APRIL 2009 IMAE-AEC-EQ-CR-2009030

ARMY AMMUNITION PRODUCTION DURING THE COLD WAR (1946-1989)

PREPARED FOR:

U.S. ARMY ENVIRONMENTAL COMMAND
ATTN: IMAE-EQN
ABERDEEN PROVING GROUND, MARYLAND 21010-5401

UNLIMITED DISTRIBUTION

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
April 2009

2. REPORT TYPE
Historic Context

3. DATES COVERED *(From - To)*
October 2006-April 2009

4. TITLE AND SUBTITLE
Army Ammunition Production During the Cold War (1946-1989) - Unrestricted

5a. CONTRACT NUMBER
W81XWH-05-2-0050

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Environmental Command
5179 Hoadley Road
APG, MD 21010

10. SPONSOR/MONITOR'S ACRONYM(S)
USAEC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
IMAE-AEC-EQ-CR-2009030

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unrestricted

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This historic context discusses the development of ammunition production technology during the Cold War, and the evolution or refurbishment of facilities designed for the production process. The report investigates the changes in the built environment necessitated by changes in weapons technology, as well as the differences in the various types of ammunition and ordnance plants. Included is a brief history of the evolution of the Army offices and commands charged with oversight of the ammunition production and storage process.

15. SUBJECT TERMS
Cold War, Ammunition Production

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	UU	200	
					19b. TELEPHONE NUMBER *(Include area code)*

Reset

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for

U.S. Army Environmental Command
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1.0 EXECUTIVE SUMMARY

This study was prepared by the Department of the Army to meet the compliance requirement associated with the *Program Comment for World War II and Cold War Era (1939-1974) Ammunition Production Facilities and Plants*, issued by the Advisory Council on Historic Preservation on August 18, 2006. A programmatic treatment for the properties was developed in compliance with Section 106 of the National Historic Preservation Act of 1966 (NHPA), as amended, to take into consideration the effects of future management activities upon this class of Army resources constructed between 1939 and 1974, which might be historic.

Under 36 CFR 800.14(e) of the Advisory Council on Historic Preservation's regulations, the Army sought to develop an integrated and cost-effective approach to NHPA requirements that is consistent with the Army's need to provide munitions and ordnance in a rapidly changing and complex military environment. The programmatic treatment includes the preparation of a nationwide historic context on ammunition production facilities and plants constructed or modified during the Cold War era (1946-1989), the completion of a popular publication on ammunition storage and production, and site visits to two Cold War era installations with representative examples of ammunition production facilities. Currently, the Army inventory for ammunition production facilities and plants contains over 14,000 buildings and structures constructed between 1939 and 1989.

The current project expands and complements an earlier study, *Historic Context for the World War II Ordnance Department's Government Owned Contractor-Operated (GOCO) Industrial Facilities, 1939-1945.* This effort was completed for the Ft. Worth District, U.S. Army Corps of Engineers (Kane 1995). This earlier document provides background information on the evolution of ammunition production plants constructed during World War II mobilization, and included detailed studies of representative examples of ammunition plants. This earlier study also examined the mechanisms for selecting the operators and the cost-plus-fixed-fee contract form, and the technology of producing propellants, explosives, and munitions. The current study investigates the development of weapons technology during the Cold War era, modifications to existing ammunition production facilities, and the design of buildings constructed during the Cold War for the manufacture of newly-developed ordnance. R. Christopher Goodwin & Associates, Inc., completed the current project on behalf of the United States Army Environmental Command (USAEC) through the United States Army Medical Research Acquisition Activity (USAMRAA).

The surrender of Japan on 2 September 1945 marked the end of hostilities in World War II and presented the U.S. military with the challenge of managing the conversion of real property constructed to support nationwide mobilization to support of a peacetime military. During the preceding six years, the Federal Government expended hundreds of millions of dollars in constructing 77 new military industrial facilities and 16 major ordnance depots. Ammunition plants, armor plate factories, vehicle assembly lines, and gun manufactories once needed to support the global war were now excess property. Numerous facilities were closed while others were placed in lay-away status should they be needed in the future. The tremendous amounts of ordnance and raw materials no longer needed for munitions production were transferred to storage depots or destroyed. The activity at Army ammunition plants declined, and many were placed on standby status or declared excess property.

The invasion of South Korea by Communist forces in June 1950 prompted the U.S. military to increase production at all active ammunition plants and reopen several plants closed at the end of World War II. Advances in weapons production were implemented at many locations, while some plants continued to load, assemble, and pack munitions using machinery and techniques developed during World War II. Communities that had experienced employment loss and depressed economic conditions due to plant closures in 1945 saw a marked, albeit brief, surge in new jobs. Many communities could not supply the needed labor, and recruitment brought new residents to areas—oftentimes with less than favorable reactions from long-time residents. As with the construction of new plants during World War II, the influx of employees strained local housing markets and community services.

During the late 1950s weapons technology became increasingly sophisticated. Guided missiles and rockets began to replace the artillery, anti-aircraft guns, and mortars that were the mainstay of munitions for the armed forces for the first half of the twentieth century. Operators of Army ammunition plants continually made capital investment in new process equipment rather than new buildings. When new buildings were required, designs were characterized by uniformity, standardization in materials, and a lack of exterior ornamentation. The critical criterion for new construction was safety—buildings generally were constructed of reinforced concrete in response to safety concerns.

Although the United States first had begun sending military advisors to Vietnam in the early 1950s, attacks on two U.S. ships in August 1964 led to America's full-scale military involvement in Southeast Asia. Ammunition plants that were idled or working under reduced capacity since the end of the Korean Conflict again were pressed into service to supply munitions to American armed forces. The social issues, housing shortages, and lack of labor experienced with the reactivation of plants in 1950 were repeated during the Vietnam era.

The relative calm following the end of the Vietnam Conflict in 1975 and the end of the Cold War allowed the U.S. Military to gradually reduce the number of ammunition plants. In 1977, the Department of Defense consolidated all ammunition production under the guidance of the Army to reduce redundancy and improve efficiency. This brought two Navy ammunition plants under Army control: McAlester, Oklahoma, and Hawthorne, Nevada. Although the design of Navy installations varied slightly from those used by the Army, including the administrative consolidation of the ammunition plant with its associated depot, the process of producing ammunition were virtually identical.

Throughout the Cold War era ammunition plants continued to supply the armed services with munitions. Unlike the World War II era, where the focus was on production of massive amounts of conventional munitions, the Cold War brought added responsibilities to the Army ammunition plants. The development of new weapons prompted continual change in manufacturing processes and the development of new machinery. The increased reliance on guided missiles in both tactical and strategic roles led to the creation of new technologies for casting large propellant grains and precision machining of the explosive warhead charge. Between 1947 and 1975, Army ammunition plants also worked under the direction of the Atomic Energy Commission (AEC) in the production of the nation's nuclear weapons. Although many projectiles were filled with explosives using technology developed prior to World War II, new processes for conditioning the finished munitions improved quality and reduced operating costs. Safety at many plants was improved by automating production lines and lessening the exposure of personnel to explosives and toxic materials.

This study examines Army ammunition production facilities constructed during the Cold War era and World War II-era facilities used and modified between 1946 and 1989. This illustrated study is the result of an integrated program of archival research, site investigation, data analysis, and report preparation undertaken in 2007. The results of the study are presented in the following technical report, which is organized into the following chapters.

- Chapter 2, *Objectives and Methodology* details the project scope and the methods used in synthesizing data included in this report.
- Chapter 3, *Ammunition Production Facilities Constructed Prior to the Cold War Era* offers background information on the types of ammunition plants facilities constructed before 1946.
- Chapter 4, *Cold War History* provides a brief synopsis of the significant military and political events of the Cold War.
- Chapter 5, *Technology and Change During the Cold War Era* addresses the manufacturing processes for explosives, propellants, and finished ammunition, and significant technological changes made during the period. This section also addresses the design and construction of ammunition production facilities, and offers examples drawn from field investigations.
- Chapter 6, *Production, Employment, and Community Impacts of Ammunition Production During the Cold War Era* discusses the nature of ammunition production during the Cold War, including employment, community reaction to ordnance plants, and environmental issues.
- Chapter 7, *The Ordnance Department and the Creation of the Army Materiel Command* describes the post-World War II reorganizations of the Ordnance Department that led to the creation of the Army Materiel Command.

The report is accompanied by seven technical appendices.

- Summarized Cold War histories for ammunition plants currently managed by the U.S. Army are included in Appendix A.
- Appendix B includes historic summaries of architects and engineers known for their contributions to the construction of Cold War era ammunition production facilities.
- Appendix C contains listings of ammunition production facilities constructed between 1939 and 1989.
- Appendix D contains information related to the funding of ammunition-related property between 1945 and 1989.
- Appendix E contains a technical glossary.

2.0 OBJECTIVES AND METHODOLOGY

2.1 Objectives

Currently, the Army manages more than 14,000 buildings associated with ammunition production that were constructed between 1939 and 1989 (US Army Real Property Inventory 2007). The majority of the structures comprise support, administration, utility, or ammunition and explosives storage facilities. Buildings used for the production of ammunition, propellants, and explosives include manufacturing buildings for acids and explosives in addition to those for loading warheads and projectiles. Among the properties at Army ammunition plants and other installations with production capabilities, there are 3,986 directly related to the manufacture of munitions during this time period. Of this number, 2,797 were constructed between 1941 and 1945. These buildings have already reached the 50-year age generally required for consideration for listing in the National Register of Historic Places, and consideration under Section 106 of the National Historic Preservation Act. Ammunition production facilities constructed during the Cold War also are approaching or have passed this 50-year age threshold. To take into account the effects of management activities on ammunition production facilities, the Army requested a Program Comment, which is a programmatic compliance alternative under the Advisory Council on Historic Preservation's regulations at 36 CFR 800.14. The programmatic treatment includes the preparation of a nationwide historic context on ammunition production facilities and plants constructed or modified during the Cold War era (1946-1989), the completion of a popular publication on ammunition storage and production, and site visits to two Cold War era installations with representative examples of ammunition production facilities.

2.2 Project Description

This illustrated technical report is the first component of this programmatic approach to ammunition production facilities and plants, and explores post-World War II methods of manufacturing weapons in a rapidly changing technological environment. To achieve this, this study examines both ammunition production facilities constructed during the Cold War, as well as modifications to the large number of facilities constructed during World War II. The report identifies architects, engineers, and contractors associated with the construction of ammunition-related facilities during World War II and the Cold War era.

The U.S. Army places ammunition production facilities into a broad category carrying a five-digit code beginning with 226. This category of buildings is further broken down to include 22 separate types (Table 2.1) (Department of the Army 2006:148-154). In addition to structures dedicated to the manufacturing of ammunition, a typical assemblage of buildings that comprise the manufacturing complex included office and administrative buildings, laboratories, change and break houses, and maintenance facilities. A typical ammunition plant also included several types of ammunition storage buildings. Earth-covered magazines held raw materials, such as smokeless powder or TNT, or the finished product prior to shipment. Aboveground magazines frequently were used to store small-caliber ammunition and larger projectiles. At load-assemble-pack plants, small frost-proof magazines stored highly volatile material such as lead azide. In addition to storage magazines, some munitions plants also contained ready magazines: a smaller aboveground structure designed to store enough explosive material for a single shift of operation.

Table 2.1 Property Codes for Ammunition Production Facilities in the Current Army Inventory Built Between 1939 and 1989 (Department of the Army 2006:148-154)

Category Code	Number in Army Inventory (as of 2007)	Description
22610	38	Bag Charge Filling Plant—a building used to fill cloth bags with propellant
22612	73	Acid Manufacturing Plant—a building used for the production of acid used to manufacture explosives
22614	13	Lead Azide Manufacturing Plant—a building used to manufacture lead azide which was used in fuzes and detonators
22616	200	Explosive Manufacturing Plant—a building used for making explosives
22618	0	Chemical, Biological, Radiological Plant—a building used for the production or demilitarization of lethal or toxic agents
22620	7	Case Overhaul and Tank Facility—a building used for the production of ammunition cases and containers
22622	169	Pyrotechnic Production—a building for manufacturing pyrotechnic and/or smoke agents
22624	55	Metal Parts Production—a building used to manufacture metal parts used in munitions
22625	91	Small Caliber Loading Plant (under 40mm)—a building used for the production of small caliber ammunition
22626	54	Bomb High Explosives Filling Plant—a building used to load explosives into bombs
22628	334	Metal Parts Loading Plant—a building used to fill ammunition metal parts with explosives
22630	34	Minor Caliber Loading Plant (40-75mm)—a building used for the production of minor caliber ammunition
22632	0	Ammunition Foundry—a building used for making metal ammunition parts by casting molten metal
22635	386	Medium Caliber Loading Plant (76-120mm)—a building for manufacturing medium caliber ammunition
22638	242	Ammunition Quality Assurance/Calibration Facility, Production—a building used for inspection and testing of ammunition components and completed munitions
22640	289	Major Caliber Loading Plant (over 120mm)—a building used to produce large caliber ammunition
22645	2	Large Caliber Rocket Motor Loading Plant—a building used for the production of large caliber (over 120mm) rocket motors
22650	12	Medium Caliber Rocket Motor Loading Plant—a building used for the production of medium caliber (76-120mm) rocket motors
22655	85	Cast High Explosive Filling Plant—a building used to melt high explosives for pouring into containers or projectiles
22660	44	Special Weapons Plant—a building used to manufacture special weapons
22665	40	Ammunition Washout Building—a building used to washout casings
22670	4	Case Filling Plant—a building used to fill casings with gunpowder
22680	1520	Propellant Plant—a building used to produce any fuel that propels the projectile when ignited, fuels can be either liquid or solid
22685	294	Ammunition Production Structure—a roofed structure not enclosed by walls used for production or assembly of munitions

The vast majority of ammunition production facilities in the Army Real Property Inventory were constructed during World War II. The ammunition production facilities built during the early years of the war were all permanent construction with concrete and steel skeletons, and hollow clay tile curtain walls. Administration and support buildings followed this trend with brick or tile structural walls. Construction during the latter years of the war continued to use permanent designs for the actual production and storage facilities, but used temporary construction for support buildings. Many of the buildings followed standardized plans adapted for a particular site, and ammunition plants with multiple load lines contained duplicate manufacturing complexes. Construction of ammunition production facilities during the Cold War focused mainly on additions and modifications to existing buildings.

2.3 Methodology

The research design for the current study incorporated four progressive tasks. These tasks were archival research, field investigation, data analysis, and report preparation. The collected data were analyzed to identify ammunition production needs during the Cold War era; policies impacting the construction of new facilities; the impact of rapidly evolving weapons systems on ammunition production; and to identify engineers, architects, contractors, or builders associated with the construction of ammunition production facilities.

2.3.1 Archival Research

A variety of sources were consulted during the preparation of this report. Previous studies reviewed included *Army Ammunition and Explosives Storage in the United States: 1775-1945* and *Historic Context for the World War II Ordnance Department's Government-Owned Contractor-Operated (GOCO) Industrial Facilities, 1939-1945* (Murphey et al. 2000; Kane 1995). These two reports provided general background information on the history of ammunition production and storage facilities of the World War II era. The current study expands on these earlier reports by discussing post-war trends and designs of ammunition production facilities.

A review of secondary sources provided considerable information on military doctrine, planning, and the introduction of improved weapons systems, but little on the design or construction of ammunition production facilities. Those sources that did discuss production focused on the massive building campaigns of the World War II era.

Review of published primary sources included Congressional reports, hearings, and related government documents at the Library of Congress. These Congressional reports provided data on appropriations for construction of ordnance installations, but rarely specified the locations or types of ammunition production facilities. The Library of Congress collections contain several pertinent reports completed in the 1980s including site documentation undertaken for the Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER). These studies include a general history of the installation and large format photographic documentation.

Record groups reviewed at the National Archives and Records Administration, College Park, Maryland included Record Group 77—Army Corps of Engineers, Record Group 544—Army Materiel Command, Record Group 156—Office of the Chief of Ordnance, and Record Group 330—Office of the Secretary of Defense. These collections include files and correspondence of key agencies, safety and ammunition handling publications, and command histories for numerous installations. Cartographic and still images at the National Archives also were reviewed.

The large number and broad distribution of ammunition production facilities created challenges in implementing the research design for this project. These challenges were compounded by the recent construction dates of many of the buildings. Studies on recent history grapple with a lack of historic perspective and the absence of associated scholarship. A similar challenge was the uniformity of design throughout the period. Ammunition production facilities were constructed from widely available plans that were adapted for site-specific conditions; project construction and administration was often at the installation level. This approach resulted in the retention of the majority of the plans and specifications at the installation level rather than in national repositories for indexing.

2.3.2 Field Investigations

The research design for this project included on-site investigations to capture installation-level information. Two Army installations were selected based on criteria of variety in design and numbers of Cold War era ammunition production facilities, the potential for unique structures, and for geographic distribution. Installations were selected based on information contained in the U.S. Army Real Property Inventory provided by the U.S. Army Environmental Command (USAEC). Criteria for site selection were developed in consultation with the USAEC and the Army Materiel Command (AMC). Field investigations included on-site architectural surveys, and a review of historic records and drawings held by the installation, and data from local repositories. The two Cold War era sites selected for this study were:

Iowa Army Ammunition Plant, Burlington, Iowa
Radford Army Ammunition Plant, Radford, Virginia

Specific on-site research for each of these installations included review of architectural drawings, real property cards, previous cultural resource reports, historic photographs, and written histories. Collections at local museums, libraries, and historic societies also were reviewed to determine the impact ordnance plants imparted on local economies and demographics.

2.4 Definition of the Historic Context

The *Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation* (48 FR 44716) and technical guidance provided by the National Register Program, the National Park Service, and the Department of the Army were consulted in the development of the historic context. The theoretical framework that allows the grouping of information on related properties is a historic context. Three elements comprise a historic context: theme, place, and time. For this study, the context was based on the following:

Time period:	1946 to 1989
Geographic Area:	United States
Theme:	Army Ammunition Production

The time period covers the entire Cold War era, defined as the emergence of the Soviet state in the immediate post-World War II period and ending with the fall of the Berlin Wall in 1989. The geographic area includes the 48 contiguous states, Alaska, and Hawaii.

Several sub-themes relating to the construction of ammunition production facilities were developed as part of this study. They include:

1) weapons technology focusing on the impact that new weapons systems exerted on the design and construction of new ammunition production facilities and the modification to existing facilities;

2) missions developed at ammunition plants after World War II, including the long-term surveillance of munitions and demilitarization; and

3) architecture/engineering emphasizing the development of new building types to produce more advanced weapons systems and associations with significant architects, engineers, or builders.

3.0 ARMY AMMUNITION PRODUCTION FACILITIES PRIOR TO THE COLD WAR ERA

3.1 Introduction

The ammunition production installations currently under the Army Materiel Command originally were built by several different entities, including the Ordnance Department and the Chemical Warfare Service in the U.S. Army, and the Bureau of Ordnance in the U.S. Navy. The majority of the installations currently are government-owned contractor-operated, though a few installations have historically been and remain government owned and government operated. This report focuses on the history of ammunition production in the U.S. rather than the production of artillery pieces and carriages, tanks, and trucks.

3.2 Ammunition Production Prior to World War II

The Cold War-era system of ammunition production had its antecedents in the munitions production accomplished during World Wars I and II. Prior to the military reorganizations during the Cold War era, the Army and the Navy operated separate and independent ammunition production and supply systems. The Army assigned the responsibility to develop, produce, store, and maintain weapons and ammunition to the Ordnance Department. From its beginning in 1812, the Ordnance Department operated a small number of arsenals and armories to perform these tasks. The Navy established its own installations to produce armaments. The Washington Navy Yard was the Navy's primary gun foundry during the nineteenth and early-twentieth centuries. In 1900, the Navy established its own smokeless powder plant at Indian Head, Maryland (Cannan et al. 1995:60-62).

With the United States entry into World War I, the ammunition required to support the Army and Navy quickly exceeded previous expectations. Government installations were unable to produce the quantity of munitions needed during the war. The military relied upon private industry to supplement the production of government installations. Military planners anticipated that American industries would adapt to fill military supply orders. However, the munitions industry already had expanded to near capacity to fill orders from England, France, and Russia. The industrial capacity available to the Army was limited further by the decision to give the Navy first priority in any remaining munitions production capability. To assure an adequate supply, the Army had to establish its own system for munitions production (Engelbrecht and Hanighen 1937:173-175; Green et al. 1955:24-25).

In 1917, the Ordnance Department initiated an industrial program that approached ordnance manufacturing as a nationwide process. Each new facility established under the program produced one component of the final ordnance product, such as shell casings, smokeless powder, or TNT. All of the components were shipped to assembly plants, where they were assembled into completed rounds. During World War I, the U.S. government erected 53 separate munitions plants. This program was the government's first attempt to mass produce munitions on a national level (Crowell and Wilson 1921:57).

Under the ordnance industrial program, the government leased land from private owners and erected industrial buildings at government expense. The government contracted with private companies to build and operate the new facilities. The industrial plants comprised two powder plants, three bag-loading plants, two nitrate plants, two nitrogen-fixing plants, two TNT plants, one Trinitroaniline (TNA) plant, three picric acid plants, one tetryl plant, and fourteen shell loading plants. Leases negotiated under this program stipulated that the facilities would be dismantled after the war. Since the factories were intended only for temporary use, the military did not invest in permanent construction. Thus, buildings were constructed of wood, when possible, to alleviate building costs (Crowell 1919: 107-120).

Unlike civilian factories where production lines typically were housed under one roof, the new munitions plants were constructed using separate buildings, connected by covered walkways. Buildings were limited to one story when possible. Some buildings incorporated concrete fire walls to separate work stations within a production section. The separated buildings and fire walls were intended to reduce the risk of a single explosion triggering sympathetic explosions throughout multiple production lines.

Munitions production began to produce in quantity by mid-1918. In February 1918, American industry supplied 138,000 rounds of artillery ammunition to the American Expeditionary Force; in May, 1,034,000 rounds; in August, 1,984,000 rounds; and in October 1918, 3,062,000 rounds. When the war ended, the United States was producing twice as much powder as Britain and France combined (Crowell and Wilson 1921:155, 193).

After the Armistice in November 1918, the U.S. government abruptly terminated its war-time contracts. Facilities around the nation built solely for the production of war materials during the emergency were closed. Land leased during the war was returned to its owners; structures were dismantled and building materials salvaged (Cannan et al. 1996:16).

The industrial mobilization for World War I demonstrated the ability of the United States to mobilize quickly. It also highlighted substantial weaknesses in the military's ability to equip a large force. The lack of overall planning and the competition for resources among the services hampered effective mobilization. The lessons of World War I included the importance of training Ordnance officers and enlisted men, and the need for cooperation between the Ordnance Department and the combat arms to develop and to produce weapons. Another key lesson was the critical need for advance preparation; at least one year of production was required prior to the start of combat to arm a large fighting force (Green et al. 1955:28-29, 51).

The hope for permanent peace following World War I limited military appropriations during the inter-war years. Congress was reluctant to spend money for new weapons and equipment with a large World War I surplus still available, even though the World War I equipment rapidly was becoming obsolete. New weapons systems, especially tanks, developed slowly, if at all. There was little coordination between the military and industry (Weigley 1984:415-417). By the late 1930s, American arms companies produced only sporting ammunition. The Army's own arsenals received little funding (Cannan et al. 1996:17).

3.3 The Interwar Period

In 1936, the Ordnance Department requested $21 million for new construction and repair at various ordnance installations, including manufacturing arsenals and depots. Prior to funding the large monetary request, the War Department required a study to determine the ideal system of ammunition manufacturing and storage. The critical considerations in the plan submitted for review were: strategic location of new installations to avoid destruction by enemy attack; nearness to essential raw materials for production; nearness to probable theaters of military operations; economy of operation; and climate. The board of officers reviewing the plan determined that the most critical criteria were strategic location and proximity to potential theaters of operations. The location of new installations also was directed by the Secretary of War, who directed that no further construction of permanent installations to store wartime reserves would occur east of the Appalachian Mountains or west of the Cascade and Sierra Nevada mountain ranges. Ordnance Department planners also proposed that new installations be located at reasonable distances inland from the northern and southern U.S. borders for additional protection from enemy attack (Thomson and Mayo 1991:362). This area became known as the Zone of Interior.

In 1937, the War Department established a Protective Mobilization Plan. This plan described the steps required to expand the Army from its current 200,000 troop level to a force of 400,000, and provided for further expansion of up to 1,000,000 soldiers within a year of the initiation of the program. The following year, Congress authorized a few "educational orders" to facilitate industrial mobilization. Educational orders provided private firms with experience in producing military munitions to supplement the limited capacity of government arsenals. The Congressional approval of funds specifically for privately-manufactured military munitions helped to overcome the reluctance by private firms to be associated with munitions production. A review committee, led by Brig. Gen. Benedict Crowell and including leading industrialists, reviewed the conduct of the educational orders and recommended continuation of the program. The educational orders provided private firms with important experience in the particular requirements of military ordnance, and set the stage for closer cooperation between the War Department and private industry. Although educational orders provided some manufacturers with experience in supplying the military, they did not alleviate the problem of inadequate supplies (Green et al. 1955:52-55, 57-59).

U.S. Army and Navy planners were increasingly concerned over German expansion in Europe and Japanese aggression in the Pacific. In September 1939, Germany invaded Poland and in less than one year, both Poland and France fell. German forces occupied most of continental Europe. In the U.S., preparations began for possible war. The Munitions Program enacted in 30 June 1940 created a program for the production of $994,000,000 of ammunition to arm an estimated military force of 2 million (Thomson and Mayo 1991:365). This figure represented greater expansion in ordnance operations over any previous war. Factory conversions to produce munitions and construction of new ammunition production plants and storage depots were mandated. Huge stocks of weapons and ammunition needed to be produced, stored, and distributed (Thomson and Mayo 1991:7). In addition, the Lend-Lease Act in March 1941 provided further stimulus to the munitions program. The Lend-Lease Act allowed Great Britain to acquire military supplies from the U.S., which President Franklin D. Roosevelt declared must become “an arsenal for democracy.” After Germany invaded the Soviet Union in summer 1941, the lend-lease policy was extended to include the Soviet Union (Whelan et al. 1997:30).

In 1940, Army’s ammunition production capacity was contained in six old line arsenals (Cannan et al. 1995:12, 31). The Army's Picatinny and Frankford Arsenals and the Navy's Indian Head facility preserved the knowledge of the special requirements of military ammunition production, but these installations could not produce the required quantities. The United States lacked even one day's supply of the ammunition that would be required later in the war, and, even worse, it also lacked the facilities to produce large quantities of military ammunition (Thomson and Mayo 1991:104-105; Cannan et al. 1996:17). During summer 1940, the Army completed contracts for two smokeless powder works (Indiana and Radford), a TNT works (Kankakee), and two shell loading plants (Ravenna and Elwood). These contracts marked the beginning of the massive buildup of U.S. ammunition production (Fine and Remington 1989:340-341; Thomson and Mayo 1991:110).

The Navy’s ammunition production facilities were contained at the gun foundry at the Washington Navy Yard, the smokeless powder plant in Indian Head, Maryland, and load lines at its major depots to complete the loading of projectiles, mines, and bombs, and assembly of finished ammunition. The Navy’s policy was to purchase shells, bomb cases, and other metal components from private industry (US Navy Department, Bureau of Yards and Docks 1947:325). However, the Navy relied upon the Army for propellants and high explosives beyond the capacity of its powder factory at

Indian Head, Maryland. This arrangement was the result of a 1920s agreement that prevented the Army and the Navy from competing against each other for materiel. The Army agreed to provide the necessary explosive material for both services (Cannan et al. 1996:128-129).

3.4 Mobilization for World War II

Between 1940 and December 1941, the Construction Branch of the Quartermaster Corps coordinated construction of the ammunition plants. Speed of construction was essential to effective mobilization, since planners estimated that 12-18 months were required to place a new plant in operation. Site selection, land acquisition, and construction contract negotiations proceeded as quickly as possible. Construction contracts generally were cost-plus-a-fixed-fee (CPFF) contracts, a process similar to that utilized during the World War I mobilization (Kane 1995:36-43). Unlike fixed-price contracts, in which fees were negotiated on a project-by-project basis, fee schedules for CPFF contracts were determined by standard government estimates. Contracts issued based on government estimates streamlined the award process. In addition, such contracts eliminated the need for renegotiation with project changes (Fine and Remington 1989:155).

Competitive bids also were suspended (Kane 1995:37). The Construction Branch solicited company profiles from firms throughout the construction industry. A Construction Advisory Committee evaluated the qualifications of architectural, engineering, and construction firms to undertake anticipated projects. Factors in firm selection were current work load, performance during the past five years, company size, record of completing projects within schedule, financial stability, and geographic location (Fine and Remington 1989:123-126). Contractors generally were limited to one project award. This recommended policy was made to expedite construction, so that one project would not overextend the firms beyond their capabilities. This recommended policy also was made to deflect political attack. Politicians complained that large, national firms were favored over small, local companies for construction contracts awarded. However, since many of the munitions production installations were technologically complex undertakings, the choice of contractors was restricted to specialists in their fields, particularly the explosives industry (Kane 1995:82). In all, the work to build the industrial munitions facilities employed approximately 300 architect-engineer firms and 5,300 contractors, particularly after changes in contracts under the Corps of Engineers opened competition for contracts to smaller firms (Cannan et al. 1996:27; Kane 1995:82).

The Quartermaster Corps and Corps of Engineers had been rivals for control of all Army construction since World War I. On December 1, 1941, all military construction, including the industrial expansion program, was placed under the jurisdiction of the Corps of Engineers. Personnel assigned to the construction programs within the Quartermaster Corps were transferred to the Corps of Engineers (Fine and Remington 1989:471-472). In addition, early in 1942, the War Department reorganized the technical services, including the Ordnance Department, the Quartermaster Corps, and the Corps of Engineers, among others, and placed them all under the Army Service Forces. One purpose of the Army Service Forces was to provide collaborative planning among all the technical services to coordinate procurement and distribution of supplies to support the Army Air Forces and the Army Ground Forces engaged in combat. Another advantage of this organization was to organize procurement and supply along functional lines, rather than remaining commodity driven. This wartime organization was a precursor to the organization of the Army Materiel Command during the Cold War era (Kane 1995:64).

The large ammunition works and plants constructed during the early 1940s generally were operated as Government-Owned, Contractor-Operated (GOCO) installations. The government purchased the land and paid for the construction of the buildings; private contractors then assumed operation of the installations. This method allowed corporations with expertise in industrial production and management to operate the plants. The contractors also assumed responsibility for most personnel actions, production schedules, quality control, and other tasks associated with factory operations. In a few cases, the contractor also assumed responsibility for the design and construction of the installation. The services assigned a small contingent to each GOCO installation plant to represent on-site the interests of the government (Cannan et al. 1996:127). Government ownership of the production facilities offered an additional advantage from the government's point of view. After the crisis, ordnance facilities could be placed on stand-by status, and be available for future emergencies. If stand-by buildings were available, then the military could enter wartime production without the construction delays experienced in 1940 and 1941 (Fine and Remington 1989:310).

3.5 World War II

The Japanese attack upon Pearl Harbor, and subsequent declaration of war upon Japan, ended the Protective Mobilization phase and war began. During the first two years of the war, defense construction continued at an unprecedented rate. The pace of construction activities during the mobilization phase had seemed hectic, but now the tempo of construction activities accelerated even faster. War Department construction programs reached their peak in the summer of 1942, and then declined precipitously. For the month of July 1942, the Ordnance Department reported that a million-person workforce completed Ordnance construction projects valued at $720 million. By the close of 1942, the War Department had completed 85 percent of its war construction program, both temporary and permanent; by 1943, that figure rose to 98 percent (Fine and Remington 1989:593-606; Kane 1995:52).

Facilities associated with ammunition production accounted for one of the largest categories of World War II permanent construction. These plants cost approximately three billion dollars in capital investment, and operated with annual budgets approaching one billion dollars. Government ammunition plants employed an estimated quarter million workers, and occupied a land area equaling that of New York City, Philadelphia, and Chicago combined (Thomson and Mayo 1991:105).

Seventy-seven GOCO installations were constructed for the World War II munitions program. The 77 installations included 25 load, assemble and pack plants; 23 propellant and explosive works; 11 chemical works; 12 small arms ammunition plants; 2 gun tube plants; 1 case cup plant; 1 incendiary (magnesium metal powder works); 1 tank plant; and 1 plant for the production of metal components for artillery ammunition (Kane 1995:13). In addition, the Chemical Warfare Service operated four arsenals to produce chemical munitions that were government-owned and government-operated. The Navy also operated government-owned and government-operated ammunition loading lines at its ammunition depots, including Hawthorne, Crane, McAlester, Hastings, and Yorktown (Cannan et al. 1996:128-129, 141-142). Ordnance works produced high explosives, smokeless powder, ammonia, or the chemical ingredients for explosives, while finished rounds of ammunition or weapons were finished or manufactured in plants.

Ammunition production at many of the newly-constructed installations began by mid-July 1941 and rapidly increased as more of the plants and works became operational during 1942. By May 1943, all but one of the GOCO installations were operational; the last GOCO opened in January 1944 (Kane 1995:53). During 1943, the GOCOs were producing at or near full capacity and meeting and exceeding planned production schedules, so that reserves of ammunition were increasing. By fall 1943, the military cut back the production schedules and the first GOCOs were closed and operations at other GOCOs were curtailed. In addition, the need for certain types of ammunition shifted as the war progressed. Ammunition useful against submarines declined in importance after 1942, while the requirements for bombs and medium and heavy artillery were increased, so that some production lines were less busy than others (Kane 1995:53-54). By the latter years of the war, the American supply system simply overwhelmed its enemies. The facilities that are now part of Army Materiel Command produced this logistical superiority. In ammunition alone, Army ordnance facilities produced 10,958,454 tons of artillery ammunition, 476,312 tons of mortar ammunition, 5,989,603 tons of bombs and rockets, and 38,866,000,000 rounds of small arms ammunition (Cannan et al. 1996:134).

3.6 The Technology of Ammunition Production

The ammunition production facilities operated during World War II at first relied on existing technology that had been preserved during the inter-war era at the Army's old-line arsenals and Navy yards. To increase productivity to meet wartime demands, while maintaining quality and a safe working environment, new technologies were developed at the GOCOs. These included reverse nitration of TNT, manufacture of toluene from petroleum, mechanical loading, and the development of wood pulp, RDX, and rocket powder (Thomson and Mayo 1991:133-134; Cannan et al. 1996:70-73). The ammunition production plants were to the fullest extent possible laid out in efficient assembly lines, with standardized equipment and interchangeable parts, and using as much automation as possible. Many filling and loading processes formerly accomplished by hand were automated by the end of the war (Kane 1995:115-119).

3.7 Industrial Design and Architecture of Ammunition Production Facilities

Ammunition facilities were located in the interior of the country, away from the coastlines and borders, to minimize the dangers from enemy air raids. Other requirements for site selection included access to transportation, especially rail lines, and an abundant supply of water. The installations were located in rural areas, to obtain the large tracts of land required. These site selection criteria resulted in the construction of most of the ammunition facilities in the Midwest and Southeast (Thomson and Mayo 1991:108-109).

Government-owned ammunition installations were constructed along functional designs based on assembly-line production work flow using as much standardization as possible. However, the designs of the different types of GOCOs varied based on the products manufactured at them and the contractors who oversaw their construction. The production lines, the machines, and the work flow came first, while the designs of the buildings that housed the production lines were of secondary importance (Kane 1995:82-84). In general, the appearance of the production buildings constructed at the government munitions plants were utilitarian, functional buildings with no ornamentation (Kane 1995:100).

The earliest construction contracts issued by the Army in August 1940 specified the construction of permanent buildings at ammunition production installations. As the cost of permanent construction became apparent, Army officers sought to contain costs as much as possible, as well as to increase the speed with which the ordnance plants and works were constructed. Requirements for substantial masonry and steel construction that normally characterized industrial facilities were revised to allow for buildings with steel frames and lightweight exterior materials. The resulting buildings reflected a compromise between permanent and temporary construction. The trend toward expedient, less substantial, building construction became more pronounced as the war progressed, especially after some materials, particularly steel, became a scarce commodity. A general trend from the use of steel to reinforced concrete to wood accompanied the material shortages of the war years (Fine and Remington 1989:327-335, 530, 536; Kane 1995:84-85).

Ordnance plants frequently resembled self-contained communities where buildings were specialized by building and area. Ordnance facilities were designed to comply with strict requirements regarding the siting of buildings and the distance between functional areas. Plants generally were divided into administration areas, which typically included an administration building, a security building, a fire station, a mess hall, and other office facilities; storage areas that typically were divided into above-ground non-explosives storage and earth-bermed, igloo explosives storage; production areas, which included the production lines; and small housing areas for plant operators. The areas were connected by an internal network of roads and railroads.

Similar to contemporary civilian industries, the military production factories adopted assembly line production techniques. When practical, production facilities were housed within one building. The Detroit Tank Arsenal, aircraft factories, and small arms production facilities housed individual receiving, production, and assembly functions under one roof. The volatile nature of explosives productions and assembly, however, dictated that various steps in a production line were housed in separate buildings located at prescribed distances from each other. This separation was intended to prevent the spread of explosions. Buildings constructed for the explosives production and assembly generally were designed with structurally stronger interior walls than exterior walls to direct the effects of potential explosions outward (Cannan et al. 1996:33-35). Safety at munitions production installations was a major concern to ensure retention of workers, completion of production schedules, and protection of property (Kane 1995:87-88).

3.8 Social History of Ammunition Production Facilities

All stages of World War II, including the build-up and demobilization, had profound effects upon civilian life, which were reflected in changes in the labor force and in impacts to communities across the nation. The process of constructing and operating huge munitions plants often transformed former agricultural communities into boom towns. The earliest impacts were felt by established residents as government representatives acquired large tracts of land on which to build the production facilities. The sites most often selected were productive farmland. Families often surrendered family farms that had been occupied for several generations. The U.S. government held the advantage in these negotiations and could use the right to condemn or the threat to condemn land to exert pressure upon land owners. Local residents sometimes complained about the government's methods and the compensation that they received, but often could do little to prevent the construction of a defense plant (Kane 1995: 189-191).

The construction of a new defense plant was accompanied by an influx of short-term construction workers. Thousands of new workers flooded the construction site, resulting in a boom town effect for the local community. Construction workers required some sort of short-term housing for the construction phase of a defense facility. Once the initial construction of a defense plant was completed, the numbers of persons actually employed by defense manufacturing facilities stabilized at lower levels than during the construction phases of the plants, but workers required longer-term housing and more social amenities (Kane 1995:191-192).

Shortages, however, were evident almost everywhere, including: labor, particularly of skilled construction personnel; construction materials; skilled workers once plants were operational; and housing and local amenities. The influx of workers to areas with new war related industries prompted housing and infrastructure crises in local communities. Severe labor shortages to operate the plants prompted the entry of women, African-Americans, Native Americans, and other minorities into the industrial work force in unprecedented numbers. The thousands of new jobs created by the defense industry were located in rural areas, requiring workers to relocate. During the course of World War II, over 15 million civilians migrated across the United States, usually in search of jobs (Cannan et al. 1996: 39-41).

Living conditions for defense workers varied from tolerable to squalid. Boarding houses and available rental rooms were filled rapidly. Housing conditions and shortages resulted in delayed war production goals and contributed to high worker turn-over. In time, the government and plant operators took steps to address the housing shortage. In October 1940, Congress passed the Lanham Act, which authorized public housing in areas with defense industries. Later, President Roosevelt established the Federal Public Housing Authority to coordinate defense housing. By the end of the war, the Federal Public Housing Authority had managed the construction of over 700,000 housing units, principally near defense industries (Cannan et al. 1996:39-41).

In addition to the housing situation, workers at industrial facilities also often coped with a substantially different work and social environment from anything in their previous experience. Workers lived in new communities, usually separated from their families. Although the Lanham Act authorized funding for day care for children of working mothers, adequate child care was seldom available. The war disrupted the lives of defense workers as well as soldiers (Cannan et al. 1996:39-41).

3.9 Demobilization and Preparing for Peace

During mid 1943, Ordnance Department planners turned their attention to demobilization. All demobilization plans were based on the premise that the United States would emerge from the war as the

> greatest military power in the world and would remain, for at least several postwar years, in a state of preparedness for action in widely dispersed areas; that operations in the European theater would terminate before those in the Pacific; that the United States would deploy troops in occupied areas for an extended period; that public opinion in the United States would demand speedy repatriation of forces abroad and quick demobilization of manpower and war industry at home (McMullen 1946:5).

In addition, the Ordnance Department was determined to retain sufficient postwar production capacity to maintain emergency ammunition reserves and to support a postwar army proposed at 4.5 million personnel comprising 60 percent ground troops and 40 percent air forces (McMullen 1946:5-7).

For Army planning purposes, demobilization was divided into three phases. Period I began with Victory in Europe and ended with Victory in Japan and was estimated to last about a year. During this phase, military operations would be concluded in Europe and men and materiel refocused on the war with Japan. Immediately upon official confirmation of Germany's surrender, the Ordnance Department planned to terminate the maximum quantity of war production aside from what was required to complete the war with Japan, to terminate expeditiously contracts and remove surplus machinery as plants were shut down, and to dispose of government property no longer needed. In addition, the Ordnance Department determined to retain in pilot production or standby reserve government plants to produce non-commercial Ordnance items "to provide continuing development and provide sufficient manufacturing capacity to insure military security" (McMullen 1946:6). The industrial plants to be released first from wartime production were the privately-owned plants that had been adapted to wartime production to stimulate consumer production in the postwar period as soon as possible. Government-owned plants would be operated or retained in standby condition until it was determined that there was no use for them. Considerations for terminating contracts included an analysis of relative production costs for similar items; plant locations in relation to subcontracting facilities, availability of labor, raw materials, and transportation networks; accessibility to storage depots; security; and cushioning the shock of unemployment on communities

(McMullen 1946:10-11). The first phase of demobilization was activated on 1 May 1945. Between May and 30 July 1945, the Ordnance Department terminated 19,000 contracts valued at over $7.8 billion using the "negotiated settlement" procedure (McMullen 1946:13, 16-17).

Period II began with the cessation of hostilities on Victory over Japan Day, 15 August 1945, and lasted for approximately six months. The Army Service Forces directed the Ordnance Department to halt production of all items except tires, tubes, vehicle spare parts, and materiel needed for active research projects. With the victory over Japan, the Ordnance Department was confronted with the task of demobilizing a vast ammunition industry including more than 60 government-owned contractor-operated works and plants, and numerous privately owned metal parts plants; the total investment in the GOCO plants was roughly $2,200,000,000 and employed more than 200,000 people (McMullen 1946:77-78). By the end of August, an additional 14,013 Ordnance Department contracts, including the majority of the GOCO plants, were in the process of termination for goods valued at just over $7.2 billion (McMullen 1946:13-14, 17, 81). Contract termination required a complete physical inventory of each plant; later it was determined that a selective inventory was sufficient. Ordnance Corps Historian Richard F. McMullen reported in his summary of the demobilization program that, as of 15 December 1945, the estimated total cost of terminating sixty-nine GOCO Plants was $72,484,000 (1946:81)

As part of the peace planning, the Ordnance Department determined to retain a nucleus of government-owned ammunition production plants and proving grounds "that would provide a reasonably balanced capacity for the production of all types of loading, explosives, and subsidiary materials, other than those readily available from commercial sources or other Government agencies" (National Archives and Records Administration [NARA] Record Group [RG] 156, Hardy 1944). During 1944, the Ordnance Department circulated numerous proposals detailing which production plants should be retained. The numbers of plants to be retained comprised the old line arsenals and 22 ordnance works, ordnance plants, and proving grounds (NARA, RG 156, Hardy 1944). Debate continued on which plants to retain, however, and the number of changes to the retention list prompted the Chief of the Requirements and Demobilization Branch, Army Service Forces, to issue governing rules on plant selection in April 1945 (McMullen 1946:119-121).

Although the decision-making process on plant retention was the subject of continued discussion, the directives from the Chief of the Demobilization Branch streamlined the process. It was quickly established that Picatinny Arsenal would remain as the center for development of all ammunition items (except for small arms), preservation of production know-how, and training center for ammunition inspectors. As the demobilization planning progressed, several GOCO plants were recommended for postwar standby status. Some plants were to serve as nucleus plants capable of resuming production at full capacity, while other plants would be equipped to permit resumption of production at 40 percent capacity. Plans also were formulated to renovate arsenals by transferring modern equipment in use at excess plants to standby and permanent establishments. In September 1945, 22 GOCO plants were approved for retention by the government and placed in standby status, but, as of 31 December 1945, no official list of production plants for postwar retention had been published (McMullen 1946:79-81).

4.0 THE COLD WAR: 1946-1989

4.1 Origins of the Cold War: 1946-1950

4.1.1 Introduction

Ideological, military, and economic conflict between the United States and the USSR over Communist aggression characterized the Cold War. The Cold War was an unforeseen consequence of the post-World War II realignment of Europe negotiated among the primary victors: the United States, the United Kingdom, and the Soviet Union. The general policy adopted by the Allies was to occupy recently liberated territories until elections could be held. As a result, the Communist Soviet Union was able to exert pressure on the governments of Eastern European countries, thereby creating the division between east and west.

During WWII, the Allies held a series of meetings to discuss postwar Europe; the most significant of these occurred in February 1945 at Yalta, and was attended by Franklin Roosevelt, Winston Churchill, and Joseph Stalin. During the discussions, political and territorial questions that had been avoided in the effort to defeat Nazi Germany were addressed.

Roosevelt, Churchill, and Stalin reached agreement on several key issues in Yalta, including the future of Poland, Eastern Europe and Germany; the war in Asia; and the creation of a postwar international organization (Palmer and Colton 1978:821; Gaddis 2005:31). At that time all parties, including Stalin, pledged to establish freely-elected provisional governments representing all political parties in territories occupied by the Soviet army (Palmer and Colton 1978:821; Gaddis 2005:31). It was understood among the Allied powers that the country liberating a formerly German-occupied nation would exercise political control over that nation until final peace treaties were signed (Palmer and Colton 1978:850). As the liberating country, the Soviet Union was able to influence political outcomes in Eastern Europe.

Also at Yalta, Poland's eastern boundary was set at the Curzon line and its northern and western borders were extended at the expense of Germany. German disarmament and the partition of Germany by the Big Three powers and France also were discussed (Palmer and Colton 1978:821).

The third major issue discussed at Yalta concerned the creation of the United Nations (UN). Roosevelt was a strong proponent of cooperation among the world powers. He believed this cooperation could be achieved within the framework of the United Nations (Palmer and Colton 1978:824). He further believed that by acting as international policemen, the big powers could preserve future peace and security around the world. Roosevelt would never see the end of hostilities; on April 12, 1945 he passed away, leaving Harry S. Truman as President (Palmer and Colton 1978:824).

Immediately before the end of the war and right after the war the United States and the Soviet Union aggressively sought to appropriate German military secrets and the cooperation of German scientists. The Americans conducted their efforts under the name "Operation Paperclip." The purpose of the program was to "exploit German scientists for American research, and to deny these intellectual resources to the Soviet Union" (Advisory Committee Staff 1995:1; Walker 2005). Denying the Soviets the opportunity to recruit German scientists was the highest priority for Pentagon officials, regardless of whether or not the Germans were active members in the Nazi party (Advisory Committee Staff 1995:4). In March 1948, Captain Bosquet N. Wev outlined the government's position. He stated that "Nazism no longer should be a serious consideration from a viewpoint of national security when the far greater threat of Communism is now jeopardizing the entire world" (Advisory Committee Staff 1995:4).

As a result of the program, approximately 1,600 scientists and their families were brought to the United States (Advisory Committee Staff 1995:1). Scientists with backgrounds in aeromedicine, radiobiology, and ophthalmology were recruited to work at the Air Force's School of Aviation Medicine at Brooks Air Force Base, Texas; and other military installations, including the Army's Chemical Corps at Edgewood Arsenal, Maryland (Advisory Committee Staff 1995:2). Other scientists with backgrounds in radiation biology and physics also were recruited (Advisory Committee Staff 1995:3).

As part of this project, German engineer Wernher von Braun and a group of German scientists were recruited and transported to White Sands Missile Range in New Mexico, along with "enough captured rocket parts, equipment, and research data to build and launch 67 V-2s" (Library of Congress 2007:3). The group of scientists relocated in 1945, and agreed to work with the United States in order to develop and test the V-2. While in Germany, von Braun had worked on the early development of the V-2's predecessors, the A-1 thru the A-5, and the V-1. His experiments with the V-2 at White Sands were crucial to future rocket development in the United States.

4.1.2 The Truman Doctrine

Efforts to stop the spread of Communism guided much of the United States' foreign policy during the postwar years. In a 12 March 1947 speech before the joint houses of Congress, President Truman outlined his foreign policy, which became known as the Truman Doctrine. The Truman Doctrine evolved out of a desire by the American government to respond to perceived Soviet threats. Under the Truman Doctrine, the United States would provide political, economic, and military aid to any anti-Communist government threatened by "indigenous insurgents, foreign invasion, or even diplomatic pressure" (Ambrose 1971:150; Gaddis 1972:351, 352, 356). The Truman Doctrine governed American foreign policy for the next twenty years (Ambrose 1971:150). The first beneficiaries of the Truman Doctrine were Greece and Turkey, who received military aid to combat Communist insurgencies.

4.1.3 The Marshall Plan

Immediately following the Second World War, the United States undertook an ambitious plan to revitalize Europe's economy. Secretary of State George C. Marshall outlined his plan to revive Western Europe's economy in a 5 June 1947 speech at Harvard University. Marshall hoped that economic aid would discourage Europeans from electing Communist governments out of despair (Gaddis 2005:32). The plan initially met Congressional opposition. However, the Communist coup in Czechoslovakia and threat of Soviet Communist expansion into Europe prompted Congress to support Marshall's economic aid package. Economic aid was offered to all countries in Europe, including the countries in Eastern Europe; however, the Soviet Union prohibited its satellite countries of Eastern Europe from participating (Palmer and Colton 1978:845, 846).

The Marshall Plan sought to build European economic independence from American support. American financial aid was contingent upon European countries establishing individual economic policies, coordinating joint European economic policies to strengthen Europe's overall economy, and assuming a role in international trade (Palmer and Colton 1978:847). The American government encouraged European governments to reduce tariffs and currency controls and to create a European-wide internal market that would lead to mass production and lower costs (Palmer and Colton 1978:847). The Marshall Plan was an overwhelming success. By 1950, West German industrial production exceeded prewar levels, and by the early 1950s, the economic boom had spread to Italy and France (Palmer and Colton 1978:847). The Marshall Plan was, in part, responsible for the creation of the European Economic Community and eventually the European Union (Palmer and Colton 1978:847).

4.1.4 The Creation of Two Germanys

After World War II, Germany was divided into four occupation zones: Soviet to the east, American to the south, British to the northwest, and French to the southwest. The French, American, and British zones eventually combined to create West Germany (Federal Republic of Germany). West Germany became an independent country on 23 May 1949. East Germany (German Democratic Republic) was created 7 October 1949 with Soviet authorization. In addition, Berlin was divided into four sectors, similar to how Germany as a whole was partitioned (Gaddis 2005:105).

4.1.5 The Berlin Blockade

Tensions in Europe spiked during the late 1940s as the result of the Soviet blockade of Berlin. On 24 June 1948, the Soviets began a blockade of ground and water traffic into West Berlin. Stalin's reasons for imposing the blockade are unclear, but historians have speculated that the blockade was a response to the American introduction of a new currency in West Berlin, or efforts to unify the American, British, and French occupation zones under a newly created West Germany. Another theory posits that the Soviets were attempting to force the American, British, and French withdrawal from their respective sectors by taking advantage of their dependence on Soviet supply lines running through the Soviet zone (Gaddis 2005:33-34; Palmer and Colton 1978:846; Grathwol and Moorhus 1994:32).

The Berlin blockade threatened to launch a war-weary Europe into another armed conflict. The British and Americans retaliated to the blockade by imposing their own blockade on goods from the east to West Germany (Ambrose 1971:172). The Americans intensified their response to Soviet actions by conducting round-the-clock flying missions to Berlin. The airlift began on 26 June 1948 and supplied up to 13,000 tons of goods a day (Ambrose 1971:173). The Soviets lifted the blockade of West Berlin on 12 May 1949; however, the airlift continued until 30 September 1949. The airlift extended beyond the blockade because American military officials, suspicious that the Soviets would reinstate the blockade, wanted a stockpile of goods in West Berlin (Grathwol and Moorhus 1994:54).

4.1.6 The North Atlantic Treaty Organization (NATO)

While the West was supplying the citizens of West Berlin, the governments of Western Europe and the United States were creating a military organization to provide mutual defense to member nations. On 4 April 1949, Great Britain, France, Belgium, the Netherlands, Italy, Portugal, Denmark, Iceland, Norway, Canada, and the United States executed a treaty creating NATO. Greece, Turkey, and West Germany joined NATO in 1952 and 1955 (Ambrose 1971:174). The organization was created in an effort by countries assisted under the Marshall plan to provide for mutual military defense. After it was ratified by the Senate, President Truman signed the NATO treaty on 23 July 1949. The formation of NATO represented the first time the United States pledged defense of Western Europe during peacetime. Eastern European nations responded to the creation of NATO, and in particular the inclusion of West Germany in NATO, by forming the Warsaw Pact in May 1955 (Gaddis 2005:34).

4.1.7 China

Although the communist threat in Europe gained the most attention, communism was also a dominant force in Asian politics. The civil war in China was a flashpoint during the Cold War. Tensions between the Soviet Union and the United States were heightened as the threat of the most populous country in the world becoming Communist became a reality. The Nationalist (Kuomintang) and the Communist forces were fighting for control over China as early as 1927. In 1937, the Japanese invasion and occupation of China united competing Chinese forces in an uneasy alliance under Kuomintang leadership, helmed by Chiang Kai-shek. The Japanese defeat and withdrawal from China led to renewed hostilities between the Nationalists and the Communists. Open conflict broke out in the spring of 1946 and continued until September 1949. The Nationalists received aid from the United States while the Communists were given limited aid by the Soviet Union. Plagued by corruption, the Nationalists were unable to repel the Communist forces and fled in defeat to the island of Taiwan. Communist leader Mao Zedong proclaimed the creation of the People's Republic of China on 1 October 1949; the Soviet Union recognized the People's Republic of China the following day.

4.2 The Korean Conflict: 1950-1953

4.2.1 Introduction

The Cold War intensified during the 1950s through the 1970s. American foreign policy focused on limiting the spread of Communism, particularly to those nations previously unaffiliated with a Communist government. As a result of American foreign policy, the United States and the Soviet Union engaged in a series of proxy wars, whereby they fought each other indirectly, thus averting a nuclear war. Each Presidential administration attempted to address perceived Communist threats.

4.2.2 The Korean Conflict

Korea, which had been part of the Japanese empire since 1910, was jointly occupied by Soviet and American troops after World War II. Soviet troops occupied the northern half (above the 38th parallel) of the peninsula, while American forces occupied the southern half. The 38th parallel split the Korean peninsula in half and served as the line of demarcation until elections could be held and occupying forces withdrawn (Gaddis 2005:41). It was anticipated that a new government would unify the peninsula.

Although occupying forces left the Korean peninsula in 1948 and 1949, peninsula-wide elections did not take place. United Nations-sanctioned elections were held in the Republic of Korea (South Korea); the Democratic Republic of Korea (North Korea), which was supported by the Soviets, did not hold elections. Each government claimed legitimacy and threatened to cross the 38th parallel (Gaddis 2005:41). However, neither government could act without assistance from their respective supporters (Gaddis 2005:41).

Tensions came to a head when the North Koreans took decisive military action against the South. With Soviet approval, the North Koreans crossed the 38th parallel on 25 June 1950. The United States, with the support of the UN, came to the aid of the South Korean government. The hostilities on the Korean peninsula represented the first time that the recently-created United Nations (UN) intervened in military action. The Soviet Union, boycotting the UN for its failure to recognize the People's Republic of China, was absent from the Security Council during the vote to commit troops to South Korea.

A cease-fire was established in July 1951; however, fighting did not end until July 1953 when the Chinese, Americans, and the North and South Koreans agreed to an armistice. The North Koreans, Chinese, and Soviets continued to refuse peninsula-wide elections. The conflict did not result in a clear victory for either the United States and its allies or the Soviet Union and its allies. The boundary between North and South Korea essentially was unchanged (Gaddis 2005:50).

United Nations assistance during the Korean Conflict was necessary as the United States was poorly prepared for combat, and an inadequate number of soldiers, heavy weapons, and supplies plagued military efforts (Betts 1995:17). The U.S. no longer maintained the large standing Army it created in WWII. Post war demobilization had been completed in June 1947, releasing approximately 1.2 million troops every month. The efforts decreased troop forces from approximately eight million to 685,458. Also as part of demobilization, the number of Army divisions had gone from 89 to 12. By the beginning of the Korean War the Army had 593,167 troops; however, by 1952, there were a total of approximately 1,596,419 Army personnel available for duty (Table 4.1) (Shrader 1995:10, 6; Epley 1993a; 4-5, 7).

Although the size of the Army more than doubled, the numbers deployed to Korea never surpassed 275,000. The need to maintain a strong force in the event of a Soviet strike was paramount to American policy during this period, and continued throughout the later years of the Cold War (Shrader 1995:10). The resultant decline in the number of troops after the Korean Conflict was less dramatic than after previous conflicts. Troop strength declined from 1,025,778 in June 1956, to 997,994 in June 1957, a reduction of only 27,784 troops (Table 4.2). The Cold War was a unique period in the Army's history, because the size of the regular Army remained consistently high compared to previous peacetime levels. The size of the Army leveled off around 900,000 in the late 1950s (Department of the Army 1956).

Table 4.1. Size of the Army during the Korean Conflict (Kuranda et al. 2003*)*

Year	Actual Size	Enlisted Men	Officers
1950	593,167	518,921	72,566
1951	1,531,774	1,399,362	130,540
1952	1,596,419	1,446,266	148,427
1953	1,533,815	1,386,500	145,633

Table 4.2. Size of the Army during the post-Korea Cold War (Kuranda et al. 2003)

Year	Actual Size	Enlisted Men	Officers
1954	1,404,598	1,274,803	128,208
1955	1,109,296	985,659	121,947
1956	1,025,778	905,711	118,364
1957	997,994	885,056	111,187
1958	898,925	792,508	104,716
1959	861,964	758,458	101,690
1960	873,078	770,112	101,236

4.3 Post-Korea Cold War: 1954-1960

4.3.1 The Domino Theory and Non-Alignment

Following the cessation of hostilities in Korea, countries non-aligned with the Soviet Union or the United States became a concern for American policymakers. These concerns were particularly acute in regards to countries newly declaring their independence from colonial powers. At a 7 April 1954 press conference, President Eisenhower voiced what became known as the "Domino Theory" regarding the political alignment of countries newly independent from European colonial powers. Eisenhower stated that "'You have a row of dominos set up, you knock over the first one, and… the last one will go very quickly'" (Gaddis 2005:123). Many situations could create this domino effect, including outside pressures, or overthrows within a country (Gaddis 2005:123). Debate ensued over whom, the United States or the Soviet Union, would have influence over these countries. Non-aligned countries were those nations, particularly in the third world, that would commit to neither the Soviet Union nor the United States while leaving open the possibility of such a commitment (Gaddis

2005:124). Countries being pressured from either superpower would threaten to align with the other (Gaddis 2005:124).

4.3.2 The New Look and Massive Retaliation

President Eisenhower developed his own policy for addressing potential Soviet threats during the early 1950s. Termed the New Look, his policy was based on the assumption that American superiority in the numbers of nuclear weapons and American abilities to deliver those weapons would serve as a deterrent to Soviet hostilities. Eisenhower's reliance on nuclear weapons as a deterrent translated into reduced funding for conventional weapons. Indeed, nuclear firepower would be used to substitute for troops and aircraft (Betts 1995:20).

During the years immediately following the end of World War II, Congress was reluctant to appropriate funds for military spending. To achieve his policy goals, Eisenhower's budget priorities resulted in the Air Force receiving the bulk of military spending. Some political leaders advocated the elimination of the Army and Navy in favor of a strong Air Force (Ambrose 1971:162). The Air Force used its funding for long-range bombers and Intercontinental Ballistic Missiles (ICBM). The Navy also was a recipient of generous military budgets and used its funding to support the development of Submarine Launched Ballistic Missiles (US Army Environmental Center [USAEC] 1997:23). President Eisenhower felt that weapons superiority was sufficient and refused to increase military manpower (Ambrose 1971:222).

Coupled with the New Look policy was the strategy of massive retaliation. This tactic threatened to destroy the Soviet Union. They would be able to retaliate, but would not have sufficient capabilities for defense (Ambrose 1971:222). As a deterrent, massive retaliation would make a nuclear war too destructive to fight, blurring the lines between winner and loser with the aim of eliminating war altogether (Shrader 1995:43-44). The New Look lasted until new policies for addressing potential Soviet threats were adopted under the Kennedy administration.

4.3.3 Hungary

Although the Unites States possessed the ability to retaliate against Soviet aggression, they were hesitant to use it. Soviet intervention in Hungary angered the Western powers, but did not result in Western retaliation. Riots in Budapest in October 1956 lead to a Soviet crackdown across the country. The moderate Imre Nagy sought political reforms, which led to a demand by students and workers for further liberalization of political freedom. After rioting broke out in Budapest, the Soviet Union responded by sending troops and quashing riots. A pro-Soviet government headed by János Kadár was installed. The incident demonstrated to Eastern and Western European leaders that the Soviet Union was willing to use force to preserve its influence (Gaddis 2005:240-241).

4.4 The Vietnam Era: 1960-1974

4.4.1 The Cuban Missile Crisis

The potential of nuclear war became a reality for most Americans in October 1962. The Soviet Union began constructing medium-range missile sites on Cuba in August 1962. Launch pads at the missile sites could fire missiles with a range of 1,000 miles. On 14 October 1962, an American spy plane photographed the construction of the missile sites, proving months of rumors. In a 22 October 1962 televised statement, President Kennedy alerted the American public about the presence of the missile sites and warned the Soviet Union that the United States would consider a "nuclear missile launched from Cuba against any nation in the Western Hemisphere as an attack by the Soviet Union on the United States" (Ambrose 1971:289). President Kennedy directed the Navy to intercept Soviet ships headed towards Cuba. The crisis was resolved on 28 October 1962 when the United States promised not to invade the island and Soviet Leader Nikita Khrushchev announced the missiles would be removed.

4.4.2 Flexible Response

Increased military spending occurred during the Kennedy administration, bringing an end to fiscal conservatism, a hallmark of the Truman and Eisenhower administrations. By the second year of his administration, Kennedy had increased the Department of Defense budget to $56 billion and increased the size of the Armed Forces by 300,000 troops; this level of expansion in funding and troops was similar to the intensity of growth during the Korean War (Ambrose 1971:277, 283; Shrader 1995:116). The Kennedy administration reorganized the policies of the Truman and Eisenhower administrations of relying on nuclear weapons to deter Soviet aggression. President Kennedy wanted the ability to intervene in any crisis using either the threat of nuclear retaliation or using conventional weapons or troops (Ambrose 1971:278; USAEC 1997:36). The policy was known as Flexible Response. Flexible Response first was advocated by Army Chief of Staff Maxwell Taylor, who served under the Eisenhower administration. Regardless of his proposed reliance on troop strength, Kennedy did follow Eisenhower's role in continuing efforts toward missile development. The Soviets responded to changing U.S. policy by increasing their nuclear capabilities.

4.4.3 Mutual Assured Destruction (MAD)

President Kennedy's Secretary of Defense Robert McNamara developed the policy known as Mutual Assured Destruction that paralleled the paradigm of massive retaliation. Under this policy, the United States and the Soviet Union would target each other's major cities; the purpose of such targeting was to create the maximum number of casualties as possible. The rationale behind MAD was that if no one was assured of surviving a nuclear war, such a war would not occur (Gaddis 2005:80).

4.4.4 The Vietnam Conflict

The tensions between the Soviet Union and the United States intensified in Southeast Asia during the mid-1950s and early 1970s. The U.S. commitment to the government of South Vietnam began after the French left the country in 1954 and continued through 1973, when American troops pulled out. American intervention in the region, which began slowly under the Eisenhower administration and escalated after the Gulf of Tonkin incident in 1964, was predicated on efforts to stop the spread of Communism, specifically in Southeast Asia.

The American involvement in Southeast Asia began during the mid-1950s when the U.S. government provided assistance to the French. During the 1950s, the French were engaged in a conflict with Communist forces loyal to North Vietnamese leader Ho Chi Minh. After the French abandoned the outpost at Dien Bien Phu in May 1954, the United States sent military and economic advisors to Ho Chi Minh's opponents in South Vietnam (Gaddis 2005:132).

After the French defeat in 1954, the Americans, the British, the Soviets, and the Chinese agreed during the Geneva peace conference that the country should be divided at the 17^{th} parallel. Ho Chi Minh established a Communist government in the north. Ngo Dinh Diem became the leader in South Vietnam. Elections in North and South Vietnam were scheduled to decide the fate of the country: continued division or unification. However, the elections were never held. The Viet Cong, guerrilla soldiers left behind in South Vietnam after the 1954 Geneva conference, began harassing South Vietnamese authorities. The South Vietnamese government appealed to the United States for additional aid (Palmer and Colton 1978:920).

American policy, from Eisenhower through Nixon, sought to check Communist expansion into South Vietnam and to fill the vacuum created by the French withdrawal from the region (Palmer and Colton 1978:920). This afforded American policy makers an opportunity to take action to prevent realization of the Domino Theory (Palmer and Colton 1978:920). Consequently, the U.S. sent substantial military forces to the region.

American participation in the conflict in Vietnam increased dramatically in 1964. Amid reports that American destroyers had been fired upon in the Gulf of Tonkin in August 1964, Congress passed the Gulf of Tonkin Resolution. The resolution gave the president broad powers to commit U.S. troops in Vietnam without prior consultation with Congress (Ambrose 1971:311). In effect, Congress enabled President Johnson to use "all necessary measures to repel any armed attack against American forces" (Ambrose 1971:311). In late 1964 and early 1965, President Johnson made the decision to initiate a bombing campaign against the North Vietnamese (Ambrose 1971:315). American military involvement in the conflict continued to escalate during the late 1960s. The Tonkin Gulf Resolution resulted in the deployment of 184,000 American soldiers to Vietnam by the end of 1965 (Tindall and Shi 1992:1358-1359). The number of Army personnel deployed to Vietnam climbed steadily for the next four years reaching a peak of over 500,000 in 1968.

President Richard Nixon initiated the steps that led to the United States withdrawal from Vietnam, despite seemingly contradictory policies. In the election of 1968, presidential candidate Richard M. Nixon promised to withdraw U.S. troops from Vietnam with "peace and honor." In June 1969, President Nixon announced the withdrawal of 25,000 troops. By May 1972, the regular Army had been reduced to 850,000 troops from its wartime peak of 1.5 million (Tindall and Shi 1992:1387).

Although the Nixon administration invigorated peace negotiations in the early 1970s and began turning over bases and equipment to the South Vietnamese, increased bombing of North Vietnam and the secret bombing of Cambodia contradicted Nixon's pledge of an early end to the war (Palmer and Colton 1978:923). Although an apparent escalation of military activity, progress toward a peaceful solution continued. The Nixon administration negotiated an agreement that returned American prisoners of war; the United States withdrew its forces in 1973 while the North and South Vietnamese governments remained in place (USAEC 1997:41). By 1974, the Army was reduced further to 783,000, a level that the Army maintained for the remainder of the Cold War era (Table 4.3) (Tindall and Shi 1992:1387). Two years later, North Vietnamese forces initiated a military offensive that resulted in the collapse of the South Vietnamese government. The country was reunified under a Communist government, and the People's Democratic Republic of Vietnam was declared in July 1976.

4.4.5 The Berlin Wall

After World War II, a divided Berlin became a way of life for its citizens. However, residents of the city could cross from east to west with relative ease, regardless of the political and military tensions. The city became physically divided after the East German government constructed a barrier to prohibit the movement of East Germans leaving the east for better opportunities and greater freedom in the west.

Highly educated, highly trained East Germans fled East Berlin for improved living standards in the west. Residents of East Germany were able to immigrate to West Germany via West Berlin. The annual number of immigrants leaving East Germany for West Germany exceeded 178,000 between 1952 and 1959; nearly half the immigrants were under 25 years of age (Grathwol and Moorhus 1994:76). Approximately twenty percent, or 4 million residents, of the East German population fled the country for West Germany by the end of the 1950s (Grathwol and Moorhus 1994:76). Immigration further increased during the early 1960s. During the first twelve days of August 1961, over 45,000 immigrants left the east (Grathwol and Moorhus 1994:84).

Table 4.3. Size of the Army during the late Cold War: 1960-1989 (Kuranda et al. 2003)

Year	Actual Size	Enlisted Men	Officers
1961	858,622	756,932	99,921
1962	1,066,404	948,597	116,050
1963	975,916	865,768	108,302
1964	973,238	860,514	110,870
1965	969,066	854,929	112,120
1966	1,199,784	1,079,682	117,786
1967	1,442,498	1,296,603	143,517
1968	1,570,343	1,401,727	166,173
1969	1,512,169	1,337,047	172,590
1970	1,322,548	1,153,013	166,721
1971	1,123,810	971,872	148,950
1972	810,960	686,695	121,290
1973	800,973	681,972	116,205
1974	783,330	674,466	105,998
1975	784,333	678,324	102,992
1976	779,417	677,725	98,647
1977	782,246	680,062	97,738
1978	771,624	669,515	97,785
1979	758,852	657,184	97,381
1980	777,036	673,944	98,717
1981	781,419	675,087	101,850
1982	780,391	672,699	103,109
1983	779,643	669,364	105,674
1984	780,180	667,711	107,883
1985	780,787	666,557	109,687
1986	780,980	666,668	109,757
1987	780,815	668,410	107,964
1988	771,847	660,445	106,963
1989	769,741	658,321	106,877

In an effort to staunch the flow of immigrants, the Soviet government constructed a wall cutting East Berlin off from West Berlin in August 1961. A barbed wire fence was constructed overnight on 12-13 August 1961. A more substantial and permanent concrete wall was constructed later. The twelve-foot tall concrete wall extended for 100 miles and was protected by guard towers, minefields, police dogs, and sentries ordered to shoot to kill anyone who tried to cross the wall (Gaddis 2005:115).

Construction of the Berlin Wall stabilized the political situation in Berlin between East and West. Khrushchev no longer needed to force Western powers out of Berlin because the wall separated West Berlin from East Berlin and East Germany (Gaddis 2005:115). The United States responded to the construction of the Berlin Wall by sending additional Army forces to West Berlin (USAEC 1997:40). The wall succeeded in halting the number of immigrants fleeing East Berlin for the west; the number of East Germans entering West Berlin nearly came to a halt (Grathwol and Moorhus 1994:107). The wall remained a physical reminder of Cold War tensions until it was opened in 1989.

4.4.6 Tensions Between China and the Soviet Union

Although the Soviet Union provided limited support to the Chinese Communists during the civil war with the Chinese Nationalists, relations between Mao and Stalin remained cool (Palmer and Colton 1978:863). During the early years of Communist rule, the Chinese government relied on economic and military aid from the Soviet Union. However, relations between China and the Soviet Union were measured, and at times hostile, by the late 1950s and early 1960s. The two countries disagreed over sharing nuclear technology, the construction of long-wave radio stations, and a joint fleet. The Chinese government declared its independence from Soviet influence after Stalin's death (Palmer and Colton 1978:864). Sino-Soviet relations remained restrained through the remainder of the Cold War. The Chinese relationship with the United States reached an important milestone when President Nixon paid a significant visit to China in February 1972, which reopened political and economic relations between the two nations (Gaddis 2005:151-152).

4.4.7 Détente and the Helsinki Conference

By the early 1970s, American foreign policy evolved yet again to respond to current world conditions. The Soviet Union and the United States sought ways to peacefully resolve their differences. Détente was the term used to describe Soviet and American efforts to reduce tensions (USAEC 1997:46; Palmer and Colton 1978:928).

President Nixon and Soviet leader Brezhnev signed an agreement on 29 May 1972 which, in addition to attempting to reduce tensions, recognized the spheres of Soviet and American influence and sought to improve economic, commercial, and cultural ties between the two countries (The American Presidency Project 1972). Under détente, 35 countries, including the United States, Canada, the Soviet Union, and NATO and Warsaw Pact countries, pledged to work towards peaceful cooperation and permanent peace in Europe at Helsinki in 1975 at the Conference on Security and Cooperation in Europe (Palmer and Colton 1978:928). The conference, which opened on 3 July 1973 and concluded on 1 August 1975, resulted in the adoption of the Helsinki Accords. Brezhnev encouraged the formation of the conference because he wanted western recognition of the Soviet Union's postwar borders (Gaddis 2005:187).

By signing the accords, the 35 countries agreed to accept the Oder-Neisse German-Polish boundary established at Potsdam in 1945 but never ratified in a treaty (Palmer and Colton 1978:928). The Helsinki Accords also stipulated that participating nations had to give prior notification of military maneuvers; outlined cooperation in the fields of economics, science, technology, and the environment; and recognized human rights and the fundamental freedoms in conformance with the "purposes and principles of the Charter of the United Nations and with the Universal Declaration of Human Rights" (Gaddis 2005:188; Conference on Security and Co-operation in Europe 1975:7). Détente came to an end during the Carter administration.

4.5 The Late Cold War: 1975-1989

The Cold War came to a virtually peaceful end in 1989 after a series of nearly simultaneous events. Soviet leader Mikhail Gorbachev played an influential role in the collapse of Communism in the Soviet Union and Eastern Europe. His programs of *perestroika*, the term he coined for restructuring the Soviet economy along western models, and *glasnost*, or opening issues to public debate and criticism, were partially responsible for the breakup of the Soviet Union. In addition, unlike previous Soviet leaders, Gorbachev did not respond militarily when Eastern block countries acted independently of Soviet authority (Gaddis 2005:253).

The end of the Cold War began in early 1989 when Hungarian Prime Minister Miklós Németh refused to approve funds for the maintenance of the barbed wire fences between the

Austrian and Hungarian borders. Shortly thereafter, he ordered the fence to be dismantled. The result was Hungarians, East Germans, and other Eastern Europeans could now pass through Hungary to the West with relative ease. By fall 1989, the number of East Germans traveling to Hungary approached 130,000; the Hungarian government announced it would not stop their emigration to the West (Gaddis 2005:243-245).

The political situation in Poland throughout the 1980s contributed to the demise of Communism in that country. The trade union Solidarity was formed in 1980 in Gdańsk in response to growing economic and social crises, and advocated anti-communist ideals such as open trade and free elections. Although the Communist government of Poland initially recognized the union, Solidarity later suffered repression and had its leaders imprisoned. As economic conditions continued to deteriorate, however, the government invited Solidarity to put forth candidates to compete in a 1989 election for a newly created two-house legislature; they won all seats contested in the lower house and all but one seat in the upper house (Gaddis 2005:241; NSZZ Solidarność n.d.). On 24 August 1989, postwar Eastern Europe's first non–Communist government took power (Gaddis 2005:241, 242). The Communist Party of Poland dissolved in early 1990 (NSZZ Solidarność n.d.).

The Berlin Wall officially opened to allow East Germans to travel to the West on 9 November 1989. The East German government intended only to relax border crossings from the East to the West (Gaddis 2005:245). However, during a botched press conference, an East German official announced that travel through any of the border crossings would be unrestricted, effective immediately (Gaddis 2005:245). Within hours East Germans began gathering at crossing points; East German border guards, who had been given no previous instructions, opened the gates at Bornholmer Strasse, thereby allowing East Germans to cross into West Berlin unimpeded (Gaddis 2005:245).

Events in Eastern Europe did not leave the Soviet Union unaffected. A coup attempt in August 1991 destabilized the Soviet government. A politically weakened Gorbachev resigned as President of the Union of Soviet Socialist Republics on 25 December 1991, following a decree terminating the existence of the Soviet Union. The fall of Communism is antithetical to the Domino Theory put forward during the 1950s. Rather than continued communist aggression, it was the Soviet Union that collapsed.

4.6 The Nuclear Age

4.6.1 Introduction

Weapons became more deadly as the Cold War progressed. Larger and more powerful weapons than the atomic bombs dropped on Hiroshima and Nagasaki were developed. The governments of Soviet Union and the United States built large stockpiles of nuclear weapons in an effort to protect their respective countries. The growth of nuclear power became a defining characteristic of the Cold War.

4.6.2 Nuclear Weapons

The atomic bomb was seen as a tool that could effectively deter the Soviets from aggressive action towards its neighbors (Ambrose 1971:128). The United States could keep the Soviets in check without calling upon Americans to make sacrifices (Ambrose 1971:128). Increasing the nuclear arsenal was more cost effective than increasing the number of conventional weapons and increasing the size of the military to their World War II levels (Gaddis 2005:36). Four years after the bombing of Hiroshima and Nagasaki, President Truman announced on 22 September 1949 that the Soviet Union had exploded an atomic bomb.

The United States developed the hydrogen bomb, known at the time as a "super-bomb," during the early 1950s. A hydrogen bomb fused atoms as opposed to splitting them, as in the case of the atomic bomb. The Truman administration thought the hydrogen bomb, or thermonuclear bomb, was psychologically necessary in that Soviet possession of the hydrogen bomb would instill fear and panic in the West. American development and possession of the hydrogen bomb would negate any advantage the Soviet Union might gain from developing the atom bomb. The United States first tested the hydrogen bomb on 1 November 1952 on an island in the Pacific Ocean. Almost a year later, the Soviet Union tested its first hydrogen bomb in the Central Asian desert. Americans tested a more powerful thermonuclear weapon on 1 March 1954 in the Pacific Ocean. The weapon yielded fifteen megatons, or 750 times the size of the atomic bomb dropped on Hiroshima (Gaddis 2005:61-64).

The Soviet Union tested its first air-dropped thermonuclear bomb in November 1955, and in August 1957 tested the world's first intercontinental ballistic missile (Gaddis 2005:68). As early as 1958, the world's nuclear powers met in Geneva at the Conference on the Discontinuance of Nuclear Tests. At this conference, the Soviet Union and the United States agreed to a moratorium on nuclear testing while a formal treaty was under development. The parties expected to resolve certain issues at a summit in early 1961; however, the political scandal generated by the downing of an American U-2 spy plane overshadowed the nuclear treaty, and the summit was never held. The Soviet Union began testing nuclear weapons in August 1961, and the United States responded by detonating its own nuclear weapon the following month (Ambrose 1971:285).

4.6.3 The Army's Development of Nuclear Weapons

The Army developed a series of nuclear weapons to respond to potential Soviet threats. The Army sought to develop weapons that were distinct from strategic weapons such as intercontinental ballistic missiles (ICBMs) and submarine-launched ballistic missiles (SLBMs) (USAEC 1997:25). The Army developed several new weapons systems that had limited practical use. The 280mm "atomic cannon," presented in 1953 could deliver nuclear or high-explosive warheads a distance of approximately 17 miles. The weapon needed to be kept well behind friendly lines to protect it against enemy attack, thus limiting its use as a tactical weapon (USAEC 1997:25, 26). The "Davy Crockett" was another nuclear weapon with limited tactical applications. The low-yield weapon could be fired from a small rocket. Its 1.5-mile range and limited accuracy made its use difficult (USAEC 1997:26). NIKE missiles also were developed to provide air defense against a possible Soviet nuclear missile attack. NIKE missile stations were located throughout the United States. Other missile systems including the CORPORAL, the HONEST JOHN, and the LITTLE JOHN were developed at White Sands Proving Ground and Redstone Arsenal in an effort to create parity with numerically superior Warsaw Pact forces.

During the 1960s and 1970s, the Army gradually moved away from developing antiaircraft missiles to developing antiballistic missiles (ABMs) (USAEC 1997:46). The Army developed a couple of ABM systems, the SENTINEL in 1967 and the SAFEGUARD in 1975 (USAEC 1997:46).

4.6.4 Treaties Regulating Nuclear Weapons

Beginning in the 1960s, the Soviet Union and the United States signed a number of treaties and entered into agreements limiting the testing and number of nuclear weapons.

4.6.4.1 The Treaty Banning Nuclear Weapon Tests in the Atmosphere, Outer Space and Under Water (1963)

Popularly referred to as the Limited Test Ban Treaty, the Treaty Banning Nuclear Weapon Tests in the Atmosphere, Outer Space and Under Water, was signed on 5 August 1963 by the "Original Parties" that included the United States, the Soviet Union, and the United Kingdom. The

Limited Test Ban Treaty abolished nuclear tests in the atmosphere, including outer space and under water by signatory states (Gaddis 2005:81).

4.6.4.2 The Treaty on the Non-Proliferation of Nuclear Weapons (1968)

The Treaty on the Non-Proliferation of Nuclear Weapons required signatory and acceding nations with nuclear weapons not to assist other nations with acquiring them. Non-nuclear-weapon participating countries agreed not to receive nuclear weapons or to seek assistance in the manufacture of nuclear weapons. The treaty was signed on 1 July 1968 by the United States, the Soviet Union, and the United Kingdom (Treaty on the Non-Proliferation of Nuclear Weapons 1968).

4.6.4.3 The Strategic Arms Limitation Talks (SALT I) and the Treaty on the Limitations of Anti-Ballistic Missile Systems Between the United States and the Soviet Union (1972)

Between 1969 and 1972, the United States and the Soviet Union were involved in a series of negotiations regarding ballistic missiles. Signed on 26 May 1972 by President Nixon and Soviet leader Leonid Brezhnev, the resulting Treaty on the Limitation of Anti-Ballistic Missile Systems restricted the number of land- and sea-based, long-range ballistic missiles. The treaty, popularly referred to as the Anti-Ballistic Missile (ABM) Treaty, limited the Soviet Union and the United States to two ABM sites each. Compliance would be verified through satellites. Anything other than symbolic defenses, including missiles, also was banned under the treaty (Gaddis 2005:200; Limitations of the Anti-Ballistic Missile-Defense Systems 1972). In 1973, Congress restricted the number of ABM sites to one, at Grand Forks, North Dakota. A protocol limiting each country to one ABM site was signed by the United States and the Soviet Union in 1974 (USAEC 1997:46).

Under the agreement, the Soviet Union would retain superiority in the number of ICBMs. A vocal opponent to the treaty, Senator Henry Jackson, proposed an amendment that would have required that “all subsequent arms control agreements provide for numerical equality in all weapons systems covered” (Gaddis 2005:200). This provision impacted the subsequent SALT II negotiations.

On-going negotiations between the Soviet Union and the United States regarding the number of nuclear of weapons continued under the Carter administration. This series of talks were referred to as SALT II. President Carter and Soviet leader Brezhnev signed the Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Limitation of Strategic Offensive Arms, Together with Agreed Statements and Common Understandings Regarding the Treaty on 18 June 1979. However, the United States Senate refused to ratify the agreement because senators thought it did little to reduce the nuclear danger and it allowed the Soviet Union improvements in capabilities (Gaddis 2005:202). World events, namely, the NATO decision to deploy Pershing II and cruise missiles and the Soviet invasion of Afghanistan, also contributed to the Senate’s failure to act on the treaty (Gaddis 2005:203, 211). Consequently, President Carter withdrew the SALT II treaty from the Senate in January 1980.

4.6.4.4 Strategic Arms Reduction Treaties (START)

President Reagan proposed the Strategic Arms Reduction Talks (START) in May 1982. The talks aimed to reduce the number of ICBMs and the number of strategic nuclear weapons. The Soviet Union and the United States began developing agreements for reducing the risk of war (Department of Defense 1994:91). A number of treaties resulted from the START process.

4.6.4.5 Treaty on Elimination of Intermediate-Range and Shorter-Range Missiles- Between USA and USSR (1987)

Commonly referred to as the Intermediate-range Nuclear Forces (INF) Treaty, the Treaty on Elimination of Intermediate-Range and Shorter-Range Missiles-Between USA and USSR was signed by President Reagan and Mikhail Gorbachev on 8 December 1987. Prompted by START, the treaty stipulated the removal and destruction of 2,611 American and Soviet nuclear weapons. Verification of destruction of the missiles would be completed through inspections (Gaddis 2005:235).

4.6.5 Strategic Defense Initiative (SDI)

On 23 March 1983, President Reagan announced the Strategic Defense Initiative (SDI). The new program effectively signaled the end of MAD (USAEC 1997:60). SDI operated on the premise that a system could be developed that would be able to intercept and destroy strategic ballistic missiles before they reached the United States (Gaddis 2005:226). SDI was envisioned to be a space-based program that relied on x-ray lasers or other advanced technology (USAEC 1997:60). For the remainder of the Cold War, SDI continued in the research and the development phases, but was never made operational. Development of the SDI program enabled the United States to fulfill the terms of the 1972 ABM treaty, which limited operational systems but not research and development (USAEC 1997:60).

4.7 Summary

The Cold War began and ended rather peacefully. Although the Cold War was marked by a series of armed conflict and hostilities, nuclear annihilation was avoided. The fear of nuclear destruction meant that the two superpowers came close to nuclear war without actually deploying nuclear weapons. While the Soviet Union and the United States were engaged in indirect military conflicts around the world, they also were engaged in negotiations limiting the number and spread of nuclear weapons. In the late 1980s, a series of political events, particularly in Eastern Europe, heralded the end of the Cold War.

5.0 TECHNOLOGY AND CHANGE DURING THE COLD WAR ERA

5.1 Introduction

At the end of World War II, the Army controlled 77 government-owned contractor-operated plants for the production of ammunition. These included plants for manufacturing chemicals used in propellant or explosive production; facilities for combining materials into various explosives mixtures; plants to load, assemble, and pack munitions; small arms ammunition plants; and facilities to manufacture gun tubes, incendiaries, tanks, and metal components. In addition to the contractor-operated installations, the Army managed government-owned government-operated plants such as Rocky Mountain, Pine Bluff, and Huntsville arsenals where chemical agents were manufactured and stored. Other government-owned installations with limited production capabilities included research and development (R&D) centers such as Redstone Arsenal (guided missiles) and Edgewood Arsenal (pyrotechnics and chemical agents). Small-arms ammunition facilities included both metal parts manufacturing and load-assemble-pack operations because of their small size and high production rates (Williams 1978:ix).

With the end of hostilities, the number of ammunition plants rapidly declined, and by 1995, only 27 government-owned contractor-operated plants remained under Army control (Kane 1995). Over the next 12 years, seven additional plants were removed from the real property inventory. The majority of ammunition production facilities currently in the Army real property inventory are located at 13 Army ammunition plants classified as active, inactive, or excess. Other production facilities are located at various Army installations where ammunition production was not the primary mission. As of 2007, the Army retains 3,986 buildings and structures built between 1939 and 1989 that were used in the production of munitions or components. These facilities are located at 28 installations (Table 5.1). However, through the passage of time and various excess and closure actions, two installations classified as Army ammunition plants retain fewer than 30 buildings directly related to ammunition production, and two no longer contain any buildings that were used to manufacture ammunition. The most commonly represented types of plant in the current Army inventory are facilities for manufacturing propellants and explosives (P&E), and load, assemble, pack (LAP) installations. While the Army currently refers to all types of ammunition-related facilities as ammunition plants, P&E plants were historically called ordnance works while installations for LAP were known as ordnance plants.

Although the Army's ammunition production base consisted of GOCO and GOGO plants for the production of propellants and explosives, the majority of ammunition and other types of ordnance obtained during the Cold War were procured from private industry. Commodity Centers, arsenals, and national stock control points submitted ordnance requests to the fourteen ordnance districts. The district offices obtained proposals; negotiated, executed, and administered contracts; and determined supplier capabilities (NARA RG 156 Ordnance Corps 1952:16). There were exceptions, however. Some GOCO plants manufactured metal components that industry was not capable of manufacturing or for which it could not provide sufficient capacity (NARA RG 156 Ford 1953b:1; NARA RG 156 Ford 1953a:4, Williams 1978:x). These components included shells; cartridge cases; metal parts for fuzes, boosters and primers; containers; and boxes (NARA RG 156 Medaris 1953:2). Another example is small arms ammunition, which remained under Army control throughout the Cold War. These types of facilities were government-owned because industry, which was market-driven, could not provide a production base that met long-term ammunition needs (Williams 1978:ix).

Table 5.1 Types of Ammunition Plants with Cold War era Production Facilities (2007 Army Real Property Inventory)

Type of Plant	Number of Facilities	Number of Active	Number of Inactive	Number of Excess
R&D	3	2	0	1
P&E	9	3	0	6
LAP	11	6	3	2
metal parts	2	0	2	0
small arms	3	1	1	1

5.2 Propellant and Explosives Manufacture During the Cold War

Technology currently used by the Army for the production of ammunition has changed little from the processes used during World War II. The majority of the buildings were constructed between 1941 and 1945, and much of the equipment still in use dates from the same era. A detailed discussion of ammunition production during World War II is provided in *Historic Context for the World War II Ordnance Department's Government-Owned Contractor-Operated (GOCO) Industrial Facilities, 1939-1945* (Kane 1995), but a brief explanation of some of the processes is provided to familiarize the reader with certain terms and procedures. Developments during the Cold War are also discussed; however, detailed descriptions of many of the processes for producing the high-energy explosives currently used by the Army are not publicly available.

The term explosives as applied to Army ammunition plants are compounds with a high burning rate and an intense, almost immediate detonation. This type of explosive is usually used as the main charge in munitions. Other types of high explosives include compounds referred to as initiators, which are used in primers and fuzes. Examples of this type include highly-sensitive materials such as fulminate of mercury and lead azide. Propellants are explosives of a lower order with a slower burning rate, referred to as deflagration, and are used primarily to propel the explosive charge to its target (Bodeau 1993:310). During World War II, 23 GOCO facilities produced explosives and propellants. By 2007 that number had declined to only two: Radford, Virginia, and Holston, Tennessee.

The process of creating both propellants and explosives relied on the chemical reaction of nitration. Nitration is completed when the chemical composition of one compound is altered by the addition of a second, high-nitrogen agent, usually in an acidic environment. The reaction of strong acids with most other compounds generates extreme heat and many applications for the manufacture of propellants and explosives are completed in water-filled vessels, or vessels equipped with a water deluge system if the reaction overheats. Following the initial nitration, both propellants and explosives required numerous steps for purifying or drying the material before it was packaged and stored. During periods of conflict, such as in Korea or Vietnam, production levels increased and finished explosives or propellants were frequently shipped to assembly plants once completed without interim storage at the manufacturing installation.

5.2.1 Trinitrotoluene (TNT)

TNT was the most widely used high explosive of World War II, and it was produced by 15 ordnance works (Kane 1995). Until the 1960s, TNT was manufactured in separate steps that required the addition of toluene to a mixture of acids creating mono-oil (mono-nitrating); fortifying the mono-oil with progressively stronger acids to create bi-oil or dinitrotoluene (bi-nitrating); continued additions of strong acids to create TNT; and final washing to remove excess acid followed by a purification process. Each step of the process involved the manual blending of the liquid components. This exposed workers to numerous health risks including skin and hair discoloration, headaches, respiratory disease, and corrosive burns. Developments in continuous nitration eliminated most of these risks.

Continuous nitration facilities were first installed at Radford Army Ammunition Plant (RFAAP) in 1968. The process used eight mixing vessels and separators for nitration, and two purifiers. Each of the vessels was interconnected, allowing continuous flows of acids and nitrated toluene from one nitrator to the next. Toluene and weak acid were mixed in nitrator one (Plate 5.1). Cooling coils within the vessels maintained the temperature and agitators mixed the solution. From the nitrator, the solution moved to a gravity separator. The lighter nitro-bodies (partially nitrated toluene) rose to the surface of the separator and were pumped to the next nitrator. The weak acid was returned to the mixing vessel. The same processes took place in nitrators two and three with continued additions of acid and separation of nitro-bodies (RFAAP n.d.a).

By the time the nitrated toluene reached nitration vessel four, it had reached the level of mononitrotoluene. In nitrators four through six, the solution was converted to dinitroluene (DNT) through the addition of strong acid. Separators allowed for the nitro-bodies to move to the next vessel with the acid solution recycled through the nitrator. Cooling coils maintained the temperature of the DNT. In the final two nitrators, the DNT was converted to TNT with the addition of strong acid. The final step in the nitration process included the addition of concentrated acid to nitrator number eight. The concentrated acid mixed with the recycled acid solution and moved down the set of vessels, becoming weaker until it emerged from nitrator number one as weak acid (RFAAP n.d.a). The final steps in the process converted the crude TNT to a pure form (RFAAP n.d.a).

The pure TNT/water slurry was pumped to a finishing house where the water was removed and air bubbled through the slurry to complete drying. The molten TNT moved to a holding tank. A water cooled drum revolved slowly through the slurry and picked up a thin layer which solidified on contact. A thin blade then cut the pure TNT from the drum and flaked it into small pieces. Hoppers beneath the blade collected the flaked TNT where it was manually removed and packed into boxes (RFAAP n.d.a).

Continuous process TNT lines were later installed in the Kankakee portion of Joliet Army Ammunition Plant (1973) and Volunteer Army Ammunition Plant (1970-1972) (McDonald and Mack 1984a:39; MacDonald and Mack 1984b:33). During the Vietnam era, the United States produced approximately 200,000 tons of TNT using the continuous nitration process. Production of TNT in the United States dropped significantly by the end of the Cold War due to public concern over environmental contamination (Bodeau 1993:331).

5.2.2 Nitroglycerin

Nitroglycerin was another high-explosive that was batch-mixed during World War II. The manufacture of nitroglycerin is one of the most hazardous operations in explosives manufacturing. The essential process is the nitration of glycerin through the addition of acid. Historic manufacturing processes called for the ingredients to be metered and mixed by plant personnel, exposing them to the corrosive mix of acids and the ever-present threat of explosion. The acid and glycerin were mixed in batches, and the oily, straw-colored explosive carefully decanted. To maintain efficiency in the manufacturing process, it was necessary to work with large batches of material, and produce comparatively large amounts of a highly-sensitive and powerful explosive (RFAAP 1989).

In the years immediately following World War II, research began on the development of manufacturing processes that removed the worker from the mixing area, and produced smaller amounts of explosive, but on a continuous basis. The most successful of these was developed by the Swiss engineer Mario Biazzi. The Biazzi process was considered one of the major successes in the automation of explosives manufacturing during the 1950s. Closed circuit television monitors and computer controlled circuitry allowed for the construction of control rooms at a safe distance from the nitrating operation, and the removal of all employees from the process area. An added benefit was that continuous nitration produced only a small amount of nitroglycerin at any given moment, lessening the chance of a catastrophic explosion (RFAAP 1989: n.p.). Biazzi process equipment was installed at Radford, Virginia, and Sunflower, Kansas, during the late 1960s and early 1970s (MacDonald and Mack 1984c:42).

5.2.3 Research Department Explosive (RDX)

Large-scale production of research department explosive (RDX) is considered one of the key technological achievements of the Second World War. It acquired its name through British scientists who wished to mask their research with cyclonite, a highly sensitive, yet powerful explosive. Having almost 30 times the explosive power of TNT, cyclonite held great promise as a military explosive, but difficulty in handling limited its applications. Researchers at Woolwich Arsenal discovered that cyclonite, when mixed with TNT, plasticizers, and wax was stable enough for use in munitions (Kane 1993:137-138).

Production methods for RDX were developed in 1940. RDX is rarely used alone, and frequently mixed with other explosive compounds.

During World War II, both Wabash River Ordnance Works, Indiana, and Holston Ordnance Works, Tennessee, produced RDX. Holston remained in operation throughout the Cold War and during the Vietnam Conflict produced as much as 750,000 pounds of RDX each day. Holston Army Ammunition plant is the only installation in the current Army inventory that continues to manufacture RDX (Kane 1995:137-138; Bodeau 1993:340).

5.2.4 RDX Compositions

One group of explosives developed during World War II with production continuing into the Cold War era were three mixtures of RDX. Composition A was produced at Wabash River Ordnance Works (now the Newport Chemical Depot) during World War II, and continued production of both RDX and composition A during the Korean Conflict. Composition A was used as the primary charge of artillery ammunition (MacDonald and Mack 1984j:2). Composition B is the second explosive with a high percentage of RDX. (Department of Ordnance and Gunnery:1955). Composition B was the most widely used RDX compound of World War II, and was used in torpedoes and aerial bombs. Holston and Wabash River Army ammunition plants produced Composition B into the Cold War with both plants active during the Korean Conflict (Kane 1995 138-139). Composition C was only produced at Wabash River. Its plastic properties made it ideal for demolition charges. Upon its reactivation for the Korean Conflict, Wabash resumed production of composition C (MacDonald and Mack 1984j:35: Department of Ordnance and Gunnery 1955).

5.2.5 High Melting-point Explosive/Homocyclonite (HMX)

The most powerful solid explosive produced in volume in the United States is HMX. HMX is produced by a similar process to RDX, and was initially discovered during the 1940s as a byproduct of RDX manufacture; however, its high cost of production and issues with availability limited its military applications until a process for continuous manufacture was developed in the 1950s. Modifications for the installation of this process equipment began on Line 6 at the Holston Army Ammunition Plant in the late 1950s and production began in 1961 (Swanson 1996:92). Holston remains the only plant producing HMX in the United States as the explosive is carefully regulated by many state agencies and the State Department that oversees export of the product. HMX is the explosive used in detonating the fissionable material of nuclear weapons, in plastic-bonded explosives, and in solid rocket propellants (Bodeau 1993:343-344).

5.2.6 Plastic Bonded Explosives (PBX)

Plastic-bonded explosives (PBX) were developed at Los Alamos National Research Laboratory in 1947, but were not widely available until the 1960s. PBX is a high explosive with similar characteristics to TNT and other mixtures used during the early Cold War, but was less sensitive and could be pressed into shape. PBX is produced as small granules. Using a hydraulic press with extreme pressure, the PBX powder is compacted into a solid mass. The ability of a pressed PBX charge to retain its shape even when subjected to outside mechanical forces made it ideal for use in nuclear and other high-precession weapons (Lundberg 1996:13). The charge of PBX was heated to increase its plasticity, and then shaped in the die of a hydraulic press. The finished charge required minimal machining, and could be accurately tooled.

Plastic bonded explosives are well suited to modern applications in guided missiles and improved conventional munitions. The high energy of PBX leads to high lethality and its machining characteristics made it applicable to a wide range of applications. Many of the military service's guided missiles use PBX as the warhead explosive including the Army's TOW and PATRIOT systems.

5.2.7 Single Base Propellant Production

The most common type of propellant was smokeless powder (Kane 1995:126-127). Smokeless powder was developed in the latter years of the nineteenth century, and by World War I was the most widely-used high explosive for military applications. Cotton linters, the short fibers not used in textile manufacturing, formed the base for smokeless powders. The process began with the addition of strong acid to a pre-measured quantity of cotton linters. Small amounts of acid were added to absorb any excess water generated during the initial nitration. After a brief period of agitation, the mixture, now called nitrocellulose, was moved to a centrifuge where the spent acid was removed. The nitrocellulose slurry was then boiled and washed several times to remove any residual acid or un-nitrated cellulose fibers. After passing through pulping equipment where the nitrocellulose fibers were beat to create a uniform consistency, the slurry was again boiled and filtered to remove impurities, and then run through wringers to remove as much water as possible. Next, large hydraulic presses were used to press water out of the slurry and force alcohol into the mass (Plate 5.2). The alcohol helped to further the drying process. The blocks of nitrocellulose produced by the presses were manually broken apart, and the product was transported to the mix house were a variety of chemicals were added to form a plastic mass called a colloid. Additional hydraulic presses were used to form the colloid into cylindrical blocks (Plates 5.3 and 5.4). These blocks were taken to the finish or final press house where they were forced through heated dies to create long threads, which were then cut to the desired length. The dies could be changed to create threads of varying diameter (Plate 5.5) (Kane 1995:127-132).

At this stage of the process, the formation of what is called a smokeless powder grain was completed. The term grain is somewhat misleading as the final shape is cylindrical. Powder grains varied in size from small flakes or spheres used in small arms to artillery powder over an inch in length. With the development of solid propellants for guided missiles, a single powder grain could measure several feet in length. The burning rate of the powder was also varied by increasing the surface area. Grains were extruded in a variety of shapes including cruciform and slotted. Another method of increasing the surface area was to perforate the grain with multiple holes (Kane 1995:132-133).

Although the powder grains were formed at this point, the solvents used in forming the colloid had to be removed as slow evaporation of the solvent altered the burning characteristics of the powder resulting in poor performance. The finished grains were first taken to a solvent recovery area where warm air was forced through the powder (Plate 5.6). This was followed by soaking the powder in water, which further reduced the solvent content (Plate 5.7). Hot-air drying completed the process. To obtain the desired burning qualities, it was often necessary to combine powder from different lots, and laboratory tests were completed to determine how much of each should be blended in the final product. The finished product was then loaded into boxes, stamped with an identification number, tested to make sure the box was airtight, and then either shipped or moved to the magazine storage area (Kane 1995:131).

5.2.8 Double-Base Propellants

Propellants based on nitrocellulose alone were called single-base propellants; however, more powerful agents were needed for weapons such as guided missiles. Double-base powders were developed for that purpose. The manufacture of double-base powders was similar to that used for nitrocellulose alone. The nitration of cotton linters and the boiling and rinsing processes were identical. After the nitrocellulose was produced, the production method varied. To produce double-base propellants, a solvent was added to the nitrocellulose and thoroughly mixed; then additional components were added. A series of presses served to remove the liquid and completely blend the mixture into a colloid. At this point, the finishing of double-base propellant grains was the same as for single-base, and included extrusion, cutting the grains to length, and drying (Plate 5.8). This method worked well for smaller powder grains and for less concentrated double-base powders, but for large missile grains and mixtures with higher concentrations, a different process was needed (Bodeau 1993:321).

5.2.9 Solventless Propellants

If a solvent was used to form a large double-base grain, the time required to completely dry the propellant often resulted in the grain deforming. If that occurred, the propellant would not fit tightly into the missile casing. Solventless powders were manufacturing using a process referred to as carpet rolls. Production began by mixing the components in a large water tank until a paste was formed. The paste was then placed in a centrifuge and spun to remove as much water as possible (Plate 5.9). After additional air drying, the paste was passed through heated rollers and pressed into thin sheets. The sheets were allowed to cool, and were stacked and passed through a second set of rollers creating a final sheet (Plate 5.10). The subsequent steps in the process created the actual carpet roll. A sheet of powder was fed into a slitting machine which cut it into strips about four-inches wide (Plate 5.11). An inspection of the strips was completed and the powder was formed into a roll about 14 inches in diameter (Plates 5.12 and 5.13). These carpet rolls were placed into a press which first compressed the strips into a single mass, and then extruded it under high pressure into grains (Plates 5.14 and 5.15). Each grain was X-rayed to detect any voids or flaws (Plate 5.16). If needed, the grains were turned on a lathe to the proper diameter, cut to finished length, and wrapped with cellulose (Plates 5.17 and 5.18). The finished grains were packed in steel-lined wood boxes for storage and shipment (Department of Ordnance and Gunnery 1955; Bodeau 1993:321; US Army Real Property Office 2007).

5.2.10 Rocket Propellants

Although the solventless extrusion process formed large propellant grains for rockets, the size of guided missiles in the military's arsenal continued to grow during the 1950s. Early American experimentation into rockets was based on research and development completed by German scientists during World War II. The V-1 and V-2 rockets launched against Great Britain and Belgium used combinations of liquids for propulsion, and initial attempts at developing American guided missiles continued this earlier research. Liquid propulsion systems provide high thrusts and can carry sizeable warheads. The difficulty with this propellant system is that the two liquid components present considerable risks to personnel, can prematurely detonate, and can only remain in the rocket engine for a short time. Cold War era intercontinental ballistic missiles were frequently stored un-fueled, and only readied if launch was imminent.

The need for a rocket propellant that overcame these problems resulted from an increased threat of Soviet, long-range, land-based bombers. In the event of attack, surface-to-air missiles would be required for interception before a liquid-fueled rocket could be readied, and multiple missiles would be needed for mass attacks. The need for a quick response to a Soviet aerial attack required a missile propelled by a solid propellant motor. New processes and propellants were developed to produce these grains (Department of Ordnance and Gunnery 1955).

As early as 1950, Radford Army Ammunition Plant began producing an experimental, solventless, double-base, carpet roll propellant then known only as X-4. By 1951, the powder received the designation JPN. During the second half of 1951, one plant produced over $8 million worth of JPN (RFAAP 1951:24).

Supplement No. 17 to the operating contract for Hercules Powder Company, issued on 19 September 1951, called for the design and reactivation of facilities for the manufacture of 1,250,000 pounds of JPN each month to be used for JATO 14 DS-1000 grains and JATO 2.5 DS-59000 grains for use in the NIKE booster (RFAAP 1951:24-16; 1952:20). Although not specified in the contract supplement, it is likely that existing buildings were modified for the manufacture of these large grains; however, one propellant manufacturing building measuring over 10,000 square feet is size was completed in 1952, but its association with this specific program are unclear. A different method was needed to form grains of the size needed for the NIKE missile system.

The solution was to cast the propellant grain. This casting process differed significantly from the methods used to melt and pour high explosives into bombs or artillery projectiles. The basic strategy was to fill a cylindrical mold with solventless propellant, then add a solvent that consolidated the propellant into a single mass. The casting procedure started with the manufacture of the plastic outer shell of the propellant grain, or beaker (Plate 5.19). To manufacture the beaker, thin sheets of dampened plastic were tightly wrapped around a form creating a perfect cylinder. The beaker was then placed on the base plate of the mold and the mandrel needed to form the core of the propellant grain was inserted. The core defined the internal configuration of the propellant casting and regulated the rate of burn as only the surface of the grain burned during flight. The top plate was placed next and an outer mold bolted around the beaker (US Army n.d.b.).

The completed mold was then moved to the casting area where the beaker was filled with propellant. A process called “evacuation” removed air from the propellant mold prior to the introduction of the solvent. The solvent used in manufacturing rocket grains arrived at the casting area in stainless steel desiccators to insure that no moisture was present, and was connected by a grounding wire to the mold (Plate 5.20). After evacuation, the solvent was forced under gas pressure into the mold (Plate 5.21). The mold then moved to a curing oven where the propellant solidified into a rubbery mass (Plate 5.22). After curing, the outer mold and end plates were removed, the mandrel pulled, and a large saw cut the grain to the desired length (Plate 5.23). The grain was later wrapped with cellulose (Plates 5.24). The grain was then inserted into the motor casing, the assembly painted, and the completed motor crated for shipping (Plate 5.25) (US Army n.d.b.).

Production of cast motors began at Radford Army Ammunition Plant in 1952, and in the first sixth months of production produced 174 JATO grains, 10 grains for the NIKE system, and 1 grain for the HONEST JOHN (Plate 5.26). The basic double-base formula could be modified by the addition of other explosive components, plasticizers, or metal powder to create variety of multi-base formulations. In addition to JATO, NIKE, and HONEST JOHN propellants, Radford would also produce grains for the SHILLALAGH, LITTLE JOHN, and the launch and flight motors for the TOW (Plate 5.27) (RFAAP 1952).

5.2.11 Multi-Base propellants

A third type of smokeless powder expanded on the concept of double-base propellants by adding a third ingredient. Multi-base propellants (referred to in some sources as triple-base) were developed during the immediate post-World War II period, and offered many advantages to single- or double-base propellants including reduced muzzle flash, increased gas production and muzzle velocities, more stability in storage, and were cooler burning propellants meaning the deflagration is less intense and there is less erosion to the gun tube (Bodeau 1993:344).

The largest component of a multi-base propellant is nitroguanidine, an explosive developed in 1877 but not used until the later years of World War II. Nitroguanidine offered equivalent explosive power to TNT, but was more stable. Additives served as plasticizers and stabilizers. After mixing, the solution was held to allow crystals to form. The crystals were filtered from the solution, rinsed to remove residual acid, then dried and stored (Department of Ordnance and Gunnery 1955).

A typical multi-base propellant was known as Cordite. Manufacture of multi-base propellants parallels that used for double base propellants. A colloid was formed, which was then pressed and extruded into grains (Department of Ordnance and Gunnery 1955).

5.3 Load, Assemble, and Pack Plants

The second major type of ammunition production installation in the current Army inventory is the load, assemble, and pack (LAP) plant. The LAP plant was used to take the propellants and explosives manufactured at P&E installations and produce completed munitions. The LAP plant performed several discrete operations to accomplish this. Metal casings were filled with propellant, projectiles and bombs were filled with explosives, and separate load lines were constructed for the production of fuzes, detonators, and boosters. Plants also had extensive magazine areas for the storage of both raw materials and finished munitions. A complete description of the manufacturing processes is detailed in *Historic Context for the World War II Ordnance Department's Government-Owned Contractor-Operated (GOCO) Industrial Facilities, 1939-1945* (Kane 1995), but a brief explanation of buildings, spatial organization, and the major steps of ammunition production is outlined here.

The basic process for producing finished munitions during the Cold War was largely unchanged from that used during World War II. Propellants were loaded into shell casings by transporting grains of powder to the upper level of a shell-filling plant, and gravity-filling the empty casing. The explosive charge of an ammunition round was created by moving raw materials to the top floor of a melt-pour building. The ingredients were mixed in steam-heated kettles to a semi-liquid consistency and poured into empty rounds. The explosive was cooled, and the booster cavity drilled. Final steps included inspection, painting, stenciling, and storage, which were completed in the shipping buildings at the end of the production lines. Although the basic process was unchanged, several significant innovations were made in automating certain aspects of the production process.

5.4 Automation in Propellant and Explosives Manufacturing

5.4.1 Introduction

Army ammunition plants operated during the Cold War era continued to use technology developed during the earlier part of the twentieth century. Although new double- and multi-base propellants were developed throughout the period, they were handled identically to their predecessors. Improvements in manufacturing technology focused on three major areas: automation and the concomitant improvements in safety, the development of processes that increased the quality of finished ammunition, and the development of propellants and explosives for guided missile systems.

Automation proved the biggest challenge to the munitions industry. Techniques to automate other manufacturing processes were not applicable to environments containing explosives. Metal parts could not come into contact with one another and produce sparks, electricity had to be used with extreme caution, and the changing nature of weapons systems could render an automated line obsolete in a short period of time. Although pneumatic tools and equipment were available, reducing the electrification hazard, an attempt to automate a TNT line at Joliet Arsenal failed as the air-powered sensors were unpredictable and prone to malfunction (OAC 1956:2.)

Some success in automation was reached in the mid-1950s. Production of 155mm shell was partially automated by U.S. Industries, Inc. resulting in a 20 percent decrease in manpower and a three-fold increase in production. Kansas Ordnance Plant installed automatic equipment for the production of M51A1 fuzes. Using five machines and 25 operators, a hand line could produce 18,500 fuzes per shift. While the automatic line only completed 16,800 fuzes per shift, the manpower requirement was reduced to 11, limiting the number of workers involved in this hazardous operation (OAC 1956:3, 4).

In 1956, it was reported that industry thinking towards automation was in the "paper stage." Contractual agreements between operators and the Army set minimum production quotas, and it was risky for a contractor to attempt automation while sacrificing capacity. Plans were developed for automatic production should new plants be constructed, but in reality few new facilities were built at Army ammunition plants, and experimentation with automatic propellant and explosive manufacture met with little success (OAC 1956:6).

5.4.2 Automation of Single-Base Propellant Manufacture

Despite these limitations, the Army and its operating contractors continued to develop methods for automation and continuous processes. In the early 1970s, Hercules Corporation, developed plans for the construction of a continuous automatic single-base propellant line (CASBL). The premise of the design was to incorporate many of the processes for the production of single-base propellant into one continuous operation, and eliminate the manual movement of material between various buildings of the existing propellant lines (Plate 5.28). The process then in use was identical to that used during World War II and required manual transport of nitrocellulose from press houses, to mix houses, to finishing press houses, and then cutting houses. After the grains were cut to proper length, tractor-pulled buggies moved the powder grains to solvent recovery houses, then to water and air dry houses, and finally to blending and packing houses (Plate 5.29). This labor- and cost-intensive process limited the capacity of a propellant line, and exposed numerous employees to explosives and chemicals at all stages of production.

CASBL was completed in 1978. In operation, the nitrocellulose slurry was prepared by conventional methods of nitrating, boiling, poaching, and drying. Continuous automated production modified the process after this point. The nitrocellulose was pumped as aqueous slurry. The slurry was then pumped to the upper level of the automated process building where two thermal dehydrators used hot air to remove residual moisture. Additional compounds were added to the nitrocellulose which was then combined in mixers to form a colloidal paste. The output from the mixers moved to extruding units where the propellant paste was formed into long propellant grains. The extruders supplied a battery of cutting units that each contained three cutting machines. After the grains were completed, the propellant was moved vertically to the top of the solvent recovery/water dry section of the complex. Here, the grains moved through parallel processing lines that each held solvent removal modules and water dry modules. Warm air was used to remove most of the solvent in the solvent removal modules, and then water was used to replace additional solvent in the water dry modules. A second building of the continuous process plant contained four lines, each made up of air dry modules. Again, warm air was used to completely dry the grains. The final steps included screening, weighing, packing and sealing containers of propellant, then palletizing the containers for shipment. The entire operation was controlled remotely with few personnel near the buildings during operation. The only labor intensive portion of the process, the final packing and shipping, was carried out in a building some distance from the process lines (US Army n.d.a.).

In concept, the design seemed sound; in reality, there were numerous problems. The nitrocellulose slurry line to the top of the building frequently plugged, stopping the flow. The nitrocellulose leading from the dehydrators was often too wet to form the necessary colloid. Extruding units and cutters jammed, and the continuous solvent removal and water dry modules often failed to prepare the grains for final drying. Additional difficulty was encountered in maintaining proper calibration of machinery as the entire building vibrated excessively during operation. A final problem was that the automatic process produced too much propellant too quickly. While this may not be viewed as a problem, the CASBL took considerable time and expense to prepare for propellant production. After running for a short time, production often exceeded that needed to fill orders, and burdened storage space of the ammunition plant. After experimenting with the system, and attempting to resolve some of the mechanical issues, it was determined that the continuous automated single-base propellant line was not cost-effective and it was shut down. In 2007, an ammunition plant makes single-base propellants using technology perfected during World War II.

5.4.3 Automation of Multi-Base Propellant Manufacture

In the 1980s, Hercules once again experimented with continuous production of propellants. During the 1980s, the continuous automated multi-base propellant line (CAMBL) was designed and constructed (Plate 5.30). When completed in 1984, the complex featured four identical buildings for the production of multi-base propellants. The process was similar to that used for the CASBL. Nitrocellulose slurry was pumped from a large holding tank to the top of the building where thermal dehydrators were located. Explosives were stored in earth-barricaded bunkers at the opposite side of the multi-base plants. Conveyors supported by wood frames moved the explosives to the upper levels of the building where they were mixed with the nitrocellulose. Mixed solvents were used to prepare a colloidal paste for final extrusion and cutting into grains. Grains fell into a trough in the first floor of the building where they were transported to a tray loading building for final solvent recovery and water drying. The continuous multi-base line met with a similar lack of success. Of the four production plants constructed in the early 1980s, only a single line was operated, and then only for a short time.

5.4.4 The Single Pour Controlled Cooling Process

The Silas Mason Company (later the Mason & Hanger – Silas Mason Company) became well known for innovative approaches to ammunition production. One of the first improvements the company initiated was known as the Single Pour Controlled Cooling (SPCC) process. Older processes of pouring liquid high explosives into projectiles called for the filled shell to be moved to another portion of the assembly line and cooled at room temperature. This temperature varied considerably from plant to plant and even seasonally at the same location. If the explosive cooled too quickly or slowly, the uniformity of composition would vary. This could lead to the rejection of entire lots of ammunition and the expensive and time-consuming process of removing the hardened explosive, reconditioning the casing, and re-pouring. The SPCC process included three key steps. First, the explosive mix was heated in a vacuum melting kettle. This removed any air trapped in the mix and resulted in uniform explosive density throughout the casting. The second step incorporated a continuous crystallizer to flake and heat TNT prior to its addition to the mix at the pouring stage (Rothstein 1955:33-44).

The third, and key, component of the SPCC was the controlled conditioning of the loaded shells after pouring. This was accomplished with a lengthy steel tank partially filled with tepid water and specially designed radiant heating elements near the top. After shells were automatically filled with a volumetric loader, a skid holding nine projectiles was placed on a wheeled cart and inserted into the conditioning oven (Plates 5.31 and 5.32). A conveyor mechanism moved the cart down the length of the conditioning oven. The water temperature was maintained, and hot water circulated through the radiant elements at a constant temperature. This heating technique allowed the molten explosive to evenly cool (Plate 5.33). The tepid water aided in solidifying the thicker base of the projectile (the bourrellet) while the radiant elements prevented the thinner neck (or ogive) of the shell from crusting over. The cast shells remained in the conditioning oven for a period, and were then allowed to cool afterward with no heat. The pouring funnels remained in place throughout the cooling process, and were then removed with a hydraulic puller. This left an almost perfect cavity in the neck of the shell that needed only moderate cleanup to create the fuze well (Rothstein 1955:41-48).

The SPCC process offered considerable savings. At the time it was developed, the industry standard for producing 155mm shells was 8,000 rounds per shift. The use of the deep funnel, and leaving it in place during conditioning, eliminated the tasks of probing and multiple pours. This typically required 26 people per shift that could be assigned to other duties. The SPCC Process resulted in many other benefits. The fuze cavity created when the funnels were removed replaced the deep cavity drilling operation; shell cooling was reduced by approximately 40 percent; the level of automation required lower levels of employee training; the reliability of the process reduced X-ray requirements; fewer lots of ammunition were subject to re-pouring; and the operation required fewer people, leading to reduced exposure to high explosives. Additionally, the process could be used for TNT, Composition B, or any of the multi-based high explosives by adjusting the temperature of the water bath and radiant heaters (Holmes 1955:2-3).

The SPCC process was experimentally tested in 1950 for the loading of 3.5” rockets. During the first half of 1956, a single plant produced 15,000 TNT loaded 155mm shells; 2,000 Composition B loaded 155mm shells; and several hundred 75mm and 105mm shaped charge loads using the process. Only 10 rounds failed radiographic testing. Many of these rounds were produced for Picatinny Arsenal and Aberdeen Proving Ground where the ammunition was tested for ballistic quality and explosive density; all surpassed established standards (US Army 1956a:33-34).

The SPCC was continually used for pilot production through the remaining months of 1956. The process was adaptable to a wide range of munitions including 8” howitzer rounds, 75mm HEAT (high-explosive anti-tank) rounds; and 105mm rounds filled with Cyclotol. It proved so successful that production scale equipment was installed in Line 3A in anticipation of loading 8” shells. The versatility and dependability of the SPCC process prompted the Complete Round Sub-Committee to the Integration Committee on Ammunition Loading to reach a unanimous resolution at its September 1956 meeting as follows:

> It is recommended that [automation] for 8” projectile be adopted for new facilities in its entirety for processing 155MM or greater caliber projectile insofar as the melt-load operations are concerned (this entails use of the melting grid, continuous crystallizer, constant level reservoir, and a volumetric loader); in its entirety insofar as controlled cooling for projectiles greater than 155MM are concerned: and optionally insofar as controlled cooling of the 155MM is concerned (in addition to the melt-pour equipment this entails use of the underground conditioning oven), dependent upon comparative savings involved at the time of construction of a new facility (US Army 1956b:70-71).

The SPCC process made significant improvements in efficiency, quality, and safety, but it also had broad applicability to multiple plants. The equipment could be added to any load, assemble, pack plant with minor modifications. Existing buildings were well suited to house the machinery, and the vacuum melt pour kettles were easily installed in the same location as World War II-vintage gravity kettles.

5.4.5 Automated Fuze and Detonator Loader

Safety was always a key factor in the operation of an ammunition plant, and one process in particular required extreme caution. The highly sensitive explosive materials used in primers and detonators led to numerous hand and finger injuries (Lemert 1979:200). To minimize the dangers of manufacturing primers, fuzes, and detonators, Mason & Hanger, developed the Automated Fuze and Detonator Loader (Plate 5.34):

> A completely modern detonator and primer loading machine, featuring a unique modular concept making possible rapid change-over for production of various items, as well as a new powder guidance system and simplified memory system. All above table movement is accomplished with a precision rotary machine chassis capable of close indexing tolerances and equipped with a special design power-assisted reciprocating center column (US Army 1970).

A prototype loader was installed in 1970 for the production of M55 Detonators. In March 1971, two additional Loaders, were installed and were in operation two months later. The capacity of the Automated Fuze and Detonator Loader was 168 units/minute; it was later estimated that 1.6 million detonators per month could be produced with the new loaders (US Army 1971:19-20).

5.4.6 Improved Conventional Munitions

In 1975, after 28 years of operations, the Atomic Energy Commission (AEC) shifted it's base of operation. The previous production facility, known as Line 1, began producing components for nuclear weapons in 1947 and numerous modifications to the production plant occurred during AEC operation (a complete discussion of Line 1 is included in section 5.7.2.3). The phase out of operations was completed on 30 June 1975 and a one-year schedule for returning control of all the Line 1 facilities to the Army was created. The Army agreed to accept several buildings in their current condition, but many that had served for the assembly of nuclear weapons required that the machinery be removed and the building decontaminated (US Army 1975:i). The relocation of AEC to a new ordnance plant created an interesting opportunity for the Army. Manufacturing processes for the explosive components of nuclear weapons required extreme precision. The explosive core typically was pressed to shape in hydraulic rams, and then machined to very precise tolerances. The equipment vital to this production was already in place at the new installation and the redundant machinery remained in place in Line 1. Prior to the closure of the AEC operation at Line 1, the Army was reluctant to invest in the facilities to manufacture weapons with the newly-created high-energy, PBX; however, the windfall of hardware provided by the closure of the AEC plant allowed the Army to issue one of its first contracts for the production of improved conventional munitions (ICMs) to the Silas Mason-Mason & Hanger Co., Inc. (Lemert 1979:210).

Feasibility testing for ICMs began in 1972 using comparative studies of Dragon missile warheads produced by three methods: traditional melt-cast using Octol as the explosive; hydrostatic pressing and machining using PBX-9011 as the explosive; and mechanical pressing of a charge of PBX-9011 to finished dimensions. The hydrostatic method involved placing explosive powder in a rubber sack of approximately the same shape as the final product. The pressings were then placed in a bag of water and placed in a pressure vessel. The outer surface was then machined to final dimensions. The preferred method was to prepare a molding die and ram of precise shape and compressing the explosive powder using a hydraulic press. When the three warhead types were tested, the PBX loaded projectiles provided more energy to the target than the Octol loaded projectiles. The cost in both man hours and material was significantly lower for the pressed rounds over the traditional cast-melt process; however, the high cost of new machinery for press-loading ammunition became a significant obstacle (Polson 1974:2-9).

The return of Line 1 to Army control afforded great flexibility in munitions production. The AEC had invested millions of dollars while it controlled the production line. The ability to both cast and press explosives allowed for the production of a variety of weapons including the most advanced guided missile warheads and mines. By 1976, the plant was manufacturing VIPER and HELLFIRE missiles on Line 1. Production of the Dragon, Hawk, and TOW warheads was moved from other locations to Line 1 (US Army 1976:4, 14). New equipment for conditioning the TOW and Dragon warheads was installed in Line 1. The conditioning equipment included an automated system of heating, vibrating, and then cooling the warheads. All operations were controlled by a "state-of-the-art" computer (US Army 1976:14). The Data General Nova 1210 computer was advanced for its day with 32K of main memory and a 256K drum storage (US Army 1980:6)

5.5 Facilities at Army Ammunition Plants

5.5.1 Introduction

Generally, existing buildings were modified to meet the needs of changing technology during the Cold War era. Following the success of automated manufacturing during World War II, the use of mechanization increased during the Cold War although attempts at total automation of production lines met with limited success. Advocates cited such benefits as increased productivity, greater manufacturing precision, increased adaptability, and a reduced need for human labor (Kane 1995:178). Meanwhile, some plants retained World War II-era appearances and processes well into the Cold War. The shell forging machinery setup at Twin Cities AAP, shell manufacturing technology at St. Louis AAP, and small arms ammunition production technology at Lake City AAP all exhibited little alteration from the 1940s to the 1980s (Kane 1995:180).

5.5.2 Propellant and Explosives Plants

The buildings constructed for propellant and explosives production were utilitarian in design with little ornamentation. Construction techniques varied from buildings with concrete skeletons and brick or tile curtain walls, to wood frame buildings sheathed in a corrugated material known as Transite. Most buildings were constructed with at least one wall made with lightweight materials that would explode outward, away from other buildings, in the event of an accident. To minimize the distance between inter-related buildings of a manufacturing line, earth-filled or concrete barricades were used. Most plants contained more than one production line. Redundancy in production facilities allowed for production to continue in the event a building was damaged due to an explosion, or to increase production if needed.

A typical explosives and propellants plant is shown in Plate 5.35. This particular ammunition plant is a World War II era ordnance works designed by the Hercules Powder Company and constructed by the firm of Mason & Hanger. The ammunition plant was conceived as a propellant plant with six parallel lines; however, a disastrous explosion in a similar plant forced a re-design of the installation. Only three propellant lines were eventually constructed at the plant. While it was originally conceived as a major manufacturer of single-base propellants, by June 1941 the plant had expanded to include two nitroglycerin lines, a TNT line, a pentolite area, and areas for the manufacture of both solvent and solventless double-base, rolled powder. In addition to the buildings directly related to production, the plant contained a power house and steam plant, and acid manufacturing area, administrative offices, maintenance buildings and warehouses, a motor pool, a barracks area for the guard detachment, and housing for single employees (Plate 5.36).

The buildings used in the production of explosives and propellants were separated for safety reasons. Many of the solvent-recovery and air-drying buildings were surrounded by barricades, allowing less distance between buildings than was normally acceptable within safety standards. This separation prevented the construction of extensive conveyance systems that interconnected the process buildings. While the slurry mix of nitrocellulose was pumped from building to building, after the mix was pressed into blocks, much of the movement was undertaken by hand. "Blocking buggies" were used to take completed blocks to the final press and cutting buildings (Plate 5.37). After the grains were extruded, buggies were loaded and pulled behind small tractors to the solvent recovery and drying areas (Plate 5.38) (US Army Real Property Office 2007).

New construction at propellant or explosive works followed early precedent. Buildings constructed or modified for nitration of cotton linters used a steel skeleton with brick walls. Acid plant structures also used a steel skeleton, but frame walls covered with Transite. Tub houses followed "typical mill construction" with heavy wooden columns and trusses enclosed by frame walls (US Army 1945:59). Brick firewalls extended above the roofline and face of the building. Buildings with a higher potential for explosion were broken into four types. Type I buildings, such as final mix houses and press houses, used concrete end and rear walls with Transite-covered frame construction for the front wall. Interior concrete walls defined the process bays and the concrete extended above the roofline and front of the building. Type II buildings, used for air drying or solvent recovery, were constructed with concrete end walls and side walls filled with monolithic gypsum. The outer wall sheathing was Transite on both the interior and exterior. Type III buildings, the glaze and blend houses, used studs covered with Transite, and all floors were covered with conductive rubber. The final type, Type IV, were the rest houses. These were also frame buildings with fire resistant wall sheathing and conductive coatings. Types II, III, and IV were surrounded by Repauno-type barricades; a wooden framework that extended from grade to the eaves of the building that was backfilled with earth (Plate 5.39) (US Army 1945:57-64).

Few new buildings were constructed at Army controlled P&E installations during the Cold War era. Frequent modifications did take place, however. When constructed, many P&E plants used wooden tanks for the initial nitration. These were later replaced with steel tanks. Sophisticated, stainless steel centrifuges were installed to aid in removing excess water and acid from the raw nitrocellulose (Plate 5.40). Other modifications included the replacement of windows and doors, enhanced vapor recovery systems, and the reconstruction of acid production and handling facilities.

5.5.3 Load, Assemble, Pack Plants

The majority of buildings at current LAP plants also date from World War II. Buildings directly used in the ammunition loading process incorporated a concrete skeleton for the primary structural system and a curtain wall of clay tiles to enclose the building (Plate 5.41). The interior of the buildings contained operations bays constructed of reinforced concrete. The ends of the bays were open to direct any accidental blast toward the tile walls, which were designed to collapse in the event of an explosion (Plate 5.42). Corridors ran the length of the buildings and afforded access to the operations bays and an avenue for the movement of raw materials and finished munitions. Numerous doors were present to provide quick egress should an emergency arise. The munitions buildings terminated in gable roofs with glazed monitors. Windows in the monitors allowed for increased light and ventilation. The roofs were universally covered with corrugated asbestos sheathing.

The individual load lines for large and medium caliber projectiles were composed of numerous buildings that were widely separated for safety reasons. Additional protection was provided by earthen or concrete barricades (Plate 5.43). The central building or buildings of the line were the melt-pour houses (Plate 5.44). These three story structures held conveyors or elevators for movement of explosives to the upper levels where combinations of explosives were mixed and melted in steam-heated kettles. The liquid explosive was gravity fed to the first level where projectiles were filled. Finished rounds were moved to other areas of the building for cooling, after which the detonator cavity was drilled. Generally, drilling operations took place in a separate building. At either end of the load line were shipping/receiving buildings (Plate 5.45). One end of the line received inert materials such as projectile casings, while the companion building at the opposite end of the line received finished ammunition from the melt-pour process. The final step in the manufacturing process was the painting and stenciling of the finished round. Completed ammunition was either immediately loaded for shipment off the installation, or moved to one of the storage yards.

One side of the load line was reserved for incoming shipments of explosive with the opposite side containing the administrative and support buildings. The explosive side of the load line contained numerous ready magazines where explosives were off-loaded from railcars or trucks. The ready magazines held enough material for a single shift of production. The raw materials then were moved to the melt-pour houses for mixing. An administration building and steam generating/air compressor building were generally associated with each load line (Plate 5.46). Other miscellaneous buildings included a paint storage and mixing building, a maintenance shop, a shell sectionalizing building, earth-covered reinforced concrete bombproofs, change houses, and entrance gate houses. Typical buildings constructed on a load line are listed in Table 5.2 (US Army 1943:13).

Load lines designed for fuzes and detonators were considerably smaller than their large-caliber counterparts. Similar to the melt-pour lines, fuze and detonator lines contained numerous buildings. Processes such as the pressing of igniter pellets or the manual assembly of the product took place within these lines. The extreme volatility of some of the materials used in manufacturing percussion fuzes, such as lead azide or fulminate of mercury, required special handling of these high explosives and were performed in a separate set of buildings oftentimes referred to as the back lines. In buildings where sensitive high explosives were handled, designs included heavy concrete construction with blast walls frequently extending above the roof lines (Plate 5.47). Specialty cells with remotely operated equipment were designed to prepare high explosives for use in fuzes and detonators (Plate 5.48). Blow-out walls usually were incorporated into the designs. One element of fuze and detonator manufacture was the final testing of the finished product. This testing accomplished two purposes: to determine if the component functioned as designed and to insure that it was not too sensitive, making it overly hazardous to transport (Plates 5.49 and 5.50). Ready magazines for fuze and detonator lines were quite small with lead coated floors to eliminate any risk of static electricity. Another aspect of the fuze and detonator assembly process was the preparation of the metal components. Large buildings containing equipment for the polishing and deburring of metal parts were an integral component of the manufacturing process (Plate 5.51).

In addition to those buildings related directly to explosives production, ammunition plants contained numerous support buildings. Machine shops, vehicle maintenance facilities, and administration buildings comprised the largest group; however, the quality of the ammunition was of paramount concern. To insure that every item that left an ammunition plant would function effectively and safely, laboratories and test facilities were constructed at most Army ammunition plants. Categorized as quality assurance/quality control buildings (QA/QC), these facilities included laboratories for testing raw materials, and facilities for inspecting finished materiel. Raw materials were examined to insure that the proper mixtures were used in manufacturing explosives and propellants, or to measure the burning characteristics of finished products. Quality of finished munitions was also insured by both destructive and non-destructive methods. Finished rounds were tested at proving grounds, X-rayed to determine flaws in the casting, or cut in half for visual inspection.

Table 5.2 Buildings Constructed on Typical Load Line (US Army 1943)

Building and Use	Dimensions in Feet
Inert Storage	52 x 501
Receiving and Painting	66 x 341
Melt Loading	66 x 129 and 60 x 80
Melt Loading	66 x 129 and 60 x 80
TNT Screening	46 x 57
TNT storage	36 x 40
TNT storage	36 x 40
Ammonium Nitrate Storage	36 x 40
Ammonium Nitrate Storage	36 x 40
Drilling and Boostering	66 x 357
Booster Storage	28 x 32
Assembly and Packing	66 x 416
Fuze Storage	28 x 32
Propellant Charge	106 x 389
Primer Storage	28 x 32
Smokeless Powder Storage	66 x 136
Shipping	56 x 66
Office	31 x 61

Storage of finished ammunition and raw materials was accomplished in a complex of earth-covered and above-ground magazines. Large and small caliber finished ammunition produced on a load line were typically stored in above-ground magazines (Plate 5.52). Each magazine encompassed approximately 12,000 square feet, was constructed of clay tile, and was covered by a side-gable roof sheathed in corrugated asbestos. Smokeless powder, ammonium nitrate, and TNT were stored in earth-covered magazines. Smaller earth-covered magazines were used for sensitive explosives used in fuze and detonator manufacture such as black powder, lead azide, or tetryl. Hillside magazines, sometimes called frost-proof magazines, were used for lead azide, a powerful and very sensitive explosive that was stored in water-filled earthen crocks (Plate 5.53) (US Army 1943:1). Construction drawings for these magazines indicate they were constructed with thick, metal clad "ice box" doors.

The buildings of a load line, whether large-caliber, medium-caliber, or fuze and detonator, were connected with a system of enclosed passageways. Referred to as ramps, these passageways allowed for the movement of materials and finished products throughout the line without concerns about weather. Many of the ramps contained conveyor belts while others served as walkways (Plate 5.54). Ramps completed during the initial construction phase at many plants, were constructed with steel frames and roof trusses covered by corrugated asbestos panels (Plate 5.55). Due to material shortages during World War II, ramps constructed after 1942 used frame walls and gable roofs covered with asbestos shingles (Plate 5.56). All the ramps were constructed on concrete foundations and efforts were made to minimize grade changes using concrete piers to support the ramps over low spots or depressions.

Although few new buildings were constructed at load, assemble, pack plants following World War II, numerous modifications were made. The windows of the monitor roofs at many installations were removed and the walls clad in aluminum or vinyl siding. Wood siding was removed and replaced with synthetic materials. Expansive areas of glazing on machine shops and maintenance buildings were removed and the openings covered with new siding. Renovations often included the installation of exterior insulation and finishing systems over the original tile walls. (Plate 5.57) Insulation was installed in several ramps, and deteriorated passageways were replaced with steel framing covered with metal siding. The introduction of electric forklifts rendered the conveyor belts obsolete, and all were removed. Frame or tile change houses and cafeterias were demolished and new buildings were constructed (Plate 5.58). Changes in methods of transportation, from a system that shipped the bulk of material by rail to one based on trucks, prompted modifications to shipping and receiving facilities (Plate 5.59). The introduction of new, more powerful explosives led to the construction of additions to many of the ready magazines.

5.5.4 Other Facilities at Propellant and Explosives Plants

Propellant and explosives plants manufactured a variety of materials; few produced only a single product. In addition to explosives and propellants, some of the raw materials needed in the production process were manufactured at ordnance works. Explosives and propellant plants also contained equipment to recycle many of the materials used during production (Plate 5.60). Extensive vapor recovery systems connected buildings where solvents were used to a distillation plant. Dilute acids were also recovered from nitration processes and stored for re-use, or for sale to private industry.

5.6 Modernization of the Military Industrial Base

5.6.1 Reasons for Modernization

During the Vietnam conflict, outdated facilities constructed during World War II and the Korean conflict created mobilization delays (Williams 1978:5). In 1968, the Army received $237.9 million to modernize plants in all categories of GOCO facilities, and planned a modernization program over the following five years that anticipated total funding of $2.2 billion spread throughout the period (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:21).

A 1968 report that examined modernization of facilities stated that GOCO plants were plagued with "obsolete processes and equipment," including equipment dating from as far back as 1939 and 1940, and "provide[d] relatively low operating efficiency when related to the current state-of-the-art" (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:6). As a result, the government faced high costs in maintenance, personnel, and materials handling. For example, replacement parts were difficult to obtain because the equipment was outdated and no longer manufactured. Other negative effects were seen in product quality, production efficiency, safety, and pollution (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:6).

The report identified several benefits to modernizing facilities by installing modern construction materials. Costs of keeping plants in standby status and reactivating them would drop by as much as 50 percent in some cases; personnel costs would be reduced by as much as 60 percent because fewer workers would be needed; and lead time to full operation would be reduced. Although details are not provided on every facet of plant modernization, a cost comparison between old and new nitric plants at Joliet Army Ammunition Plant illustrated the savings (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:7).

Due to the corrosive nature of acid, mild steel could not be used and the production process relied on vitrified clay pipe, and terra cotta or glass lined vessels. Temperature fluctuations resulted in damage to these brittle materials. After three or four years of operation, an acid plant required extensive maintenance. During World War II demobilization, the nitrating towers at one plant were "dismantled because it was believed that they would disintegrate if left standing" (US Army 1945:1398). This made timely reactivation of the installation problematic.

The ready availability of steel alloys during the Cold War era, especially corrosion-resistant stainless steel, provided an opportunity to construct acid plants that would function for a longer period of time with reduced maintenance costs. At Joliet, it was estimated that a single, 300-ton per day unit could replace six, 50-ton per day of the older design. The investment cost in the new design was approximately half that of the old, and required only two operating employees per shift opposed to four. Maintenance costs per ton of acid produced dropped from $1.89 to $1.03, and the total cost to produce a ton of acid declined from $33.90 to roughly $24.00. An additional benefit was a thirty-fold reduction in air pollution. With annual savings of nearly $4 million per year, it was estimated that the investment in new technology would pay for itself in less than two years (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:24-27).

Volunteer Army Ammunition Plant was one installation extensively modernized during the late 1960s and early 1970s. When the plant was reactivated in 1965 for production during the Vietnam Conflict, ten TNT lines were rehabilitated with initial production in 1966. Between 1970 and 1972, four of these lines were demolished and six new continuous process TNT lines were constructed. For the ten years the plant operated during the Vietnam era (1965 to 1975), 117 new buildings were constructed (MacDonald and Mack 1984b:32)

A more comprehensive modernization program called the Munitions Production Base Modernization and Expansion Program (MPBME) was inaugurated during fiscal year 1974. It was described as "a comprehensive engineering and construction program that uses the technology and resources of the materials handling, machine tool, chemical processing, computer, and construction materials industries … to completely overhaul and modernize ammunition production facilities" (NARA RG 544 Cholish 1978:3). The purpose was "to improve the industrial readiness of the ammunition production base to the point it can support the materiel requirements of the United States and selected allied armed forces in combat and with the desired responsiveness" (NARA RG 544 Cholish 1978:2).

According to one annual report for the program, an Army-wide overhaul was needed because the facilities had an extensive history of insufficient management. During the late 1950s, facilities constructed during World War II and the Korean conflict had not been adequately maintained as the majority of ammunition funding was directed to the construction of facilities producing munitions for nuclear deterrence, with little focus on conventional war. During the Vietnam era, the Army focused on acquiring only those items vital to maintaining wartime production levels. These items included the limited acquisition of modern facilities, new ammunition items, and the replacement of totally unserviceable facilities and equipment. As a result, the facilities were comprehensively obsolete, the number of workers capable of operating the equipment was declining, and new equipment was not available. (NARA RG 544 Cholish 1978:3-4).

<u>5.6.2 Alterations to Existing Facilities</u>

The 1968 report outlined modernization objectives for four types of GOCO facilities, and described alterations already made:

- Load-assemble-pack: Replace worn out equipment with new equipment of the same type or with updated equipment. Automate lines where practical for improved safety and lower production costs. Automated lines were installed at the following locations: Joliet AAP's 40-mm assembly line; Kansas AAP's CBU 24 and CBU 29 bomb loading line; and Lone Star AAP's M557 fuze assembly line. In addition, a portion of Louisiana AAP's load-assemble-pack facility was automated (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:8, 10).

- Propellant: Replace or update single-base, double-base, and triple-base facilities for maximum automation and improved safety, increased operating efficiency, and decreased pollution. Radford AAP received approval for construction of three modern continuous nitration process TNT lines (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:8, 14).

- Explosive: Implement continuous operations and install equipment that minimizes maintenance costs. Use the latest manufacturing processes to increase safety and efficiency and reduce pollution. Newport AAP received approval to install five continuous process TNT lines, and Holston AAP received funding for Composition B facilities (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:8, 16).

- Metal parts: Update equipment and processes in the 105-mm, 155-mm, 175-mm, 8-inch, and mortar projectiles lines, particularly in the hot forge and cold extrusion areas. New equipment should be "versatile and capable of producing the new generation item with a change in tooling." Automate material handling where possible. Gateway AAP installed "the only truly modern automated shell facility in the industry for production of 175-mm shell." St. Louis AAP received funding to update its forge facility and modernize equipment (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:8, 18).

Modernization was occurring at smaller categories of GOCO ammunition plants. Longhorn AAP, a pyrotechnics plant, installed an assembly line for the button bomb that automatically filled and sealed the casing. This process removed many of the production workers from the bomb assembly area, providing greater safety in the event of an accident and reduced personnel exposure to the toxic fumes of explosives. Modernization was not limited to the assembly or production processes. Support facilities were also upgraded including the installation of a modern tool fabrication facility to support mass production of small arms production at Twin Cities AAP (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:6, 12).

The later modernization program pursued more comprehensive changes. For example, modernization projects in various stages during fiscal year 1977 included: 14 modernization projects at explosives facilities; construction of facilities at three propellant plants; 87 projects at load-assemble-pack plants; and 15 projects at metal parts plants. Specific projects included: construction of a 500,000 lbs/month black powder plant at Indiana AAP, the first black powder plant built at a GOCO installation; and construction of a nitroguanidine plant at Sunflower AAP, the first such facility built in the United States (NARA RG 544 Cholish 1978:43, 44, 46, 63-110). This was a long-term process, as completion of the this modernization program was not expected until the 1990s (Williams 1978:xi).

A 1978 report that included a discussion of facility modernization identified other modernization-related improvements: new, technologically advanced acid production facilities; updated forging and heat treating facilities at metal parts plants; continuous melt-pour facilities for TNT, Composition B, and other high explosives; an automated fuze production base; new fuze designs that eliminated reliance on foreign manufacturers; and examination of the need for updated technology to manage the facilities during active and layaway periods (Williams 1978:xii-xiii). During the late 1970s, experts focused on ways to protect the plants' technological and computer systems during layaway and ways to shorten reactivation time for these systems (Williams 1978:12).

5.6.3 Need for New Facilities

The majority of the plants in the Cold War ammunition production base were constructed just before or during World War II. Of 27 facilities extant in 1982 – 16 active and 11 inactive – only two first began producing ammunition during the Korean conflict. Riverbank AAP originally was built during World War I as an aluminum plant, but did not start producing ammunition until 1952. Scranton AAP was established in 1952 from the remodeled Delaware, Lackawanna, & Western Railroad shops, and produced shell metal parts (Department of the Army 1982:49-58).

By the 1980s, the Army identified age-related problems with the ammunition production base. Eighty-seven percent of the base was more than 20 years old, with obsolete equipment that received minimal maintenance and funding during periods when facilities were placed on standby status (Department of the Army 1982:21). Plans for future construction included single- and multi-base propellant plants (Williams 1978:xii).

In 1982, Mississippi AAP, the first ammunition plant built in more than 25 years, began production. The facility was built in Bay St. Louis, on the northern portion of the NASA National Space Technology Laboratories facility, and operated by Mason-Chamberlain, Inc. The facility's mission was "integrated production" of the M483A1 155-mm ICM projectile, consisting of manufacture of the projectile metal part; the cargo metal parts; and loading, assembling, and packing the finished ammunition. This was the first time that a single plant handled all aspects of finishing ammunition rounds. Historically, the metal components were manufactured elsewhere and shipped to the load, assemble, and pack installation. Concentrating all facets of large caliber ammunition production at a single location reduced costs (primarily shipping) and increased efficiency. The plant was divided into discrete areas to serve the three aspects of the mission. The plant incorporated the most sophisticated methods and manufacturing technology of its day and was designed to produce 120,000 rounds per month (Department of the Army 1982:49).

The construction of the Mississippi Army Ammunition Plant demonstrated the Army's desire to centralize and streamline ammunition manufacture. The Scranton Army Ammunition Plant is an example of a decentralized manufacturing installation. During mobilization for the Korean Conflict, the Army sought a new installation for the production of large-caliber artillery shells. Rather than construct an entirely new ammunition plant, the Ordnance Corps acquired a 15 acre site near downtown Scranton for a new metal parts fabrication plant. The buildings selected once served as the steam locomotive shops for the Delaware, Lackawanna, and Western Railroad, and were constructed in the first decade of the twentieth century. Approximately 4,000 new pieces of machinery were installed with only minor alterations to the existing buildings. The Scranton works were designed to produce 8", 115 mm, and 175 mm projectiles. The finished product was shipped to the load, assemble, pack plants where they were filled with explosives and readied for use (MacDonald and Mack 1984d:35-37).

5.7 Engineering Design, Operations, and New Construction at Army Ammunition Plants

5.7.1 The Immediate Post-World War II Period

The surrender of Japan in September 1945 officially ended World War II and the Ordnance Department quickly issued orders to stop ammunition orders and shut down production at all Army ammunition plants. Many plants operated on a limited basis to complete production runs and consume materiel on hand, but by early 1946, virtually all production of new ammunition ceased, and efforts turned to the long-term storage, surveillance, renovation and demilitarization of the vast quantities of munitions currently in storage. Most plants reverted to government-owned government-operated status with the U.S. Army Corps of Engineers overseeing storage activities and the decontamination of production equipment and buildings.

Local economies were severely impacted with the end of ammunition production. The boomtown effect of the massive influx of people to an area, both for the construction of the plants and operations reversed itself. The relative prosperity brought to some communities by the proximity to the ammunition plant was now countered by lost employment, the closure of businesses, and underutilized housing stocks. Employment at the Radford Army Ammunition Plant in Virginia dropped from 9,412 during August 1945 to only 98 by February of the following year (RFAAP 1953:14). A similar situation took place in southeastern Iowa. Peak wartime employment at the Iowa Army Ammunition Plant stood at over 12,000 persons. The end of hostilities saw employment drop to 227, and by June 1946, the operating contractor employed only 14 people (IAAAP 1946:32).

In early 1946, some plants were reactivated for a short time to produce large quantities of ammonium nitrate fertilizer to aid Germany and Japan in reestablishing their agricultural industries. Private suppliers were unable to provide the needed amounts, and the Chief of Ordnance ordered 13 plants in standby condition activated for the purpose. Several plants constructed during World War II contained the equipment necessary to manufacture ammonium nitrate; due to a shortage of TNT in the early years of the war, the U.S. developed a procedure to stretch TNT by mixing it with ammonium nitrate to produce the explosive amatol. Three ordnance works—Ohio, Morgantown, and Cactus—produced anhydrous ammonia. Aqueous ammonia and ammonium nitrate liquor were produced from the anhydrous gas at Indiana Ordnance Works, Sunflower Ordnance Plant, Radford Ordnance Works, and Joliet Arsenal. The liquid ammonium nitrate was then shipped to six ammunition plants for conversion into fertilizer grade ammonium nitrate: Cornhusker, Nebraska, Iowa, Wolf Creek, Ravenna, and Illinois. The estimated production was 85,000 tons per month (IAAAP 1950:1.1).

Only limited portions of a plant were needed for the manufacture of fertilizer components, but existing buildings required renovation and some new facilities were needed. At Radford Army Ammunition Plant, for example, the H.K. Ferguson Company of Cleveland, Ohio was awarded a contract covering renovations and additions to three existing buildings and the construction of two new facilities. The new construction included a neutralization building and five ammonia storage tanks. This contract also included renovations to non-manufacturing buildings such as offices and utilities. The total cost to prepare the plant for fertilizer manufacture was slightly over $491,000. Hercules Powder Company was awarded the operations contract for the fertilizer facility (RFAAP 1953:29).

During operation, Radford used existing facilities including a 25 by 200 foot warehouse and a smaller storage building measuring 20 by 40 feet. The production of ammonium nitrate liquor was completed using thirteen ammonia storage tanks, three ammonia burning tanks where the aqueous solution was nitrated, two ammonium nitrate storage tanks, and five scale tanks. Estimated production of the plant was 12,000 tons per month, and it would take 300 employees to run the operation (RFAAP 1953: 21-23; RFAAP 1948). Production began in December 1946 with the manufacture of 2,801 tons of nitric acid and 3,317 tons of ammonium nitrate liquor. The plant only produced nitric acid during December 1946 and January 1947, which provided sufficient stock for continued liquor production for the remainder of the process. Peak production was achieved in July 1947 when 13,086 tons of liquor was made. On the last day of production, 16 April 1949, only two ammonium nitrate storage tanks were in use. During its period of operation, Radford shipped over

291,000 tons of ammonium nitrate liquor. The plant cost $5,097,900 to operate with almost half this amount attributed to shipping. Hercules received a fee of $224,585.66 for its role in operating the installation (RFAAP 1949).

The ammonium nitrate liquor was then shipped by rail tank-car to one of the six plants activated for fertilizer production. An experienced producer of fertilizer, the Spencer Chemical Company, received the contract to operate several of the plants, and created the Emergency Export Corporation for the sole purpose of producing anhydrous ammonia and grained ammonium nitrate. The job of reactivating the plants was under the control of the U.S. Army Corps of Engineers from drawings supplied by the Spencer Chemical Company (IAAAP 1950:1.3).

A cost-plus-fixed-fee contract was entered into between the United States and the Emergency Export Corporation on 26 June 1946 for the operation of the Iowa Ordnance Plant Nitrate Area. Reactivation began during September 1946, and on 21 October 1946, H.V. Hood was hired as Plant Superintendent for the Iowa Ordnance Plant. The plant was ready to produce fertilizer on a limited basis during January 1947. The location of the facility in Iowa proved to have advantageous freight rates for both incoming ammonia solutions and for transporting the finished product to Gulf Coast ports. In March 1947 equipment from Cornhusker was relocated to Iowa. This increased capacity from 8,000 tons per month to 12,000 (Plate 5.61). In December of 1947, this figure was exceeded when the Iowa plant produced 12,289 tons of fertilizer (IAAAP 1950:2.1-2.4).

The contract with the Emergency Export Corporation was terminated at 11:59 p.m. on 22 January 1950. Decontamination of the Iowa plant included the conversion of all on-hand solution into grained fertilizer. This work was completed by 9 February 1950 and the plant was decontaminated by 15 April 1950. During the three years the plant was in operation, it produced 358,852 tons of fertilizer (IAAAP 1950:2.8, 2.10).

With the exception of those buildings needed for fertilizer manufacture, construction of new ammunition production facilities dropped precipitously between the end of World War II and 1951. Much of the activity in the immediate post-war period occurred at a single plant. At least 18 buildings were constructed to support the conversion of a production line for use by the Atomic Energy Commission. Of these new buildings, 14 were ramps connecting World War II era production facilities to each other and two of the new structures were constructed to support explosive testing at the firing site. In addition to the new buildings directly related to ammunition production, several new ready magazines were constructed at the plant during the same time period (US Army Real Property Inventory 2007).

5.7.2 The 1950s

5.7.2.1 Construction During the Korean Conflict

American involvement in the Korean Conflict prompted another period of construction for ammunition production. Although the vast reserves of ammunition in storage sufficed for the early months of the war, the development of new weapons systems and increasing levels of conflict forced the reactivation of several plants and the construction of new facilities to support advanced munitions. The most intense construction activity took place at two installations: Longhorn and Radford Army Ammunition Plants. Longhorn, a World War II era load-assemble-pack plant, became the Army’s prime center for the manufacture of solid-propellant rocket motors and pyrotechnics (Global Security 2007a).

During the Korean Conflict, the Army constructed no fewer than 36 new buildings at Longhorn; 31 were for the manufacture of pyrotechnic munitions. Although the actual number of new buildings was high, the facilities were relatively small in size. All the buildings were less than 10,000 square feet, with only four exceeding 5,000 square feet in area. Fourteen of the buildings measured between 2,000 and 5,000 square feet with the remaining less than 2,000 square feet. Most of the new buildings were small assembly or storage buildings, and it is likely that the large load-assemble-pack buildings constructed during World War II were modified for the manufacture of new munitions (US Army Real Property Inventory 2007). This trend is similar to construction at Lone Star Army Ammunition Plant. Between 1951 and 1953, the Army erected several new buildings at this location; few were larger than 1,000 square feet and most were smaller than 500 square feet in area (US Army Real Property Inventory 2007).

At least 20 buildings were constructed at Radford between 1950 and 1953. The buildings included a small propellant loading plant and ammunition production structure in 1950, and six quality assurance/quality control buildings in 1953, one of which exceeded 8,000 square feet in size. Several large propellant manufacturing buildings were constructed at Radford in 1952 and 1953. These were built in the northern part of the plant, known as the horseshoe area, in the oxbow of the New River. The buildings were large in comparison to those constructed at other ammunition plants. Constructed in 1952 and 1953, at least two buildings were over 10,000 square feet in size. Other new buildings ranged in size from about 3,600 square feet to over 6,000 square feet (US Army Real Property Inventory 2007). The construction of these buildings supported the manufacture of large, cast propellant grains for guided missile systems (Plate 5.62). During the early 1950s, Radford produced cast propellant grains for the NIKE missiles and airplane JATO units (RFAAP 1952:8).

Buildings constructed during the Cold War era for ammunition production followed construction techniques established during World War II with minor modifications. The availability of materials that were in short supply during World War II mobilization such as reinforcing steel, allowed modifications to these basic plans. Concrete was substituted for frame walls or back-filled wooden barricades, but the location, scale, and basic form of buildings constructed at Army ammunition plants during the Cold War were virtually identical to those built during the 1940s. Generally, construction at load-assemble-pack buildings used heavy reinforced-concrete end walls to contain accidental explosions. Bays within the building, where actual melt-pour or cavity drilling operations were undertaken, were also separated by reinforced concrete walls. A concrete skeleton supported the roof of the building and frame, tile, or steel curtain walls filled the areas between posts. The walls were covered with flame-proof material, and were designed to blow outward in the event of an explosion. Smaller buildings used reinforced concrete for both walls and roofs.

Conventional ammunition production facilities followed this general concept. The structural features of a typical facility for loading artillery rounds included an exterior concrete wall on the south end of the building, and interior concrete walls dividing the building into nine bays. The remaining exterior walls were corrugated asbestos siding attached to a grid of wood framing. A second story mezzanine level contained five bays. Three walls of each mezzanine bay were cast concrete with the fourth wall constructed of asbestos siding on a wood framework. An exterior walkway provided access to escape chutes on the upper level. The building was used to load propellant into the cartridges of semi-fixed ammunition. The process included transporting the propellant to the mezzanine level and loading it into hoppers. The powder was gravity fed to the loading bays of the first floor. Primers were inserted into the cartridges of the two smaller calibers, and the empty powder bag was placed into the casing. This first step was completed in Bays E and F. The casings were moved to conveyors in Bays G and H where the shell was weighed to determine the empty weight and then filled with a prescribed amount of propellant. Scales were used to determine the weight of powder loaded into each casing. After filling, the shells were moved to Bay I where a vacuum pump evacuated air from the filled cartridges and the bags were heat sealed. Completed cartridges were stored in Bays J and K. Bay D was used for renovation of ammunition.

Old primers and powder bags were removed, and the casings were prepared for refilling. This process is virtually the same as that used during World War II.

5.7.2.2 Construction during the Post-Korea Period

The end of hostilities in Korea idled many ammunition plants and reduced operations at others. In 1954, the majority of new construction took place at Radford and Longhorn. Construction at Longhorn included a 10,000 square foot propellant plant, six quality control buildings, and five facilities for the production of pyrotechnics. Sizes for the smaller buildings ranged from only 464 square feet to slightly more than 5,000. New buildings at Radford supported the production of rocket propellants with a new, 10,000 square foot propellant plant and numerous smaller structures.

The high point of ammunition plant construction in the 1950s occurred in 1955. No fewer than 95 new buildings were constructed nationwide, but the majority of these were built at only two plants: Badger and Lake City Army ammunition plants. New construction at Badger Army Ammunition Plant included 48 buildings ranging in size from under 300 square feet to over 35,000. Over 257,000 square feet of new floor area was added to Badger in 1955. The construction methods of the new propellant plant buildings differed slightly from those used during World War II. The reinforced-concrete skeleton continued to form the main structural system of the building, but rather than construct walls of clay tile or brick, the curtain wall of the new buildings were created from glass and steel panels. The panels were laterally stabilized with diagonal straps. This method of constructing major buildings at ammunition plants was used at many installations during the Cold War era (MacDonald and Mack 1984e:29).

The construction at Badger supported the production of "ball powder," first produced in 1933, but not in widespread use until the 1950s (Shaffer and Crown 1996:102). Ball powder was the first double-based smokeless powder for use in small arms. The high velocity of this double-base powder allowed for smaller caliber weapons with high lethality, and it was less corrosive on the barrels. The combination of smaller size and the ability to employ a thinner barrel greatly reduced the weight of the weapon and ammunition with no decrease in effectiveness. Ball powder was especially suited to lead free projectiles such as steel-jacketed and fragmentation. With the completion of these new facilities, Badger produced 286 million pounds of propellant before being placed in standby status in 1958 (MacDonald and Mack 1984e:29; Global Security 2007b; Guns Magazine 2001).

Between 1952 and 1955, several new buildings were erected at Lake City to manufacture small-caliber ammunition, adding nearly 123,000 square feet of new manufacturing space (US Army Real Property Inventory 2007). The new buildings at Lake City included an indoor test range, 20mm load building, 20mm detonator building, and a 20mm fuze assembly line. Construction techniques used structural clay tile with Styrofoam and panelized metal blow-out walls (MacDonald and Mack 1984f:34-35).

While new facilities were rarely constructed, the conversion of existing facilities to new purposes was frequently undertaken. The Thiokol Corporation was actively involved in the Army's guided missile program, operating a research and production facility for solid propellant rocket motors at Redstone Arsenal. In 1955, Thiokol was awarded a contract to convert a World War II era liquid propellant facility at Longhorn Army Ammunition Plant into a facility to produce solid propellant motors. This facility, designated Plant 3, began production of NIKE-HERCULES flight motors in 1956, and later manufactured motors for the FALCON, LACROSSE, HONEST JOHN, and SERGEANT missile systems. Later in the 1950s, Thiokol constructed facilities for main rocket motor assembly and a static test stand (MacDonald and Mack 1984g:29-30; Global Security 2007a).

Few new ammunition production facilities were built in the later 1950s. Between 1956 and 1959, nine new buildings were erected in 1957 at the Iowa Army Ammunition Plant in support of Atomic Energy Commission activities, and nine were built at Redstone Arsenal to enhance research and testing of guided missile systems. The remaining facilities were smaller buildings constructed to support existing missions at Army ammunition plants (US Army Real Property Inventory 2007).

5.7.2.3 Construction for the Production of Nuclear Weapons

The exception to the generalization on construction methods and materials during the Cold War was in buildings designed and constructed to support the production of nuclear weapons. Line 1 is unique among Army controlled ammunition plants and merits additional discussion. When the AEC took control of Line 1, it planned a series of extensive modifications. The exact changes are not known as the command histories from that era contain only references to "classified" activities. The new layout for Line 1 was designed by the engineering firm of Black & Veatch of Kansas City with the construction undertaken by the Mason & Hanger Corporation (Lemert 1979:165). Work began in 1948 with renovation to Line 1 and the construction of five new ready magazines. A small production building also was erected during this first building campaign (US Army Real Property Office 2007). New ramps also were built to connect the various buildings of Line 1. The need for high precision components required frequent testing of explosives. The test firing range performed these functions and recorded the results with high-speed cameras and electronic timing devices (Lemert 1979:166). This required the construction of new facilities at the firing site in 1948 (US Army Real Property Office 2007).

Work continued on the conversion of Line 1 for the manufacture of explosive components for nuclear weapons. To insure adequate steam, hot water, and electricity for the operations, a dedicated power plant was constructed in 1949. Beginning in 1950, Line 1 began assembling atomic bombs using the explosive components manufactured there. Other elements of the bombs were supplied by outside vendors. The bombs left the plant without the nuclear core; those were inserted after the device left the plant (Lemert 1979:167).

The early bombs produced at the plant were similar to the "Fat Man" design dropped on Nagasaki. By modern standards, these atomic weapons were rudimentary and used a simple trigger to detonate the explosive. During the early 1950s, the second generation design was ready to enter production. Although using less explosive, the second generation weapons contained more individual explosive components than its predecessor (Lemert 1979:168). To accommodate the mechanical equipment needed to construct the newly-designed bomb, it became apparent that new buildings would be required. This created a problem for the AEC and operator. Buildings storing or manufacturing munitions had to maintain minimum distances between each other. These standard distances were established to prevent sympathetic explosions should the munitions in one building detonate. It was impossible to locate new buildings in the vicinity of Line 1 that met these requirements while allowing for efficient movement of material from one point in the Line to another. Another consideration was security. The entire area was classified and secured by its own fencing and guards. This was in addition to the security established for the conventional ammunition plant. Constructing new buildings in widely separated areas complicated the issue (Lemert 1979:161).

Engineers with Mason & Hanger developed a creative solution—construct the buildings so that the areas handling high explosives were completely underground (Plate 5.63). This minimized the risk of sympathetic explosions by directing the force of a blast upward. Plans were drafted in 1951 for four buildings with this characteristic. When completed, the largest building of the group, covered almost 40,000 square feet of land, nearly one acre. This building was connected to two other buildings through underground tunnels. Only one of the three had direct access to the surface (US Army n.d.c.).

The largest building was constructed of thick reinforced concrete. The underground portion of the building contained reinforced-concrete bays connected by a series of corridors. The bays did not open directly into the corridors, but were accessed from the sides through short passages. Each bay performed an operation in the production of the high explosive components and contained equipment such as jeweler's lathes, milling machines, and inspection areas. The west central portion of the building held the mechanical equipment, toilets, and offices. Steel trusses supported the waterproof membrane of the roof. Escape stairways covered by a steel hatch were located at several locations around the building. The building had two-tone green walls (the lower 48" a medium green and upper portion a light green), a semi-gloss cream ceiling, light green paint on the exposed mechanicals, and a smooth-finish red-tile floor (US Army Real Property Office 2007; US Army n.d.c.).

One of the buildings was a 72 foot by 73 foot ready magazine. Eight interior bays were designed to hold 10,000 pounds of high explosive each. A wide corridor ran down the center of the building, and side corridors led to the doors of the explosive bays. The perimeter walls of the building were thick reinforced concrete while the walls adjacent to the central corridor were also thick. Double sliding doors secured the individual bays and rolled on spark-proof trolleys. This building had only one escape stair and was painted with the same scheme as the largest in the group (US Army Real Property Office 2007; US Army n.d.c.).

Only one structure of the group had an aboveground component. This steel-framed building was clad with cement-board siding. A rail spur ran along the north wall and two large sliding doors provided access to the interior. Overhead cranes in the two interior bays were used to move components to a freight elevator centrally located in the northern portion of the building; the components were then transferred to the underground bays of the complex. The underground portion of the building was larger than the above ground component. It contained ten explosive and two maintenance rooms in the southern half. The bays were designed for 6,000 pounds of high explosives each. The arrangement of the bays was similar to the largest building with a central corridor and side passages leading to the bays. Eight of the bays had overhead cranes for handling heavy objects, and the openings were larger than those seen elsewhere. The northern half of the building held offices, mechanical equipment, and toilets. The basement level of this building had reinforced-concrete walls and partitions, as well as a reinforced-concrete ceiling. Escape stairs were placed at each corner. The building was extensively modified in the late-twentieth century with an addition that increased the aboveground portion to the same dimensions as the basement (US Army Real Property Office 2007; US Army n.d.c.).

The fourth explosives handling facility constructed in 1951 was located on the opposite side of Line 1 from the underground complex (Plate 5.64). The building was constructed of thick reinforced concrete for its basement and first level, and a metal clad frame for its mezzanine. The building was served by a rail spur and a loading dock was located at the northwest corner. Elevators at the north and south ends of the building allowed explosives to be moved to the mezzanine level. Material was then loaded into hoppers and fed to a variety of machinery on the first level where it was weighed, stored, dried, screened and blended. The basement area housed mechanical equipment and cylinders for the hydraulically powered elevators. (US Army Real Property Office 2007; US Army n.d.c.).

The final, major building constructed at the plant in 1951 was constructed as a quality-control quality-assurance facility. This two-story, reinforced concrete, flat-roofed structure housed equipment for both non-destructive and destructive examination of munitions and components. The eastern portion of the building housed two 100 K.V.A. X-ray machines. The machines were surrounded by concrete walls. A lead-shielded concrete door provided access to the X-ray rooms. Electrical links between the door and X-ray machine prevented the door from opening while the machine was in operation. Munitions entered the room via a conveyor at the rear, and two thick shields prevented the escape of significant amounts of radiation. Jib cranes in the upper portion of the X-ray room aided in the movement of heavy items. The western portion of the room held four reinforced-concrete bays. Entry was through a baffled passage. These rooms contained saws that were used to bisect munitions for visual examination. The basement level of the building contained all the support functions of the X-ray operation: dark rooms, film machines, film lockers, file rooms, toilets, and an office. The building received minor modification in the late 1980s when new X-ray equipment was installed (US Army Real Property Office 2007; US Army n.d.c.).

While these buildings constituted a major investment for the production of the next generation of atomic weapon, they did not compose the entire industrial process. Existing buildings were altered to perform other functions of the manufacturing process. One building in particular was constructed in 1941 and throughout World War II was used to load, assemble, and pack large caliber ammunition. During 1951, plans were developed to add three heavily reinforced, concrete bays to the north and south ends of the building. The bays on the north measured 12 feet by 19 feet while those on the south measured 12-feet square. Both sets of bays were constructed with thick walls. Only three sides of each bay were concrete, with the fourth wall constructed of Cemesto siding. The roof was frame with Transite sheathing. This construction technique directed the force of an accidental blast away from the occupied portions of the building. During this renovation, a massive earth-filled blast wall was added slightly south of the center of the building. The wall was constructed with one-foot thick, reinforced-concrete walls and a five-foot wide cavity. The top of the wall stood approximately four feet above the ridge of the original building. Other modifications at that time included the construction of new rest rooms, the addition of a compressor room to the west wall, and the placement of five concrete-barricaded hydraulic pumps on the east side of the building. A further modification was the installation of air conditioning equipment and ductwork. To accomplish this without making penetrations in interior walls, which might compromise the building's ability to withstand an explosion, all ducting was installed in an exterior structure extending from the slope of roof (Plate 5.65). A narrow walkway provided access to the structure, and it was supported by evenly-spaced wooden posts (US Army Real Property Office 2007; US Army n.d.c.).

The plans for the building do not provide any detail on the operations undertaken in the newly-constructed bays, or what equipment was installed; however, another building underwent similar renovations the following year that illustrated the equipment and processes (Plate 5.66). The work completed during 1952 in that building included the construction of two bays to the north end of the building, and two to the west wall just south of the building's center. The bays were constructed similarly to those in the first building with thick concrete walls and "blow walls" and lightweight roofs to direct the force of any accidental explosion. A compressor room also was constructed on the west wall. A massive earth-filled barricade was added near the center of the building. Equipment placement drawings indicate that drills were installed in the two new bays to the north; drills, saws, and a lathe were placed in the new bays on the west wall; and milling machines were furnished in the existing H, I, J, and K bays (US Army n.d.c.).

An addition approximately 105 feet in length was constructed on the south end of the building during this construction period. It added six bays (named AA-FF) and a storage dock. An earth-filled barricade replaced the original south wall. The construction of the new bays differed from that of the World War II era building. The addition lacked the distinctive monitor roof and the exterior walls were comprised of Cemesto over a wooden frame rather than the tile used for the older section. The bay walls continued to be thick concrete (US Army n.d.c.).

To understand how the many components are combined to create an atomic weapon, one must first understand the equipment and processes in each building. During the early 1950s, the high explosives used in these weapons were mixtures of TNT and RDX. These materials would be brought to one building by either truck or railcar and moved to the mezzanine level. The dry ingredients would be weighed, screened, dried, and mixed on the first floor. The prepared explosive mix was then transported to either one of two World War II era melt pour buildings through covered ramps. The process for casting the explosive was very similar to those used during World War II, but it is likely that some variation of the SPCC process developed by Mason & Hanger around 1950 was used to insure a quality casting. The liquid explosive was poured into a mold to form a casting (Lemert 1979:173).

After the casting cooled, it was moved through the system of covered ramps to a third building where the billet was machined. After 1952, an additional building also was available for this task. The machined explosive charge was transported to a fourth building for X-ray inspection to insure the quality of the product. After passing quality control, a sealed elevator moved the explosive billet to the basement of that building where it moved through the underground complex for storage in a fifth location. The largest building in the underground complex likely served as an assembly building for sub-assemblies of atomic weapons. The smaller openings of the bays and the lack of overhead cranes implies that smaller items were processed. All the bays in that building held sumps for contaminated wastes, and it was likely that explosives were precision-machined to custom-fit individual components. Following the completion of the sub-assemblies, the various parts were moved to another building for final assembly. The larger bay openings, freight elevator, and heavy cranes in the assembly building suggest that complete, or nearly complete nuclear bombs were removed from the building at this point, and loaded onto rail cars.

Activity at the plant dramatically escalated in 1956. In that year, another AEC Plant began the assembly of nuclear warheads for missiles, and began handling radioactive material (Lemert 1979:169). The introduction of highly fissionable materials allowed for the production of much smaller, high-yield nuclear weapons. Initial production focused on the warhead for the air-to-air Genie missile, but soon expanded to artillery-fired projectiles, other air-to-air weapons systems, air-to-ground missiles, and a family of ground-to-ground weapons. Production of ground-to-ground nuclear weapons included warheads for both strategic, intermediate range (IRBM) and intercontinental (ICBM) ballistic missiles, but also tactical weapons for battlefield level applications (Lemert 1979:169-170). The plant continued to manufacture the high-explosive components as well as the final assembly of the nuclear warhead.

Although the accidental detonation of a completed nuclear weapon was remote due to the number of safety devices inherent to the design, it was conceivable that the high explosives could detonate, destroy the radioactive material, and spread it over a wide area. Engineers with Mason & Hanger again devised a creative solution to the problem, known as the “Gravel Gertie” (Lemert 1979:170).

A Gravel Gertie was not meant to contain an explosion, but rather was designed to prevent radioactive dust or powder from escaping in the event of an explosion. The design incorporated a reinforced-concrete cylinder. A catenary of four, steel cables were interlaced over the top opening of the cylinder. Steel clamps secured the cables to each other at each crossing. The cables were incorporated into a square reinforced-concrete ring beam that was keyed and doweled into the vertical walls of the cylinder. Four layers of wire mesh were laid over the catenary; the bottom two layers were placed perpendicular to each other, and the upper two layers placed diagonally. A single layer of fine wire mesh was then placed and covered with screened gravel. Two additional layers of wire mesh were imbedded in the gravel. The entire structure was then covered with additional gravel. Two layers of Gunite waterproofing sealed the gravel. As the catenary sagged under the weight of the gravel, it was necessary to suspend a false ceiling from the cables. A grid of gypsum board-covered two-by-fours was hung from the cables with heavy wire. When completed, the cylinder stood 21 feet 6 inches tall and it was 37 feet from the floor of the Gertie to the top of the gravel (US Army n.d.c.).

The interior of the Gravel Gerties also sought to minimize or eliminate the chance of radioactive contamination. Access to the assembly cell involved a long passage that incorporated three 90 degree turns. Massive steel safety doors were located at the outer entry to the passage with a second set further down the first leg (Plate 5.67). The doors were sealed whenever the cell was active, and opened inward so any blast would seat the doors against the concrete and steel jambs. Personnel entered the passage through a separate tunnel. A steel revolving door kept the entry sealed during use. Curing stations for explosives were located in reinforced concrete rooms along one wall of the second leg of the passage. These were framed by rooms for mechanical equipment and inert storage (US Army n.d.c.).

The concept of the Gravel Gertie was not to contain the blast but to filter any material ejected during an explosion. Theoretically, the gravel bed would lift during an explosion, and as it settled back into place trap any particulate material. Experiments were conducted at the AEC Nevada Test Site where Mason & Hanger had constructed full-size versions of Gerties. The third and final test using 550 pounds of high explosive embedded with metallic uranium was detonated in a sealed Gertie with no significant release of radioactive material (US Department of Energy 2004). The tests proved the effectiveness of the gravel cap. The design of the Gravel Gertie included two features that served as vents. Two walls of the passage were constructed of wire mesh with gravel and earth backfill on the outside. In the event of an explosion, these would release a small amount of the energy with the gravel filtering any escaping material. These walls also would control emissions should an explosion take place in the access passageways (US Army n.d.c.). The design of the Gravel Gertie was so effective that it remained unchanged for over 25 years. On 20 November 1982, one of the original test structures in Nevada was repaired and filled with 423 pounds of high explosives coupled to eight kilograms of metallic uranium. The explosive inside the Gertie was detonated and radioactivity measured both inside the test cell, and outside where atmospheric conditions were monitored with an array of aerosol collectors and analyzers mounted on masts and an additional array supported by a meteorological balloon. Again, no appreciable amounts of radioactive material were released (US Department of Energy 2004). Six Gravel Gerties were completed at one plant in 1957. A seventh Gravel Gertie was completed in 1974. Gravel Gerties later were constructed at three additional installations.

All seven Gravel Gerties at the plant were modified in 1994 (Plate 5.68). The gravel cap was removed and a 16-sided metal ring was attached to the top of the cylinder walls. Metal roofing covered the ring. This was necessary as the configuration of the cells and their access passages prevented the installation of heavy equipment. The roof sheathing system could be removed and cranes used to lower machinery into the cells. Presses used in forming the explosive charges were installed in this fashion.

5.8 Construction during the Vietnam Era

Unlike the Korean Conflict era, when over 200 new facilities were constructed at several installations in the three-year period between 1951 and 1953, the level of activity was more protracted during the Vietnam Conflict. Between 1961 and 1974, more than 400 new buildings were constructed at Army ammunition plants. The majority of the new construction was support buildings for existing ammunition production facilities. The most significant construction activity occurred at Lone Star Army Ammunition Plant. Between 1961 and 1974, no fewer than 144 new buildings were erected at Lone Star. These included numerous small buildings of less than 500 square feet in size. The construction of these small buildings coincided with technological improvements made at the plant. These included the automation of detonator manufacture, which took place in the mid-1960s. Engineers working for the plant's contractor, Day and Zimmerman, sought to increase safety by minimizing manual labor in the handling of sensitive explosives used in detonator manufacture. The Cargile Scooper and Chamlee Loader allowed for the complete automation of detonator manufacture at Lone Star (MacDonald and Mack 1984h:33). The small size of the buildings implies that they housed only process machinery, eliminating the banks of presses and benches that characterized detonator production in preceding years. Small service magazines were likely built near the process buildings to hold the small amounts of high explosive needed for each machine. The greatest activity at Lone Star took place during 1962 when a completely redesigned, large-caliber load line was completed in Area B, with over 55,000 square feet of added floor area. Work continued at the plant in 1963 with additional buildings constructed in Area B. Other installations that saw higher levels of construction during the Vietnam era include Iowa, Newport Chemical Depot, and Radford.

The AEC continued to modernize and adapt its buildings at Line 1 during the Vietnam era. Production of the newly-perfected plastic-bonded explosives allowed the AEC to begin using this new material in the construction of nuclear weapons. This required the installation of the necessary equipment for precisely shaping the explosive charge. One building at the plant was selected to house the first presses on Line 1. A 27 by 20 foot reinforced-concrete bay was constructed on the west side near the southern end of the building. Concrete walls were thick, and a blow-out wall was constructed on one side of the bay enclosing the three heavy walls. A concrete loading platform extended westward from the bay. This area was designated "Bay GG." A second, larger bay was constructed on the east side, almost opposite Bay GG. Designated "Bay Z," the construction of this section was similar to Bay GG with a three-sided, reinforced-concrete cell holding the press. Bay Z, however, differed in that a metal-sheathed building enclosed the bay on the east and south creating an access corridor and work area. A heavy steel door secured the access corridor of Bay Z. The press was installed prior to the erection of the steel enclosure. Bay Z contained an Elmes Press. Elmes Presses were installed at both of the AEC plants, during late 1960 (US Army 1960). These giant machines could exert 2,500 tons of pressure resulting in shaped charges compressed to nearly 30,000 pounds per square inch; the presses weighed 172,000 pounds and stood over 20 feet in height (Plate 5.69) (American Steel Foundries 1947:47). A die remaining in the press room indicates that hemispherical charges approximately 24 inches in diameter were formed using the Elmes Press. The press is currently undergoing renovation for continued use at the plant.

Conventional ammunition production required a limited number of new buildings. Administrative, utility, and support buildings comprise the majority of those constructed during the Cold War era. Buildings directly related to ammunition production or storage account for a small percentage of new construction. One building, constructed in 1963, is a 4,231 square foot quality control building containing X-ray equipment for the non-destructive examination of ammunition rounds. This line produced high explosive artillery projectiles using traditional melt-pour processes. The installation of X-ray equipment allowed for inspection of the rounds, either a random sample to insure quality of a production run, or complete inspection of all rounds should sampling indicate unacceptable ammunition. The building itself is a utilitarian structure with a west wall constructed of cast concrete and the remainder of the building constructed with a steel frame sheathed in metal panels. The X-ray equipment is located in the center of the building within a reinforced-concrete cell. A lead door seals the opening of the X-ray cell when the equipment is in use. The upper portion of the cell projects above the flat roof of the main building. As with all the ammunition production areas, this building is connected to the other buildings of Line 3A with enclosed ramps.

New buildings were built only when absolutely necessary and the designs were strictly utilitarian emphasizing economy rather than architectural style. An example of this is a building completed in 1968 used to assemble and pack the canisters for the XM45 and XM41E1 aerial mine programs (Plate 5.70). The mines were produced in one area and transported to this building for final assembly. The building is a metal clad, gable roofed building with few openings. Two overhead doors open the west wall and a series of double-leaf flush-panel doors line the north and south walls. A large exhaust system vented fumes from the canister filling operation to the outside. The building is connected to the remaining buildings in its area by enclosed ramps.

5.9 Construction During the Late Cold War

Construction of new facilities at Army ammunitions plants declined with the end of American involvement in Southeast Asia. The greatest activity was the construction of the Mississippi Army Ammunition Plant for the integrated production of 155mm artillery rounds. Between 1980 and 1983, no fewer than 60 buildings were constructed to support the production of the metal shell components and the loading of the projectile with high explosive (MacDonald and Mack 1984i:14). Radford Army Ammunition Plant also experienced higher levels of construction than other Army ammunition installations. This construction activity was associated with the construction of the continuous multi-base lines and the modernization of the TNT production area. Although Badger Army Ammunition Plant ceased operations in 1975 and was placed on modernization and standby status, new buildings were constructed to enable the installation to rapidly start propellant production if needed (Shaffer and Crown 1996:103; US Army Real Property Inventory:2007).

5.10 Summary

The construction of new ammunition production buildings during the Cold War era illustrated a gradual shift from the techniques incorporated during World War II and before. Although the numbers of new buildings constructed during the Cold War pales in comparison to the massive construction efforts of the early 1940s, several technological advancements increased the speed, quality, and safety of ammunition production; however, these were easily integrated into existing structures. The increased use of automation and the increasing sophistication of computer systems allowed for the remote monitoring and control of ammunition production processes. The development of continuous nitration for TNT and the Biazzi process for nitroglycerin production removed personnel from the production areas and into control centers. Computers and televisions monitored the process with minimal intervention from plant employees. This increased the safety of munitions workers and reduced the cost of ammunition production. The removal of the worker from the production area contributed to the shift to lighter construction methods. Most newly-constructed buildings used steel skeletons covered with metal or asbestos siding. Escape chutes were still constructed to provide emergency egress in the unlikely event an accident took place while employees were in the building, and concrete walls still separated process equipment; however, the reinforced-concrete skeleton, tile walls, and monitor roofs, characteristic features of ammunition production facilities constructed during the first half of the century, were no longer inherent in designs.

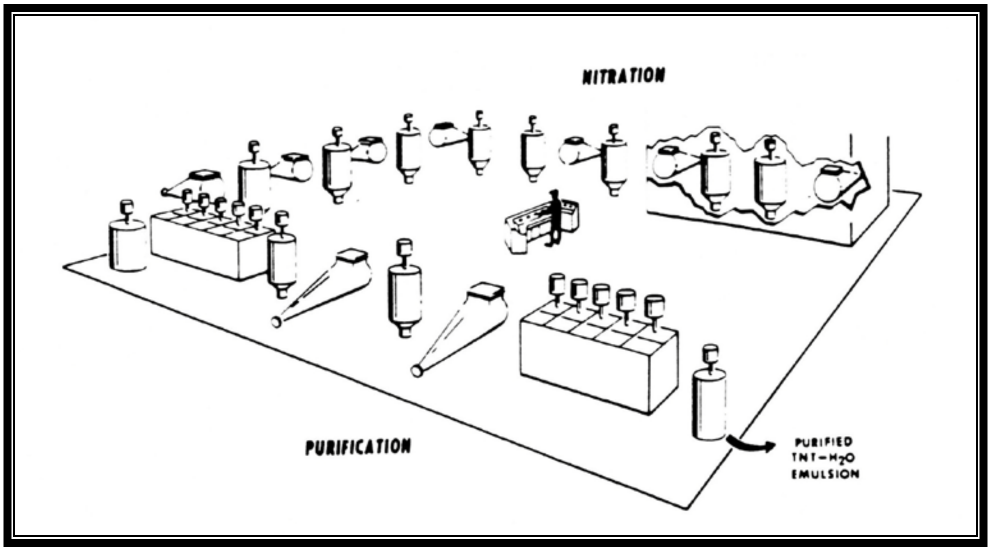

Plate 5.1 Equipment used in continuous TNT production (Courtesy US Army)

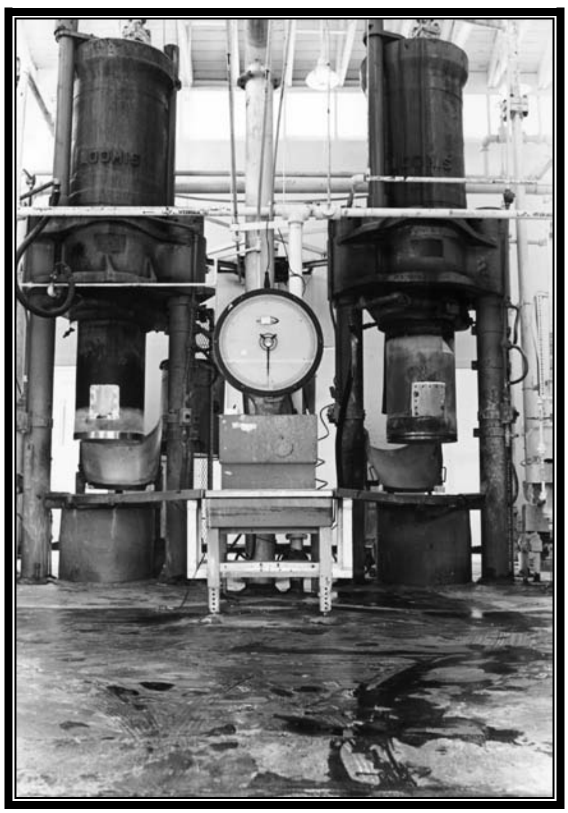
Plate 5.2 Blocking press used in nitrocellulose production, ca. 1965 (Photo courtesy US Army)

Plate 5.3 Operator using hydraulic blocking press, ca. 1965 (Photo courtesy US Army)

Plate 5.4 Block of nitrocellulose, ca.1965 (Photo courtesy US Army)

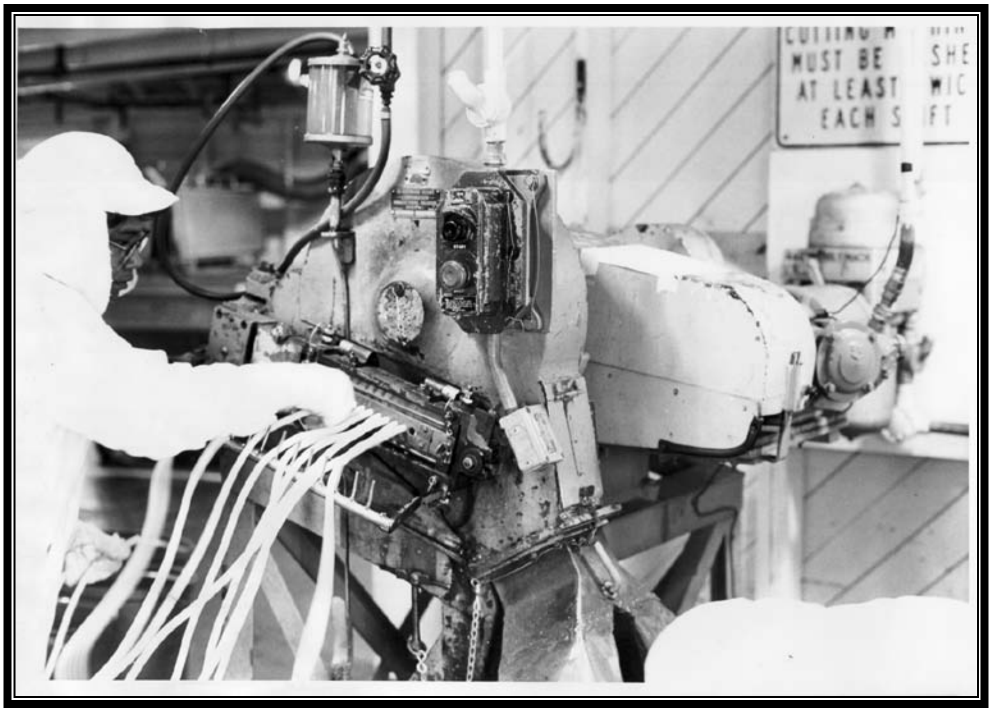

Plate 5.5 Extruding and cutting smokeless powder grains (Photo courtesy US Army)

Plate 5.6 Typical solvent recovery building surrounded by Rapauno barricade (Photo courtesy US Army)

Plate 5.7 Typical air dry building (Photo courtesy US Army

Plate 5.8 Extruding and cutting double-base propellant grains, ca. 1965 (Photo courtesy US Army)

Plate 5.9 Centrifuges used in production of solventless propellants (Photo courtesy US Army)

Plate 5.10 Sheets of solventless propellant (Photo courtesy US Army)

Plate 5.11 Machine used to cut sheets of propellant into strips (Photo courtesy US Army)


Plate 5.12 Strips of propellant at carpet roll machine (Photo courtesy US Army)

Plate 5.13 The finished carpet roll (Photo courtesy US Army)

Palte 5.14 Extruding and cutting solventless propellant (Photo courtesy US Army)

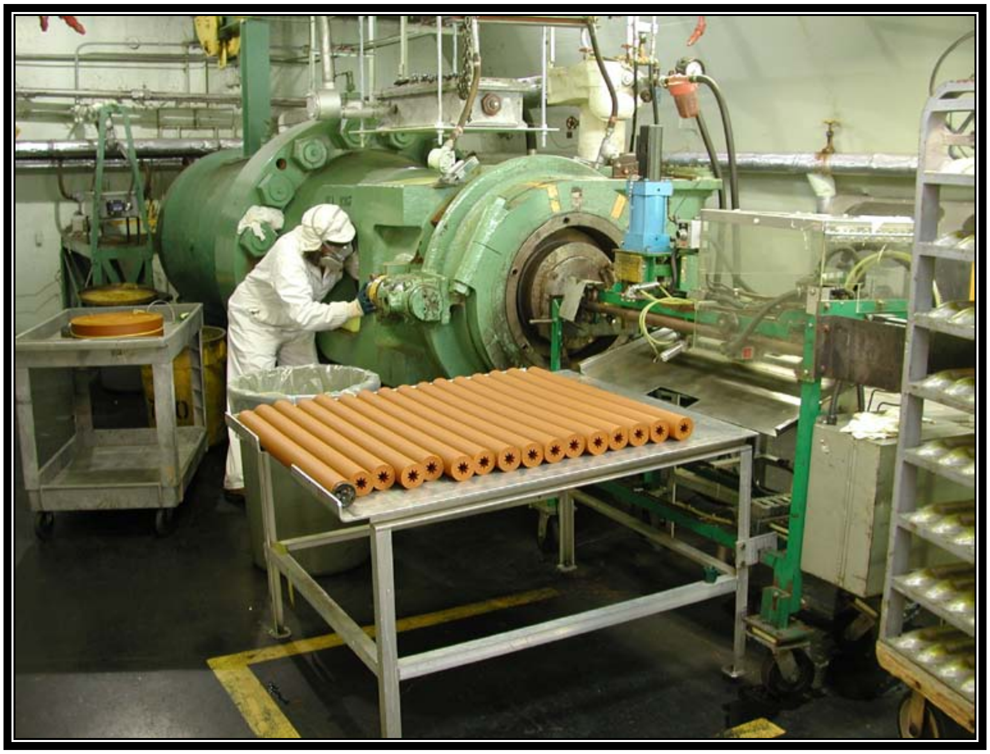

Plate 5.15 Extruding large rocket propellant grains (Photo courtesy US Army)

Plate 5.16 Inspection equipment for large propellant grains (Photo courtesy US Army)

Plate 5.17 Finishing lathe for propellant grains (Photo courtesy US Army)

Plate 5.18 Typical building where cutting and cellulose wrap are completed, note Repauno barricade (Photo courtesy US Army)

Plate 5.19 Preparing beaker for casting large rocket propellant grain (Photo courtesy US Army)

Plate 5.20 Nitroglycerin dessicator with technician connecting ground wire (Photo courtesy US Army)

Plate 5.21 Preparing to fill mold with nitroglycerin (Photo courtesy US Army)

Plate 5.22 Curing area for rocket propellant grains, these are for HONEST JOHN missiles (Photo courtesy US Army)

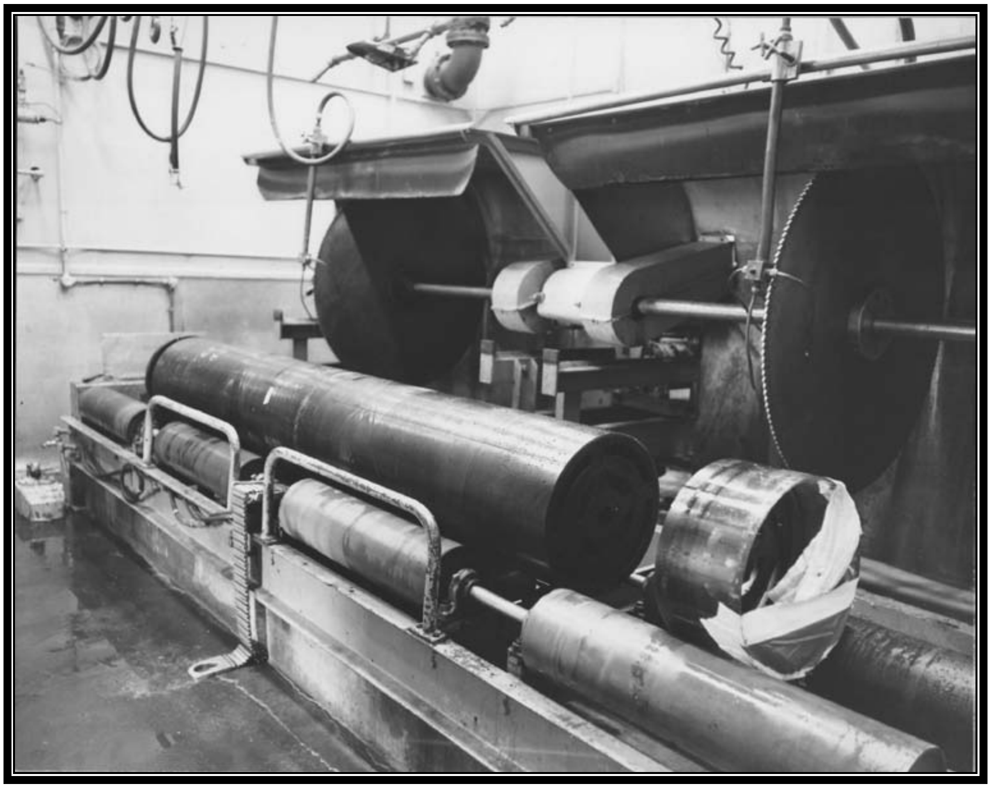

Plate 5.23 Saw used for cutting grain to the proper length (Photo courtesy US Army)

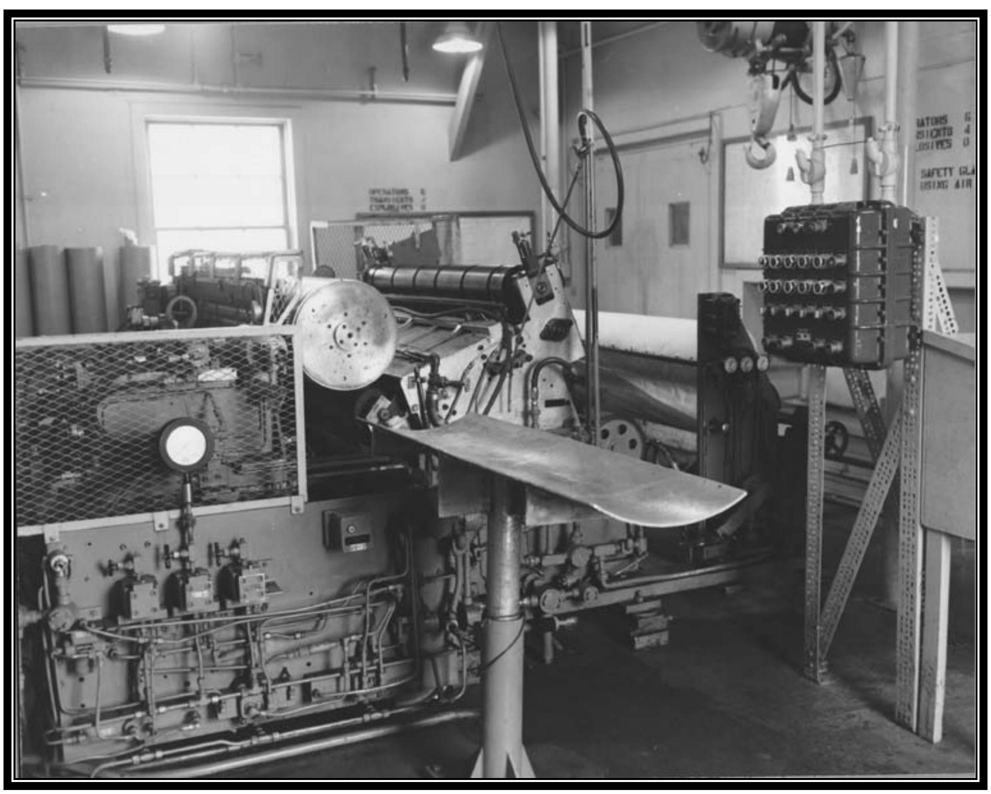

Plate 5.24 Cellulose wrap machinery (Photo courtesy US Army)

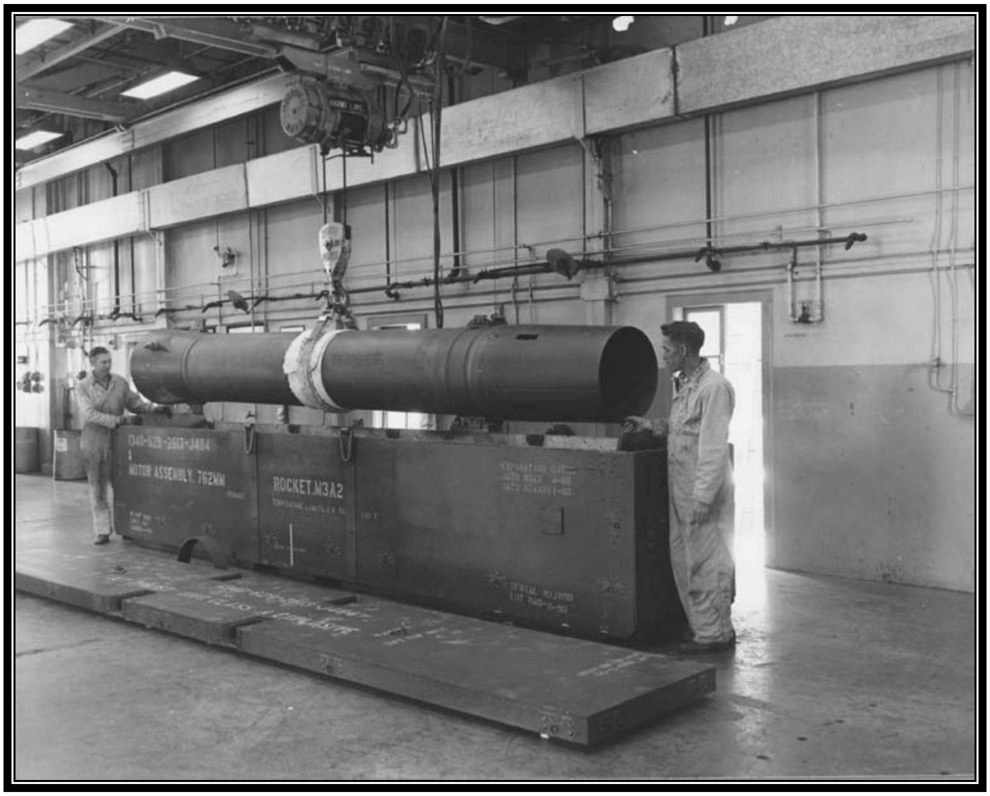

Plate 5.25 Preparing HONEST JOHN missile motor for shipment (Photo courtesy US Army)

Plate 5.26 Preparing NIKE cluster of missile motors for shipment (Photo courtesy US Army)

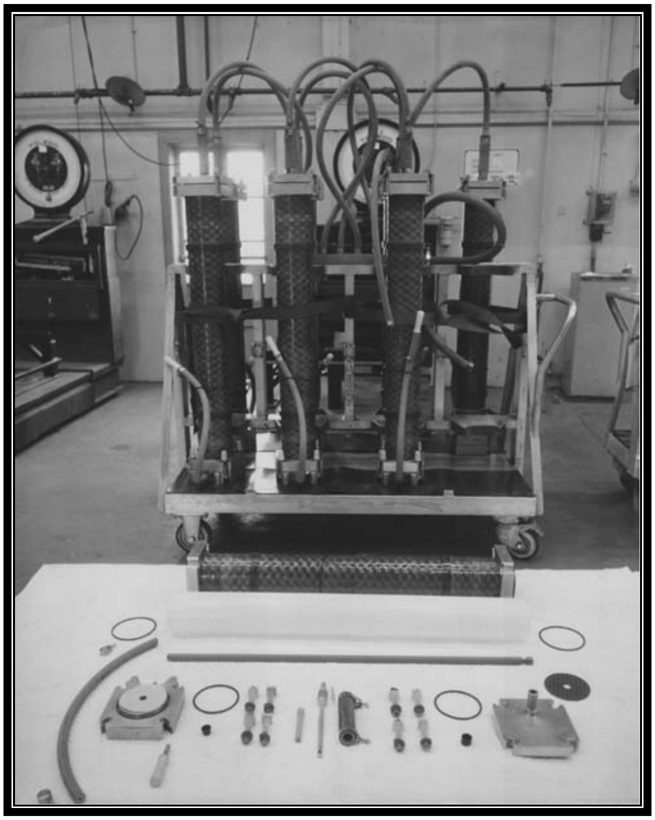

Plate 5.27 Various components of TOW missile with casting equipment shown in background (Photo courtesy US Army)

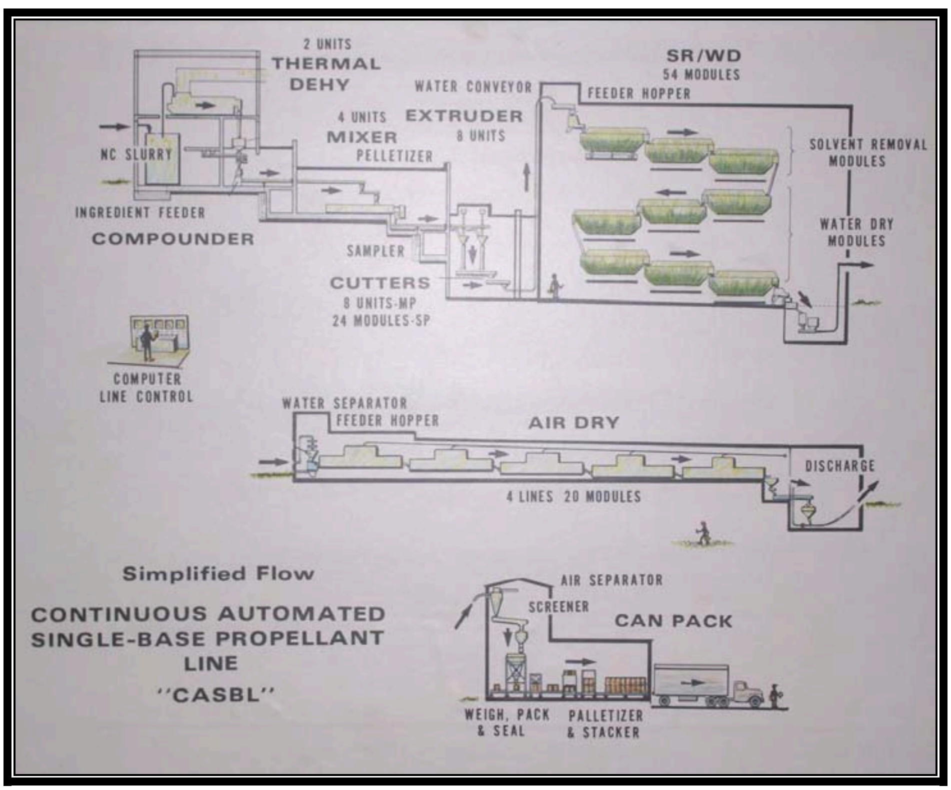

Plate 5.28 Process diagram of CASBL (Courtesy US Army)

Plate 5.29 Tractor pulling buggies of propellant grains (Photo courtesy US Army

Plate 5.30 Typical Continuous Automated Multi-Base Propellant Line (CAMBL) (Photo courtesy US Army)

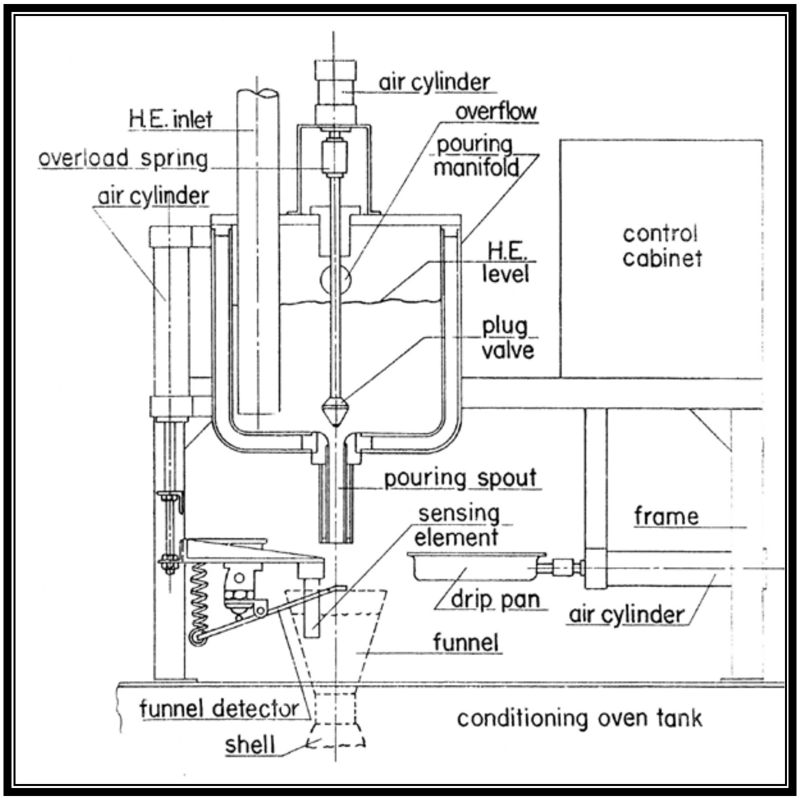

Plate 5.31 Volumetric loader developed by the Mason & Hanger-Silas Mason Co. (Rothstein 1955)

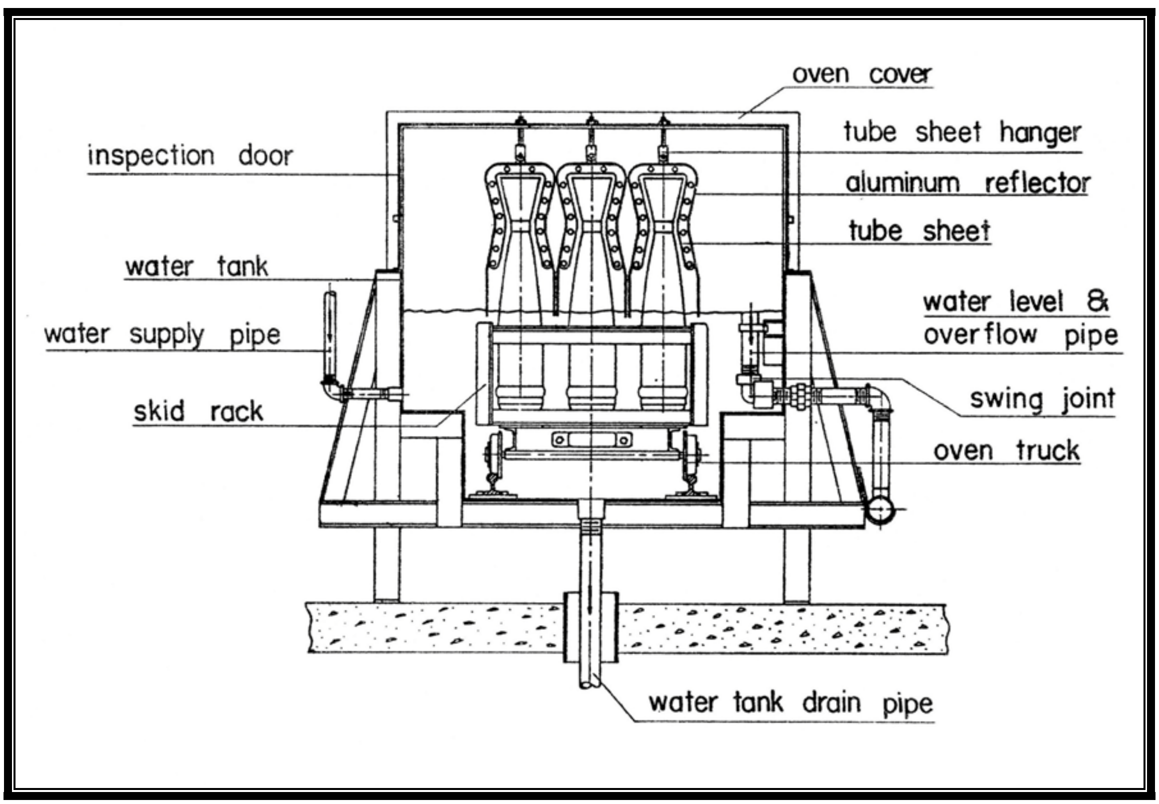

Plate 5.32 Cross section of conditioning oven used in the SPCC process (Rothstein 1955)

Plate 5.33. Conditioning ovens of SPCC process, ca. 1956 (Mason & Hanger Records, Eastern Kentucky University Archives, Richmond, KY)

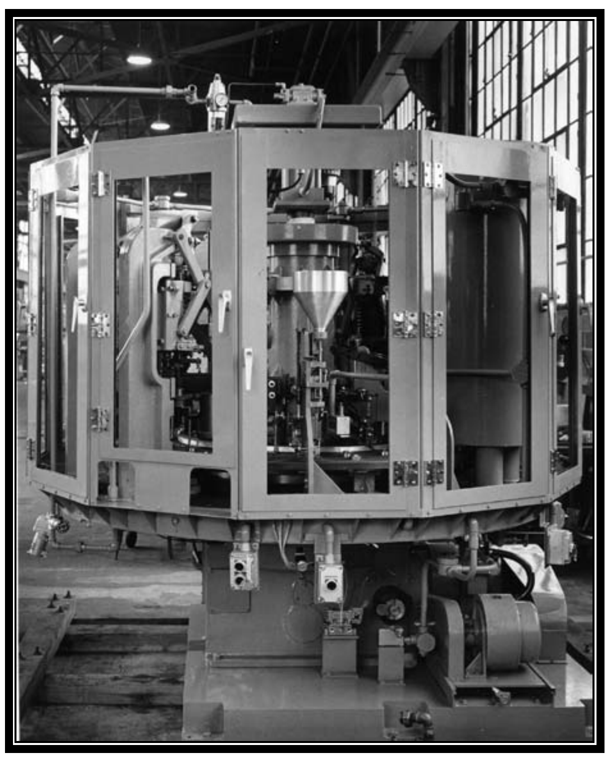

Plate 5.34 Automated fuze and detonator loader designed by Mason & Hanger-Silas Mason Company (Mason & Hanger Records, Eastern Kentucky University Archives, Richmond, KY)

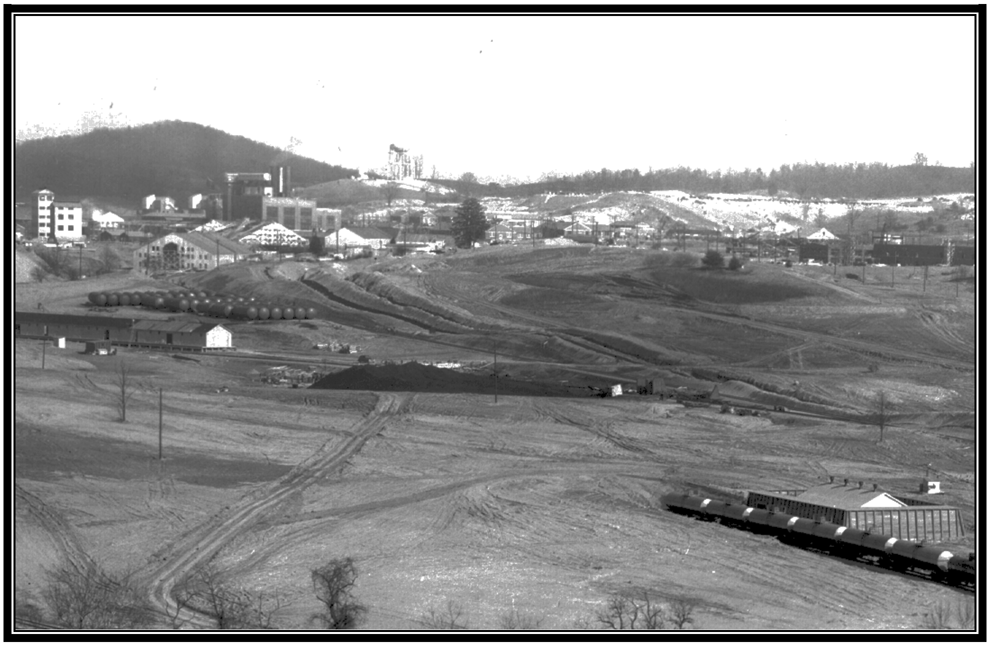

Plate 5.35 Typical Ammunition Plant, ca. 1943 (Photo courtesy US Army)

Plate 5.36 Example of a steam generating plant with World War II administration building (now demolished) in foreground (Photo courtesy US Army)

Plate 5.37 Blocking Buggy used for moving press blocks through the propellant plant (Photo courtesy US Army)

Plate 5.38 Buggy used for moving completed grains through the plant is loaded on the elevator of an air dry house (Photo courtesy US Army)

Plate 5.39 Typical solvent recovery building surrounded by Repauno barricade (Photo courtesy US Army)

Plate 5.40 Mixing area for nitrocellulose, note that one wooden tank from the World War II era is still in use (Photo courtesy US Army)

Plate 5.41 Typical melt pour building, ca. 1943 (Photo courtesy US Army)

Plate 5.42 Typical operations bay (Photo courtesy US Army, 2007)

Plate 5.43 Typical barricade (Photo courtesy US Army, 2007)

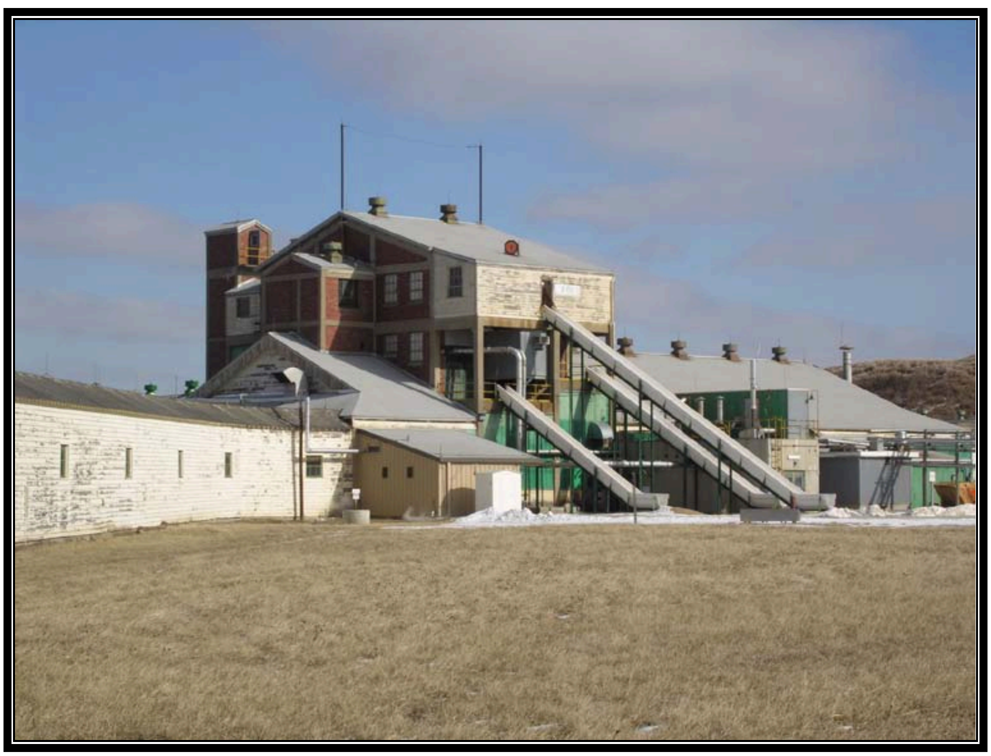

Plate 5.44 Typical melt-pour building (Photo courtesy US Army, 2007)

Plate 5.45 Typical shipping/receiving building (Photo courtesy US Army, 2007)

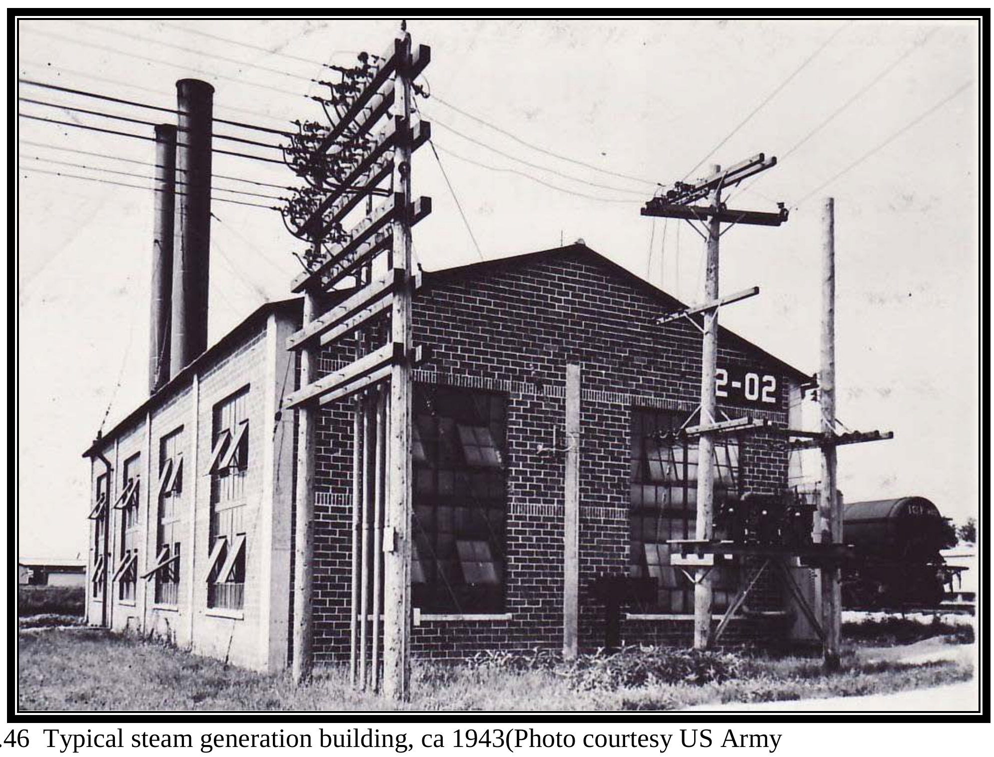

Plate 5.46 Typical steam generation building, ca 1943(Photo courtesy US Army

Plate 5.47 Typical building for production of fuzes or detonators (Photo courtesy US Army, 2007)

Plate 5.48 Typical concrete barricade for remote assembly of boosters, ca. 1943, (Photo courtesy US Army)

Plate 5.49 Typical detonator “rumbling” building, ca. 1943, (Photo courtesy US Army)

Plate 5.50 Typical concrete cell for remote testing of detonators (Photo courtesy US Army, 2007)

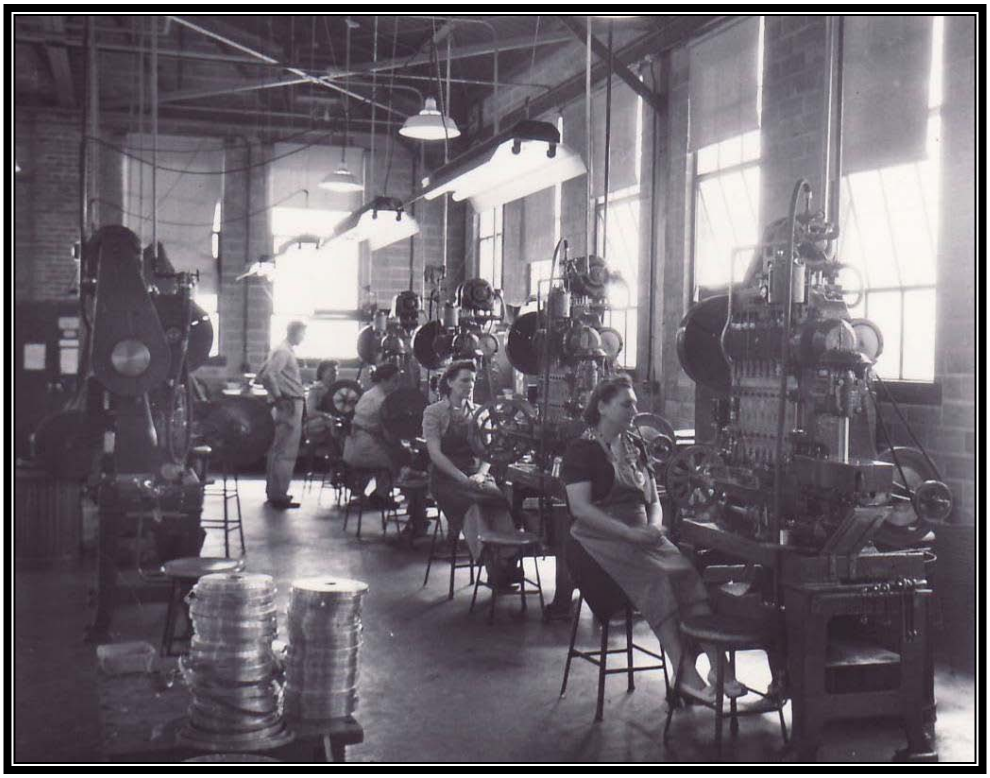

Plate 5.51 Eyelet machines, ca. 1943 (Photo courtesy US Army)

Plate 5.52 Typical above ground magazine for finished ammunition (Photo courtesy US Army, 2007)

Plate 5.53 Typical frost-proof vault (Photo courtesy US Army, 2007)

Plate 5.54 Typical ramp with conveyor, ca. 1943 (Photo courtesy US Army)

Plate 5.55 Typical ramp with conveyor removed (Photo courtesy US Army, 2007)

Plate 5.56 Typical ramp (Photo courtesy US Army, 2007)

Plate 5.57 Typical building showing modifications to windows and walls (Photo courtesy US Army, 2007)

Plate 5.58 Typical change house constructed in 1983 (Photo courtesy US Army, 2007)

Plate 5.59 Typical building showing addition to original 1941 shipping building (Photo courtesy US Army, 2007)

Plate 5.60 Typical acid concentrator (Photo courtesy US Army)

Plate 5.61 Fertilizer loading (Mason & Hanger Records, Eastern Kentucky University Archives, Richmond, KY)

Plate 5.62 Typical rocket grain casting area (Photo courtesy US Army

Plate 5.63 Construction of underground complex of buildings, ca. 1951 (Photo courtesy US Army)

Plate 5.64 Example of explosives handling facility (Photo courtesy US Army, 2007)

Plate 5.65 Typical method of installing air conditioning ductwork (Photo courtesy US Army, 2007)

Plate 5.66 Renovated building. Note large concrete machining bays and barricade near center of building (Photo courtesy US Army, 2007)

Plate 5.67 Original door stored in personnel passage (Photo courtesy US Army, 2007

Plate 5.68 Example of modified Gravel Gertie (Photo courtesy US Army, 2007)

Plate 5.69 Typical press bed (Photo courtesy US Army, 2007)

Plate 5.70 Example of utilitarian nature of later construction (ca. 1968) emphasizing economy rather than architectural style (Photo courtesy US Army, 2007)

6.0 PRODUCTION, EMPLOYMENT, AND COMMUNITY IMPACTS OF AMMUNITION PRODUCTION DURING THE COLD WAR ERA

6.1 Introduction

The Ordnance Department and the Army began planning cutbacks in defense production shortly before the end of World War II, after V-E Day in May 1945. In August, the Production Readjustment Committee of the War Production Board stopped requiring its permission for major cutbacks, and within two weeks, practically all defense production had stopped. One aspect of the cutback plans was to declare government-owned facilities as surplus as soon as possible (NARA RG 156 Ordnance Corps 1952:37). After the war, the government retained in reserve 12 powder and explosives plants, 14 load-assemble-pack plants, and 3 shell plants (NARA RG 156 Medaris 1953:3).

The Army focused on rehabilitating or modifying buildings to meet postwar needs, rather than the construction of new plants. The plants that the government retained were maintained at a cost of $23 million per year, or 1 percent of their total value. This level of maintenance did not meet standards for immediate readiness (NARA RG 156 Medaris 1953:3).

Within a few months of the end of World War II, the ammunition industry that had produced 20 million tons of ammunition during the war was now operating at a small fraction of that rate. At the beginning of U.S. involvement in Korea, the industry was virtually static as the large amounts of ammunition already in storage served the immediate needs of the Army. These reserves were so large that early military action in Korea did not justify reactivating the ammunition production base (NARA RG 156 Medaris 1953:6). Production during the immediate postwar period focused only on ammunition not available in reserve. Reflecting reduced ammunition production after World War II, in 1950 no industry existed for production of metal components. The GOCO propellant, explosive, and load-assemble-pack plants were not in immediate readiness for production (NARA RG 156 Ford 1953a:9). Not only were the facilities closed after World War II, but a large number of the government-owned tools for production had been offered to contractors for purchase (NARA RG 156 Ammunition Task Force 1953c:Tab A).

The number of plants in operation for the Korean conflict grew by ten plants in partial operation in June 1950 to 28 plants in April 1953 (NARA RG 156 Ammunition Task Force 1953a:6). From 1950 to 1953, the federal government spent $449 million to rehabilitate and reactivate the plants (NARA RG 156 Medaris 1953:6). The government experienced difficulty obtaining construction materials to rehabilitate and expand the plants (NARA RG 156 Medaris 1953:8-9).

6.2 The Cyclical Nature of Ammunition Production

The government's defense production program during the Cold War was based on a "guns and butter" approach, consisting of a limited mobilization of armed forces and industry to build military strength while maintaining a civilian-centered economy. The focus was not on accumulating large inventories of military supplies and equipment, but on building a production base that could smooth inventory peaks and valleys and could mobilize in the event of a war (NARA RG 156 Ordnance Corps 1952:6).

The Ordnance Corps increased its ammunition procurement and reactivated World War II installations in response to U.S. military involvement in the Korean conflict (NARA RG 544

Snodgrass 1951:73). At the beginning of military involvement in Korea, nearly 1.8 million tons of unserviceable but repairable ammunition were on hand, but the minimal funding of the military after World War II financed only training and testing (NARA RG 156 Ammunition Task Force 1953a:1-2). Despite the need for more ammunition and its increased production, Ordnance Corps officials believed that they had to serve their mission in this conflict while accommodating a desire for continued military austerity and for minimum disruption of the civilian economy.

While most ammunition plants were operating at capacities ranging from 3 percent to 45 percent on 1 July 1950, their capacities increased by 1 April 1953 to a range between 38 percent and 100 percent (NARA RG 156 Ammunition Task Force 1953c:Tabulation of Progress and Activation of Reserve Ammunition Plants). From July 1950 to 28 February 1953, more than 1.25 million tons of artillery ammunition were produced; more than half a million tons of ammunition were renovated and included in the supply system; more than 2 million tons of ammunition were shipped to the Far East Command; and approximately 900,000 tons were shipped to other areas of the world (NARA RG 156 Ford 1953a:2).

Production of the principal military types of small-arms ammunition also increased upon U.S. entry into Korea. There were undelivered orders for 34.1 million rounds of .30-caliber ammunition in July 1950, and an increase to 2.9 billion rounds in September 1951. There were no undelivered orders for .30-caliber carbine ammunition or 20-millimeter ammunition at the beginning of this period; these figures grew to 972.5 million rounds and 155.5 million rounds, respectively. Undelivered orders for .50-caliber ammunition grew from 19.6 million to 577.5 million rounds (NARA RG 544 Snodgrass 1951:65).

Several factors contributed to delays in ammunition production during the Korean conflict. Ordnance Corps officials asserted that the funding approval process was not designed to provide funding as quickly as it was needed; there was little flexibility for advance payments and emergency transfers of funds from other sources, and many approvals were needed before funds could be released. One progress report identified two examples: An advance funding request for E. I. DuPont Company, the operator of Indiana Arsenal, took 85 days; a similar request for U.S. Defense Corporation to rehabilitate St. Louis Ordnance Plant took 125 days (NARA RG 156 Ammunition Task Force 1953a:8). Other factors contributing to delays included machine tool shortages and a steel strike (NARA RG 156 Ordnance Corps 1953:9, 11).

The Ordnance Corps took several steps to counter these delays and speed the ammunition production process while observing the need for economy. These steps included: advance planning to complete tasks not contingent on funding, so funds could be used as soon as they were available; requesting additional funds to produce items deemed critical; delaying production cutbacks during low-use periods to develop reserves; expediting processing of funds within the Ordnance Corps bureaucracy; producing the most recent designs available for munitions rather than await the release of a new design from research and development; and establishing procurement and production guidelines, such as purchasing easily produced ammunition components only when needed and setting production schedules (NARA RG 156 Ammunition Task Force 1953a:11).

Following the Korean conflict, ammunition plants were placed on layaway or observed production schedules that met the reduced requirements of peacetime. A 1955 trade journal article on Scranton AAP, which produced 8-inch and 155mm shells, suggested that active plants focused on preventive maintenance in order to reduce downtime and allow the plant to respond as quickly as possible if an emergency were declared. At this time, Scranton was operating on one shift, and half of its facilities were on standby status. More than 20 percent of its workforce focused on maintenance (Mill & Factory 1955:98).

At the beginning of U.S. involvement in Vietnam, there were 26 government-owned ammunition production plants (NARA RG 544 Cholish 1978:3). In 1965, 11 of these plants were already active, and the ammunition production base was focused on peacetime requirements (Williams 1978:2). These installations included:

- Load-assemble-pack: Indiana AAP (bag loading); Iowa AAP; Lake City AAP; Lone Star AAP; Louisiana AAP; Milan AAP; Longhorn AAP; Newport AAP
- Propellants: Radford AAP
- Explosives: Holston AAP
- Metal parts: Scranton AAP

More of the base was reactivated as U.S. involvement escalated and combat troops were sent (Williams 1978:2-3). During fiscal year 1966, six additional plants were reactivated, including: Cornhusker AAP for load-assemble-pack operations; Twin Cities AAP for small arms load-assemble-pack operations; Badger AAP and Sunflower AAP for propellant production; and Joliet AAP and Volunteer AAP for explosives production. In fiscal year 1967, an additional eight plants were reactivated, including Joliet AAP, Kansas AAP, and Cohasset AAP for load-assemble-pack operations; and Burlington AAP, Hays AAP, St. Louis AAP, Twin Cities AAP, and Gateway AAP for metal parts production. Four plants were reactivated during fiscal year 1968: Ravenna AAP for load-assemble-pack operations, Indiana AAP for propellants production, and Newport AAP and Radford AAP for explosives production (Williams 1978:Chart 2).

By 1968, the height of U.S. involvement in Vietnam, the Army Munitions Command (ARMCOM) operated 35 installations that produced explosives, propellants, and metal ammunition components and conducted load-assemble-pack operations. The Command also controlled 200 Base Production Units (BPU), which consisted primarily of support equipment, such as machine tools and machinery that manufactured metal parts, rather than mechanisms used directly in the production of ammunition. These BPUs were in storage at various Army warehouses, or were out-leased for use by private industry (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:4).

At this time, GOCO plants were operating at 92 percent capacity for propellant production and 85 percent capacity for explosives production. The remaining capacity was located at Alabama AAP, the only idle plant at this time (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:2). The entire capacity for ammunition loading, assembly, and packing was being used, except for a few individual production lines, and more capacity was sought. The loss of Louisiana AAP's Line F in an explosion that year further limited ammunition loading capacity. Under consideration were establishment of 105-mm and 155-mm/8-inch loading lines at Savanna Ordnance Depot, Illinois, and reacquisition of the former Nebraska Ordnance Plant; however, declining U.S. involvement in Southeast Asia during the early 1970s rendered these plans unnecessary (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:2).

Two cartridge case lines at Riverbank AAP, California, represented the only idle capacity at GOCO metal parts plants in 1968. Reactivation of these lines had been approved, bringing capacity to 100 percent (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:2).

As during the Korean conflict, shortages of materials, equipment, and supplies delayed ammunition production during the Vietnam conflict. Equipment was purchased, built, or transferred from plants not using it, but it was difficult to obtain because of high demand. Used equipment and supplies presented additional problems because they were frequently outdated, salvaged for spare parts, or suffered from a lack of routine maintenance. An insufficient number of Army personnel were qualified to develop materiel requirements. For example, Kansas AAP experienced difficulty obtaining tools to produce new ammunition items because technical data packages, compiled by inexperienced personnel, were incomplete. Joliet AAP had similar problems, as well as problems obtaining metal parts and ammunition components, such as cartridge cases and propellants. Cornhusker AAP needed bomb casings that were no longer manufactured, and Twin Cities AAP had difficulty acquiring raw materials such as case cups and bullet jacket cups (Williams 1978:5-6).

By fiscal year 1975, well into the drawdown from the Vietnam conflict, the number of active plants had decreased to 16 of 26 total plants. The active plants represented four types: propellants and explosives; metal parts; small arms ammunition; and load, assemble, and pack (NARA RG 544 Historical Office, US Army Armament Command 1976:14). The status of each plant is listed below:

Propellants and explosives

Active:	Badger, Holston, Joliet, Radford, Volunteer
Standby:	Alabama (being excessed), Indiana, Newport, Phosphate Development Works, Sunflower

Small Arms

Active:	Lake City, Twin Cities

Metal Parts

Active:	Louisiana, Riverbank, Scranton, Twin Cities
Standby:	Burlington (being excessed), Gateway, Hays, St. Louis

Load-assemble-pack

Active:	Indiana, Iowa, Joliet, Kansas, Lone Star, Longhorn, Louisiana, Milan
Standby:	Cornhusker, Ravenna, Newport

The government also maintained seven arsenals, consisting of five research, development and fabrication centers for weapons and munitions and two special-mission centers (NARA RG 544 Historical Office, US Army Armament Command 1976:14).

The cyclical nature of ammunition production was demonstrated after the Vietnam conflict. As of 1982, a period when the United States was not actively involved in a conflict, an approximately equal number of GOCO production facilities were active and in layaway status. Of 25 GOCO facilities, 12 were in layaway, and 13 were active. One additional facility was under construction. Meanwhile, there were 3 GOGO production facilities; 91 contractor-owned plants utilizing government-owned plant equipment; and government-operated arsenal and laboratory facilities (see Table 6.1 at end of section) (Department of the Army 1982:17).

Plate 6.1 illustrates the changes in ammunition production during periods of conflict and peace. The data represents artillery production at a load, assemble, pack plant that remained active throughout the Cold War. The data were obtained from annual command histories prepared between 1947 and 1987. The summary represents totals of all calibers of ammunition as the plant operators were frequently forced to re-tool an existing line to complete production of another product. For this reason, there were heavy production runs of particular munitions for one or two years, then none while production focused on a different item. Tracking only a single ammunition item would indicate reduced activity in particular years even though the plant was running at near capacity to produce something different. During the Cold War, the plant produced numerous items of ammunition including 76mm, 90mm, 120mm 8” howitzer, and 175mm.

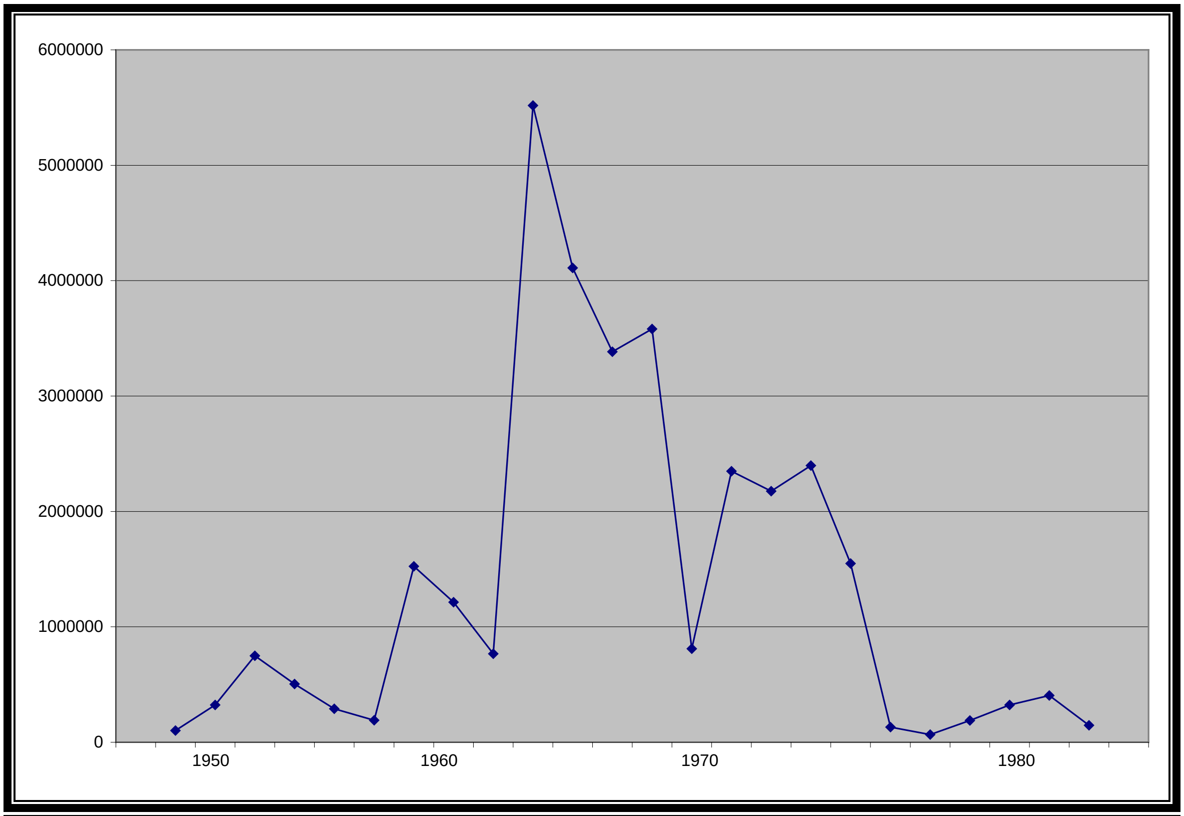

Plate 6.1 Production of Artillery Ammunition at IAAP , 1947 to 1987

6.3 Employment Fluctuations

The size of the ammunition workforce increased during U.S. involvement in the Korean and Vietnam conflicts. Civilian employment spiked in ordnance procurement districts from a “skeleton force” of 1,300 in July 1950 to 7,400 in July 1951, 13,430 in July 1952, and to 14,877 in February 1953 (NARA RG 156 Ammunition Task Force 1953b:2). Although smaller as a whole, the military workforce also increased, from 52 in August 1950 to 197 in July 1951, 244 in July 1952, and 261 in February 1953 (NARA RG 156 Ammunition Task Force 1953b:Tab B). However, the Army experienced problems filling some jobs within the plants. “Distressed labor areas” with high unemployment shifted to a labor balance as residents obtained jobs in local plants. Areas with high unemployment did not preclude shortages in specialized areas. There were labor shortages in skilled trades, such as welders, electricians, machinists, or pipefitters regardless of whether the overall labor market in a region was in surplus or shortage. Delivery schedules were affected when labor shortages prevented operation of second and third shifts (NARA RG 156 Ammunition Task Force 1953b:8).

By 1968, the height of U.S. involvement in Vietnam, the Ammunition Procurement and Supply Agency employed 120,000 people at its installations (NARA RG 544 Army Ammunition Procurement and Supply Agency 1969). Planning was difficult because of uncertainty about the country’s overall plan for involvement in the conflict and the length of involvement. No prior planning was done to determine organizational structures and employment needs to manage the reactivation process and the problems that occurred because of increased production (Williams 1978:4).

As the country's involvement in Vietnam decreased during the early 1970s, reducing the need for ammunition, employment also decreased. This lead to worries among employees and within the surrounding community. For instance, in a 1970 study of the impact of Kansas AAP on southeast Kansas during the Vietnam Conflict, an inspector worried that closure would hurt the local economy and force many people to apply for welfare benefits. One production worker, a mother of five who was on welfare before her employment at the plant, said, "We need this plant real bad. First time our children have been able to live right." Another said closure would be "a great disaster." Others noted that southeast Kansas was an economically depressed area (Macy et al. 1970:146-56). Available sources are unclear if southeast Kansas suffered the economic downturn suggested by the 1970 report.

Employment levels did drop as a result of the drawdown and end of involvement in Vietnam. The ARMCOM military workforce dropped from 1,189 in December 1972 to 1,151 in June 1974, and to 1,017 in September 1975. During the same period, the number of civilian employees dropped from 26,129 to 23,854 and to 22,659 (NARA RG 544 Historical Office, US Army Armament Command 1976:xvii). A personnel reduction in force was implemented at Frankford Arsenal, Picatinny Arsenal, and Pine Bluff Arsenal during fiscal year 1975; a total of 656 positions were eliminated at these arsenals, but management arranged the personnel structure so that only 38 employees lost their jobs (NARA RG 544 Historical Office, US Army Armament Command 1976:20, 23).

During the Vietnam conflict, ammunition plants met their needs for unskilled personnel, both male and female. A large portion of the workforce was female. Unskilled workers were recruited from areas in the vicinity of the installations as production workers, laborers, and clerical workers. It was more difficult to hire skilled workers, such as graduate engineers, professionals, administrative personnel, and supervisors (Williams 1978:7). Recruitment problems were exacerbated by a lack of livable, affordable housing, low interest in employment at what appeared to be temporary installations, and discrepancies between grade structure and standards (Williams 1978:4).

6.4 Training and Educating the Workforce

During the Vietnam conflict, most ammunition workers did not have experience working in ammunition production. Training was provided, both in the classroom and on the job. However, "training was hampered by a lack of updated methods and procedures, experienced instructors, training equipment, materials, funds, space, and time" (Williams 1978:7). The later Cold War provided more opportunities for training.

ARMCOM developed additional training programs in the 1970s. A fiscal year 1975 annual report for ARMCOM noted that management-level employees had the opportunity to attend a graduate-level management development program at Rock Island Arsenal. That year, 250 Arsenal and ARMCOM employees were enrolled. The program offered master of science degrees in systems management, professional management, and contract and procurement management (NARA RG 544 Historical Office, US Army Armament Command 1976:xviii). Employees who worked with new or modified equipment developed within ARMCOM also received training on how to operate that equipment through the New Equipment Training Program (NARA RG 544 Historical Office, US Army Armament Command 1976:41-2).

During the late Cold War period, the Army's training and education effort began to focus on employees' personal needs. The 1975 ARMCOM report detailed the activities of the Alcohol and Drug Abuse Prevention and Control Program. The program was intended to help civilian and military personnel with alcohol-abuse problems reduce consumption so that they could perform work duties without intoxicating influences. During fiscal year 1975, the program determined that 219 employees had a serious alcohol problem; served 170 employees; and provided counseling to an additional 75 employees. ARMCOM determined that $175,000 was saved in the third and fourth quarters of fiscal year 1975 because of restored job efficiency (NARA RG 544 Historical Office, US Army Armament Command 1976:49-50).

6.5 Source of Employees

In areas of the country that lacked industry, ammunition plants and related facilities were major employers. For example, Radford AAP in southwestern Virginia, built in 1940 to manufacture smokeless powder, provided ample opportunities for employment in a region still suffering from the lingering effects of the Depression, and was the largest employer in the surrounding New River Valley during the Cold War. The plant even had characteristics of a self-sufficient municipality, such as its own infrastructure, a large land base, and a federal mission independent of local influence. According to a 2001 anthropological study of the plant's impact on the region, "everyone has family members or neighbors who worked at the arsenal" (La Lone and Hartle 2001:viii, 2).

The plants drew workers based on other economic opportunities available and their ability to travel and move to the region. During World War II, most Radford workers came from the New River Valley and nearby areas of western Virginia and West Virginia, but after the war, workers commuted from farther distances, including Tennessee, Kentucky, and North Carolina. Workers who did not move to the area commuted via the bus or train (La Lone and Hartle 2001:28, 32).

Plant workers were predominantly male. When men returned after military service, women faced challenges obtaining and keeping non-clerical plant jobs well after World War II, but remained part of the workforce. At Radford, women worked on production lines and in sewing and bagging, but not in traditionally male jobs such as welder or machinist. During periods of low production, maternity leave was not provided because the need for workers was not as great (La Lone and Hartle 2001:38).

One indication that the industry was increasingly welcome to women later in the Cold War was the election of a woman, Pauline Fischer, as president of the China Lake chapter of the American Ordnance Association (AOA) in 1972. She was the first woman president of a chapter in the organization's history. Fischer owned an electronic component distribution company that worked with military installations in California and Nevada. At that time, she was a life member of the AOA and previously had been the chapter's vice president and director (*Ordnance* magazine 1972:156). Meanwhile, the 1970 study of the impact of Kansas AAP contained many comments about the plant from female employees. Biographical information provided in the report indicated that these women were numerous, represented a variety of family structures (though most had children), and held various types of positions. Occupations included inspector, production worker, and clerical worker (Macy et al. 1970:146-56).

During the 1970s, ARMCOM monitored the percentage of female employees in its workforce to ensure it was complying with the Equal Opportunity Program. According to a fiscal year 1975 annual report, female employment at ARMCOM Headquarters increased from 11.7 percent of positions at the GS-8 level and higher on 30 June 1974 to 14.7 percent a year later representing an increase of 65 employees (NARA RG 544 Historical Office, US Army Armament Command 1976:xvii).

Minority workers had limited employment opportunities, but their options gradually grew, particularly after federal civil rights laws of the 1960s forced employers to end discrimination. At Radford, a black worker interviewed as part of an anthropology project focusing on the plant said that he faced prejudice during his work as a laborer, but that plant management knew it hampered operations and that he was treated more fairly as he advanced. Eventually, he supervised a work force that included 29 white employees (La Lone and Hartle 2001:40-1).

ARMCOM also monitored the percentage of minority employees. The fiscal year 1975 annual report noted that the command employed a percentage of minorities equal to or exceeding that of the community nearest the installation. Nationwide, minorities represented 9.4 percent of the ARMCOM workforce, compared with an overall population of slightly below 9 percent. In addition, even though total employment was decreasing, minority representation in higher grades increased. During that year, the number of minorities increased from 60 to 64 for GS-13 positions, from 17 to 21 for GS-14 positions, and from 2 to 4 in GS-15 positions (NARA RG 544 Historical Office, US Army Armament Command 1976:xvii). Besides the Equal Opportunity Program, the Armament Command maintained a Race Relations Program intended "to promote understanding and an appreciation of the cultural and ethnic heritages of the people who made up the work force of the government" (NARA RG 544 Historical Office, US Army Armament Command 1976:19, 50).

Workers who worked in plants that manufactured and stored explosives or materials containing explosive components were at least 18 years old. The United States Department of Labor prohibited people younger than 18 from working in these facilities, with the exception of small-arms ammunition facilities that manufactured ammunition smaller than 60 caliber. However, 16- and 17-year-olds were allowed to work in non-explosives areas of facilities in non-explosives handling occupations (NARA RG 156 US Department of Labor 1952). ARMCOM employed students throughout the command during the summer. The 1974 Summer Employment Program employed a total of 526 "needy youth" and 149 "merit students" (NARA RG 544 Historical Office, US Army Armament Command 1976:23). During the ammunition production base modernization programs of the 1970s, some plant positions were upgraded to attract personnel qualified to maintain more technologically advanced equipment such as engineering graduates (NARA RG 544 Historical Office, US Army Armament Command 1976:xiii).

6.6 Reaction of Local Communities

Communities had various reactions to the presence of ammunition production plants. The influx of workers to ammunition plants brought economic development to entire communities. Government and private housing were built to accommodate ammunition plant workers; skilled and unskilled workers were needed to build the housing. Businesses were begun or expanded to provide such services as food and entertainment. However, spending on infrastructure also was necessary to provide such services as water, hospitals, and libraries. One example of a plant both bringing economic development and requiring infrastructure spending was Radford AAP, where the vicinity was predominantly rural before the plant was built (La Lone and Hartle 2001:32-4). During construction of the Radford Ordnance Works in 1941, employment peaked at over 23,000 workers. Housing shortages forced some workers to rent chicken houses, attics, and even back porches; shift work allowed several men to share the same bed. Commuters caused traffic jams and local railroads added extra trains at peak travel times. Water consumption nearly doubled and both the school system and police force were strained by the number of newcomers (Neville and McClane 1996:67-69). To alleviate these conditions, over 700 new housing units were constructed, the road system expanded, and the water system enlarged. Federal funds were used to construct a new hospital and community recreation building (Neville and McClane 1996:82-83). Although the boomtown effect subsided once the plant began operations, permanent employment at the ammunition plant added over 6,000 jobs to the local economy (Neville and McClane 1996:85). Some businesses in southeast Kansas near Kansas AAP noted negative impacts on them, including decreases in the labor pool and the customer base. In the 1970 study, various employers noted that they could not compete with the plant's salaries, while a bar and café owner said he had to close between noon and 3 p.m. because many of his afternoon customers had gotten jobs at the plant (Macy et al. 1970:139).

6.7 Safety

The Army took steps to ensure the safety of the communities surrounding the plants and the ammunition plant workers inside the gates. The Army attempted to locate ammunition plants on extremely large parcels of land in order to protect the surrounding communities from explosions or releases of toxic materials. The Army's organizational structure included safety offices whose missions were to ensure that the plants operated with minimal risk to employees, equipment, and property (NARA RG 544 Historical Office, US Army Armament Command 1976:109). During fiscal year 1975, the ARMCOM safety office oversaw safety programs through four divisions that included load-assemble-pack, manufacturing, chemical, and radiation and nuclear (NARA RG 544 Historical Office, US Army Armament Command 1976:110).

Local communities also reacted to safety issues dealing with the proximity of an ammunition plant. By the early 1950s, all states and many municipalities enacted laws that regulated the transportation of explosives through their jurisdictions. After a private-sector freight operator asked the Office of the Secretary of Defense Military Traffic Service to evaluate an explosives ordinance being considered by the City of Indianapolis in 1952, the four services agreed to monitor the passage of other such ordinances elsewhere in the country. Military transportation officials wanted to determine the effect of these regulations on military transportation routes (NARA RG 156 Office of the Chief Chemical Officer 1950:6; NARA RG 156 Vore 1952).

Equipment malfunctions, design defects, and employee errors led to explosions, but resulted in improvements throughout the ammunition production base. For example, an explosion occurred at one plant, which housed TNT nitration and purification activities. The explosion disabled 16 employees and caused $12 million in damage. Following a Board of Investigations evaluation, dynamic separators were considered for part of the reconstruction of the B and C lines. Dynamic separators were a major improvement over the older gravity separators in that the volatile components of the TNT manufacturing process were continually removed and only small quantities were present at any given time. The TNT lines at the plant were reconstructed with new separators, and this change was also made to the continuous TNT processes at other facilities. The explosion likely influenced future changes in such areas as distance siting and hazard analyses (NARA RG 544 Historical Office, US Army Armament Command 1976:112).

Ammunition plants were required to implement the Occupational Safety and Health Act of 1970, which established national safety and health standards in industrial, manufacturing, and construction industries. A safety survey of ARMCOM installations was completed in 1975 (NARA RG 544 Historical Office, US Army Armament Command 1976:113).

6.8 Environmental Consequences of Cold War Era Ammunition Production

In addition to munitions, ammunition production plants also generated air and water pollution. During the 1950s and 1960s, the Army focused on controlling pollution and limiting its spread after generation. A 1968 report on facility modernization suggested installing state-of-the-art building features to prevent pollution. The high initial costs of making these changes would be recouped, the report stated, because preventing pollution would be cheaper than controlling it

(NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:6). Modernization was anticipated to reduce pollution at all government-owned ammunition plants by 90 to 98 percent (NARA RG 544 Army Ammunition Procurement and Supply Agency 1969). For example, existing nitric acid plants produced 3,000 parts per million of nitrous oxides, while new plants equipped with pollution prevention devices produced only 100 parts per million, a 97 percent reduction (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:25).

The 1968 modernization program called for pollution abatement measures to be implemented at existing plants in the areas of industrial waste disposal, air pollution abatement, waste acid neutralization, fuel conversion, and sanitary waste disposal. New facilities were to include air and water pollution prevention measures as part of the design (NARA RG 544 Army Ammunition Procurement and Supply Agency 1968:22-3). Pollution prevention also was a focus of later modernization programs.

The ARMCOM Environmental Quality Office reported in fiscal year 1975 that all water quality monitoring programs met all National Pollutant Discharge Elimination System (NPDES) requirements contained in the Water Pollution Control Act of 1970 (NARA RG 544 Historical Office, US Army Armament Command 1976:241).

As facilities were declared excess during the late Cold War period, the Army faced the challenge of addressing problems with contamination in buildings and on land. For instance, buildings at a plant, which was declared excess in fiscal year 1974, were highly contaminated because the plant had produced single-based propellant and other explosives. At first, the Army intended to burn the buildings and decontaminate the property to government standards. However, because insufficient funding was available to complete both tasks, the buildings were burned but the decontamination was deferred with the intent of making it the purchaser’s responsibility (NARA FR 544 Historical Office, US Army Armament Command 1976:243-4).

Table 6.1 Production Missions at Army Active GOCO and GOGO Plants in 1982

Materials produced	Scranton AAP	Mississippi AAP (under construction)	Crane AAA**	Hawthorne AAP**	Holston AAP	Indiana AAP	Iowa AAP	Kansas AAP	Lake City AAP	Lone Star AAP	Longhorn AAP	Louisiana AAP	McAlester AAP	Milan AAP	Pine Bluff Arsenal	Radford AAP	Riverbank AAP
Metal parts—155mm projectile		XXX										XXX					
LAP* 155mm projectile		XXX					XXX	XXX		XXX		XXX					
LAP cluster bomb units			XXX	XXX				XXX					XXX	XXX			
LAP bombs			XXX	XXX									XXX				
LAP warheads			XXX	XXX													
LAP fuzes			XXX							XXX		XXX		XXX			
LAP propelling charges			XXX	XXX		XXX							XXX				
LAP pyrotechnics			XXX								XXX						
LAP rockets				XXX						XXX		XXX	XXX				
LAP fuel air explosives				XXX													
Composition A					XXX												
Composition B					XXX												
Composition C					XXX												
RDX					XXX												
HMX					XXX												
Composition A-3					XXX												
Composition B-3					XXX												
Single-base propellant						XXX										XXX	
Double-base propellant																XXX	
Triple-base propellant																XXX	
Propellant charge bags, liners						XXX											
LAP 90mm projectiles							XXX										
LAP 105mm projectiles							XXX	XXX		XXX							
LAP 240mm projectiles							XXX										
LAP 8-inch projectiles							XXX			XXX							
LAP 60mm mortars										XXX				XXX			

Materials produced	Scranton AAP	Mississippi AAP (under construction)	Crane AAA**	Hawthorne AAP**	Holston AAP	Indiana AAP	Iowa AAP	Kansas AAP	Lake City AAP	Lone Star AAP	Longhorn AAP	Louisiana AAP	McAlester AAP	Milan AAP	Pine Bluff Arsenal	Radford AAP	Riverbank AAP
LAP 81mm mortars								XXX		XXX				XXX			
Metal parts production									XXX								
LAP small-caliber ammo									XXX								
LAP .30-caliber ammunition									XXX								
LAP .50-caliber ammunition									XXX								
LAP hand grenades										XXX							
LAP 40mm grenades														XXX			
LAP boosters										XXX		XXX		XXX			
LAP delays										XXX				XXX			
LAP primers										XXX				XXX			
LAP bursters										XXX							
LAP detonators										XXX		XXX					
LAP illumination ammo for artillery, mortars											XXX						
LAP grenade and ground signals											XXX						
LAP rocket motors											XXX						
Composite propellants for rockets, missiles											XXX						
Rocket grains																XXX	
TNT																XXX	
LAP demolition charges												XXX					
LAP mines												XXX		XXX			
LAP rocket warheads												XXX					
LAP 106mm recoilless tank projectiles														XXX			

Materials produced	Scranton AAP	Mississippi AAP (under construction)	Crane AAA**	Hawthorne AAP**	Holston AAP	Indiana AAP	Iowa AAP	Kansas AAP	Lake City AAP	Lone Star AAP	Longhorn AAP	Louisiana AAP	McAlester AAP	Milan AAP	Pine Bluff Arsenal	Radford AAP	Riverbank AAP
LAP 105mm tank projectiles														XXX			
White phosphorus, smoke															XXX		
LAP smoke- and white phosphorus-filled artillery rounds, grenades, rockets															XXX		
Metal parts—ICM grenades																	XXX
Metal parts—60mm mortars																	XXX
Metal parts—81mm mortars																	XXX
Metal parts—projectiles																	XXX
Metal parts—105 mm cartridge cases																	XXX
Metal parts—155mm artillery	XXX																
Metal parts—175mm artillery	XXX																
Metal parts — 8-inch artillery	XXX																

*LAP means load-assemble-pack
**Also produced Navy ammunition components not identified here

Source: Department of the Army 1982:49-54

7.0 THE ORDNANCE DEPARTMENT AND THE CREATION OF THE ARMY MATERIEL COMMAND

7.1 Introduction: Organization at the End of World War II

Previously independent of each other, the Ordnance Department, the Chemical Corps, and the Army's other technical services temporarily were placed under one department, the Services of Supply, renamed Army Service Forces, in 1942. This reorganization represented a substantive shift in Army administrative structure, from a decentralized model of independent bureaus that each focused on producing one commodity, called a commodity structure, to a centralized model in which similar functions were grouped under one organization, called a functional structure. The change represented another turn in a debate over Army structure that had begun during the early twentieth century, when presidents Theodore Roosevelt and William H. Taft attempted to improve government efficiency by structuring it on a business model. At that time, the Dodge Commission recommended that the War Department reorganize supply functions under one department. Those who favored centralization wanted to eliminate inter-bureau competition and duplicative functions across bureaus, such as budget staffs (Kane 1995:64-5).

Reflecting the continuing debate, the Army Service Forces was eliminated in 1946, and the pre-World War II bureau structure was restored. Although the technical services had some level of collaboration with the Director of Service, Supply, and Procurement and the other five members of the Army General Staff, the technical services reported to the Chief of Staff (Hewes 1975:159). The bureau chiefs had resisted the organizational change because it reduced their authority and independence. However, steps were taken gradually to change the Army structure to a centralized form (Kane 1995:66).

7.2 Post-World War II Reorganizations

Laws and Army rules passed during the immediate post-World War II period increased the centralization of the Army and the technical services. The National Security Act of 1947 shifted all of the country's military branches from independent organizations reporting directly to the president, as they had been since the country's beginnings, to coequal branches grouped under a central agency. The Act consolidated the Army, the Navy, and the newly independent Air Force under the National Military Establishment, headed by the Secretary of Defense (the Marines remained within the Navy structure). A 1949 amendment changed the agency's name to the Department of Defense. Each military branch was headed by a civilian secretary who reported to the Secretary of Defense. Previously, the War Department and the Navy operated autonomously from each other; the Army operated the air branch, and the Marines were located within the Navy.

Following the 1946 reorganization that restored the technical services, Army staff issued an organizational chart in March 1948 that reflected a merger between the Director of Service, Supply, and Procurement and the Director of Research and Development to form a Director of Logistics, but preserved the direct link between the technical services and the chief of staff. (Hewes 1975:173). In November 1948, another revised organizational chart indicated that the Director of Logistics had direct authority over the technical services and maintained a parallel link with the Assistant Secretary of the Army responsible for procurement. However, the technical services continued to function separately, and some of their functions were overseen by the other directors at the general staff level. The Director of Logistics informed the technical services they could continue to function autonomously (Hewes 1975:190-3). An Army special regulation issued in April 1950 preserved that structure, but changed some titles. The Director of Logistics was now Assistant Chief of Staff for

Logistics, one of four assistant chiefs at the general staff level, and the procurement-focused Assistant Secretary of the Army now was the Assistant Secretary of the Army for Materiel (Hewes 1975:206).

The Army Organization Act of 1950 added real authority to the paper authority by changing the statutory basis for the technical services. The Act "gave the Secretary of the Army the authority to reassign duties of statutory agencies; in other words, the power to reorganize the technical services if he so wished" (Kane 1995:66). In 1952, indicating the short future for the technical services, the Secretary of Defense said that a reorganization of the technical services would be painful but was "long overdue" (Kane 1995:66).

7.3 Ammunition Production and Storage Organization 1950-1954

Having survived the reorganization efforts during the immediate postwar period, the Ordnance Corps structure retained the basic form that had been in place since post-World War I reorganizations reduced bureaucracy by consolidating similar functions (the Army Organization Act of 1950 changed the organization's name from Ordnance Department to Ordnance Corps) (NARA RG 156 Ordnance Corps Survey 1952a:2-4; Sterling 1987:2, 5). According to this basic form, even though some departments merged or separated and some job titles changed, the main functions of the Ordnance Corps remained production, procurement, and storage of ordnance, and research and development on ordnance. The term "ordnance" included ammunition, explosives, bombs, rockets, and guided missiles, as well as weapons, artillery, and combat vehicles (NARA RG 156 Ordnance Corps Survey 1952a:6, 10; NARA RG 156 Ordnance Corps Survey 1952b:5).

The Industrial Division oversaw ordnance production and procurement. The Field Service Division oversaw ordnance storage, maintenance, and repair. The Research and Development Division, known before World War II as Technical Staff but renamed during the war, oversaw ordnance research and development. The division heads were Assistant Chiefs of Ordnance. The Personnel and Training Division represented a fourth division, but whether an Assistant Chief of Ordnance led it is not clear (NARA RG 156 Ordnance Corps Survey 1952c:Tab D).

Within the Industrial Division were the Ordnance Ammunition Center (OAC), the Ordnance Small Arms Ammunition Center (OSAAC), and the Ordnance Tank Automotive Center (OTAC), known as Commodity Centers; manufacturing arsenals and plants that produced missile components, tanks, and other ordnance, and participated in ordnance procurement; and fourteen ordnance districts, nationwide geographic divisions that oversaw ordnance procurement. These branches of the Industrial Division oversaw plants and facilities that pertained to their missions (NARA RG 156 Ordnance Corps Survey 1952c:Tab D; NARA RG 156 Ordnance Corps Survey 1952b:4-5).

Ordnance procurement orders originated from the Office, Chief of Ordnance (OCO) to the three Commodity Centers, the manufacturing arsenals, and other installations with national stock-control missions (NARA RG 156 Ordnance Corps 1952:12). However, the Ordnance Corps practiced a policy of centralized control and decentralized operations, in which upper management in Washington, D.C. gave overall guidance through job definitions, standards, funding, personnel, training and evaluation, but the day-to-day work was distributed throughout the organization structure (NARA RG 156 Ordnance Corps 1952:6, 8).

Most ammunition production was overseen by the OAC, located in Joliet, Illinois. Established in 1951, the OAC was responsible for "mass production of standard Army ammunition other than small arms, including propellants, explosives and chemicals; supervision of renovation and demilitarization of all ammunition; supervision of certain ammunition modification;" and "the coordination and direction of procurement of components" (NARA RG 156 Ordnance Ammunition Center 1951; NARA RG 156 Snodgrass 1953:3-4). As of 1952, the OAC oversaw 23 ammunition production plants and related facilities. The OAC's mission also included procurement (NARA RG 156 Ordnance Corps Survey 1952c:Tab D; NARA RG 156 Ordnance Corps Survey 1952b:4). The OSAAC, located in St. Louis and also established in 1951, handled production of small-arms ammunition. As of 1952, it supervised three plants (NARA RG 156 Ordnance Corps Survey 1952c:Tab D; NARA RG 156 Ordnance Corps Survey 1952b:4; NARA RG 156 Snodgrass 1953:3-4).

Government-owned, contractor-operated (GOCO) plants manufactured powder and explosives. Private industry manufactured the majority of non-hazardous components of ammunition, but some GOCO plants manufactured metal components (NARA RG 156 Ford 1953b:1; NARA RG 156 Ford 1953a:4). Finished ammunition was assembled at GOCO and government-owned, government-operated (GOGO) loading and assembly plants (NARA RG 156 Ford 1953a:4).

The majority of Army ammunition and other types of ordnance was obtained through procurement from private industry, rather than through production at government-owned manufacturing arsenals and plants. Commodity Centers, arsenals, and national stock control points submitted ordnance requests to the fourteen ordnance districts. The district offices obtained proposals; negotiated, executed, and administered contracts; and determined supplier capabilities (NARA RG 156 Ordnance Corps 1952:16).

The Field Service Division oversaw storage of ammunition and related components. It included 25 depots and shops and five sub-depots. The Chief of the Field Service Division controlled operation of the six national stock control points, regardless of their locations (NARA RG 156 Ordnance Corps Survey 1952c:Tab D). The ammunition supply branch was organized by commodity, while other supply branches were organized functionally, i.e. focused on supplying all parts to a product at the same time, such as a gun that included spare parts and fire control equipment (NARA RG 156 Snodgrass 1953:9). There were three types of depots: distribution depots serving a port or geographic area; commodity depots storing specified classes of supplies in support of distribution depots; and back-up or reserve depots supporting the commodity depots by storing equipment in bulk (NARA RG 156 Snodgrass 1953:9).

The Research and Development Division directed research and development of "new and improved ordnance materiel and materials" and coordinated the guided missiles program (NARA RG 156 Ordnance Corps Survey 1953b). It oversaw Aberdeen Proving Ground, White Sands Proving Ground, Redstone Arsenal, and the Office of Ordnance Research (NARA RG 156 Ordnance Corps Survey 1952b:Tab D).

The Chemical Warfare Service (CWS), too, survived post-World War II reorganizing. Formed as a temporary wartime organization in 1918 to consolidate offensive chemical production, defensive equipment production, training, testing, and basic research, the Chemical Warfare Service was made permanent in 1920 (Smart 1997:13, 22). Following post-World War I demobilization, the CWS grew during World War II in personnel and facilities, but underwent substantial cuts after World War II and faced elimination. One observer at this time called gas warfare "obsolete" (Smart 1997:45). However, the chief of the CWS convinced an Army board in charge of postwar organization that the agency should be retained. Not only was it retained, but it was elevated to corps level, and its name was changed to the Chemical Corps in 1946. The Chemical Corps' mission included chemical and biological research and development, radiological protection, and production of nerve agent weapons and associated detection and decontamination equipment (Smart 1997:45).

7.4 Ammunition Production and Storage Organization -- Korean Conflict

The Ordnance Corps's focus during this period was on supplying ammunition and other ordnance to military forces in Korea. Other priorities were supplying ordnance to other countries as required under the Mutual Defense Assistance Program and maintaining a mobilization reserve (NARA RG 156 Snodgrass 1953:1). The Ordnance Corps faced the challenge of meeting these needs with reduced supplies and facilities as a result of post-World War II demobilization.

As a result of these demands, according to an events summary of fiscal year 1953, the Ordnance Corps faced "many challenging problems in the field of organization, personnel, and management" during this period. General James A. Van Fleet, former commander of the Eighth Army in Korea, told the Senate Subcommittee on Ammunition Shortages in 1953 that there were "serious and at times critical" ammunition shortages during his 22-month command (NARA RG 156 Snodgrass 1953:102). Of particular concern was whether the Ordnance Corps could serve its missions under its current structure in the event of full mobilization for a larger conflict (NARA RG 156 Snodgrass 1953:3).

Meanwhile, in the wake of the high cost of the Korean conflict, Department of Defense efficiency became an issue in the 1952 presidential campaign. The Secretary of the Army consulted businessmen who said the Ordnance Corps plan of partial decentralization resulted in "divided authority and responsibility," and recommended "true" decentralization. However, the Chief of Ordnance found only one instance of delay in ordnance procurement caused by divided authority. He argued that the organization and its procedures were not problematic but merely confusing to outsiders because of the vastness and complexity of its operations. Some changes were needed, he said, but substantial changes would paralyze operations (NARA RG 156 Snodgrass 1953:5, 11).

To solve these problems, the Chief of Ordnance had taken several actions during the conflict to improve efficiency. These actions centered around streamlining the structure and decentralizing some operations. The OAC and the SAAC were formed to decentralize ammunition production operations, and national stock control and maintenance points were established to decentralize depot and supply functions (NARA RG 156 Snodgrass 1953:4, 9). Personnel costs were reduced when contractors resumed operation of some plants and storage facilities, as in World War II, and the contractors absorbed the personnel costs (NARA RG 156 Snodgrass 1953:12). A Depot Realignment Plan begun in May 1952 distributed responsibilities more broadly across the depot system, particularly so distribution depots could accomplish their missions (NARA RG 156 Snodgrass 1953:27). A proposal to decentralize the Research and Development, Industrial, and Field Service divisions by moving them out of Washington was rejected (NARA RG 156 Snodgrass 1953:103-4).

Some military leaders disagreed with aligning the military with a business model because their military had goals that differed from business organizations, as summarized in the fiscal year 1953 summary of Ordnance Corps events and problems:

> War is definitely an uneconomical operation, in which it would seem extremely difficult to achieve the economy possible when most factors are controllable. Hence, defense, and economy as defined in private industry, might not be compatible. In war, success is not measured in dollar profits, but rather by the speed and degree of effectiveness of supply in response to troop needs. Traditionally, American Army commanders have called for guns and ammunition to control the expenditure of lives. It would take time before the success of business concepts, as applied to defense management, could be determined (NARA RG 156 Snodgrass 1953:5, 12).

Similarly, in 1952. Lt. Gen. L.B. Palmer, the Assistant Chief of Ordnance for Supply, praised the Ordnance Corps's mobilization and expansion effort for the Korean conflict despite reduced resources as a result of post-World War II demobilization. "Their machinery is running soundly and is in no danger of collapse," he said (NARA RG 156 Snodgrass 1953:103).

The Senate subcommittee investigating the allegations of ammunition shortages disagreed. In a preliminary report issued in May 1953, the subcommittee asserted that the ammunition procurement system "indicated unconscionable inefficiency, waste, and unbelievable red tape." Testimony indicated that some procurement documents traveled more than 10,000 miles and sat on 154 desks before a contract was let, and that the time between appropriation and ammunition delivery was 24 months. The ammunition shortage had caused "a needless loss of American lives" (NARA RG 156 Snodgrass 1953:50). However, in a second report in August, the subcommittee reported that "steady progress" had been made in increasing ammunition stockpiles (NARA RG 156 Snodgrass 1953:50).

Meanwhile, the Chemical Corps faced the opposite problem. "The corps quickly implemented an increased procurement program to supply the army with a retaliatory chemical capability and defensive equipment," but these weapons were not used because of a U.S. policy against first use of chemical weapons and a lack of use by North Korean and other enemy forces (Smart 1997:49). Instead, the Chemical Corps supported the Army by providing other weaponry, such as those using smoke and flame (Smart 1997:49). The Chemical Corps already had shifted from a combat arm to a combat support arm after losing its high-visibility ground weapon, the 4.2-inch chemical mortar, in 1947. The Ordnance Department was given responsibility for all 4.2-inch mortars, including research, development, procurement, storage, issue, and maintenance, leaving the Chemical Corps with responsibility for chemical fillings for mortar shells (Smart 1997:49).

7.5 Ammunition Production and Storage Organization 1954-1962

The Army's ammunition production and storage structure continued to receive attention in response to supply problems identified during the Korean conflict. The Army continued attempts to control the Ordnance Corps and the other technical services as part of its effort to increase the efficiency of its supply system. Reflecting several years of reorganization proposals and committee studies, the Army staff was reorganized during the mid-1950s. The reorganizations were the strongest move yet toward increased authority over the technical services. In addition, to make use of advances in weapons technology and update the Army's World War II-era weapons and tactical doctrines, a need identified during the Korean conflict, the reorganizations removed research and development functions from the procurement and supply services (Hewes 1975:217).

In September 1954, a change to the 1950 special regulation removed the rest of the general staff from direct responsibility over the technical services, and appointed a Deputy Chief of Staff for Logistics with direct command over the technical services that was more strongly articulated than in previous reorganizations. John Slezak, Secretary of the Army, stated that the purpose of the reorganization:

> is to combine the seven technical services into an integrated logistical system, subordinating the Chiefs of Technical Services to the head of this system and giving him authority to modify the respective Technical Service missions in order to achieve one integrated system in place of seven autonomies. Accordingly, it is intended that wherever the authority granted the Deputy Chief of Staff for Logistics involves transfer to him of authority heretofore exercised by other parts of the Army staff, the extent of the transfer shall be

interpreted so as to insure that the Deputy Chief of Staff for Logistics can carry out the objectives set forth [above] (Hewes 1975:233-4).

A 1955 revision more clearly stated the comprehensive authority of the Deputy Chief of Staff for Logistics position. The officeholder possessed Department of the Army staff responsibility for "development and supervision of an integrated Army logistics organization and system, including all controls over policies, procedures, and personnel which are essential to the discharge of this responsibility" (Hewes 1975:235).

Subsequent reorganization proposals reflected a debate over whether the Deputy Chief of Staff for Logistics should stay involved in operations or focus on logistics planning, and whether an entirely new organization should be formed that eliminated the technical services altogether. The next Army reorganization, effective 3 January 1956, retained a Deputy Chief of Staff with authority over the technical services, reporting to the Assistant Secretary of the Army for Logistics (Hewes 1975:239-40). No further reorganization of the Army occurred until Robert F. McNamara was appointed Secretary of Defense in 1961 (Hewes 1975:241).

The Ordnance Corps, however, continued to examine its structure to ensure optimum efficiency, particularly as it faced the prospect of declining budgets and fewer employees following the Korean conflict. During fiscal year 1957, it completed a Corps-wide integrated system of programming, budgeting, and analysis known as the Ordnance Command Management System. Ordnance Corps procurement and supply procedures and policies also were scrutinized from the outside, by Congressional committees, the Bureau of the Budget, and defense and Army agencies (NARA RG 544 Snodgrass 1957:3-4).

During the late 1950s, the Ordnance Corps structure included three Assistant Chiefs of Ordnance who oversaw the organization's largely unchanged major functions: the Research and Development, Industrial, and Field Service divisions. Two other department heads – Chief, Office of Manpower, and Chief, Office of Program Coordination – were given Assistant Chief status in 1956. Its approximately 125 installations and activities included: 3 commodity commands, renamed from commodity centers and including the Ordnance Ammunition Command, the Ordnance Tank-Automotive Command, and the Ordnance Weapons Command; 4 proving grounds; 14 ordnance districts; 8 manufacturing arsenals; 20 depots; 26 active plants and works; 25 inactive plants and works, and 20 other facilities and activities (NARA RG 544 Snodgrass 1957:4b, 5-6).

Various internal reorganizations occurred during this period to place a new focus on guided missiles and other special weapons and continue improving efficiency. For example, at the end of fiscal year 1957, there were plans for the Industrial Division to eliminate its three civilian executives and appoint two special consultants, one for artillery, vehicles, and infantry systems, and the other for guided missile and aircraft armament systems (NARA RG 544 Snodgrass 1957:7). North Storage Activity at Seneca Ordnance Depot was established in 1956 to meet storage needs for special weapons (NARA RG 544 Snodgrass 1957:9).

Another significant efficiency-related event, resulting from the post-Korean conflict slowdown in ammunition procurement and supply, was the closure of several ordnance installations and development of plans to close additional facilities. Lordstown Ordnance Depot was redesignated Lordstown Storage Activity and then closed; Volunteer and Wabash River Ordnance Works also were closed. Inactivation plans were approved for Aberdeen Ordnance Depot, Delaware Storage Activity, Curtis Bay Storage Activity, and Camp Stanley Storage Activity. Gopher, Cactus, and Morgantown Ordnance Works, Gulf Ordnance Plant, and Maynard Test Station were declared excess; Burlington, Cornhusker, and Kansas Ordnance plants and Volunteer and Wabash River Ordnance works were placed on standby (NARA RG 544 Snodgrass 1957:8-9).

The Chief of Ordnance focused during this period on “centralized control and decentralized operations.” The Ordnance Board conducted a study of an organizational structure for the future. It favored extending the command structure to include an Ordnance Missile Command, a Research and Development Command, and a Procurement Command, and removing control functions from the Office of the Chief of Ordnance staff, leaving it to handle planning, monitoring, and appraising (NARA RG 544 Snodgrass 1957:11). However, a new emphasis also was placed on contact between Office of the Chief of Ordnance personnel and field personnel regarding procurement and production, “toward an effort to better acquaint field personnel with current policies and objectives, and to acquaint OCO personnel with current field operating problems” (NARA RG 544 Snodgrass 1957:75).

Several other organizational changes were made. Two new management positions reported to the OCO, one to assist managers of commands and arsenals and the other to provide advice on nuclear weapons. The Special Assistant for Commands and Arsenals, appointed in March 1959, provided managers of commands and arsenals an OCO representative to assist them with management problems the Chief of Ordnance did not have time to handle. The Special Assistant for Nuclear Applications, appointed in August 1959, assisted and advised the Chief of Ordnance “in all matters pertaining to Ordnance application of nuclear energy” (NARA RG 156 Snodgrass 1961:9-10).

Two field organizations became operational during fiscal year 1960. The Ordnance Special Weapons-Ammunition Command, established at Picatinny Arsenal in New Jersey, provided atomic munitions and items of conventional ammunition to the tactical forces. The U.S. Army Ordnance Industrial Data Agency, located near Radford Arsenal in Virginia, gathered nationwide data on ordnance industrial capabilities and managed the Ordnance Industrial Central Records Repository (NARA RG 156 Snodgrass 1961:15).

By mid-1960, the Ordnance Corps comprised 123 field installations and activities, which consisted of eight arsenals, eleven district procurement offices, twenty depots, five commodity commands, one training command, two proving grounds, a coordination office for basic research, two missile agencies, a technical intelligence agency, an industrial data agency, and several smaller field offices and agencies. These entities oversaw approximately 70 other field organizations, including ordnance plants and works, storage activities, industrial facilities, and Ordnance sections of general depots (NARA RG 156 Snodgrass 1961:12-13).

7.6 Transition to Army Materiel Command

The technical services were eliminated in 1962 as the result of a study of the Department of the Army instigated by Secretary of Defense Robert S. McNamara, called Project 80 or Study of the Functions, Organization, and Procedures of the Department of the Army (Kane 1995:66; Hewes 1975:316).

A result of the Project 80 study was the creation of the Army Materiel Command (AMC), assigned the mission of “the life cycle management of materiel from concept through research and development, procurement and production, supply, distribution and maintenance, and finally, into disposal” (Kane 1995:66). Materiel included not only conventional and chemical ammunition, but also other commodities such as weapons and general supplies. The offices of most technical services chiefs were eliminated, including the chief of ordnance and the chief chemical officer.

Responsibility for their various functions – both primary functions and auxiliary functions such as personnel management – was distributed among the Army Materiel Command and other Army departments and commands (Kane 1995:66).

While the change represented a loss of autonomy for the technical services, it also represented increasing prominence for Chemical Corps activities. Project 112, a study concurrent with Project 80, evaluated the chemical and biological weapons program and concluded that the program needed more emphasis and greater long-term funding. Defense Secretary McNamara, agreeing with the conclusions of Project 80, said that the "knowledge, experience, and training" of the Chemical Corps in particular was not circulating throughout the Army. McNamara wanted to end the structural separation of the Chemical Corps from the rest of the Army (Smart 1997:58).

The AMC used both functional and commodity forms of organization. Functional commands within AMC were the Supply and Maintenance Command and the Test and Evaluation Command; commodity commands were the Electronics Command, Missile Command, Munitions Command, Mobility Command, and Weapons Command (Kane 1995:66).

The Army Materiel Command assumed responsibility from the chief of ordnance for eight arsenals, four proving grounds, nineteen depots, five depot activities, one laboratory, eleven procurement district offices, seventeen active plants and works, twenty-one inactive plants and works, nine excess plants and works, three industrial equipment storage sites, four commodity commands, one tank modification center, and ten other activities (Kane 1995:66). Appropriation and construction authorization laws passed during this period indicated that ammunition-related facilities were located within the Missile Command, the Munitions Command, and the Test and Evaluations Command.

7.7 Organization of Ammunition Production and Storage during the Vietnam Conflict and Late Cold War Eras

In contrast to organizational changes made for the Korean conflict, such as the formation of the Ordnance Ammunition Center to oversee ammunition production and procurement, the ordnance organization did not appear to change substantially during the Vietnam conflict.

The end of the war nearly brought an end to the Chemical Corps. After peace treaties were signed in 1973 and the draft ended, the Army recommended reducing the size of the Chemical Corps and merging it with the Ordnance Corps (Smart 1997:70). Previously, in 1969, President Richard M. Nixon reaffirmed the policy against first use of chemical weapons, renounced biological weapons and restricted research to biological defense (Smart 1997:68-9). The Chemical School at Fort McClellan, Alabama, was combined with the Ordnance School at Aberdeen Proving Ground, Maryland, but Congress blocked the dismantling of the corps (Smart 1997:70). The secretary of the Army decided to preserve the Chemical Corps in 1976, believing that the Soviet Union was increasing its chemical warfare capability. The unsuccessful effort to form a chemical weapons ban agreement with the Soviet Union played a role in the re-establishment of the Chemical School at Fort McClellan in 1979 (Smart 1997:71).

AMC was reorganized during the early 1970s to accommodate cutbacks in the number of federal employees and the reduction in the Army as the country's involvement in Vietnam wound down. Several commodity commands within the Army Materiel Command were consolidated in 1973 as part of the Army reorganization of that year and two reorganization projects, Total Optimum Army Materiel Command (TOMAC) and the Department of the Army's Baseline Development and Utilization Planning Project (CONCISE). As part of this reorganization, the Munitions Command

and the Weapons Command were consolidated into the Armament Command (Army Materiel Command Historical Office 2007a).

The Army Materiel Acquisition Review Committee (AMARC) was charged to study ways to further improve AMC's efficiency as federal cutbacks, consolidations, and base closures continued. The industry-heavy committee's recommendations focused on decentralization by reducing the number of managers and aligning the organization more closely with a business structure, so that managers throughout the organization had more individual freedom. One result was that AMC was renamed the U.S. Army Materiel Development and Readiness Command (DARCOM) on 23 January 1976, a name retained until 1 August 1984 (Kane 1995:67; Army Materiel Command Historical Office 2007a; Army Materiel Command Historical Office 2007b). The name change was intended to "symbolize the change to a more corporate structure" (Army Materiel Command Historical Office 2007b).

Another result was an increase in commands. Depot functions were decentralized through the establishment of the Depot System Command (DESCOM) on 1 September 1976 (Army Materiel Command Historical Office 2007b). The number of commodity commands increased from six in early 1976 to eleven by the end of the year, and totaled thirteen by January 1979 (Army Materiel Command Historical Office 2007a; Army Materiel Command Historical Office 2007b).

The organizational changes recommended by AMARC had mixed results. Although its emphasis on development caused an increase in development of weapons and other equipment, the decentralization of and increase in commands "split responsibilities, resources, and facilities; required greater coordination of projects; prevented the smooth transition of projects from the R&D to the test and fielding phases; and caused animosity between R&D and logistics support personnel within the DARCOM community" (Army Materiel Command Historical Office 2007a). Between 1979 and 1984, through two efforts, AMARC Revisited and the Resource Self-Help Affordability Planning Effort, commodity commands were reconsolidated and other improvements were made (Army Materiel Command Historical Office 2007a; Army Materiel Command Historical Office 2007b).

By 1984, DARCOM oversaw ten subordinate commands. They included the Armament, Munitions and Chemical Command (AMCCOM), which oversaw 4 arsenals, 29 ammunition plants (15 active and 14 on standby or inactive), and 2 research and development centers; DESCOM, which oversaw 11 depots and 6 depot activities; and the Missile Command (MICOM), which managed all aspects of Army missile systems including air defense, field artillery, and antitank. The other commands included: Aviation Systems Command, Communications-Electronics Command, Tank-Automotive Command, the Troop Support Command, Electronics Research and Development Command, and Test and Evaluation Command (Babers 1984:18).

Further changes were made to return DARCOM to a military structure and away from a corporate structure. In 1984, directorates were renamed deputy chiefs of staff, and the command's name was returned to Army Materiel Command (Army Materiel Command Historical Office 2007b). Other changes were made throughout the remainder of the decade as AMC responded to declining resources, functional changes, structural reviews and evaluations, and Base Realignment and Closure Commission recommendations. One planned change included "consolidation of all AMC industrial activities – depots, ammunition plants, and arsenals – in a new Industrial Operations Command (IOC) at Rock Island Arsenal" (Army Materiel Command Historical Office 2007b).

As of 1993, AMC consisted of six commodity commands and five functional commands and elements. The six commodity commands were: Missile Command; Armament, Munitions, and

Chemical Command; Tank-Automotive Command; Aviation and Troop Command; Chemical and Biological Defense Command; and Communications-Electronics Command. The five functional commands were: Test and Evaluation Command; Depot Systems Command; U.S. Army Security Assistance Command; Army Research Laboratory; and Simulation, Training, and Instrumentation Command (Kane 1995:67).

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APPENDIX A. SUMMARY HISTORIES OF ARMY AMMUNITION PLANTS

1.0 Introduction

This appendix provides brief historical summaries of ammunition plants currently managed by the U.S. Army. Information related to construction, production, periods of inactivity, and status at the close of the Cold War is included. Additional information on these installations is available from the sources listed in the bibliography including in-depth studies completed in conjunction with the preparation of *Historic Context for the World War II Ordnance Department's Government-Owned Contractor-Operated (GOCO) Industrial Facilities, 1939-1945* (Kane 1995), and documentation completed for the Army Materiel Command that is on file at Library of Congress.

2.0 Badger Army Ammunition Plant

The Badger Army Ammunition Plant (BAAP) is located in Sauk County, Wisconsin, and was a complex composed of over 1,400 buildings covering over 7,354 acres. It was founded in 1941 as one of the government-owned, contractor-operated (GOCO) ordnance plants established by the federal government to ready the nation for war. The Badger Ordnance Works (BOW), as it was then called, made rocket propellant (GlobalSecurity.org 2005a). The BOW was put on standby status after the end of World War II (in late 1945) and remained inactive until 1951. During this time, it maintained a small number of government employees (Shaffer and Crown 1996:100).

The plant was reactivated in March 1951, as the conflict in Korea escalated. The Olin Corporation, via their subsidiary, the Liberty Powder Defense Corporation, managed the plant, which once again produced single and double-based rocket propellants and their chemical components (Library of Congress 2007a:28). What distinguished the BOW was its additional contract to produce Western Ball Powder, an innovative smokeless powder that was in high demand during the Korean War. In March 1954, the construction of a new facility to manufacture this ball powder commenced, and was finished in July 1955 (Library of Congress 2007a:29).

The process of manufacturing double-base smokeless ball powder began with a watery, slurry medium which was then transformed into a lacquer form with the integration of solvents and nitrocellulose. The lacquer was then dehydrated and separated into droplets. The solvents were then extracted from the solution, which produced pellets suspended in water; imperfect pellets were then removed through a process of wet screening, while good pellets were then coated, dried, glazed, blended, and finally packaged (Library of Congress 2007a:31). The methods used to produce the ball powder in a semi-liquid state were less volatile and prone to accident, and also the product's viscosity made it easier to transport between stages of manufacture. The process was refined enough to provide a "very precise control of grain size and shape, making for a uniform, predictable propellant." It also greatly increased the rate of manufacture, reducing the total production time to one-fifth the amount it had formerly taken, and thus increased the final net output (Library of Congress 2007a:32).

With the Korean Armistice came the suspension of rocket propellant production, and in March 1958, the BOW was once again put on a standby status, with the Olin Corporation managing its upkeep. In 1963, it was renamed the Badger Army Ammunitions Plant (GlobalSecurity.org 2005a). It remained inactive until early January 1966, when it was again reactivated and Olin Corporation assumed its rocket propellant production duties. The decade between 1966-1975 saw a number of changes in the social climate at BAAP: there were labor disputes among the workers; peaceful protestors against the Vietnam War demonstrated at the plant on a number of occasions; and environmentalism became a priority with the management who initiated numerous clean-up programs during the early 1970s. The failures of certain work-place safety measures were addressed in 1971, and in 1972, a program of modernization was begun at the plant that involved introducing safety improvements, undergoing utility upgrades, and formulating pollution regulations (Shaffer and Crown 1996:102). A number of facilities were renovated and some new structures were erected in this period (Library of Congress 2007a:33). Productivity was good: between 1966 and 1975, the plant had manufactured close to half of a billion pounds of rocket propellant (GlobalSecurity.org 2005a). With the end of the Vietnam War, the plant again became inactive as of June 1975 (Library of Congress 2007a:32). It is still overseen by Olin Corporation, which leased some facilities to various private entities.

3.0 Holston Army Ammunition Plant

The Holston Army Ammunition Plant (HSAAP) began its career as the Holston Ordnance Works (HOW) in 1941, as one of the government-owned, contractor-operated munitions factories built by the federal government in order to mobilize America for impending war. Located in Hawkins County, Tennessee, HSAAP was composed of two plants (Plant A and Plant B), located four miles apart and linked by a railway. It was constructed between 1942 and 1944, and was originally contracted to the Tennessee Eastman Corporation, a holding of the Eastman Kodak company. The facility was designed to produce Composition B (GlobalSecurity.org 2005b). Starting in 1943, it also produced RDX. By 1945, it was deemed the largest explosives manufacturer in the world (Swanson 1996:91).

In August 1945, the production of Composition B was ceased, and the plant was put on standby status and reverted to government management that November (Library of Congress 2007b:45). From 1946 to 1949, the plant produced fertilizer for foreign aid projects, as well as storing large quantities of Composition B, which it accepted from other facilities, such as the Bluebonnet Ordnance Plant in McGregor, Texas (GlobalSecurity.org 2005b; Swanson 1996:91). It was reinstated as an active production facility in April 1949, and the government awarded the operator contract to the newly-created Holston Defense Corporation, a firm founded by Eastman Kodak. Initial work was conducted on a limited scale, and involved the modification of the leftover Composition B that the facility had been storing, as well as rehabilitating the machinery that had been laid away for the past four years. As the conflict in Korea heightened, however, the plant was ordered to up production levels and produce new batches of Composition B, as well as RDX (Library of Congress 2007b:45).

From 1951-1954, eight operation lines were rehabilitated, new lines were erected, and nearly a dozen new structures were constructed at HSAAP (Library of Congress 2007b:46). The greatest change to the facility occurred in 1952, with the alteration of Production Line 4 to produce a high explosive called HMX. HMX had been developed and experimented with at the HSAAP in the mid-1940s, but had not been manufactured in high quantities during World War II due to high cost ratios compared to other explosive matters. 1952 proved to be an important year for HSAAP, as it was also in that year that a magnesium nitrate facility for concentrating nitric acid was perfected that was based on methods developed at HSAAP during World War II (Library of Congress 2007b:47). Besides these innovations, though, production methods remained greatly unchanged from those implemented in World War II. Regardless, in August 1953, fabrication of Composition B reached its maximum rate of output, at 15.2 million pounds in one month (Library of Congress 2007b:46). Soon thereafter, however, consequent to the Korean Armistice, production was cut to a single line (GlobalSecurity.org 2005b).

The worst accident to occur at HSAAP happened in May 1957, when a building caught fire during a run of HMX production. Subsequently, new machinery was installed on Production Line 5 for the manufacture of the high explosive (Library of Congress 2007b:47). Net productivity increased in the early 1960s, following the construction of the Berlin Wall and the Cuban Missile Crisis in 1961. Although output was increased, wholesale manufacture of high explosives did not take up again until the mid-1960s, with the escalation of tensions in Southeast Asia. In 1968, all ten production lines at HSAAP were operating and generating approximately 33 million pounds of Composition B per month. By 1973, however, production once again reached a nadir as hostilities in Vietnam ceased (Library of Congress 2007b:48).

The Holston Defense Corporation had supervised production at HSAAP throughout the 1960s and 1970s, and continued to do so well into the 1980s. From the end of production for the Vietnam War in 1973, until 1984, HSAAP produced HMX for the Navy's Trident Program. During these decades, the plant was subject to a modernization agenda that included the construction of approximately 100 new structures, numerous alterations of machinery for improved production levels, and a switch from earlier nitric-acid concentrating procedures to the magnesium-nitrate method (Library of Congress 2007b:49). The replacement of the nitric-acid concentration process with magnesium-nitrate concentration necessitated the construction of new concentrators (called "maggie units") and resulted in the elimination of the original Nitric-Acid Concentration and Sulfuric-Acid Concentration plants. The Acetic Acid Production Plant was also de-accessioned at this time, and was pulled down in 1982 (Library of Congress 2007b:50). This era also witnessed a concern for environmental regulations, consequent to the passage of the Clean Air and Clean Water acts, and the plant applied measures to limit pollution (Library of Congress 2007b:51).

In 1988, HSAAP was the only plant in the country that produced RDX and HMX (Swanson 1996:92); sources attest that HSAAP is the sole producer for all such high explosives for American use, as well as for use by countries on amicable terms with the United States (GlobalSecurity.org 2005b). As of 2007, the facility remains active.

4.0 Indiana Army Ammunition Plant

Located near Charlestown, Indiana, the Indiana Army Ammunition Plant (INAAP) was one of the largest munitions factories in the nation's Industrial Operations Command (IOC) complex, with close to 10,000 acres and over 1,400 structures. It was constructed between 1940-1941 as a government-owned, contractor-operated ammunition facility, and was originally divided into three separate manufacturing areas: a smokeless powder plant; a rocket-propellant plant; and a bag-manufacturing-and-loading facility for artillery, cannon, and mortar ammunition. The construction of the rocket-propellant plant, however, was not finished before the cessation of World War II, and was only operational for one month (GlobalSecurity.org 2005c).

The three entities were known as the Indiana Ordnance Works (smokeless powder and rocket propellant), and the Hoosier Ordnance Plant (bag manufacturing and loading). In October 1945, the three facilities were merged and renamed the Indiana Arsenal. In February 1946, the recently designated Indiana Arsenal was returned to the federal government, which put it on standby; a few months later, however, in June 1946, the government renegotiated a contract with DuPont to produce ammonium nitrate for agricultural use and as part of a foreign aid program. During the post-war years, the majority of the structures at the INAAP were used as storage facilities for smokeless powder, explosives, ammunition, and other surplus items (Kane 1995:130).

In 1949, the bag-manufacturing-and-loading area of the plant was reopened by the government, but full production across the entire plant was not begun again until 1952. In that year, Goodyear was awarded the operator contract for the supervision of loading the munitions, while DuPont was assigned with producing smokeless powder; these duties were reflective of these companies' roles at INAAP during World War II (Library of Congress 2007c:41). Production rates hit their climax in August 1953, but six months later, the deceleration commenced as American troops demobilized from the Korean War (Kane 1995:132). By September 1957, the plant was once again placed on standby. Goodyear and Du Pont retained their contractor statuses at INAAP, in the roles of care-takers, maintaining the structures in standby, until 1959, when the contract was awarded to Liberty Powder Defense Corporation, a holding of the Olin Mathieson Chemical Corporation (Library of Congress 2007c:41).

The plant was partially reactivated in November 1961, when the Liberty Powder Defense Corporation reopened the bag manufacturing building in order to assemble cloth cases for 105mm shell charges. Two months later, in January 1962, Olin Corporation terminated their subsidiary, Liberty Powder Defense Corporation, and assumed responsibility of overseeing operations at INAAP. This restructuring concurred with the reactivation of the igniter- and propellant-loading lines at the plant, at which black and smokeless powders received from other ordnance plants were loaded into charges (Library of Congress 2007c:41). In the latter part of the decade, the activities performed at the plant multiplied as the war waging in Vietnam intensified: in 1969, Olin Corporation was allowed to open a part of the smokeless powder manufacturing area (which had been idle since DuPont had left the plant) in order to produce the substance on site (Library of Congress 2007c:42). In the previous year (October 1968), however, production at INAAP ground to a halt when a factory-wide labor strike waged for three weeks, drawing the attention to officials at the Pentagon (Kane 1995:132).

This increased productivity was short-lived, however: the cessation of the conflict in Southeast Asia resulted in a gradual decrease in production and the laying-off of staff beginning in 1970. In May 1972, the operator-contractor was switched from Olin Corporation to ICI Americas, Inc., a subsidiary of Imperial Chemical Industries PLC, centered in Britain (Kane 1995:133). Major attempts on the part of the federal government to modernize the INAAP facilities occurred during the 1970s. Many of the structures dated to World War II, and the government opted to build three new facilities to automate the operations at INAAP: “The first, completed in 1978, was a highly automated, black-powder manufacturing operation… erected on the site of the World-War-II, rocket-propellant plant,” while the other two new facilities (which were completed in the early 1980s) housed semi-automated loading lines for 105mm and 155mm charges (Library of Congress 2007c:43).

During the 1980s, the bag-manufacturing-and-loading lines were used infrequently, while the smokeless powder lines were put on standby (Library of Congress 2007c:45). Bags were created here in the early 1990s for the Persian Gulf War (Gaither and Kane 1995:133). The manufacture of bags stopped entirely in 1992, and in 1995, the plant was closed, renamed “Facility One,” and put on modified caretaker status. As of 2007, it continues to be supervised by ICI Americas, who leases many of the facilities to private interests (GlobalSecurity.org 2005c).

5.0 Iowa Army Ammunition Plant

Iowa Army Ammunition Plant (IAAAP) is located in southeastern Iowa in Des Moines County. The installation is sited on 18,995 acres approximately seven miles west of the city of Burlington, Iowa. The installation is an active government-owned contractor-operated munitions plant operated by American Ordnance, a joint venture company owned by Mason & Hanger and General Dynamics. The primary mission of IAAAP remains the loading, assembly, and packing of artillery rounds, tank shells, and guided missiles. Over 1,100 buildings and structures comprise the industrial and support facilities of the ammunition plant.

The Day & Zimmerman Corporation constructed IAAAP and operated the plant during World War II. The cost of operating the plant approached $108 million. The IAAAP employed over 12,000 persons during its World War II peak; employment dropped to only 227 with the end of hostilities and by June 1946, the contractor only employed 14 people (IAAAP 1946:32). During the war, IAAAP loaded mines, mortar rounds, 75 and 155mm shells, and bombs ranging from 100 to 1,000 pound bombs. The total munitions loaded at IAAAP included:

> 13,718,000 shells, bombs, and antitank mines, containing 229,146,000 lbs. of high explosives, and over 118,017,000 fuzes, boosters, detonators, artillery primers, and percussion elements containing 1,825,000 lbs. of black powder, fulminate of mercury, lead azide and tetryl. To load the quantities stated during the period involved the handling of 160,000,000 lbs. of TNT; the manufacture of 47,000,000 lbs. of ammonium nitrate crystals from neutral liquor; the preparation and use of 35,000,000 lbs. of crystals shipped into the Plant from outside sources; and the screening, blending, and pelleting of over 1,900,000 lbs. of fulminate of mercury, lead azide and tetryl (IAAAP 1967:1-5).

On 1 August 1949, production of new ammunition resumed at IAAAP for the first time since the Japanese surrender. The detonator line (Line 6) began producing the .05 second delay element for the M51A5 Delay Fuze at that time, and on Line 9 shortly after. Lines 6 and 9 continued producing various fuzes, detonators, and primers under the supervision of the Ordnance Corps until 1951 (IAAAP 1951a:70).

Iowa Army Ammunition Plant reverted to a government-owned contractor-operated installation on 30 January 1951 with the firm of Silas Mason Company as operator. With the execution of this contract, the Silas Mason Company would assume complete control of all shell, bomb, and component lines at the plant. The Ordnance Corps was still operating Lines 6 and 9 on an occasional basis, and were reactivating Line 2. Once Silas Mason Company took over operation of the plant on 1 March 1951, the private firm would absorb as many Civil Service employees as possible. Of the 486 individuals available for hire, 436 accepted employment with the new contractor (IAAAP 1951b:1).

During the second quarter of 1951, IAAAP began increasing production to supply United Nations Forces in the Korean peninsula. Line 2 was increased to two shifts per day and produced 23,961 57mm projectiles during April. Production increased in May with over 51,000 projectiles loaded, and the number of production employees on the line rose to 237. In addition to loading the 57mm projectile, tasks on Line 2 included the renovation of 155mm shells. Production was also started on Line 3 during mid-1951. This line was re-tooled to fill the 155mm shells renovated on Line 2. Although the melt-pour operation filled only 88 shells its first day, production quickly rose to 200 shells per shift. While several pouring methods were tested, an identical procedure to that used at IAAAP during World War II was eventually chosen. Lines 4, 5, 6, and 9 were also active producing fuzes, primers, and detonators (IAAAP 1951b:23-29). The workforce at IAAAP continued to grow throughout 1951. By the end of the year, 3,936 new employees were hired and extra shifts were added. By the end of the year, new products were added to operating lines; Line 2 began producing 81mm trench mortar rounds and Line 3 added 8" shells and 4.2" mortar rounds (IAAAP 51c:13, 37-40).

During the late 1950s, IAAAP continued to develop new techniques for munitions handling. During 1958, fragmentation warheads for the NIKE HERCULES missile system were first cast with molten HBX-6. It was anticipated that as many as 160 warheads per month could be handled. The SPCC process was further enhanced with the development of methods for cooling 120mm and 76mm fin-stabilized HEAT rounds (IAAAP 1958a:96). By the end of 1958, 718 warheads for the NIKE were completed (IAAAP 1958b:92). New items were continually added including warheads for the HONEST JOHN (Line 3), LaCROSSE (Line 2), HAWK, and CORPORAL guided missiles (IAAAP 1959:13,25-26, 73).

Lines 4B and 6 were reactivated in early 1963 for the production of 90mm ammunition and primers respectively. Line 7 was brought back into production later the same year for M-20 rocket igniters (IAAAP 1963:17-19). In the second half of 1963, after completion of the X-ray building, Line 3A was opened for the production of 175mm shells. The IAAAP received nationwide attention when on 24 November 1963, it air-shipped 1,500 rounds of blank 75mm ammunition to Washington for memorial salutes in honor of President Kennedy. The plant also provided local National Guard units with blank ammunition for memorial services (IAAAP 1963:10-11).

As the conflict in Vietnam escalated, facilities for the manufacture of the XM47 mine system on Line 4A was approved in 1967; however construction was delayed due to a shortage of experienced craftsmen despite mailed requests to over 200 local unions (IAAAP 1967:15). Manufacturing operations were moved continually within the installation. Personnel at IAAAP assembled the missile from components supplied by the Aeronutronic Division of Philco Ford Corporation (IAAAP 1967:25).

During the early 1970s, the "accelerations to meet SEA requirements [at IAAAP] were slowed, stopped, and reversed" as expenditures for ammunition decreased (IAAAP 1970:1). Manufacturing personnel declined to 2,791 by the end of July 1969 and continued to decrease to only 1,423 in June 1970. Production of 4.2" mortar rounds was only half of that completed in 1969, and the 34,508 155mm high-explosive rounds represented only ten percent of the number produced the preceding year. While the production of mortar and artillery rounds declined, the IAAAP produced record numbers of fuzes and detonators. For the year ending in June 1970, over 63 million detonators were manufactured. The IAAAP continued warhead production for, and assembly of the Shillelagh Missile at Line 4b (IAAAP 1970:11-12, 17, 9).

Activities on Line 2 during the 1980s included melt-pour operations for filling 155mm projectiles. The 8" howitzer shell was produced on Line 3, and Line 3A supported 155mm projectile production. The principal activity on Line 6 was the production of fuzes and rocket igniters for the missile warheads (IAAAP 1981:13-15). As of 2007, Iowa Army Ammunition Plant remains active.

6.0 Joliet Army Ammunition Plant

Joliet Army Ammunition Plant (JAAP) had its origins as one of the 77 government-owned, contractor-operated (GOCO) munitions facilities built in the early 1940s. What is now known as the JAAP was initially founded as two separate installations: the Elwood Ordnance Plant (EOP) and the Kankakee Ordnance Works (KOW); they were united in 1945 and renamed the Joliet Arsenal (it received its present designation in 1963). In 1940, the federal government appropriated funds to establish ordnance facilities across the country; a site of over 36,000 acres was procured in Will County, Illinois, some forty miles southwest of Chicago. The vast amounts of acreage and the substantial costs incurred in construction and in purchasing the land (nearly $90 million) suggest that Joliet was meant to be one of the most important munitions centers in America: when constructed, the Joliet plants were considered the largest, most advanced installations in the world (GlobalSecurity.org 2005d).

During World War II, Elwood, which was a load, assemble, pack (LAP) facility, loaded over 900 million bombs, shells, mines, detonators, fuzes, and boosters, while Kankakee, an explosive and propellant works, produced one billion pounds of TNT, establishing itself as the greatest producer of that substance in America. The production of TNT at Kankakee was supervised by DuPont Chemical Corporation, which held the operator contract until April 1944, when it was transferred to U.S. Rubber Company. The plants were placed on standby in September 1945, with the close of the war. Although the plants were given standby status, certain portions of the site were still utilized in the years following the war (Library of Congress 2007d:36). Three acid areas in Kankakee were leased to DuPont for the production of ammonium nitrate for fertilizers, in accord with the foreign aid program to Europe. Elwood was used for storage and ammunition reclamation (Walsh and Wingo 1995:113).

With the onset of the Korean War, the U.S. Army Corps of Engineers rehabilitated the facilities at JAAP for resumption of operations (Library of Congress 2007d:36). In 1951, Kankakee was reactivated and the U.S. Rubber Company once again assumed the role of contractor operator; Elwood was also reactivated that year, but continued to be managed by the government (Walsh and Wingo 1995:113). By 1952, both were in full production. At Kankakee, crews produced TNT, tetryl, and lead azide among other products (Library of Congress 2007d:36). To increase production at Kankakee, acid facilities were relocated from Kentucky Ordnance Works, and the TNT lines were mechanized. At the height of the tensions in Korea, the engineers at Kankakee implemented a method of continuous nitration of TNT. At Elwood, workers loaded, assembled, and packed a slew of munitions, including 57mm, 70mm, 90mm, and 105mm shells; anti-personnel mines; and fuzes, boosters, supplementary charges, and delay detonators (Library of Congress 2007d:38).

In 1957, Kankakee was deactivated, and the acid facilities were rented first by the Wabash Chemical Corporation and then by the Wilson Company, Inc., from 1964-1973, while the rest of the plant was put into layaway (Walsh and Wingo 1995:113). Elwood was not deactivated until 1965; in the interim, it continued production on a much reduced scale. In August of that year, Kankakee was reactivated to produce explosives for the war waging in Southeast Asia. The U.S. Rubber Company once again assumed the role of manager of the Kankakee plant (Library of Congress 2007d:38). That company also reopened Elwood a year later, in August 1966, to produce 105mm ammunition. 1967 marked the highest rate of production during the Vietnam War. In 1968, Elwood's workers were producing eight-inch Naval ammunition, cluster bombs, and 40mm grenades in addition to their usual products (Library of Congress 2007d:42).

As the conflict in Southeast Asia began to taper at the beginning of the 1970s, so did production at JAAP. 1970 was an important year at JAAP, due to the implementation of measures meant to modernize the facilities and mitigate environmental problems wrought by the production processes. As early as 1966, toxic waste disposal was an issue addressed by the engineers at JAAP, who constructed a Redwater Treatment Facility at Kankakee. The facility took the hazardous by-products from the manufacture of TNT and evaporated and burned off the noxious substances. In 1970, a new acid area was created and a continuous-process TNT line was installed. The latter marked a great technological achievement, which, unlike the former batch method, was cleaner, less pollutive, and labor efficient. The process necessitated interconnected tanks, and was developed at JAAP as well as other plants producing and experimenting with TNT (Library of Congress 2007d:39).

All production of TNT at Kankakee was terminated in 1976, and other activities gradually ceased at the JAAP by the end of the decade (GlobalSecurity.org 2005d). Most of the facilities at Elwood were leased to Honeywell, Inc., which began to produce medium caliber ammunition in 1982 and AT4 anti-tank weapons in 1989. In October 1990, Alliant Tech Systems, a firm owned and operated by Honeywell, assumed the role of supervisor of production at Elwood.

7.0 Kansas Army Ammunition Plant

The Kansas Army Ammunition Plant (KAAP) is one of the 77 government-owned, contractor-operated (GOCO) munitions plants established at the brink of World War II by the Department of Defense. Originally known as the Kansas Ordnance Plant (KOP), it was built between 1941 and 1942 on 17,321 acres of agricultural land in Labette County, Kansas. Approximately a quarter of the facilities at KAAP were storage facilities and magazines, built in the forms of standard warehouses or igloos, which provided over 900,000 square feet of storage volume (GlobalSecurity.org 2005e).

The KAAP has primarily been used throughout its existence as a storage facility with manufacturing capabilities. Unlike other contemporary munitions plant, research and technological development were not undertaken here. The primary functions of the plant included the loading, assembling, and packaging of ammunitions; the manufacture of explosives and their loading, assembling, and packaging; and the maintenance of the facilities when not in use. During World War II, the contractor-operator of KAAP, the Johns Manville Corporation, employed over 700 persons to perform these limited activities (Library of Congress 2007e:20).

In 1945, with the end of the Second World War, all manufacturing lines closed down; the government assumed control of the installation, and the plant was put on standby. At first, the government had declared the plant to be excess land, and attempted to sell it; however, the government soon changed its status to active and designated it as a storage hub. Surplus equipment and machinery from other government-owned facilities that had been assigned excess status were sent to the plant (Gaither 1996:98). For five years, the only activities at the plant, besides the maintenance of machinery and buildings and the storage of equipment, were the reception, storage, and renovation of ammunition. Some land inside the of plant's boundaries was leased to local farmers for agricultural use (Library of Congress 2007e:20).

This status as a central storage facility changed as the Korean War commenced, and the Army Corps of Engineers rehabilitated the KAAP for future use. In 1950 the plant was partially reactivated for the manufacture of explosives, artillery ammunition, and other components. In April 1951, the operating contract was given to the National Gypsum Company. By 1954, all production lines were in operation (Gaither 1996:98). During the Korean War, lines were devoted to the loading of fuzes; the manufacture of boosters; the assembly of detonators and relays; the assembly of primers; the reworking of 105mm cartridge cases; and the loading of demolition bombs, among other productions (Library of Congress 2007e:22-23). An ammonium nitrate and a lead azide plant were also activated. Finished products were stored (prior to shipment) in the various storage facilities on the plant's grounds (Library of Congress 2007e:25).

Production approached a stand-still as of April 1956, due to demobilization following the end of the Korean Conflict, and the plant was once again put on standby in 1957. The contractor-operator returned the plant to the government, which maintained certain buildings for continued use and rented the remainder to private interests (Gaither 1996:98). From October through December of 1959, the United States Bureau of Census rented buildings in the administration area to use as headquarters for surveys staff members were conducting in the region.

In December 1966, the plant was reopened and rehabilitated for use consequent to the United States' involvement in Southeast Asia. In 1968, new construction at the site included the erection of lead azide and sodium azide facilities designed by DuPont (Gaither 1996:99). Production was much of the same as it had been, but by 1970, lay-away of equipment began, and in 1971, the plant was again put on standby status (Library of Congress 2007e:21). In March 1970, Day & Zimmerman, Inc., of Philadelphia, assumed the role of contracted operator, which they currently retain. From 1972 to 1976, the government and the contractors instituted a program to modernize the facilities at KAAP, which involved the automation of many of the production lines (GlobalSecurity.org 2005e). Throughout the 1980s and into the early 1990s, Day & Zimmerman had two lines operating, and manufactured 155mm shells and detonators, as well as Combined Effects Munitions (CEM), Antiarmor Cluster Munitions (ACM) bombs, Extended Range Anti-armor Munitions (ERAM), among other products. In 1996, the plant was designated inactive, and only a small portion of the facility was still in operation (Gaither 1996:99).

8.0 Lake City Army Ammunition Plant

The Lake City Army Ammunition Plant (LCAAP), is located in Jackson County, Missouri, and is thought to be the largest small-arms manufacturing plant in the world. Constructed to meet ammunition demand during World War II, LCAAP is one of the few GOCO facilities to operate continuously since its inception in 1941, save for five idle years from 1945-1950 (GlobalSecurity.org 2005f). During these years, the government's managerial objectives at LCAAP were:

> …the protection and maintenance of the basic buildings; machinery; and equipment, tools and facilities that were necessary to meet future needs for small arms ammunition. Additional responsibilities included the receipt, storage, issue, inventory, upkeep of property records, surveillance, inspection, and preservation of War Dept permanent war reserve machinery and equipment and stocks of small arms munitions, components, materials, and explosives necessary to meet its primary mission. LCA was also to perform assigned manufacturing, repacking, and demilitarization operations as directed… (Shaffer et. al. 1996:89).

As American involvement in Korea heightened, the federal government reactivated LCAAP in August 1950 for the production of small arms ammunition (Shaffer et. al. 1996:89). In December 1951, the government awarded the operator contract to Remington Arms Company, Inc., which had operated the facility during World War II. Remington Arms Company supervised the production of 30-, 50-caliber, and 20mm ammunition at LCAAP (Library of Congress 2007f:35). The technology and the operational methodologies at LCAAP did not differ greatly from those employed at the facility ten years previously. However, in 1954, some of the 30-caliber machinery was reconfigured to produce 7.62mm ammunition, and in 1955, some of the 20mm lines were revamped for the manufacture of 30mm cases (Library of Congress 2007f:36). In 1956, various new lines relating to the production of fuzes for 20mm rounds and their packaging made a test run (Library of Congress 2007f:37). The plant also saw a series of new constructions during these years, including the erection of a large test-range building (Library of Congress 2007f:34).

1956 witnessed a decrease in production, as the nation demilitarized following the cessation of hostilities with Korea. The 30- and 50-caliber lines were laid away in situ, and while most of the production facilities were put into standby status, a minimal amount of production persisted (Library of Congress 2007f:34, 35). In June 1960, the LCAAP was used for the experimentation and development of the "Davy Crockett," a "low-yield tactical nuclear weapon with an atomic warhead that held considerable destructive force," as well as having an "effective radius… small enough that troops using the weapon, nearby friendly troops, and civilian populations would not be endangered by the blast" (Shaffer et. al. 1996:89). By 1965, the government had determined that the Davy Crockett was impractical and production was halted (Shaffer et. al. 1996:90).

Due to this continual usage (even at a drastically reduced scale) without any lapses, the LCAAP was in a good position to quickly and efficiently meet the needs of increased production when the Vietnam War broke out and the demand for small arms manufacture resurged (Library of Congress 2007f:37). In 1966, the LCAAP production output was tripled from that output from five years prior. That same year, the plant began to manufacture – in addition to its previous stock – 5.56mm ammunition for the M-16 rifle, a weapon much used in the Southeast Asian conflicts, on reconfigured machinery that had previously produced 30-caliber rounds (Library of Congress 2007f:38).

When the conflict in Southeast Asia was brought to a close, the plant once again returned to a diminished rate of production (Library of Congress 2007f:37). The latter part of the 1970s saw an interest in upgrading the facilities at LCAAP. In 1977, up-to-date equipment for the production of 5.56mm rounds was brought to the plant from the Twin Cities Army Ammunition Plant (TCAAP) in Minnesota; this machinery had been developed at TCAAP with financial backing from the federal government's Small Caliber Ammunition Modernization Program (SCAMP) (Library of Congress 2007f:38). This equipment was touted for its cost-effective production methods: "Employing compact, high-speed, computer-monitored, rotary machines, the SCAMP system used only a fraction of the manpower and space required by conventional production methods" (Library of Congress 2007f:40). The new equipment reduced the man-power needed to only four line operators (Shaffer et. al. 1996:92). Although the intentions to modernize LCAAP introduced SCAMP to the facility, most of the machinery there dates to the 1940s (Library of Congress 2007f:40).

The Remington Arms Company, which had run the facility for nearly 40 consecutive years, lost the contract to manage LCAAP to the Olin Corporation in 1985. The latter operates the facility presently, and LCAAP is the only active GOCO, small-caliber ammunition plant in the federal government's nation-wide industrial complex (Library of Congress 2007f:37). Since 1975, the technology used at LCAAP has been distinguished by the gradual replacement of antiquated equipment with high-speed, computer-monitored machinery (Shaffer et. al. 1996:92).

9.0 Lone Star Army Ammunition Plant

The Lone Star Army Ammunition Plant (LSAAP) is located in Bowie County, Texas, 12 miles west of the city of Texarkana. It began its lifespan as the Lone Star Ordnance Plant (LSOP),[1] one of the 77 government-owned, contractor-operated (GOCO) munitions plants established in the 1940s. Adjacent to the plant is the Red River Army Depot (RRAD), originally called the Red River Ordnance Depot (RROD), which shipped and stored the munitions manufactured at LSOP. Both LSOP and RROD were built between 1941 and 1942, on land that formerly had been used for agricultural and logging purposes; LSOP comprised over 15,500 acres and contained nearly 900 structures. LSOP began to produce munitions in the summer of 1942, under the supervision of the Lone Star Defense Corporation, a holding of the B.F. Goodrich Company (GlobalSecurity.org 2005g).

Victory over Japan (V-J) Day during August 1945, marked the end of combat in World War II. It also signaled the gradual cessation of munitions production and the closure of most of the GOCO munitions plants. The LSOP fully stopped their operations that November; concurrently, the contracting agent had readied the facility for standby status and handed LSOP back over to the government. At that time, LSOP and RROD were joined to create the Red River Arsenal, and both facilities were employed in the demilitarization of ammunition from 1945 until 1951. During this period, the arsenal also produced fertilizer to be sent to Europe as part of a foreign aid initiative (Library of Congress 2007g:31).

The government once again took interest in its munitions plants when the Korean Conflict commenced; in 1950, the Army began to refit the Red River Arsenal for future production (Library of Congress 2007g:31). In early 1951, the Philadelphia-based firm of Day & Zimmermann, Inc. became the contractual agent directed to produce munitions at Red River Arsenal. That fall, the two units that formed Red River Arsenal were separated, and what is now LSAAP was called LSOP once more. The first year was spent rehabilitating all of the equipment which had been refitted for the demilitarization of ammunition after World War II. Much of the original machinery at LSOP had been shipped to other plants during those peace-time years, and what was available was old and tattered (Library of

[1] LSOP was given its current moniker, Lone Star Army Ammunition Plant (LSAAP), in 1963.

Congress 2007g:32). Production did continue, despite these set-backs; the methods used in the manufacturing processes were unchanged from those employed during World War II (Library of Congress 2007g:33).

Output quotas were reduced after the end of the Korean Conflict in 1953, although the plant remained in limited operation through 1960. Only a small portion of the plant was utilized during those years, and idle areas were maintained in layaway mode. Production began to quickly increase in 1961, as America became entangled in the conflict raging in Southeast Asia. The plant was once again put on active status, and directed to produce ammunition not unlike those produced at the plant previously. The only differences introduced at the plant were technological advancements that made some of the manufacturing processes safer. For instance, engineers at Day & Zimmermann developed tools to measure and convey small quantities of explosive substances on the detonator line (Library of Congress 2007g:33). Equipment for loading 155mm shells with multiple charges was installed at LSAAP, as well as other munitions plants (Library of Congress 2007g:34).

Production once again decreased with the end of the Vietnam War, and the focus of activities at LSAAP was switched to a modernization and rehabilitation program of the plant's facilities. Tasks included automating lines of production and decontaminating sites with remediation facilities. In 1981, a new apparatus for the assembly of fuzes was installed (Library of Congress 2007g:36). As of 2007, the plant is active, and loads, assembles, and packs primers, fuzes, grenades, boosters, bursters, detonators, and tracers, as well as ammunition items ranging from mortars to 155mm projectiles. Some of the facilities are leased to private entities (GlobalSecurity.org 2005g).

10.0 Longhorn Army Ammunition Plant

Located in Marshall, Texas, the Longhorn Army Ammunition Plant (LHAAP) is one of the 77 government-owned, contractor-operated (GOCO) munitions plants established in the 1940s. (GlobalSecurity.org 2005h) It produced armaments through the duration of World War II. It was officially deactivated in late August, 1945. Outstanding building projects were cancelled, and the facilities were closed and put on standby until tensions in Korea necessitated its reactivation (Library of Congress 2007h:28).

On the first of February, 1952, the plant was reactivated and the Universal Match Corporation, based in St. Louis, was awarded the contract of operation. Universal Match Corporation had been a main producer of aircraft signal flares and magnesium powder in the previous war. At LHAAP, they set about transforming a portion of Plant No. 2 into a pyrotechnic ammunition load-assemble-and-pack (LAP) facility. They built about 40 new buildings and renovated existing ones, forming a connected, horseshoe-shaped complex with a 2,600-foot conveyor system. From June 1952 through April 1956, Universal Match Corporation manufactured about 3.5 million pyrotechnic devices at LHAAP, including photoflash bombs, ground signals, simulators, and shell tracer elements. Their contract was terminated in 1956, and Plant No. 2 was returned to the government and made inactive (Library of Congress 2007h:28-29).

During the 1950s, Thiokol Corporation, based in Newton, Pennsylvania, inhabited another portion of Plant No. 2 at LHAAP, which was renamed Plant No. 3. There, they built a facility to fabricate solid fuel rocket motors through a process they had refined at the Redstone Arsenal, in the vicinity of Huntsville, Alabama. They built a number of new buildings and renovated existing structures in the former solid propellant production area that had been left uncompleted when the plant went on standby in 1945. Thiokol Corporation produced rocket motors for tactical missiles such as the HONEST JOHN, FALCON, LaCROSSE, NIKE HERCULES, and SERGEANT. In 1959, Thiokol Corporation erected a vast complex of structures that included a "Main Rocket Motor

Assembly Building" and a "Static Test Building," in which they manufactured rocket motors for Pershing IA missiles (Library of Congress 2007h:29). This line of production continued for twenty years (Library of Congress 2007h:35).

The pyrotechnic facilities at Plant No. 2 were reactivated by Thiokol Corporation in 1963, as the Vietnam Conflict necessitated increased armament production. The pyrotechnic plant reworked previously manufactured ground signals; manufactured illuminating cartridges for 60mm, 81mm, and 4.2" mortars; produced illuminating projectiles for 105mm and 155mm howitzers; and produced simulators, signals, and infrared flares. In 1979, the plant was automated. This production continued long after American troops were withdrawn from Vietnam, and figures state that through August 1983, the plant had produced nearly 45 million pyrotechnic pieces (Library of Congress 2007h:35).

In December 1987, the focus of operations at LHAAP shifted, with the signing of the Intermediate-Range Nuclear Forces (INF) Treaty, which called for the destruction of nuclear and conventional missiles. The LHAAP (along with Pueblo Depot, in Colorado) was activated for the destruction of Pershing missiles (GlobalSecurity.org 2005h). In 2007, LHAAP is inactive and designated as excess property.

11.0 Louisiana Army Ammunition Plant

Louisiana Army Ammunition Plant (LAAP) is a government-owned, contractor-operated (GOCO) munitions facility first established in 1941, as America mobilized for the Second World War. It is located near the town of Minden, Louisiana, and is 22 miles east of Shreveport. It was a load-assemble-and-pack (LAP) facility for various types of ammunition, including bombs, mines, and projectiles (Library of Congress 2007i:14).

The LAAP facility was sited on nearly 15,000 acres of land that was selected because it met various preconditions: it was inland, away from the coasts, in an isolated area that was nonetheless close to urban centers that could provide a labor force; accessible by a major highway and two rail lines; and water, natural gas, and electricity were all available. In July 1941, The Silas Mason Company – which had been a munitions producer in World War I, and had an integral part in the construction of Radford Ordnance Plant (which became RFAAP) and the Elwood Ordnance Works (which later became part of Joliet AAP) – was awarded the operator contract and authorized to begin construction. The LAAP was initially intended to be an impermanent facility for the production of munitions for the duration of World War II, and thus, only low-quality, temporary construction was authorized. Following America's entry into the war, in early 1942, the Army Corps of Engineers came to LAAP to oversee the building projects. A number of structures that were already present on the land were temporarily adapted as office buildings, yet most of these were dismantled before the end of the war (Library of Congress 2007i:18-20).

By May 1942, eight lines were in production and 709 structures had been built. The plant was zoned by function, and the production areas were isolated from one another to mitigate damage in case of an explosive accident. Within the zones, known as "Areas," the buildings were grouped by purpose, and the plan also considered safety: "Typically, production areas featured an extended, linear arrangement of widely spaced buildings interconnected by enclosed 'ramps' which housed conveying systems." The structures were built to last for a short period only, and were constructed of concrete baffle walls, with concrete pad floors, wooden frames, corrugated asbestos siding, and asbestos shingles attached to sheathing laid over wooden trusses in the roofs (Library of Congress 2007i:20-24).

Early in 1945, a ninth production line was added. LAAP fabricated about 65 types of ammunition, including 75mm and 76mm rounds; 3” fixed rounds; anti-tank mines; 100-pound and 250-pound bombs; M56 and M85 fuzes; boosters; and 155mm projectiles, among others. The combined amount of ammunitions produced at LAAP over a three-year period, from 1942-1945, was over 100 million pieces. During those years, the assembly lines and equipment were constantly retooled in order to produce the latest types of ammunition, as requirements shifted. Technological advances at LAAP included the installation of a volumetric-multiple-pour machine procedure in the assembly lines. This innovative machinery made it possible to load up to 60 shells at the same time, and was a more efficient, automated, and better controlled process than the previous method (Library of Congress 2007i:20-30)

Plant-wide manufacture came to a standstill at the end of the war, in August 1945. In the next month, the plant was put on standby status It was not reactivated again until February 1951, during the conflict in Korea. This time, Remington Rand Corporation was retained as the contacted operator for LAAP. For the first few years, the plant underwent renovation on nine existing manufacturing lines, which were quickly made ready for production; the erection of 63 new structures, which were mostly storage facilities; and the construction of a metal parts facility for the manufacture of 155mm shell casings (called ‘Area Y’). This last facility was constructed under the guidance of the Army Corps of Engineers, and it included a 325,000 square foot shell plant building as its focus. Area Y began to produce 155mm casings in fall 1953, and was the “only munitions plant in the United States at that time to both manufacture and load 155mm artillery shell casings.” Despite this addition, production at LAAP remained virtually the same as it had in the previous decade; besides 155mm casings, the plant produced 57mm, 75mm, and 76mm cartridges; antipersonnel and anti-tank mines; and fuzes (Library of Congress 2007i:28-31).

Production came to a halt in 1958, and the LAAP was once again put on standby. It was reactivated only three years later, in September 1961, when the LAP and metal parts facilities were once more reopened for manufacture of armaments to be used in Southeast Asia. During the 1960s, 134 new buildings were constructed, mostly for storage purposes, and a metal parts facility was constructed that manufactured the components of small grenades. Activities at the LAP facilities were continually amended with advancements made in technology. The plant produced about 60 different forms of artillery, including mines, shaped charges, fuzes, boosters, bombs, demolition blocks, 2.75” rockets, 57mm cartridges, mortars, and 155mm projectiles and their casings. One of the production lines was refitted in the late 1970s to construct 155mm M692 ADAM (Area Denial Artillery Munitions) projectiles, which hold anti-personnel mines, and Area Y was updated for the assembly of M483 ADAM projectiles. (Library of Congress 2007i:30-34)

At the beginning of 1976, the Thiokol Corporation assumed responsibility of operations at LAAP (Library of Congress 2007i:33). The production of armaments came to a close in October 1994. Currently, the facility is in a “modified Caretaker” status, and is governed by the Valentec Corporation (GlobalSecurity.org 2001).

12.0 McAlester Army Ammunition Plant

McAlester Army Ammunition Plant (MCAAP) was originally founded as the McAlester Naval Ammunition Depot (MCNAD)[2] in the early 1940s, as America entered the Second World War. It extended over 42,000 acres of former pastoral land in southeastern Oklahoma, and housed over

[2] The plant was renamed McAlester Army Ammunition Plant (MCAAP) on October 1, 1977, when the U.S. Army took control. (See Library of Congress 2006j: 38) For consistency, “MCAAP” will be used throughout despite anachronisms.

2,400 structures. As a Navy depot, it was intended as a center for Naval munitions production and storage (GlobalSecurity.org 2005i).

The present-day site was chosen because it offered the U.S. Navy over 30,000 acres of contiguous, flat terrain; proximity to rail lines and highway systems; a sufficient source of electricity; and, most importantly, access to large amounts of unemployed labor. McAlester's townspeople had sought federal investment, in terms of jobs and development, since the late 1930s, to arrest their economic depression. After the Navy had announced its intention to construct three new inland ammunition centers, Oklahoma Senator Elmer Thomas insured that McAlester would be considered for one of the three[3] projected installations; it was chosen by the Navy for development in June 1942 (Library of Congress 2007j:17).

Two Chicago-based architectural and engineering firms and one local firm were hired to draw the plans for MCAAP; the Brown, Root & Bellows company of Houston, Texas, was hired to do the construction. The only extant building on the site which was retained was a stone schoolhouse built in 1934. Construction commenced in August 1942; originally, approximately 1,040 storage magazines, 100 inert storage structures, six ammunition loading plants, and two bomb and mine production plants were built. Enlargement of the facilities (especially storage) continued throughout the war, and by May 1945, 2 rocket motor loading facilities, 127 storage magazines, and 52 inert storage structures had either been completed or were underway. The site was zoned by function, with the production facilities focused in the center of the plant, next to inert storage structures, and surrounded by both high explosive storage and inert storage structures. Distances between assembly and cargo facilities were calculated to reduce impairment to the neighboring buildings if an explosion occurred in one. The majority of the structures were designed with concrete structural systems and the exteriors were clad in stone; the quality of the building material and methods suggests that MCAAP was intended as a permanent facility (Library of Congress 2007j:18-21).

Production began in September 1942, and continued unabated until August 1945, when the Japanese capitulated. During those three years of production, the loading lines at MCAAP produced and assembled over 25 separate types of ammunition, including filled projectiles and bag charges from 5" to 14", cartridges and cases from 3" to 6", 20mm and 40mm ammunition, three types of rockets, and a variety of mines. The production lines were constantly refitted for new products as technologies advanced and material requirements were altered (Library of Congress 2007j:32-33). The plant hired over 8,000 laborers and manufactured 325,000 tons of munitions during World War II (GlobalSecurity.org 2005i).

With the end of the war came a cessation of production, and the objectives at MCAAP were changed to meet new demands. In-progress building projects were finished but nothing new was undertaken, and the manufacturing machinery and equipment were put on standby. A number of workers were retained to salvage and rework returned ammunition. The plant was also used for a short time as a veterans' center. Full-scale operations were restored to MCAAP some years later, with the onset of the Korean Conflict. Between 1952 and 1953, new storage facilities were built and the production lines were reopened. The manufacture methods employed during the Korean Conflict were not much changed from those used in the last war. However, some new machines were installed to replace older ones, and others were refitted to produce new types of ammunition. Production reached its height in 1953, and began to slow the following year; in 1955, full-scale production ended and the base once again undertook salvage and repair work (Library of Congress 2007j:36-37).

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[3] The other two were located at Shumaker, Arkansas, and Hastings, Nebraska. Facilities already existed at Hawthorne, Nevada, and Crane, Indiana. (See Library of Congress 2006j: 18)

After nearly a decade of limited activity, MCAAP was once again reactivated for munitions manufacture during the Vietnam era. During the late 1960s, a modernization program was utilized which focused on the production and assembly equipment and facilities. The only major building program during this era was in the residential sector of the plant: 30 new houses were erected in 1969. Production tapered in the early 1970s, as the troops deployed in Vietnam returned, but it did not completely stop: the production of 20mm cartridges, 5" projectiles, APAM (antipersonnel, antimaterial) bombs, 500-pound bombs, and inert bombs continued at the base well into the 1980s. In November 1975, the proprietorship of the naval depot was transferred to the U.S. Army, when the Department of Defense named the Army as the "Single Manager for Conventional Ammunition;" it was officially renamed MCAAP in 1977. Production methods have not significantly altered under the Army's supervision (Library of Congress 2007j:38).

The MCAAP is currently active, and it functions as a storage depot for surplus ammunitions and a manufacturing plant for small-, medium-, and major-caliber ammunition, rockets, bombs, and mines. It is considered a Tier 1 installation, meaning that it remains ready to rapidly deploy munitions within the first 30 days of conflict; it is one of four tier 1 installations, and has the largest storage capacity of all (GlobalSecurity.org 2005i).

13.0 Milan Army Ammunition Plant

Milan Army Ammunition Plant (MAAP) is a government-owned, contractor-operated (GOCO) munitions plant founded during World War II. It covered over 22,500 acres in Carroll and Gibson counties, in western Tennessee. It is approximately 100 miles to the northeast of Memphis and 30 miles north of Jackson. The plant once was comprised over 1,460 structures, and had six lines of manufacture (GlobalSecurity.org 2005j). A majority of the structures at the plant date to the original period of construction; however, most of the early machinery is not present (Library of Congress 2007k:14).

Construction for two detached, adjacent ordnance works began in January 1941 and was completed in one year: the Milan Ordnance Depot (MOD), which was intended to be a storage facility; and the Wolf Creek Ordnance Plant (WCOP), which loaded, assembled, and packed both minor and major caliber ammunition, ranging from 20mm armor-piercing shot to 155mm howitzer projectiles. The two facilities were merged to form the Milan Ordnance Center in 1943; it is this conjoined entity that was renamed the Milan Army Ammunition Plant (MAAP) in 1963. The MOD was located on the southern portion of the plant, and was divided into eight yards, with 700 igloo magazines and 100 other structures total. The WCOP was built on the northern portion of the plant, and consisted of 660 structures, 13 production lines, and over 200 magazines (Library of Congress 2007k:15, 24).

The ordnance facilities were sited on land that was carefully chosen according to a number of conditions, all of which the MAAP site met. These included convenience to major transportation venues, such as rail lines; plentiful water and electricity supplies; proximity to a potentially large labor pool; distance from larger urban areas; and vast amounts of under-developed land. The two plants originally covered 28,500 acres of agricultural land, on which were situated over 1,500 structures used for farming purposes. It also encompassed a hamlet, Whitthorne, which had a small number of buildings, most notably a ca. 1900 schoolhouse with a 1930s brick gymnasium addition. A few of the these buildings were incorporated into the plant and used for administrative or training purposes (Library of Congress 2007k:17).

The WCOP remained in production fabricating 60mm trench mortar shells, 250-pound bombs, and anti-tank rockets, among other ammunition types, until August 1945. Later that year, the contracted operator, Proctor and Gamble Defense Corporation (a subsidiary of Proctor and Gamble

Company) returned the plant to the government, which put all facilities on either standby or "extended storage" status. The plant was reopened around 1950, and the Proctor and Gamble Defense Corporation again managed the production of ammunitions at MAAP. Few changes were made to the plant at this time, in terms of technological advancements or new construction. Production dwindled beginning in 1954, and by 1957 all operations at MAAP had terminated. In the fall of that year, the operating contract was awarded to Harvey Aluminum Sales, Inc., which was bought out by Martin Marietta Aluminum Sales, Inc. two years later (Library of Congress 2007k:31, 35).

The plant was once again reopened in 1960 for manufacture of ammunition for the Vietnam Conflict. Throughout that decade and the next, the MAAP underwent substantial technological overhauls and new building campaigns. (Library of Congress 2007k:36) Milan Army Ammunition Plant is active for the production of fuzes, demolition charges, mortar rounds, and 155mm projectiles.

14.0 Mississippi Army Ammunition Plant

The Mississippi Army Ammunitions Plant (MSAAP) differs from other government-owned, contractor-operated (GOCO) installations in that it is the only such facility to be built after the Korean Conflict (GlobalSecurity.org 2005k). It is also distinct from other arsenals in that multiple phases of production are conducted on site:

> [The MSAAP] represents a radical departure from traditional American practice in artillery-projectile manufacturing. According to the munitions-production model developed during World War II and kept intact during the Korean and Vietnam Wars, projectiles were manufactured at one plant, and then loaded with explosives at another, often distant, facility. …the MSAAP was designed to reap the economic benefits of integrated production, consolidating at one location virtually all metal-parts manufacturing, assembling, and loading operations (Library of Congress 2007l:23).

The MSAAP is located in Hancock County, Mississippi, and is sited on the northern portion of the National Aeronautics and Space Administration's (NASA) National Space Technology Laboratories compound. This complex has its origins in the era of early space exploration. In 1961, the federal government procured over 13,000 acres of undeveloped land in this area of Mississippi in order to build a test site for NASA's Apollo space program. The compound, where Saturn V rocket engines were test-fired, was initially called the "Saturn Static Test site." Later in the decade, the compound was given its current name and transferred to various federal agencies besides NASA, including the United States Geological Survey (USGS), the National Park Service (NPS), and the Navy, for use as an environmental and space research center. The Army first became interested in establishing a facility on this site in the late 1970s. In 1977, the Army allocated funds to construct a new munitions plant on the undeveloped northern half of the National Space Technologies Laboratories compound. Construction began in January 1978, and continued through the first few months of 1983; on March 31, 1983, the new facility was dedicated and opened (Library of Congress 2007l:14-25).

MSAAP encompassed over 4,000 acres. The installation, which integrates production, loading, and assembling functions on one large site, was divided into three major areas: the Projectile Metal Parts area; the Cargo Metal parts area; and the Load, Assemble and Pack area. Administrative and utility buildings were also present on the complex. (GlobalSecurity.org 2005k) The facility produced "recently developed, grenade loaded, 155mm artillery projectile with both armor-piercing and anti-personnel capabilities" (Library of Congress 2007l:14). The plant operated until 1990, when production was terminated and the status of the plant became inactive. The contractor-operator selected to maintain the inactive plant is Mason Technologies, Inc., a subsidiary of Mason and Hanger-Silas Co., Inc. (GlobalSecurity.org 2005k).

15.0 Radford Army Ammunition Plant

The Radford Army Ammunition Plant (RFAAP), located 40 miles west of Roanoke, Virginia, began its lifespan as one of the 77 government-owned, contractor-operated (GOCO) munitions plants established in the 1940s. Radford's mission was to produce the powder used in high explosives. It consists of two units – the Radford Unit, near the city of the same name, and the New River Unit, near the town of Dublin, Virginia – which were united after the end of the Second World War. The combined land coverage is nearly 7,000 acres, and over 1,000 structures are located on the two units (GlobalSecurity.org 2005l).

Production of high explosive powder at Radford slowed in 1944, and ceased altogether in September 1945, when the plant was turned over to the government and put on standby. The New River Unit was designated as inactive and put on standby in 1946; it simultaneously was made a division of the Radford complex. Portions of the New River Unit were systematically sold off between 1946 and 1948. By February 1946, all of the staff at both units had either been transferred to other plants or let go (Neville and McClane 1996:95). That summer, Radford was chosen as one of 15 plants to produce ammonium nitrate for fertilizers sent to Europe as a foreign aid measure. Consequently, modifications were made to the acid plant; Hercules Powder Company, who had been the contractor-operator during the war, reassumed supervision of the manufacturing facilities (Library of Congress 2007m:30).

The production of ammonium nitrate continued to be the main objective at Radford until April 1949, when the facilities were once again rehabilitated for the manufacture of smokeless powder for explosives. Hercules Powder Company was awarded the contract to generate a limited amount of powders, and the engineering firm of Hayes, Seay, Mattern and Mattern of Roanoke was awarded the contract to refit the facilities for such production. By the early 1950s, operations were fully running, and production included single-, double-, and triple-based propellant powders, rolled powder, acid, solvent, nitrocellulose, nitroglycerin, as well as the manufacture of rocket propellant (Library of Congress 2007m:31). Elements for missiles were manufactured by Goodyear Aircraft Corporation at Radford. Modern facilities were constructed to cast propellants for rockets, such as the HONEST JOHN, LITTLE JOHN, NIKE ATLAS, and NIKE HERCULES (Neville and McClane 1996:96). New structures were also built to create the triple-based propellant powder and nitroglycerin. From 1953 through 1956, the plant was extensively renovated, and a great number of structures (including the World-War-II-era TNT manufacturing area) were pulled down (Library of Congress 2007m:31).

After the cessation of hostilities in Korea, the RFAAP continued to produce solvent and solventless powders, but at a lesser quantity than during the war. Manufacturing levels stepped up again beginning in 1962, due to the tensions in Southeast Asia, and reached their maximum output in 1968. During these years, the existing facilities were not notably altered, and neither were the production methods used. However, beginning in 1968, a modernization program was introduced that resulted in the erection of new facilities, including: three continuous, automated TNT lines (completed in 1968); an acid generator; numerous acid concentrators; a continuous nitrocellulose nitration facility; an ammonium oxidation plant; a continuous automated single-base line (CASBL); a continuous automated multi-base line (CAMBL); and an administration building. Most of these were constructed between 1972 and 1975; the CAMBL was not completed until the 1980s (Library of Congress 2007m:31-32). The new TNT facility was notable, as it was the first facility built in the United States for continuous nitration and purification of TNT (Neville and McClane 1996:96).

The 1980s proved to be a dry decade for munitions production. By July 1986, the TNT manufacturing site had closed and reverted to standby condition. As of 2007, the plant still manufactures solvent single- and multiple-based propellant powders and cast rocket propellant (Neville and McClane 1996:96).

16.0 Ravenna Army Ammunition Plant

The Ravenna Army Ammunition Plant (RVAAP), located in Portage County, Ohio, is the product of a reorganization of two World-War-II-era ordnance facilities in 1945: the Ravenna Ordnance Plant (ROP) and the Portage Ordnance Depot (POD). The two installations were founded in late 1941 as a government-owned, contractor-operated (GOCO) munitions plant and storage depot. By early 1942, the ROP was loading shells and bombs, as well as producing Amatol and ammonia nitrate, under the direction of the Atlas Powder Company. Various structures on site stocked ammunition, as well. The Ravenna Arsenal (as it was known from 1945 until 1963, when it was renamed the RVAAP) consisted of over 1,300 structures spanned across 21,418 acres (GlobalSecurity.org 2005m).

During RVAAP's productive war-time years, from 1942-1945, engineers at the plant innovatively developed a better production process for TNT, which gained attention for the arsenal (GlobalSecurity.org 2005m). As with most GOCO plants, production rapidly decreased following the end of the war; by 15 August 1945, the plant was restored to the government and subsequently placed on standby. A few activities were sustained by a skeleton crew after this designation was applied, including the maintenance of equipment, the storage of ammunition, and the production of ammonium nitrate for fertilizers bound for Europe as part of a foreign aid agenda. The Silas Mason Company, of Shreveport, Louisiana, refitted the old Ammonium Nitrate Line for this latter purpose. Most of the plant, however, was utilized for ammunition salvage work: ammunition was sent to Ravenna from other plants for either storage or discarding; explosives were melted down and resold to other munitions industries; and reclaimed scrap metal was sold for profit (Walsh 1995:88-89).

The plant was reactivated in April 1951, to produce armaments under the direction of a new contractor-operator, Ravenna Arsenal, Inc., a firm owned by Firestone Tire and Rubber Company. Their mission was to manufacture 90mm, 120mm, and 155mm shells; 8" shells; and anti-tank mines. The last was a wholly new product at Ravenna, and Load Line 4 was refitted and mechanized to produce the mines. At the same time, much of the equipment was revamped for the increased production levels, and a variety of new conveyor systems were installed. Many of the edifices were restored and amended: ramps between buildings were covered, and new loading and receiving docks were built in Loading Lines 1, 2, and 3. One of the most interesting additions was the installation of a pneumatic system to transport TNT between buildings at Loading Line 1. This conveying system was the only one of its kind in America as late as 1970, and it was the first time principles of vacuum lines were applied to explosives production (Library of Congress 2007n:43-45).

Operations again ceased after the end of the Korean Conflict, and during October 1957, the plant was once again designated as on standby. Nonetheless, limited activities – such as the reworking and storage of ammunition types – continued well into the 1960s. In October 1960, kettle furnaces were designed and built at Loading Line 12 for melting down bombs (Library of Congress 2007n:45). The runway at RVAAP was utilized by the National Advisory Committee for Aeronautics (the precursor to NASA) for testing experimental fuel tank designs on airplanes (Walsh 1995:89).

As the tensions in Southeast Asia heightened, so did activity at ordnance installations across the country. During the early years of the conflict, the majority of ammunition needs were met with munitions held in storage. As the number of American combatants increased, and it became obvious that hostilities would continue, ordnance plants were readied to resume production. At RVAAP, maintenance activities increased, as equipment and machinery received from munitions plants across the country were cleaned, repaired, and prepared for use. In May 1968, RVAAP was officially reactivated, and quickly began to produce 155mm, 175mm, and 8" shells; 40mm cartridges; and two types of primers. Loading Line 7 was changed from a booster-production line to one that handled the newly added 40mm charges in 1969. Lines 2 and 3, which had not been mechanized previously, were now remodeled for automation, and a cooling system was placed at the Loading Line 2 facility. Loading Line 4, which had been made over in the early 1950s to produce anti-tank mines was now refitted with 8" shell loading equipment. After all this extensive renovation and modernization, however, production sharply decreased starting in 1970, and by 31 August 1971, the plant was once again on standby status (Library of Congress 2007n:46). Limited activities, such as the demilitarization of ammunitions, continued at the site until 1984 (GlobalSecurity.org 2005m). In 1983, the "vertical kettles or furnaces [on Loading Line 12], which remained unique to Ravenna AAP, had been adapted for 90mm shells" (Library of Congress 2007n:45). That same year, Firestone sold its subsidiary, Ravenna Arsenal, Inc., to Physics International Company. In 1993, the operator contract at RVAAP was transferred to Mason & Hangar-Silas Mason Company, Inc., which assumed the role of caretaker for the inactive plant, which was utilized only for the storage of explosive matter and other industrial goods (Walsh 1995:89).

17.0 Riverbank Army Ammunition Plant

East of the city of San Francisco, and near the towns of Riverbank and Modesto, is the Riverbank Army Ammunition Plant (RBAAP), a government-owned, contractor-operated (GOCO) munitions plants established during World War II. Operated by the Aluminum Company of America (ALCOA), it was originally an aluminum reduction facility. It is situated in the northern stretch of San Joaquin Valley, on approximately 170 acres of land that had previously been agricultural (Library of Congress 2007o:13).

In late 1939, as war engulfed Europe, America urgently mobilized, and the government was made aware that the country had very few manufacturing facilities for aluminum, which was an integral material in aircraft production. From 1939 through 1942, a number of aluminum plants were built throughout the western United States. These plants were financed with the aid of the Defense Plant Corporation, a subsidiary of the Reconstruction Finance Corporation, and most were managed by ALCOA. The plant at Riverbank was authorized in August 1941; construction began the next year. Originally, only 27 structures were erected, designed in a utilitarian style, on land that was chosen because it was near the Atchison, Topeka & Santa Fe Rail, as well as the Hetch Hetchy power transmission line. By 1943, ALCOA was operating the plant with a manufacturing volume of 96 million pounds per year (Library of Congress 2007o:17).

The output of aluminum decreased beginning in 1944, and soon thereafter the plant was closed and declared excess property. The machinery for aluminum production was sold to Kaiser Corporation, and the facilities remained on standby for the next six years. In 1951, the facilities at RBAAP were altered to produce steel cartridge cases, and in 1952, the plant was once again reactivated and production began that September. Norris Industries was retained to direct the plant's productions, and they in turn hired Bechtel Corporation to design, build, and oversee six new production lines. At the height of the struggle in Korea, the plant turned out 90mm cartridge case, 105mm cartridge cases, and U.S. Naval 3"/50 and 5"/38 caliber cases; over 12 million such cases were produced at RBAAP by the end of the war. During those years, it was internationally considered the foremost shell-casing plant (Library of Congress 2007o:19, 28).

In the final stages of the Korean Conflict, in 1953, the manufacturing schedules were slowly decreased, but production continued in limited quantities until 1958. RBAAP was closed in that year and put on standby. In 1963, it was once again deemed excess property, and the government attempted to sell it, but with no results. Reactivation came to the plant in June 1966, when Norris Industries was ordered to open the facilities and produce shell and mortar casings for the Vietnam Conflict. Their partner, the Bechtel Corporation, reopened four lines to fabricate 105mm cartridge cases, and refitted lines to make 60mm and 81mm mortar projectiles. In 1975-1976, the 60mm line was changed to an 81mm line, and in December 1976, an eighth line was built at the plant for M42/M46 grenade body assemblies for use in 155mm M483 and 8" M509 cargo-load projectiles (Library of Congress 2007o:28, 30). By 1981, the plant was inactive; Norris Industries remains the contracted operator in charge of maintaining the facilities in a standby condition. They have leased some structures to private interests.

18.0 Scranton Army Ammunition Plant

The Scranton Army Ammunition Plant (SAAP) is the most unique of the government-owned, contractor-operated (GOCO) munitions plants on many accounts. It was not built as a munitions manufacturing facility, but was constructed at the turn of the nineteenth- and twentieth-centuries as a rail line smithy; the main buildings dated from that period. It was purchased by the federal government during the Korean War era, and thus was one of the few ordnance plants to post-date World War II. It was also the smallest ordnance plant, encompassing only 15.3 acres and 14 structures, and was sited in the core of an urban center. Its situation in downtown Scranton, Pennsylvania, rather than in an undeveloped remote area, signifies that it has never been a production center for high explosives; rather, shells were fabricated at Scranton AAP and sent to other plants for loading (Library of Congress 2007p:14, 17).

Northeastern Pennsylvania, in which Scranton is located, has been a center for iron production since the eighteenth century. In 1840, the brothers Scranton (George and Sheldon) purchased over 500 acres of land in what was then known as Slocum's Hollow (Ebenezer Slocum had founded a blacksmith shop in that area in 1798), and launched a coal mining and iron smithy enterprise, using anthracite coal for smelting iron. 1848, the firm of Scranton and Platt began producing iron rails for railroad use, and by 1853, they had expanded into the transportation business, with the establishment of the Delaware, Lackawanna & Western Railroad Company, which, by 1900, was considered to be one of the most advanced rail systems in the country (Library of Congress 2007p:17-19).

The present-day SAAP is located on the site of the former Scranton Locomotive Shops, on land that was purchased by the Delaware, Lackawanna & Western Railroad Company from the Lackawanna Coal & Iron Company circa 1907. Four buildings on the site were built between 1907 and 1909 and were adapted for munitions production. These included: the five-story pattern shop, which was the administration building; the Foundry, which was converted to a forge; the former blacksmith shop, which held the heat-treatment services for the entire plant; and the machine and erecting shop, which accommodated the manufacturing lines. The U.S. Army Ordnance Corps attained this portion of the Scranton Locomotive Shops property from the Delaware, Lackawanna & Western Railroad Company when it was condemned in 1951, and the present precinct excludes other structures once utilized by the railroad firm, including the office and storage building, gas house, the sand blast house, power house, and other minor storage facilities. The Army Ordnance Corps discarded all of the original rail-manufacturing equipment (Library of Congress 2007p:14-37).

The remodeling of the old locomotive workshops for large-caliber shell production was undertaken between 1952 and 1953, according to the designs of the Philadelphia architectural firm of Gilboy & O'Malley, and under the supervision of the locally-based contracted operator, the U.S. Hoffman Machinery Corporation. The production lines were started in December 1953, and at the outset, only 8" (M106) and 155mm (M107) projectiles were manufactured. Four years later, the production capacity expanded to 175mm projectiles. At its zenith, the plant produced over 200,000 shells monthly. During this decade, the U.S. Hoffman Machinery Corporation experimented with manufacturing materials, and found that shells could be produced using commercial-grade steel at a significantly reduced cost (Library of Congress 2007p:17-40).

In 1963, the operating contract was transferred from the U.S. Hoffman Machinery Corporation to the Chamberlain Manufacturing Corporation, a holding of the Duchossois-Thrall Group, which was directed by the government to produce 175mm (M437) projectiles. Beginning in 1967, under the guidance of Chamberlain Corporation, a modernization program was executed at SAAP. (GlobalSecurity.org 2005o) A number of new pieces of machinery were introduced to the plant, including electrochemical milling machines, a microprocessor lathe, and automated furnaces. In 1970, a large, steel-frame joiner building was erected adjacent to the production shop for testing material hardness and for cleaning equipment (Library of Congress 2007p:40-42).

Excluding a three-month period in 1963, when titles were transferred from U.S. Hoffman to Chamberlain Corporation, SAAP has never suspended operations (Library of Congress 2007p:41). Even though it is currently listed as inactive, the Production Shop continues to manufacture 5" naval shells, 120mm mortar rounds, and various 155mm projectiles (M898, M795, and XM982) with cooperation from the Picatinny Arsenal in New Jersey (GlobalSecurity.org 2005o).

19.0 Sunflower Army Ammunition Plant

The Sunflower Army Ammunition Plant (SFAAP) is one of the 77 government-owned, contractor-operated (GOCO) munitions plants established in the 1940s. SFAAP was built in 1941, southwest of Kansas City, Missouri, on 9,500 acres. It contained some 1,100 structures. SFAAP began to produce explosive powders in 1942, under the supervision of the Hercules Powder Company, and was considered at the time one of the world's largest powder plants (GlobalSecurity.org 2005p).

After the Second World War officially ended, in August 1945, SFAAP was ordered to reduce its levels of production. However, the contracted operator stayed on until 1948, and created ammonium nitrate fertilizer in the interim. In June 1948, Hercules Powder Company returned the facility to the government, which then placed it on standby. This lasted for only two years: in 1951, the plant was reactivated to produce rocket powders to be utilized in the Korean Conflict, and Hercules Powder once again assumed control of operations. Major rehabilitation of the facilities and some limited new building occurred at the plant from 1951 to 1955, concurrent with production. Double-based and triple-based cannon powders, rifle powders, and rocket propellant grains were the mainstays of production at the SFAAP through the 1950s (Library of Congress 2007q:37). 1953 marked an important year for SFAAP:

> An important development at SFAAP during the Korean War period was the invention of the "Sunflower Blender." The disadvantage of the Sweetie Barrels used for blending solventless rocket propellant paste (they were slow, dangerous, and space-consuming) had led to a search for an alternative. …The Sunflower Blender… incorporated the cement mixer's revolving barrel and its interior fins for mixing and scraping the sides of the barrel. …Fulfilling their intended purpose, Sunflower Blenders replaced Sweetie Barrels at SFAAP, where new buildings to accommodate the new blenders were constructed in 1955… The Sunflower Blender was also adopted by other smokeless powder plants (Library of Congress 2007q:38).

Production persisted at SFAAP until 1957; the facility was not officially deactivated until 1960. In the interim, engineers at SFAAP used the facilities to experiment with developing technologies; one such experiment was a procedure to mechanize the rocket propellant sheet-rolling process. During these years, the contracted operator put inactive facilities and machinery into layaway

– a process which lasted until 1960, when they then turned the management of the plant back over to the government. From 1960 to 1965, the plant was once again put on standby, and the only portion of the site functioning during these years was the acid production area, run by the U.S. Industrial Chemical Company of New York. (Library of Congress 2007q:38-41)

The plant was once again activated in August 1965, and was authorized to manufacture the propellant for the light-weight 2.75" Folding Fin Air Rocket, also known as the "Mighty Mouse," which first had been used in the early 1950s. There were no major building campaigns at the plant during this era, save the new automated facility for the continuous nitration of nitroglycerin, built by the contracted agent and the Army Corps of Engineers from 1965 to 1971. The new system did not necessarily produce higher quantities of nitroglycerin than the older "batch" system, but it offered a cleaner, safer, and a more controlled process (Library of Congress 2007q:42).

Production of propellants for the Vietnam Conflict ceased in June 1971, and the SFAAP was once again deactivated. However, the next decade witnessed modernization and renovation programs implemented at the plant. New machinery for the assembly of fuzes was brought into the plant in 1981. In 1983, a nitroguanidine plant was built at SFAAP and began production the next year. Hercules Powder Company (which had become Hercules, Inc. in 1966) remained manager of the plant, and continue to do so today (now they are known as Hercules Aerospace Company). (GlobalSecurity.org 2005p) Today, the plant is inactive, and has been listed as excess property by the government.

20.0 Twin Cities Army Ammunition Plant

The Twin Cities Army Ammunition Plant (TCAAP), located in Ramsey County, Minnesota, built in 1941 as the Twin Cities Ordnance Plant, is a government-owned, contractor-operated munitions facility. During the first half of the 1940s, corresponding with America's involvement in the war, the Twin Cities Ordnance Plant (TCOP) produced four billion rounds of ammunition. (GlobalSecurity.org 2005q) At the close of the war the facility was placed on a standby status, and the contractor operator, Federal Cartridge Corporation, handed over management of the plant to the United States Army. The facility continued to operate, however, through the latter years of the 1940s under the supervision of the Army, which conducted repacking ammunition and demilitarizing functions. One event of note that occurred during the Army's tenure at Twin Cities was the invention of an automatic cartridge disassembly machine in 1949 (Vogel and Crown 1995:58).

In August 1950, the Army reactivated the installation and awarded the operator contract to Federal Cartridge Corporation. During the Korean War, from 1950 to 1957, the plant produced small arms ammunition, 105mm shells, and 155mm shells; Federal Cartridge Corporation supervised the small ammunition lines, but Minneapolis-Moline Corporation operated the 105mm shell production lines and Donovan Company operated those lines that manufactured 155mm shells. Apparently, apart from the addition of the 155mm shell production, the operations at the plant during the 1950s did not differ from those during the 1940s in technological and operational terms (Library of Congress 2007r:35). In 1957, the plant was again put on standby status (Vogel and Crown 1995:58).

In 1963, subsequent to a measure implemented by then-Secretary of Defense Robert McNamara, the Twin Cities Ordnance Plant was renamed Twin Cities Army Ammunition Plant (TCAAP). Two years later, in December 1965, as America became entangled in the conflict in Southeast Asia, TCAAP was reactivated (Vogel and Crown 1995:58). Federal Cartridge Corporation was once again nominated to supervise the production of small ammunitions, and Donovan Company was retained to operate the 155mm shell production lines. Various advancements in weapon technology which occurred during the years in which the plant was inactive resulted in a change in the plant's operations. The 105mm shell production lines were dismantled, and the small arms ammunition lines were modified to manufacture smaller cartridges: the 45- and 50-caliber machines were dismantled, while the 30-caliber machines were adapted to produce 5.56mm and 7.62mm ammunition. The production process was re-evaluated and streamlined, although much of the original machinery was still employed (Library of Congress 2007r:37).

Another event that marked this era in the plant's history is that in the late 1960s, Federal Cartridge Corporation was "awarded an additional contract to assist in the development of a highly automated Small Caliber Ammunition Modernization Program (SCAMP), which was intended to revolutionize manufacturing procedures." The introduction of computer-operated machinery was supposed to further streamline the production process and make it more cost-effective. As the production of ammunition slowly wound down, beginning in 1971, the engineering of computer-operated machinery dominated the focus of the operations at TCAAP (GlobalSecurity.org 2005q). In 1974, the first prototype of SCAMP was installed at TCAAP, and produced in a trial run ten million pieces of 5.56mm ammunition. The numbers were greatly increased in the next year, when the SCAMP system was able to produce 45 million pieces in a trial run. In 1976, the facility at Twin Cities was once again deactivated and put on standby status, and the SCAMP equipment was relocated to the Lake City Army Ammunition Plant in Lake City, Missouri (Library of Congress 2007r:37-38).

While on standby status, the plant was once again opened for a small-scale production of small arms ammunition for Operation Desert Storm in 1990. This was the final production sequence operated at the facility (Vogel and Crown 1995:58). When Bear Creek Archeology, Inc., conducted a survey of the site ca. 1995, they had this to report:

> As of 1994 the TCAAP is in modified caretaker status, with most of the former TCOP manufacturing and support buildings vacant. Most of the small arms production line machinery has been dismantled, along with parts of the plant infrastructure, and several buildings have been demolished or are slated for imminent removal. While the Army and FCC presence has been reduced to a skeleton caretaker force, two industrial tenants continue to utilize parts of the installation. Alliant Techsystems, Inc. (formerly part of Honeywell, Inc.), and 3M Company (formerly Minnesota Mining and Manufacturing Company), have both had a presence at the TCAAP since the 1950s. Several areas and buildings have been leased for storage by various entities, including a historic railroad restoration group (Vogel and Crown 1995:59).

The current status of the plant is inactive.

21.0 Volunteer Army Ammunition Plant

The Volunteer Army Ammunition Plant (VAAP) is located 12 miles from the city of Chattanooga, Tennessee. It was built between 1941 and 1942 as one of the 77 government-owned, contractor-operated (GOCO) munitions plants established prior to World War II. Its mission was to produce explosives. VAAP comprised 6,681 acres and over 400 structures (GlobalSecurity.org 2005r).

The end of World War II with victory over Japan marked the end of combat, and also signaled the cessation of munitions production and the closure of many GOCO munitions plants; the VAAP was one of many such factories to stop their operations that August. However, contracted operator, Hercules Powder Company, continued managing the facility until it was ready to be handed over to the government in January 1946. From 1946 until 1952, the government superintended the plant in a standby status. (Library of Congress 2007s:32)

In June 1952, VAAP was reopened for production, with a new contracted operator: the Atlas Powder Company, of Wilmington, Delaware. The facilities at the plant had not been well cared for during the six years of dormancy, and the structures and machinery required major repair work and rehabilitation. The main administration building had been razed by fire, and needed reconstruction. Of the original load lines, six were beyond repair and torn down. In the place of the lost facilities, 25 new facilities were built. Due to the needed construction, manufacturing did not begin until November 1953. New facilities did not entail new processes: the manufacturing methods and technologies utilized at VAAP were the same as those used in the previous decade (Library of Congress 2007s:32).

With the end of hostilities in Korea came the gradual cessation of production at munitions factories across the country; VAAP was once again closed and put on standby in March 1957. This standby status – which meant that a skeleton crew would be consistently present, maintaining the integrity of the plant to such a degree that operations could be running again 120 days after receiving notice – was later reduced to a protective surveillance status. The VAAP remained relatively unmanned until October 1965, when it was reactivated to produce explosives for the war in Southeast Asia (Library of Congress 2007s:32). No more than four lines were running at this time, but during the height of production, from 1967-1969, VAAP was fabricating 30 million pounds of TNT each month (GlobalSecurity.org 2005r).

From 1965 through 1975, a policy to upgrade facilities was implemented at VAAP concurrent with production schedules. Over 100 new structures were built, which changed the overall site plan of the plant. A new acid area was erected between 1970 and 1972, and the three earlier acid areas were razed. A hospital, storehouses, and shops were also built at this time. Immediately upon reopening the plant, ten TNT loading lines were completely renovated, four old TNT lines were taken down, and six new continuous process TNT lines were assembled. Production began in March 1966 (Library of Congress 2007s:32-33). The new construction also affected the production techniques:

> The production of TNT by continuous process, rather than by the batch method, represented a major technological advancement. While the daily output of each line is approximately equal to the output of each batch line, the continuous production process offered advantages in the areas of cleanliness, reduced pollution, labor savings, and greater control over the operations. The continuous process line at VAAP employed techniques developed and refined at other locations; VAAP was unique in utilizing a direct computer process control system (Library of Congress 2007s:33).

While the plant underwent these modernizations, it was deactivated following the end of the Vietnam War. The maintenance of the facility is currently supervised by ICI Americas, Inc., and there are tenants leasing spaces within the plant (GlobalSecurity.org 2005r). VAAP is considered excess property.

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APPENDIX B: WORLD WAR II AND COLD WAR AMMUNITION PRODUCTION ARCHITECTS, ENGINEERS, AND CONTRACTORS

1.0 Summary

This section presents the results of archival research completed in regards to information on the architects, engineers, and contractors that were involved in the planning and construction of Army ammunition storage and production facilities during WWII and the Cold War (Table B.1). Archival research was conducted at the National Archives and Records Administration (NARA), College Park, Maryland; Library of Congress, Washington, DC; and the American Institute of Architects (AIA). A repository dedicated to the field of professional engineering was not located. As a result, information on engineers and contractors was located at NARA and the Library of Congress, but is somewhat limited. Background information on architects is typically gathered through the AIA's *American Architects Directory*; however, these directories only date to 1955, 1962, and 1970. Architectural firms or architects involved with construction during WWII are only included in the directory if they remained active through 1955. If a firm changed names, or merged with another firm, it may be impossible to trace this change. As a result, even though a repository of information on architects exists, the information can be limited.

In cases where a significant amount of information was located in regards to a particular architectural or engineering firm or company, a brief history was developed to chronicle the creation and activities of the business. Companies with extensive information include: Black & Veatch, Day & Zimmerman, The Hunkin-Conkey Construction Company, Mason & Hanger, and Wilbur Watson & Associates. These firms demonstrated considerable expertise in large construction projects including many dams and bridges that gained them experience with reinforced concrete, a material widely used in ammunition production facilities. Many of these firms also constructed Army ammunition plants that included large numbers of ammunition storage buildings. The remaining firms and companies are included in a chart outlining information such as firm location, previous work, associations, or accomplishments.

2.0 Black & Veatch

Black & Veatch was formed in 1915 by Ernest Bateman Black and Nathan Thomas Veatch in Kansas City, Missouri. Some of their first work included utility projects, such as power plants and water systems. Only two years after the firm was founded, the War Department contacted the company asking them to oversee the creation of WWI war camps in Arkansas, New Mexico, and Oklahoma. Following the war, the company returned to utility work and successfully formed relationships with city governments in Topeka, Kansas and Kansas City, Missouri (Black & Veatch 2005:2-3).

In 1942, Ernest Black was named president of the American Society of Civil Engineers. During his acceptance speech he designated WWII as the "engineer's war" (Black & Veatch 2005:7). Though military work kept the company busy, Black & Veatch continued to work in Kansas and Missouri on water treatment facilities. They also provided financial assessments for companies, primarily in the western United States. After the war ended the company remained busy, despite the lack of military work (Black & Veatch 2005:7).

In 1947, the company served as designers for construction and rehabilitation at the Iowa Army Ammunition Plant, working for the Atomic Energy Commission once again. In 1949, Ernest Black died, leaving Veatch as the only owner of the firm. During the 1950s, Veatch restructured the company by creating a civil division, a power division, and an appraisals department" (Black & Veatch 2005:9). Work during this period included the construction of a dam in Colorado and a large power plant in Iowa.

During the late 1940s and early 1950s, Black & Veatch designed the Loring Air Force Base Weapons Storage Area. This portion of the facility was used for the storage of nuclear weapons. The buildings designed by Black & Veatch were in what was considered the "Q Area," where security was at a maximum (Lemert 1979:164; Earth Tech, Inc. 1999:3; Global Security 2000-2007:n.p.). As of 2007, the company is still in existence, with a worldwide clientele (Black & Veatch 2006).

3.0 Day & Zimmermann

Dodge & Day, the precursor to Day & Zimmermann, was originally formed in 1901 when Charles Day and Kern Dodge formed a partnership. Charles Day graduated as an electrical engineer from the University of Pennsylvania in 1899. Kern Dodge had graduated the same year with a degree in engineering from the Drexel Institute in Philadelphia. Day and Dodge had known each other as neighbors. Both were associated with the Link-Belt Manufacturing Company in Philadelphia; Day was an employee, and Dodge was the son of the company's owner, James Mapes Dodge (Rodengen 2001:11-14).

Day first joined Link-Belt in 1899, and was quickly made "superintendent of installation of power plant equipment" (Rodengen 2001:11-14). Day worked with another associate of Link-Belt, Conrad Lauer. Lauer and Day specifically worked on exposing the company to what was known as the Taylor Method, a scientific or manufacturing management process developed by Frederick Winslow Taylor. According to the Taylor Method, manufacturing could be streamlined if it was assessed as an entire process rather than individual tasks. Though he did not necessarily center his theories on improved technology, many people influenced by Taylor implemented new technology as a means of improving efficiency based on his teachings. Taylor brought this assembly line idea to Henry Ford, and also influenced others, such as Day, Lauer, and Dodge. As a result, Day and Lauer created what was is considered the country's first entirely electric plant at Link-Belt. They incorporated new pulley systems and new machinery including steel cutting machines that saved the company time and money (Rodengen 2001:11, 14; Stross 1989:59).

In 1907, the firm began work in electrical railway engineering and construction (Rodengen 2001:18). Their first two projects in this new area of engineering and construction were located in Pennsylvania and North Carolina. The following year, Dodge & Day was hired to assist in the construction of the Panama Canal. This was a significant project because it gave them nationwide exposure, and experience with monumental concrete works. The firm proved it was adequate for the job, and even broke the world record for hauling concrete (Rodengen 2001:19). With a system of cables and lifts, constructed by Dodge & Day, the firm was able to move "2,000 cubic yards of concrete per 10-hour day" (Rodengen 2001:19).

Directly after the passage of the National Defense Act of 1916, Day enlisted in the Army and was assigned to an infantry company. He soon was asked to assist in organizing the country's industrial mobilization during WWI. He served on boards for the military, assessing ammunition storage plans as well as the organization of moving troops and supplies throughout the country overseas. During this same time, the firm, now known as Day & Zimmermann after John Zimmerman who joined the firm in 1907, thrived due to contracts related to the war. Much of their work was associated with transforming industrial companies into war materiel producers. Zimmermann managed the company while Day remained in the Army (Rodengen 2001:26-27). Day & Zimmerman continued their relationship with military departments after the Armistice. In fall of 1917, Day was asked to assist in the assessment of England's abilities to accept war materiel and troops, and in 1918 the firm was contracted to perform design, site planning, and construction management of the U.S. Philadelphia Quartermaster Terminal.

In November 1940, the company was hired for the design and construction of the Iowa Ordnance Plant (Jerabek-Wuellner 2005:3-83). The firm was also contracted to operate the plant after its completion late 1941. The contract was worth an estimated $30,000. During construction, Day & Zimmermann had as many as 1,938 employees working at the plant. In addition to the manufacturing and munitions storage buildings, the facility included a full complement of support buildings such as a fire department and hospital (Rodengen 2001:48-49). Day & Zimmermann grew significantly as a result of war related contracts. By 1943 they employed 18,000 people (Rodengen 2001:55, 61).

In the late 1950s, Day & Zimmermann was hired to complete a feasibility study for construction of Lincoln Square in Manhattan. The project was significant, because it was unlike any city events center ever proposed, which gather numerous cultural institutions in a central downtown location. Although Day & Zimmerman would not participate in actual construction, the report completed by the firm illustrated that the proposed center was feasible from all perspectives. The company was praised for going to such an extent to complete a thorough study (Rodengen 2001:59-60).

During the 1960s, H.L. Yoh, who joined the firm in 1962, worked on a contract with McDonnell Aircraft to create the Mercury and Gemini capsules for the National Aeronautics and Space Administration. Also during this time, the company designed a monorail system for the 1964 World's Fair in New York. Day & Zimmerman maintained a diverse client base. They worked for the Hershey Chocolate Company providing design and management services for candy production (Rodengen 2001:73-76). In 1999, Day & Zimmermann acquired Mason & Hanger (Rodengen 2001:132).

4.0 The Hunkin-Conkey Construction Company

Samuel Hunkin and William Hunkin both worked in construction in Cleveland during the late nineteenth century. In 1900 the brothers joined to form Hunkin Brothers Construction Company. Shortly after creation of the company, Guy E. Conkey joined the firm; Conkey was a nephew of the Hunkins. In 1903 Samuel Hunkin died, leaving the firm with William Hunkin as president and Conkey as vice-president. Four years later, the firm was renamed Hunkin-Conkey Construction Company. In 1906, following the San Francisco earthquake, the firm traveled west to aid in reconstruction efforts. After returning to Cleveland, the firm worked on projects in Ohio, Michigan, Maryland, and New York. Projects included harbors, docks, and bridges, but also included major manufacturing plants such as Firestone Tire & Rubber's facilities in Akron and Goodyear Tire & Rubber in Akron and California (U.S. Ordnance Department 1940:n.p.; Case Western Reserve University 2007:n.p.).

Hunkin-Conkey's work also included dam construction. By the late 1930s and early 1940s, they were involved in the construction of Shasta Dam in California and Confluence Dam in Pennsylvania. With experience in a variety of projects, Hunkin-Conkey was a natural choice for constructing the Ravenna Ordnance Plant and Depot. The firm's familiarity with Ohio likely gave them an advantage as well (U.S. Ordnance Department 1940; Case Western Reserve University 2007:n.p.).

Following WWII, Hunkin-Conkey constructed bridges, hospitals, plants, and turnpikes. By 1970 the company was considered the nation's 11th largest construction firm (Case Western Reserve University 2007:n.p.). The firm closed down only two years later (Case Western Reserve University 2007:n.p.).

5.0 Mason & Hanger

Around 1827, Claiborne R. Mason of Virginia established Mason Syndicate. The company worked on the early stages of the Chesapeake & Ohio Railroad, and by the mid-nineteenth century the Mason name became synonymous with railroad construction, including bridge and tunnel building . Around 1870, the name of the firm was changed to Mason and Hoge (Lemert 1979:3-4, 22). By the late 1800s, the company won a contract to build part of the Chicago Drainage Canal. The project was significant because it was considered the world's largest construction project at the time (Lemert 1979:27). During the late nineteenth and early twentieth century, the company worked on heavy construction projects including additional canals, as well as river locks and dams. In 1907, the company was renamed Mason & Hanger, with Harry Baylor Hanger as president, Silas B. Mason II as treasurer, and John J. Watts as secretary. The company took on several large projects prior to WWI, but once the war began some projects were suspended and the company turned toward military construction (Lemert 1979:29-34).

Silas Mason was made president of Mason & Hanger in 1925, after the death of Harry Hanger. The following year, the company was awarded contracts to work on construction of the Independent Subway Line in New York. A branch of the company, Silas Mason Company, was created during this time and began construction on the subway tunnels. This subsidiary company also won a contract to construct piers for the George Washington Bridge over the Hudson River. In 1927, Mason & Hanger was awarded a large subway contract to build tunnels between Manhattan and Brooklyn. Other projects included subway tunnels in Boston, portions of the Lincoln Tunnel in New York, tunnels associated with Fort Peck Dam in Montana, Rays Hill Tunnel in Pennsylvania, the Brooklyn-Battery Tunnel, and the Merriman Dam in Delaware. Through these projects, the company proved to be dependable, efficient, and inventive. The projects also allowed the company to technologically advance, with the use of new machinery and new construction methods (Lemert 1979:45, 49, 52-64).

During the 1930s, Mason & Hanger bid on their largest project since the company's creation, the Grand Coulee Dam. The company joined Guy F. Atkinson Company and E. L. and W. E. Kier, forming Mason, Walsh, Atkinsin & Kier (MWAK) in order to bid on the initial phase of construction for the dam on the Columbia River in Washington state. MWAK won the bid, and in May 1937 completed the foundation for the dam. The following December MWAK joined with another company, Interior Construction, and won the contract for the second phase of construction. By January 1942, MWAK and Interior Construction completed the Grand Coulee Dam and its associated powerhouse (Lemert 1979:92-107). According to a history of the company, titled *First You Take a Pick & A Shovel*, the dam was considered the largest masonry structure in the world, occupying 35 acres and using over 15 million cubic yards of concrete (Lemert 1979:92). The company's official history placed the dam in historical perspective, saying that "eclips(ed) the Great Pyramid of Cheops, celebrated for 4,500 years as the largest masonry structure in the world" (Lemert 1979:92).

Upon completion of the Grand Coulee Dam, Mason & Hanger was awarded several military contracts in preparation for WWII. These included: Radford Ordnance Works, Virginia; New River Ordnance Plant, Virginia; Louisiana Ordnance Plant; and Badger Ordnance Works, Wisconsin. Mason & Hanger would serve as the operator of the Louisiana facility near Minden, east of Shreveport. (War Department 1941:1).

After the conclusion of WWII, the company resumed work on the Brooklyn-Battery tunnel, while also constructing tunnels for a reservoir in South Dakota. Silas Mason Company and Mason & Hanger Company maintained their relationships with the Federal government when they contracted to produce fertilizer at several idle ammunition plants including Louisiana, Lone Star, Milan, Illinois, and Ravenna. (Mason & Hanger-Silas Mason Co., Inc. 1950:82, 88). In 1947, Mason & Hanger was awarded a contract to rehabilitate an ammunition plant for the US Atomic Energy Commission. The contract included adapting the plant from medium caliber loading to high explosive production (Mason & Hanger-Silas Mason Co., Inc. n.d.:21-22).

During this time, the company began designing a new structure that would avoid the release of radioactive material in the event of an explosion. In 1957, Mason & Hanger was awarded a design and engineering contract for supervising tests of a new structure termed the "Gravel Gertie" (Lemert 1979:170). The Gravel Gertie was a concrete tube with a thirty foot diameter. The roof of the structure was constructed of wire screen and tar paper covered by gravel (Lemert 1979:170). This design allowed the gravel to serve as a filter, eliminating the risk of a large release of radioactive particles. After completing three tests, one with 120 pounds of explosives and two with 550 pounds of explosives, Mason & Hanger was confident in the design of the Gravel Gertie, and began construction of the structures (Lemert 1979:170; U.S. Department of Energy 2004:n.p.). The company ran a variety of blast resistance experiments between 1951 and 1954 (Mason & Hanger-Silas Mason Co., Inc. n.d.:4).

The company headed in quite the opposite direction after the close of the Cold War. With the United States disarmament program in motion, Chairman and CEO of the company in 1992, Dwight E. Heffelbower, remarked in an interview that the company's "biggest challenge is to divert away from the Department of Defense work. Conventional ammunition obviously is going down in volume" (Petros 1992:D3). During this time, the company joined into agreements with the Department of Defense for ammunition clean up. This process included testing for hazardous waste, as well as the demilitarization of all types of weapons including chemical, nuclear, and conventional (Liem 1992:B5). In 1994, Mason & Hanger was included in the Forbes 500 list. This list of top earning privately owned companies placed Mason & Hanger at 429th place with a value of $420 million (Lexington Herald Leader 1994:A13).

Mason & Hanger-Silas Mason Company was purchased by the company Day & Zimmermann, Inc. in 1999. At this time, several of Mason & Hanger's subsidiary company's merged under Day & Zimmermann as well (Jordan 1999:D1). When the merger occurred, Mason & Hanger employed 5,000 workers, while Day & Zimmermann employed 17,000 (Jordan 1999:D1). Today, as a company of Day & Zimmermann, Mason & Hanger provides services related to architecture, interior design, civil engineering, structural engineering, mechanical engineering, electrical engineering, and chemical engineering.

6.0 Wilbur Watson & Associates

Wilbur J. Watson and Company was formed in 1907. Watson attended Case School of Applied Science, where he received an undergraduate degree in civil engineering. He worked as an engineer for one of the oldest engineering firms in Ohio, Osborn Engineering Company in Cleveland (Case Western Reserve University 2007:n.p.). Watson gravitated toward bridge design, designing bridges while at Osborn, and continuing to do so once he created his own firm. Watson & Company constructed numerous bridges in Ohio, including the Third Avenue Bridge and King Avenue Bridge, both in Columbus, and the Howard Street Bridge in Akron. A number of the bridges were constructed as part of the "City Beautiful" movement. Watson introduced new theories in bridge design throughout his career, including the use of pre-cast concrete beams (Case Western Reserve University 2007:n.p.). He also wrote essays and books on creative options in bridge design.

In 1917, the firm became The Watson Engineering Company; the name once again was changed in 1924 when the firm became Wilbur Watson and Associates. During this time, civil engineer Ralph Harding and architect Carl Nau were included in the firm (US Ordnance Department 1940:21).

In 1928, the firm was granted the daunting task of designing the largest uninterrupted enclosed space in the world (Case Western Reserve University 2007:n.p.). The Goodyear Airdock, located in Akron, Ohio, was designed to house the construction of Navy zeppelins. The structure was over 1,100 feet long and 300 feet wide; an area equal to eight football fields (American Society of Civil Engineers 2007a:n.p.). The need for such a large open interior was a challenge that Watson remedied with the use of steel arches. The building, still extant, is distinctive for its size and design, but also for its mound shape. This allowed the 211 foot tall massive structure to avoid being heavily affected by wind (American Society of Civil Engineers 2007a:n.p.). The building was designated a Civil Engineering Landmark in 1980 (American Society of Civil Engineers 2007b:n.p.).

Wilbur Watson died in 1939, leaving Harding and Nau to continue operation of the firm. When granted the contract to construct the Ravenna Ordnance Plant, Harding agreed to stay in Cleveland and manage the firm; Nau traveled to Ravenna where he served as architect-engineer on construction of the Ordnance Plant along with the Hunkin-Conkey Construction Company (US Ordnance Department 1940:21-22).

Table B.1 World War II and Cold War Ammunition Production Architects, Engineers, and Contractors

Firm/Company Name	Location of Firm/Company	Year Established	Army Ammunition Related Projects	Previous Work
A. Guthrie & Co., Inc.	Portland, OR	No information	Cornhusker AAP (contract 1942 architect/engineer and construction supervision)	Baring Creek Bridge, Montana (1931-HABS/HAER); Kettle River Bridge, Oregon (1948-NRHP and HAER); Willamette River Bridge, Oregon (1922-NRHP and HAER); Derby Street Grand Trunk Western Railroad Bridge, Michigan (ca 1930-NRHP); Trowbridge Road Grand Trunk Western Railroad Bridge, Michigan (NRHP)
Austin Willmott Earl (spelling in HABS Willmott and Wilmott)	San Francisco, CA	ca 1940	Hawthorne Army Depot (1942)	United Engineering Company Shipyard Electrical Services and Switching Station, California (1945-HAER)
Blanchard & Maher Architects	San Francisco, CA	No information	Hawthorne Army Depot (1942)	Designs for state parks during the 1930s
C.F. Haglin & Sons, Inc.	Minneapolis, MN	C.F. Haglin established in 1873, Sons joined firm in early 1900s	Lone Star AAP; Shumaker/Camden, AZ (HE mags and smokeless powder mags); Indiana AAP (1941)	Minneapolis Grain Exchange, Minnesota (1902, 1909, 1928-NRHP); Androy Hotel, Minnesota (1919-NRHP); Graybar Electric Company building, Michigan (1926-NRHP); Rand Tower, Minnesota (1929-NRHP);
C.G. Kershaw Contracting Co.	Birmingham, AL	1909	Redstone Arsenal (1941)	No information
Charles Ramsey and Co.	Lubbock, TX	No information	McAlester AAP; Lone Star (1941)	No information
Charles T. Main, Inc.	Boston, MA	No information	Holston AAP (subcontractor under Fraser-Brace 1942)	Warrenton Woolen Mill, Connecticut (ca 1908-NRHP)
Chester Engineers	Dallas, TX	No information	Lone Star AAP (1941); Lone Star AAP (1945 – for demilitarization of ammo)	Omohundro Water Filtration Complex District, Tennessee (ca 1930-NRHP)
Dinwiddie Construction Co.	San Francisco, CA	No information	Hawthorne Army Depot (1942)	Columbia Gorge Hotel, Oregon (1921–NRHP)
Fegles Construction Co.	Minneapolis, MN	No information	Badger AAP (1951 Rehab of plant for Korean War)	No information
Foley Brothers, Inc.	St. Paul, MN	No information	Lake City AAP (1940)	St. Paul City Hall and Ramsey County Courthouse (construction contractors), Minnesota (1931-NRHP and HABS)
Ford Bacon and Davis	New York, NY	No information	Longhorn AAP	No information
Fraser-Brace Co., Inc.	New York, NY	No information	Holston AAP (contract general contactor and project manager 1942)	No information
George W. Condon Co.	Omaha, NE	No information	Kansas AAP(1941)	No information
Ruby Construction	No information	No information	Anniston Army Depot (CWE)	No information
Sanderson & Porter	New York, NY	1894	Joliet AAP Elwood (1941); Pine Bluff Arsenal (1941)	US Rubber Company, Charlotte, NC (1942); Nine Mile Hydroelectric Power Plant, Washington (1906/08-NRHP and HAER)
Tankersley Construction Co.	Oklahoma City	No information	McAlester AAP	McIntosh County Courthouse, Oklahoma (ca 1930-NRHP); Cleveland County Courthouse, Oklahoma (ca 1930-NRHP)
Winston Brothers, Co.	No information	No information	Lone Star AAP; Indiana AAP (1941)	Skagit Power Development, Diablo Dam and Powerhouse, Washington (ca 1935-NRHP and HAER)
Hayes, Seay, Mattern and Mattern	Roanoke, VA	No information	Radford AAP (rehab engineers 1953/56)	No information
H.K. Ferguson Construction	Cleveland, OH	No information	Milan AAP (contract 1941 architect/engineer, in partnership with O'nan Construction)	Continental Gin Co, Alabama (ca 1848-NRHP and HAER)
J.A. Jones Construction	Charlotte, NC	No information	Radford AAP (rehab contractor 1953/56)	High rises in Charlotte (1923, 1926), Nashville (1937), Birmingham (1950)
Jennings-Lawrence	Columbus, OH	No information	Ravenna AAP (contract 1940 architect/engineer)	No information
J.M. Brown Construction Co.	No information	No information	Lone Star AAP (CWE)	No information
Johns Manville Corp.	No information	No information	Kansas AAP	No information

Firm/Company Name	Location of Firm/Company	Year Established	Army Ammunition Related Projects	Previous Work
Mittry Brothers Construction Co.	No information	No information	Hawthorne Army Depot	First Street Bridge Spanning Los Angeles River, California (1926/28-HAER)
Monson Brothers	No information	No information	Hawthorne AAP	(Brothers Olaf and Arthur)
Onan Construction Co.	No information	No information	Milan AAP (1941 in partnership with H.K. Ferguson)	No information
Paschen Contractors, Inc.	Chicago, IL	No information	Kansas AAP (1941)	No information
Peter Kiewit & Sons Co.	Omaha, NE	1884	Kansas AAP; Tooele Army Depot (1942 as part of “Inter-Mountain Contractors”)	Life Stock Exchange Building, Nebraska (ca 1920-HAER); Union Passenger Terminal, Nebraska (NRHP); Plum Bush Creek Bridges, Colorado (NRHP)
Prack & Prack Architects	Pittsburgh, PA	No information	Lone Star AAP (1941); Lone Star AAP (1945 – for demilitarization of ammo)	Gordon Square Building, Ohio (ca 1920-NRHP)
R. Allison Co.	Albuquerque, NM	No information	Fort Wingate (construction contractors 1940/41)	No information
R.J. Tipton Co.	Denver, CO	No information	Cornhusker AAP	No information
Sanderson & Porter	New York, NY	1894	Joliet AAP Elwood (1941); Pine Bluff Arsenal (1941)	US Rubber Company, Charlotte, NC (1942); Nine Mile Hydroelectric Power Plant, Washington (1906/08-NRHP and HAER)
Shreve, Anderson & Walker, Inc.	Detroit, MI	No information	Indiana AAP	No information
Smith, Hinchman & Grylls, Inc.	Detroit, MI	Early 1900s	Lake City AAP; Twin Cities AAP	Edwin Derby High School, Michigan (NRHP); League of Catholic Women Building, Michigan (1928-NRHP); St. Paul Catholic Church Complex, Michigan (NRHP); Piquette Avenue Industrial District for Ford Motor Co., Michigan (ca. 1904-NRHP); Detroit-Columbia Central Office Building, Michigan (1927-NRHP);Eastern Michigan Asylum Chapel (1907-NRHP); Allen Park Veterans Administration Hospital, Michigan (HAER); Dodge Brothers Motor Car Company Plant, Michigan (ca 1910-HAER)
Sollitt Construction Co., Inc.	No information	Circa 1920	Lone Star AAP (1941); Indiana AAP (1941)	No information
Stevens & Koon	Portland, OR	No information	Umatilla Army Depot (1940 engineers)	No information
Stone & Webster Engineering Corp.	No information	No information	Joliet AAP Kankakee; Volunteer AAP	Seattle Electric Company Georgetown Steam Plant, Washington (1906/08-NRHP)
Tankersley Construction Co.	Oklahoma City	No information	McAlester AAP	McIntosh County Courthouse, Oklahoma (ca 1930-NRHP); Cleveland County Courthouse, Oklahoma (ca 1930-NRHP)
T.H. Buell & Company (Temple Hoyne)	Denver, CO	No information	Fort Wingate (design contract 1940)	Denver Medical Depot, Colorado (1942-NRHP); Paramount Theatre, Colorado (1930-NRHP); US Customhouse (NRHP)
Walbridge-Aldinger Co.	Detroit, MI	No information	Lake City AAP	Women’s City Club, Michigan (ca 1920-NRHP); Metropolitan Building (General contractors), Michigan (ca 1925-HABS)
Walter Butler Co.	St. Paul, MN	No information	Redstone Arsenal	No information
Whitman, Requardt, & Smith	Baltimore, MD	No information	Redstone Arsenal	No information
William Lozier, Inc.	Rochester, NY	No information	Letterkenny Army Depot (architect/engineer 1941)	No information
Winston Brothers, Co.	No information	No information	Lone Star AAP; Indiana AAP (1941)	Skagit Power Development, Diablo Dam and Powerhouse, Washington (ca 1935-NRHP and HAER)

CWE = Cold War Era; NRHP=National Register of Historic Places; HABS=Historic American Buildings Survey; HAER=Historic American Engineering Record

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APPENDIX C. AMMUNITION PRODUCTION FACILITIES AT ACTIVE ARMY INSTALLATIONS (1939-1989)

1.0 Ammunition Production

The following tables provide details on the types of ammunition production facilities currently managed by the U.S. Army. The data is current as of June 2007 and includes those facilities constructed between 1939 and 1989 in the current Army Real Property Inventory. The three tables are broken down by the types of facilities at each installation, the number constructed at each installation by year, and the number constructed at all Army installations by year. The facility types are referenced by the Category Code for that particular building type.

1.1 Production Facilities Built 1939-1989

Category Code	Number in Current Army Inventory	Description
22610	38	Bag Charge Filling Plant—a building used to fill cloth bags with propellant
22612	73	Acid Manufacturing Plant—a building used for the production of acid used to manufacture explosives
22614	13	Lead Azide Manufacturing Plant—a building used to manufacture lead azide which was used in fuzes and detonators
22616	200	Explosive Manufacturing Plant—a building used for making explosives
22618	0	Chemical, Biological, Radiological Plant—a building used for the production or demilitarization of lethal or toxic agents
22620	7	Case Overhaul and Tank Facility—a building used for the production of ammunition cases and containers
22622	169	Pyrotechnic Production—a building for manufacturing pyrotechnic and/or smoke agents
22624	55	Metal Parts Production—a building used to manufacture metal parts used in munitions
22625	91	Small Caliber Loading Plant (under 40mm)—a building used for the production of small caliber ammunition
22626	54	Bomb High Explosives Filling Plant—a building used to load explosives into bombs

Category Code	Number In Current Army Inventory	Description
22628	334	Metal Parts Loading Plant—a building used to fill ammunition metal parts with explosives
22630	34	Minor Caliber Loading Plant (40-75mm)—a building used for the production of minor caliber ammunition
22632	0	Ammunition Foundry—a building used for making metal ammunition parts by casting molten metal
22635	386	Medium Caliber Loading Plant (76-120mm)—a building for manufacturing medium caliber ammunition
22638	242	Ammunition Quality Assurance/ Calibration Facility, Production—a building used for inspection and testing of ammunition components and completed munitions
22640	289	Major Caliber Loading Plant (over 120mm)—a building used to produce large caliber ammunition
22645	2	Large Caliber Rocket Motor Loading Plant—a building used for the production of large caliber (over 120mm) rocket motors
22650	12	Medium Caliber Rocket Motor Loading Plant—a building used for the production of medium caliber (76-120mm) rocket motors
22655	85	Cast High Explosive Filling Plant—a building used to melt high explosives for pouring into containers or projectiles
22660	44	Special Weapons Plant—a building used to manufacture special weapons
22665	40	Ammunition Washout Building—a building used to washout casings
22670	4	Case Filling Plant—a building used to fill casings with gunpowder
22680	1520	Propellant Plant—a building used to produce any fuel that propels the projectile when ignited, fuels can be either liquid or solid
22685	294	Ammunition Production Structure—a roofed structure not enclosed by walls used for production or assembly of munitions

Source: Department of the Army 2006; U.S. Army Real Property Inventory 2007

Table C.1 Numbers and Types of Ammunition Production Facilities at Active Army Installations Constructed 1939-1989.

	Category Codes for Ammunition Production Facilities																						
Location	22610	22612	22614	22616	22620	22622	22624	22625	22626	22628	22630	22635	22638	22640	22645	22650	22655	22660	22665	22670	22680	22685	**Total**
Aberdeen Proving Ground, Maryland																	3						**3**
Badger Army Ammunition Plant, Wisconsin		8		31									9								584	61	**693**
Fort Bragg, North Carolina													2										**2**
Fort Hood, Texas																		2					**2**
Hawthorne Army Depot, Nevada					3					2			10				28	3	1	1		4	**52**
Holston Army Ammunition Plant, Tennessee		28		109									10									4	**151**
Indiana Army Ammunition Plant, Indiana	37	18		3									7								404	4	**473**
Iowa Army Ammunition Plant, Iowa			2	5				16		42		105	15	97			23		25			1	**331**
Jefferson Proving Ground, Indiana													17										**17**
Joliet Army Ammunition Plant, Elwood, Illinois								1	18		8	22	2	12					7				**70**
Joliet Army Ammunition Plant, Kankakee, Illinois				16																			**16**
Kansas Army Ammunition Plant, Kansas			11							70		52	6	7								9	**155**
Lake City Army Ammunition Plant, Missouri				4			2	64			1		37								2		**110**
Lone Star Army Ammunition Plant, Texas						19				160		74	37	49				35				103	**477**
Longhorn Army Ammunition Plant, Texas						110							12		1						31	22	**176**
Louisiana Army Ammunition Plant, Louisiana						1	3	2	7		4	14	8	24			17	3	6				**89**
McAlester Army Ammunition Plant, Oklahoma	1			2	4			3	29		8	11	12	7		8	14		1	2		13	**115**
Milan Army Ammunition Plant, Tennessee				1								88	14	8									**111**
Mississippi Army Ammunition Plant, Mississippi							2						3	16									**21**
Newport Chemical Depot, Indiana		7		10																		21	**38**
Pine Bluff Arsenal, Arkansas						33							5							1		1	**40**
Radford Army Ammunition Plant, Virginia		12		9									30								468	51	**570**
Ravenna Army Ammunition Plant, Ohio										54	9		1	32									**96**
Ravenna Training and Logistics Site, Ohio										6	4	20		37									**67**
Redstone Arsenal, Alabama															1	4					31		**36**
Riverbank Army Ammunition Plant, California							43						1										**44**
Scranton Army Ammunition Plant, Pennsylvania							3																**3**
St. Louis Ordnance Plant, Missouri				1																			**1**
Twin Cities Army Ammunition Plant, Minnesota				9		6	2	5					4					1					**27**
Total	**38**	**73**	**13**	**200**	**7**	**169**	**55**	**91**	**54**	**334**	**34**	**386**	**242**	**289**	**2**	**12**	**85**	**44**	**40**	**4**	**1520**	**294**	**3986**
Source: U.S. Army Real Property Inventory 2007																							

Table C.2 Numbers and Types of Ammunition Production Facilities at Active Army Installations by Year of Construction (1939-1989).

	Category Codes for Ammunition Production Facilities																						
Year	22610	22612	22614	22616	22620	22622	22624	22625	22626	22628	22630	22635	22638	22640	22645	22650	22655	22660	22665	22670	22680	22685	**Total**
1940																	1						**1**
1941	9	20	2	9			3	28		56		189	25	77			19		2		395	13	**847**
1942		7		6		43	13	16	15	190	22	52	58	52	1	1	18	29	7		605	74	**1209**
1943	1	11		104	7	7		4	21	1	8	7	20	6		1	5			3	95	18	**319**
1944	6			16					5	1		5	2	4		3	14	3			217	8	**284**
1945	6					53			2			12	6	25		5	4		11		12	2	**138**
1946		1										1	1									1	**4**
1948												14	2	1			2						**19**
1949													2										**2**
1950												2	1								1	1	**5**
1951							12			1		14	2	10									**39**
1952		1					15	2	1	2		3	26	7			7		1		4		**69**
1953						32	5	7		3		6	5	9			1	1	7		7	10	**93**
1954		2				7	1					4	10	6					3		10	8	**51**
1955						6	1	26		2	1		4						1		45	9	**95**
1956													1								2		**3**
1957				1						1		3		6							4		**15**
1958																					3		**3**
1959													2								5	1	**8**
1960								1	7	5		4									11	2	**30**
1961										1			3	1					1		2	2	**10**
1962							1			7		11	8	14			1	6			3	28	**79**
1963		1				3				13		5	5	9				3	1			1	**41**
1964										1		1	4				1				4		**11**
1965		2				1				3		2		1							2		**11**
1966		2								2		3	1	6								1	**15**
1967		1										1	12	2						1	1		**18**
1968		2	11	7		1			1	7		1	1						2			8	**41**
1969		1				2		4		4	3	6	1	6			1	2			2	2	**34**
1970				7		2	1			1			1	1							1		**14**
1971		1				1		1					2									2	**7**
1972		7		1						5			1	1							3	4	**22**
1973		1		25				1		14		3	2	5							4	17	**72**
1974		5		2						1		4	2	11					1		2	5	**33**
1975				1		1						4	1	1								2	**10**
1976				2						1		1	8								3	16	**31**
1977		1											1	1			9				9		**21**
1978							1			2		17	1				1		1		12	7	**42**
1979		1				9							1						1		5	13	**30**
1980	6			17						1		8	2	3			1				3	12	**53**
1981							1					1	6						1		1	2	**12**
1982	6	6				1	1							14							3	2	**33**
1983										7			3	1							15	9	**35**
1984	1									2				3							9	1	**16**
1985	1												1								5		**7**
1986	1												1								2	1	**5**
1987	1											1	3			2					5		**12**
1988												1	4	2							7	4	**18**
1989				2				1	2					4	1						1	8	**19**
Total	**38**	**73**	**13**	**200**	**7**	**169**	**55**	**91**	**54**	**334**	**34**	**386**	**242**	**289**	**2**	**12**	**85**	**44**	**40**	**4**	**1520**	**294**	**3986**

Source: U.S. Army Real Property Inventory 2007

Table C.3 Numbers of Ammunition Production Facilities at Active Army Installations by Year of Construction (1939-1989).

Location	1940	1941	1942	1943	1944	1945	1946	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Aberdeen Proving Ground, Maryland								1														1		1						
Badger Army Ammunition Plant, Wisconsin			327	24	241										48														1	1
Fort Bragg, North Carolina																					1									
Fort Hood, Texas																													2	
Hawthorne Army Depot, Nevada	1	9	1	8	17	2						2			1											1			1	
Holston Army Ammunition Plant, Tennessee				124								1		2									1		2	2	1	3		
Indiana Army Ammunition Plant, Indiana		419			7	6							1	1			1													
Iowa Army Ammunition Plant, Iowa		155	37	1	1	11		18	2		7	8	6	3	1		9			1	1		2	2		2	4	4	8	
Jefferson Proving Ground, Indiana		2	3	2			1					7		2																
Joliet Army Ammunition Plant, Elwood, Illinois		16	27			10				3	1			1						11								1		
Joliet Army Ammunition Plant, Kankakee, Illinois																														
Kansas Army Ammunition Plant, Kansas		90	26								2		1															17	4	
Lake City Army Ammunition Plant, Missouri		43	10								1	14	9		28	1														
Lone Star Army Ammunition Plant, Texas			268		2		2				1	3	15	5	2		1			5		65	36	1	7	6	9	1	5	2
Longhorn Army Ammunition Plant, Texas			2			64							36	12	14		3	1	1	10	3	1			1			1	3	1
Louisiana Army Ammunition Plant, Louisiana		1	49			12						6	7	1							1	3	2					1		
McAlester Army Ammunition Plant, Oklahoma				75	9	15						1							1											
Milan Army Ammunition Plant, Tennessee		61	1	2	2						3	1	3	1							2	7		3		4			1	
Mississippi Army Ammunition Plant, Mississippi																														
Newport Chemical Depot, Indiana			3																											
Pine Bluff Arsenal, Arkansas			31	5																							1			1
Radford Army Ammunition Plant, Virginia		18	317	72			1			2		10	8	16				1	1			1		4				13	2	
Ravenna Army Ammunition Plant, Ohio		12	72		3	4								3															1	1
Ravenna Training and Logistics Site, Ohio		21	10		1	11					12			2							1								6	
Redstone Arsenal, Alabama			3	2	1	3										2	1	1	5	3	1	1			1		1			
Riverbank Army Ammunition Plant, California			11								12	13	5		1															1
Scranton Army Ammunition Plant, Pennsylvania												3																		
St. Louis Ordnance Plant, Missouri			1																											
Twin Cities Army Ammunition Plant, Minnesota			10	4									2	2													2			7
Source: U.S. Army Real Property Inventory 2007																														

Table C.3 Numbers of Ammunition Production Facilities at Active Army Installations by Year of Construction (1939-1989).

Location	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Aberdeen Proving Ground, Maryland																			
Badger Army Ammunition Plant, Wisconsin			1			15		1		26		8							
Fort Bragg, North Carolina																	1		
Fort Hood, Texas																			
Hawthorne Army Depot, Nevada	2			3	2			2											
Holston Army Ammunition Plant, Tennessee		4		3	1	3	1		1										2
Indiana Army Ammunition Plant, Indiana		2				1	7	2		6		6	6	1	1	1	1	4	
Iowa Army Ammunition Plant, Iowa	1	2	9	17	3				1	1	1		7	3		1			2
Jefferson Proving Ground, Indiana																			
Joliet Army Ammunition Plant, Elwood, Illinois																			
Joliet Army Ammunition Plant, Kankakee, Illinois			16																
Kansas Army Ammunition Plant, Kansas		5			1	3	2				1			2		1			
Lake City Army Ammunition Plant, Missouri				1													2		1
Lone Star Army Ammunition Plant, Texas			11	1	1	1		25		2									
Longhorn Army Ammunition Plant, Texas		1			1				20						1				
Louisiana Army Ammunition Plant, Louisiana			3							2							1		
McAlester Army Ammunition Plant, Oklahoma			1				9	1											3
Milan Army Ammunition Plant, Tennessee			2		1	1				9	7								
Mississippi Army Ammunition Plant, Mississippi											1	15	4						1
Newport Chemical Depot, Indiana	3	6	26																
Pine Bluff Arsenal, Arkansas	1											1							
Radford Army Ammunition Plant, Virginia		2	3	8		7	2	6	8	7	2	3	18	10	3	2	4	11	8
Ravenna Army Ammunition Plant, Ohio																			
Ravenna Training and Logistics Site, Ohio																		3	
Redstone Arsenal, Alabama								4							2		3		2
Riverbank Army Ammunition Plant, California								1											
Scranton Army Ammunition Plant, Pennsylvania																			
St. Louis Ordnance Plant, Missouri																			
Twin Cities Army Ammunition Plant, Minnesota																			
Source: U.S. Army Real Property Inventory 2007																			

APPENDIX D. FUNDING THE CONSTRUCTION OF AMMUNITION-RELATED FACILITIES

1.0 Introduction: Austerity During the Immediate Post-World War II Period (1946-1950)

Congressional appropriations for ammunition production and storage during the immediate post-World War II period reflected a transition from an immense military budget required to meet emergency needs to a peacetime budget designed to meet minimum defense requirements during a period of spending austerity. By 1950, however, Congress was increasing ammunition-related spending to finance the development of new ammunition technology. Many appropriations made during the Cold War era are not installation specific, referring only to general Ordnance Corps funding for new facilities.

Ammunition-related appropriations for fiscal years 1946 to 1948 indicated that Congress was shifting to peacetime funding of the Army and was hesitant to expand the Army's infrastructure through land acquisition or building construction. While World War II appropriations for the Ordnance Department and the Chemical Warfare Service reflected the wartime buildup of the military, appropriations for these two departments were drastically reduced shortly after the war. The Ordnance Department's appropriation declined to $327.7 million for fiscal year 1947 and then to $245.5 million for 1948. The Chemical Warfare Service appropriation dropped to $25.9 million for fiscal year 1947, and then to $19.9 million for 1948.

The Army Corps of Engineers, which oversaw construction on military installations, was appropriated $115.5 million for Army construction for fiscal year 1947. The appropriation did not identify construction projects to be funded, and no separate authorization listing authorized Army construction projects was located. The appropriation did indicate that Congress wanted to limit new Army construction. Two conditions of the appropriation were that the Secretary of War approve all land purchases, and that land be acquired through purchase only if that was cheaper than leasing it (United States Code Congressional Service 1946:528). The Army Corps of Engineers received no military construction appropriation during fiscal year 1948 (United States Code Congressional Service 1947:561-2).

Meanwhile, the Military Appropriation Act of 1948 reduced portions of appropriations made available between fiscal years 1942 and 1946. The Army Corps of Engineers had to return $13 million intended for construction at military posts, while the Ordnance Department returned $363 million and the Chemical Warfare Service returned $30 million (United States Code Congressional Service 1947:562). However, the following year's appropriation provided the Ordnance Department $10 million to pay expenses on contracts executed before July 1, 1946 (United States Code Congressional Service 1948:672).

Appropriations for the Ordnance Department and the Chemical Service increased for fiscal years 1949 and 1950. The Ordnance Department's fiscal year 1949 appropriation nearly tripled to $610 million, and then increased to $730 million for fiscal year 1950. The Chemical Service appropriation increased approximately one-third in fiscal year 1949, to $26 million, and then by an additional one-third in fiscal year 1950, to $35 million (United States Code Congressional Service 1948a:671-2; United States Code Congressional Service 1949:1008-9).

For military construction, Congress appropriated $76 million to the Army Corps of Engineers for fiscal year 1949 and $85.7 million for fiscal year 1950 (United States Code Congressional Service 1948a:671; United States Code Congressional Service 1949:1008). These appropriations were directed to finance construction authorized in June 1948. This authorization included approximately

$7 million in construction at seven ammunition-related installations. Construction directly related to ammunition housed research and development on ammunition-related materials. It included chemical laboratory facilities at Edgewood Arsenal, Maryland; research and development facilities for high explosives, completed bombs, rockets, and rocket powders at Picatinny Arsenal, New Jersey; and laboratory, storage, and testing facilities for rocket development at White Sands Proving Ground, New Mexico. Other construction financed at these installations under this appropriation consisted of support structures such as utilities, family quarters, and administration buildings (United States Code Congressional Service 1948:390-92).

2.0 Increase in Appropriations During the Korean Conflict

Ammunition-related military spending increased dramatically when the United States became involved in military action in Korea in fall 1950. Equipment and supplies was one of three areas of the military the Department of Defense targeted for expansion at the start of the Korean conflict (United States Code Congressional and Administrative Service 1951a:2213). As a result, multiple appropriations during fiscal year 1951 dramatically increased that year's funding for the Ordnance Department, the Chemical Corps, and construction. Four appropriations provided the Ordnance Department a total of $7 billion, and the Chemical Corps received $120.2 million spread over three appropriations (United States Code Congressional Service 1950a:1052; United States Code Congressional Service 1950b:801-2; United States Code Congressional Service 1950c:1246; United States Code Congressional Service 1951a:48).

Appropriations for ammunition-related spending remained elevated through fiscal year 1954, although not as high as at the beginning of the Korean conflict. The Ordnance Corps received $8 billion in fiscal year 1952, $2.7 billion in 1953, and $3.2 billion in 1954. The Chemical Corps received $122.5 million in 1952, slightly higher than its 1951 total appropriation, but was not financed under a separate line item in 1953 and 1954 (United States Code Congressional and Administrative Service 1951b:571-2; United States Code Congressional and Administrative News 1952a:498-9; United States Code Congressional and Administrative News 1953a:380).

Ammunition-related construction during the early 1950s focused on ammunition storage facilities as well as research and development. During fiscal year 1951, three appropriations provided the Army Corps of Engineers a total of $500 million for Army construction, the first substantial Army construction appropriation since the end of World War II. The majority of the money was appropriated in the second supplemental appropriation halfway through the fiscal year, after the United States became involved in Korea (United States Code Congressional Service 1950a:1052; United States Code Congressional Service 1950b:801; United States Code Congressional Service 1950c:1246).

These funds were directed to finance two construction authorizations. The first two appropriations financed an authorization that included $11.6 million in construction at ten ammunition-related installations. The significant construction projects at these installations focused on research and development and included: rocket development and test facilities at Picatinny Arsenal; chemical laboratories and testing facilities, cluster and firebomb assembly facilities, and an experimental loading and filling building at the Army Chemical Center, Maryland; and laboratories, rocket motor test stands, and a nitroglycerin plant at Redstone Arsenal, Alabama (United States Code Congressional Service 1950d:240-1). The third appropriation funded an authorization that included $38 million in construction for the Ordnance Corps and $21.1 million for the Chemical Corps, for unspecified installations (United States Code Congressional Service 1950e:1238).

Army construction appropriations during fiscal year 1952 were even greater than in the previous year. This growth reflected attention to another aspect of the military expansion program: "namely, the provision for adequate airfields, forts, camps, stations, depots, bases, and other facilities needed to meet the operational requirements of the approved forces and to permit the utilization of the newer types of equipment now coming off the production lines" (United States Code Congressional and Administrative Service 1951a:2213-4).

The first appropriation of $48.3 million was directed to finance construction authorized during previous years. A supplemental appropriation of $1 billion financed previous authorizations and a new authorization that included $160 million in ammunition-related construction, the first substantial outlay under this category during the postwar period. For the Ordnance Corps, $123 million in construction was authorized at 34 installations, including storage buildings at 22 installations and research and development buildings at eight installations. The Chemical Corps was authorized to spend $37 million at six installations; all were slated to receive storage buildings. Research and development buildings were authorized at two installations (United States Code Congressional and Administrative Service 1951c:485-7; United States Code Congressional and Administrative Service 1951b:571; United States Code Congressional and Administrative Service 1951d:772).

Authorized ammunition-related construction for fiscal year 1953 focused on research and development buildings, but returned to storage buildings in 1954. Of the overall Army construction appropriation, nearly $50 million was authorized for ammunition-related construction during 1953, divided roughly equally between the Ordnance Corps and the Chemical Corps. Research and development buildings were authorized for six of the nine Ordnance Corps installations and all four authorized Chemical Corps installations (United States Code Congressional and Administrative News 1952b:579-80). Of the overall Army construction appropriation for 1954, $10.5 million was authorized for 10 Ordnance Corps installations, including storage buildings at five installations and research and development buildings at two installations (United States Code Congressional and Administrative News 1953b:486-7). No military construction line items were contained in appropriations for either year, but the line item that funded ammunition procurement and production permitted the use of funds in that category for construction (United States Code Congressional and Administrative News 1952a:498-9; United States Code Congressional and Administrative News 1953a:380).

3.0 Reduced Spending During the Mid- to Late-1950s

Reflecting a return to a peacetime budget, ammunition-related spending on operations and construction declined during the mid- and late 1950s. Unlike appropriations for previous fiscal years, appropriations for fiscal years 1955 to 1958 contained no ammunition-related line items. The fiscal year 1955 appropriation even contained a provision requiring the Army to return $500 million previously appropriated for ammunition procurement and production (United States Congressional and Administrative News 1954a:401-3; United States Code Congressional and Administrative News 1955a:334-6; United States Code Congressional and Administrative News 1956a:518-20; United States Code Congressional and Administrative News 1957a:329-31). This absence indicated that wartime production of ammunition had ceased. Peacetime production likely was drastically reduced, and few new munitions were manufactured. Activity at most ammunition plants and depots focused on demilitarization and surveillance. Ammunition production and storage costs might have been financed through other appropriation line items, such as "Military Personnel" or "Maintenance and Operations."

Spending on Army construction was reduced during the mid- and late 1950s too. No construction line items were contained in fiscal year 1955 appropriations. For fiscal year 1956, $485 million was appropriated, but it was intended to fund five prior construction authorizations as well as the current authorization, which only authorized $20 million in ammunition-related construction at 22 installations. The majority of the construction related to support buildings, such as utilities, administration, maintenance, and housing. Research and development buildings were authorized for two installations, and storage buildings were authorized at one installation, although the specific installations were not named (United States Code Congressional and Administrative News 1954a:401-3; United States Code Congressional and Administrative News 1954b:955-6; United States Code Congressional and Administrative News 1955b:502-3; United States Code Congressional and Administrative News 1955c:534-5).

Congress appropriated $202 million for Army construction during fiscal year 1957. However, as with the 1956 appropriation, the money was directed to fund construction authorized for several prior years, in addition to the current authorization, which included $12.3 million for ten ammunition-related installations. As in the previous authorization, most of the construction consisted of utility, maintenance, administrative, and housing buildings. Research and development buildings were authorized at two installations, and storage buildings were authorized at three installations (United States Code Congressional and Administrative News 1956b:1174; United States Code Congressional and Administrative News 1956c:795).

For fiscal year 1958, $310 million was appropriated for Army construction to finance authorizations from several prior years, as well as the current authorization, which included $22.6 million at eight ammunition-related installations. Most of the authorized construction consisted of utility, maintenance, housing, and administrative buildings; White Sands Proving Ground was authorized to receive buildings for research and development, and storage (United States Code Congressional and Administrative News 1957b:583-4; United States Code Congressional and Administrative News 1957c:457-8).

4.0 Slow Escalation in Ammunition Spending 1959-1966

Appropriations for ammunition-related spending resumed in fiscal year 1959, but were lower than appropriations earlier in the decade. For the first time, ammunition-related appropriations included funding for missiles, reflecting increased interest in the development of guided missile systems. Through fiscal year 1966, ammunition spending hovered between $1.2 billion and $1.7 billion (United States Code Congressional and Administrative News 1958a:842; United States Code Congressional and Administrative News 1959a:408; United States Code Congressional and Administrative News 1960a:401; United States Code Congressional and Administrative News 1964a:544; United States Code and Administrative News 1965a:836).

Ammunition-related construction authorizations during this period ranged from $8.5 million in fiscal year 1960 to $28.2 million in fiscal year 1959, and relied on appropriations as low as $20 million in fiscal year 1961 and as high as $323.4 million for fiscal year 1966 (United States Code Congressional and Administrative News 1958b:744; United States Code Congressional and Administrative News 1958c:1288-9; United States Code Congressional and Administrative News 1959b:333; United States Code Congressional and Administrative News 1959c:617; United States Code Congressional and Administrative News 1960b:188-9; United States Code Congressional and Administrative News 1960c:527-8; United States Code Congressional and Administrative News 1961a:112; United States Code Congressional and Administrative News 1961b:740; United States Code Congressional and Administrative News 1962a:276; United States Code Congressional and Administrative News 1962b:677-8; United States Code Congressional and Administrative News 1963a:339-40; United States Code Congressional and Administrative News 1963b:508; United States Code Congressional and Administrative News 1964b:401; United States Code Congressional and

Administrative News 1964c:1010; United States Code Congressional and Administrative News 1965b:759-60; United States Code Congressional and Administrative News 1965c:799).

The majority of funding was authorized for support buildings, such as utility, maintenance, administration, and housing buildings. Funding for buildings more specifically related to ammunition production financed research and development buildings. Production facilities were authorized for fiscal year 1965 at Picatinny Arsenal, New Jersey (United States Code Congressional and Administrative News 1964b:401). No ammunition storage buildings were authorized during this period.

5.0 Vietnam-Era Ammunition Appropriations

Corresponding with the nation's increasing involvement in the Vietnam conflict, ammunition-related spending grew during the late 1960s and early 1970s. Ammunition appropriations grew to $2.1 billion for fiscal year 1967 and $5.5 billion in 1968. For the first time, the 1968 appropriation specified that $269 million be used for the NIKE-X anti-ballistic missile system (United States Code Congressional and Administrative News 1967a:9; United States Code Congressional and Administrative News 1967b:267). Fiscal year 1969 appropriations included $5.6 billion and an additional $510 million, the largest ammunition appropriation of this period and the first time additional funding was provided (United States Code Congressional and Administrative News 1968a:1299). This practice continued through fiscal year 1974.

While still high, appropriations declined to $4.3 billion plus $50 million for 1970, to $2.9 billion plus $50 million for 1971, and to $2.3 billion plus $300 million for 1972, but rose to $3 billion plus $90 million for fiscal year 1973. Beginning in fiscal year 1972, appropriations were listed separately for ammunition and missiles (United States Code Congressional and Administrative News 1969a:498; United States Code Congressional and Administrative News 1970a:2366-7; United States Code Congressional and Administrative News 1971a:815; United States Code Congressional and Administrative News 1972a:1383).

For the first time during the postwar period, spending on ammunition-related construction included buildings for ammunition production facilities as well as arsenals and depots. This spending coincided with the peak in ammunition-related construction spending during this period, fiscal years 1968 to 1971.

During fiscal year 1967, seven installations were authorized to receive $10.5 million in new buildings, financed by two Army construction appropriations totaling $402 million. Five of the installations were to receive research, development, and test buildings, while the other two installations were authorized utilities and supply facilities (United States Code Congressional and Administrative News 1966a:874; United States Code Congressional and Administrative News 1966b:1373; United States Code Congressional and Administrative News 1967a:10). The 1968 authorization – financed by a $372 million Army construction appropriation – grew to $22.9 million at 17 installations, including research, development, and test buildings at six installations and production facilities at Pine Bluff Arsenal, Arkansas. The other buildings included utilities, maintenance buildings, housing, administration buildings, and supply buildings (United States Code Congressional and Administrative News 1967c:314; United States Code Congressional and Administrative News 1967d:596-7).

The 1969 ammunition-related construction authorization declined slightly to $22 million but listed 19 facilities, including four ammunition plants. The authorization was financed by a $548 million Army construction appropriation (United States Code Congressional and Administrative News

1968b:1004). Although the buildings authorized at the plants were only utilities, the authorization is significant for being the first during the post-World War II period that provided buildings for plants. The four facilities were Burlington Army Ammunition Plant, New Jersey; Joliet Army Ammunition Plant, Illinois; Lake City Army Ammunition Plant, Missouri; and Sunflower Army Ammunition Plant, Kansas. Other authorized construction included production facilities at Rock Island Arsenal; research, development, and test facilities at four other installations; and several types of support buildings (United States Code Congressional and Administrative News 1968c:436-7).

The 1970 construction authorization, the largest of this period, permitted $26.7 million in construction at 21 facilities, financed by a $287 million Army construction appropriation. Included were utilities at five plants: Badger Army Ammunition Plant, Wisconsin; Holston Army Ammunition Plant, Tennessee; Iowa Army Ammunition Plant; Joliet; and Sunflower. Also included were research, development, and test buildings at four installations and utilities and other support buildings at various installations (United States Code Congressional and Administrative News 1969b:323; United States Code Congressional and Administrative News 1969c:490). The 1971 construction authorization of $15 million at 15 facilities included unspecified buildings at six ammunition plants: Alabama Army Ammunition Plant, Badger; Burlington; Cornhusker Army Ammunition Plant, Nebraska; Iowa; and Radford Army Ammunition Plant, Virginia. The authorization was funded by a $647 million Army construction appropriation (United States Code Congressional and Administrative News 1970b:1407-8; United States Code Congressional and Administrative News 1970c:1643). Beginning with this authorization, the types of buildings authorized for each installation were no longer specified.

The 1972 authorization was considerably lower, authorizing $7.4 million at five installations: Aberdeen Proving Ground, Maryland; Letterkenny Army Depot, Pennsylvania; Redstone Arsenal, Alabama; White Sands Missile Range, New Mexico; and Yuma Proving Ground, Arizona. The authorization was financed by a $438.3 million Army construction appropriation (United States Code Congressional and Administrative News 1971b:422; United States Code Congressional and Administrative News 1971c:527). For fiscal year 1973, $10.2 million in construction was authorized at eight installations. As with the prior year, no plants were included; all authorizations were for arsenals, depots, and proving grounds. The authorization was financed by a $413.9 million Army construction appropriation (United States Code Congressional and Administrative News 1972b:1325; United States Code Congressional and Administrative News 1972c:1344).

6.0 Appropriations during the Post-Vietnam Conflict Period

Ammunition spending declined through the mid-1970s as the Army budget transitioned to a peacetime focus. Fiscal years 1974 through 1976 represented declines in spending on both ammunition and missiles. Spending increased during the late 1970s, but there was a greater increase in spending on missiles than on ammunition. For fiscal year 1974, ammunition spending declined to $784.3 million plus $146.1 million, while missile spending declined to $602 million plus $22 million (United States Code Congressional and Administrative News 1973a:1158-9). Ammunition spending for fiscal year 1976 declined to $637.2 million, and missile spending declined to $422.6 million (United States Code Congressional and Administrative News 1976a:161-2).

Spending on ammunition-related construction increased, although the number of installations authorized for construction funds did not increase substantially. For example, $27.6 million was authorized at 10 facilities for fiscal year 1974, and $35.4 million was authorized at 12 facilities in 1975. A comparison of the authorizations' lists of installations and funding levels during this period and the prior one indicates that more funds were allocated to each installation than in previous years. This suggests that either a greater number of buildings or more-substantial buildings were authorized

(United States Code Congressional and Administrative News 1974b:727; United States Code Congressional and Administrative News 1974a:2011-12).

Ammunition-related spending increased during the late 1970s, both in ammunition and missile production and in building construction, particularly at ammunition plants. For fiscal year 1977, the ammunition appropriation totaled $903 million and the missile appropriation totaled $497 million. Appropriations increased again in 1978, to $1.2 billion for ammunition and $537 million for missiles. The ammunition appropriation remained at $1.2 billion for fiscal years 1979 and 1980, but the missile appropriation increased to $737 million for 1979 and $1.1 billion in 1980 (United States Code Congressional and Administrative News 1976c:1285-6; United States Code Congressional and Administrative News 1977a:892-3; United States Code Congressional and Administrative News 1978a:1237-8; United States Code Congressional and Administrative News 1979a:1145-6).

Spending on ammunition-related construction increased dramatically during the late 1970s, notably because a number of plants were authorized to receive new buildings. For fiscal year 1977, $81.6 million was authorized, a 130 percent increase over the previous year. Of 24 installations authorized for new construction, 11 were ammunition plants (Radford Army Ammunition Plant was listed twice, authorized to receive two different funding amounts). For the first time, the authorization listed some of these plants separately, for unknown reasons (United States Code Congressional and Administrative News 1976b:1350). The fiscal year 1978 construction authorization increased even more dramatically, to $571.3 million for 28 named installations and one “unspecified” ammunition facility that was authorized for construction totaling $334.7 million, representing the majority of the authorized funds. The named installations included 14 plants (two ammunition plants, Iowa and Indiana, were listed twice) (United States Code Congressional and Administrative News 1977b:359).

While still elevated compared with earlier in the decade, the fiscal year 1979 authorization was lower than in the previous year, $106 million for 27 installations. Seventeen were plants, but six of them were listed twice: Holston, Iowa, Kansas, Longhorn, Milan, and Sunflower (United States code Congressional and Administrative News 1978b:566). The construction authorization increased again for fiscal year 1980, to $188 million for 38 installations. Eighteen were plants; five of them were listed twice: Indiana, Lake City, Radford, Riverbank, and Scranton (United States Code Congressional and Administrative News 1979b:929).

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APPENDIX E: TECHNICAL GLOSSARY

A well-developed technical glossary of numerous terms and phrases related to ammunition production is included in *Historic Context for the World War II Ordnance Department's Government-Owned Contractor-Operated (GOCO) Industrial Facilities, 1939-1945* (Kane 1995), the companion volume to this study. The earlier study can be consulted for additional information. Several terms used throughout this current study are defined here for quick reference.

Automated Fuse and Detonator Loader: A machine developed for the automatic production of fuzes and detonators developed by the Mason and Hanger Company. Automatic production of fuzes and detonators was seen as significant achievement as it eliminated most of the hand assembly of these devices and removed personnel from frequent contact with explosives.

Biazzi Process: A process for the continuous manufacture of nitroglycerin. The Biazzi process was considered one of the major successes in the automation of explosives manufacturing during the 1950s. An added benefit was that continuous nitration produced only a small amount of nitroglycerin at any given moment, lessening the change of a catastrophic explosion.

Cemesto: Developed by the Celotex Company and used extensively during World War II for the construction of housing and defense plants. Cemesto is made-up of a Celotex core coated with an asbestos-cement mixture. The panels were fitted together through interlocking grooves.

Continuous Automated Multi-Base Propellant Line (CAMBL): Completed in 1984, CAMBL was a process developed for the continuous manufacture of multi-base propellants. The manufacturing processes including pumping nitrocellulose slurry to the plant where additional explosive compounds were added and the finishing steps in propellant production were fully automated.

Continuous Automated Single-Base Propellant Line (CASBL): Completed in 1978, CASBL was a process developed at for the continuous manufacture of single-base propellants. The manufacturing processes included pumping nitrocellulose slurry to the plant where the finishing steps in propellant production were fully automated.

Double-Base Propellant: A propellant mixture composed of nitrocellulose and one additional explosive. Double-base propellants were more powerful than nitrocellulose alone, and were widely used for the manufacture of rocket motors. Double-base propellants were manufactured with processes similar to that for single-base powders.

Explosive A compound with a high burning rate and an intense, almost immediate detonation. Explosives include trinitrotoluene (TNT) that is often used as the main charge in munitions, and initiating explosives used in the manufacture of fuzes and detonators.

Fulminate of Mercury: An extremely sensitive explosive used in the manufacture of fuzes and detonators.

Government-Owned Contractor-Operated Installation (GOCO): An Army installation designed and constructed by private-sector firms with Government funds. The Army retains ownership of all facilities at the installation, and enters into contracts with private firms for day-to-day operation.

Government-Owned Government-Operated Installation (GOGO): Similar to a GOCO, but the Army both retain ownership and operate the installation.

Lead Azide: An extremely sensitive explosive used in the manufacture of fuzes and detonators.

High Melting-point Explosive/Homocyclonite (HMX): The most powerful solid explosive manufactured in volume in the United States. HMX was originally discovered in the 1940s; however, its high cost of production and issues with availability limited its military applications until a process for continuous manufacture was developed in the 1950s. HMX is a byproduct of RDX manufacture.

Improved Conventional Munitions (ICM): Improved conventional munitions use plasticized explosives that were formed in large hydraulic presses then machined to final shape. The ability of a plastic explosive to be finely machined and hold its shape made it ideal for modern weapons systems including many guided missiles.

Multi-Base Propellant: A propellant mixture composed of nitrocellulose and other explosives. Multi-base propellants were manufactured with processes similar to that for single-base powders.

Nitration: A chemical process where the chemical composition of one compound is altered by the addition of second, high-nitrogen agent, usually in an acidic environment. This chemical reaction is the initial step in the manufacture of most propellants and explosives.

Nitrocellulose: This compound is formed by nitrating cotton fibers or wood pulp. It is the prime component of the majority of propellants including both single- and multi-base mixtures.

Nitroglycerin: An oily, straw-colored high explosive used in multi-base propellants. Historical manufacturing processes called for the ingredients to be metered and mixed by plant personnel exposing them the hazardous chemicals and placing them at risk in the event of an explosion. The batch-mixing of nitroglycerin producing comparatively large amounts of the highly-sensitive explosive. The Biazzi, continuous process replaced batch mixing in the 1950s.

Nitroguanadine: Nitroguanadine offered equivalent explosive power to TNT, but was more stable.

Plastic-Bonded Explosive (PBX): Plastic-bonded explosives were developed in 1947, but were not widely available until the 1960s. PBX is a high explosive with characteristics similar to TNT but is less sensitive. The explosive can be shaped and accurately machined to fit various applications. Plastic-bonded explosives are well-suited to modern applications in guided missiles and improved conventional munitions.

Propellant: Propellants are explosives of a lower order with a slower burning rate, referred to as deflagration, and are used primarily to propel the explosive charge to its target.

Research Development Explosive (RDX): Large-scale development of RDX is considered one of the key technological achievements of the Second World War. It acquired its name through British scientists who wished to mask their research with cyclonite, a highly sensitive, yet powerful explosive. The compound is rarely used alone, and is mixed with other components to produce numerous explosives including Compositions A, B, and C.

Single-Base Propellant: The most common type of single-base propellant was smokeless powder, a development of the late-nineteenth century.

Solventless Propellants: Solventless propellants are double-base compounds that are manufactured without any form of solvent to aid in the manufacturing process. They are ideally suited for making large propellant grains, as the drying process for this type of propellant frequently caused deformities that prevent the grain from fitting tightly into the missile case.

Single-Pour Controlled Cooling (SPCC): The SPCC process was developed by Mason and Hanger. The process used volumetric loading of artillery projectiles and a controlled cooling system that prevented shrinking of the semi-molten explosive and subsequent steps to top-off the charge. The SPCC process was considered a significant technological achievement of the 1950s.

Rocket Propellants: While moderate size propellant grains were extruded, cut to length, and machined, large propellant grains for many guided missiles required an alternate production method. Grains for larger missiles, such as the HONEST JOHN and NIKE were cast in cellulose sleeves called beakers.

Transite: A type of corrugated asbestos siding widely used in the explosives industry due to fire resistance.

Trinitrotoluene (TNT): Trinitrotoluene was the most widely used high explosive of World War II, and it continues in widespread use for both commercial and military applications. Until the 1960s, TNT was manufactured in separate steps in large batches exposing workers to numerous health risks including skin and hair discoloration, headaches, respiratory disease, and corrosive burns. Continuous nitration, developed in the late 1960s, used a series of temperature-controlled vessels to manufacture TNT with minimal human interaction. Continuous nitration of TNT was considered a significant technological achievement for explosives production during the Cold War.