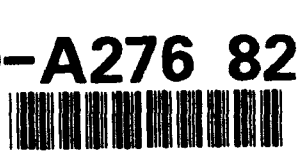

1992
Executive Research Project
F36a

Propellant Industry: Past, Present, Future

Lieutenant Colonel
Clifton J. Broderick
U. S. Army

Faculty Research Advisor
Colonel Marcus R. Erlandson, USA

The Industrial College of the Armed Forces
National Defense University
Fort McNair, Washington, D.C. 20319-6000

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT Distribution Statement A: Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NDU-ICAF-92-F36A	5. MONITORING ORGANIZATION REPORT NUMBER(S) Same
6a. NAME OF PERFORMING ORGANIZATION Industrial College of the Armed Forces 6b OFFICE SYMBOL (If applicable) ICAF-FAP	7a. NAME OF MONITORING ORGANIZATION National Defense University
6c. ADDRESS (City, State, and ZIP Code) Fort Lesley J. McNair Washington, D.C. 20319-6000	7b. ADDRESS (City, State, and ZIP Code) Fort Lesley J. McNair Washington, D.C. 20319-6000
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Propellant Industry: Past, Present, Future

12. PERSONAL AUTHOR(S) Clifton J. Broderick

13a. TYPE OF REPORT Research	13b. TIME COVERED FROM Aug 91 TO Apr 92	14. DATE OF REPORT (Year, Month, Day) April 92	15. PAGE COUNT 31

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	

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

SEE ATTACHED

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Judy Clark	22b. TELEPHONE (Include Area Code) (202) 475-1889 22c. OFFICE SYMBOL ICAF-FAP

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

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DISCLAIMER

A soldier can survive in combat for:

-- seven days without food;

-- for three days without water;

-- but, not one minute without ammunition.

anonymous

The purpose of this essay is to examine the development of the propellant production base from its past, present, and its future state. Some of the questions I hope to answer are: If the production base for propellant is drawn down; will this affect the United States' ability to meet its security needs? What - if any - influence will the overseas sources play in meeting our production and mobilization requirements? What are the environmental impacts on the propellant production base - present and future? How is the propellant production base integrated with the overall ammunition industrial base?

What does the phrase defense industrial base mean? The definition that is used most often -- "the defense industrial base is broadly viewed as encompassing those elements of American industry that contribute to defense related work and whose production capacity and technical expertise are required to meet national security."(1) Ammunition production is a critical element of the defense industrial base.

The United States national security strategy has recently undergone a major change, concerning the security risk or threat that the United States was prepared to engage if provoked.

This is due largely to a change in the East - West relations that occurred with the falling of the Berlin Wall and ultimately the failure of communism. Previously the threat was established when other governments procured armaments for essentially three purposes: to enhance their national security, to promote regime stability and to expand economic growth.(2) The national security of the United States was tied directly to our ability to counter these threats. The key question now is -- what is the threat to the United States? Should our strategy be built and maintained on a capability based strategy or a threat based strategy?

The Department of Defense is presently developing a new security strategy based on President Bush's guidance: "Our new strategy must provide the framework to guide our deliberate reductions to no more than the forces we need to guard our enduring interests - - the forces to exercise forward presence in key areas, to respond effectively to crises, to retain the national capacity to rebuild our forces should this be needed"...and to..."maintain an effective deterrent."(3) Until this question concerning how the United States strategy will be structured is resolved, uncertainty in all defense industries, including the armaments industry, will exist. How much ammunition is necessary? Do you keep the ammunition production base warm or place it in a stand-by status?

In the armaments industry, and looking specifically at the propellant industry, the long pole in the tent is the <u>time</u> necessary to start up and then sustain production. Propellants are a critical element in all ammunition explosive chains.

They basically provide the power that propels a piece of ammunition from the weapon after ignition. The manufacturing of propellants is a very unique process and has limited utilization outside of the government. From an economic prospective, the propellant industry would be classified as a **"demand element"**(4) in relation to the overall ammunition industrial base. Ammunition will not function without some type of propelling charge. The propellant industry is therefore tied directly to the ammunition industrial base. Presently, the overall ammunition base is shrinking -- therefore so will the propellant base. Except for the requirement for hunting and sporting ammunition (rifle and pistol), there is no private commercial counterpart or a real market that exists outside of orders from federal and other government customers for the armament industry. (5) A unique market does exist for propellants that are used in rocket motors that propel space crafts for the National Aeronautics and Space Administration (NASA).

The market for ammunition procurement is one of a single buyer or a monopsony condition. The free market system is not at all sensitive to the United States national security or defense. Private industry's incentive to produce a product is basically for profit. Their operating method is that of self-interest rather than what would be in the best interest of this country. The government has to be sensitive to these conditions and not rely on the myth that a free market will foster efficiency and innovation through competition. This is especially pertinent in the armament industry, where the

product is so unique. The government has to provide incentives for corporations to be interested in operating a defense armament plant. Additionally, once a plant is placed in layaway or a caretaker status, the capability for reactivation must be retained.

One method that is being explored to keep these plants open is a facilities contract. Today, the government is trying to generate interest among the operating contractors of ammunition plants that are scheduled to close, to operate the plants under a facilities contract. This type of contract would allow each contractor to independently bid on government, and possible civilian contracts. Thiokol Corporation has been considering this type of contract at Louisiana Army Ammunition Plant (AAP). The biggest drawback according to Thiokol is the ongoing environmental responsibility. The most critical area, and probably the hardest to maintain, is the loss of trained workers. They have the knowledge and capability to operate these manufacturing processes. The maintenance and modernization in each of the plants is critical for the ability to restart the production lines.

If the propellant base follows the downward trend that is projected for the armament industry, would the United States utilize overseas sources to meet our requirements? Talking with several armaments industry experts, the same message came across. No! The congressional and political structure would not allow this government to purchase products from an overseas source when the capability (i.e. plants and jobs) is available

here at home

Propellant manufacturing is a very dirty and hazardous production process. A key issue that continues to come up concerning the manufacturing of propellants -- what is this process doing to the environment? Presently there are waivers in place that allow production to continue. The government, both state and federal, are monitoring very closely this situation and each ammunition plant is continuing to correct and upgrade the facilities to comply with all environment and safety conditions as dollars become available. Modernization of these plants have continued to show both governments that each plant is trying to act in good faith and comply with all regulatory requirements. If the United States Army ever closed a propellant plant and then wanted to start up production five years later, the same relationship between governments and the plant may not exist. These waivers that have been granted in the past may not be approved for a restart of operations and the plant would then have to meet all letters of the law. This definitely would drive the cost of operation up, and again, economically it may not be feasible. If the ammunition plant is needed to support a declared war effort, economics would not be a factor that would prevent opening operations, but the environmental issues surrounding the plant still might. It would depend on the actual situation and the environmental impact to the area or region.

First, it is necessary to discuss the basics, what is propellant and how is it used?

WHAT IS PROPELLANT?

A common definition of propellant is: an explosive used to propel a projectile or missile, or to do other work by the expansion of high pressure gas produced by burning.(6) The military used black powder as the principal propellant worldwide until the late 19th century. Then a new method was discovered by which cellulose fibers in the form of cotton wool could be treated with nitric acid to form a new substance called nitrocellulose. This new propellant substance, called a smokeless powder, had several important advantages over black powder.

-- It produced about three times as much energy as black powder for the same weight of charge.
-- The products of combustion were substantially all gaseous, whereas the combustion of black powder produced approximately 40 percent gaseous and 60 percent solid products.
-- The solid products produced most of the smoke upon firing the black powder and the new powder was pronounced "smokeless" by comparison, although it was not literally so.
-- Elimination of solid combustion products also greatly reduced fouling of the bores of rifles and cannons.
-- Smokeless powder was not destroyed by exposure to moisture.(7)

The compounds in this newly developed single based propellants quickly proved their dangerous properties. In A Textbook of Ordnance and Gunnery, published in 1896: Captain Lawrence L. Bruff points out that free acids in nitrocellulose "caused spontaneous decomposition with elevation of temperature and increased sensitiveness, so that explosions frequently

resulted."(8) To counter this explosive tendency, stabilizers were added to the compounds. Depletion of stabilizers can reintroduce the hazards of spontaneous ignition. As propellant ages in storage, stabilization of the contents also drops.

Other components of the single based propellant add to its functional and reliability characteristics. One functional characteristic which had to be adjusted was the propellant consistency. Propellant must have a smooth burning rate or it will explode. Control of the burning rate is achieved by the propellants composition, size, and configuration of the propellant grains. The goal is to produce a propellant that is slowly converted to a gas in the initial stages of the burning and then more rapidly as the burning progresses. In addition to the single based propellant, a double based propellant and a triple based propellant have been developed. These compositions were produced by adjusting the mixture of the chemical ingredients to achieve different ballistic charges. Different types of propelling charges are manufactured for different application, for example, between a small arms and artillery ammunition.(9) The propellant production base is an integral part of ammunition production. Every round of ammunition needs to have some type of propellant for it to properly function. Manufacturing of propellant is a very dangerous process due to its ability to spontaneously ignite. Not only will propellant spontaneously ignite during manufacture, but also in storage. The majority of the explosions that have occurred in storage were from propellants awaiting demilitarization.

Explosions in storage magazines at both Lexington-Blue Grass Depot and a Korean Ammunition Depot in 1985, prompted the Commander of the U.S. Army Materiel Command to establish an independent investigation.(10) This series of explosions and other accidents required the ammunition community to review its procedures on the storage and demilitarization of propellants. A very comprehensive study of these procedures was accomplished by a team of experts headed by LTG (Ret) Harold F. Hardin Jr.(11) The recommendations and corrective action taken by the individual plants and arsenals has insured that propellants continue to be handled safely in the ammunition production base.(12)

Now that we have briefly overviewed what the major ingredients are in propellant, how did the overall ammunition production base develop? Historically, how did the production base support the wars and conflicts?

PRODUCTION BASE HISTORY

The system to produce ammunition is unusual and very complex for several reasons: there are many different items produced and most are produced in volume; there are a large number of production lines, most of which can produce many different conventional ammunition items; none of the items produced, and few of the factories have economical peacetime use; and there are a variety of administrative procedures and arrangements.(13) The U.S. Army's ammunition production base is large in size and complexity. There are three distinct industrial processes necessary to produce a complete round of ammunition, regardless of whether it's 5.56mm (M-16 ammunition)

or a 155mm Howitzer. The manufacturing process basically consists of single items being made in one plant and then transported to another plant for assembly.

The three manufacturing processes are:

1. Metal Parts (MPTS) Production.
2. Propellants and Explosive (P&E) Production.
3. Load Assemble and Pack (LAP) Operations.

The metal parts components (e.g., shell projectile bodies, rotating bands, cartridge cases) and the propellants and explosives components (e.g., propelling charges, explosive fillers, primers) are integrated into the complete end item or round of ammunition at the load, assemble and pack facility.(14) Ammunition requirements naturally have increased during periods of wars and conflicts.

Prior to World War II, the Department of the Army had done some mobilization planning, but no one foresaw the magnitude or scope of World War II. Consequently, when World War II started, the United States had a very inadequate ammunition production and again had to re-establish the ammunition production base to support the U.S. Army's requirements. Between 1941 and 1945, Congress authorized the construction for a production base of 112 ammunition plants of which only 84 plants were ever built.(15) These plants were usually designed for a single item of production -- propellants, TNT, shell forgings, ammonia, smokeless powder, loading, assembling and packing, etc. All of these plants were owned by the government, but operated by civilian industries. The government reasoned that, if a

company had the managerial background and capabilities to operate a commercial activity, then they could use the same principles to manage a military plant. The key point was that it worked and the same philosophy is still being applied today.

At the end of World War II, the national military policy presumed that any future war would be marked by a formal mobilization of the economy with accompanying emergency controls over critical industries.(16) Additionally, a very critical point that was missed is the **time** to conduct the mobilization operation of the plants and equipment. Consequently, mobilization planning was based on the assumed ability to secure nearly all necessary services and goods from private industry. The War Department did not see any reason for maintaining these ammunition manufacturing plants and sold many of these plants to private industry. By 1950, the government had reduced the number of its ammunition plants from 84 to 38.(17) Although the government retained the remainder of these plants, the majority of them were placed in a mothball state with little or no facility maintenance program.

When the Korean conflict occurred, the United States was better prepared than at the start of either World War I or II. However, because of the lack of plant maintenance it took over nine months to bring the ammunition base up to full production.(18) This was very quick compared to today's estimation for a plant reactivation of approximately 24 months. The bulk of the ammunition used in Korea came from the stockpiles that were leftover after World War II. Although there were

reports of ammunition shortages and Congress conducted an investigation, these reports were never fully substantiated. A Preparedness Subcommittee of the U. S. Senate Armed Services Committee reported after an extensive investigation into the alleged ammunition shortages: "There is a limit to which any stockpile can be called upon to meet continuing demand; it must be augmented continually with new production.(19)

After the Korean conflict, the Department of Defense recognized that it could not completely demobilize our industrial base. The new Secretary of Defense, Charles E. Wilson, launched an economy drive to get "more bang for a buck" in which long-termed preparedness was sacrificed on the alter of immediate cost savings as the production base was again permitted to shrink.(20) The decision to maintain the ammunition base on a very reduced scale, left eleven ammunition plants in full operation and the remainder in a maintenance layaway program. The majority of the ammunition production at this time produced training requirements and some limited new production items.

In 1965, the United States became fully committed to the Southeast Asia conflict, providing military support. Again, the requirement for more ammunition focused directly on the production base and required the reactivation of several inactive ammunition plants. In 1966, the U.S. Army reopened six additional ammunition plants; in 1967, eight additional plants; and four more in 1968.

During the Vietnam War, the U.S. Army activated: 100% of the Load Assemble and Pack facilities; 100% of the Metal Parts

Production; and 85% of the explosive and propellants facilities in the existing ammunition production base.(21) After the conclusion of the Vietnam War, the U.S. Army drew down the production base, due to the shrinking ammunition requirements and budget constraints. Rather than follow the historical method of laying away the plants without any facility maintenance, they started a modernization program for the ammunition production base. The U.S. Army recognized the need to modernize and provide facility maintenance dollars for the ammunition base. This was necessary to insure that the ammunition production base would be available to deter the projected threat that the United States could face.

The principle ingredient in a round of ammunition is the "**propellant**". How was the propellant industry built and how has the United States maintained this very important portion of the ammunition production base?

PROPELLANT PRODUCTION BASE

During the early 1940's, the War Department initially established the propellant production base at four separate Army Ammunition Plants (AAP); Radford AAP, Indiana AAP, Sunflower AAP and Badger AAP. These plants provided the propellant necessary to support the production of ammunition for the U.S. Army during World War II. The propellant production base was viewed as unnecessary at the end of World War II and completely deactivated by the War Department.

During the Korean conflict the propellant base was reactivated to support the conflict's ammunition requirements. Radford

AAP remained as the only active propellant plant, maintained by the U.S. Army, at the conclusion of the Korean conflict.

At the start of the Vietnam conflict, the propellant production base again was called upon to support the ammunition requirement of the U.S. Army. The reactivation of Badger AAP and Sunflower AAP in 1966 and Indiana AAP in 1968, increased the overall production base to four propellant plants throughout this conflict. As ammunition requirements declined, so did the active producers of propellant. Sunflower AAP ceased operation in 1971, Indiana AAP in 1973 and Badger AAP in 1975. Today, Radford AAP remains as the only active propellant production base in the U.S. Army inventory. Sunflower AAP was reactivated in 1984 to produce nitroguanidine which is transported to Radford AAP for the production of triple base propellant. The following is a brief review of the four propellant production facility and their individual roles for providing propellants to meet the U.S. Army ammunition requirement in peace and war.

RADFORD AAP

Radford AAP (RAAP), is a government owned and contractor operated (GOCO) facility located near Radford, Virginia. RAAP is the only active propellant plant and has the capability to produce single, double and triple base propellant, rocket propellant grains, TNT and carpet roll (rolled powder).(22) Hercules Incorporated, has been the operating contractor at RAAP since it was built. RAAP started operation in 1941 and produced 596,482,846 pounds of various propellant, before being

placed in a stand-by status at the conclusion of World War II.(23) In 1949, limited production of propellants started up again, and Radford produced 578,782,073 pounds(24) of single, double and triple base propellant until 1965. Noteworthy, is the production capacity RAAP achieved through surging, during a one year period:

1943 -- 150,000,000 pounds

1953 -- 137,000,000 pounds

1968 -- 162,000,000 pounds (25)

Presently, RAAP is the government's primary plant for the production of propellants. Numerous modifications have been accomplished at RAAP to increase the plants overall production capability. The continuous automated single base cannon propellant line (CASBL), constructed in 1982, is designed to produce a maximum of 2.5 million pounds of single based propellant per month from the two automated lines (CASBL #1 and #2).(26) The CASBL lines continue to have processing problems and only one of the lines CASBL #2, completed acceptance testing. With the declining production requirements, further prove out projects for CASBL have been canceled.(27)

SUNFLOWER AAP

Sunflower AAP (SFAAP), is a GOCO facility located near the town of DeSoto, Kansas, and operated by Hercules Incorporated. SFAAP has the capability to produce triple base propellant, rocket grain propellant and nitroguanidine.(28) SFAAP started production of propellant in 1943 and produced over 200 million pounds of propellant(29) before being placed in a stand-by

status, at the end of World War II. SFAAP manufacturing reactivated for both Korea and Vietnam to meet peak production requirement for propellant. In 1984, the Army spent approximately $160 million dollars to install the production capability of nitroguanidine at SFAAP.(30) Nitroguanidine is the principal explosive component in triple base propellant that is used in artillery and tank ammunition. It offers two distinct advantages over other propellants -- extends the life of the gun tubs and reduces the firing flashes normally visible to the enemy.(31) SFAAP is presently the only producer of nitroguanidine in the ammunition production base. SFAAP is scheduled to be layawayed in May 1992, upon completion of the present production workload.(32)

The following two ammunition plants are capable of producing propellant, but presently their propellant production lines are in a layawayed status. Indiana AAP is still an active GOCO, presently workloaded only to bag propellant charges for the 8 inch and 155mm artillery rounds. Badger AAP is inactive and layawayed.

INDIANA AAP

Indiana AAP (INAAP), is a GOCO facility located near Charlestown, Indiana and being operated by ICI Americas, Inc. INAAP capabilities includes powder manufacturing, bag manufacturing and propellant charge loading facility.(33) In 1945, three separate ammunition facilities, Indiana Ordnance Works Plant, Hoosier Ordnance Plant and the Indiana Ordnance Works, were consolidated into the present INAAP.(34) INAAP

propellant lines were activated during World War II, Korea and Vietnam, but shutdown quickly after the termination of each conflict. Presently, the plant has the capability to manufacture propellant, but is not workloaded for production.

BADGER AAP

Badger AAP (BAAP), is a GOCO located in Baraboo, Wisconsin. Hercules Incorporated became the operating contractor in 1943. BAAP was designed and built as a duplicate facility of the Radford AAP. It is capable of manufacturing propellants and chemical materials.(35) BAAP produced 271,365,595 pounds of propellant (36) before being placed in a stand-by status in 1945. BAAP was reactivated in 1951 during the Korean conflict with Olin Mathieson Corporation taking over as the operating contractor. BAAP produced 286,058,304 pounds of propellant(37) before being layawayed again in 1958. Reactivated during the Vietnam conflict in 1966, BAAP produced a total of 445,849,702 pounds of propellant(38) before being placed in stand-by status in 1975. BAAP remains in a layawayed status.

The future of the propellant base will follow the lead of the overall ammunition industrial base. What will the production base look like in the future?

PROPELLANT PRODUCTION BASE - FUTURE

Unless there is a mobilization for a war or conflict that would require the opening of another propellant manufacturing plant, Radford AAP will remain as the only active propellant production facilities. The capability at Radford AAP, far exceeds the present requirement for propellant. Radford AAP

has the capability to produce about 96 million pounds of single base propellant per year, without expanding the present plant capacity (workforce and facilities). To meet the U.S. Army's present requirements for propellant, Radford AAP must produce approximately five million pounds of propellant per year. This allows for a surplus of approximately 89 million pounds of propellant, that could be produced without changing the workforce or the opening of any additional production lines. During Operation Desert Shield/Storm, Radford AAP did not change their production schedule or operation in order to meet the propellant required to support the ammunition base. Because of the excessive capability at Radford AAP, it definitely has the capability to support the needs of the total ammunition base if a short notice conflict occurred.

The total ammunition plant production levels (for all types of ammunition) is scheduled to decline from 20,900 manyears of work required in FY 91 to 7,104 manyears in FY 98.(39) The biggest drop in requirements is projected between FY 92 (20,070 manyears) to FY 95 (8,920 manyears) or a loss of 11,150 manyears of work.(40) This decrease in overall ammunition production requirements will be passed directly to the propellant production. Projected workload in manyears at Radford AAP will be reduced from 2,642 (FY 91) to 1,170 (FY 95) or a drop of 1,472 manyears of work.(41) This reduction for ammunition will require the closing of a total of seven active ammunition plants by FY 95.

Since the government has identified these closures, where

will this put the United States in its ability to meet its security needs and to protect its regional interests and concerns?

WAR RESERVE STOCKPILE

The requirements for ammunition are definitely declining. In the past the U.S. Army has purchased ammunition based on the assumption that sufficient ammunition in the war reserve stockpile would be on hand at the start of a war (D-Day), which would be adequate to satisfy consumption requirements until the industrial base could build production to the level of the consumption requirement (P-Day).(42) This has been known as the D to P concept. In the future, the total requirements (training, stockpile, research, etc.) will be the only method for forecasting the amount of ammunition that will be produced in any given year. The question then becomes what will occur to the war reserve stockpile and how much of stockpile is necessary considering the present world situation? During Operation Desert Shield/Storm, the ammunition needed to achieve victory, was provided from the existing stockpiles that had been built around the world. This stockpile was to sustain the force in a conflict between the United States and Soviet Union. The challenge now, becomes to determine the amount of ammunition necessary to be held in the stockpile and the amount that the remaining ammunition industrial base will be capable of producing. This decision is presently being worked by the logistic officers at the Department of Defense and the individual Services.

SECURITY NEEDS

The driving force behind the amount of ammunition produced is the requirement. The future war -- will it be a regional conflict or global war? The key factor that drove the requirements in the past was the threat! Now that the threat is not clearly identified, the United States must be prepared to fight in different types of scenarios (global and regional). A short conflict does not require the ammunition base be surged or plants be reactivated. Ammunition would be drawn from the war reserve stockpile. For an extended conflict or global war, reactivation of the ammunition production base would be necessary to meet requirements. The U.S. Army operation planners must realize during the requirement development phases, that it will take up to 24 months to reactivate a plant from a layawayed status. To increase the national security posture in peacetime, for a possible conventional conflict, the United States basically has two choices: to take the actions and make the investments to have a responsive defense industry, or to stockpile enough military equipment to sustain a conflict for the time it would take the defense industry to get up to speed.(43) The positive identification of the threat will drive the requirement for ammunition.

Can or will overseas propellant production sources from Mexico, France, Germany, etc, have any affect on the decision to layaway U.S. ammunition production bases?

OVERSEAS/INTERNATIONAL CAPABILITY

Historically, the United States has not purchased ammunition

through the international market. The question is why not? The United States does not want to be dependent on a foreign nation to provide the ammunition. There are definite risks involved (i.e. a foreign supplier not willing to support the United States actions and refusing to provide ammunition) and that has to be weighed against the projected threat. All other major military systems have numerous parts that are imported to the U.S. for final assembly. Could the U.S. purchase propellant from an overseas source - Mexico, France, or Germany? The answer is yes, but there is a risk involved. A strategy and risk assessment must be developed concerning the actions and agreements that would occur during a crisis situation. There is a definite political impact that must be considered concerning the loss of jobs and foreign dependency created by reducing or eliminating the production base and the possible negative technology transfer. The answer is the U.S. can purchase propellant overseas, but the risk associated with this decision would have nothing to do with economics. It's a political decision.

Environmental awareness by the general population has been on the upswing during the past twenty years. What will be the future impact to the propellant and ammunition production base?

ENVIRONMENTAL ISSUES

Environmental laws and issues are a fact in the United States political and social cultures. Ammunition plants built in the 1940's, cannot comply with the present environmental

laws. Presently, there are numerous waivers granted by the federal and state government environmental offices, specifically for air and water pollution quality, allowing the ammunition plants to continue to operate. A "good faith" issue between each plant and the respective government does exist, because each plant is demonstrating that they are trying to comply with all regulatory requirements. Modernization dollars for the plants are only being used to correct environmental and safety deficiencies. Without these waivers the ammunition production base would not exist. The major concern is, if the existing propellant plant is closed, it would probably not be able to reactivate, because of the strict environmental rules and regulations at both the state and federal government levels.

CONCLUSION

The future ammunition budget is declining and it is presently the real driver of the total requirements. The biggest drop projected in ammunition production requirements will be between FY 92 and FY 95. Exactly what the impact will be, is not known. The ammunition industrial base is truly a unique and separate industrial base. There are very few products that can be crossed over from the ammunition manufacturing to commercial business. Contractors who have been running the GOCO's are reviewing their business positions, is it profitable to stay in the ammunition business? In World War II, American industry mobilized to create the legendary "Arsenal of Democracy" that turned its output from consumer goods to war materiel and achieving

extraordinary rates of production.(44) But, it lasted only as long as the war did. Ammunition is a complex industry that produces items that can range from very low to highly technical ammunition. It will continue to be difficult to entice private contractors to invest in a business that is shrinking and really has only one customer. A facilities type contract would allow the operating contractors of GOCO's scheduled to close, to bid on government contracts and perhaps also do private contracting at these plants. This concept ties directly back to the concern of production availability and the sufficient capability to support future military emergencies or contingencies.

The United States government can not lose the capability to manufacture ammunition. In order to support a reconstitution effort, the existing Metal Parts, Propellant and LAP production facilities must be available - even if it is not cost effective. Additionally, to support a global or regional conflict, an adequate ammunition stockpile must be retained, with the overall requirements being built around the preferred/smart munitions.

The ammunition production base needs to maintain a viable propellant facility to support any future global or regional conflicts. Propellant is a unique and very important item in every piece of ammunition. Radford AAP is fully capable to support the present ammunition requirement and has more than sufficient unused capacity for any reconstitution operation. The propellant production process at Radford AAP is very labor intensive to operate, basically still using 1940's technology,

but it is also very capable of producing a high quality product. Based upon the world situation and the excessive capacity at Radford AAP, deactivation and closing the propellant capability at Badger, Indiana and Sunflower AAP's would be a good cost effective measure. However, as the only remaining propellant facility, it is necessary for Radford AAP to be funded for continuous modernization and facilities maintenance. To protect the future of the overall ammunition industrial base, the government must maintain the capability to produce propellant at Radford AAP.

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(11) Ibid., pp. II-1 thru II-5.
(12) Ibid., pp. IV-1 and V-1.
(13) Logistic Management Institute, Condition and Operation of DOD Ammunition Production Facilities, Phase II Task 68-19 (Washington D.C., 1970), p. 5.
(14) For complete detail production process of complete rounds of ammunition see -- Ennis Harry F., Peacetime Industrial Preparedness for Wartime (mmunition Production, (Washington D.C.: National Defense University, 1980, p.54-56; and Department of Ordnance, Ammunition, (New York, West Point, 1951, pp 31-35.
(15) Smith, R. E., The Army and Economic Mobilization, (Office of the Chief of Military History, Department of the Army, 1959), p. 499.
(16) Logistic Management Institute, Conditions and operations of DOD Ammunition Production Facilities, p. 17.
(17) Hammond, R. J. Profile on Munitions, p. 6.
(18) U.S. Congress. Senate. Committee on Armed Services. Investigation of the Ammunition Shortages in the Armed Services, Interim Report, (Washington D.C.: United States Government Printing Office, 1953), p. 20. Senator Estes Kefauver (Tennessee) stated during hearings - "One of the reasons that we (U.S.) were so slow in getting ammunition delivery, according

to testimony before the committee, was because when plants in stand-by status were put in operation, it was found that they had deteriorated and much more work than was anticipated was necessary before they started producing. Having learned that, we should profit by the lesson and seek to keep more plants in actual operating condition."
(19) Whether a shortage of ammunition did exist on the front lines in Korea was disapproved, however there were shortages in the rear supply lines that were due to the lack of immediate ammunition production capability. -- U.S. Congress, Senate, Committee on Armed Services, Investigation of the Ammunition Shortages in the Armed Services. Second Report of the Preparedness Subcommittee No. 2, 83rd Congress, 1st session, p. 39-40.
(20) Huston, J., The Sinews of War, Army Logistics, (Washington D.C.: Office of the Chief of Military History, United States Army, 1966), p. 658.
(21) Hammond, R. J. Profile on Munitions, p. 9. Although smaller in terms of plants and personnel than its predecessors of World War I & II and Korea, the GOCO complex was, on 31 Dec 68, still a vast enterprise which spread from New Jersey to California and from Texas to Nebraska. It should be noted that the U.S. activated 100% of our L/A/P and metal parts capability and utilized that capability at 96% and 94% respectively. Reactivating 85% of the explosive manufacturing capacity the U.S. utilized 89% of that capability. In propellants manufacturing, activated 92% of total capacity and utilized 70% of the capacity.
(22) U.S. Army Armament, Munitions and Chemical Command, AMCCOM PAM 5-1, AMCCOM FACTS, (Resource and Management Directorate, Rock Island, IL, October, 1990), p. 65.
(23) Hammond, R.J., Profile on Munitions, p. 91.
(24) Ibid., p. 91.
(25) Ibid., p. 91.
(26) For a discussion on the benefits of the CASBL production line see: United States Army, Army Materiel Command, Radford Army Ammunition Plant, (Plant Brochure, 1977), p. 16.
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(39) Headquarters, U.S. Army Armament, Munitions and Chemical Command, Ammunition Plant Production Levels, Chart: " Ammunition Plant Production Levels."
(40) Ibid. Chart "Ammunition Plant Production Levels."
(41) Headquarters, U.S. Army Armament, Munitions and Chemical Command, Ammunition Plant Production Levels, Chart, "Radford AAP."
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