges. Explosions or "blows" as they are frequently called, occur most often in consolidation of the priming charge because it is very sensitive and requires the highest consolidation pressure, up to 100,000 psi. However, its output is primarily flame and hot particles and even if it should detonate, there is only minor damage because the quantity of charge is quite small. Twenty-five milligrams is typical.

However, lead azide is also very sensitive and when initiated it always detonates. It is usually consolidated (on top of the priming mix) at about 20,000 psi and "blows" frequently result usually destroying the tooling and sometimes propagating (via dust) to the metering station and other parts of the line. Primarily for this reason, no more than one ounce of initiating or primary explosives are brought into the line at a time. Output charges, usually RDX, PETN or Tetryl are high explosives and considerably less sensitive than primary explosives. However, they too are consolidated at about 20,000 psi on top of the primary and intermediate charges and although less frequent, when "blows" occur, the damage is greater.

These characteristics impose certain basic limitations on manufacturing equipment which indeed may be considered design criteria as discussed in Para. 4.2.9.

The survey attempted to cover all conceivable sources where useful information might be available, but because of obvious limitations on time and funds, had to be selective. A sampling technique was used. The sources included known literature, detonator lines, loading plants, arsenals, libraries, patents, trade associations, consultants and industry.

A form letter explaining the purpose of the survey was prepared and mailed to numerous industrial organizations. These were selected from trade magazines and catalogs primarily. Notices were published in the COMMERCE BUSINESS DAILY and AUTOMATION MAGAZINE. In most cases, when responses were received, they were acknowledged via the form letter.

From these activities a rather imposing volume of brochure material was acquired as well as extensive address list of industrial organizations available to contribute their special talents and equipment to the effort. These are under separate cover.

3. CONCLUSIONS AND RECOMMENDATIONS

3.1 General Concepts

The problems of high-volume production of detonators begin on the so-called "back-line" where the explosives are received and conditioned prior to being moved into the "front-line" where they are incorporated into detonators. The explosives are both sensitive and powerful and safety dictates that they be handled in small quantities and by very carefully evolved procedures.

"New Techniques" that were surveyed included better methods of desensitizing the explosives and methods of automating the conditioning procedures.

New desensitizing techniques will require considerable investigation and development. The most direct and economical approach with highest probability of success is simply to automate the present back-line procedures. Effort is already underway in this direction (Picatinny funded program at Lone Star AAP). The centrifuge method of washing and drying lead azide developed at ARC ("Rolliex) for Picatinny Arsenal is one example of this.

Experience gained in the GO-CO plants over the years has determined the maximum safe quantities of explosives and rates at which they can be processed safely. It is recommended that these limits not be exceeded in the new, fully-automatic, 1200 ppm production line.

The design of the new line must provide for bringing safe quantities of explosives into the line and processing them fast enough to maintain the required 1200 ppm output. Thus, any operation that takes longer than 0.05 second $\left(\frac{60 \text{ sec.}}{1200 \text{ ppm}} = 0.05 \text{ sec.}\right)$ will require multiple parallel processing stations. (Actually the time is even less to allow for rejects and samples for functioning tests.)

Judging from operations observed at three GO-CO plants (Lone Star, Iowa and Lake City), at least two seconds are required to consolidate the explosive charges. Even at this rate, occasional "blows" occur. In the Iowa Loader, it was reported that increasing the rate increased the frequency of "blows".

The Lake City system uses multiple, parallel processing stations in the form of multiple cavity tooling (110 die cavities per platen). In this manner, 110 cups are processed at a time and the consolidation operation takes about 20 seconds, 10 times that at Iowa and Lone Star. Even at this longer operating time, the Lake City production rate is about 300 per minute (10 times that at Lone Star and Iowa). This is an example of how the multiple, parallel operation concept can increase production rates. However, even though the Lake City consolidation rate is slower than Iowa's or Lone Star's, they have occasional blows. These destroy the expensive tooling.

The recommended design approach for the new line is to combine the best features of both methods. This points to multiple, parallel tool stations that are designed to survive a "blow" or at least limit the destruction to an absolute minimum so that replacement can be simple, quick and inexpensive.

This concept applies equally to all of the tool stations. An additional requirement is to prevent propagation of a blow from one station to another. Good dust control systems and positive acting barriers between tool stations should solve this problem, but development work is needed.

The nature of the explosive materials and the methods in current use to load them into detonators that will perform properly evidently preclude all hope of designing high-volume automatic equipment that will never experience a blow. Design goals should be to minimize the frequency of blows and the damage they cause.

3.2 Metering

In the present GO-CO lines, explosive charges are metered by volume rather than by weight, although they are gravity-fed. With the multiple parallel tooling concept, the gravity feed rate is fast enough. In view of the fact that blows sometimes occur in the metering stations, attempts to speed up this operation are not recommended. Any efforts to improve the metering operation should include improving accuracy and precision and reducing the cost of the equipment which is usually destroyed when an explosion occurs. Another approach would be to design the equipment to survive a blow.

Still another approach that appears worthy of further investigation is to load the material in a wet condition which should make it less sensitive and hazardous. Drying can be accomplished either after metering or after consolidation in the cup or both.

3.3 Consolidation Rate and Pressure

Optimum design of the new automatic line will be facilitated by accurate data on safe consolidation rates and pressure for each of the explosive materials to be used. In the survey it was possible to calculate approximate values for some explosives as used in the existing lines, but it is not known how accurate these are or whether or not they represent limits.

Quite possibly, consolidation rate and pressure are not the only factors to consider in avoiding blows. Friction causing impurities and pinching of explosive between punch and die should be avoided. Too little clearance between punch and die may prevent the entrapped air from escaping, resulting in adiabatic heating and possible blows. Even without a blow, the compressed air may cause spring-back after the punch is withdrawn.

Pressure dwell is necessary for some types of materials and in some cases where clearances are small. It will allow time for trapped air to escape. At Lone Star and Iowa, clearances of .002-.003 inch appear adequate so that no pressure dwell is required.

The type of press used for consolidation is a matter of designer's choice, but it is recommended that it be capable of controlled rate of approach of the ram or punch to the explosive. A good example of the desired rate control is that produced by a spring loaded toggle linkage. This causes the ram to move rapidly as it approaches the loose explosive charge, but as consolidation proceeds the ram slows down to a stop at the desired pressure, which is maintained by the pre-set spring. The Iowa Loader uses this method.

3.4 Barricades

The consolidation operation is the most hazardous and must be performed within a barricade. In fact, all of the operations require a barricade of some sort especially designed and tested to suit the particular process. Not only must the barricade be designed to withstand the "worst-case" explosion, it must also prevent propagation, be easy to clean and maintain, have fail-safe features and arrangements for safe clearing of jams. Barricades are a major feature of the new automatic line and will require considerable design and development work, and, of course, thorough testing.

3.5 Anti-Propagation Designs

A detonation or explosion can propagate by means of shock, flame, flying fragments and combinations of these. The line should be designed so that detonation or explosion products from one station will be intercepted and neutralized before they can reach another station.

A suggested approach is to develop reciprocating barriers between work stations that continuously clean themselves of dust and always present a barrier to a possible explosion even when the workpieces are moving from station to station.

This is another area where development work will be required. In this same category, methods of dust control and disposal of rejects should be investigated.

The reject disposal method used at Iowa AAP has many attractive features. Two heavy metal plates in a box-like barricade form the sides of a "V", but do not quite make contact. Rejected detonators are dropped into the box and roll down to the bottom of the "V". The metal plates are charged electrically one positive, the other negative. When a detonator reaches the bottom of the "V", it closes the circuit causing a heavy current to flow which heats and fires the detonator.

This method is quick, positive, safe, reliable, leaves little scrap to be disposed of and avoids accumulation of large quantities of rejects.

3.6 Automatic Flaw Inspection

Fully automatic, fail-safe inspection at rates in excess of 1200 ppm is probably the most difficult, complex and expensive capability required of the new generation production line.

The explosive materials can be tested on a sampling basis from each batch prior to entering the "front-line" section but the metal parts must have 100% inspection for dimensions, physical properties and flaws.

Tests required on the explosive materials include moisture content, grain size, purity, output and microstructure. If these are to be fully automated, much development work remains to be done.

Similarly, the metal used for cups and closures can be tested for physical properties and metallurgical properties on a batch or lot basis. However, once in the line, inspection for dimensions and flaws must be on a 100% basis and fully automatic.

Results of the survey indicate that systems for dimensional checks are within the state-of-the-art and though probably expensive and somewhat complex, should present no unusual problems. Flaw detection is another matter. Examination for flaws such as cracks, thin spots, splits, perforations, dents, burrs, scratches, exposed explosive, missing closure discs, missing lacquer seal, foreign materials, improper crimp and the like have always been done visually by human operators. Although there are a number of efforts underway to develop automatic systems to perform these inspection functions, much development work remains.

Gulf + Western and Frankford Arsenal together with their subcontractors in developing automatic inspection equipment for small caliber ammunition have probably achieved the most advanced state-of-the-art.

In the general inspection category also is the problem of leak testing at high rates. Present methods (either batch or individual) do not appear to be adequate. A new approach is needed.

3.7 Automatic Functioning Tests

Traditionally, results of functioning tests are ultimate factors in the decision to accept or reject a lot of detonators. The usual definition of a "lot" is a quantity of detonators made with the same equipment and processes from the same batch of raw materials in a continuous production operation.

A number of detonators are randomly selected and tested in accordance with specifications drawn up by quality assurance experts.

For detonators, the most important performance or functioning characteristics are input sensitivity, output and functioning time.

In the case of stab initiated detonators for instance, the specifications will require that all fire when the firing pin is actuated by a specified minimum number of inch-ounces force applied by a steel ball of specified weight falling a specified distance. The detonator output must produce a dent of at least a certain depth in a steel witness plate.

The functioning time, measured from firing pin impact to output shock must not exceed a specified maximum value.

This "functioning" test is conducted using prescribed testing apparatus and instrumentation; parts of which are expended in each test. The tests are conducted at a separate facility from the production line and performed at the rate of perhaps one per minute.

The new, high-rate, automatic production line concept implies that sampling and functioning tests be performed on-line and concurrently with production.

It appears that this will require some revisions in concepts and procedures regarding acceptance testing.

If a "lot" is defined as a continuous production run made by the same methods, using the same materials, and all from the same batches (or lots) of raw materials, then the smallest batch of raw materials determines a lot. For instance, lead azide is made in batches or lots of 10, 15 or 25 pounds.

The M57E1 detonator (used in the 20mm fuze) requires .096 grams of lead azide, so a 10 pound batch will make about 47,291 detonators.

$$\frac{10 \text{ lbs.} \times 454 \text{ grams/lb.}}{.096 \text{ grams/detonator}} = 47,291$$

At 1200 per minute, this represents a 40 minute run (assuming no rejects). A 15 pound batch of lead azide will produce 70,936 detonators in 60 minutes and a 25 pound batch, 118,227 in 100 minutes.

Lot Sizes		
Lead Azide Batch (lbs.)	No. of M57E1 Detonators	Run Time at 1200 ppm (min.)
10	47,291	40
15	70,936	60
25	118,227	100

It is readily apparent that in continuous production at 1200 per minute, safe storage capacity for large quantities of detonators will be required. If the present concept of acceptance testing of random samples from a lot is to be retained, then means must be devised to random sample automatically and maintain identity of the sample with the lot from which it came.

Functioning tests of the samples must be performed quickly to avoid having to hold large quantities of detonators in temporary status pending outcome of the tests. Even so, there is the risk of continuing to produce additional lots of unacceptable detonators while the functioning acceptance tests are being performed.

Perhaps it would be better to adopt a scheme whereby say every tenth or one hundredth (the number would be continuously varied to sample all the tool modules) detonator is subjected to a functioning test. This might be more sensitive to changes caused by tool wear and system degradation, yet still permit test results to be related to conventional lot designations. Even conventional statistical treatments should not suffer too much.

For instance, assuming the conventional binomial distribution, 45 consecutive successful tests indicates the production run will perform with at least 96% reliability (with 90% confidence). As the run continues, if the number of successful tests continues to increase, the reliability prediction can be increased and with greater confidence in being correct. If a malfunction should occur, there should be a system of instrumentation and a computer to quickly identify the tooling involved and take corrective action.

Corrective action might be to replace a tool module, adjust consolidation pressure, adjust charge metering, or even shut down the line.

It appears that the automatic functioning test feature will require considerable thought and development effort.

3.8 Automatic/Remotely Controlled Maintenance, Repair, and Trouble Shooting

A malfunction such as a jam, a broken tool, or a blow will require repairs. Because of the high volume production, relatively large quantities of explosives are being processed and present a hazard to maintenance personnel who might attempt to enter the line. It is therefore recommended that consideration be given to such problems in the design of the equipment in order to facilitate making repairs by remotely controlled devices. Quick change tool modules have already been specified as a requirement. It is entirely possible to make such changes automatically or semi-automatically using remotely controlled robot-like devices.

One of the "new techniques" explored in the survey was the use of robots and "teleoperators" to perform the most hazardous tasks. Many industries are now using them. Some researchers are even developing artificial intelligence systems.

3.9 Safety and OSHA Standards

In designing the new line, safety is the most important consideration. Hazards to be avoided include static electricity, fire, explosion, noise, toxic fumes, dust, sparks, arcs, friction, heat and moving parts of machinery. It will be necessary to comply with the standards of the Occupational Safety and Health Act (OSHA) of 1970 (Public Law 91-596) which specifies that employers must provide work areas free from hazards. See Appendix 18 for more details.

Primary and initiating explosives are so sensitive and powerful, they present serious safety hazards. Much effort in the survey was expended on finding ways to solve this problem. Desensitizing the explosive with liquid or gaseous inert materials seems like a good approach and should be investigated further. However, many of the people interviewed do not seem to think the chances for success are very good. They feel that the problems will outweigh the advantages of increased safety. Even so-called desensitized material; water-alcohol wet lead azide for instance is reputed to detonate if initiated strongly.

3.10 Leak Testing

If it is a requirement that detonators be hermetically sealed, it will be necessary to test them for leakage and most probably on a 100% basis. There are various methods in current use, some of which are sensitive enough but tend to be too slow, cumbersome, expensive and elaborate. The usual approach is to subject the detonator to a vacuum, then introduce a gas under pressure, then evacuate again and attempt to detect gas leakage. A simpler method is to submerge the detonator in water under partial vacuum and look for air bubbles. These methods are relatively slow and tend to lead to batch processes and the safety hazards of having large quantities of detonators in close proximity. A new approach is needed. Some ideas are suggested under "New Techniques", Para. 4.3.13.

4. DETAILS OF THE SURVEY

4.1 Literature Search

The modernization program has been underway for several years and it seemed logical to check on the efforts of the various government agencies and their contractors for possibly applicable techniques and equipment. The Small Caliber Ammunition Modernization Program (SCAMP) mission is assigned to Frankford Arsenal. Fully automatic equipment is being developed to produce 5.56mm, 7.62mm, caliber .30, and caliber .30 carbine rounds at the rate of 1200 ppm and caliber .50, 20mm and 30mm rounds at 600 ppm. Gulf + Western is a major contractor in this program. Much of the experience gained in this effort is directly applicable to development of the new, high volume detonator production line. A brief description of the G+W approach appears as Appendix 2.

The Frankford Arsenal effort together with their contractors and suppliers to develop high speed automatic inspection techniques and equipment for cartridge cases and bullets is paving the way for similar capabilities in the detonator line.

In recent years, a number of concept studies for automatic production lines have been made by various contractors. A number of their reports were reviewed as part of this survey. They are listed in Appendix 17.

Information was gleaned from many sources, the main ones will be discussed briefly in the following paragraphs.

4.2 Information Sources

4.2.1 Automated Lines

Most of the Army non-electric detonators are made in the GO-CO plants; primarily Lone Star, Iowa and Lake City. These loading plants were visited and much useful information obtained; however, none of the existing lines operate at anywhere near 1200 ppm. There are a number of lines in industry that make detonators and blasting caps (including electric), but none were found with capability approaching that required for the new line.

A sampling of about 27 industrial organizations in the ordnance business were contacted via the form letter. Apparently, none have lines with high rate capability. However, the Bendix Corp., under contract to Frankford Arsenal, is developing a primer charging machine that will be capable of producing about 5,000 per minute (a report is in the literature file). The primer mix is pressed wet into a 1,416 cavity metering plate, doctored off level then punched into primer cups by gang punches. Paper covering discs are punched out at the same time and keep the mix from sticking to the punches. Wet primer mix is not usually consolidated at high pressure as the dry detonator charges are. However, the Brunswick Corp. at Sugar Grove, Virginia successfully loads consummable primers with wet FA982 mix (12-30% H_2O) and consolidates it at 20,000 psi. This is a manual process, but it is planned to be semi-automatic in the near future.

The search was not limited to detonator lines, but extended into many fields such as pharmaceutical, electrical and electronic, cosmetics, food and drug, containers, ceramics, rivets, screws, nails, fasteners, matches, packaging, automotive, cigarettes, anything that is made by automatic machinery and processes.

It soon became obvious that the people who manufacture a product rarely manufacture the automated production equipment. The survey was much more efficient and productive when the effort was directed toward the suppliers of automatic equipment.

In most industries making consumer products by automatic or semi-automatic means, there are several primary considerations resulting in "trade-offs" which determine the type of process, type of equipment used, and the production rate.

The automatic process equipment designer starts by determining the characteristics of the raw materials to be processed. He then attempts to choose the processes and equipments best suited for the job. At this point, cost and production rates are considered before the process and type of equipment are finally decided upon.

This is, of course, a greatly oversimplified description as there are many other important factors involved. However, the point is perfectly valid that in the case of the new detonator line the characteristics of the raw explosives and safety requirements are the overriding considerations in the choice of processes and types of equipment, as well as the production rate. It is therefore of little value to inspect automatic lines that were designed for products other than detonators. It should be more fruitful to concentrate attention on techniques and equipment that can help to solve the major problems in detonator manufacture. The survey has identified many problem areas and these are listed in Para. 4.6.

4.2.2 Loading Plants

The loading plants where detonators are currently being produced; Lone Star, Lake City and Iowa, are fertile sources of information on conditioning of explosives, manufacturing techniques, safety and problem areas. All of these are important, but probably the most significant are the concepts and approximate limits on the maximum quantity of raw explosive (one ounce) that can be handled safely and the maximum consolidation rates. These concepts lead to the conclusion that a multiplicity of tooling rather than high speed tooling is the way to high-volume production of detonators (see Para. 4.2.9 for analysis).

Additional details will be found in the trip reports of loading plants visits; Appendices 6, 7 and 11.

4.2.3 Industry

Various industries were contacted by direct mail, telephone, sales representative interviews and visits. A form letter explaining the purpose of the survey was prepared and used whenever appropriate.

An article was published in AUTOMATION Magazine and in the COMMERCE BUSINESS DAILY.

Interested industrial organizations with applicable techniques and equipment were requested to forward descriptive brochure material. These were filed in various appropriate categories corresponding to the various processes in detonator manufacture. This approach was intended to be selective and the material in the file pertinent to specific processes required by the new detonator line.

Three hundred forty-four (344) selected industrial organizations were contacted by direct mail and reader's service cards. Of these, 219 responded with brochure material, 43 indicated no applicable capability and, as of this writing, 68 have not yet replied.

Additionally, material has been gathered from various sources without direct contact.

It appears certain that industry will be capable of supplying the necessary equipment if it is described and specified in sufficient detail except for those problem areas requiring more development work as listed in Para. 4.6.

4.2.4 Trade Associations, Magazines

Industry reaches its potential customers by a variety of means not the least of which are magazines, trade association publications and activities and trade shows. The survey made good use of these within the short time available. Typical magazines and trade journals used are listed in Appendix 17.

4.2.5 Technical Libraries

Although the main emphasis in the survey was on direct contact with industry much useful information was obtained at the Franklin Institute and Gulf + Western libraries which are both convenient to the base of operations.

4.2.6 Patent Literature

It was planned to conduct a patent search on a subcontract basis. A proposal and cost estimate was prepared by the Franklin Institute Research Laboratories. However, a preliminary trial search indicated that the cost of the effort would not be justified. The reason for this is that there are so many categories and years to search. Results of the trial search indicated that any applicable, worthwhile patents are incorporated into products currently on the market and will thus turn up in the brochures submitted by industry.

In the case where a specific patent is known a copy was readily obtained from the Franklin Institute. However, even in such cases it is difficult to determine how successful it has proven without considerable detailed follow-up.

A typical example is the Olin-Winchester Patent No. 3,423,259 on the use of Karaya Gum binder in priming mixtures.

4.2.7 The Arsenals

The commodity arsenals most intimately associated with development, manufacture and use of non-electric detonators are Picatinny and Frankford. Much pertinent information was gained from these sources via reports, telephone and personal visits. See Appendices for details.

4.2.8 Consultants

Many of the individuals interviewed in the survey may be considered consultants in their own right, but only a few were consultants by profession. These include Dr. Herbert Ellern and Professor Joseph H. McLain. Informal discussions with these men were helpful and good use was made of their publications (referenced in Appendix 17).

4.2.9 Design Criteria Analysis

The most hazardous operation in the manufacture of detonators is that of consolidating the charges, particularly the lead azide. In this operation inadvertent explosions frequently occur. This is easily understandable because the consolidation ram at about 20,000 psi is doing considerable work upon the explosive. To fire detonators and primers intentionally, they are most often struck by a firing pin. The initiation mechanism is a concentration of energy resulting in rapid heating of the explosive by a combination of compressive force, friction, and pinching action. If the resultant heating exceeds the threshold level for a long enough period of time, a self-sustaining reaction will be initiated and an explosion will occur. It makes no difference whether the cause is a firing pin or a consolidation ram; the basic mechanisms are the same.

Therefore, in the design of automatic, high-volume production equipment a basic limiting design criterion is the maximum safe rate that the consolidation ram can move against the explosive material. If this rate is known in terms of the minimum time required for consolidation, then the number of consolidation stations required to produce at a given rate can be calculated. As an example, if the desired rate is 1200 ppm amd the minimum consolidation time is two seconds, then $\frac{60 \text{ secs.}}{1200 \text{ ppm}}$ = 0.05 seconds and N x .05 = 2 seconds

Where N = Number of Consolidation Stations Operating Simultaneously

In this case, N = 40 (40 x .05 = 2)

Lone Star Army Ammunition Plant is currently producing detonators in a semi-automatic, Ferguson "Trans-O-Mater" at 30-60 ppm. Thus, consolidation is done in one to two seconds (assuming only one press station), and no pressure dwell is used by Lone Star. The Iowa Loader operates best at 32 ppm and employs no dwell.

At Lake City Army Ammunition Plant, consolidation is performed at about 20 inches/minute using 110 (gang) punches and eight seconds dwell.

Roughly calculated, the Lake City ram speed is about three to ten times slower than that used at Lone Star and Iowa, yet blows occasionally occur.

In addition to the consolidation time, it is necessary also to allow time to accelerate the punches and to move the workpieces into and out of the station. Thus, for the Lake City type of operation, about five consolidation stations operating simultaneously would be required for 1200 ppm and the Lone Star system would require about 40 (assuming continuous motion).

In each case, if one ounce batches of lead azide are fed periodically into each station, the Lake City system would require about one ounce per minute to each of the five stations and the Lone Star system would require about one ounce every 10 minutes to each of the 40 stations (for the M57E1 Detonator).

<u>Calculations [M57E1 Detonator]</u>

454 grams/pound

16 ounces/pound

1 ounce $= \frac{454}{16} = 28.375$ grams

M57E1 Detonators use .096 gram (max.) charge of lead azide

1200 ppm requires 1200 x .096 = 115.2 grams of lead azide/minute

If five stations are used, $\frac{115.2}{5} = 23.04$ gram/min. per station

If 40 stations are used, $\frac{115.2}{40} = 2.88$ grams/min./station

(About .1 ounce/min./station)

Calculations [M57E1 Detonator]

$\frac{28.375}{.096}$ = 295.57 Charges/Ounce

295.57 Charges/Ounce x .1 ounce/min/station x 40 stations =~1200

One ounce of lead azide seems to be the maximum amount that a reasonably heavy (about 1/2" thick steel) barricade can withstand and which will not seriously damage the press. However, a one ounce "blow" will destroy the metering device and the tooling.

Thus, unless a means can be found to load desensitized lead azide, two major design criteria are established: (1) the rate at which consolidation can be performed; and (2) the rate at which lead azide can be fed to the line.

Design criteria for other production operations can be developed by similar reasoning processes.

4.2.10 Visits

Visits were arranged during the course of the survey to places where it was expected that useful and detailed information could be obtained. In some cases where it was feared that proprietary interests might inhibit information gathering, Mr. Hal Wanger of Picatinny Arsenal made the trip rather than G+W personnel.

Trip reports constitute Appendices 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14 and 19.

4.3 New Techniques

A number of "new techniques" were surveyed for potential applicability to high volume manufacture of detonators. They are discussed briefly in the following paragraphs and additional details are in the Appendices, the project files and the originating sources.

4.3.1 Machine Design Concepts

Present detonator lines in the GO-CO plants are, at best, semi-automatic, indexing, low rate operations. So basic to the problem as to be easily overlooked is the concept of continuously moving, captive, oriented workpieces being processed by multiple tool stations mounted on rotating interconnected turrets. One hundred percent inspection is carried out on the line. The operation is fully automatic and fail safe. This concept is being applied by the Gulf + Western Advanced Development and Engineering Center to the Small Caliber Ammunition Modernization Program to produce small caliber ammunition at the rate of 1200 per minute. It should be seriously considered for the high volume detonator production line. This and other concepts for automatic production of munitions have been proposed and evaluated by various research and development organizations. Their reports are listed in Appendix 17.

4.3.2 Desensitized Explosives

It has been proposed to desensitize explosives by means of inert liquids, gases and/or solids in order to reduce the safety hazards and make it possible to process larger quantities of explosives at one time.

It is a well known fact that some sensitive explosives are shipped and stored in a wet condition. A combination of water and alcohol or sometimes just water is usually used for this purpose. Current practice at the detonator loading plants is to "condition" the explosives before they are loaded into detonators which includes drying them. They are much more sensitive and hazardous in the dry condition.

It has been proposed to use an inert material to desensitize the explosives during handling and loading, then remove the material after the detonators have been safely packaged or assembled in fuzes. There has been some work done along these lines and the survey uncovered several patents on specific processes and materials.

It appears that safe handling of bulk explosives is the key to success of the modernization program, not merely the detonator line. However, the detonator is unique in that it incorporates sensitive initiating and transition materials in the same casing with powerful high explosives. At the high-rate production line these materials must flow steadily into the consolidation presses. To maintain the flow, relatively large quantities of hazardous materials must be on hand in close proximity. Approximate quantities required for even the smallest detonators, typified by the M55 and M57E1, are, per eight hour shift, 1200 ppm; priming mix 19-32 pounds; intermediate charge 78-118 pounds; output charge 24-45 pounds for a total of 120-192 pounds.

The priming mixes and intermediate charge materials are extremely sensitive and also capable of powerful detonation. Detonation of even a few ounces of the material is certain to damage machinery components in the immediate vicinity and larger quantities would constitute a major catastrophe.

Present practice is to ship, store and handle sensitive materials in a water-alcohol wet condition, which greatly reduces their sensitivity and permits handling of larger quantities safely. However, before loading into detonators, small quantities are removed and dried in a slow laborious process behind heavy barricades.

Gun primers are generally loaded in the water-wet condition and dried later; sometimes after being assembled in the cartridge case. However, high pressure consolidation is usually not required of gun primer mixes as it is for detonator charges. Water tends to interfere with consolidation and the wet mixes often tend to stick to the punches and dies.

Moreover, water mixes are prone to separate on standing and during compression. Current practice in loading plants is to dry the mixtures prior to loading. However, the dry mixes are very sensitive and hazardous and so only very small quantities (about one ounce) are put into the heavily barricaded metering stations at one time.

Other substances than water, alcohol and oil are known to be effective desensitizers and there is evidence that some of these can be used during the complete manufacturing process.

Explosive mixtures used in detonators are granular crystalline solids. Even when consolidated at 20,000 psi, there is considerable volume in the interstices occupied only by air. If the interstices are filled with inert material such as water, oil, wax, freon, etc., the explosive is much more difficult to initiate or detonate. The mechanism appears to be a combination of effects, including reduced friction between particles, cooling of hot spots, and a physical barrier to high energy, high velocity particles (from decomposing explosive molecules).

The following is quoted from Explosive Trains AMCP 706-179, Page 37: "The addition of a few percent of a waxy substance such as calcium stearate reduces the sensitivity of RDX by a factor of 2 or 3 as indicated by the air gap test." However, it is also observed that the lubricating effect of the calcium stearate permits higher loading density (at the same pressure) which makes the charge more difficult to initiate, thus accounting for part of the desensitizing effect.

Robert Heinemann at Picatinny Arsenal experimented with Freon 113 to desensitize detonators. He found that as little as 5-6% Freon absorbed into the interstices between the explosive particles prevented initiation even at input energies several times the normal all-fire amount. As the

Freon was driven off (by heating), the detonators regained their sensitivity and in 5 minutes began to exhibit some output (as measured by dents in steel witness blocks). In 15 minutes, the detonators completely regained normal sensitivity and output.

This work was reported at the 6th EED Symposium in San Francisco July 8-10, 1969, in U.S. Patent No. 3667388 and in Picatinny Arsenal reports. An additional benefit claimed by Mr. Heinemann is that water is not permitted to be absorbed when the explosive materials are surrounded by Freon.

t is suggested that the inert desensitizer such as Freon might be added to the explosive in super-cold condition to improve its effectiveness as a desensitizer. The consolidation operation generates heat which would help to drive off the desensitizer.

If wet mixes are allowed to dry during storage or processing, they become hazardous. Frankford Arsenal priming mixes are considered "dry" when they contain less than 2% moisture.

A new development by Olin-Winchester Group (U.S. Patent No. 3423259) is the use of a small amount of karaya gum (3 pph) in Frankford Arsenal primer mix FA956 (water-wet) which makes it extrudable and non-sticking. It also prevents the water and the various different sized particles from separating out (stratification).

The gum remains in the mix after it is dried and apparently has no significant effect on the sensitivity or output of the primer. Yet, because of its ability to hold water in a gel form within the interstices when the mix is wet, it has a great desensitizing influence.

It would be interesting to see if karaya gum or a similar material can be as beneficial in a Freon desensitized mix and permit the necessary consolidation to be performed. It should be noted that in Mr. Heinemann's experiments, the detonators were loaded dry in the usual manner. Porous closures were used which permitted the Freon to be absorbed and later driven off by heating. It remains to be shown that detonators can be made using explosive mixes that are desensitized by inert liquids and/or other substances. Other substances that have been used as lubricants and desensitizers include gum arabic, tragacanth, gelatin, dextrin, wax, calcium stearate, and polyvinyl alcohol. These are used in very small quantities and remain in the final product. Perhaps something like this could be used with an excess of inert desensitizer which is later completely removed.

Complete removal of Freon for instance is apparently readily accomplished by evaporation. A new process for drying water-alcohol wet lead azide in a centrifuge rinses it with water, then alcohol and finally with Freon.

Freon is a comparatively expensive material, but as it is evaporated from the finished detonators, it can be recovered, condensed and used again and again.

In this connection it would be well to keep the Freon "wet" explosives cool to minimize evaporation, but also because cool explosives are generally less sensitive than hot ones.

Explosives are metastable compounds and even at room temperature are continuously decomposing. Their decomposition is always exothermic. Thus, a decomposing molecule causes a momentary "hot-spot" and if several molecules in close proximity should decompose at the same time, enough local heating could excite other molecules into decomposition. Chemical reaction rates generally double or triple for each ten degree increase in temperature so it is easy to see how a run-away reaction (explosion) can get started unless the heat can be dissipated more rapidly than it is generated. Keeping the explosive cool and flooded with inert material with high heat capacity can help a great deal.

If metering and consolidation of Freon-wet explosives does not prove feasible, it should not be difficult to drive the Freon off quickly using heat and vacuum just before the metering step in the automatic process line.

4.3.3 Consolidation Aids

It has been noted that consolidation of dry granular explosive at high rate and high pressure tends to heat the explosive by virtue of the work being done on it and on the entrapped air. Some investigators have suggested evacuating the mold during consolidation and performing the consolidation in several short strokes rather than one continuous compression. It has already been mentioned that the addition of even very small quantities of such substances as wax and calcium stearate tend to reduce friction and sensitivity and enable consolidation to higher density at less pressure.

It has been demonstrated that these consolidation aids produce more uniform density distribution which is an important consideration in columns with high length over diameter ratios.

Another application of the friction reducing effect of wax like inert materials might be to use such materials as a lubricant in drawing the detonator cups and then it would not have to be removed, thus eliminating a cleaning operation. There may be a problem here because in most high speed cup drawing operations it is necessary to apply a coolant as well as a lubricant in order to keep the tooling from overheating although one material could perform both functions.

This would make it feasible to form the cup right in the die or workpiece holder that moves through the line and this could even be used as part of the packaging (reusable).

4.3.4 Sealing Techniques

A method of hermetic sealing of detonators by ultrasonic ring welding has been proposed in some detail by Aeroprojects Inc. of West Chester, Pa. The method is fast, clean, safe and reliable and can readily be automated .

The detonator cups would have to be formed with a flange on the open end. The closure disc would be ring welded to the flange and then crimped 180°. This would leave a double thickness of the closure disc in the ring area and probably necessitate drawing and specification changes. For most applications this should not cause any change in detonator performance because closure discs are only a few thousandths of an inch thick at the most.

Another sealing technique that appears feasible and in fact has been used on some types of explosive initiators is known as the hot-melt process. The closure disc is pre-coated with a sealing adhesive material. After it is crimped into place a heat pulse is applied just long enough and hot enough to melt then quickly cool the adhesive, thus effecting a seal. The hot-melt could be made electrically conductive to overcome any adverse static electricity effects.

4.3.5 Electroplating

The idea of consolidating explosives in a die without a cup and then forming a protective metallic covering by electroplating has been investigated. Although not actually done with stab detonators, the Naval Ordnance Laboratory at White Oak, Silver Spring, Maryland successfully plated silver and copper on explosive charges. The small scale laboratory experimental program is reported in NOLTR 64-131, October 1964, reference 26 of Appendix 17.

Although there are many attractive features offered by the electroplating approach, close scrutiny led to the conclusion that it is not suitable for the contemplated high volume detonator line within the present frame of reference. The analysis leading to this conclusion appears as Appendix 15.

4.3.6 Plastic Encapsulation

The idea of using plastics in some manner to encapsulate the explosive charges rather than using metal cups has been suggested. Evidently the idea is to capitalize on advances in plastics technology. To switch to plastics would require changes in drawings, specifications and probably re-qualification testing.

In general, plastics do not have the dimensional and temperature stability of metals, nor the physical strength and stiffness. There are very few applications in the ordnance field where a plastic can be directly substituted for a metal.

It is doubtful that any plastic material available today could survive a twenty-five year surveillance test as a detonator cup and meet all of the other stringent requirements (assuming direct substitution for the present metal cup).

However, if constraints of existing design specifications are removed, plastic encapsulation should be investigated.

4.3.7 <u>Drying Explosives</u>

One conditioning process currently performed at the GO-CO plants "back-line" which is both time consuming and hazardous is that of drying lead azide and lead stypnate. A new technique is being developed by the Atlantic Research Corporation under contract to Picatinny Arsenal. Known as "ROLLIEX", the system uses centrifugal force to wash, rinse and dry lead azide in two-ounce batches.

4.3.8 <u>Sheet and Drawn Explosives</u>

It has been suggested that if detonator explosives were prepared in sheet form with just the right thickness for a particular detonator charge, it would facilitate automation. Individual charges could be cut out with a "cookie cutter" type of punch directly into the cup. It seems entirely feasible that primary explosives can be formed in sheets and ribbons just as readily as they are consolidated into detonator cups. However, this will present handling and safety problems unless a binder material is added to give flexibility, strength and reduced sensitivity. If this is done, every detonator will have to be requalified and the specifications changed.

The well known sheet explosive DuPont "DETASHEET" is PETN, RDX or HMX mixed with an elastomeric binder. The more binder the more flexible, but less sensitive and less powerful (detonation velocity is lower). Data published by DuPont bears this out. Most detonators cannot afford much reduction in sensitivity, and/or functioning time.

The idea of punching detonator charge increments from sheets made of the currently used and unadulterated primary explosives may not prove economically sound because of additional process steps and waste (plus handling and safety hazards). The explosive must first be conditioned then metered and formed into sheets or ribbons, then punched, then consolidated, waste must be removed and destroyed or recycled. The present method eliminates the sheet forming and waste recycling operations and minimizes safety problems. It should be more economical in both cost of equipment and operating costs, unless of course the sheet method can be developed to be highly efficient and to eliminate some of the other steps.

Another, similar approach is to load the explosive materials into metal tubes, then draw them through dies or swage them to the proper consolidation and physical dimensions. This method is currently being used to make MDF (Mild Detonating Fuse, Reference 29, Appendix 17). The proper quantity of consolidated explosive for a particular detonator could be automatically sliced off the end of the rod and inserted into a detonator cup by high speed equipment and would not require reconsolidation.

4.3.9 Robots

It is true that robots are both blind and stupid, but the same can be said of all automatic equipment. Much progress has been made in recent years to improve the versatility and capability of robots or robot-like machines (Appendix 17, Reference 33). At the very least, their use should be considered for the most hazardous tasks in detonator manufacture. These would include various operations on the "back-line" where relatively large quantities of explosives are "conditioned" and for trouble shooting anywhere on the line.

For such tasks, it would probably be feasible to operate the device by remote control rather than automatically even though a human operator is required. Devices are currently under development with binocular television "eyes" for improved depth perception. Some are even being provided with artificial intelligence and can recognize and sort such things as paper back books. So it seems entirely probable that devices can be developed to perform "visual" inspection of detonators without human eyes being required.

4.3.10 Noiseless Crimping

As an example of a "new technique" aimed at reducing the noise level of high speed automatic machinery, a method of noiseless crimping is described in Reference 35, Appendix 17. OSHA regulations place a maximum of 85 decibels on such operations as riveting and crimping. The method described in the reference is a rolling process called orbital headforming.

4.3.11 Ferrofluidic Solenoid*

A new device with possible application to the new detonator line is described in Reference 32 Appendix 17. A totally enclosed solenoid, it has no sliding or rotating parts, and imparts maximum force at the extreme end of its stroke. Its efficiency is high because it has no air gap and can provide either variable force at constant displacement or variable displacement with constant force.

4.3.12 Quartz Crystal Microbalance

Most conventional balance type weighing systems are much tooslow for the 1200 per minute rate desired for the new line. Frankford Arsenal is developing a system capable of weighing cups for cartridge case manufacture at 800 per minute. It uses a servo-motor to restore balance when a cup is placed on the pan. The electric current required is a measure of the weight of the cup. Two of these operating in parallel can weigh up to 1500 cups per minute.

Another approach which appears feasible and capable of even faster response is described in Reference 30, Appendix 17. Instead of the one "g" environment of conventional weighing systems, the Quartz Crystal Microbalance detects mass (weight equals mass times the acceleration of gravity, "g") in terms of the change in vibrational frequency to produce or rather re-establish resonance. Piezoelectric materials such as quartz, Rochelle salt, tourmaline and barium titanate become electrically charged when mechanically stressed. And, conversely

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*See also brochure material from Ferrofluidics Corp. in file under 23, Machinery and Miscellaneous.

undergo change in dimensions (strain) when electrically stressed. A wafer of piezoelectric material silvered on opposite surfaces can be made to expand and contract in the thickness dimension by application of an alternating electrical voltage. A wafer has a natural or resonant frequency that is a function of its density (mass), thickness and elasticity (also temperature). If a mass such as a detonator cup or charge of explosive material is placed upon the wafer, it will cause the resonant frequency of the system to change. The difference in resonant frequencies is directly proportional to the weight of material added.

Proper choice of materials, dimensions and electrical components should produce a system having great accuracy, precision and very rapid response.

4.3.13 Leakage Testing

A new technique for leak testing is described in Reference 31, Appendix 17. It is an innovation applied to the standard method of helium bombardment leak testing. This method measures the rate at which the leak rate decays rather than the magnitude of the leak rate. It provides a more precise and repeatable measure and eases the requirement for tracer gas bombardment pressure and time as well as the time constraint on measurement following bombardment. However, it remains to be seen how fast the test can be made which will determine how many parallel operating work stations will be required or whether a batch process will be the best way.

Gulf + Western has developed a concept for an automatic leak detection system for small caliber ammunition. It uses the water submergence method and detects air bubbles. However, it is slow (1-4 per minute) and could be considered a destructive test.

Perhaps an explosives "sniffer" detector could detect leaks if one can be found with sufficient sensitivity and rapid response. After all explosives being metastable compounds are continuously decomposing.

4.3.14 Static Electricity Control

Static electricity is generated whenever two materials come into contact and then separate. If the materials are good conductors of electricity and a circuit is available, whether planned or not, the charges are quickly neutralized. However, if the materials are poor conductors, they may retain the charge and constitute a potential hazard to sensitive explosives. Care is taken to electrically bond and ground all machinery and equipment where explosives are stored, handled and processed, but even with these precautions, static electricity is still considered a possible cause of "blows" and spontaneous explosions in the GO-CO plants.

A technique suggested in the course of the survey is to use radio active materials to ionize air and then cause this air to flow through the process line to neutralize any electrostatic charges as they are formed. Care must be taken to isolate the radio active source so that an accidental explosion cannot spread it around in an uncontrolled manner.

Equipment is available commerically, but apparently an acceptable application to detonator production lines has not been worked out (see file no. 14, Safety, No. 6).

4.3.15 Functioning Tests

The usual method of performing functioning tests on stab type detonators requires a special test set and expendable components which include firing pins, firing pin guides and witness blocks. After firing, the dent depth in the witness block must be measured. Compared to the planned production rate of 1200 ppm, the present method of testing is too slow and cumbersome.

A new technique that can lend itself more readily to automation is practically a must. This author suggests the use of detonation light, a little known phenomenon, to obtain an accurate measure of detonation velocity and functioning time simultaneously using remotely located light sensors. This will eliminate witness blocks and the dent measuring function. The functioning time measurement using detonation light gives an immediate acceptance or failure signal. The detonator is initiated by the specified minimum all-fire stimulus so if it fails to fire or "hang-fires", it is an immediate reject. Detonation light is described in Reference 24, Appendix 17, and a method of using it in functioning tests is described in Reference 36, Appendix 17.

Briefly, detonation light in granular explosives is an "extremely brilliant, short-lived flash of light produced when detonation products, after expanding from a crystal into an interstice are stagnated against the next grain". It is not to be confused with light produced by the shock wave in the air surrounding a detonation. The detonation light is produced only in the interstices as a discrete band of light about the size of the interstices. Thus, a photodetector aligned with the end of an explosive column (such as a detonator) and collimated by slits so only light from the end of the column can be "seen", makes an excellent sensor for providing a "stop" signal to a chronograph or oscilloscope. The start signal can be provided by the firing pin contacting the input end of the detonator (breaking a light beam).

To be a successful test, the time interval must be equal or less than some predetermined value which assures that the detonation velocity at output attained the required value. Detonation velocity and pressure are related so that a measure of detonation velocity is as good as dent depth in a steel witness block without having to expend the block.

A fixture to automatically position each detonator for the test can be designed to last for several firings and to be self renewing.

Another type of remotely located, passive type of functioning tester is described in Reference 37, Appendix 17 .

The device consists of two broad band, high speed photomultipliers having a spectral sensitivity in different portions of the spectrum. The photomultipliers are directed to sense the explosion, and the ratio of their outputs is recorded as a function of time. Since the light source will emit a spectral distribution which is dependent upon the temperature and energy of the source, the two-photomultiplier technique should reveal the differences between acceptable and unacceptable explosive devices.

Some of the salient features of the detector are rapid response of at least 0.1 microsecond and the ability to measure temperature in the range 2000°K to at least 10,000°K without limitations on source size or emissivity. This development appears worthy of further consideration for functioning tests of detonators at high rates with automatic read out of results.

4.4 Equipment

4.4.1 General Considerations

The search for applicable equipment for the new high-volume, high-rate detonator production line included equipment for carrying out the multitude of operations as listed in Para. 4.5, following. Obviously, time and funds did not permit a comprehensive, all inclusive search. Instead, a selective sampling was made of those industries believed to be active in the areas of interest. The anticipated new line was described and they were asked to respond with brochure material about their equipment and capabilities. These are filed in the categories of the major operations. Additional material is contained in the correspondence file and the index to the brochure material as well as in the appendices to this report.

With the exception of the problem areas listed in Para. 4.6, it appears that industry can provide equipment to do the job. However, before making trade-off analyses and specific recommendations, it will first be necessary to work out an overall design approach.

4.4.2 Design Approach

The general concepts and performance characteristics of the new detonator line are pretty well spelled out in Appendix 1, Description of Overall Systems Concepts, Appendix B, Project No. 5724000. It remains to work out detailed designs of systems and equipment to implement the overall concepts.

For instance, orienting and feeding metal parts, metering explosive and consolidation of the charges can be performed by various types of mechanisms. Several different types are described in the appended documents and referenced reports, some of which represent efforts at comparative evaluation of different design approaches. Some designs feature continuous motion of individual workpieces being processed by a multiplicity of tool modules mounted on rotating turrets. Some designs feature multiple cavity workpiece holders which are moved synchronously or non-synchronously (work demand system) from work station to work station. Other designs combine such features. Unfortunately, without some basic data to work with it is difficult to make objective evaluations of the different designs and equipments available.

Probably the best place to start is with the characteristics of the explosives to be loaded and the detonator design and performance specifications. These are basic restraints within which framework the designers of the new line must work.

Flow characteristics, sensitivity and destructive capability of the various explosives must be considered in designing conditioning systems, transport, metering devices, consolidation tooling and rates, barricades and other safety devices. It appears that the best approach is to design prototype equipment and test it, modifying as required before finalizing the design. Concurrently with this activity a program should be implemented to resolve the problems in areas requiring further study (Para. 4.6).

Descriptions of the various types of equipment currently offered by industry will be found in the various brochures in the files. Examples of selected types are described in Appendix 5.

4.5 Major Operations in Detonator Manufacture

4.5.1 Conditioning the Explosives

4.5.1.1 Shipping and Receiving

4.5.1.2 Storage

4.5.1.3 Conveying

4.5.1.4 Washing

4.5.1.5 Drying

4.5.1.6 Blending (priming mixes only)

4.5.1.7 Sieving (sifting)

4.5.1.8 Dividing into One-Ounce Lots

4.5.1.9 Inspection Testing

4.5.2 Metal Parts

4.5.2.1 Physical and Metallurgical Tests

4.5.2.2 Cup Fabrication

4.5.2.3 Closure Disc Fabrication

4.5.2.4 Cleaning

4.5.2.5 Inspect for Dimensions and Flaws

4.5.2.6 Feed and Orient in Dies (cups)

4.5.2.7 Feed and Insert (closure discs)

4.5.3 Metering of Explosive Charges

4.5.3.1 Metering (adjustable)

4.5.3.2 Pelleting (output charges only)

4.5.3.3 Cleaning and Dust Control

4.5.4 <u>Consolidation of Charges</u>

4.5.4.1 Pressing at Controlled Rate & Pressure

4.5.4.2 Measuring Charge Height

4.5.4.3 Cleaning & Dust Control

4.5.4.4 Reject Disposal

4.5.5 <u>End Closure</u>

4.5.5.1 Blank & Feed Discs

4.5.5.2 Crimp

4.5.5.3 Inspection

4.5.5.4 Sealing Lacquer Application

4.5.5.5 Inspection

4.5.5.6 Leakage Testing

4.5.6 <u>Functioning Tests</u>

4.5.6.1 Sensitivity Test

4.5.6.2 Output Test

4.5.6.3 Functioning Time Test

4.5.6.4 Evaluate Test Results

4.5.6.5 Accept - Reject

4.5.7 <u>Packaging</u>

4.5.7.1 Package or Assemble in Fuze

4.5.7.2 Stack Packages in Cartons and Seal

4.5.7.3 Mark (identify) Cartons and Inspect

4.5.7.4 Convey to shipping or Storage Facility

4.5.8 <u>Auxiliary Operations & Equipment</u>

4.5.8.1 Controls & Display

4.5.8.2 Sensors

4.5.8.3 Counters

4.5.8.4 Timers

4.5.8.5 Computers

4.5.8.6 Vacuum Systems

4.5.8.7 Compressed Air Supply

4.5.8.8 Reject Disposal System

4.5.8.9 Waste Collection, "Kill" and Disposal Systems

4.5.8.10 Air Conditioning & Heating Systems

4.5.8.11 Pollution (environmental) Control Systems

4.5.8.12 Static Electricity Control Systems

4.5.8.13 Fire Protection Systems

4.5.8.14 Explosion Protection Barricades

4.5.8.15 Warning Devices & Systems

4.5.8.16 Noise Abatement Systems

4.5.8.17 Maintenance, Repair & Troubleshooting Systems and Equipment

4.5.8.18 Off-Line Gaging Standards

4.5.8.19 Power and Utility Services

4.6 Problem Areas Requiring More Study

4.6.1 Automating the Back Line Safely

4.6.2 Metering

4.6.2.1 Accuracy

4.6.2.2 Precision

4.6.2.3 Safety

4.6.3 Consolidation

4.6.3.1 Rate

4.6.3.2 Pressure

4.6.3.3 Clearances

4.6.3.4 Dwell

4.6.3.5 Safety

4.6.4 Barricades

4.6.4.1 Conditioning

4.6.4.2 Conveying

4.6.4.3 Storage (ready box)

4.6.4.4 Metering

4.6.4.5 Consolidation

4.6.4.6 End Closure and Seal

4.6.4.7 Functioning Tests

4.6.4.8 Packaging

4.6.4.9 Dust and Reject Disposal

4.6.5 Anti-Propagation Designs

4.6.5.1 Including Dust and Reject Disposal

4.6.6 Automatic Flaw Inspection

4.6.6.1 Leakage Test

4.6.7 <u>Automatic Functioning Tests</u>

4.6.7.1 Sensitivity

4.6.7.2 Output

4.6.7.3 Functioning Time

4.6.8 <u>Automatic/Remotely Controlled Maintenance and Repair</u>

4.7 Supporting Data

4.7.1 Correspondence*

4.7.2 Documents*

4.7.3 Vendor's Brochures*

4.7.4 Visit Reports (appended)

4.7.5 Monthly Progress Reports*

4.7.6 Form Letters*

* (Under separate cover.)

4.8 Appendices

1. Description of Overall Systems Concepts
2. G+W Cartridge Module "A"
3. Trip Report - H. Wanger - Perry Industries
4. Trip Report - H. Wanger - Olin Corporation
5. Trip Report - M. Friedland - Machine Tool Show
6. Trip Report - H. Wanger, E. Hannum - Lone Star AAP
7. Trip Report - H. Wanger, M. Friedland - Lake City AAP
8. Trip Report - E. Hannum - Frankford Arsenal
9. Trip Report - J. Kelly - Frankford Arsenal
10. Trip Report - E. Hannum - Phila. Scientific Controls
11. Trip Report - H. Wanger, E. Hannum - Iowa AAP
12. Olin Patent
13. Trip Report - E. Hannum - Picatinny Arsenal
14. Trip Report - E. Hannum - Picatinny Arsenal
15. Analysis of Electroplating as Detonator Manufacturing Technique
16. Automation Editorial on Productivity
17. Literature Reviewed
18. OSHA Standards
19. Trip Report - H. Wanger - Western Electric, MRC. Baltimore, Md.

A P P E N D I C E S

APPENDIX 1

Excerpts From

Description of Overall Systems Concepts
Appendix B
Project No. 5724000
Picatinny Arsenal
MTD

[Figures 2, 3 and 4 only]

APPENDIX B

Project No. 5724000

A. Automated Line:

The automated line will be a continuous operation monitored and controlled by computer. The operator will observe a display panel which will inform him of the status of the operation at any time. The line will include the following features:

1. All stations will be plug-in modules.

2. All stations will be linked to the computer and display panel.

3. Capability for varying the number, weight and density of increments.

4. No operation will be required outside the system except for feed of raw materials and removal of packed product.

5. Automatic feed back.

6. Automatic shutdown of a module in case of malfunction or initiation.

7. In case of shutdown of a module, the work flow will be directed toward the operating modules by passing the malfunctioning units. Extra modules will be included which can be automatically inserted into the system to replace the malfunctioning unit. No setup time necessary.

8. System will identify source of malfunction on panel.

9. The computer will include a memory bank containing necessary information for manufacture of several initiators (eventually all initiators). Selection of the item to be produced and the number will require no further action on part of the operator. The computer will automatically switch the proper modules into the line, select the appropriate inspection plan, dwell times, increments, etc.

10. Functioning tests will be performed on the line as well as the usual inspection tests.

11. The display panel will at all times inform the operator as to which modules are in use, the number of items completed, the status of inspection tests, and an alarm system will immediately alert him if malfunctions, stoppages, initiations, etc., should occur.

APPENDIX B

Project No. 5724000

The automated line will integrate all manufacturing operations (work handling, loading, crimping, sealing, in-process inspection, assembly and test) into a single continuous system. Figure 3 illustrates some of the possible modes of operation for an interlocking, computerized system.

Operations:

1. Inspection of Metal Parts:

Dimensions, integrity, compressive and tensile strengths will be inspected for adherence to specifications. Magnaflux, radiation and electronic techniques will be utilized where applicable. Mechanical probes, pneumatic measuring systems, etc., will also be employed.

2. Feed:

All feed systems will be completely automated and will be continuous. Feedback from the various stations will halt the flow of parts and explosive (if necessary) should a stoppage or malfunction occur. The quantity of explosive maintained in the primary feed hoppers will depend on type of explosive and safety limitations. Powder will be dispensed in measured amounts corresponding to weight or volume required for the individual increments at the consolidation points. Vibratory type feed mechanisms, forced feed types, moving belt, gravity and pneumatic feeds will all be considered.

3. Inspection of Loaded Parts:

Height of charge will be determined by automatic probes, weight by automatic weighing devices. Rejected parts will be cycled out of the system for recycling or discard as required.

4. Sealing and Crimping:

Automatic sealing and crimping will be utilized. Available sealing equipment does not appear suitable for high volume automated production. It will probably be necessary to design and build entirely new equipment for this operation.

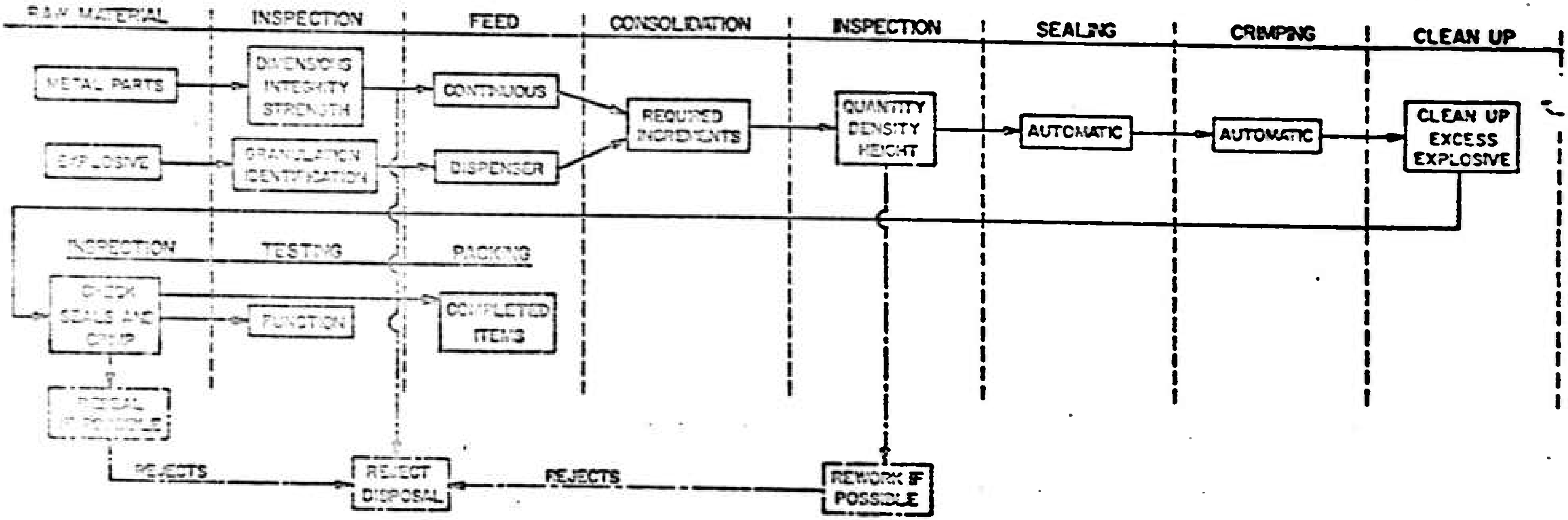
5. Testing:

The sampling procedure to be followed will be set up by the computer. Functioning tests will be performed automatically with the results displayed on the control panel. Failure beyond specficiation limits will close down operations if this should be desired. The system will provide an override so that operation can continue despite failure to meet specifications.

6. Packing:

Automatic packing equipment will be developed. The high rate equipment in industrial use will be studied for adaptability to explosive operations. Vacuum, air pressure, magnetic, and mechanical pickups will all be considered.

The use of a carrier as the vehicle for transferring the detonators through the system which will also be the inner packing container may solve the problem of orientation of the items since many detonators have L/D ratios of unity or close to it. Design of the overall system with the intent of utilizing the basic packing container as the carrier is a desirable approach since the ultimate destination of the packed detonators will be loading and assembly plants where complete munitions will be produced. Return of the packing containers to the point of origin should present no problem.



BASIC PROCESS FLOW FOR DETONATOR LOADING

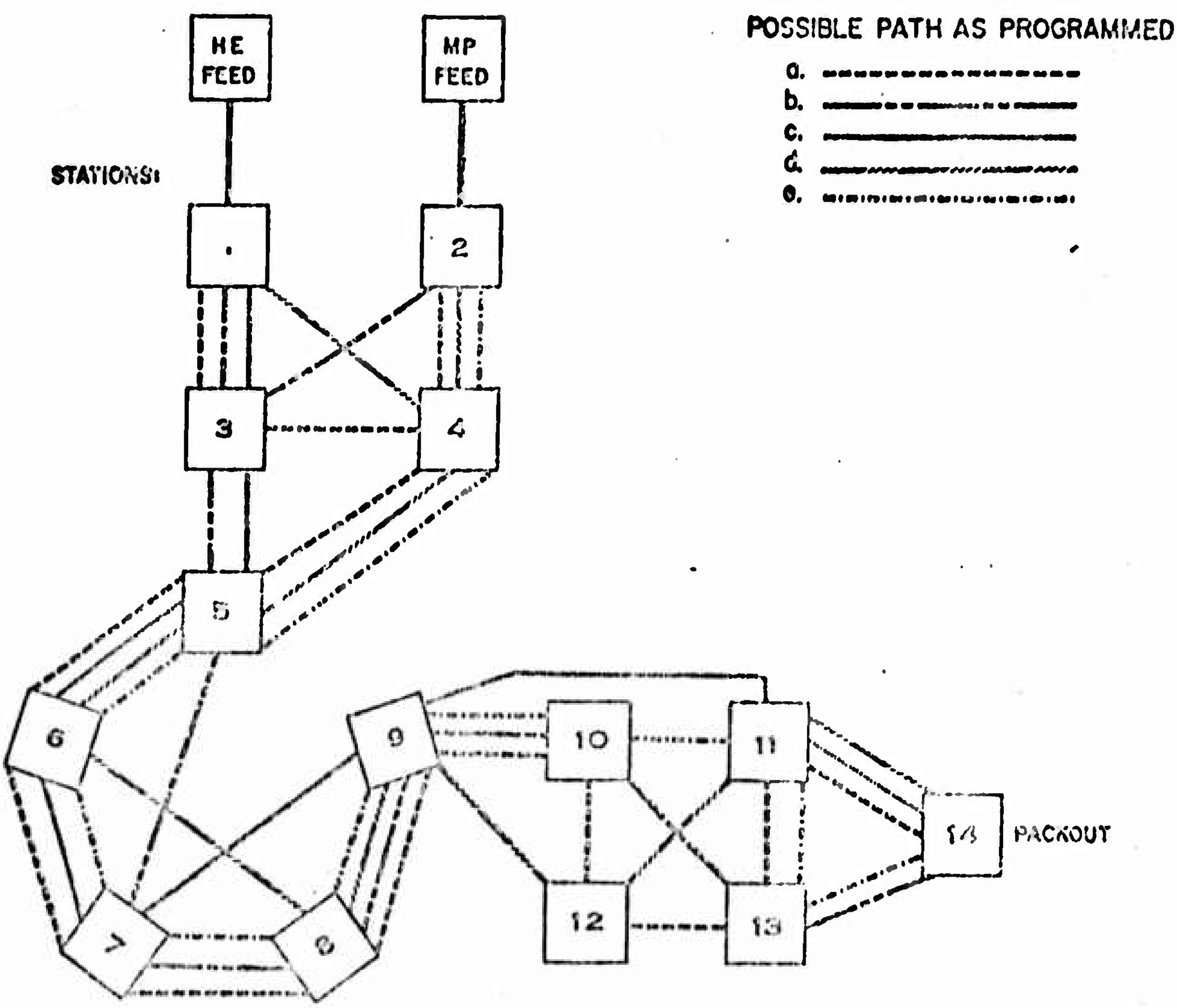
Fig. 2

COMPUTER

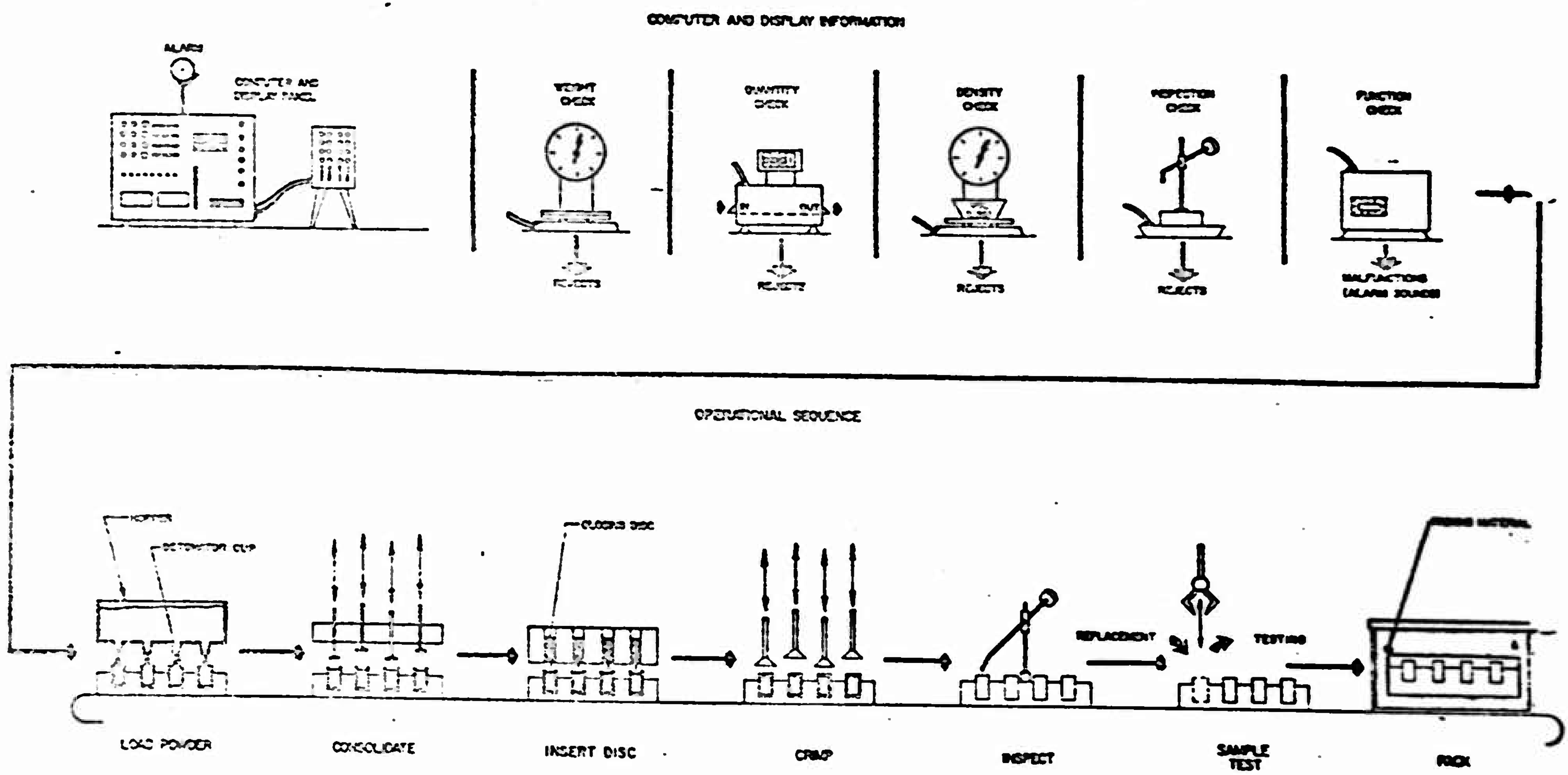
ITEM
NO. OF INCREMENTS
PRESSURES
SEAL, TYPE
CRIMP, TYPE & PRESSURE
MARKING
NO. OF ITEMS
LINK-UP OF STATIONS
TIMING SEQUENCE
INSPECTION PLAN
SAMPLING PLAN
WEIGHT PER INCREMENT

DISPLAY

NO. OF ITEMS THRU EACH STATION
NO. OF ITEMS REJECTED & ACCEPTED
SOURCE & TYPE OF MALFUNCTION
SOURCE & TYPE OF TEST FAILURE
PRESSURES, ETC FOR EACH STATION



COMPUTERIZED INTERLOCKING DETONATOR LOADING SYSTEM



COMPUTERIZED AUTOMATED PRODUCTION LINE

Fig. 4

APPENDIX 2

Gulf + Western Cartridge Module "A"

The Cartridge Module (A) is a manufacturing system for producing a complete cartridge. It is composed of sub-modules for manufacturing and assembling the cartridge's major components which are inter-connected by the Component Transfer System.

A sub-module is a group of equipment required for the manufacture or assembly functions necessary for the production of a complete cartridge. Associated sub-modules which make up the Module (A) are; Case Sub-Module, Bullet Sub-Module, Primer Insert Sub-Module, Load and Assemble Sub-Module, and Packaging Sub-Module.

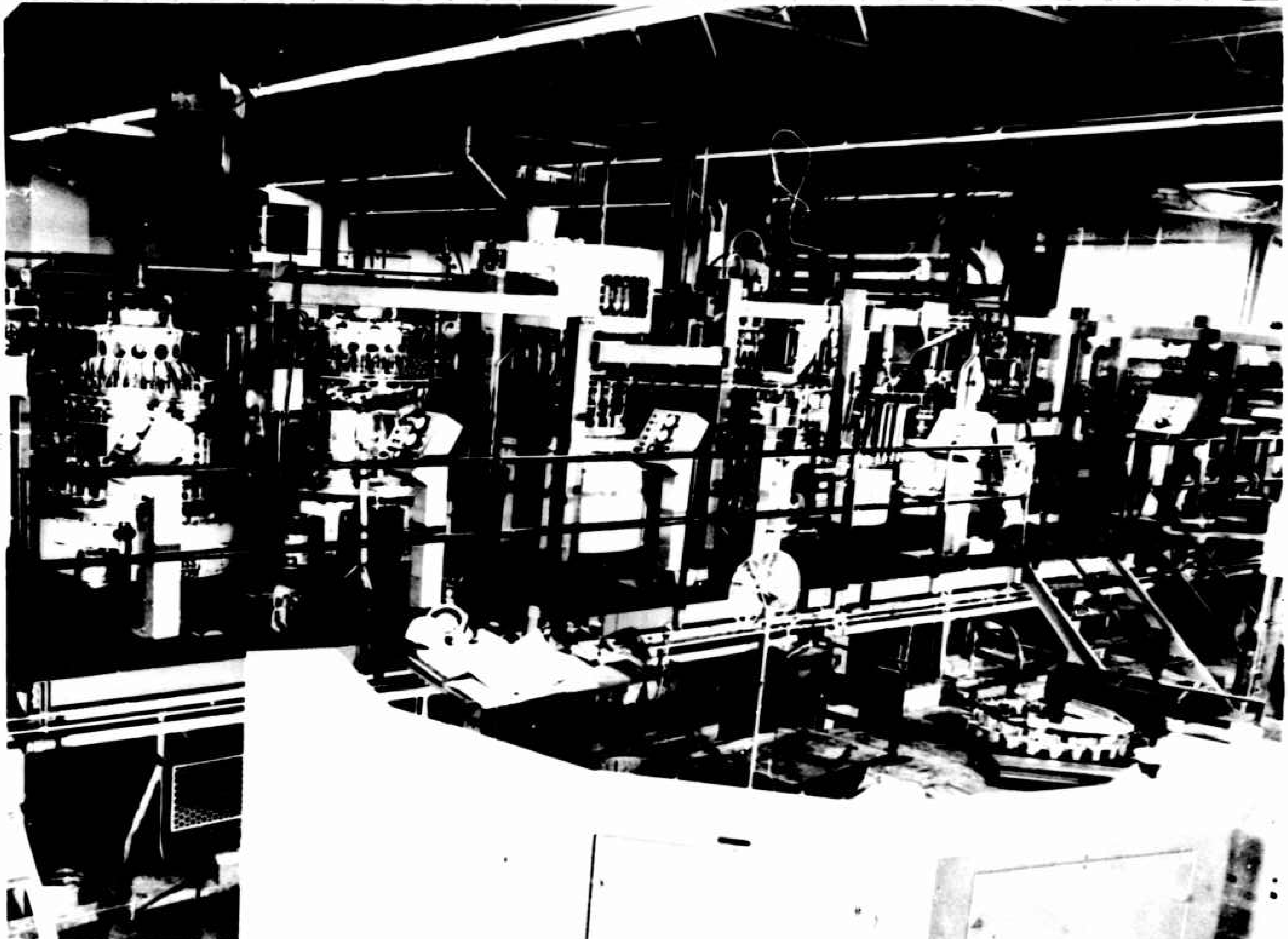
The Case Sub-Module (B) is tooled for the 5.56mm cartridge case, and with minimum alteration, is readily adaptable to the manufacture of 7.62mm, caliber .30, and caliber .30 carbine cartridge cases.

The sub-module is an in-line machine system of interconnected rotary presses and associated machinery. Continuous and positive movement is provided by the rotary forming equipment and workpiece transfer system. Twenty-four tooling stations are used on the presses throughout the Bullet Sub-Module. Two tool modules are installed on each of twelve slide and roller assemblies, except for the Trim Press and the First Boattail Press which have two tools on each module. The presses operate at a maximum of 50 rpm to produce up to 1200 parts per minute. The linear velocity of the workpiece is 6.67 feet per second during press rotation of 50 rpm.

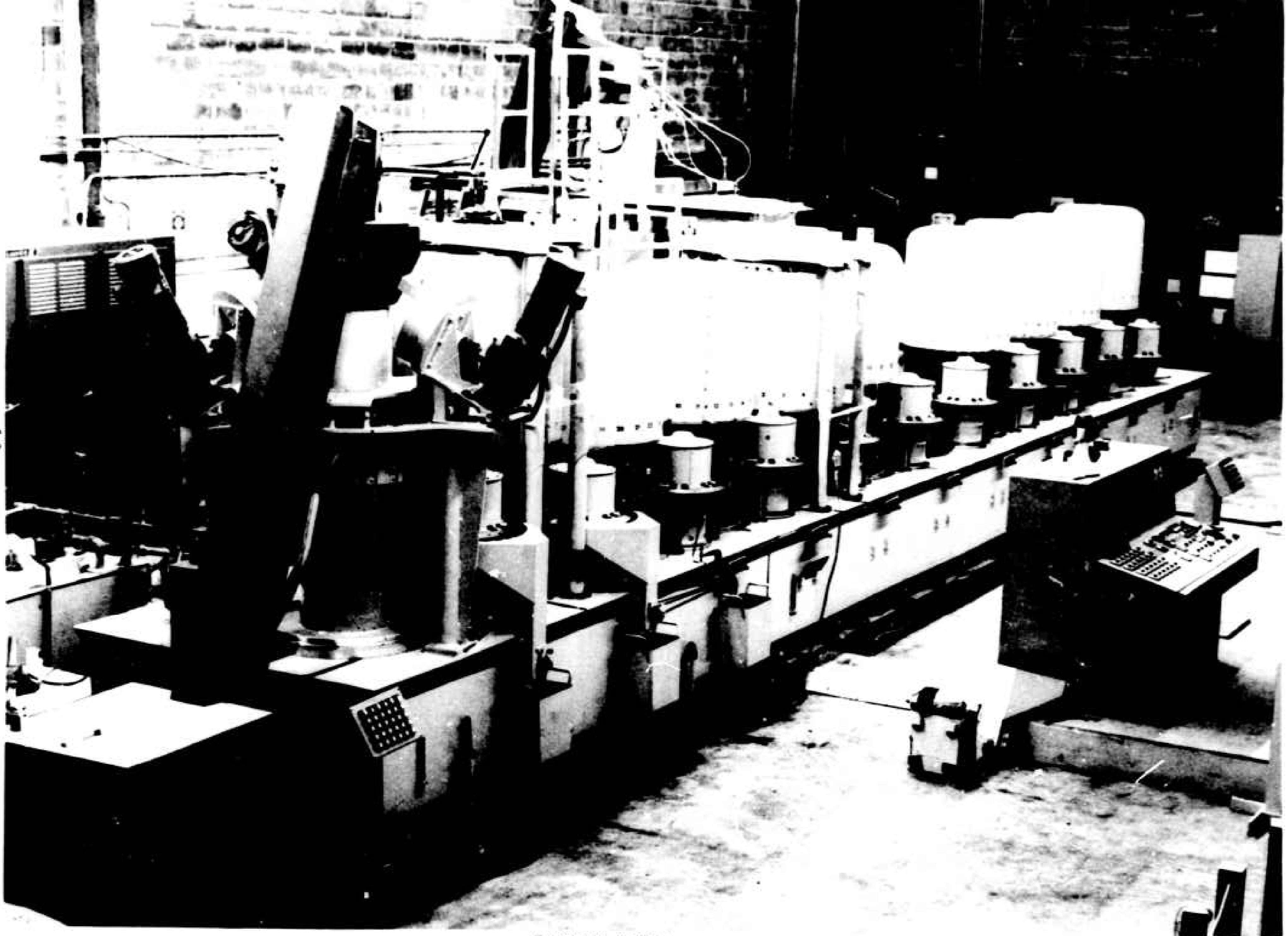
Workpiece identity is constantly maintained on a 24-station basis. The physical arrangement of the forming and transfer turrets ensures that a workpiece once entering the sub-module at a designated tooling station will be subsequently operated on by a corresponding numbered station through the entire process cycle.

The Bullet Sub-Module is tooled for the 5.56mm bullet, and with minimum alteration, is readily adaptable to the manufacture of 7.62mm, caliber .30, and caliber .30 carbine bullets.

The "Case Line" and "Bullet Line" are shown in the accompanying photographs in their current stage of development (early 1973).



CASE LINE



BULLET LINE

APPENDIX 3

Trip Report Extracts

Hal Wanger

to

Perry Industries
Hicksville, N.Y.

9-19-72

Wm. Kalmar
Dave Wilson

Mr. Kalmar discussed various jobs Perry had done, among them the following:

(1) The automatic micrograval machine delivered to Picatinny which had tested out at 20 units/min. but which has never been run at Picatinny due to cancellation of the program.

(2) The 40mm grenade assembly machines (M406) which ran at 45 units/min. Three lines each were set up at Ravenna, Joliet and Milan.

(3) An assortment of filling station machines for Atlas Chemical (now ICI) to fill micro detonators, 15 mg of L.A. and 12 mg of HMX, built to operate at 30-40/minute.

(4) An assortment of inert filler machines to operate up to 1300 units/ min. for the food, drug and chemical industry.

(5) A line to operate at 20 units/min. to manufacture a rubber cartridge filled with CS for Edgewood Arsenal.

(6) A cigarette filter machine to insert filters into cigarettes and cut them at 2400 units/min. for a major cigarette manufacturer.

All of the above equipment had been delivered and were seen only on photos they happened to have. Mr. Kalmer demonstrated the Accufill system of alternate vacuum pickup and pressure delivery by means of lab equipment and then showed me some equipment (not actually run) which is shown in the Perry literature.

Perry is supplying a sub-module to load propellant and assemble bullets into cartridge cases for the Gulf + Western Cartridge Module "A". It is designed to operate at 1200 ppm but is still in the building stage. The propellant loading module (NC844 and IMR282M) and some of the gaging was demonstrated with the computer (without cartridge cases). The series type dispenser might possibly be used for lead azide, but there are pinch points. A "nuclear counter" is used to measure charge height.

A number of machines in the 250-300/min. range includes a sterile liquid filler, a sealed capsule assembler and a stopper machine.

APPENDIX 4

Trip Report Extracts

Hal Wanger

to

Olin-Winchester
New Haven, Conn.

9-28/29-72

Dave Findlay
Edward Staba

Frankford Arsenal
Geo. Miller
Ed Rempfer

Olin is under contract to Frankford Arsenal to build a demonstration model of an automatic primer loading machine which uses an extrudable mix. They have a patented process which uses about 2% Karaya Gum in a water-wet primer mix. Karaya Gum is a natural gum, but is modified by deacetylation (partial removal of vapor constituents by heat). See U.S. Patent No. 3,423,259, Jan. 21, 1969, Edw. A. Staba for details.

The mix is extruded into metering cavities, doctored off by teflon blades, then punched into primer cups underpaper discs which are punched out in the same operation. (They serve to keep the punches clean and prevent dusting when the primer mix is dry.) The loaded cups then receive anvils and are dried. When dry, a drop of shellac is added to assist in prevention of dusting and contamination.*

Observations:

1. Test results to date tend to indicate a slight increase in functioning time of primers made with Karaya Gum. (Most of the gum remains even after the moisture has been driven off.)

2. The thin film of mix left on parts can dry rapidly and be hazardous.

3. There is a question as to whether such mixes can be consolidated at high pressure as required in detonators.

4. Detonators must be sealed, so complete drying would be required prior to sealing.

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* Current production practice is to apply the shellac or lacquer before drying the primers.

APPENDIX 5

Trip Report

Martin Friedland

to

International Machine Tool Show
Chicago, Ill.

9-12/13-72

Trip Report - The International Machine Tool Show
Chicago, Illinois
Sept. 12 & 13, 1972

Purpose of the trip was to investigate machines and processes which may be applicable to the high-volume, high-rate production of detonators. The following companies were visited at the booth in the Chicago Show:

Dake Corporation, Grand Haven, Michigan

This company builds high speed hydraulic presses for blanking and assembly operations. The hydraulic press is capable of operating at 900 strokes a minute, with a stroke of 1/4" to 1/2". The presses are used predominantly in the manufacture of small metal parts.

Sacma Company, Italy

This company makes thread rolling equipment which utilizes a pair of flat dies. The dies reciprocate in opposite directions with the part trapped between the dies. In this manner, the threads are formed on the part. They are capable of feeding and handling up to 450 parts per minute. Feeding is accomplished by vibratory bowl and feed chute arrangement.

Bruderer of Germany

This company makes a short stroke, high-speed blanking press. The press on exhibit was being utilized to blank small electric motor laminations at a rate of 550 parts per minute. The material was fed in in the form of pre-coated steel stock. The parts were blanked out, two parts being blanked at one time, one inside the other. The parts were separated and discharged into a stacking device.

Vibramatic Co., Inc., Noblesville, Indiana

I spoke to Mr. David Nelson, President of the company. The company makes vibratory hoppers and feeders. They have made feeders for detonator cups which operate satisfactorily up to 1800 per minute. They have supplied these cup feeders to such companies as U.S. Royal, Gilman Engrg. Co., Swansen Erie, and the Clyde Corp. They have also made feeding equipment which is capable of feeding brass cartridge cups and orienting them at high speeds. The equipment on exhibit seemed to operate quite satisfactorily.

Prutton Corp.

This company is a manufacturer of thread rolling machines. The thread rolling is done with a cylindrical roll and convex segments, which bear against the outside of the cylindrical roll. The screw blank is fed in between the rotating circular roll and the stationary segment is rolled in that manner. The machine on exhibit was rolling a 10-32 thread machine screws about 1-1/2" long at the rate of 640 pieces a minute. Feeding of the screw blanks was accomplished by means of a vibratory bowl and feed track system.

U.S. Baird, Stratford, Conn.

I spoke to Mr. Charles N. Warner, Sales Promotion Manager. They had a number of pieces of equipment on demonstration at the booth. One was a 28-station horizontal press utilizing strip stock which was being used to form and assemble 100 hose clamps per minute. Also on exhibit was a transfer press operating at 300 strokes a minute making hollow spherical balls for the jewelry industry. This press is capable of making 600 parts per minute by utilizing a double-ended feed system. The company makes cam-operated machines which are capable of exerting as high as 150 tons per station by use of 50-ton cams and a 3:1 toggle linkage system. At one time, this company made special equipment which was utilized in the ordnance field. However, at this time, they do not manufacture any highly specialized equipment, but rather stick to a standardized line of machines.

Minster Machine Co., Minster, Ohio

They had on exhibit a motor lamination machine which consisted of two high speed mechanical presses and a large dial table. The dial table was used to index the motor lamination blanks to each of the presses. The high speed presses would then blank out the motor lamination notches, one at a time, while the blank was rotated underneath the punch. The presses operate at a rate of 1700 to 2000 strokes per minute.

National Acme Co., Cleveland, Ohio

Manufacturers of Acme-Gridley screw machines. They had a number of various sizes and model screw machines on demonstration at the booth. The highest production rate screw machine requires about 0.7 second per cycle which will produce approximately 100 finished parts per minute. These machines are capable of performing eight (8) operations on each part at this high speed. The machines utilize a wire feed system or are capable of handling bar stock.

V&O Press Co., Hudson, New York

The company had on exhibit a high speed transfer press doing a blanking operation at the rate of 200 parts per minute. This company had provided equipment for munitions industry, but refuses to discuss it, since we are competitors.

Schuler Company, Germany

The company had an electric motor lamination line in operation. The line consisted of three presses and a large dial index machine. Strip stock was fed into the first press, which blanked out the rotor and stator blanks. The blanks were then separated and fed into the lamination notching machines. There the blank was rotated under the punch which was operating at 1300 strokes per minute. The equipment is of first class quality and is well engineered.

Townstead Rivet Co., Div. of Texton

The company makes riveting machines as well as rivet making machines. The maximum speed of riveting is only 80 to 90 parts per minute. The limitation of high speed riveting is handling of the parts. They feel that riveting machines will operate as high as 600 parts per minute if the solution of feeding of the parts can be accomplished.

Bihler Company, Germany

This company had on exhibit two (2) very fine operating rotary forming machines. The machine consists of a coil stock feed, feeding into a 3-station blanking die. Here the parts are blanked and separated. They are then fed into a 6-station rotary cam operated machine which forms the part into the finished shape. One machine was operating at 600 parts per minute utilizing steel strip stock. A second smaller machine doing a similar operation on brass stock was operating at 1,000 parts per minute. Both of these machines operated very nicely. However, the noise level of the larger machine started to increase at a very significant rate at about 400 parts per minute. At 600 parts per minute, the noise level of the equipment was quite severe. It should be noted, however, that the machine covers had been removed to allow viewing into the operating mechanism of the machine. Undoubtedly, with covers in place, the noise level would be considerably reduced.

Fastener Engineers, Inc., Rockford, Ill.

This company makes machines for heading and slotting of fasteners such as screws. They had two fastener slotting machines operating. The machines are quite small in size and use the vibrating bowl and feed track system to feed the parts. The machines have a rotary turret with v-notches cut at the edge of the turret. A pusher device pushes the blank into the v-notch. Since the turret rotates, the blank is carried around with it trapped against a stationary plate. The turret then rotates the head of the screw under a pair of slitting saws which are used to cut the slots in the screw heads. The two machines operated at 600 and 1200 parts per minute. The feeding of the parts into the machine appeared to be no problem.

Esab Company, Sweden

This company had a wire draw and cut-off machine. This is used to draw wire to final diameter and then cut the wire off into pre-determined lengths. The machine was capable of operating at 1050 parts per minute.

Clearing Div. of U.S. Industries, Chicago

Clearing had on exhibit a machine which is designed and manufactured in England for which they have the American Rights. The machine is a high speed transfer press, which was tooled up for blanking out small parts. The transfer press is available from 4 to 8 stations. The transfer mechanisms were all cam actuated. The machine operated very smoothly and made parts at the rate of approximately 300 per minute. I discussed with two members of the English Company which built the machine, the use of this type of equipment for the manufacture of ordnance components. They are suppliers to the government arsenal in England. However, due to low production requirements, they are able to satisfy the government requirements by the use of this type of transfer press. They have tooled these machines for making parts for 5.56mm and 7.62mm cartridge cases and bullets. The machine was very well-built and operated with practically no vibration.

M. Friedland

APPENDIX 6

Trip Report

H. Wanger
E.E. Hannum

to

Lone Star AAP
Texarkana, Texas

10-3/5-72

TRIP REPORT

LACE: LONE STAR ARMY AMMUNITION PLANT
TEXARKANA, TEXAS

PROJECT: 05308

DATE: 10-3/5-72

VISITORS: HAL WANGER, PICATINNY ARSENAL, MTD
E.E. HANNUM, G+W R&D CENTER

PURPOSE: TO STUDY TECHNIQUES AND EQUIPMENT CURRENTLY USED AT LONE STAR TO MANUFACTURE NON-ELECTRIC DETONATORS

DISCUSSION

1. Our guide was Ken Elliott of Day & Zimmerman, operators of the GO-CO Plant for the past 20 years. The production line is in two sections; the "back line" where the explosive materials are received and conditioned, and the "front line" where the dry explosives are loaded into detonator cups.

2. The "Back Line"

The back line consists of a number of thick-walled, reinforced concrete and masonary buildings dispersed in a large field and connected by covered concrete sidewalks. The distance between the buildings conforms to the Quantity-Distance Tables in the AMCR 385-100 Safety Manual. Each type of explosive is received and conditioned separately. Lead Azide, for instance, is received in 55-gallon drums that weigh about 600 pounds when loaded and contain 10 conductive-rubber-lined cloth bags each containing 15 pounds of wet lead azide. It is drowned in a water-alcohol solution and the individual bags are separated by quantities of wet sawdust.

The bags are removed from the drum, washed and placed in stainless steel buckets and covered with alcohol. Each building has an open drain through to a basin or ditch outside, where waste materials are flushed into a "kill" solution which consists of Nitric Acid and Sodium Nitrite in water. At the end of each shift, the pool is boiled with steam then the residue is tested. If "killed", it is then drained off to a disposal area and allowed to "leach out" into the ground.

The concrete floors (conductive, some are covered with lead) are kept water-wet and all personnel must wear conductive shoes and anti-static clothing (cotton). Shoes must be cleaned on a wet rubber mat before entering buildings. Personnel are not permitted to step off of the concrete walks.

The reason for this is that they have had several injuries caused by the ground exploding under peoples' feet. They don't seem to know why this happens. However, the explanation seems obvious. In each building, filtered air is forced in, but allowed to leak out through whatever openings exist. The air leaking out carries explosive dust and evidently deposits a lot of it on the ground nearby. The grinding action of peoples' feet on the explosive dust and gritty earth cause explosions.

This line of reasoning is supported by similar phenomena in the front line. Even though every effort is made to clean away dust from the machines (using vacuum pick ups after each step in the process) dust evidently still accumulates on the equipment, though hardly visible. Sometimes, when a "blow" occurs in a consolidation operation, it will propogate around the entire machine via the accumulated dust.

This serves to illustrate the hazard involved in loading dry, sensitive primary explosives and "initiating" explosives such as lead azide, lead styphnate and priming mixes. At Lone Star only one ounce at a time of these materials is placed in the barricaded, metering-consolidation stations. When a blow occurs, the metering device is destroyed and the punch and die usually damaged (but readily replaced). Many spare metering devices are kept on hand.

Single 15-pound bags of wet lead azide are transferred via a "baby carriage" pushed by an operator to another building where it is kneaded and mixed by rubber-gloved human hands. Conductive rubber cylinders lined with a cloth strainer are filled with about 2 pounds of wet lead azide and then placed over an aspirator flask and most of the liquid is drawn off.

Six of these (approx.) 2-pound containers are placed in a conductive rubber box and wheeled in the baby buggy to the dry house. Here they are placed in a rack and warm air forced thru until the material is thoroughly dry. There may be as much as 600 pounds in the dry house at one time!

Two-pound batches of dry azide are sieved in a "jelly bag" strainer, in a heavily barricaded room, by remote control. At this point, samples are taken to determine acceptability of the batch. Moisture content, purity, and grain size are among the tests performed. If acceptable, the 2-pound batch is placed in a barricade which contains a scale balance and remotely-operated manipulating devices. By this means, one-ounce quantities are placed into steel cups in separate, conductive-rubber-containers. These are then moved into the front line, one at a time as needed.

Other primary explosives such a lead styphnate are handled in similar fashion, but in a separate line.

The priming mix materials are received separately and blended in a barricaded, remotely-controlled operation.

Output charge explosives such as RDX are received in moist condition in 50 # containers. In some operations, the output charges are loaded in pellet form then reconsolidated when loaded into detonator cups.

The buildings and covered walkways are fitted with lightning rods and heavy ground conductor cables and, of course, all precautions are taken to avoid static electricity and other sources of stray energy.

3. The "Front Line"

From the outside, the front line looks like two rows of horse stables you might see at any race track. At Lone Star, two rows of about 18 "stalls" each face each other across a "no-man's land" of about 30 yards. Each stall has three thick reinforced concrete walls with steel doors forming the fourth wall (front), and houses a complete assembly "front line" for a particular type of detonator, lead or delay.

Outside of the stalls, used for making detonators and leads, are heavy steel barricaded "ready box" storage chambers for the priming, intermediate and output charge materials waiting to go into the line (in one-ounce increments).

Barricades are of welded steel construction, usually rectangular in cross-section and extend from the concrete floor up through the roof in order to vent the explosive end-products in case of a "blow". Access doors are also heavy steel plate, are larger than the opening and open inward so that internal pressure cannot blow them off their hinges. Although of mostly welded construction, where bolts are necessary, the heads are inside the barricade. If studs and nuts are used, the threaded holes do not penetrate through the steel wall. This is to avoid making projectiles of nuts and bolts in case of an explosion within the barricade.

View ports are small and fitted with about 4 thicknesses of 1/8" thick LEXAN (G.E. Co. polycarbonate), the number depending upon the results of safety tests.

The production lines differ depending upon the item being manufactured and the quantities required. Some are almost completely manual and others are almost completely automatic. The highest degree of automation is probably accomplished with the Lone Star modified, Ferguson "Trans-o-mater". It is capable of producing from about 30 to 60 finished items per minute (depending upon the complexity of the item) with very little assistance from the human operators. The operators must manually supply raw, bulk (one-ounce quantities) of explosives to the metering stations, detonator cups to the cup feeder-orienter and reels of metal to the closure disc blank and insert stations.

The Trans-o-mater is an indexing, in-line system on a continuous conveyor featuring a transfer belt with flexible steel segments. Each segment mounts alignment fixtures for centering dies under the metering devices and consolidation rams. The dies receive cups, open end up, then are moved into barricades where an explosive charge is metered in.

Consolidation pressure is regulated by calibrated, spring-loaded rams (there is no dwell time) and charge height is monitored by detectors on the rams. One highly regarded device is the "Electricator" an electric dial indicator made by Federal Products Corp.

In some cases output charges such as RDX are loaded in pellet form then reconsolidated. Closure discs are blanked from strip stock and punched right into the detonator cup. Crimping is done in two steps, 45° and 90°. The 90° crimp is used as a sizing operation to bring the detonator into the length tolerance.

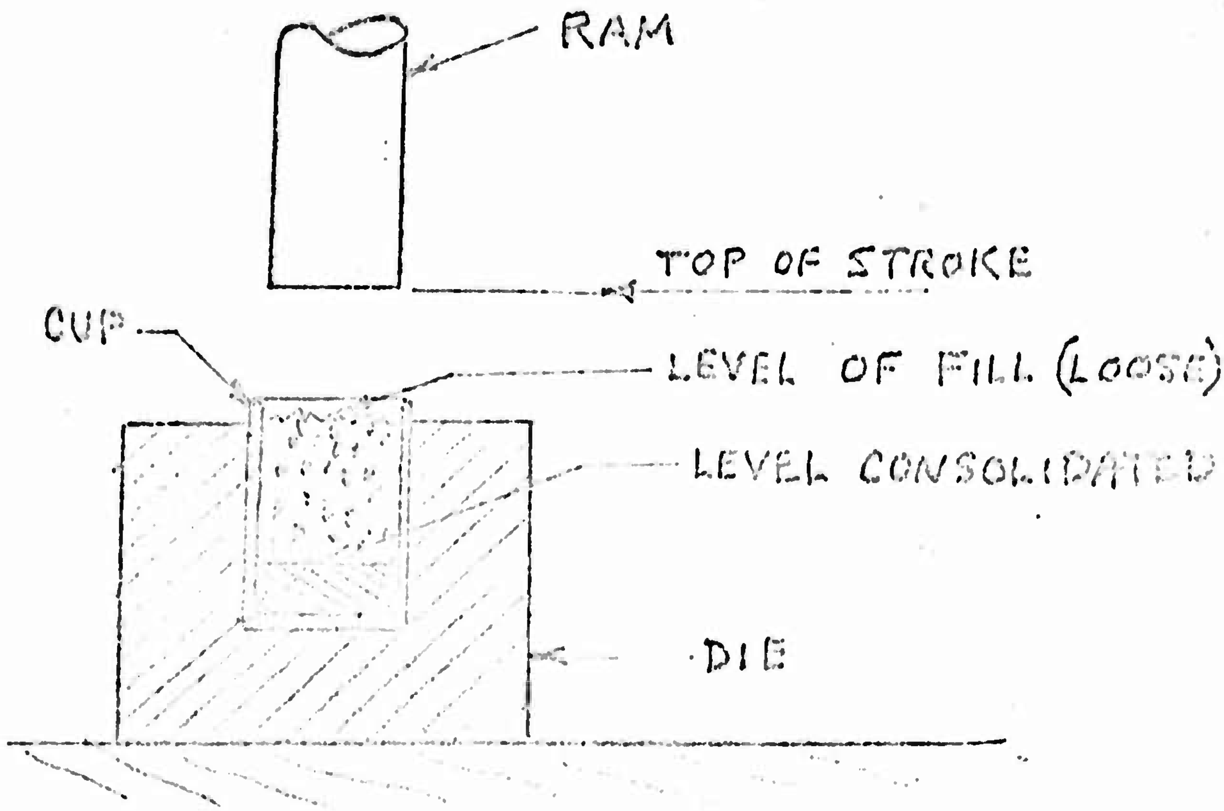
Inspection is 100% and is completely manual and visual. Rejection rate is reported as high as 30%.

4. Miscellaneous Notes

4.1 Pressure dwell during consolidation is not considered necessary. When called for in the specifications, Lone Star usually demonstrates that it is not needed.

4.2 It was reported that the system used at Lake City AAP, which features a 110-cavity metering platen system, suffered such a serious explosion that they were out of production for about 2 years. Lone Star loads only one cup at a time.

4.3 No one seemed to know how fast the consolidation rams move during consolidation. However, we can calculate an approximate speed. At 30 ppm (one every 2 seconds) if we assume 1/2 second to move the workpiece into the consolidation station and 1/2 second to move it out, there is one second for consolidation. If we assume the ram contacts the loose explosive 1/2 way down its stroke and consolidates from a height of .250 inch to .050 inch, the consolidation stroke is .200 inch and performed in 1/4 second (see sketch). Thus, the consolidation rate is .200 inch per 1/4 second or .8 in./sec. or 48 in./min. or .067 ft./sec.


RAM
TOP OF STROKE
CUP
LEVEL OF FILL (LOOSE)
LEVEL CONSOLIDATED
DIE

There are two metering devices currently in use. One is the Cargil Scooper which is simply a small shallow spoon that dips into the mix (used mostly for priming and delay mixes) and is leveled off by a "doctor" blade. This is also used manually.

The second metering device is a little more complex. It is the Chamlee Loader. It consists of a lucite or plexiglas block about 3.5 inches long and 3/4" square into which are drilled two intersecting cylindrical passages, each about the same diameter as a detonator cup. The intersection angle is acute about 30° or less. Lead azide feeds down a flexible tube, from the one-ounce capacity funnel-hopper located just above, into the cavity formed in the lucite block just beyond the intersection of the two intersecting passages. Flexible, vacuum-air hoses supply tiny air cylinders which adjust the cavity if it meters too much or too little. This adjustable volume cavity is the metering cavity. When a detonator cup in a funnel-die is positioned beneath the metering device, the device is inverted and the metered charge drops into the detonator cup. The "doctoring" occurs at the sharp shouldered intersection of the two cylindrical passages.

This device seems to give accurate and consistent results, but the quantity of lead azide frequently exceeds one ounce because the funnel must be filled before it is quite empty and the tubing holds almost one ounce. If a blow occurs, the entire device is destroyed. For this reason, about 20 spares are always maintained in ready condition.

4.4 Detonators are too small to have any identification marking other than the colored lacquer used to seal and identify the output end. Their identification is on the packages into which they are placed after acceptance inspection.

4.5 Lone Star makes all kinds of non-electric detonators, leads and delays. Among those in current or recent production are the following:

M55	M80
M42	MK95
M76	M59
M35	M58
M24	M87
M63	

4.6 It was generally agreed that one of the most difficult problems to be solved in high-volume, high-rate detonator production is that of bringing sufficient quantities of sensitive explosive to and through the line safely.

4.7 Lone Star has been working on an automated conditioning system, funded by Picatinny Arsenal. Ken Elliott has a prototype system in operation with which he plans to demonstrate feasibility of the approach. From this, he hopes to be able to design a functional system. His prototype is essentially automation of the current "back line" processes all consolidated behind one heavy barricade. It processes two pounds at a time and has the obvious disadvantage that a blow will wreck the entire system.

4.8 It appears that new approaches are needed. Current safety regulations almost dictate a batch process. However, if a simpler more effective means of desensitizing the bulk explosives so they could be handled and loaded safely in larger quantities were possible, this would not be such a limiting restraint.

Another concept is to simply automate the present back line and feed the one-ounce or less quantities steadily into the line in isolated, barricaded containers.

4.9 One great stumbling block was reported. Apparently, the U.S. Government has stock piled enough lead azide (stored in the customary water-alcohol wet 15-pound bags) to meet all requirements for the next 40 years! So whatever scheme is used, it will have to start from these.

5. Dust Control

It is interesting to note that the mechanisms used in the front line are not covered. The Lone Star philosophy is that covers tend to hide accumulations of explosive dust, thus creating "big bombs". Thorough cleaning at periodic intervals is standard procedure. All surfaces must be easily accessible or they might be neglected. Vacuum cleaner lines with water traps are plentiful at Lone Star. Much use is made of air jet (venturi effect) pumps.

E.E. HANNUM

APPENDIX 7

Trip Report

H. Wanger
M. Friedland

to

Lake City AAP
Independence, Mo.

10-10/12-72

Project 05308

TRIP REPORT

Date: 10-12 October 1972

Location: LCAAP, Independence, Mo.

Purpose: To study techniques and equipment currently used at LCAAP to manufacture non-electric detonators.

Contacts: Mr. Frank Green, Chief of Operations Review
Mr. Ed Thornton, Industrial specialist
Mr. Frank Lowrey, Supt. of Loading Bldg. - Remington

Visitors: Hal Wanger, Picatinny Arsenal MTD
M. Friedland, G+W R&D Center

1. DETONATOR LINE

We were given a brief visit of the back line which consists of a number of thick-walled, reinforced concrete and masonry buildings dug into large mounds of earth. These buildings are used to store and separate the various explosives from large quantities to smaller quantities. After the explosives have been reduced to smaller size packages, they are taken into to drying rooms for drying and subsequent transfer to the loading areas. The back line at Lake City is quite similar to that at Lone Star. Most of the procedures used are quite similar to that at Lone Star for handling and weighing the explosives. Ted Hannum's trip report (Lone Star) contains an extensive explanation of the handling system for handling explosives in the back line area and since Lake City's procedures are almost identical, details of these operations are not included.

2. DETONATOR FRONT LINE

Lake City currently produces only the M57E1 detonator which is used in the 20mm cartridge. They are producing these detonators at between 200 and 300 per minute on one line. Lake City uses the 110-hole loading plate system. The detonator cups, which are made in a separate building are shaken in a bag to lubricate them with graphite. The graphited cups are loaded into a bin. Several female operators take the 110-hole loading plates, lay them into the bin full of cups, pour cups over the top of the loading plate and very slowly move the loading plate back and forth. After some 10 or 15 seconds, most of the holes in the loading plates have been filled with detonator cups which fall into the holes with closed end down. Any cups that are inverted are removed and any holes that are not filled with cups are filled individually. A solid plate underneath the loading plate prevents the cups from falling through. The loading plates now are assembled with a filling plate which contains 110 small funnel-shaped openings. The three plates are then clipped together by means of spring clips which hold them together in proper alignment.

At this time, the plates are taken into the loading area. The powder loading area consists of a series of 8 or 10 cubicles arranged in pairs. The left hand cubicle of each pair contains a filling machine, while the right hand cubicle contains a 100-ton, Oilgear, "C", frame hydraulic press. The first cubicle is therefore used to load the first powder which is the primer mix. The operator withdraws approximately 1 ounce of the primer mix from a closed box in the back of the cubicle, puts the mix into a rubber boat mounted just above the machine hopper. The operator then goes outside and locks the door. The primer mix in the rubber boat is then tilted by the operator so that the mix falls into a square shaped hopper in the machine. The hopper plate has a recess about 2 inches deep, and the bottom of the plate has 110 holes on the same centers as the loading plate. Each of the holes has a funnel shape. Directly underneath the funnel shaped plate is the metering plate. This metering plate has 110 holes of the correct diameter and by adjusting the thickness of the metering plate is able to meter the correct volume of powder into each hole. The operator loads the loading plate filled with cups onto a chain conveyor outside of the cubicle. The door in the cubicle is opened and the loading plate is pushed inside by the chain conveyor, and the door is then closed. The loading plate and hopper plates are off-set slightly in one direction so that the powder does not fall through. The operator, using manual controls from the outside, then agitates the powder very gently by means of a rubber paddle, and the powder flows into the metering plate. The metering plate is then moved about 1/4" by means of a remote control so that the holes in the metering plate and the holes in the loading plate are directly in line with each other. The powder in the metering plate then falls through the loading plate and into the detonator cup. At the same time, since the holes in the metering plate are now offset from the holes in the hopper, the hopper is effectively closed off from any flow of the powder. The plate with the detonators loaded with the primer mix is then removed by the operator in the same manner as it was loaded. The plate with the powder is now handed over to the operator in the next cubicle.

The next cubicle has the consolidation press. The press has a die set installed in it which in turn has a plate with 110 punches attached to it. The primer mix is consolidated at approximately 24,000 psi and does not utilize any stops at the bottom of the stroke. Consolidation is determined by pressure buildup rather than by a fixed height. The operation of the compaction station is similar to the loading station in that the operator loads it outside, opens the door and the conveyor takes it inside. After closing the door, the press goes through an automatic cycle. The cycle consists of approximately 3 seconds of travel in which the punches travel approximately 1 inch. An 8-second dwell at the bottom and then approximately 3 seconds to return to the top. This means that the punches are compacting at a rate of approximately 20 inches per minute. After finishing, the door is opened and the plate is removed by the conveyor and is then transferred to the next machine for loading the second charge. Three charges are being used for the 20mm detonator. Lead Azide is the second charge which is compacted to 23,000 psi and PBX is the third charge, which is compacted to 2[illegible],000 psi. The compacting of the other two charges is done on exactly the same equipment and in exactly the same manner as described for the primer mix.

In discussing the hazards of this operation, we found out that the Lead Azide compaction was by far the most dangerous of all the operations. Apparently, the Lead Azide is pinched, which causes it to blow. While no exact figures could be given, they indicated that they have 10 to 20 blows a year, primarily in the Lead Azide compaction station. They have not had any fatalities in this area for a long period of time. When the Lead Azide blows, it ruins the entire tool set, but it does not damage the press. Most of the time, in addition, it will blow out either the back wall of the building or the roof.

After compacting the RDX, the loading plate then goes to an inspection machine which was built by Sheffield and utilizes a fluidic gaging process to check the height of the compacted detonator mix. Any detonators which are not within height tolerance are removed.

The loading plate then goes to the next cubicle in which the plate is inserted into the cubicle remotely, aluminum foil is fed into the machine, and by means of suitable punches, a disc of the foil is inserted on top of the detonator powder mix. This aluminum foil serves as the closure for the open end of the detonator. After inspection to see that the aluminum disc is in place, the loading plate is then transferred to a small air-operated press. Here, the girl inserts a crimp plate over the top of the detonator cups which are now sticking out of the loading plate; the funnel plate having been previously removed. The entire assembly is inserted under the air-operated press, resulting in a 45° crimp. The loading plate is then removed from the press and put into another cubicle to perform the 90° crimp. The 90° crimping is done by covering the loading plate with a second crimp plate and a 50-ton hydraulic press. In addition, the detonator height is determined by this operation. The detonators are inspected and then the crimped end is coated with a green lacquer which acts as a sealant as well as an identification for the detonators. At the final operation, the detonators are assembled into the balls which are to be ultimately used in the 20mm fuze. After this operation, the detonator and ball assembly is removed from this building and sent to the fuze assembly area.

Standard Process Records were not available at Lake City. Drawings of the loading plates and all of the rest of the tooling are available, but they will have to be obtained through Picatinny Arsenal.

3. MANUFACTURE OF PELLETS FOR THE 20MM BOOSTER

The 20mm booster uses two compacted pellets of RDX. This job is done in a remote building, automatically. They are using a 27-station rotary Stokes machine. It is arranged so that two pellets are compacted at a time. Since the machine operates at 50 rpm, 100 pellets per minute are produced. The machine uses a cam track to raise and lower the punches; both the bottom and the top punches.

For compacting, the punch head goes underneath a round wheel (both top and bottom punches). These wheels are adjusted to deliver the proper compacting pressure. There are two wheels; at 180° from each other which permits the two pellets to be compacted at the same time. Powder feed system is conventional for a compacting machine.

4. <u>5.56MM PRIMER LOADING</u>

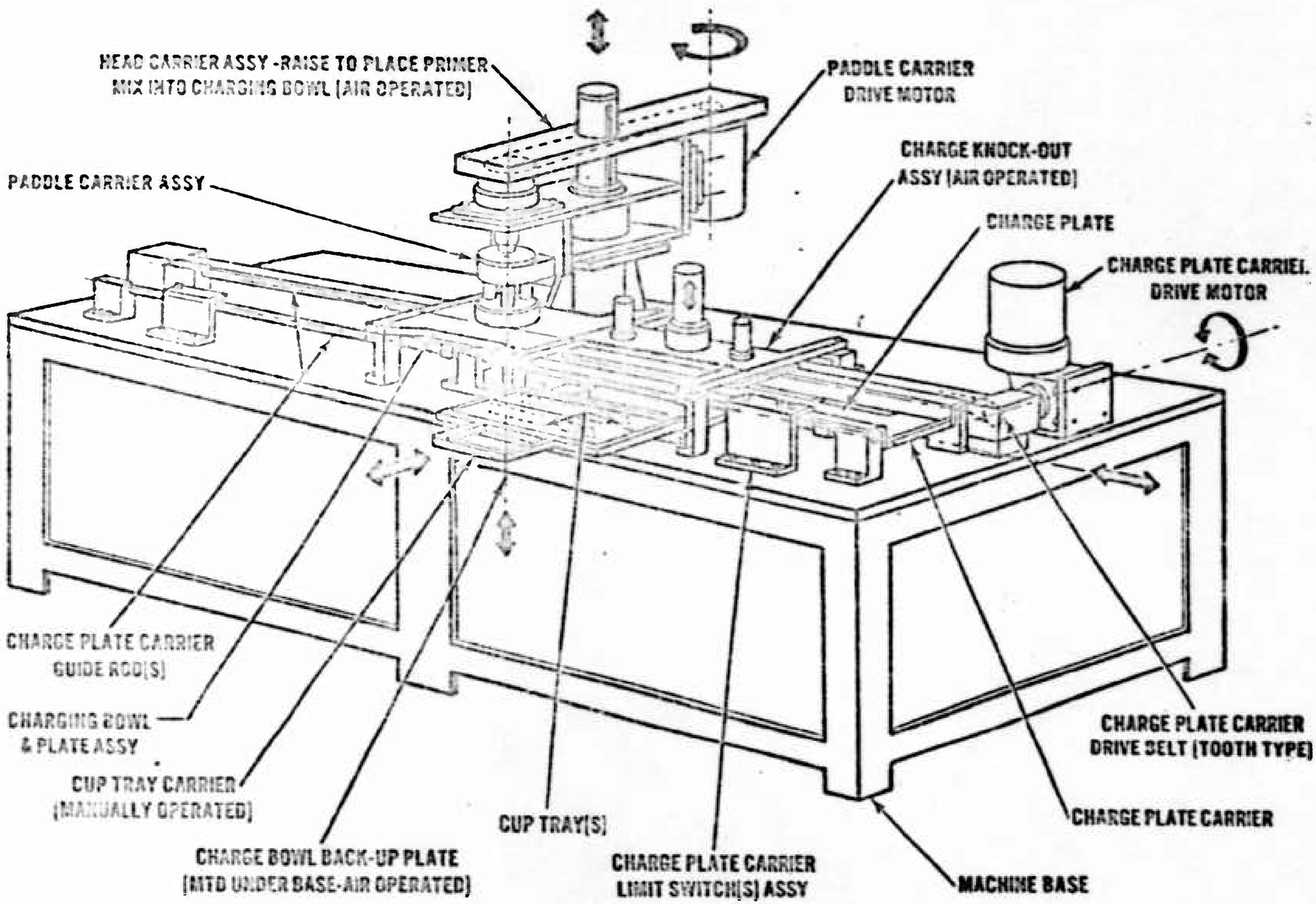
This loading system utilizes a loading plate with 1416 holes. The cups are vibrated into the loading plate, base down in the first operation. The primer mix is pressed into a 1416-hole metering plate by hand, utilizing a rubber tool. The operator presses this rubber tool against the plate to force the wet primer mix into the plate. Filling is done from both sides, and excess material is doctored off. The plate with the mix and the plate with the primer cups are put together under a pneumatic press fitted with 1416 pins, which pushes the mix out of the metering plate and into the cup, and, in addition, compacts the mix. A paper closure is then inserted into each primer cup one row at a time. The primer anvils are loaded into another loading plate also by means of vibration. The plate with the anvils and the plate with the loaded cups are put together and indexed under a press one row at a time, which then pushes the anvils from the plate into the primer cups. Lacquer sealant is then put on the primer by means of a pin fixture, by dipping the pin into the lacquer and then transferring the drop of lacquer on the end of each pin to the primer in the loading plate.

5. <u>THE BENDIX PRIMER CUP LOADING MACHINE</u>

Bendix has a contract with Lake City to make a primer cup loading machine. The machine has been built and is now being debugged at Lake City. The machine has successfully loaded inert material, but problems have arisen when the machine was utilized to make actual primers. The machine utilizes the 1416-hole loading plate concept. In production, they feel that up to four plates per minute could be processed. A schematic is enclosed which shows the basic operation of this machine.

6. <u>20MM BOOSTER LOADING MACHINE</u>

This was a Stokes in-line press which operates at 50 strokes a minute and is double tooled and therefore makes 100 parts per minute. Present production is approximately 26,000 parts per 8-hour shift. This press loads the 20mm booster with two (2) pellets and consolidates the pellets. The operation is as follows: Feed the metal booster part in the first station. The second station feeds two pellets at a time into the booster. The third station consolidates it. The fourth station punches out an aluminum closure disc and inserts the disc on top of the powder. The next station is a 45° crimp, and the last operation is a 90° crimp.


HEAD CARRIER ASSY -RAISE TO PLACE PRIMER MIX INTO CHARGING BOWL (AIR OPERATED)
PADDLE CARRIER DRIVE MOTOR
PADDLE CARRIER ASSY
CHARGE KNOCK-OUT ASSY (AIR OPERATED)
CHARGE PLATE
CHARGE PLATE CARRIEL DRIVE MOTOR
CHARGE PLATE CARRIER GUIDE ROD(S)
CHARGING BOWL & PLATE ASSY
CUP TRAY CARRIER (MANUALLY OPERATED)
CUP TRAY(S)
CHARGE BOWL BACK-UP PLATE (MTD UNDER BASE-AIR OPERATED)
CHARGE PLATE CARRIER LIMIT SWITCH(S) ASSY
MACHINE BASE
CHARGE PLATE CARRIER
CHARGE PLATE CARRIER DRIVE BELT (TOOTH TYPE)

The machine operates like a transfer press, except that the booster parts are carried in metal carriers and attached to endless chains. At each station the chain dwells and the one operation is accomplished. The entire machine is enclosed in the blast-proof cubicle and is operated automatically without attendance. The press is a mechanical press of fairly large bed size but rather light tonnage.

7. THE V&O 5.56MM PRIMER INSERT MACHINE

The primer insert machine is a 300 stroke a minute mechanical press together with a rotary dial table of approximately 20 stations. The cups are fed from a hopper into a set of Mollen's rolls by means of a vibratory feeder. The Mollen's rolls orient the cartridges in a point downward position, and they are then fed down a chute. A pin attached to the slide pushes them from the chute onto a mandrel on the dial table. (The dial table indexes through a start and stop motion 300 times a minute.) The dial table then moves the piece to the next station which checks for the presence of the pocket in the end of the cartridge case.

The next operation pierces the vent hole. Next, a checking operation checks for the presence of the vent hole. Then, upon further indexing, the primer is fed and placed into the primer pocket in the cartridge case. The primers are fed from a hopper down a chute and transferred by means of a starwheel device.

The next index inserts the primer by means of a punch to the proper depth. Presence of the primer is then checked in the next station. The checking operations do not remove the defective part, but stop the machine and a fault light comes on and the operator removes the bad part.

The last station inserts the cartridge into a hollow tube at the bottom. The tube which travels in a vertical direction is attached to the press slide. The bottom end of the tube moves down over the case and holds the case by spring fingers. In each successive operation, another cartridge goes in the bottom and another case then comes out the top of the tube, where a set of fingers grab the case. The case is moved into a device which applies the sealant. The cartridges are then removed on a track device. The presses utilize Honeywell pneumatic controls. Apparently, these are fluidic controls and they have not found them to be entirely reliable. They indicated that the press otherwise operates satisfactorily.

8. 5.56MM CLIPPING AND PACKAGING LINE

The 5.56mm clipping line utilizes the old type rotary clipping machines which feed 5 cartridges at a time into a slot in a rotary wheel by feeding at two positions; ten cartridges are loaded into each slot. The clips were oriented into a belt containing slots by means of a vibrating feeder. Any of the clips which are inverted are blown off by an air jet. The clips are then pushed onto the load of ten cartridges. By this means, approximately 140 cartridges a minute are clipped. The loaded clips are delivered from the clipping machine by means of a conveyor to girls who put the point protectors on the clips and put the two clips into the cardboard carton. They are then conveyed to machines which are used to load the cartons into the bandoleer. This is a "shoe-horn" type loader in which the girl fits the bandoleer over stainless steel horns and upon activating the switch, seven cartons fall down the chute into the bandoleer. About 50% of the time, one or two of the cartons would not enter the bandoleer opening properly and the girl had to jiggle the bandoleers to make the cartons fall in properly. The loaded bandoleers are then put on a conveyor belt where several girls fold the bandoleers and load them into the ammunition cans by hand. The loaded ammunition cans are then delivered to the crating area where the crate is formed around the cans by hand. The crates are sealed manually and sent to a "Gottscho" crate marking machine which markes three sides of the crate. The crates are then conveyed to the palletizing area and palletized and banded manually.

9. 7.62MM LINKING AND PACKING LINE

Lake City has lines for linking both 7.62mm and .30 caliber cartridges. The linking machines run at 550 to 600 cartridges per minute. The 7.62mm linking machine utilizes three feeding hoppers. At the time I was there, they were linking one tracer and four ball bullet-ratio belts, of 100 round length. The machine utilizes three sets of Mollen's rolls. One set of Mollen's rolls feeds the tracer cartridges, while two sets feed the ball bullets. The tracer cartridges come off the Mollen's rolls into a banana tube and are fed into a roller with a slot in it for one cartridge. Adjacent are two sets of rollers with slots for two cartridges in each roller. These are fed by the Mollen's rollers for the ball bullets and appropriate banana tubes. By this means, one tracer is placed into every fifth slot in the grooved belt, and the other four slots filled by two ball cartridges from each of the two rollers, thereby obtaining the one tracer and four ball bullet configuration.

The belt goes up an incline where the cartridges fall into a short magazine tube. The magazine tube then feeds the grooved assembly wheel. The assembly wheel picks off one cartridge in each groove at 600 per minute. A girl feeds the links out of the box of 20 into a chute which in turn feeds the links into the assembly wheel in the same groove, but at the opposite end of the cartridge. As the assembly wheel turns, a cam pushes the cartridge axially into the links and thereby accomplished the linking. An arm with a finger on it directly under the magazine which feeds the assembly wheel is used to determine the length of each belt of ammunition by stopping the feed at every 100th round. This missing cartridge prevents linking and the belts are then made into proper length.

The belts were then conveyed to a table where three girls were inspecting them. The girls checked the belt against an aluminum fixture with holes matching the centers of the cartridges. She then put the belt on a stretching device which checked for broken or weak links. She next turned the belt and inserted the points of the cartridges into this checking fixture and seated them.

The checking fixture which is made up of foldable bars is then accordian folded with the belt in place into the configuration required for packing. She then turns the entire assembly over so that the cartridges are sitting on the ends. The assembly device is removed and the folded belt is pushed into the card-board carton. The cartons are then put on a conveyor belt and delivered to the next operation whereby girls insert the cartons into the bandoleers by hand. The girls then take the filled bandoleer and insert two bandoleers into an ammunition box. The bandoleer strap presents a problem and requires that the girl use a blade to push the loose end of the strap into the ammunition box. The girls then close the boxes and put them on a conveyor belt where they are delivered to the crating operation. The crating operation is done by hand, and the crate is folded around the ammunition boxes. The ammunition boxes are closed and sealed by hand and delivered on a conveyor to a "Gottscho" crate printer. The cartons are printed on three sides and then delivered to the palletizing and banding area. They are loaded and banded manually, and are ultimately removed by fork lift truck.

COMMENT: The visit to Lake City was very interesting and informative. In general, the plant seems to be very well operated, quite clean and the personnel appear to be very knowledgeable. They are extremely safety conscious at this plant. While most of the equipment is quite old, it appears to be in good repair and fairly well maintained. We were very well received at this installation and found the personnel to be extremely cooperative, and were permitted to observe and question any of the operations.

M. Friedland

M. Friedland

MF/sg

APPENDIX 8

Trip Report

E.E. Hannum

to

Frankford Arsenal

10-13-72

TRIP REPORT

PLACE: Frankford Arsenal
Phila., Pa.
Mr. Mel Smith
Ammo Modernization Div.

DATE: 10-13-72

PROJECT NO.: 05308

VISITOR: E.E. Hannum, G+W R&D Center

PURPOSE: To investigate techniques and equipment that may be applicable to high-volume, high-rate detonator production.

Frankford Arsenal is developing automatic inspection equipment to be used in small arms ammunition production. Production rates are in the order of 1500 parts per minute. The objective is 100% inspection of all necessary physical dimensions, weight, hardness and detection of flaws.

Cup Inspection

Brass cups from which the cartridge cases are made are received in bulk and loaded by conveyor into a hopper. From the hopper, they are fed into orienting devices, then into accelerating and spacing screws. There are two parallel systems, each capable of processing 800 cups per minute. Various measuring devices are set-up at stations along the screws to make measurements on the cups as they pass by.

Average hardness is measured by an eddy current device. Wall thickness is measured at six locations by ultrasonic echo ranging using water jets as the transfer medium (also bottom thickness).

Diameter is measured with an (optical) infrared detector (echo technique) with the screw as a reference.

At one point in the screw there is no thread so when a cup arrives, it stops and is supported only by the pan of a servo-motor balanced scale which weighs it. When the next cup arrives, it pushes the cup ahead of it off of the scale and into the lead screw again.

Cartridge Case Inspection

Finished standard cases are gaged automatically using probes that contact the case and drive linear transducers which feed signals into a computer which prints out a profile of the case. This profile is used by the computer with another system that features a mask and backlighting to inspect the case profile with scanning photocells (OPTRON). Primer pocket diameter, depth, concentricity and vent hole dimensions and location are measured with probe type sensors, proximity detectors and fluidic devices. Much of the case inspection system is still under development with Battelle, Pacific Northwest; one of Frankford Arsenal's main contractors in the effort.

Among the developments still in progress are techniques and equipment for flaw detection. This is essentially automation of inspection that has always been done visually by human operators.

An indexing machine supplied by the Commercial Cam & Machine Co. of Chicago, Illinois is capable of indexing at the rate of 1200 per minute with 0.015 second stationary periods.

This may be used with optical systems that detect the scattered light that reflects from a flaw. The main reflected beam is blanked out.

Hardness profile and thickness measurements are made on finished cases at four locations using eddy currents.

Among Frankford's suppliers and contractors for inspection equipment are the following:

Kaman Corp. - Optron Corp. - Itek Corp. - Sonic Instruments Inc.
Commercial Cam & Machinery Corp. - Federal Products Corp.
Automation Industries, Inc. - Battelle Pacific Northwest - Ade Corp.

All have been contacted in our survey.

Ted Hannum

Dist: 05308 File, M. Connor
M. Friedland, J. Davis

APPENDIX 9

Trip Report

Dave Weigand
Jack Kelly

to

Frankford Arsenal

9-12-72

Trip Report: Frankford Arsenal 9/12/72

Purpose: Familiarization with tested gaging and inspection systems for dimensional and flaw measurements

Participants: Mr. Mel Smith, Frankford
Dave Weigand, G+W
Jack Kelly, G+W

Discussed with Mr. Smith the general inspection requirements for the HEI Program covering charge height, projectile O.D., and flaw parameters. Generally reviewed the techniques used or investigated by Frankford and their potential application.

Dimensional systems discussed for which hardware existed and had been tested are listed below with comments obtained. It should be noted that all units were designed for 5.56 mm case inspection and the parameter characteristics inherent with the case. In addition, each system had associated with its use a single purpose material handling arrangement which in many instances was the limiting system parameter.

1. Kaman Displacement Measuring System--eddy current device with linear output signal; found to be accurate and repeatable within .0002" in static test; require 20-30 min. warmup prior to use; electronics modified by Frankford to improve reliability and speed.

2. Optron Measuring System--light counter device using "Reticon" chip with suitable optics; applied in defining case profile but unable to discern area around extractor groove; relatively large transducer package requiring light source and receiver; quite satisfactory in profile outside of extractor groove area.

3. Physitech & Federal Products Measuring Units--supplied by G+W and described in Report #267 to F.C.C.

4. Batelle & FMC Flaw Detection Systems--demonstration hardware utilizing an optical system with light source and photomultiplier tubes; Batelle System blocks reflected light to the PM thereby reading only the fringes at high sensitivity; resolution of flaws is good (folds, dents, discoloration); material handling quite poor and shielding very elaborate.

   FMC System uses same basic optical system with fibre optics transmission and photo-diode amplification; main point of departure is the reading of all reflected light which causes problems with flaw characterization and reliability; material handling system much cleaner incorporating a rotary turret concept.

5. Aerotech Inc. LVDT--right angle translation device obtaining a differential measurement on case diameter; found to be of sufficient response and accuracy; simple and reliable device.

6. Itek-Kingsbury Ranging Optical Probe--part of a cup measurement system giving

   (a) Cup weight--continuous weight tested to 800 ppm in 5-8 millisecond dwell on leadscrew feed; does not contact leadscrew during measurement.

   (b) Cup diameter by Optical Probe--accuracy, speed, and reliability high; system simple and compact.

   (c) Cup thickness (wall & bottom)--ultrasonic thickness measurement via six (6) transducer immersion system; multitransducer gives average wall thickness, one transducer gives point base thickness; operation very satisfactory.

   System employs optical encoder for part location identity (primarily for ejection operation).

The question of what constituted a flaw for the 20 mm projectile was brought up. Mr. Smith could suggest little more than to contact the following people--

1. For flaw quantitative definition from the Q.A. viewpoint.....Mr. Warren Auch
   Frankford Arsenal

2. For flaw quantitative definition from the Operating viewpoint......Mr. Dan Mara
   Industrial Engineering Dept.
   LCAAP
   Army Group

He did indicate that an on line system for projectile flaw definition existed at the projectile vendors, and that they inspected 100% at a 350-400 ppm rate. Mr. Mara will be contacted by the writer in this regard.

J. F. KELLY

APPENDIX 10

Trip Report

E.E. Hannum

to

Philadelphia Scientific Controls
Mercury Data Systems
Croydon, Pa.

11-4-72

TRIP REPORT

Place: Phila. Scientific Controls
Mercury Data Systems
1117 Cedar Ave.
Croydon, Pa.

Date: November 4, 1972

Project No.: 05308

Contacts: Gene Martoccia, Joe Spadafora, Don Butterly, Al Bozzelli

Visitor: E.E. Hannum, G+W AD&E Center

Purpose: To investigate techniques and equipment that may be applicable to high-volume production of detonators.

1.- An automatic detonator line is being fabricated to produce the M55 detonator (for Picatinny Arsenal). The maximum production rate will be 40 per minute. Cups are drawn and coined in four stages in a Bliss press at about 135/min., then go into a degreaser for cleaning.

A system for inspecting the cups is being designed by PSC. It uses eddy-currents(I didn't see it because it has not yet been delivered). Accepted cups go into the main machine which is a six feet diameter rotary indexing table. The cups are supported in individual dies on the table and are indexed from station to station as the table rotates. There are three loading stations which are heavily barricaded with 1/2 inch thick steel. The priming mix is loaded dry and metering is done volumetrically by the Cargill scooper. The lead azide intermediate charge is metered with an Iowa loader, and the base charge is preformed with RDX pellets.

After consolidation of the final charge to a set pressure the charge height is measured with a strain-gage device. Closing discs are blanked and inserted and then crimped in two steps; 45° and 90°, and sealed with a drop of lacquer.

After final inspection, accepted detonators are packaged in chip board boxes.

All in all, the equipment is pretty conventional and quite similar to detonator lines at Picatinny, Lone Star and Iowa AAP.

2.- We had a quick look at the equipment being built for Frankford Arsenal to feed and inspect cups for the G+W 5.56mm Case Line. It will be capable of processing 1500 cups per minute. It consists of an indexing table with many "fingers" to hold the cups while eddy current devices measure wall thickness at six points and bottom thickness. The measuring signals are fed into a computer-like device which displays the results by means of lights on the front panel. I missed a demonstration by one day. Frankford Arsenal personnel (Mel Smith) had been there the day before with a television camera to record the operation to check on accuracy and reproducibility of measurements at high speed.

This system could probably be adapted to feed and inspect detonator cups at 1500 ppm.

Ted Hannum

EEH/sg

APPENDIX 11

Trip Report

H. Wanger
E.E. Hannum

to

Iowa AAP
Burlington, Iowa

10-14-72

Trip Report

Place: Iowa Army Ammunition Plant
Box 561, Burlington, Iowa
(319)-754-5731

Date: November 14, 1972

Travelers: Mr. Hal Wanger, Picatinny Arsenal
Mr. E.E. Hannum, Gulf + Western

Iowa Ordnance Personnel:

K.D. Ogden T.C. Padley Jerry Miller	Gov't Civil Service Quality Assurance
James Lewis Irv Foster Richard H. Tiemeier Wm. R. VanBrussel A.W. Hausner	Mason & Hanger Silas Mason Co. Inc. Supervisory Personnel For Detonator Production

Purpose: To observe and discuss techniques and equipment used at Iowa AAP to manufacture detonators.

The major activity at Iowa AAP is loading of artillery shells and this is almost exclusively a melt-pour operation. The smallest caliber is either 40mm or 90mm.

Iowa also manufactures detonators. Their "back-line" where the explosives are received and conditioned is quite similar to back-lines at Lone Star and Lake City Army Ammunition Plants. One interesting difference (from Lone Star at least) is that they filter air both entering and leaving the conditioning buildings. The explosive dust caught in the exit filter is wet down and disposed of in a "kill" solution.

The front line consists of a few old World War II vintage Jones loaders and many Iowa Loaders. They will soon have 18 of these.

The Iowa Loader is a Mason-Hanger development and is essentially a much improved Jones loader. However, the production rate is about the same. Although capable of operating at about 45 ppm, the optimum rate is 32 ppm, because at higher rates the reject rate increases and the frequency of "blows" increases. These are mainly the result of increased inertial forces associated with the start and stop motions of the various mechanisms.

The Iowa loaders are rotary indexing machines with 48 workpiece positions* on 54 inch diameter tables. There is only one station for each operation. A central hydraulic cylinder with a pneumatic booster raises and lowers a heavy column to which are attached the rods and linkages that operate the various work stations. Although the work table is quite rugged (one inch thick) it does not have to provide the reaction forces at the consolidation stations. These stations are heavy "C" clamp type castings bolted to the frame of the machine. The clearance beneath the table at these stations is about .003 inch which permits the "C" clamp to take the reaction forces from the consolidation rams.

Toggle linkages are used to operate the rams. These provide rapid up and down travel at no load, but slow application of the consolidation force. A spring on the ram controls the maximum pressure and a dial indicator measures the height of charge. Like Lone Star, no pressure dwell is used at Iowa.

Mason-Hanger has a sizable and apparently competent engineering group working on improvement and modernization of plant and equipment. They are developing improved feeders, dispensers, traying and packaging devices. Most inspection is still done manually. Visual inspection is performed 100% for the following: (1) Cuts, splits, cracks; (2) Caked explosive on exterior; and (3) Exposed explosive.

Cups are supplied by vendors and must be inspected prior to entering the line. Some are very fragile, particularly the M55 cup. Jim Lewis claims this to be one of their most troublesome problems.

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* Two workpiece stations at each of 24 work stations.

Metering Dispensers

1.- The Cargill scooper is used to meter priming mix which is very powdery (like talc) and does not flow well.

2.- The ball dispenser is used for lead azide and other free flowing powders. It is a Mason-Hanger development (Mr. Wm. VanBrussel) and is highly regarded for its accuracy, simplicity, versatility and economy. The metering cavity is adjustable and a device has been developed to do this automatically if three successive charges measure too high or too low.

The estimated replacement cost of a ball dispenser, about $300, is considerably lower than that of the Chamlee dispenser used at Lone Star. Mr. VanBrussel has made some improvements and simplified the Chamlee dispenser so that it can be made for about $250. Cost is important because in detonator manufacture, "blows" are a frequent and evidently unavoidable occurrence. A blow in the lead azide dispenser usually destroys it. And a blow in consolidation of the intermediate charge (lead azide) and the base charge (RDX) usually destroys the tooling.

Lake City AAP uses tooling with 110-cavity, precision-made plates for metering and consolidation. The production rate is potentially higher (about 300/minute) than the Lone Star or Iowa methods, but the tooling cost is much higher, probably by a factor of ten or more.

3.- The base charge is an RDX pellet which is made off-line in standard rotary tabletting machines. They are reconsolidated in the detonator line. This is followed by insertion of the closure disc which is punched from a ribbon then crimping is performed in two steps, 45° and 90°.

4.- Another type of dispenser, called the "Valve Dispenser", has been used at Iowa AAP. It is simply a flexible plastic tube which feeds the explosive from a reservoir funnel by gravity into the detonator cup. An air cylinder is used to pinch the tubing to cut off the flow of powder. Metering is accomplished by timing the opening and closing of the "valve". It is really a modified hour glass with many potentially attractive features; simple, inexpensive, readily adaptable to automatic control and adjustment.

In advanced models of the Iowa Loader, the finished detonators are drawn by vacuum into metal trays which contain 10 rows of 5 each. These pass through the inspection process and acceptable ones are sealed with a drop of green lacquer then packaged in non-propagating chip-board boxes containing 50 each.

Rejection rate runs 1-2%.

Iowa Loaders are made to Mason-Hanger specifications by whatever bidder is awarded a contract. Current manufacturer is Processes Inc., of Cedar Rapids, Iowa. Cost is $57,000 to $60,000 per machine.

The tour of the detonator lines was very interesting and informative, but our main interest is in techniques and equipment for manufacturing detonators at 1200 ppm or more.

About half the time was devoted to discussion of this objective, which produced several significant factors to be considered.

Discussion of High Rate Detonator Production

1.- The most frequent occurrence of blows is in consolidation of the priming mix because it is the most sensitive material and is compacted at the highest pressure, 70,000 psi. However, the quantities are very small, .025 grams, and they usually deflagrate or explode rather than detonate. Quick change tooling is the answer to this problem with precautions to avoid propagation to the feed reservoir or other parts of the line.

At 1200 ppm, Jim Lewis estimates ten blows per shift.

2.- Lead azide "blows" are estimated to occur five times per shift and will destroy the tooling and sometimes destroy the dispensing device. Here again, quick change tooling, adequate barricades and prevention of propagation are essential features of the design.

3.- It is expected that a "blow" in the RDX consolidation will occur about once a week. This is the most powerful detonation and therefore will require the greatest degree of isolation.

4.- In addition to on-line inspection for various physical parameters no lot can be accepted without successful firing tests of randomly sampled detonators. This means that firing tests must be performed and the results evaluated quickly to avoid having to accumulate and hold large quantities of finished detonators which in themselves can present a serious potential hazard.

5.- Similarly, rejects and misfires are potential hazards and must be disposed of quickly and safely. At Iowa, these are detonated immediately, one at a time by dropping them into a barricaded chamber where they fall into a gap between two inclined electrically charged metal plates. The detonator in the gap completes the electrical circuit causing a heavy current to pass through the detonator causing it to detonate. This is the approved method for disposing of detonators.

6.- Again it is generally conceded that the most difficult problem in high rate production of detonators is to safely condition and bring to the line the large quantities of sensitive, powerful explosives that are required. The people at Iowa feel that the only practical approach is to automate the present methods and bring small, individually barricaded quantities to the line as needed, but spaced at safe intervals. They evidently are giving serious consideration to the use of robot type devices for the most hazardous handling tasks. The "teleoperator", developed by M.B. Associates, San Ramon, Calif., was one of these devices mentioned.

7.- Several problems associated with lead azide particularly were mentioned. Azide is made in batches of 10, 15 and 25 pounds and the flow properties can vary from batch to batch. It is claimed that the suppliers (Olin & DuPont) will not screen it for particle size uniformity. Screening is done dry in two pound batches in the back line, but apparently very little does not pass through the screen. Three kinds of lead azide are used; RD 1333, dextrinated and "special purpose". The special purpose material was purchased in huge quantities for use in special area-denial mines, but that program was cancelled. The lead azide is now being used in detonators. Flow properties differ and since all currently used dispensers operate on gravity, this presents problems.

APPENDIX 12

U.S. Patent No. 3,423,259

January 21, 1969

Ammunition Priming Composition of Dry Particulate Ingredients With Karaya Gum Binder

Edward A. Staba
Olin-Mathieson Chemical Corporation

United States Patent Office

3,423,259

Patented Jan. 21, 1969

1

3,423,259

AMMUNITION PRIMING COMPOSITION OF DRY PARTICULATE INGREDIENTS WITH KARAYA GUM BINDER

Edward A. Staba, Higganum, Conn., assignor to Olin Mathieson Chemical Corporation, a corporation of Virginia

No Drawing. Continuation-in-part of application Ser. No. 537,699, Mar. 28, 1966. This application May 18, 1967, Ser. No. 639,289

U.S. Cl. 149—24 6 Claims

Int. Cl. C06c 1/00; C06b 15/00, 9/00

ABSTRACT OF THE DISCLOSURE

Ammunition priming compositions having improved handling properties, including enhanced safety during handling, are obtained through the use of karaya gum as binding agent. Such mixtures permit the use of higher and more effectively distributed contents of water during the handling stages than the natural or synthetic gums of the prior art, while avoiding the undesired flow of the mixture or the settling thereof and caking of the primer ingredients. Preferably, the karaya gum is initially subjected to a chemical modification corresponding to a partial deacetylation, as accomplished by heating the powdered gum and removing the evolved vapor constituents.

CROSS-REFERENCE

This application is a continuation-in-part of my copending application Ser. No. 537,699 filed Mar. 28, 1966, now U.S. Patent 3,321,343 issued May 23, 1967.

BACKGROUND OF THE INVENTION

This invention relates to priming compositions for ammunition, as exemplified by priming mixtures for center-fire and rim-fire ammunition.

Generally, priming compositions are prepared and handled in water-wet condition in order to reduce the possibility of unintended explosion, as water is known to decrease the sensitivity to impact and friction of the explosive ingredients and also of the priming mixtures of such explosives with the other ingredients commonly used, such as the sensitizer, oxidizer, fuel and abrasive materials

In common practice, a dry mixture of the inert ingredients, or optionally a water-wet mixture thereof, is suitably mixed with the water-wet explosive, and the moist priming mixture is stored for later use in charging shells or primer cups. Such charging may be carried out by spreading the moist mixture back and forth over a plate provided with rows of openings of the proper volume. After the openings have been filled to the level of the plate surfaces, empty shells or primer cups are placed thereunder and each is charged with a primer pellet liberated from the appropriate opening by a knock-out pin. In the case of rim-fire shells, the primer is then spun into the hollow rim of the shell and dried. In the case of primer cups intended for use in shot-shell or center-fire ammunition, the charged cup is combined with other elements such as the anvil and cover to complete the assembled primer.

In order to obtain adhesion of the particles of the dried primer ingredients to each other and to the metal container, it has been customary to utilize a water-soluble natural gum or synthetic gum as a component of the primer composition. For example, the use of metal caseinates as binder was disclosed in U.S. 1,718,358; starch esters in U.S. 2,095,333; and polyvinyl alcohol in U.S. 2,341,262. However, gum arabic, as disclosed in U.S. 2,662,818 to Schuricht, has probably been the most widely used binder for priming compositions.

The use of prior art priming compositions wherein the binder ingredient consisted of gum arabic or other water-soluble gums has involved a number of problems. While these have been partly overcome by the practice of certain precautions and extra procedures by the operators, there remained a need for improvement in order to avoid the extra effort and the potentially dangerous situations that were necessarily involved.

The main disadvantage arose from the need for meticulous control of the water content. If insufficient water were present to wet the particle surfaces thoroughly, the danger of premature explosion of the composition during the mixing and charging operations was greatly increased. However, the presence of excess water in the composition could lead to a similarly dangerous situation at one stage and introduce other difficulties in the operations.

During storage of a priming mixture containing an appreciable excess of water, the particles of solid ingredients tend to settle and deposit a dense clay-like mass at the bottom of the container, a layer of fluid is present at the surface, and some stratification of ingredients is inevitable. If the settling has occurred to the extent that hardened cakes of material have formed, the mixture is scrapped because of the danger and difficulty of the reclaiming process. In the absence of such caking, the settled composition must be thoroughly re-mixed before it can be successfully used in the charging operation.

In the charging operation, the priming mixture is manually spread over the surface of the charge plate and rubbed into the openings until they have been filled. Then, the excess mixture is scraped away from the plate surface and collected in a pile on the charging table. In mixtures in which the binder consists of gum arabic or other prior art gums, the collected piles slump and spread rather than retain the compact mass shape and the mixture often tends to smear and creep on the plate and table. This results in the loss of moisture through evaporation, and the operator must be alert to add water and re-mix the mass to continue the charging operation properly. However, such adjustments are made in accordance with the judgment and skill of the operator and may at times result in sufficient variation of the texture, flow characteristics or tackiness of the mixture to bring about non-uniformity of the charging. This may be due to the incomplete filling of the charge plate openings, for example because of the presence of voids in the charge. At times, also, the knock-out operation is not cleanly effected, so that some of the primer cups or shells may receive an incomplete charge.

SUMMARY OF THE INVENTION

In accordance with the present invention, generally stated, ammunition priming compositions are provided wherein the binder ingredient is comprised of karaya gum. The disadvantages and deficiencies of prior art priming mixtures, as above outlined, are thereby overcome. Priming compositions in accordance with the present invention are characterized by enhanced safety during the mixing, storage and charging operations, by increased ease of handling, by simplification of the required operations and by the ready attainment of improved uniformity.

The karaya gum binder is effective in providing increased safety in the handling of priming compositions by enabling the mixing, storage and charging operations to be effected in the presence of sufficient water to wet the particle surfaces thoroughly and, in addition, to fill the interstitial spaces between the particles with viscous gel-like fluid. Thus, compositions having a water content of about 25%, or higher, of the dry weight of the composition may be advantageously handled throughout the mixing, storing and charging sequence, this content being significantly higher than the approximately 15% content generally characteristic of prior practice.

In addition to the enhanced safety of operation thus provided by priming compositions having karaya gum as binder, this ingredient exerts profound and advantageous effects on the texture, fluidity, and other essential handling qualities of the composition. It is compatible with the usual ingredients of priming compositions, displays excellent stability and adhesive power, and is free of adverse hygroscopicity effects. The effective range of the karaya gum binder content is generally between about 0.2% and 4% of the total dry ingredients, and preferably between about 0.5% and 3%.

Karaya gum is prepared by the physical purification, grinding and blending of the exudate of trees belonging to the genus Sterculia, usually of the species *Sterculia urens*, as described in "Encyclopedia of Chemical Technology" (2nd ed.), Kirk-Othmer, vol. 10, pp. 746–48 (1966). It is a complex partially acetylated polysaccharide of high molecular weight, the main constituents being L-rhamnose, D-galactose, and D-galacturonic acid. The purer grades of the gum, meeting the specifications set in the National Formulary for food and pharmaceutical uses are preferred for use in accordance with this invention.

For some percussion primer applications, a primary explosive may be used as the sole or preponderant ingredient, the particles being mixed, while wet with water, with the karaya gum binder, charged into the primer housing and dried. In the completed primer, the particles of explosive are adhered as a pellet which is bonded to the housing. As suitable explosives, use may be made of a primary explosive, or mixture, such as lead styphnate, double salts of lead styphnate as with lead nitroaminotetrazole ("Stabanate") or with lead hypophosphite or with lead propionate, lead azide, lead picrate or its double salts, lead dinitroresorcinate, diazodinitrophenol and the like.

It may be desirable to include with such primary explosive up to about 5% of its weight of a sensitizing explosive such as tetrazene (guanylnitrosamino-guanyltetrazene).

In ammunition priming compositions, an oxidizing agent, or mixture, is generally included in the range of 5% to 60%, preferably 15% to 30% (percentages being by weight of the total dry ingredients). Suitable oxidizing agents are generally metal nitrates, metal oxides or peroxides and metal chromates or permanganates, such as barium nitrate, potassium nitrate, potassium permanganate, barium chromate, lead chromate, the peroxides of lead, barium or strontium, manganese dioxide, or ferric oxide.

Another commonly used class of primer ingredient is that of combustible fuels such as antimony sulfide, lead thiocyanate, aluminum, calcium silicide, carbon, nitro compounds such as di- or trinitrotoluene, and nitrate esters such as pentaerythritol tetranitrate. The content of such fuel ingredient or mixture thereof is in the range of about 5% to 25% of the total dry weight of the composition.

In addition to the above-listed ingredients, rim-fire primer compositions usually are provided with a "frictionator" ingredient such as ground glass or a granulated amorphous carbon which exhibits conchoidal fracture, such as ground anthracite coal. Such ingredient may be present in the range of about 4% to 40%, preferably between 10% and 25% by weight of the dry mixture.

In the case of percussion primers utilized for purposes where corrosive effects of combustion residues are immaterial, it should be noted that mercury fulminate may be used in place of the primary explosives listed above, in whole or in part. Likewise, in such applications, the primer composition may be based on a potassium chlorate or perchlorate mixture with one or more fuels such as antimony sulfide or lead thiocyanate or others as listed above. In such compositions, the karaya gum binder of this invention is found to provide advantageous safety and improved handling qualities, as described herein with respect to other specific formulations.

PREFERRED EMBODIMENTS

Preferred percussion priming compositions embodying the present invention are tabulated below, the numerals representing percentages by weight of the dried mixture.

	Examples		
	1	2	3
Lead styphnate	20	45	......
Stabanate [1]	25	......	30
Tetrazene	3	3	3
Barium nitrate	30.25	22.25	40.25
Lead peroxide		7	......
Ground glass		22	......
Ground anthracite coal (Concholdal Fracture)	15	......	20
Karaya gum	0.75	0.75	0.75

[1] Double salt of lead nitroaminotetrazole and lead styphnate U.S. 3,310,569.

	Examples		
	4	5	6
Lead styphnate	40	40	37
Tetrazene	4	4	4
Barium nitrate	29.5	29.5	29.5
Antimony sulfide	16	15	25
PETN [1]	5	5	......
Aluminum	5	6	4
Karaya gum	0.5	0.5	0.5

[1] Pentaerythritoltetranitrate.

	Examples		
	7	8	9
Stabanate [1]	20	25	20
Tetrazene	4	4	4
Barium nitrate	61.5	52.5	49.5
Antimony sulfide		10	16
Calcium silicide		8	......
Aluminum	5	......	10
Ground anthracite coal (Concholdal Fracture)	9	......	......
Karaya gum	0.5	0.5	0.5

[1] Double salt of lead nitroaminotetrazole and lead styphnate U.S. 3,310,569.

In the above percussion primer compositions for ammunition, Examples 1–3 are for rim-fire, Examples 4–6 are for use in centerfire, and Examples 7–9 are for use in shotshells. It will be understood by those skilled in the art that the proportions may be varied somewhat and that other explosives, oxidizers and fuels, as listed previously, may be substituted in whole or in part in the tabulated compositions.

The above priming mixtures comprising karaya gum as the binder ingredient may be mixed, stored and charged readily, uniformly and without handling difficulties at water contents of about 20% to 25%. In identical compositions differing only in the substitution of gum arabic or other gums of the prior art, even at somewhat higher contents, the water content must be maintained at about 12% to 16% in order to avoid the problems of settling and caking during storage, and non-uniform charging because of insufficient fluidity of the mixture if inadequately moist and excessive fluidity at higher water contents. Such mixtures frequently undergo a segregation of the lighter and heavier ingredients when water is added for the adjustment of fluidity, particularly a tendency for the fine lighter particles to "float off" the mixture surface. As pointed out above, such difficulties are overcome or avoided by the use of karaya gum as the binder in accordance with this invention.

Karaya gum differs in a number of pertinent properties from gum arabic and other primer binder gums of the prior art. When dispersed in water at equal concentrations, karaya gum yields aqueous dispersions of much higher viscosity which display a gel-like structure. While priming composition containing gum arabic are frequently difficult to distinguish in appearance, texture and fluidity from identical mixtures from which the gum has been omitted, the effect of the presence of karaya gum is immediately evident in each of these qualities.

The gel-like structure of mixtures containing karaya gum is illustrated by the resistance to penetration of a mass of mixture by a gently falling stream of water. In contrast, with mixtures using gum arabic and other prior art gum binders, such streams readily enter and dilute the mass. The presence of a structured surface in mixtures in accordance with this invention, thus indicated, is likewise believed to be effective in reducing the evaporation of moisture from masses of the composition.

When the karaya gum of this invention is used as a binder or adhesive, in place of the usual gum arabic or other adhesive yielding a low viscosity dispersion, the viscous aqueous karaya gel obtained provides a matrix in which the solid particles of the priming mixture are suspended. Because of the high viscosity of this matrix, solids will not settle out of the mixture even though interstitial spaces are entirely filled with the fluid dispersion. It is possible to increase the water content of the mixture well beyond the point at which separation of solids and the fluid medium would occur with a low viscosity adhesive. Typically, mixtures prepared with a low viscosity adhesive such as gum arabic are mixed at a water content of 10–15% by weight depending on how bulky the ingredients are. Additional water is added at the time of charging to increase fluidity so that the holes in the charge plate may be filled with less manual effort. Generally the water content as charged is about 14–19%. When karaya gum is used there is no specific limit to the percentage of water used in the mixture as separation of solids and the fluid medium does not occur. A logical amount of water to use is the amount required to fill the interstitial spaces. Any further addition of water will add to the bulk of the mixture but is otherwise not objectionable. The mixture may be mixed at the water content that is desirable for charging so that the later steps of adding water and blending preparatory to charging can be eliminated. Mixtures containing karaya gum (0.2%–4%) have been prepared with a water content of about 15% to 30%. The larger amount of water that can be added to mixtures containing karaya gum greatly increases the handling safety.

Supplementing the effect of a larger percentage of water in enhancing the handling safety of priming mixtures, karaya gum dispersions provide another safety advantage. The manner in which water, oil, or other liquids desensitize primary explosives is believed to involve the heat absorbing action of the liquid which tends to limit the temperature rise caused by friction or percussion. In addition to the heat absorbing effect, liquids provide lubricity which tends to minimize the heating effect of interparticle friction as the mixture is handled. If one visualizes the crystals of primary explosive as being covered with a film of liquid which tends to absorb heat developed by mechanical means, it is seen that the thickness of the film of liquid is an important factor in the desensitizing effect. The thickness of the film of liquid on crystal surfaces when gum arabic or other low viscosity dispersion is used is similar to that obtained with water alone. When a karaya gum dispersion is used, however, a substantially thicker film of liquid on crystal surfaces is obtained due to the effect of viscosity. The well known profound desensitizing effect of lubricating oil on primary explosives is probably due to the viscosity which results in a thicker film. Even though the specific heat of oil is substantially lower than that of water, the greater amount present due to the thicker film provides a greater heat capacity. Karaya gum dispersions possess the advantage of oil in forming a thick film plus the added advantage of the higher heat capacity of water.

As described above, the viscous dispersion of karaya gum forms a lubricating and protective film of substantial thickness over the surface of the solid particles. Particles slide by each other more readily, and thus less manual effort is required to rub the mixture across the surface of the charge plate and fill the cavities therein. Yet because of the viscosity of the medium in which the solid particles are suspended, unintentional movement or flow of the wet priming mass on the charge table, due to effects of gravity, does not occur. The priming mass molds readily with very little manual effort to achieve any desired disposition or mass shape, but will not slump, creep, or otherwise change shape. Manual charging involves spreading the priming mixture over the surface of the charge plate and rubbing it into the holes therein. After the holes have been filled, the excess mixture is scraped off the charge plate and collected in a pile on the charging table. The lubricity provided by karaya gum dispersions and the cohesiveness of the gel cause the mixture to scrape cleanly off the metal charge plate surfaces without leaving a smear of solid constituents of the mixture, as frequently occurs with mixtures containing gum arabic or other low viscosity binders. Portions of mixture that are scattered during the rubbing operation are easily and quickly brought together into a compact pile as the excess is scraped off the filled charge plate. This helps reduce the drying rate, and consequent need for frequent rewetting, as loss of water is much more rapid if the mixture is spread out than when the mixture is in a compact pile. The effect of the advantageous charging characteristics is to permit greater productivity due to the greater ease and speed with which the charging operation may be performed.

Priming mixtures prepared with karaya gum can be wetted sufficiently, without encountering separation of the solid and liquid phases to provide the fluidity required for the extrusion of the bulk material. The mixture is sufficiently plastic and flows readily enough to permit feeding the bulk material into a pellet forming mechanism capable of charging primers mechanically.

Rather specific, stable, rheological properties are required to permit mechanical charging as defined above. Separation of the solid and liquid phase must not occur, even on rather prolonged storage. The fluidity must remain fairly constant despite effects of storage, temperature changes, moderate variation in water content, and agitation or mechanical manipulation. The interstitial spaces must be filled with the liquid medium, so that the priming mass is homogeneous and not interrupted by air-filled voids. This characteristic is required to permit dispensing accurate unit priming charges by volumetric means. The karaya gum of this invention provides mixtures which fulfill these requirements. In contrast, when gum arabic or other low viscosity binder is used, the mixture is clay-like and is not amenable to charging by such mechanical techniques.

Comparative tests were carried out in order to obtain quantitative data showing the effects on flow characteristics and on settling behavior when a typical prior art binder, gum arabic, is replaced in a representative priming composition by karaya gum.

The priming composition was Mix "C" (CNG-35) of Table 1, page 7, of my copending application Ser. No. 537,699 now U.S. Patent 3,321,343, as follows:

Stabanate	35
Tetrazene	3
Barium nitrate	51
Ground coke	10
Gum binder	1

A batch of the above ingredients except gum was prepared containing 198 grams total of solids (dry basis). The explosive materials in this batch were weighed wet in a pycnometer and mixing was conducted manually to minimize loss of material. After the blending of the 198 gram batch had been completed, the wet batch was weighed and divided into two portions of equal weight.

identical composition, and especially having equal water In this manner, two 99 gram portions of Mix "C" of identical composition, and especially having equal water content, were obtained. To one portion of mixture, a 1 gram portion (1%) of dry powdered gum arabic was added and blended in; to the other an equal quantity of dry powdered karaya gum was added and blended in. In this manner, two equal portions of Mix "C" composition were obtained which differed only with respect to the gum binder.

The procedure following in making the slump test was essentially as presented in the ASTM test procedure C143-66, but using a mold consisting of the frustrum of a cone having a base 34 millimeters in diameter, a top diameter of 24.5 millimeters, and a height of 50 millimeters. The mold specified in the ASTM procedure has base, top and height dimensions of 8, 4, and 12 inches, respectively. The smaller size of the mold used for slump tests on priming was desirable for reasons of safety.

The slump tests were conducted by adding mixture to the top end of the cone frustrum with the base resting on a smooth steel surface. Successive portions were packed with a tamping rod to permit thorough filling of the mold. The excess mixture was removed from the top as prescribed in the ASTM procedure and the mold was removed carefully to minimize deformation of the molded mass due to manipulation. A measurement of the average height of the top surface was obtained promptly. After a slump determination was completed all of the priming was carefully gathered together, an additional gram of water was blended into it, and another slump determination was conducted. In this manner successive slump determinations were conducted on each of the two batches of priming at each increment of added water. The operation was conducted in a room humidified to near the dew point to minimize error due to evaporative loss of water. The process of making repetitive slump determinations as each increment of water was added was continued until a profound slump effect was obtained. The degree of slump at each level of wetness obtained with each mixture portion is presented in Table I.

TABLE I.—SLUMP TESTS ON MIX "C" COMPOSITION CONTAINING GUM ARABIC COMPARED TO THE SAME MIX CONTAINING KARAYA GUM AT VARIOUS LEVELS OF WETNESS

Water Content of Mixture	Degree of Slump in Millimeters	
	Gum Arabic Mix	Karaya Gum Mix
8.6	16	0
9.5	26	0
10.4	34	0
11.3	39	0
12.2	....	2
13.8	....	8
15.4	....	14
16.9	....	19
18.4	....	25

At the conclusion of the slump tests the two portions of Mix "C" were utilized to determine the comparative rates of separation of solids and water. At the conclusion of the slump tests the water content of the mix containing gum arabic was 11.3% (88.7% solids) and the water content of the mix containing karaya gum was 18.4% (81.6% solids). Although the mix containing karaya gum had considerably more water in it, it appeared drier and exhibited less fluidity than the mix containing gum arabic. These mixtures were used without further adjustment of water content for the initial settling tests.

The settling rate tests were conducted by packing the mixtures into cylindrical precision bore calibrated glass tubes, with a closed end, which had a bore of 20 mm. and were calibrated to 45.0 ml. The mixtures were packed carefully to prevent voids. After filling, the tubes were supported with open end uppermost in a wooden block having close fitting bored cavities. The time was noted and the tubes were allowed to stand undisturbed while the presence of any water separating at the surface was observed and its volume was estimated by means of the milliliter scale on the cylinder. After making an appropriate number of observations with the cylinders in an undisturbed condition, the wooden block was clamped to the table to prevent movement and the assembly was subjected to vibration. The source of vibration was a primer cup plate shaker to which the table was affixed. The type of vibration developed was quite similar to that encountered when priming mixture is hand trucked from one plant location to another. Observations made before and after vibration was started are presented in Table II.

TABLE II.—SETTLING RATE OF MIX "C" CONTAINING GUM ARABIC COMPARED WITH THE SAME MIX CONTAINING KARAYA GUM

Time Interval, Minutes	Volume of Separated Water (ml.)	
	Mix Containing Gum Arabic (mix contained 11.3% water) Vol. 41.5 ml.	Mix Containing Karaya Gum (mix contained 18.4% water) Vol. 44.2 ml.
12	1.0	0.0
32	1.2	0.0
52 (vibrator started)	1.2	0.0
57	2.0	0.7
67	2.1	0.7
77	2.5	0.9
87	2.9	1.1
97	3.1	1.2
137	4.0	1.4
177 (vibrator stopped)	5.0	1.7
197 (vibrator started)	5.0	1.7
227	5.1	1.7

After the test data presented in Table II were obtained, the mixture containing gum arabic was removed from the tube used for the settling test, and additional water was blended into the batch so that the water content would equal that of the mixture containing karaya gum (18.4%). The calibrated glass tube was refilled and another settling test was conducted with the mixture in a wetter condition. Results of this test are presented in Table III below. Initially the tube was allowed to stand and then the vibrator was started.

TABLE III.—SETTLING RATE OF MIX "C" CONTAINING GUM ARABIC—MIXTURE, WATER 18.4%

Time interval, minutes:	Volume of separated fluid, ml.
30	6.0
60 vibrator started	6.7
95	8.0
140	8.1

It is clear from the above data that karaya gum has a significant benefical effect on the flow and settling characteristics of wet priming mixtures. The stability to change in priming slump characteristics as successive increments of water are added, indicates that mixtures containing it may be charged successfully through a comparatively wide range of actual water content. Such latitude is decidedly beneficial in improving charge weight uniformity, and with less frequent replacement of water lost through evaporation as charging progresses, productivity is improved.

The comparative slump test data establish much lower degree of slump at a given moisture content for the mixture containing karaya gum. The tests results obtained at 9.5% and 18.4% water content show that the karaya gum mixture showing a slump of 25 mm. contained almost twice the water content of the gum arabic mixture with the 26 mm. slump.

The settling test results likewise establish far less settling and separation of solids and fluid for the mixture with karaya gum, even though it had a much higher water content. At the same water content, the gum arabic mix showed the separation of a still higher amount of fluid in a given time. It is further noteworthy that in the mix containing karaya gum, the separated fluid could easily be redistributed in the mixture by gentle stirring.

In accordance with a further embodiment of the invention, which results in additional significant advantages 119 and is therefore highly preferred, karaya gum which has been chemically modified through heat treatment is used as the binder ingredient in percussion priming compositions. The chemical modification effected by the heat treatment is a partial deacetylation and dehydration of the karaya gum. The beneficial effect of such chemical modification is to eliminate difficulties arising from the tackiness of some compositions using unmodified karaya gum, when handled in conventional charging and spinning equipment.

Such difficulties may be significantly decreased by the use of equipment having non-adherent surfaces, as obtainable for example by coating the surfaces with polytetrafluoroethylene or silicone polymers. Likewise, the karaya gum content of such compositions may be reduced or it may be in part replaced by gum arabic or other water-soluble gum.

However, the above expedients are not required when the karaya gum has been subjected to the indicated chemical modification. The desired modification is readily accomplished by heating the raw powder gum under ventilated conditions at a suitable elevated temperature for the required period of time.

When the chemical modification is effected by heating, excellent results are obtained at temperatures ranging from about 120° C. to 180° C. for a period of about 4 to 48 hours, the time of treatment being shorter as the temperature is increased. The powdered unmodified karaya gum may be spread as a rather shallow layer in an open tray and heated in a well-ventilated oven, thus permitting the removal of the evolved vapors which include water vapor and acetic acid. The temperature and time of treatment are selected to cause the partial elimination of acetic acid to the extent of at least about 20% and up to about 80% of the total that could be removed by heating for longer periods. Preferably, the partial deacetylation is carried out to the extent of 50% to 75% as the resulting modified karaya gum is found to be an excellent binder, in all respects for percussion priming compositions. Such compositions are characterized by all the advantageous features, described above in detail, including freedom from any difficulty due to tackiness.

The following temperatures-time schedules have been found effective for the modification of karaya gum, for example, "Superior III N.F. grade" karaya gum (Morningstar-Paisley Co.), and may be considered illustrative:

Temperature, ° C.:	Time (at temperature), hrs.
(A) 130–135	24
(B) 130–135	48
(C) 148–152	24

In each case, a shallow layer of the powdered gum was placed in a tray and heated in a well-ventilated oven maintained at the indicated temperature. At the end of the heating period, the modified gum which was essentially unchanged in appearance and texture was transferred to suitable containers and sealed.

The desired chemical modification may be effected by other procedures. For example, a uniform partly deacetylated karaya gum can be obtained by suspending the gum in a solvent of high boiling point, such as xylene, and boiling the mixture under reflux, while separating the condensed aqueous phase and returning the condensed solvent to the mixture. The treatment may then be stopped at a desired extent of deacetylation as soon as a predetermined volume of aqueous phase has been collected.

Analytical tests were carried out on karaya gum, both before and following treatment (heating at 148°–152° C. in open tray for 24 hours). The unmodified gum had an acid number of 24.3 (mg. KOH per gram) and saponification number (corrected for acid number) of 161.6 (mg. KOH per gram), while the modified gum had an acid number of 42.7 and saponification number of 182.1. Thus, both values were substantially increased as a result of the modification.

In a further analytical test, 50 gram samples were suspended in 100 ml. of xylene and heated under reflux for an hour after the first condensate appeared. The condensed aqueous layer was separated in a Dean-Stark trap. The measured volumes of the aqueous layers and determination of their acid content yielded the following values:

	Unmodified gum	Modified gum
Percent water evolved	15.6	8.4
Percent acetic acid evolved	0.12	0.038

It can be concluded that this effective treatment causes the liberation of volatile acid, mainly acetic acid, as well as of water, and further, that the number of available carboxyl groups and of saponifiable groups was increased.

As the partly deacetylated karaya gum is advantageous as binder for percussion priming compositions in all the essential functional aspects, it is preferred for use in accordance with the invention. It is readily dispersed in water to yield a highly viscous gel-like fluid which is readily mixed with the particles of the solid priming ingredients to yield homogeneous compositions of excellent storage and handling qualities, as described.

Accordingly, it will be understood that the binder ingredient comprising karaya gum is widely applicable with advantage to percussion priming compositions of a variety of components and proportions, as indicated above. Modifications may therefore be made in the specified illustrative details within the spirit and scope of the appended claims.

What is claimed is:

1. Ammunition priming composition consisting essentially of a charge of dry particles of solid substantially water-insoluble priming ingredients, said particles being adhered together by a minor proportion of karaya gum, and said ingredients consisting essentially of at least about 15% by weight of primary explosive selected from the group consisting of percussion-sensitive explosive metal salts, diazodinitrophenol and tetrazene, and substantially any balance thereof of up to 25% by weight of a combustible fuel, up to 40% by weight of a frictionator, and up to 60% by weight of an oxidizing agent.

2. A priming composition according to claim 1, wherein the proportion of said karaya gum is about 0.2% to 4% of the composition.

3. A priming composition according to claim 1, wherein said karaya gum has been partly deacetylated.

4. A priming composition according to claim 1, wherein said karaya gum has been deacetylated to the extent of about 50% to 75%.

5. A priming composition according to claim 1, wherein said charge includes an explosive lead salt.

6. A priming composition according to claim 1, wherein said charge includes lead styphnate.

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BENJAMIN R. PADGETT, *Primary Examiner.*

S. LECHERT, *Assistant Examiner.*

U.S. Cl. X.R.

149—25, 27, 28, 38, 39, 43, 44, 61, 105

120

APPENDIX 13

Trip Report

E.E. Hannum

to

Picatinny Arsenal
AED
PD

12-5/6-72

TRIP REPORT

Traveler: E. E. Hannum, G+W
AD&E Center

Date: 5-6 December 1972

Place: Picatinny Arsenal
Dover, New Jersey

Project: 05308

Picatinny Personnel:
Mr. N. Catsos, P.D.
Mrs. L. B. Gula, P.D.
Mr. Wm. Bondemore, A.D.E.D.
Mr. Ed Demberg, A.D.E.D.
Mr. Ed. Jescerzewski, A.D.E.D.
Mr. Ted Warshall, A.D.E.D.
Mr. Robert Wagner, A.D.E.D.

The purpose of the visit was to discuss our survey of techniques and equipment that may be applicable to high-volume, high-rate production of non-electric detonators.

DISCUSSION

The people we interviewed are all in the Ammunition Development and Engineering Directorate rather than the Manufacturing Technology Directorate and represent many years of experience in development and research related to detonators and initiators in general. Bill Bondemore had been interviewed on 5-6 October 1971 by Mr. Roger Schroeder of Midwest Research Institute and Mr. Don Hoberecht of Remington Arms (Lake City Army Ammunition Plant). LCAAP sponsored a concept study for an automatic sub-module to charge and assemble the M57E1 detonator at the rate of 600 per minute. We have reviewed their reports and have copies in our file. However, there are a number of questions and answers that we felt require further discussion. We'll list them briefly as follows:

1. Sensitivity and output of various types of lead azide.

   The three types of lead azide are: dextrinated, RD1333 and special purpose.

   There seems to be considerable difference of opinion about the relative sensitivities and output of these three types.

Atlas Chemical Industries found that after sieving out the "fines" that RD1333 was less hazardous. Apparently RD1333 has stronger output than dextrinated lead azide However, just about every user that we interviewed claims there are considerable variations from batch-to-batch so it seems likely that this could explain a good portion of the confusion and disagreement.

2. Ed Demberg has planned a program to determine the safe limit on consolidation tool pressure. It is to be carried out at Lone Star AAP and should be completed in about three months. Hopefully, this will also shed some light on maximum ram speed which is an all-important parameter in press design. This can be a deceptively tricky thing to determine because the bulk density of the explosive can vary as does the ratio of bulk density to final consolidated density.

In a machine like the Iowa Loader for instance the linkages are purposely designed to move the ram rapidly when not in contact with the explosive then slow down as the actual consolidation begins. But even though the linkage speed can be measured or calculated the ram is actually driven via a force limiting spring so it's speed to some extent depends upon the resistance presented by the explosive being compacted.

(Ed Jescerzewski has contributed to the design and development of the Iowa Loader.)

3. A few years ago there was a high incidence of "spontaneous" explosions in the loading plants. A committee was formed to investigate. Several reports were issued which should be located and reviewed for this survey.

It was noted that spontaneous detonation most often occurred within seventy-two (72) hours after the detonator was loaded. This suggests that the cause was some sort of residual stress which could be mechanical, electrostatic, electrochemical or combinations of these. Evidently the research was never completed due to lack of funding and lack of interest.

The reasons for these lacks can be explained by the development of the non-propagating chip-board box. When these boxes are used a detonator can detonate without propagating to adjacent detonators or to another box. This has reduced the problem to one of academic interest only.

4. It was generally agreed that the safety problems of handling the large quantities of sensitive primary explosives needed for production of detonators at 1200 per minute is the major problem. The idea of loading desensitized explosives (wet) was not enthusiastically received. There are problems with sticking, flow, metering, cleaning, consolidation, drying and some people claim the explosives are still too sensitive and can detonate.

Most people think that the only practical approach is to automate the conditioning, handling and loading of small quantities of dry explosives. The operations that require more than .05 seconds to complete will have to be performed simultaneously by multiple tool modules. This seems inescapable.

Even with this basic principle established there are still many problems to be solved. "Blows" must be reduced to a minimum and must not cause shut-down of the line, severe damage or injury.

It is toward these ends that our survey should be directed.

T. E. HANNUM

TEH/bja

APPENDIX 14

Trip Report

E.E. Hannum

to

Picatinny Arsenal
Manufacturing Technology Directorate

12-19/20-72

Trip Report

Traveler: E.E. Hannum Date: 19-20 Dec. 1972

Picatinny Personnel: Stan Wachtell, Stan Adelman, Hal Wanger, Toufie Mazzawy, Ed Lischick

Place: Picatinny Arsenal, Dover, N.J.

Project: 05308

1. Picatinny has a contractor, AMMANN & WHITNEY, that is practically "sole source" for design of structures to house explosive operations and store explosives. However, there is no comparable agency for design of safety barricades for automatic production machinery. In this field, it is every man for himself.

2. Stan Adelman gave me a document that he calls a "P16" entitled "Description of Overall System Concepts". It is evidently a summary of the effort that they (Picatinny) have put into the detonator manufacturing modernization program up until they went out on contracts.

3. I briefly summarized for Stan Adelman what I'll say in the final report. He said that is what they want, "tell them what we found, not what we think they want to hear".

4. I understand that Ed Demberg has written a "P16" for spontaneous detonation studies. I'm trying to get a copy.

5. Stan Adelman clarified his answers to questions posed by Roger Schroeder of MRI and quoted in their Final Report, Feb. 1972 on the M57E1 Detonator Sub-Module Concept Study.

   a. Cherry-Burrell presses operating at 2000/min. was not confirmed and they are only used to pelletize RDX.

   b. Perry Industries vacuum-pressure metering system appears capable of up to 6000/min., but has only been used for inert materials.

6. They didn't know anything about the Lee Metals concept study for LCAAP on automatic blending of tracer mixes.

7. They have advertised for bids to develop methods of forming primary explosives in sheets. They think punching out detonator charges from the sheets with a "cookie cutter" (which is similar to the way closure discs are now assembled) would lend itself to high volume automatic production. They have discussed this with several explosives manufacturers, and quote them as thinking it is feasible. DuPont sells secondary high explosive (much less sensitive than primary HE) in sheet form (trade name "Detasheet"). It is PETN mixed with an elastomeric binder and a plasticizer. It is

7. (cont'd)

made by extrusion into various shapes starting in cylindrical form. Sheets are made by slitting the cylinder as it is extruded, thus avoiding edge effects.

Detasheet has been extensively tested for sensitivity to rifle bullet impact, high voltage arcs, cutting, friction, various standard "drop tests", fire and flame, hot bar, and detonation. It is amazingly insensitive and safe to handle, yet can be detonated reliably with a No. 6 blasting cap or larger (No. 6 cap contains 5 grains of HE).

It is interesting to note, however, that the ordinary PETN is much more sensitive to all the various stimuli mentioned. For instance, .03 grams of lead azide will detonate it compared to about .30 grams for Detasheet; a factor of ten.

This probably means that to make primary explosives in sheet form, they too must be desensitized and by more than a factor of ten because they are inherently more sensitive than PETN. This then will present the problem of how to initiate a detonator that is so insensitive. Perhaps a method can be found; possibly irradiation or vacuum and heat to change or drive off the binder-desensitizer.

It has been noted that the binder is thixotropric. A small, steadily applied pressure will cause it to flow, but it will resist a large rapidly applied pressure (like a viscous fluid or gel). It may be this property of the binder that permits extrusion, but does not interfere too seriously with propagation of a strong detonation. It has been noted, however, that the binder does reduce the bulk density, detonation velocity and output strength as well as the sensitivity.

E.E. Hannum

E.E. Hannum

APPENDIX 15

Analysis of Electroplating As Detonator Manufacturing Technique

Martin Friedland

Subject: Manufacture of Non-Electric Detonators By Electro-Chemical Deposition

Investigation was made to determine the feasibility of forming the metal container around a compacted explosive charge by means of electro-chemical deposition.

1. The only metals which are presently being used to make parts by electro-chemical deposition are copper, nickel, gold, and silver.

2. Alloys are not presently being utilized.

3. Aluminum and stainless steel are not being electro-formed.

4. Rate of forming is approximately .001 inch per hour.

5. Direct current is used in the plating bath of several amperes, and therefore a spark hazard would exist when plating explosives.

6. The bath is a solution of the metal salt and therefore would require the detonator compact to be coated by a vapor barrier coating prior to plating.

7. Electro-forming would also require a second coating of conductive material such as a conductive plastic to provide a current bath for the plating process.

8. The entire surface of the cylindrical shaped detonator must be formed, and, since electrical contact must be made with the part, would necessitate putting the part through two plating operations and shifting the contact area on the detonator between the two operations.

9. Some question exists as to the resulting porosity of the metal deposited by electro forming. Tests would be required to determine the suitability of the plated coating to resist environment conditions such as moisture penetration.

10. Since the plating process is slow, the number of detonators in the bath at one time would be quite high (could approach 1/2 million) resulting in a serious safety hazard.

Conclusions: The use of electro-chemical deposition for enclosing the explosive charge in a detonator does not appear to be an economically and technically acceptable process for high speed - high volume production, due to limitations of metals available, long processing time, excessive number of processing operations, and the safety hazard.

M. Friedland

APPENDIX 16

Productivity - Key to Combating Inflation

AUTOMATION MAGAZINE
Guest Editorial
C.B. McCoy

PRODUCTIVITY—Key to Combating Inflation

Gains in productivity are the key to fighting inflation and enabling the nation to meet its social and economic goals. Because productivity increases are the ultimate source of any true improvement in national wealth, we cannot accelerate social progress without accelerating gains in productivity.

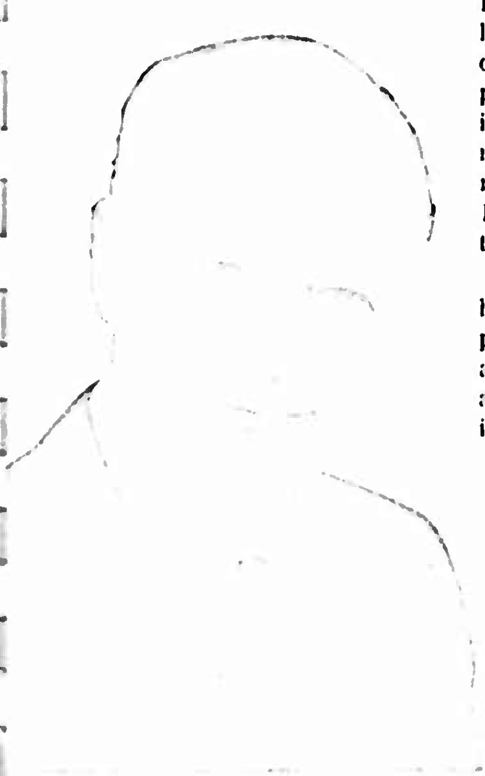
A rise in productivity rates is needed to insure that businesses can expand and create new jobs, to generate funds to pay for environmental cleanup and other pressing needs of society, and to maintain the competitive position of U. S. firms in world markets.

Also, as a means of combating inflation, productivity gains are superior to wage and price controls, or to government fiscal and monetary policies. Productivity gains combat inflation by lowering unit costs; the other methods—higher taxes, cutbacks in government spending, and tight money—accomplish the same objective, but tend to dampen demand and raise unemployment.

We cannot be satisfied with recent productivity increases. Between 1966 and 1971, output per manhour in manufacturing rose 2.2 per cent annually, while hourly earnings increased at an annual rate of 5.8 per cent. Unit labor costs climbed at a rate of 3.7 per cent during a five-year period when other costs rose also. In effect, all of the productivity gains have been absorbed by labor with no benefits accruing to the owners of business. The result is sharply declining profit margins since the mid-1960's.

The problem has been aggravated in the chemical industry by downward pressure on selling prices, and by the high rate of productivity gain in chemical companies in other nations. Productivity of U. S. chemical companies has grown more rapidly than the average for all U. S. manufacturers, chiefly because of increased capital investment in plant and equipment per employee. However, the U. S. chemical industry's gains (averaging about 6 per cent annually between 1960 and 1970) are overmatched by the rise in productivity in German chemical companies (nearly 9 per cent per year) and the Japanese (nearly 11 per cent per year) over the same period. This improved their competitive position and weakened ours.

If American industry is to remain competitive, there must be a sharing of productivity gains with stockholders. Unless profit margins are improved, productivity growth will slow down as industry will have less to spend on capital improvements and new technology which are the sources of productivity growth in the first place.



C. B. McCoy

C. B. McCOY
Chairman and President
E. I. du Pont de Nemours & Co. Inc.

APPENDIX 17

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Literature Reviewed

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APPENDIX 18

OSHA Standards
(abstracted)

OSHA STANDARDS

Occupational Safety and Health Act of 1970
(Public Law 91-596, Williams-Steiger Act, Dec. 29, 1970)

Employers must provide work areas free from hazards and must keep workers informed of their rights and obligations. Effective April 28, 1971. Standards included pertain to:

1. Walking and working surfaces.
2. Platforms.
3. Environmental controls.
4. Hazardous materials.
5. Personal protective equipment.
6. Fire protection.
7. Compressed gas equipment.
8. Materials handling and storage.
9. Machinery and machine guarding.
10. Hand and portable power tools.
11. Welding.
12. Cutting and brazing.
13. Electrical equipment.
14. Section 1910.217, B11.1 - 1971

    "Safety Requirements for the Construction, Care and use of Mechanical Power Presses". Deadline Aug. 31, 1974. However, safeguarding the point of operation and other care and use requirements will be enforced starting Feb. 15, 1972.

APPENDIX 19

Trip Report

H. Wanger

to

Western Electric and MRC

12-5/6-72

Trip Report

Submitted by: H. Wanger

Place Visited: Western Electric, Baltimore, Md.
MRC, Baltimore, Md.

Departure Date: Dec. 5, 1972 Return Date: Dec. 6, 1972

Personnel Contacted: Mr. Thorp - Western Electric
Mr. Issacs - MRC
Mr. Marshand - MRC

Purpose: To determine if electroplating a detonator cup is feasible.

Discussion:

At Western Electric, the writer toured the plating facilities. Contained within were:

(1) an automated batch plating line
(2) an automated wire plating facility
(3) an automated rack plate line
(4) several individual rack plate cells.

With respect to (1) above, the line was built in ovaloid form approximately 30-40 feet long and 15 feet wide. At selected intervals, large polyethylene sieve baskets (capable of handling 20 lbs. of small parts) were hung from a heavy chain drive. The baskets were connected to gear sectors capable of lowering and raising the baskets as well as continually turning them. Tanks and drying cells were emplaced on the periphery of the baskets. The sequence of operations was as follows: The automated loading of 20 lbs. of small parts (connectors, eyelets, plugs) into an empty basket and its subsequent passage through degreasing tanks, washes, empty drip tanks, plating tanks, drip tanks, washes, drip tanks, 3 hot air blowers each increasing in temperature and a dump operation for unloading.

An anode lead was brought down the side of each basket and was inserted into its center where it was left dangling so it could eventually contact all parts moving within the basket thus forming one electrode for the plating process ... the other was mounted on the side of the tank and utilized replaceable rods of the material being plated.

The index time was 2/2.5 minutes from one operation to the next with the entire sequence taking 16/20 minutes. They could produce 25-30 loads/8 hr. shift - depending on size of parts, this could be 200,000 parts. Plate thickness was generally on the order of .2 mil which was satisfactory for telephone operations.

The wire plating facility consisted of 6 reels of wire fed through washing, degreasing, plating tanks, washing and drying tanks to 6 take up reels. Each reel was separately controlled, on coming to an end the reel was stopped, another reel emplaced manually and welded to the previous end. When the take up reel was full, the wire was cut and an empty take up reel was substituted for the full one. The wire moved at speeds of 40 feet/min. but a similar line in the Buffalo Plant could be run at 2000 ft./min. This line was straight-forward and demonstrated nothing unusual. The wire acted as one electrode; the other being mounted on the sides of the plating tank.

The automated rack plater was not in operation. It consisted of narrow tanks with racks capable of being loaded manually and then moved by means of chain drive down a line and dipped into various plating solutions. This, Mr. Thorp said, was much slower and was generally used for larger parts that could be hung from the racks.

At MRC the writer toured the facilities and discussed an automated tracer loading facility that MRC is building for Frankford Arsenal on subcontract to G+W.

Conclusions & Recommendations:

The lines were very interesting - however, it is felt that neither operation could fit in with a detonator plating line for the following reasons:

(1) too many detonators would be congregated in one place.
(2) the plating is basically a slow batch type operation that must be done in large quantities to achieve the 1200 per min. desired rate.
(3) detonator increments do not have the basic strength to survive the banging around they'd receive in the polyethylene baskets.
(4) there are many questions to be answered:
  a) safety of the plate operation ...
  b) water proofing of the detonator increments ...
  c) integrity of the plate operation ...

Action Taken:

In view of the above, it is felt that the consideration of electroplating of detonators can be dropped and this engineer concurs with Mr. Friedland of G+W.

H. Wanger