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Technical Report ARMET-TR-09062

M112 DEMOLITION BLOCK PACK-OUT LINE MODERNIZATION

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U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Munitions Engineering Technology Center

Picatinny Arsenal, New Jersey

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14. ABSTRACT

This report covers the modernization of the M112 demolition block pack-out at Milan Army Ammunition Plant performed using FY07 congressional funding. The scope of the project was to upgrade the existing pack-out line, improve line capacity, improve quality of life for the operator while supplying the same high quality ammunition to the soldier.

This report discusses the feasibility studies that were performed to upgrade and automate the line, actual line improvements, and the benefits and paybacks that resulted from the project.

15. SUBJECT TERMS

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OVERVIEW

American Ordnance (AO) has been producing the M112 demolition block on the I-line at Milan Army Ammunition Plant (AAP) for over 10 yrs. The current production line recently had a new extruder installed to produce the M112 pellet; however, the extrusion die needed to be improved in order to improve the quality of the pellet being extruded and simplify the cleaning process at the end of each shift. The remaining production and pack-out equipment on the line was in bad need of repair or replacement due to outdated technologies and labor intensive processes. The production line was also not a friendly work environment for the operators. In summary, the entire production line needed to be modernized.

Each of the operations after the extruder could be considered a bottleneck in the process. The extruder is capable of producing 30 pellets per minute, but the operators downstream could not keep up with this rate of production due to the equipment that was being used and the high level of manual labor required to conduct each operation. On average, the extruder produced 15 pellets per minute and the pack-out operations could meet this capacity on a regular basis. The building that housed the pack-out line only had 50% of its floor space available to support pack-out operations; this left very little room for in-process material storage if the production rate were improved.

The poor work environment for the operators was a result of the emissions from the composition-4 (C-4) material, which are harmful if inhaled and poor ergonomics associated with individual operations (lifting, turning motions). Due to the existing air quality, the operators were required to wear respirators attached to breathable air in the bagging and tipper tie areas. In the warmer months, the combination of the respirator and Tennessee weather made this a heavy burden on the operator.

The goal of this modernization project was to maximize the capacity of the production line, reduce operating costs related to the production of the M112 demolition block, and improve the quality of life of the operators on the I-Line. To do this, new equipment and operations had to be identified, investigated, and implemented, when appropriate. The result would be that the same quality ammunition is supplied to the Solider while improving all facets of the production line.

DISCUSSION

The modernization of the M112 production line was completed in two phases. The first phase of the project required AO (the contractor) to conduct feasibility studies in order to determine if an operation could be modernized and also if the solution had a significant risk that might cause the solution to fail. The second phase was to implement the recommended solution of the feasibility study (when applicable) if the solution met military standards, safety standards, and was within the available funding. The following paragraphs will discuss the options considered for each operation, the recommended solution, and the results of any implementations that were carried forth.

Improved Extrusion Die

The original extrusion die was designed with a single hot water source that caused only one end of the extrusion die to be heated to the hot water temperature; the end opposite of the hot water inlet would never reach the desired temperature and would cause C-4 to cake up in the die. This caking required the operators to constantly adjust the extrusion parameters during the course of the shift and then at the end of the shift the die would need to be removed and all of the built-up C-4 material had to be removed. A new die was designed to the same specification as the existing die except for the hot water jacket system. The new die has two different heating zones dividing the front and back end of the die (fig. 1). This allows the two zones to run at different temperatures and provides better temperature control and minimizes caking in the die.

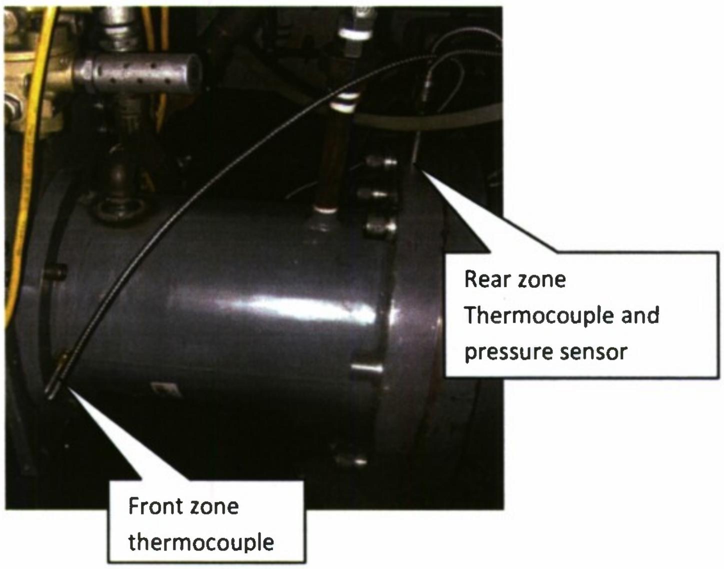


Figure 1
New extruder die installed on the existing extruder on I-Line at Milan AAP

Bagging and Tipper Tie Operations

A feasibility study was performed in order to determine if the bagging and tipper tie operations could be automated. The existing process required the extruded C-4 pellets to be manually removed from the conveyor belt and placed into Mylar bags and then placed back onto the conveyor belt where they would arrive at the tipper tie operation. The tipper tie operation required the bagged pellets to be manually removed from the conveyor, attached to a vacuum to remove the air from the bag, the end of the bag sealed, and then placed onto an overhead conveyor. The excessive handling can cause the blocks to be deformed, broken, or the Mylar bag to be ripped; the operation also required many operators.

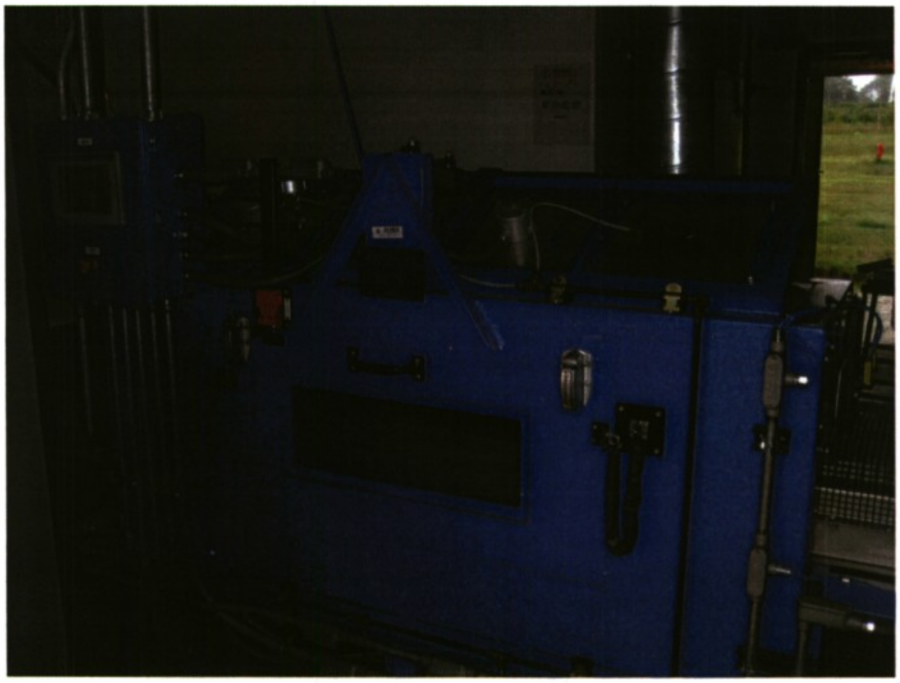
Multiple automation contractors were contacted and some automation concept designs were developed during the feasibility study. Each of different concepts considered different levels of automation from fully automated to partially automated. Each of the automation steps listed in the feasibility report listed a number of risks and unknowns related to automating the process. It was the opinion of the automation contractors and the government that the concept designs were very high risk and that the contractor would require too large a premium to build the equipment under a firm-fixed price contract. A cost benefit analysis was performed comparing the automated designs with the option of adding two additional tipper tie machines (fig. 2) that would allow the tipper tie and bagging operations (no additional bagging equipment is necessary, only additional operators) to meet the maximum capacity of the extruder (up to 30 pellets per minute). It was determined that adding two additional tipper tie machines and four additional operators would be the cheaper, lower risk option. The contractor proposal and feasibility studies (including automation concept designs) are available in the appendix A.

Figure 2
Tipper tie operation with two additional tipper tie machines installed

Heat Shrink Oven

A feasibility study was performed to determine if the Mylar bag heat shrink operation could be upgraded to an infrared (IR) oven or if the existing hot water bath should be improved. The existing operation required the operators to place the bags from the tipper tie operation into an overhead conveyor that conveyed the blocks through a hot water bath. The bags were then manually removed from the overhead conveyor and manually dried by an operator with a towel and then placed back on a conveyor belt to go to the next operation. The study was completed and it was determine that the purchase and installation of an IR heat shrink oven in lieu of upgrading the existing hot water bath had more benefits. Accordingly, the contractor was tasked with procuring and installing an IR heat shrink system with redundant safety controls to ensure that the individual M112 demolition block was not exposed to heat from the oven for a prolonged period of time.

American Ordnance purchased an IR oven from Wisconsin Oven. Wisconsin Oven designed and manufactured an IR oven to meet the specifications and requirements for the heat shrink operation of the M112 demolition block. The oven is designed to open up and exhaust the chamber heat if any issue is detected with the oven itself or any equipment downstream. If a failure is detected, the top and bottom heater elements will open up away from the process conveyor and a fan designed to cool the oven chamber will increase in speed to quickly cool the oven chamber (fig. 3). There is a duel system in place to detect the temperature of the oven chamber. If the air temperature in the oven exceeds 294°F, the oven will open up and the fan will increase speed to pull cool air into the oven chamber.



Emergency doors are open illustrating operation during an emergency or operational error that allows for quick cooling.

Figure 3
IR oven used to shrink Mylar bags after tipper tie operation

The IR oven is an operational improvement in many ways. The operator that dried the blocks by towel was removed from the process. The energy requirement of the IR oven is much less due to the fact that the electricity is used more efficiently and the blower and compressed air power requirements that were used to assist the operator in drying the blocks were both eliminated. In addition, the IR oven will easily dry blocks at a 30-block per minute rate.

Taping Operation

The taping operation on the M112 demolition block production line was 100% manual and required one operator to perform the task. The operator's throughput was approximately 15 blocks per minute. The modernization effort replaced this manual operation with an automated taping machine. The tape machine was designed and manufactured by Ryco Design and Research, Inc. in Madison, Alabama. The tape machine is designed to position each pellet under a tape head, apply the tape in the proper orientation and at the correct length, and then reposition the C-4 pellet in the proper orientation for the ink jet printers (fig. 4).

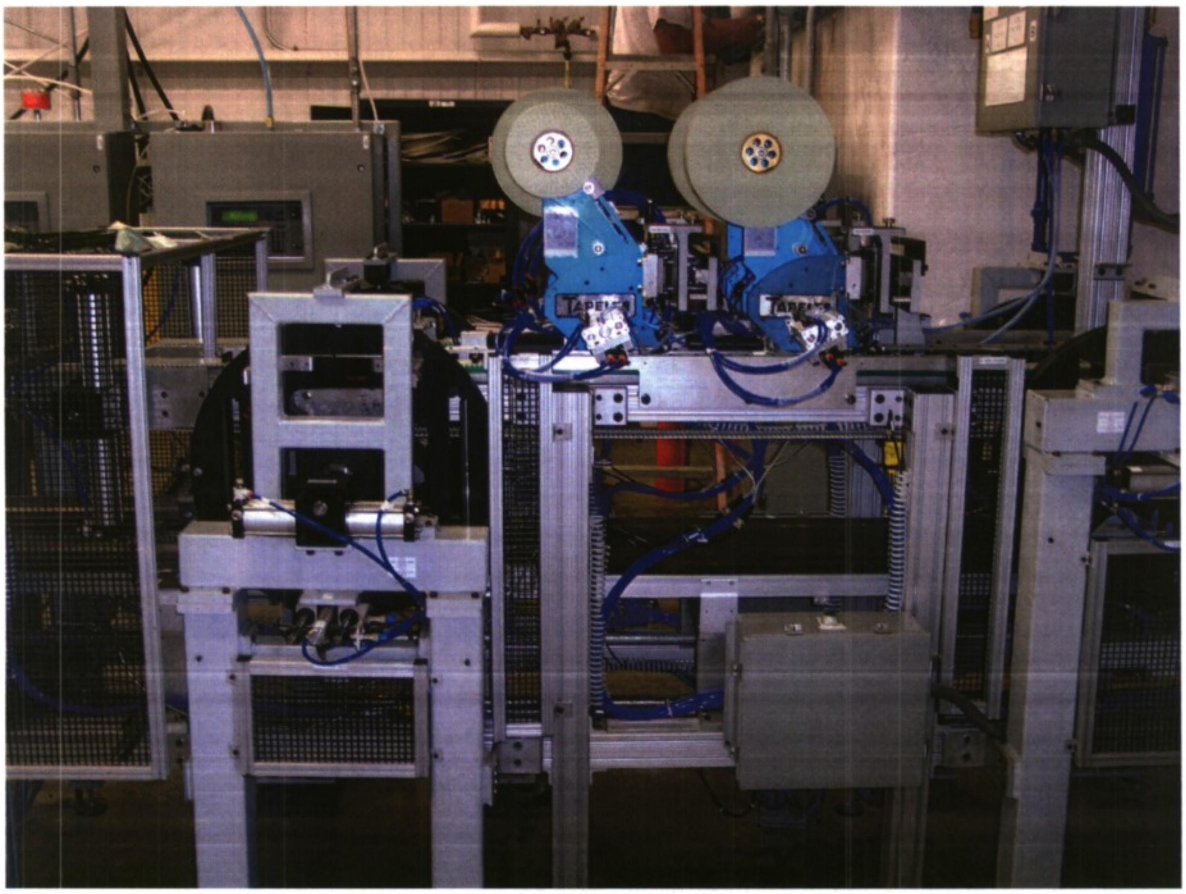


Figure 4
View of automatic taping machine from the side showing two of the four taping heads

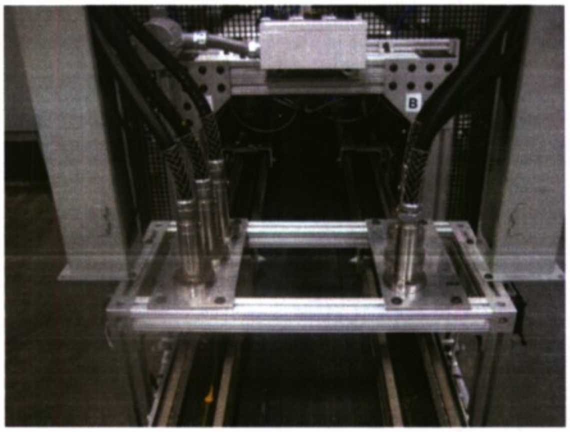
The cycle time is 4 sec/block and the machine is capable of taping two blocks simultaneously. The machine is capable of delivering a part every 2 sec for a rate of 30 parts per minute. There are two tape heads per side to allow for reloading tape on the run (one tape head runs at a time). The operator is eliminated from this operation, but other operators must reload the tape heads occasionally during production.

Marking Operation

The method of marking M112 demolition blocks in the past was to use a stenciling machine after the block had been passed through the taping process. The stenciling equipment was effective and provided marking with high quality, but the paint that was used smeared occasionally due to slow drying time and the throughput of the process was very slow, approximately 15 blocks per minute. The goal of upgrading the marking operation was to implement inkjet equipment, if there was an ink that would meet the military standard.

After an initial investigation it was determined that there was not an inkjet ink that was available that would meet the original marking standard due to a lower level of contrast. However, the government found that military standard A-A-59383 was more applicable to the M112 demolition block and made this the new marking requirement for the M112 demolition block. The contractor identified an ink that met this standard that was commercially available through VideoJet. The ink is designed to dry fast and the product is ready to be handled and inspected within seconds after printing. Independent ink testing was provided by Saint Louis Testing in St. Louis, Missouri, certifying that the selected ink meets the military standard A-A-59383.

VideoJet also provided inkjet equipment (fig. 5). VideoJet supplied three machines per side (two sides), each printing one line of information on the bagged C-4 pellet as it moved through the tape machine and under the printer heads.



The picture on the left shows the inkjet heads that mark blocks as they pass under on the conveyor and the figure on the right shows the control cabinets that store the ink and control the operation.

Figure 5
VideoJet equipment used to mark the M112 demolition block

The inkjet equipment easily met the desired production rate of 30 blocks per minute and reduced the amount of personnel by one. The contrast of the ink on the Mylar bag has been reduced; however, the loss of contrast quality was acceptable to the M112 quality IPT members when weighed against the benefits that the new ink provided.

Pack-out Operation

The pack-out operations of the M112 demolition block required operators to receive the final block that had been bagged, tied, heat shrunk, taped, and marked; the operator would then inspect the block and place it in wooden crate with a liner that was heat sealed after it was filled with the demolition blocks, the crate is then weighed, palletized, and stored for transfer at the end of the shift. The previous pack-out area was conducted in a building that used only 50% of the available floor space due to pre-existing explosive bay walls and other obstructions that were not used during the pack-out process. The old building was replaced by a new 36 ft by 80 ft steel frame building with 4 in. insulated roof and wall panels, 6 in. concrete floor with rebar reinforcement on 12 in. centers (figs. 6 and 7). The building is well lit and provides the additional work space needed for increased production requirements. The line layout of the previous building and new building is available in appendix B.

The new pack-out building increased useable floor space and working conditions.

Figure 6
The new pack-out building replaced the old pack-out building on the end of I-Line

Figure 7
The new pack-out line now houses dual conveyor belts that doubled the production capacity

The contractor demolished the old building and erected a new steel structure that allowed the operators to use 100% of the floor space. The increased floor space allowed for dual operations for the heat sealers, weigh stations, craters, and palletizing operations, which in turn, increased the pack-out operational capacity to 30 blocks per minute. In addition, many of the new pieces of equipment and the production line were designed to improve the ergonomics of each operation and the quality of life for the operators (figs. 8 and 9).

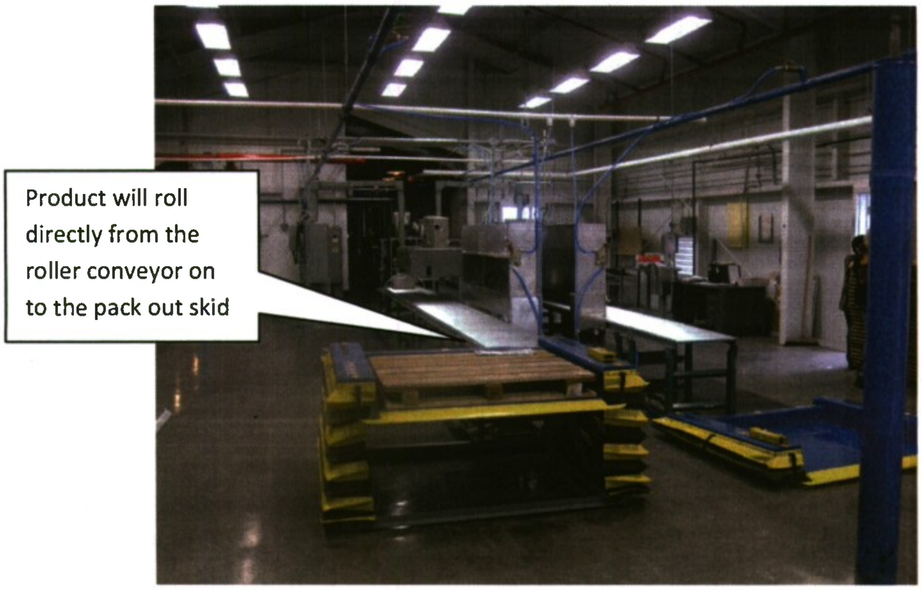


Figure 8
New pack-out using pallet lifts that improve ergonomics for the operator by eliminating many lifting and bending motions

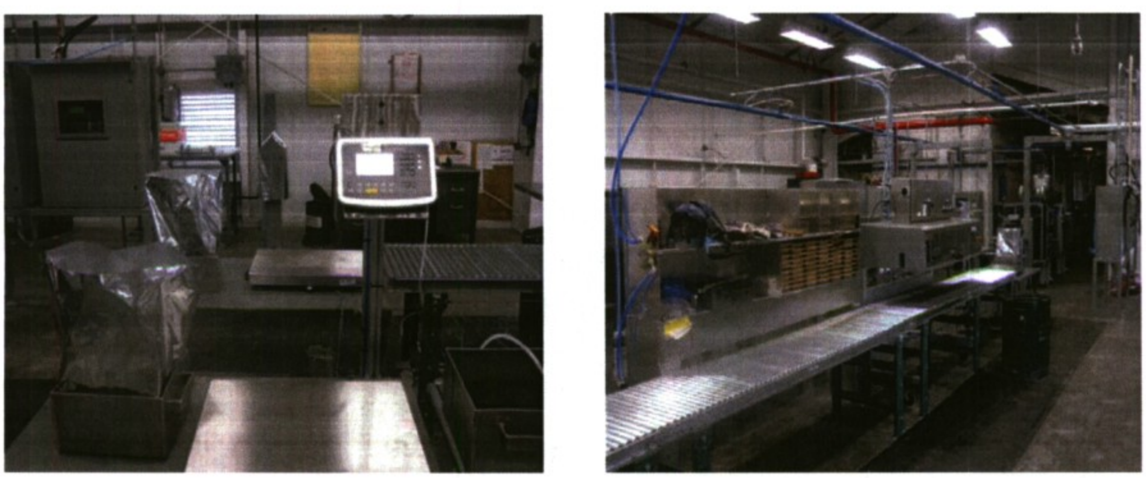


Figure 9
Dual pack-out line using dual weigh stations and heat sealers to double the capacity of the line

Conveyor System

Each of the operations described as part of the modernization project are fed from the previous operation using a continuous conveyor belt. In order to implement each of these improvements, upgraded conveyors were required to position the demolition blocks correctly for the automation processes. In addition to adding new conveyor belts, each conveyor belt had to be integrated with the existing conveyor belts, controls, and the new process equipment.

An integration system was designed and installed with the capability of identifying a failure or fault with the IR oven, tape machine, and inkjet. When a failure is identified with either of these pieces of equipment, the integration system will shut down the in-process conveyors and stop feeding the system, which will prevent equipment or material damage. A signal is then sent to the extruder operator alerting him of the failure. The IR heaters in the oven will open up to remove direct heat from the product and the oven conveyor will continue to run until all of the material in the oven at the time of the failure has exited the oven before the conveyor is allowed to stop (fig. 10).

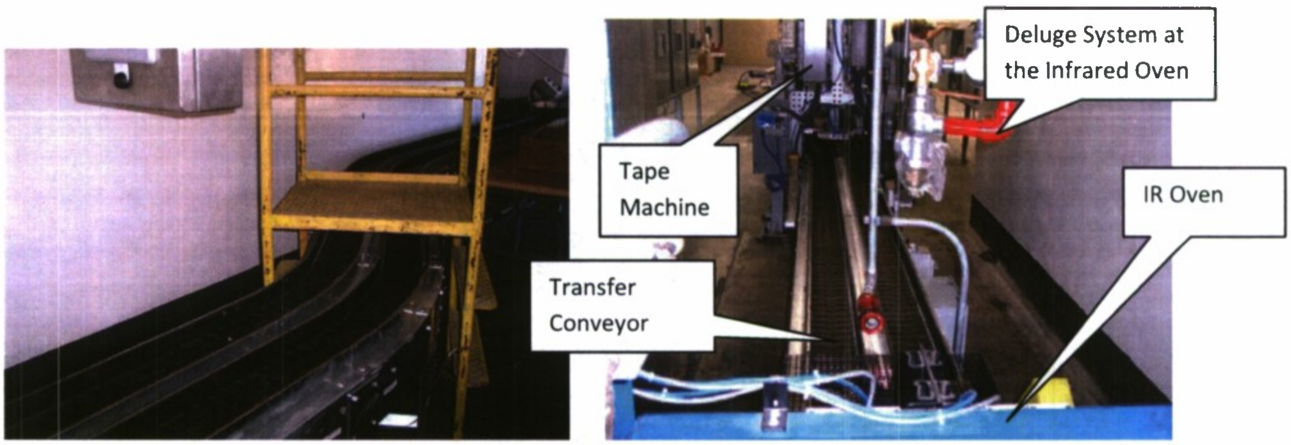


Figure 10
Conveyors on production line upgraded to position demolition blocks more precisely for the automated processes

Ventilation System

In addition to the process improvements that were made to increase the line capacity, reduce labor costs, and improve quality; this project also had the goal of improving the quality of life for the operators. A major source of discomfort for the operators was the requirement for the tipper tie and bagging operators to wear respirators connected to breathable oxygen due to the fumes given off of the un-bagged/un-sealed C-4 pellets. In order to remove this requirement, it was necessary to minimize the exposure of the operator to the pellets and also to improve the ventilation in the bagging and tipper tie areas.

To achieve this requirement, a new 6000 CFM fan was purchased and installed on the roof of I-4 and 20-in. duct work (fig. 11) was installed along with vent hoods at the bagging operation connecting the system to the new fan. In addition, the in-process conveyor from the extruder to the bagging operation was covered with a tunnel to prevent inhalation of fumes by the operators (fig. 12).

The improvements increased the average air flow across the face of each vent hood to 1800 lin ft/min and the average air flow at each operator station is 150 lin ft/min (fig. 13). Air testing was performed to ensure that the operators could work without respirators in the new work areas. The respirator requirement for the tipper tie operators has been vacated, but testing was not performed in the bagging area before production was completed. Further testing to remove respirators in this area will be conducted during the next production run.

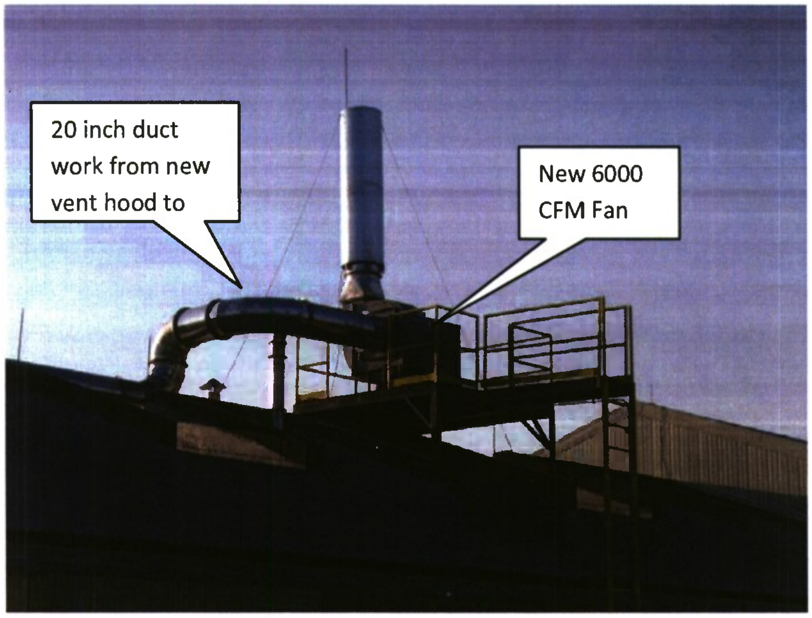


Figure 11
New 6000 CFM fan mounted on roof of I-4 building to improve ventilation

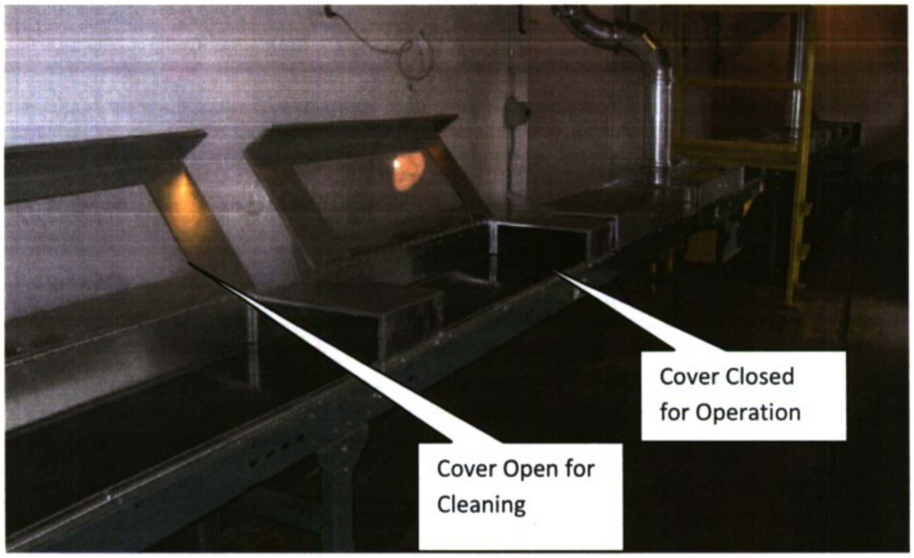


Figure 12
Conveyors covered to minimize fugitive emissions to operators

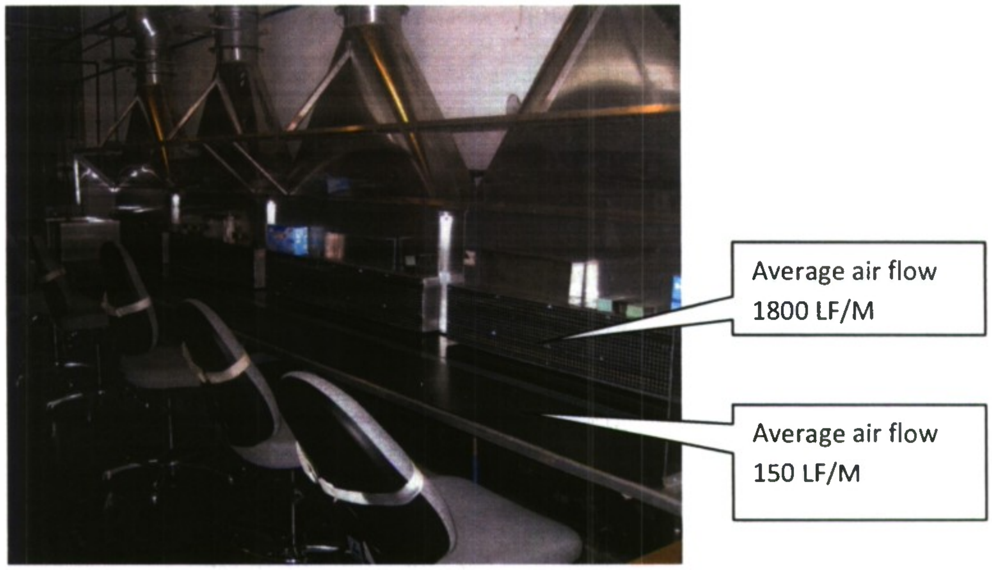


Figure 13
Improved ventilation at bagging operation necessary to eliminate need for operators to wear respirators pending air testing

Benefits

The M112 demolition block modernization effort will benefit the Army and the Soldier in a number of ways. The capacity of the line is effectively doubled and the bottleneck in the process is no longer any of the pack-out operations, rather, it is the extruder and how fast the M112 pellets can actually be made. The new line uses the same number of operators, but is capable of producing double the number of M112 demolition blocks in the same amount of time. This equates to a cost savings of $3.20/block assuming an increase from 17 blocks per minute to 25 blocks per minute and a $4.16 cost savings per block at 30 blocks per minute.

The IR oven reduces energy costs by an estimated $35,000/yr. This is based on the conservative power savings estimate related to the IR oven and the elimination of the inefficient hot water tank and compressed air requirements associated with the hot water bath.

Using the capital expenditure of the project (~$1.75M), the estimated production requirements for the next 8 yrs, the annual cost savings related to power, a production rate of 25 blocks per minute, and a discount rate of 3%; the net present value (NPV) of this project is over $850K. The NPV is over $1.5M when the production rate is increased to the 30 blocks per minute capacity that is estimated by AO.

In addition to the cost savings and quality improvements brought by the new line, there are quality of life and ergonomic improvements for the line operators. These improvements cannot be quantified, but they should not be overlooked as workplace injuries and morale can be very costly to organizations.

PATH FORWARD/FOLLOW-UP

In summary, congressional project 3474 was completed on time and within budget. American Ordnance (AO) designed, procured, installed, and debugged all new equipment, buildings, and systems in time to meet the contract date. The line is now capable of producing 30 parts per minute through the complete system with the improvements that were made. The ventilation improvement made to the bagging area produces air flow levels of 1800 lin ft/m at the face of the air vents and 150 lin ft/m at the operator stations. The building improvements have doubled the pack out capacity and the new infrared (IR) oven, tape machine, and ink jet printer are capable of producing thirty good parts per minute. The new die has two zone temperature controls with the ability of improving the quality of the product produced.

The line modernization was successful and met all the needs and contractual requirements of the contract. Additional issues can be addressed before production begins and before future production contracts are awarded.

- AO should investigate option to self-invest in automated length measurement and use same reject marking at the automated pellet weigh station if the length problem persists.
- AO should investigate improving contrast of ink marking against the Mylar bag through evaluation of thicker inkjet application, adjusting IR heat shrink operating parameters, or determining if bags used during prove-out were lighter in color than bags that will be used during production.
- AO should implement a visual inspection standard for marking (i.e., picture of levels of acceptability related inkjet marking for inspection operators)
- AO should conduct breathable air tests to eliminate respirator requirement for bagging operators
- The government should evaluate per unit cost of the M112 demolition block in light of the cost benefits associated with the modernization project.

APPENDIX A
FEASIBILITY STUDIES
BAG INSERTION FEASIBILITY STUDY

Recommendations:

1. Add two (2) additional tipper tie machines and two (2) additional bagging stations. This provides savings for the work currently underway and can be completed quickly. It should be noted that implementation of this option requires additional ventilation as this option adds two (2) additional personnel bagging the charges and two (2) additional personnel operating two (2) additional tipper tie machines. The payback resulting from these changes is due to increasing line throughput.

2. The automation concepts presented allow for significant M112 direct labor savings, but the concept designs are not sufficiently mature to warrant investment at this time. Additional studies should be conducted on the automatic C4 pellet insertion station. The Stahle study explicitly identifies risks associated with bag feeding and pellet handling, and the Ryco study implicitly identifies risks associated with pellet handling. The additional studies should focus on development and testing of prototype bag feeders and C4 pellet handling equipment. These studies can be completed prior to 30 September 2008, and the outcome of these efforts can be incorporated into a final design specification for the automation projects.

Background

Two (2) contractors submitted feasibility studies (studies attached). The design recommended by the Stahle Company was for two (2) identical stations that automatically performed the bagging and tipper tie application in one machine. The Ryco concept provides two (2) separate machines-one for bagging and one for tipper tie application-and includes two options of the bagging operation-an automatically loaded bagging station and a manually loaded bagging station. One other option that was investigated involved increasing the number of tipper tie machines to increase line production capacity to equal C4 extruder capacity.

Return on investment calculations were performed (spreadsheet attached) for the various designs, and the results are summarized in the table below:

Design concept	Design description	Cost	Delivery	Return on investment	Savings net present value
Stahle	Two identical machines, fully automatic	$945,300	22-26 weeks ARO	5.76%	$1,025,403
Ryco #1	Two separate stations-(1) block insertion and (2) tipper tie-automatically loaded	$535,500	24 weeks ARO (provided in separate communication)	18.15%	$980,984
Ryco #2	Two separate stations-(1) block insertion and (2) tipper tie-automatically loaded	$445,300	16 weeks ARO (provided in separate communication)	22.15%	$936,566
Ryco Option 1 Autobagging only	Automatically loaded autobagging station only	$268,850	24 weeks ARO (provided in separate communication)	36.5%	$847,729

Ryco Option 2 Autobagging only	Manually loaded automatic bagging station	$154,425	16 weeks ARO (provided in separate communication)	62.5%	$803,811
Ryco Tipper Tie only	Automates tipper tie application operation	$268,850	16 weeks ARO (provided in separate communication)	31%	$758,892
Two (2) Additional Tipper Tie machine	Addition of two (2) tipper tie machines identical to the machines in use plus modifications to the breathing oxygen system	$36,927	8-10 weeks ARO	175%	$268,400

Risks/Design Evaluation

The risks in this automation project include bag feeding, pellet handling, bag damage during pellet insertion and clip application and integration of the system into the existing production line.

The Stahle feasibility study identifies these risks and addresses means of reducing the risks or sensing the process anomalies. The proposed Stahle design reduces material handling by performing the pellet insertion and clip application on a common machine. The Stahle design is more desirable from a conceptual standpoint because it is a pair of identical machines with no material handling between the pellet insertion and clip application operations.

The Ryco feasibility study does not explicitly identify the risks to this automation effort, but C4 pellet handling risk is implied by including both manual and automatic options for pellet handling.

Both studies refer to the need for C4 pellets to accumulate on the belt conveyor and references are made to gates to stop C4 pellets or chutes to slide the pellets into position on the conveyor belt. These are areas of concern for C4 pellet handling, as the relative sliding motion between the C4 pellet and the conveyor belt implicit in these statements may lead to C4 pellet degradation and may cause the removal of material from the C4 blocks. Additionally, picking and placing C4 pellets with grippers may cause local pellet deformation that may hamper pellet insertion operations.

Discussion

Stahle study

The Stahle feasibility study recommends two (2) identical stations that automatically inserts the pellet into the bag and applies the tipper tie to the bag.

Ryco study

The Ryco feasibility study recommends two (2) separate stations, with the first station inserting the C4 block into the bag, and the second station applying the tipper tie to the bag. The Ryco feasibility study provides two options for the automatic pellet insertion station; one with the pellet automatically placed onto the pellet insertion station and a second with the pellet manually placed onto the insertion station.

Economic analysis of both studies demonstrates that there are significant savings that result from the proposed automation. Automatic bag feeding and automatic C4 pellet handling may not be successful, and the risk associated with the design and performance of these stations undermines projected schedule and savings validity.

In the case of the bag feeder, the vendor can design and test the bag feeder at the vendor's plant, and bag feeder design modifications could be incorporated prior to delivering the equipment to Milan. In the case of C4 pellet handling, the vendor will be unable to test the design with C4 pellets until the equipment is transferred to Milan, and any testing failures will cause schedule delays at the end of the automation project.

The following risk mitigation process is recommended:

1. Develop an M112 bag feeder design specification. The specification should include demonstrating the bag feeder at the desired design rate, and it should also include demonstrating the ability to automatically open the bag. The feeder should be designed and tested at the vendor's plant. Since bag feeding has been identified as a potential design problem, the contract with the bag feeder designer should be a time and material contract. This effort should be completed within 16 weeks.

2. Develop a test plan for C4 pellet material handling. The test plan should include studies conducted at Milan to determine pellet damage caused by relative motion between the C4 pellet and the supply conveyor belt and pellet damage during automated pellet gripping and transfer. The initial portion of this effort should be completed within 16 weeks, but initial tests may identify additional tests which should be conducted.

3. Upon completion of the M112 bag feeder design and completion of the C4 pellet material handling test plan, develop a specification for the automatic C4 pellet insertion station. This specification will include the results of the bag feeder design and testing and C4 pellet material handling tests.

Contract No. W52P1J-04-0002/0101
Project 3474, IM High Shear Mixer
Heat Shrink Improvement Feasibility Study Report
Completed by American Ordnance LLC
6/12/08

Summary:

Feasibility study has been completed in accordance with contract scope of work, Para. 5.5.6 to evaluate heat shrink improvements on the C-4 pack-out line. Options compared were: Option 1 - Continue to use hot water bath, replacing the steam heating source from the Line B fuel-oil fired boiler with an electric boiler located at I-Line; and improving the M112 pellet drying system; and Option 2 - Replace the hot water bath with infrared technology and eliminate the need for a drying system. Recommendation is to proceed with Option 2 due to economic benefit, safety and ergonomic improvement, reduced risk of quality problems for follow-on operations, and implementation feasibility.

Background

Item specification for M112 Pellet allows for heat shrink to be completed by hot water bath or infrared oven, provided safety requirements are met per Army Safety Manual AMC-R-385-100. A hot water dip tank, utilizing steam from the Line B boiler plant as the heating source, was installed in 2001 and is still in use for the heat shrink operation. Bagged and tied M112 pellets are manually placed in carriers on an overhead monorail conveyor at the Tipper Tie operation and automatically conveyed through the dip tank. Air knives, supplied by the Line B air compressor, are used to blow excess water from the pellets while still in the carriers at the tank exit point. The bagged pellets are then manually removed from the overhead monorail, dried with a hand towel, and placed in a holding tray for manual placement into the taping machine. Concerns and issues with this system are high operating cost due to increased fuel oil cost and inefficient heating method, inefficient drying operation at air knives, increased labor cost for manual pellet removal and drying, quality risk at follow-on operations due to residual moisture on the bags, and ergonomic safety issues. Feasibility study for either improving the hot water bath and drying operation or replacing it with an infrared oven has been requested by the government to address and correct these concerns.

Quality Improvement

Government Drawing 9204248, Charge, Demolition M112; Note 17 provides quality guidelines for evaluating the heat shrink operation. This note specifically states that heat shrink wrinkles in charge surface and areas fully shrunk, but not in intimate contact with the explosive surface, are not cause for rejection. Heat shrunk pellets from the water bath operation at Milan Army Ammunition Plant and the infrared oven operation at Crane Army Ammunition Activity have been visually observed by the Milan Army Ammunition Plant Quality Assurance Representative and an American Ordnance Engineering Department representative. There is very little noticeable difference, if any, in the heat shrink quality from these operations. Both operations meet the quality guidelines for the heat shrink operation if set up and run properly.

Quality risk at follow-on operations, which are taping and marking of the bagged pellet, will not be completely eliminated with Option 1. This quality risk is inherent to the water bath design, as the bagged pellets will always be subjected to moisture and must be dried prior to taping and marking. Any malfunction of the drying operation, whether it is the existing air knives and manual drying or an improved drying operation, will result in quality defects at the taping and marking operations. Government Drawing 9204248, Note 7 f. states that charge should be allowed to dry and cool prior to applying pressure sensitive tape. Drying to complete removal of all moisture around seams and wrinkles in the sealing clip area is very difficult, if not impossible, prior to the taping operation with the water bath method. Implementing Option 2 (infrared oven technology) will result in the bagged pellets never being subjected to moisture, so quality risk at taping and marking operations due to residual moisture is completely eliminated with this option.

Economic Analysis

An estimate to complete each of the two alternatives and economic analysis comparing each option to the current process were completed (spreadsheet attached), with results summarized in table below:

	Description	Cost	Delivery	Return on Investment	Savings Net Present Value
Option 1	Improve Existing Hot Water Bath/Drying Operation	$128,764	16-18 weeks ARO, Installation Complete by 12/31/08	23.1%	$281,488
Option 2	Replace Hot Water Bath with Infrared Technology	$158,372	16 -18 weeks ARO, Installation Complete by 12/31/08	30.8%	$437,456

The economic analysis was completed based on the current production rate of 16 parts per minute, or approximately 7200 parts per shift. . Pricing for both options includes variable production rate capability, with rate as high as 35 parts per minute, to allow for an increased production rate if additional funding is made available for other improvements and building modifications.

Safety

Safety for each option has been evaluated. Both options have risk of overheating the C-4 material due to control system failure, and redundant controls are included in the system designs for each option to address this risk. Option 1, Improving Existing Hot Water Bath and Drying Operation, has personnel safety risks inherent with boiler operations, steam piping, and 180 deg water in an open dip tank. Hearing protection is required at the drying area due to excessive noise from compressed air being discharged at the air knives. An ergonomics issue exists due to the Tipper- Tie operators having to reach up slightly to place the bagged pellets into carriers on the overhead monorail system so they can be conveyed to the dip tank.

Safety concerns for Option 2, Replace Water Bath with Infrared Technology, are primarily due to potential overheating of the bagged pellet if the oven temperature controls fail, the conveyor stops, or the exhaust fan from the oven malfunctions. All of these failure modes have been addressed in the design specification for the infrared heating system. Testing of the control system will include fail-safe testing of all safety interlocks and control features to ensure that bagged pellets will not be subjected to excessive temperature. A site visit was made to Crane Army Ammunition Activity in April 2008 to view operation of their infrared heating system for heat shrinking a similar bagged C-4 pellet. The system was operating acceptably, with voltage regulation to the infrared lamps for temperature control and a safety interlock to shut down system operation if the exhaust fan malfunctioned and did not provide airflow from the oven.

Crane's extensive use of the equipment without a safety incident provides validation that this technology can be safely used for the purpose intended. MLAAP's proposed design for the infrared heat shrink system includes similar safety features, with added safety features to include closed loop temperature control using thermocouples, redundant temperature controls with excessive temperature shutdown, safety interlocks to sense conveyor stoppage, and high-speed deluge with UV fire detection. Installation and operation of the proposed infrared heat shrink system will comply with all safety requirements of AMC REG 385-100, as stated on Drawing 9204248, Note 16. Use of the proposed infrared system will improve ergonomics at the preceding operation and eliminate the requirement for hearing protection.

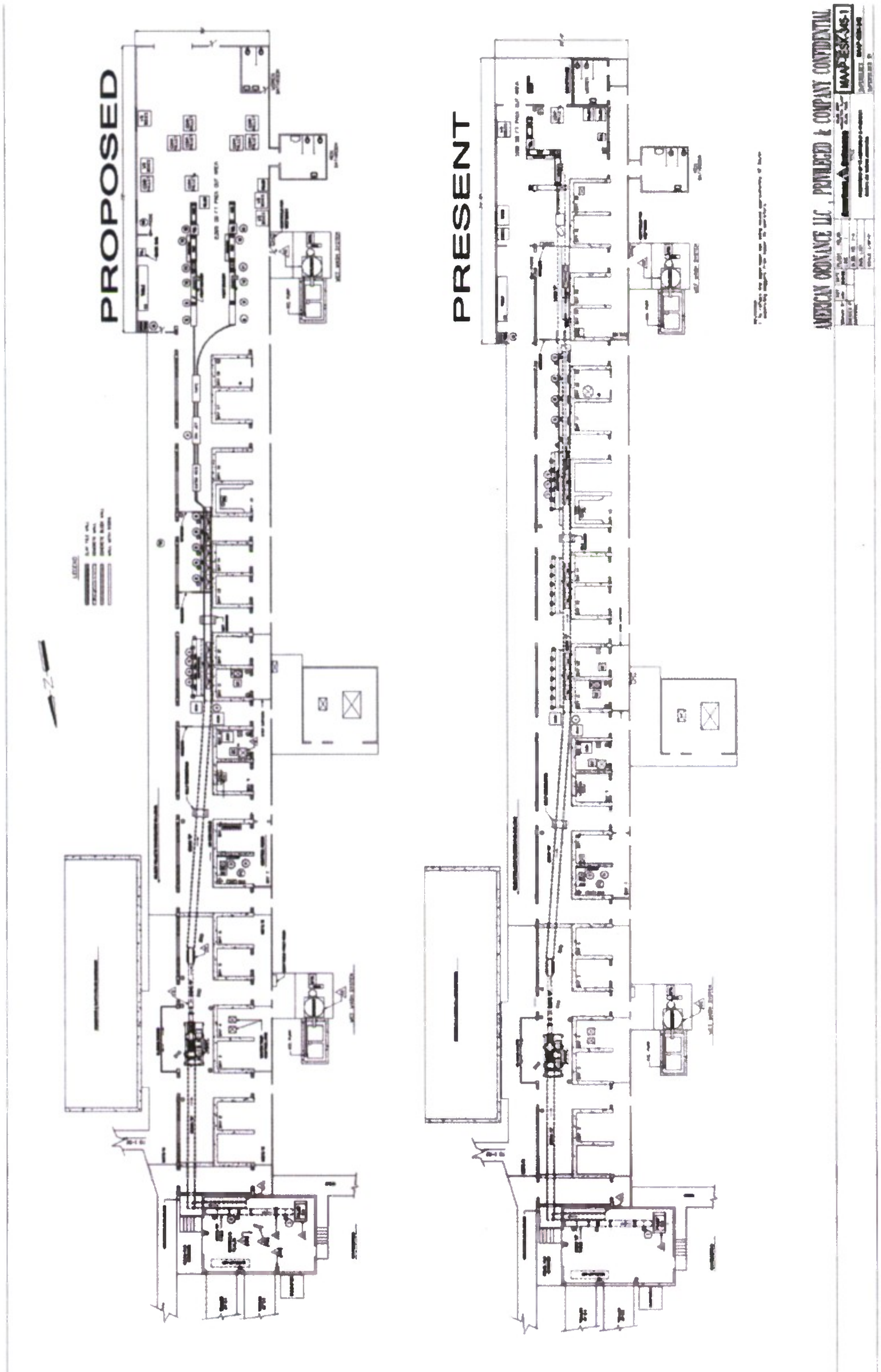
Feasibility

Feasibility of implementing the two options concurrent with other improvements to the M112 assembly and pack-out operation has been evaluated. Both systems are capable of running the desired increase in production rate of up to 35 parts per minute. Relocation of the heat shrink operation is critical to implementing other improvements that will create more working space for the pack-out operation at the south end of Building I-4. Replacing the existing hot water bath and drying system provides an operational process that has proven to provide acceptable quality results. However, implementation of this option would also require that the existing overhead monorail system be relocated or replaced in order to relocate the Tipper-Tie, taping, and marking operations. Feasibility of infrared technology for the M112 heat shrink operation has been evaluated based on site visit to Crane Army Ammunition Activity and evaluation of technical proposal from Wisconsin Infrared Systems on a proposed system design. Crane Army Ammunition Activity's successful use of an infrared heat shrink system for a similar C-4 pellet application provides verification that infrared technology is feasible for the M112 pellet operation. The available system design and controls provided in the proposal from Wisconsin Infrared Systems will provide a closely-controlled heat shrink process with adequate safety interlocks. Installation of the heat shrink system concurrent with other improvements will be easier to accomplish, and operation of the system will require less maintenance and operating costs.

Conclusion and Recommendation

Installation of an infrared system for the M112 pellet heat shrink operation provides several benefits compared to continuing to use the hot water bath with a new electric boiler and drying system improvements. Quality of the process will be improved by eliminating residual moisture on the bagged pellets that causes quality issues at taping and marking operations. Return on investment is higher with the infrared system than with operating a new hot water bath/drying operation. Payback of capital investment for the infrared system occurs during Year 5, which is 1 year less than Option 1. A properly designed and maintained infrared system will provide safety benefits due to elimination of hearing protection and ergonomic concerns with the hot water bath and drying operation. Feasibility of concurrent implementation with other M112 assembly and pack-out improvements is better with the infrared heating system than with installation of an electric boiler and other required equipment moves. American Ordnance recommends that Option 2, Replace the Hot Water Bath with Infrared Technology, be approved and funded to improve the M112 pellet heat shrink process.

APPENDIX B
LINE LAYOUT OF PREVIOUS AND NEW BUILDINGS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