NAVAL PROVING GROUND INDIAN HEAD
Bounded by the Mattawoman Creek to the south, the Potomac River to the west and north, and Benson Road and State Route 210 to the east
Indian Head
Charles County
Maryland

HAER MD-179
HAER MD-179

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
NORTHEAST REGIONAL OFFICE
National Park Service
U.S. Department of the Interior
U.S. Custom House, 3rd Floor
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HISTORIC AMERICAN ENGINEERING RECORD

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Location: Bounded by the Mattawoman Creek to the south, the Potomac River to the west and north, and Benson Road and State Route 210 to the east, Indian Head, Charles County, Maryland.

Universal Transverse Mercator (UTM) coordinates:
UTM 18 311854 4275302, 18 310231 4274868, 18 308125 4272044, 18 307689 4270683, 18 308828 4270851, 18 309788 4272357, 18 310199 4271854, 18 311649 4272953, (representative UTM coordinates for the Naval Proving Ground Indian Head) U.S.G.S. Indian Head, MD-VA 7.5 minute Quadrangle, 1978

Present Owner: U.S. Department of the Navy

Present Use: Naval Support Facility

Significance: The Naval Proving Ground Indian Head was established in 1890 as a testing facility for guns, ammunition, and armor plate for Navy ships. In 1900, a smokeless powder factory was created. In 1943, a ballistics laboratory and an Extrusion Plant were established. The facility continued to develop through the 1950s, when four pilot plants were created. During the 1960s, the facility shifted from production to research. It continues to serve as a Naval Support Facility.

Historian: Roger Lee Ciuffo, Senior Project Manager and Rebecca Gatewood, Project Manager, R. Christopher Goodwin & Associates, Inc., Frederick, Maryland, October 2011.

Project: Approximately 207 excess buildings are scheduled for removal to control utility costs and to provide space for future construction. The undertaking includes the demolition of contributing elements to the Naval Powder Factory Historic District and the Extrusion Plant Historic District. Measures to mitigate the adverse effects are identified in a September 2010 MOA executed among the Commandant, Naval District Washington; the Commanding Officer, Naval Support Activity South Potomac; and the Maryland SHPO pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended. Documentation of Naval Powder Factory Historic District (MIHP # CH-491) and the Extrusion Plant Historic District (MIHP # CH-493) to the standards of the Historic American Engineering Record is among these measures. The recordation project was undertaken by R. Christopher Goodwin & Associates, Inc. on behalf of the Eastern Research Group, Inc. for the Department of the Navy. Technical oversight was provided by the Naval Surface Warfare Center Indian Head Division, Naval Facilities Engineering Command Washington, NPS, and the Maryland Historical Trust.

NAVAL PROVING GROUND INDIAN HEAD

Natural Setting

The Naval Proving Ground Indian Head is located along the Potomac River in western Charles County, Maryland. The property encompasses the northern bank of Mattawoman and Chicamuxen Creeks tributaries of the Potomac River. The approximately 3,383 acres (1,369.1 hectares) active Navy installation is composed of two principal areas: (1) the northern Indian Head area (Cornwallis Neck), which includes approximately 1,970 acres (793.3 hectares); and the southern Stump Neck Annex, which contains approximately 1,170 acres (473 hectares). Cornwallis Neck is densely developed with offices, research and development facilities and base housing. The primary mission of the area historically has been the production of explosive materials. The Stump Neck Annex is less developed and serves as an explosive training and testing area. Other properties associated with the installation include: Marsh Island, 25 acres (10.1 hectares); Thoroughfare Island, 10 acres (4.0 hectares); and Bullitt Neck, 47 acres (19.0 hectares).

Historic Context

The text for the following section is excerpted, with minor modifications, from *Phase I Cultural Resources Survey of Stump Neck Annex and Supplemental Architectural Investigations, Indian Head Naval Surface Warfare Center, Charles County, Maryland* prepared for Engineering Field Activity – Chesapeake, Washington, D.C. (Goodwin 1998) and *Historical and Architectural Investigation of 1950s-Era Industrial Areas and Miscellaneous Buildings, Indian Head Division, Naval Surface Warfare Center, Indian Head, Charles County, Maryland* prepared for the Indian Head Division Naval Surface Warfare Center, Indian Head, Maryland (Goodwin 2005).

Historic Overview of the Naval Proving Ground Indian Head

In 1890, the U.S. Navy purchased land at Cornwallis Neck to develop a weapons testing facility to replace the Annapolis Proving Ground. With increased recreational use of the Chesapeake Bay, testing at the Annapolis Proving Ground had become problematic by the late 1880s. The ordnance was fired from the U.S. Naval Academy across the Severn River and presented a safety hazard to pleasure boats and steam boat traffic destined for the port of Annapolis. The Navy became concerned that the occasional wild shot or ricochet from an experimental shell fired at the Annapolis Proving Ground, posed a danger not only to boaters, but to individuals using the banks of the river (Carlisle 2002:4). The Indian Head site was located in an isolated undeveloped area that bordered the Potomac River. This location offered the advantage of a large test area-firing area removed from population centers, as well as river access to the gun factory at the Washington Navy Yard located upriver on the Potomac.

Ensign Robert B. Dashiell was directed by the U.S. Navy to establish a new base for testing guns, ammunition, and armor plate for Navy ships (Bowlin 1988:5-6; Carlisle 2002:4-5; Cannan et al. 1995:231; Stevens et al. 1995). To accommodate the proving ground, the Navy purchased two semi-rectangular tracts of land including 473 acres at Cornwallis Neck and 186 acres at the Mount Pleasant Farm and Fishery. The proving ground was concentrated in “the Valley,” a ravine in the northern part of the tract near the Potomac River (Stevens et. al. 1995). Early improvements focused on clearing the land, draining marshes, and erecting a dock to accommodate barges laden with new guns requiring testing from the Washington gun factory. (Carlisle 2002:8-9). The name of the facility was Naval Proving Ground Indian Head.

The first gun testing at Indian Head occurred in January 1890 (Carlisle 2002:9). Early gun testing generally involved mounting weapons to be tested on the south side of the Valley and firing at a steel plate located across the Valley. This method enabled the Navy to simultaneously test shells, guns, gun mounts, powder charges, and armor. Range testing was conducted over the Potomac River towards Virginia. The Indian Head facility also tested gunpowder and armor plate produced by civilian suppliers, including Du Pont and Bethlehem Steel. Through these testing efforts, Indian Head played a vital role in the development of new ordnance for the U.S. Navy (Carlisle 2002:17).

Development activity during the first decade of the proving ground included the installation of railroad tracks between the wharf and the batteries, and the construction of gun platforms, magazines, storehouses, and a chronograph house. Before 1900, housing initially was limited to a few homes. Nineteenth-century military housing at the station comprised a Queen Anne-style house on Dashiell Road occupied by Ensign Dashiell, and cottages for personnel and their families. The cottages were located in the vicinity of Dashiell’s residence, along Pickens Lane and Tisdale Road (Bowlin 1988:8).

Increased traffic on the Potomac River and the development of longer-range guns prompted the expansion of the proving ground on Cornwallis Neck within ten years of its establishment. Civilian safety concerns over testing on Cornwallis Neck also were raised by residents located down river from the original testing site. In response, the Navy purchased a 1,084 acre site on Stump Neck, southwest of Cornwallis Neck across Mattawoman Creek to expand the proving ground in 1901. A U.S. Marine Corps barracks to house station guards was constructed on the property soon after its acquisition. Physical expansion of the proving ground was intended to assure safe testing of longer-range guns in the secure and isolated area spanning the banks of Mattawoman Creek. The success of this solution was short lived as shells endangered the Marine barracks during test firing (Carlisle 2002:35-36).

The Navy argued for moving the proving ground. The Chief of the Bureau commented on the suitability, noting that the location was

> “…by no means as satisfactory for its purpose as it formerly was. The great increase in the power of the guns in recent years, and their greatly extended range, renders a more isolated location necessary for proving and ranging them” (Carlisle 2002:36).

Securing funds for land acquisition and for the construction of a new testing facility was problematic; the existing proving ground continued to operate along side the growing civilian community of workers employed at the Powder Factory. Test firing continued towards Stump Neck over the Marine barracks and down the sometimes crowded Potomac River; range safety continued to be an issue.

In 1913, a board, under the direction of Commander Volney Chase, recommended that the Navy purchase additional Stump Neck land on the Maryland bank of the Potomac River to accommodate over land testing and to increase the safety buffer for down-river shots. Congress rejected the recommendation and funding for additional land was denied (Carlisle 2002:47).

Nevertheless, the Navy had acquired an additional 1,272 acres for the testing range by 1918. In that year, Naval Proving Ground Indian Head comprised 3,208 acres, including marshlands. Additional land made possible expansion of the Powder Factory, officer housing, and the valley proving ground; however, the safety problems associated with long range testing over the Marine barracks on Stump Neck and the risk to river traffic continued (Carlisle 2002:47).

The Powder Factory eventually supplanted the proof testing mission at Indian Head Proving Ground; however, the proving ground remained active until 1921. Important testing functions were undertaken at the proving ground during World War I. During this period, the number of batteries was increased to four, making possible test firing up and down the Potomac River. Despite the important role of the proving ground during the war, it became evident that the Indian Head facility geographically was unsuitable for testing longer-range weapons. The U.S. Navy established a new proving ground in Dahlgren, Virginia, in July 1919; all proof work was transferred to Dahlgren in 1921 (Carlisle 2002:62).

Naval Proving Ground (1900-1938)

In 1900, the U.S. Navy expanded its mission with the establishment of a smokeless powder factory. This factory represented the first chemical manufacturing plant operated by the Navy (Cannan et al. 1995:60). The site chosen for the new factory was southeast of the proving ground in an S-shaped valley that drained into the Mattawoman Creek. The factory became known as the Single Base Line because the powder produced was composed of a single base, nitrocellulose. A distinctive factory complex comprising twenty-nine production and support buildings, including cotton warehouses, dehydrating houses, press houses, solvent recovery houses, dryhouses, blending towers, and large magazines, housed the production process (Carlisle 2002:22-23).

Indian Head produced its first smokeless powder in June 1900. During the first full year of operation, the Indian Head plant produced 250,000 pounds of smokeless powder, 181,500 pounds of ether, and 546,000 pounds of nitric acid (Carlisle 2002:26). Between 1904 and 1907, additional nitric acid and sulfuric acid plants were constructed at Indian Head. These plants supplied the large quantities of acids necessary for manufacturing smokeless powder. Another function of the

Naval Powder Factory was reworking old powder. The plant at Indian Head, even in combination with all of the private sector plants, could not produce enough powder to supply a Navy at war. As a result, it was essential to develop methods to safely stockpile smokeless powder (Hammer 1990:10).

During World War I, the level of activity at the Indian Head facility increased dramatically and employment at the facility reached 1,475 employees. Consequently, many changes occurred at the installation as well as in the nearby town of Indian Head. The U.S. Navy purchased the remaining 1,239 acres of Cornwallis Neck for expansion of the station. To support increased production, existing structures at the factory were expanded and additional buildings were erected. A 14.5-mile railroad spur was constructed between the Indian Head facility and the Pennsylvania Railroad Junction at White Plains, Maryland to improve access to the Naval facility (Davis and Campbell 2001:19).

Indian Head experienced a dramatic slowdown following World War I and the number of workers at the facility dropped to approximately 500 employees. The plant did not languish for long after the war. In 1932, the name was changed to Naval Powder Factory Indian Head when the Bureau of Ordnance appropriated funds to equip a new plant for re-crystallizing stockpiles of explosive D powder that were becoming increasingly unstable (Bowlin 1988:40; Stevens et al 1995).

World War II Expansion of Indian Head (1938-1945)

Wholesale mobilization of the U.S. Navy began in earnest after the fall of France in 1940 and spurred development at Naval installations throughout the country. Due to time and material constraints, the Navy initiated a massive shore establishment build-up that consisted largely of temporary facilities (Cannan et al. 1995:18-19; Goodwin 1998:41-42).

At the beginning of the war, Indian Head was one of only two military facilities equipped to produce explosives and propellant materials. Because Indian Head retained a working knowledge of explosive production through the inter-war period, the facility was indispensable to the World War II mobilization effort (Hirrel et al. 1994:169). The Chemical Investigation and Development Laboratory (Buildings 101 and 102), established by George Patterson during the first decades of the twentieth century, continued to provide expert knowledge in explosive and propellant chemistry (Davis and Campbell 2001:19-20). Indian Head maintained and expanded the existing powder factory and added a number of new laboratories and facilities including: the Explosives Investigation Laboratory (Building 704), a facility aimed at studying enemy and ally explosives; the Extrusion Plant, a rocket propellant production facility; the Jet Propulsion Laboratory (Building 292), a research and development facility for small rockets; and, a new research and development laboratory (Carlisle 2002:105-120).

In 1941, a large number of new buildings were erected within the powder factory to accommodate a variety of new laboratories and to facilitate the expansion of existing facilities. Du Pont served as the major contractor during these expansions of the powder factory. The expansion called for new distillation, storage, solvent recovery, and magazine buildings. New power facilities, steam lines, railroad tracks, and water lines were constructed to support these buildings. The expansion of the powder factory facilities was completed in 1942 (Carlisle 2002:106).

During World War II, Indian Head initiated research into solid propellants for rocketry and into the development of air-to-ground, anti-tank weapons. Solid propellants were attractive for military use primarily because they were storable. Research at Indian Head focused on double-base propellants, which were composed of nitrocellulose and nitroglycerine blended into a homogeneous mass. These propellants were a direct extension of the extensive work undertaken at the facility on gun propellants. Double-base propellants could be produced by either extrusion or casting techniques (U.S. Congress 1958:546).

In cooperation with researchers at the Guggenheim Aeronautical Laboratory, California Institute of Technology (GALCIT), Indian Head constructed an Extrusion Plant in 1943 to produce double-base propellants for small missiles and rockets. In addition, the Ballistics Laboratory (known today as the Small Motor Test Area) (Ballistics Test Building 544, Ballistics Laboratory 547, Magazines 589 and 1065 – 1068, Miscellaneous Support Buildings 544A, 544B, 544D, 558 – 559) was established in 1943 to test rocket propellant produced at the Extrusion Plant (*Wartime History* 1946:19-20).

The Indian Head Division also became involved in reworking rocket propellant. Reworking is the process where older, obsolete powder was taken and passed through the manufacturing process for the second time. Propellant storage conditions in the fleet varied and could, over time, affect the shape and size of the grains. The shape and size of propellant grains were designed to exacting standards; any changes affected weapon performance. During the reworking process, the grains were reshaped and re-inhibited. During the reworking process, the motor was disassembled; it subsequently was reassembled and returned to fleet service (Naval Ordnance Station n.d.:17-22).

The expansion into extruded grains was a precursor of the transformation of the facility's mission. By 1945, the station not only was making smokeless powder but also was testing solid-fuel rockets and experimenting with mines and other ordnance (Carlisle 2002:118-123).

Post-War Period (1945-1950)

The immediate effect of the Allied victory in World War II was a precipitous drop in the strength of the armed forces. The end of the war resulted in a slowdown at Indian Head, but not in the base closure that many anticipated. By 1948, deteriorating relations with the Soviet Union resulted in a resurgence of military build-up. Consequently, peacetime military forces grew to an unprecedented size (Best et al. 1995:20-30; Hammer 1990:13; Goodwin 1998:47).

The Research and Development Laboratory (Building 600), which opened in 1945, was typical of the type of development that occurred at Indian Head during the Cold War era. While powder production was a priority during World War II, emphasis was placed on research in the postwar period. Research and development of propellants was added to the station mission. The Chemical Laboratory (Building 101), built in 1899, continued to be used; however, due to the expanded scope of research and development work, a new laboratory was necessary. Work related to problems in powder production was undertaken in the older laboratory and the new research and development lab housed investigations into high explosives, rocket and missile propellants, and related ordnance materials (Carlisle 2002:120).

In 1944, the Bureau of Ordnance took over control of the development of Jet-Assisted Take-Off (JATO) units. Nine of the units arrived from GALCIT in June. The propellant used in the units was called GALCIT 61-C, an unreliable petroleum-based substance. The Bureau requested that the Powder Factory test the units over a temperature range. At low temperatures, the propellant cracked and burned unevenly; at high temperatures the propellant softened and flowed. This testing of the JATO units led Indian Head, in March 1945, to initiate a loaded rocket motor surveillance program to determine the safe life of various propellants. This marked the beginning of Indian Head as a testing station for solid-fuel rockets (Carlisle 2002:123).

Indian Head began testing larger JATO motors produced by Aerojet Engineering Corporation of Azuza, California, in fall 1946. Over the next several years, Indian Head continued to evaluate JATOs developed at Aerojet, the Allegany Ballistics Laboratory (ABL), and the Naval Ordnance Test Station (NOTS) at Inyokern, California. The tests determined the safe life of the propellants and determined if the motors met specifications (Carlisle 2002:123).

Although Indian Head was developing its research and development capabilities, the main workforce provided labor for production facilities. The decline in smokeless powder production created political pressure on the Navy to determine if Indian Head could be shifted to the production of new propellants. The Bureau of Ordnance agreed to the establishment of a set of pilot plants with the capacity to produce experimental new propellants for naval research use at Indian Head. Pilot plants are engineering field facilities where industrial processes are field tested for the capability of mass production. Pilot plants represent the intermediate stage between research and industrial production where the production process is tested physically at a scale sufficient to anticipate such reactions as heat and fumes while avoiding the cost of full production (Carlisle 2002:127-128; Goodwin 1998:48).

The Patterson Pilot Plant (Plant Offices 863, Magazines 1069 – 1102, Miscellaneous Support Buildings 670 – 701, 854 – 857, 1117 – 1127, 1169 – 1176, 1261 – 1280) was established in 1949 to support the research and development focus at Indian Head in the post-war years. The Patterson plant was the Navy's first research, development, and experimental production facility for solid propellants for all types of weapons. The 86-acre plant was named for Dr. Patterson, an authority on the development and manufacture of explosives and propellants who devoted his forty-one-year career to Indian Head (U.S. Naval Powder Factory July 8, 1949:2). With the construction of the pilot plant, the Navy expanded the work of the Naval Powder Factory. The pilot plant allowed for the small-scale manufacture of experimental powders that had been developed in laboratories. Small batches produced at the pilot plant were sufficient for testing and evaluation. At the pilot plant, propellants were tested at all stages of production: mixing, curing, drying, blending, rolling, and extrusion. Full-scale production was initiated only after experimental batches processed at the pilot plant were successfully tested during all stages of production (Goodwin 1998:47).

Continued Development of Indian Head (1950-Present)

The Korean War in 1950 again led to increased activity at Indian Head. Old facilities were reactivated and new facilities for missile propellant production were established. Over 100 new buildings were erected during the 1950s. New facilities included four new pilot plants: the Cast Propellant Plant (Inspection/Test Building 716, Miscellaneous Support Buildings 712 – 715, and 727A – 729D), the Biazzi Nitroglycerin Plant (Laboratory and Engineering Offices 766, Nitration House 786, Magazines 804, 807), the Nitroguanidine Plant (Production Building 859), and the Cordite N Plant (Office Building 702, Miscellaneous Support Buildings 703 – 711 and 874 - 876). The JATO area was built in conjunction with the cast propellant plant. The test facility, known as the Large Motor Test Facility, consisted of firing bays, loading facilities, and recording room with capabilities for handling rockets with up to 200,000-lbs thrust (Carlisle 2002:149).

The first of these four plants, the Cast Propellant Plant, was placed in operation on November 16, 1953. The Cast Plant was a large-scale industrial facility designed for the production of solid cast propellants for guided missiles and rockets. The Biazzi Nitroglycerine Plant started operations on April 23, 1954. This pilot plant was a continuous-type, rather than a batch-type, facility and produced nitroglycerine, an ingredient in double-base, multi-base, and cast-type solid propellants. The third plant, the Nitroguanidine Plant, opened for operation on June 23, 1954. Nitroguanidine was an ingredient used in a lot of propellants, including composite and multi-base propellants. Many Standard Missile rocket motors at one time contained both; a number of gas generators including Tomahawk and strategic systems also used multi-base propellants. The fourth plant was the Cordite N Plant, which opened on August 6, 1954. This facility produced new cool-burning multi-base gun propellants (U.S. Naval Powder Factory ca. 1955; Email Correspondence Anderson 2012). New facilities at Indian Head included over 100 new buildings erected during the 1950s to provide the Navy with modern solid propellants for guided missiles with nitroglycerin as an essential ingredient. Reflecting its new mission, the name of the station was changed to the “Naval Propellant Plant” in 1958 (Goodwin 1998:48).

Indian Head’s background in extruded rockets during the 1940s and its addition of the casting plant during the mid-1950s suggest that the base played a major role in the history of rocket development (Carlisle 2002:141). The opening of the casting plant led Indian Head into the production of larger propellant grains. These large grains were cast in beakers and then loaded into motor cases rather than being extruded through a die. Two of the first cast products Indian Head produced were the grains for Weapon A (also designated Weapon Alpha), a device for launching depth charges at ranges up to 950 yards, and for the first and second stages of the Terrier weapon (a large, short-range surface-to-air weapon) (Carlisle 2002:146-148).

In the period from 1954 to 1956, Indian Head worked in conjunction with ABL located in Cumberland, Maryland, and with NOTS at China Lake, California. In fall 1955, Indian Head began producing first-stage Terrier grains and, in early 1956, began casting Terrier second-stage grains (Carlisle 2002:146-147).

Other projects conducted at Indian Head covered the storage and periodic testing of Weapon A, the Sidewinder Propulsion Unit, and Rocket-Assisted-Torpedo, together with surveillance on Terrier motors. Surveillance entailed a cycle of controlled temperature storage and programs incorporating pretest conditioning, static firing, data assessment, and equipment recovery (Carlisle 2002:147).

The life expectancy of a pilot plant for field testing an industrial process is limited. Within a few years, the pilot plants at the Indian Head Division began to be updated or converted to new uses. By January 1956, equipment designs were completed for the conversion of the Cordite N facilities to multi-base casting manufacture (U.S. Naval Propellant Plant 1959). By 1961, the Nitroguanidine Plant was converted to the production of Nitroplastisers, and the remaining two plants were modified to test a new approach in propellant processing for handling high energy propellants. Modifications included the addition of remote controls, barricades, thicker reinforcement concrete walls, and new curing facilities (Carlisle 2002:140-141, 165).

Although Indian Head developed many important projects, its mission and role in missile development were subjects of a congressional investigation in mid-1958. During these hearings, a subcommittee of the House Armed Services Committee investigated why a Polaris research and development contract was awarded to the Aerojet Company in Sacramento rather than completed by the Navy at Indian Head. Testimony by Admiral William F. Raborn, Director of Special Projects Office; Admiral Paul Stoop, Chief of Bureau of Ordnance; and Dan Kimball, former Secretary of the Navy (then serving as president of Aerojet-General) determined that Aerojet was better suited to undertake the project because of its expert personnel and research facilities (Carlisle 2002:142-143).

Indian Head also was involved in projects related to Polaris testing, but its role was limited. In February 1958, the facility conducted studies for a Polaris fire suppression system. In 1958, as the installation moved away from powder production, the name of the facility was changed to the Naval Propellant Plant. Later, in 1958 and through 1959, Indian Head developed plans for producing and testing Polaris motors at one-third scale. By November 1959, the Naval Propellant Plant had fabricated and fired six one-third-scale Polaris second-stage motors. From December 1959 through mid-May 1960, the Naval Propellant Plant processed forty-nine of the scale model motors and conducted a series of approximately seventy-five tests (Carlisle 2002:156-157). Meanwhile, development, testing, and production of Polaris missiles continued at three Hercules-operated facilities: ABL; Radford, Virginia; and Bacchus, Utah (Carlisle 2002:158).

In 1966, emphasis shifted from production to research and development of propellants, chemicals, and explosives and the facility again was renamed the Naval Ordnance Station. Some buildings within the Extrusion Plant area continued to be refitted to meet new production needs (Hammer 1990:13, 93). Over the next few years the name of the facility changed as the mission changed. In 1987 the facility was known as the Naval Surface Warfare Center Indian Head. By 2005, the named changed once more to Naval Support Activity South Potomac; this name reflected the change in land ownership not the mission. Today the facility is known as Naval Support Facility Indian Head. Currently, the facility comprises more than 1,600 buildings. Production, development, and support for the U.S. Navy's Energetics systems (explosives, propellants, and pyrotechnics) are the facility's primary roles. The main production facilities include a casting and loading facility, an Extrusion Plant, and chemical manufacturing (Goodwin 1998:48).

INDIAN HEAD NAVAL POWDER FACTORY

The disadvantages of the black powder historically used in military field engagements were recognized throughout the nineteenth century. Powder smoke decreased visibility, thus affecting the accuracy of weapon sighting. Powder smoke also provided a highly visible enemy target. Efforts to develop a smokeless powder date to the late-nineteenth century. Smokeless powder was invented by French chemist Paul Maria Eugene Vielle in 1884. Vielle's new powder was three times more powerful than black powder for the same weight and left very little residues of combustion. In 1886, Vielle used ether and alcohol to colloid the gun cotton to create a new product adopted by the French Military. Lieutenant Jean Baptist Bernadou, working out of the Naval Torpedo Station in Newport, Rhode Island, led the research and development of smokeless powder for the U.S. (Davis 1943:289; Milner 1995:29; Carlisle 2002:22-23).

The strategic challenges of black powder again rose to the forefront of military concern during the Spanish-American War (1898). Before the war was over, a portion of the fifty-million-dollar defense fund was earmarked for the establishment of a new facility to produce smokeless powder. The Naval Powder Factory was established at the Naval Proving Ground Indian Head under the direction of Rear-Admiral O'Neil, Chief of the Bureau of Ordnance. The Indian Head Naval Powder Factory is located within the current Naval Proving Ground Indian Head (Naval Support Facility Indian Head). In July 1900, the first grains of the new explosive were produced. Since then, the original plant has been modified and expanded numerous times to accommodate new technologies and production requirements. Lieutenant Bernadou oversaw the construction of the new production facilities at Indian Head. Much of the machinery housed in the buildings was transported from the Newport facility (Skerrett 1918:562; Carlisle 2002:23-24).

With the nation's entry into World War I, the Navy's activities expanded at an extraordinary rate. The war multiplied the activities of the Navy's Ordnance Department, which had responsibility for production of weapons and ammunition, storage of ammunition, and testing activities (Carlisle 2002:105-120).

By the mid-1930s, activity at Indian Head accelerated rapidly as conflicts mounted in Europe and the Far East. When Franklin D. Roosevelt was elected president in 1932, he developed the New Deal program (the New Deal was a series of economic programs implemented in the United States between 1933 and 1936). Under Roosevelt's New Deal, funds began trickling back into the Navy. Production at Indian Head increased following Roosevelt's 1935 cash-and-carry policy that allowed European governments to purchase American weaponry, providing they paid cash and arranged for transport. In 1939, Indian Head was producing an average of 17,000 pounds of new powder and reconditioning 4,000 pounds of old powder each day. One year later, new powder production had increased to 25,000 pounds per day, surpassing the output levels during World War I (Goodwin 1998:42-42).

World War II brought a surge of activity to the Naval Powder Factory. At the beginning of the war, Indian Head was one of only two military facilities equipped to produce explosives. Because Indian Head retained a working knowledge of explosive production through the inter-war period, the facility was indispensible to the production mobilization effort for the war (Carlisle 2002:105-120; Goodwin 1998:42).

At Indian Head the most significant changes during the post-war period included a shift in production from smokeless powder to rocket propellant, and an increased level of research and development. In 1956, the Single Base Line produced its last lot of smokeless powder. (Goodwin 1998:47; Milner 1995:34).

Overview of Naval Powder Factory Smokeless Powder Process

The process for producing smokeless powder combined a cellulose compound (i.e., cotton) with a nitrate and refined mixture. The production process of the Single Base Line began at the south end of the valley, where cotton bales were stored in cotton storehouses. First, cotton was cleaned in a caustic soda bath to remove dirt and other impurities. The cotton is then bleached with chlorine and washed with cold water to remove the original impurities and then dried. After washing, cotton was transported to picking houses where it was mechanically combed, carded, and dried. When dry, the cotton was ready for nitration. Nitration was performed by soaking the cotton in a bath of sulfuric and nitric acid to create nitrocellulose. Employees boiled the cotton mixture in water to remove excess acid. The cotton mixture was purified further by alternate baths in boiling water and cold water, with sodium carbonate added to the water bath. Once the cotton mixture was purified, the water was removed by centrifugal wringers. Then, the mass was sent to the dehydrating houses where alcohol was added to accelerate the drying process. The addition of ether changed the mixture into a paste-like substance, which could be shaped (Goodwin 1998:39-40).

These shaped powder grains, referred to as green powder (despite not being in a particulate, granular form), still contained excess solvent. The solvent recovery houses were used to heat the material, by steam, in order to release the remaining ether and alcohol. A current of heated air was passed through the powder grains, volatizing a part of the excess solvent. The current of air was then passed through or around brine-cooled coils, where the vapors of the solvent are condensed and the liquid led off to a collector (U.S. Navy Bureau of Ordnance 1914:9). The ether and alcohol vapors were then piped to the attached buildings where they were condensed into liquids and piped into storage tanks for re-use (Goodwin 1998:40).

Dryhouses were the next step in the process. The dehydrated powder grains were carried by rail to the dryhouses where they were left to dry for five to six weeks. When the powder grains were first received, they were placed in small bins and were usually dried without heating for 60-days. The temperature is then raised by steam heat and maintained at the desired temperature until the drying is complete (U.S. Navy Bureau of Ordnance 1914:9). After drying, the grains were coated with graphite and mixed in a blending tower. The powder grains were coated with graphite to reduce the possibility of build-up of a charge of static electricity. The powder grains were screened to remove any powder grains which were not the proper size and then blended to reduce the variation between lots. These blended powder grains were then placed in metal boxes and stored in magazines before they were shipped from the facility.

The principal raw materials and the steps in the manufacturing of smokeless powder at Indian Head are noted below. The following two resources, *Smokeless Powder: Details of its Manufacture as Conducted at the Government Naval Powder Factory, Indian Head, Maryland* (Skerrett 1918) and *Manufacture of U.S. Navy Smokeless Powder Ordnance Pamphlet Number 19* (U.S. Navy Bureau of Ordnance 1914), provided the background information for these two sections.

<u>Raw Materials</u>

Five categories of raw materials were used in the manufacture of smokeless powder. These are cotton, acids, ether and alcohol, carbonate of soda, and diphenylamine. The following materials were used for the production of single base grains at the Indian Head Powder Factory.

Cotton was the cellulose material nitrated in the production process. Bleached and purified un-spun cotton wastes or short-fibered cotton was used. Short fibered cotton particularly was suitable for nitration because the nitrating acids were readily absorbed by the material contributing to uniformity in nitration (Skerrett 1918:563; U.S. Navy Bureau of Ordnance 1914:3).

An *acid mixture* of nitric and sulfuric acids was used in the nitrating process. The acid mixture was either premixed by a supplier or made at the factory. The acid mixture met exacting specifications for purity and strength. The mixture, which contained a total acid content of about ninety-five per cent, comprised equal parts nitric and sulfuric acid (Skerrett 1918:564; U.S. Navy Bureau of Ordnance 1914:4).

An *Ether and alcohol* mixture of ethyl ether and ethyl alcohol was used as a solvent for the nitrocellulose. High purity was required (Skerrett 1918:564; U.S. Navy Bureau of Ordnance 1914:564-65).

Carbonate of Soda served as a pH regulator in the water used to boil the nitrocellulose during certain stages of the purification process (Skerrett 1918:565).

Diphenylamine, a pale yellow crystalline organic substance with a slightly alkaline reaction, was incorporated with the powder to neutralize any acid products that might have formed in the powder as a result of gradual decomposition. Diphenylamine prevents progressive decomposition and contributes to the powder's chemical stability (Skerrett 1918:566; U.S. Navy Bureau of Ordnance 1914:7-8).

<u>Principal Manufacturing Steps</u>

The manufacture of smokeless powder was a sequential, thirteen-step process. These steps are described briefly in the following text (U.S. Navy Bureau of Ordnance 1914:4-11).

(1) *Picking the cotton* – The purified cotton passed though a picking machine, which separated knots and tangled fibers.

(2) *Drying the cotton* – The cotton then was placed in driers to reduce the moisture content to approximately one per cent. Excess moisture in the cotton increased the potential for combustion during the nitration process, due to the exothermic (heat-generating) reaction between water and the sulfuric/nitric acid mixture.

(3) *Mixing acids* - The mixture of sulfuric and nitric acids used in nitration was created by fortifying spent acids. The mixture was heated to a temperature of about 30 degrees Celsius by steam in heating tanks before delivery to the nitrators.

(4) *Nitrating* - Approximately sixty pounds of cotton were placed into a nitrating pot containing the acid mixture. The nitration process took about twenty minutes. The cotton and acids were thoroughly agitated by revolving paddles to saturate the cotton. The cotton was converted into nitrocellulose containing approximately 12.60 per cent nitrogen. This conversion was commonly called "pyrocellulose." Each charge of nitrocellulose and acid was then run through a wringer located below the dipping pot. Spent acids are removed by centrifugal force for re-use.

(5) *Purifying* - The purification process comprised four steps: drowning, preliminary boiling, pulping, and poaching.

> (a) *Drowning* **-** The pyrocellulose was forked from the centrifugal wringers as quickly as possible to drowning troughs of running water. Exposing pyrocellulose to the air for an

extended period created the risk of fire if the nitrating acids were removed completely in the wringing process.

(b) *Preliminary boiling* - The pyrocellulose was boiled for approximately forty hours in the boiling tubs to remove any free acids. The water used in this process was changed up to five times. The material then was transferred into a trough of running water and then moved to wooden boxes with false bottoms to facilitate drainage. These boxes were located over the pulpers in the pulping and poaching house.

(c) *Pulping* – The pyrocellulose was cut and ground in the pulpers to ensure full saturation in the next stage in the purification process and to shape the fiber to the desired consistency.

(d) *Poaching* – The pyrocellulose was then boiled in water and carbonate of soda in poaching tubs, large open vessels that accommodated 3,600 pounds of equivalent dry powder similar in design to the boiling tubs. The first poaching bath was followed by several baths in water, which was drained and renewed after each boiling cycle. Following this final stage of purification, a sample of the poached lot chemically was tested. The pure lot of pyrocellulose was pumped into stock tubs and then to centrifugal wringers located in the dehydrating house.

(6) *Dehydrating* - The pyrocellulose was transferred to centrifugal wringers to remove excess water. Fifty pounds of the material then was loaded into the cylinder of a vertical hydraulic press that applied approximately 200 pounds per square inch (psi) of pressure. A dense cake was formed but very little water was removed. Residual water was removed from the cake by injecting alcohol at 75 psi, which formulated the desired colloid. The pyrocellulose cake was subjected to a final press to remove the excess alcohol.

(7) *Mixing* - The compressed cake was transferred to the mixing house where it first was broken up in a rotating drum or a block breaker to create a fine grain material. This enabled the material to be mixed easily and ensured a more uniform colloid. The pyrocellulose then was transferred to the mixer where the ether constituent of the solvent and the diphenylamine stabilizer were added. The product was mixed for approximately one-half hour during which time it became partially dissolved or colloided by the ether and alcohol. The material was once again formed into blocks using a hydraulic press.

(8) *Pressing* - The pyrocellulose block was forced through the small holes of a strainer (macaroni) press to thoroughly mix and ensure homogeneity in the colloid. It was again re-blocked and forced through a die press to create a continuous cord of the desired diameter, generally seven perforations per die. The colloid was forced through the die by a pressure of 4,000 to 6,000 psi, depending upon the size of the desired grain. The cord was led to a machine cutter which divided it into grains of the desired uniform length. The length of the finished grain is determined by the desired finished product.

(9) *Recovery of Solvents* – The solvent recovery houses were used to heat the material, by steam, in order to release the remaining ether and alcohol. A current of heated air was passed through the powder grains, volatizing a part of the excess solvent. The current of air was then passed through or around brine-cooled coils, where the vapors of the solvent are condensed and the liquid led off to a collector. The ether and alcohol vapors were then piped to the attached buildings where they were condensed into liquids and piped into storage tanks for re-use.

(10) *Drying* - After leaving the solvent recovery houses, the dehydrated powder grains were carried by rail to the dryhouses where they were left to dry for approximately five to six weeks. When the powder grains were first received, they were placed in small bins and were air dried. The air temperature was then raised by steam heat and maintained at the desired temperature until the drying was complete. The powder grains were then stored for two to four months in a controlled environment of constantly circulated air maintained at 40° C. The duration of the drying period depended upon the size of the powder grain and the percentage of volatiles to be evaporated. The powder grains were next conveyed to the powder picking house.

(11) *Picking* - The powder grains were picked over by hand to remove any powder grains of abnormal size or appearance.

(12) *Blending* – The powder grains in the dryhouses were separated into poacher lots. Each poacher lot contained powder grains of the same size. Uniform lots of powder grains were created by blending several poacher lots following the order they were manufactured.

After the drying and before blending, the powder grains were exposed to the atmosphere for 24 to 60 hours to ensure uniform surface moisture. Blending usually was carried out in blending towers. The tower consisted of a series of bins in groups, one group above the other, with a space of about 20 feet between. The bins in each group usually were arranged in polygons with a trap or gate valve in the center of the group. In blending, the uppermost groups of bins were filled with powder grains from different poacher lots. The traps or gate valves were opened simultaneously and the powder from the bins fell to the next level in a single stream. The single stream was divided equally as the powder grains entered the next level of bins. The blended powder grains finally were removed through a hopper at the bottom of the blending tower and packaged in powder boxes. Samples of the blended powder grains were analyzed to confirm uniformity.

(13) *Proof and Disposition* – Each powder grain lot was field tested. A firing sample for proofing was selected from the lot of powder grains and the balance was stored in a magazine pending acceptance. Once the lot was found field ready, the Bureau of Ordnance assigned a service index number issued in regular numerical sequence in the order of acceptance. The lot was shipped upon the order of the Bureau of Ordnance.

Naval Powder Factory Buildings Utilized for the Smokeless Powder Process

The buildings within the Naval Powder Factory were dispersed throughout the rolling terrain and were connected by a network of paved and gravel roads, and railroad tracks.

The railroad played an integral part of the development of the Powder Factory area. The Indian Head – White Plains Railroad opened in 1919 as an important transportation link to support the powder factory activities at the facility. The 14.5 mile line, which carried raw materials and finished products, connected the Pennsylvania Railroad with the internal network at Indian Head, especially the Single Base Line process area. Prior to the construction of the rail line, finished powder was shipped via barges to the Washington Navy Yard. After 1919, much of the powder grains were shipped using the new railroad (Goodwin 1998b:3).

The main manufacturing corridor, known as the Single Base Line, was constructed following the natural curve of the valley that drains into the Mattawoman Creek. Raw materials would enter the line at the south end and were transported from building to building by gravel road or by rail (post-1919).

Patterson Road serves as the entrance to the restricted area of the base. Buildings devoted to research and development are located south of the entrance and south of the west end of the Single Base Line. These buildings include Buildings 600, 101, 102, 103, and 303. Building 101, constructed in 1899, is the oldest original building located at Indian Head and it is the focal point for this group of laboratories. Building 103, constructed in 1865, originally was constructed at the Washington Naval Yard and subsequently moved to Indian Head in 1902.

The majority of the buildings located within the Powder Factory area were constructed by base personnel or local contractors. The initial factory buildings were designed by Washington, D.C. architect Hunter Jones. Those structures included Building 101 and Buildings 164 & 164A. The buildings were designed for manufacturing efficiency and to house processing equipment and machinery. Fireproof materials, such as metal, brick, and concrete were utilized due to the volatile nature of the overall process (Milner 1995, Skerrett 1918).

The volatile nature of the product manufactured at Indian Head also prompted the inclusion of numerous safety features in the complex. Buildings included features such as copper flashing for grounding, lightning rods, escape chutes, spark proof floors, bells/alarms, shower stations and explosion proof light fixtures.

The buildings associated with the Single Base Line are sited in a linear plan. All buildings had some access to the road or the former rail line. While some sections of the rail line survive, primary access to the area currently is by Thomas Road. The first and second buildings on the line are cotton storehouses, Buildings 222 and 157. Both are one-story, rectangular, corrugated metal-over-metal frame buildings. Both include concrete platforms, which originally served as loading docks accessible to the rail line.

A former cotton dryhouse, Building 160, is located at the corner of Hersey and Thomas Roads. Cotton, placed in wire bottom bins, was exposed to a constant flow of heat to reduce its moisture content in the building. North of Building 160, the railroad tracks forked to the east. The railroad continued through the center of a large Poaching and Blending House (Building 292). In this building, the pyrocellulose was boiled and rinsed to remove free acids, a major step in the production process. The former Boiling Tub House (Building 154) was located north of the Poaching and Blending House.

The 1936 Indian Head base map of the Powder Factory area indicates a cluster of approximately fourteen buildings originally located to the northeast of Building 292. This group of buildings included a Acid Weighing House (Building 149), Reservoir Number 1 (Building 153), Nitrating House (Building 189), Acid Tanks (Building 198), Fire House (Building 223A), Cotton Dry House (Building 225), Nitrating House Number 2 (Building 281), Nitrating House Fume Exhaust Buildings (Buildings 281A-281B), Nitrating House Repair Shop (Building 284), Cotton Dry House Number 3 (Building 285), Cotton Dry House Number 4 (Building 286), Reservoir Number 2 (Building 418), and a Transformer (Building 432). These buildings are no longer extant.

Ether Vault No. 3 (Building 164) and an addition (Building 164A) are located west of Building 292. Building 164A originally was a Distillation House and was used to distill or concentrate high quality ether for manufacturing various explosives. The ether then was sent to Building 164 for storage. Building 163, a Dehydrating House where alcohol was forced into the cotton pulp to draw out water, was located north of Building 292. This building is no longer extant. Ether Vault No. 2 (Building 167), which is similar in design to Ether Vault No.1 (Building 165), was located north of Building 163. The Ether Pump House (Building 164B) is located southeast of Buildings 164 and 164A. It was used to transfer the ether to and from the ether vaults. Buildings 165, 167 and 164A were designed by architect Hunter Jones.

Adjacent to Building 167 stands a rectangular, wood frame structure, Building 166. It was used for storing alcohol. The alcohol was used in the dehydrating process. The tanks had a capacity to hold up to 11,000 gallons of alcohol. The adjacent Mixing House (Building 169), where the pyrocellulose achieved a dough-like consistency, is no longer standing. To the north, Press House No.2 (Building 295) is where pyrocellulose was formed into powder grains of differing sizes, depending upon the caliber of the guns for which they were intended. A small brick office building (Building 295A) is located to the southwest.

In Powder Picking Houses (Buildings 296 and 297) the shaped powder grains were screened and glazed. Located at the end of the Single Base Line were Solvent Recovery Houses (Buildings 300 and 301). Building 453, located east of Buildings 300 and 301, also served as a Solvent Recovery House. Inside of these buildings the shaped powder grains were heated once again in order to evaporate any remaining solvents. Due to the volatility of nitrocellulose at this stage of manufacturing, these buildings were segmented into a series of rectangular rooms divided by brick partition walls to prevent sympathetic explosions. These two-story buildings also featured emergency escape chutes from the second floor. As the solvents were evaporated from the powder grains, they were piped to small condensing buildings lined up along the rear of the buildings. Condenser Houses (Buildings 930-933) are located to the rear of Solvent Recovery Building 453 (Milner 1995, Skerrett 1918).

After the final step of solvent recovery on the Single Base Line, the powder grains were picked over by hand to remove any powder grains of abnormal size or appearance. The powder grains were then dried for five to six weeks in the powder dryhouses. After drying, the powder grains were glazed or coated with graphite and blended into a homogenous mixture in the blending tower. The graphite provided some measure of water resistance to the grains. A sample of the powder grains would be taken to the proving ground for testing. The blended powder grains were then stored in large storage magazines, located throughout the base, before being shipped from the base.

These dryhouses are located in a relatively flat region in the northeast corner of the base. The dryhouses were built in four rows along four lines of railroad tracks connected to the Single Base Line. After the powder was dried, it was stockpiled and stored in Magazines located throughout the Indian Head Base (Goodwin 1998:40).

The majority of the original buildings used in the Single Base Line are vacant or have been removed. Some of the remaining buildings have gained new uses as offices, a library, storage facilities, and laboratories for research and development.

INDIAN HEAD EXTRUSION PLANT

Portions of the following section is excerpted, with minor modifications, from *Phase I Cultural Resources Survey of Stump Neck Annex and Supplemental Architectural Investigations, Indian Head Naval Surface Warfare Center, Charles County, Maryland* prepared for Engineering Field Activity – Chesapeake, Washington, D.C. (Goodwin 1998).

The following sections are intended as a brief summary of the history and construction of the Extrusion Plant and the Small Motor Area (Ballistics Laboratory). In addition, the Extrusion Plant production process and the subsequent testing of the finished propellant produced in this area of Indian Head also are discussed.

History and Construction of the Extrusion Plant

The Indian Head Extrusion Plant area encompasses both the Extrusion Plant and the Small Motor Test area. The Extrusion Plant was established in 1943 to produce rocket propellant; the Ballistics Laboratory was established the same year for the purpose of testing the rocket propellant produced at the Extrusion Plant. Both areas have changed over the years as new buildings were constructed and older ones were replaced or modified. These changes are documented in the Indian Head base maps, which depict changes to the Extrusion Plant in 1950, 1966, 1972, and 1988 (Indian Head Facilities Engineering Archives – Department of the Navy). An enclosed table provides a list of buildings associated with the Extrusion Plant and Small Motor Test area; the table includes current (as of 2010) and historic uses of the buildings.

These facilities are located adjacent to one another, along the southern edge of the installation facing Mattawoman Creek. Both facilities were designed to take full advantage of the natural terrain. The buildings and structures associated with the Extrusion Plant are built into a hillside in a terraced manner. The facility forms a semi-circular configuration. The production process generally flows from the top of the hill to the base along Hersey Road. The Ballistics Laboratory is sited west of the Extrusion Plant on comparatively level land adjacent to the creek. The testing facility contains static firing bays oriented toward the water.

The Extrusion Plant design was based on information obtained from two members of the Indian Head staff, Ensign T.F. Dixon and civilian chemist J.B. Nichols. These men visited the California Institute of Technology (Cal Tech) research laboratory in Pasadena, California, where they observed scientists who were conducting research into the production and ballistic properties of solventless ballistic propellants (Carlisle 2002:108). Cal Tech supplied much of the original equipment, including two extrusion presses. Other machinery was constructed from plans produced by Cal Tech scientists (*Wartime History* 1946:12). Three presses used for the production of smokeless powder at the Indian Head Powder Factory were modified for use at the Extrusion Plant.

The plant was constructed by Naval Powder Factory personnel. Facility records indicate that the cost of the Extrusion Plant and its equipment totaled $1,366,969.45 (*Wartime History* 1946:13-14). The total cost comprised the following amounts:

- Buildings - $588,572.19
- Miscellaneous Equipment - $10,608.46
- Plant Appliances - $63,102.17
- Machinery - $130,811.71
- Unclassified - $573,874.92

The Extrusion Plant is arranged according to function: production, storage, testing, and administrative. The production area is located on the south-facing slope of the hill overlooking Mattawoman Creek. The storage areas are located north and west of the production area; their location at the base of the hill offered protection against accidental explosions. The testing area is located south of the main production area. The administration area is situated at the base of the hill along Hersey Road. The production area was organized into production lines, each consisting of several buildings organized in a linear fashion and extending down the hill. Each stage of production was housed in a separate building as a precaution against the spread of accidental fires or explosion. A typical production line at the Extrusion Plant extends from the top of the hill to the base and consists of an electronic heating building, a preheating oven building, a slide to convey the material down the hill, and a press house. These production lines are arranged in a semicircular configuration, radiating from the centralized Machining Building (Building 571) at the base of the hill, which forms the nucleus of the plant (Goodwin 1998:122-23).

Extrusion Plant Process

The following discussion is based on the 1998 Goodwin *Phase I Cultural Resources Survey of Stump Neck Annex and Supplemental Architectural Investigations, Indian Head Naval Surface Warfare Center, Charles County, Maryland* and is supplemented by information provided by Jose Leon, Rocket Manufacturer and Engineer for the Extrusion Plant (Personal Interview Leon 2011).

Plant operations generally proceeded from north to south. Materials arrived via rail at the storage area on the north side of the plant and were housed in concrete import magazines (Buildings 539, 578, 586). From there, the materials were routed through the production process. Following production, the finished propellant was tested in the buildings on the southwest end of the complex, and, after approval, the finished propellant was shipped. Export magazines (Buildings 574, 540, 593), located south of the production area were used to store the finished propellant before shipping. A rail spur, which led to these export magazines, was used to transport propellant from the plant (Goodwin 1998:95).

The Extrusion Plant was named for the method of production adopted at the plant. The extrusion method uses a press to extrude material through a die. Propellant produced at the Extrusion Plant was a type of solid propellant. The shape of the grain (i.e., the inner diameter) determined burning time. Different dies were used in the extrusion presses to achieve different shapes. Indian Head received powder in either a sheet form or in "carpet rolls." The propellant had the consistency of soft leather. The carpet roll consisted of thin strips of solid fuel rolled like a rug. Although Indian Head had the capability to manufacture carpet rolls, the rolls typically were obtained from an outside manufacturer, such as the Radford Ordnance Works (Personal Interview Leon 2011; Goodwin 1998:95).

The extrusion process consisted of six steps:

(1) Heating the rolls of propellant to a temperature suitable for extrusion;
(2) Extruding the propellant using a hydraulic press;
(3) Annealing;
(4) Machining;
(5) Finishing; and
(6) Packout.

Prior to extrusion, the sheet and/or carpet rolls were stored in the ready service magazine (Building 583) located at the top of the hill along West Schoeffel Road. From the ready service magazine, the carpet rolls were transferred on rolling carts to the Charge Rolling Buildings (Buildings 537, 538, 577, and 584). These buildings were used for rolling and weighing the strips of cut sheet powder (Higbie 1943:21). The four buildings are located on the west side of West Schoeffel Road (Goodwin 1998:95).

The first step in the production process involved heating the carpet rolls. Since the storage magazines were not heated, the carpet rolls were far below room temperature when they were brought to the extrusion presses. For effective extrusion, the rolls were heated to approximately 105 degrees Fahrenheit (*Wartime History* 1946:30). Buildings were constructed at the Extrusion Plant specifically for this purpose. Two types of oven buildings were constructed: electronic heating buildings (Buildings 557, 576, 585) and preheating ovens (Buildings 534-536, 567-570). The carpets were heated to the proper temperature in the electronic heating buildings and then were transferred to the preheating ovens, where they were maintained at this temperature. Buildings 557, 576, and 585 are similar in construction materials but differ slightly in plan. The structures are all one-story concrete buildings with concrete slab roofs, projecting eaves, and fiberboard exterior sheathing. The preheating ovens, located at the crest of the hill south of West Schoeffel Road, are slightly smaller than the electronic heating buildings. These structures are one-story, two-bay concrete buildings that terminate in low, front-gable roofs with wide overhanging eaves or in flat roofs with parapets and overhanging eaves that project over the front elevations. Typically, a projecting concrete firewall divides the front elevation into two bays. Small sheds (Buildings 1232-1235), which were used as shelters for personnel assigned to the facility, are located adjacent the oven buildings (Goodwin 1998:95-96).

The heated carpet rolls were then ready for extrusion in the Press Houses (Buildings 529-533, 560-566), which contained the hydraulic presses. The production area consisted of twelve press lines arranged in a linear fashion extending down the hill, perpendicular to the roads. The carpet rolls were conveyed on a slide (i.e., ramp) down the hill to the press buildings. At the end of the slide, the rolls entered an elevator shaft leading to the extrusion bay. Press buildings 529-532 housed vertical presses; Buildings 533 and 560-566 were designed to contain horizontal presses (Goodwin 1998:96).

All press houses were constructed into the hillside and face East Schoeffel Road. Press buildings 529-532 are composed of two sections: a concrete lower level and a metal-frame upper level clad with corrugated metal siding. A metal I-beam projects from the top of the metal building. The rear and sides of the structure are bermed into the hillside. Two control houses (Buildings 527 and 528 [no longer extant]) were located across the road from the four presses. Each control house was a one-story, three-by-four-bay brick structure terminating in a concrete-slab roof. Each structure was built into an earth hollow to limit damage from an accidental explosion; a concrete blast wall extends along the side of each structure (Goodwin 1998:96).

Buildings 533 and 560-566, the horizontal press houses, are composed of three sections: (1) a two-story concrete block section with a flat roof; (2) a one-story, flat-roofed brick section adjoining the front of the concrete block; and (3) an elevator shaft that projects from the rear of the structure. The rear, sides, and rear planes of the roof are bermed into the hillside. One of the sides of the structure features a concrete retaining wall (Goodwin 1998:96).

Once the press operators prepared the press for extrusion, the press area was cleared and personnel moved to the control room. The press area and the control room are separated by approximately twelve feet of concrete. From the control room, the extrusion process was monitored by the press operator by a video monitor (Goodwin 1998:96).

Seven of the press houses (Buildings 560-566) survive intact. Although the hydraulics equipment has changed, the original machinery remains intact and in operating order in these seven structures. Building 533 was converted to an X-ray facility, and the original machinery has been removed from Buildings 529-532 (Goodwin 1998:96).

Following extrusion, the extruded grains were transported by truck to the Annealing Oven Building 579 and later to Building 871, which was added in 1953 (both buildings are no longer extant). When the grains are extruded, a tremendous amount of pressure and stress is placed on the material. The process of annealing, which requires approximately sixteen hours, stabilizes or "relaxes" the grains, to ensure that the material will not change in dimension as the production process continues. The annealing process involves heating the extruded grains in an oven at a high temperature (Minnesota Mining and Manufacturing Company 1955:10; Goodwin 1998:96, 106).

An additional step—a preliminary X-ray inspection of the grains—was added to the production process when the two Radiographic Buildings (Buildings 587 and 588) were added to the plant in 1944. This step usually occurred after extrusion and prior to annealing. X-ray technology was added to the testing methods used at the Ballistics Laboratory in order to detect internal flaws in the individual grains of rocket propellant. Prior to the use of X-ray equipment, propellant lots were proved entirely by static firing. This entailed the firing of a rocket motor or rocket engine in a hold-down position to measure thrust and to carry out other tests as needed. A data recorder attached to the motor documented the test results. The facility consisted of several firing bays. Static testing posed limitations in accuracy, and exclusive use of static firing required the rejection of an entire lot of powder when only one grain tested as defective. X-ray technology afforded a greater degree of accuracy so that defective grains could be detected and isolated without rejecting an entire powder lot. X-ray technology in testing increased efficiency and reduced costs (*Wartime History* 1946:19-20). Buildings 587 and 588 are no longer in service as X-ray facilities. Building 587 subsequently served as a calibration laboratory, and Building 588 became a motor loading facility (Goodwin 1998:109).

Following X-ray and annealing, the grains were stored temporarily in a magazine (Building 573) before transfer to either the Machining Building (Building 571) or to the Machining and Packing Building (Building 543). In general, when a grain was extruded, it was longer than its intended finished length to allow for shrinkage during the annealing process. When a grain was sent to the Machining Building, approximately one to three inches were cut from the grain. Building 571 is located in the center of the complex. It is oriented to the north, facing the press houses, and is accessed by a U-shaped drive from East Schoeffel Road. The second machining building,

Building 543, is located west of the main production area. Buildings 336, 571, and 874 are currently used for machining (Goodwin 1998:109).

The final step in the extruding process—the finishing process—occurred in Building 572. This step was intended to shape the grain to precise measurements. The step involved several procedures: cutting the outside diameter of the grain; placing "inhibitor" materials at each end of the grain; spiral wrapping an inhibitor around the outside of the grain; trimming the inhibitor; coning the interior of the grain; and, placing a sleeve on the end of the grain. The inhibitor is a type of plastic (i.e., ethylcellulose) designed to prevent the propellant from burning on the surface; the propellant must burn from the inside out. Building 572, located just east of Building 571, is similar in configuration to Building 571 (Goodwin 1998:109-110).

In the later twentieth century, the finishing process occurred in several different buildings, including Buildings 336, 337, 571, 808, and 874 (Goodwin 1998:110).

After all six steps of the production process were complete, the grains were tested and the exterior and interior dimensions were checked. The grains then were either loaded into motors or packed in fiberboard containers and shipped to the contractors who assembled the motors. Historically, the packing occurred in Building 543 (Machining and Packing Building) or in Building 580 (Double Base Powder Packing Building) (Goodwin 1998:110).

If the motor loading was done in the plant, the grains were delivered to the motor loading facilities. These facilities were located in Building 572 (Rocket Loading Building) and in Building 588 (Motor Load Building). After loading, the motors were sent to the Ballistics Laboratory on the southwest side of the plant for static firing tests (Goodwin 1998:110).

Due to the explosive nature of the materials handled at the Extrusion Plant, the buildings were constructed of non-flammable, semi-permanent materials. Buildings at the Extrusion Plant generally were constructed of concrete and incorporated safety features such as blast walls, concrete fire walls, and concrete-slab roofs. The press houses were designed to contain both a press area and control room; the control rooms are separated by approximately 12 feet of concrete (Goodwin 1998:126).

When the plant first was designed, there was no concept of how rockets would be used during warfare or how much demand there would be for rocket propellant. Early plans for the plant called for only five 8-inch hydraulic presses. As demand for propellant increased from 150,000 pounds per month in April 1944 to 670,000 pounds per month in November of that year, the Navy installed seven 10.5-inch horizontal presses (Carlisle 2002:107-9). During 1945, the production level at the Extrusion Plant was further increased when two 15-inch horizontal presses were added (*Wartime History* 1946:13). As the plant came online, it saw several events that led to delays such as explosions, equipment failure and personnel shortages. No 8-inch or 10.5-inch presses remain at Indian Head. Buildings 560-566 retain 15-inch horizontal presses. Buildings 529, 531, and 532 retain 12-inch vertical presses.

Since World War II, the growth of the plant has reflected U.S. involvement in combat activity. The plant expanded slightly during the Korean War in the 1950s. New buildings during this period included the Annealing Building (Building 871) and the Lunch House (Building 866), both constructed in 1953. A second, more significant expansion of the plant occurred during the 1960s as a result of the Vietnam War. Over the years, the types of products produced at the Extrusion Plant also changed. During the 1960s, the Extrusion Plant was a leader in the production of motors for the Zuni, Anti-Submarine Rocket (ASROC), Sidewinder, Mighty Mouse, Rocket-Assisted Pilot Ejection Catapult (RAPEC), and JATO units. Over forty buildings and structures were added to the plant between 1961 and 1970. These additions consisted mainly of magazines and storage sheds (Goodwin 1998:149).

There were no significant changes in facilities or production equipment during the 1970s. In 1973, Indian Head received $15.8 million for the production of grains for the MK71 Mod 1 Zuni rocket; the money was for a two year production period (Naval Ordnance Station 1973:1). The program extended into the early 1990s. The propellant for the MK71 Mod 1 was produced at Radford Army Ammunition Plant (RAAP) and was shipped to Indian Head. The Extrusion Plant then extruded and further processed (finished) the product into a propellant grain. The grains were produced using the same process as earlier grains and did not require new equipment. The grains then were transported to a load-assembly-pack (LAP) facility, primarily McAlester Army Ammunition Plant, where they were assembled into a finished rocket motor (Email Correspondence Wilmoth 2014).

In the 1980s, the 2.75-inch and 5-inch Zuni grain production lines were reactivated. Facility improvements during this period included: an upgrade of the extrusion presses, with hydraulic, pneumatic and control systems; installation of a real-time X-ray facility to inspect grains for visual defects; and installation of a computer controlled milling machine to process grains for aircraft seat ejection systems. In the 1990s, two extrusion presses were upgraded by installing new hydraulic and computer control systems. In the 2000s, a state-of -the-art annealing oven facility was installed to comply with federal and local environmental regulations. A Zuni motor load and pack out facility also was established, including a digital X-ray machine (Email Correspondence McConnell 2012). During this time, Indian Head was producing MK88 grain and igniters and was loading all motors for the Mod 2 Zuni rocket. More than 10,000 units were produced at Indian Head between the early 2000s and 2011 (Email Correspondence Wilmoth 2014).

In 2011, the MK90 (2.75-inch) grain production line was upgraded and reactivated. This included bringing the cut-to-length, 2.75-inch dowel rod, and multi-wrap operations back on line to meet present day safety and environmental standards. Ultrasonic systems also were installed to inspect the finished grain for internal defects (Email Correspondence McConnell 2012).

Zuni Propellant Grain and MK90 Propellant Grain

The Zuni rocket utilizes a solventless double-base grain solid rocket motor. The Zuni rocket was created for air-to-ground and air-to-air attacks. It utilizes a motor with an "internal-burning solid propellant grain" that allows for greater velocity and enhanced targeting speed (U.S. Naval Ordnance Test Station 1959:3). The production lines introduced at Indian Head during the 1980s accommodated 2.75-inch and 5-inch grains for the Zuni rocket (Email Correspondence McConnell 2012).

The MK90 grain production, introduced at Indian Head in 2011, supported creation of a 2.75-inch grain. It is a solventless double-base grain propellant utilizing nitroglycerin and nitrocellulose. This results in minimal smoke, or a "low signature," when ignited to allow for concealment during combat missions. The propellant grain is used for the MK 66 rocket motor (Alliant Techsystems, Inc. 2011:n.p.).

Although both the Zuni grain and the MK90 grain are the same type of propellants, there are some differences in the chemicals used in manufacturing and processing. In some cases, additional facilities were required to manufacture MK90 propellant and some changes to facilities were made to meet safety and environmental standards. In addition, technological advancements have led to enhanced inspection capabilities, such as the introduction of ultrasonic systems (Email Correspondence Wright 2013; Email Correspondence McConnell 2012).

History and Construction of the Small Motor Test Area (historically known as the Ballistics Laboratory)

The Small Motor Test area at the facility was charged with testing the rocket powder extruded at the adjoining Extrusion Plant. The laboratory used static testing methods to determine what could be expected of the extruded propellant in actual combat performance (*Wartime History* 1946:19-20). Facility records indicate that the cost of the new Ballistics Laboratory (constructed by Naval Powder Factory personnel) and equipment totaled $1,450,991.00. The total cost comprised the following amounts:

- Buildings - $316,028.00
- Miscellaneous Equipment - $862,000.00
- Plant Appliances - $66,032.00
- Machinery - $3,225.00
- Unclassified - $203,706.00

The majority of the equipment used in the Ballistics Laboratory area was constructed in the shops within the Naval Powder Factory by the facility employees (*Wartime History* 1946:19-21).

Static testing methods were used to determine if the extruded propellant could stand up to actual combat performance. In static firing, the Bourdon Gauge was used to measure instantaneous pressure against the length of the explosion time. The Bourdon Gauge is a type of aneroid pressure gauge consisting of a flattened curved tube attached to a pointer that moves around a dial. As the pressure in the tube increases, the tube tends to straighten and the pointer indicates the applied pressure. The static testing of rocket powder was dependent on the powder's actual performance during the testing process and was used to determine what could be expected of the powder in combat (*Wartime History* 1946:17). This approach was one of the most reliable testing methods at the time and proved invaluable for Indian Head in producing the most efficient rocket powder.

In December 1943, continuous firing and production of the powder began with Lot Number 396. The peak firing record at the facility was established in February and March 1945, when approximately 45,000 shots were fired per month by civilian and naval personnel. The facility operated twenty-four hours a day (*Wartime History* 1946:18).

The plant also became involved in reworking rocket propellant, which involved disassembling the rocket motor. Reworking was the process in which older, obsolete powder was taken and passed through the manufacturing process for the second time. One of the complications of smokeless powder is that as it ages, the powder becomes less stable. Reworking of this powder saved money and disposal costs. During the reworking of the grains, the grains were reshaped and re-inhibited. Following these procedures, the rocket motor was reassembled and returned to service (Naval Ordnance Station n.d.:17-22).

Both civilian and naval personnel, including Women Accepted for Volunteer Emergency Service (WAVES), were employed at the Ballistics Laboratory (Carlisle 2002:111). By April 1945, employment at the Ballistics Laboratory reached 129 civilians and 146 enlisted personnel (*Wartime History* 1946:21).

Safety at production installations was a major concern. Construction techniques and safety protocols were implemented to safeguard workers, complete production schedules, and protect property. The volatile nature of explosives 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 incorporated firewalls, blast walls, and hillside construction to direct the blast energy away from other buildings and limit damage from an explosion. Buildings also were assigned specific limits on the amount and type of explosives within them. Signage was posted on each building, and in some cases for each separate bay of a building, to specify personnel occupancy limits. In addition, employees working in restricted areas were required to wear cotton clothing, including cotton undergarments and socks, and conductive shoes to avoid the creation of static electricity (Kane 1995:87-88, Cannan et al. 1996:33-35; Goodwin 1998:96; Email Correspondence Wright 2013).

GLOSSARY OF TERMS *

Ammonium Nitrate – A colorless, crystalline salt which serves as a very stable and insensitive high explosive; also used in fertilizer.

Anti-Submarine Rocket (ASROC) - A torpedo designed to destroy fast, deep-running submarines. The rocket driven torpedo is surface launched and is made of a solid propellant

Ballistite – A smokeless propellant containing nitrocellulose and nitroglycerin; used in some rocket, mortar, and small-arms ammunition.

Bourdon Gauge – A type of aneroid pressure gauge consisting of a flattened, curved tube attached to a pointer that moves around a dial. As the pressure in the tube increases, the tube tends to straighten and the pointer indicates the applied pressure.

Cellulose – The main polysaccharide in living plants, forming the skeletal structure of the plant cell wall.

Diphenylamine – Colorless leaflets; used as an additive in propellants to increase the storage life by neutralizing the acid products formed when the nitrocellulose decomposes.

Explosive D – Compound with stable yellow and forms of orthorhombic crystals; used as a military explosive for armor-piercing shells, also known as ammonium trintrophenolate and ammonium picrate.

Extrusion – A process in which a hot or cold semisoft solid material, such as metal or plastic, is forced through the orifice of a die to produce a continuously formed piece in the shape of the desired product.

Gun Cotton – Any of various nitrocellulose explosives of high nitration made by treating cotton with nitric and sulfuric acids; used principally in the manufacture of single-base and double-based propellants.

Jet-Assisted Take -Off (JATO) Unit – An auxiliary jet-producing unit or units, usually rockets, added to an engine to provide additional thrust.

Mighty Mouse – A 2.75-inch solid rocket propellant, folding-fin aircraft rocket intended for use against ground targets.

Nitrocellulose – Any of several esters of nitric acid, produced by treating cotton or some other form of cellulose with a mixture of nitric and sulfuric acids; used as an explosive and propellant.

Propellant – A combustible substance which produces large quantities of heat and ejection particles.

Powder Grain – A single, elongated molding or extrusion of solid rocket propellant, regardless of size or shape.

Pyrocellulose - A cellulose nitrate used as a component of smokeless powder.

Rocket-Assisted Pilot Ejection Catapult (RAPEC) – A rocket attached to a pilot's seat; used for emergency ejections.

Sidewinder – A U.S. Navy air-to-air missile with an infrared guidance system and a speed of over Mach 2; the missile seeks enemy planes by honing in on the heat emitted by the target.

Single-Base Powder – An explosive or propellant powder in which nitrocellulose is the only active ingredient.

Smokeless powder – Nitrocellulose containing 13.1 per cent nitrogen with small amounts of stabilizers (amines) and plasticizers usually present, as well as various modifying agents (nitrotoluene and nitroglycerin salts); used in ammunition.

Static Firing – The test firing of a rocket motor that is bolted to a test stand.

Trinitrotoluene – (TNT) Highly explosive compound used in shells, bombs, and missiles.

Zuni – A folding-fin, air-to-surface unguided rocket with solid rocket propellant; can be armed with various types of heads, including flares, fragmentation, and armor-piercing.

***Carlisle 2002:303-310**

SOURCES OF INFORMATION

Architectural Drawings and Historic Photographs

The Indian Head Facilities Engineering Archives maintains an archive of drawings for buildings located within the base dating from 1918 through 2011. These drawings are maintained as hard copy images. Select drawings for many of the buildings located in the Indian Head Powder Factory area and the Indian Head Extrusion Plant area are included in this documentation package as supplemental graphic material for the individual building forms.

The College of Southern Maryland, Southern Maryland Studies Center located in La Plata, Maryland has an extensive collection of historic photographs pertaining to the Naval Proving

Ground Indian Head. The majority of those photographs can be located in the Indian Head Centennial Collection (accession number 2009.102) housed at the studies center.

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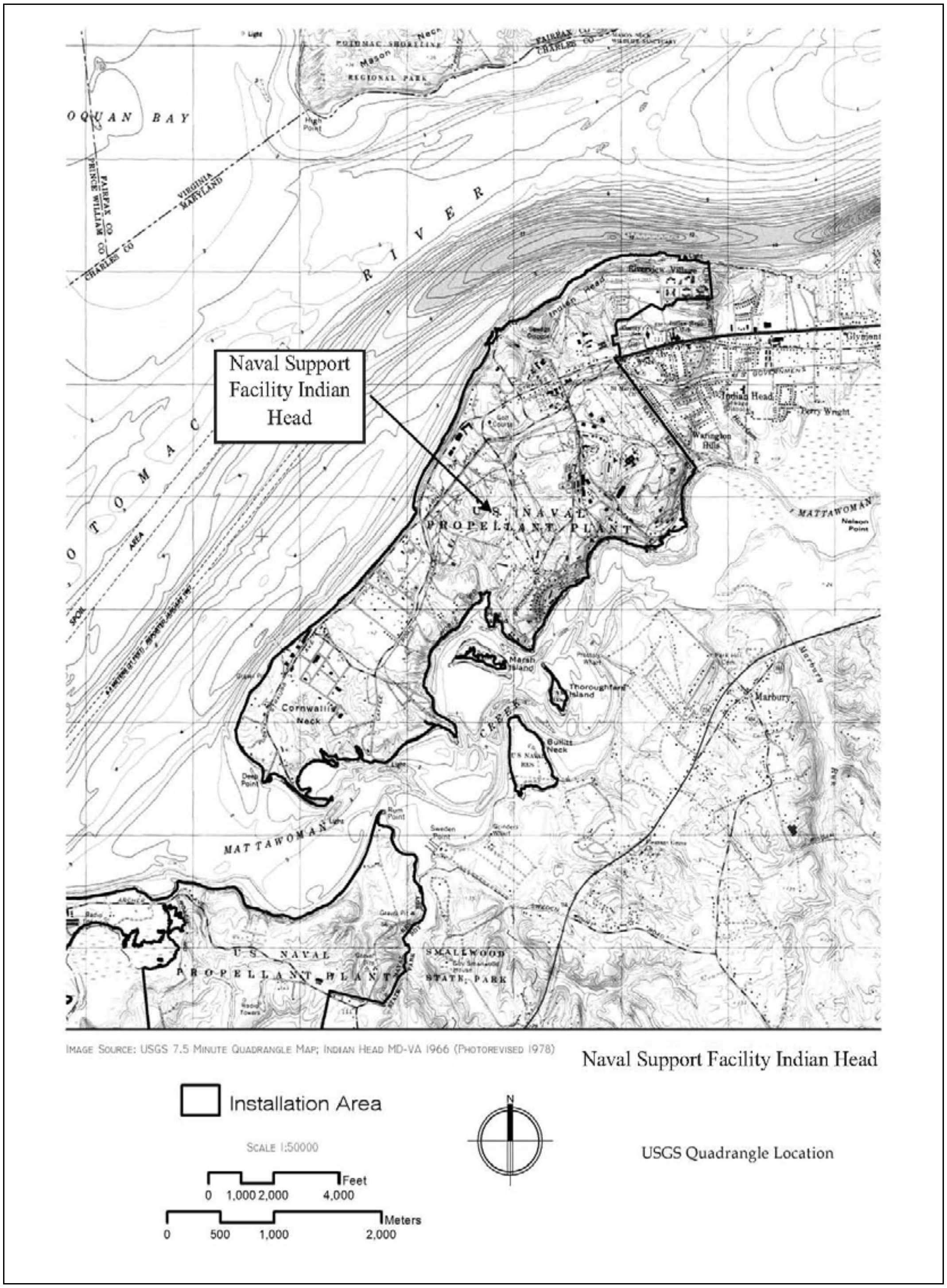
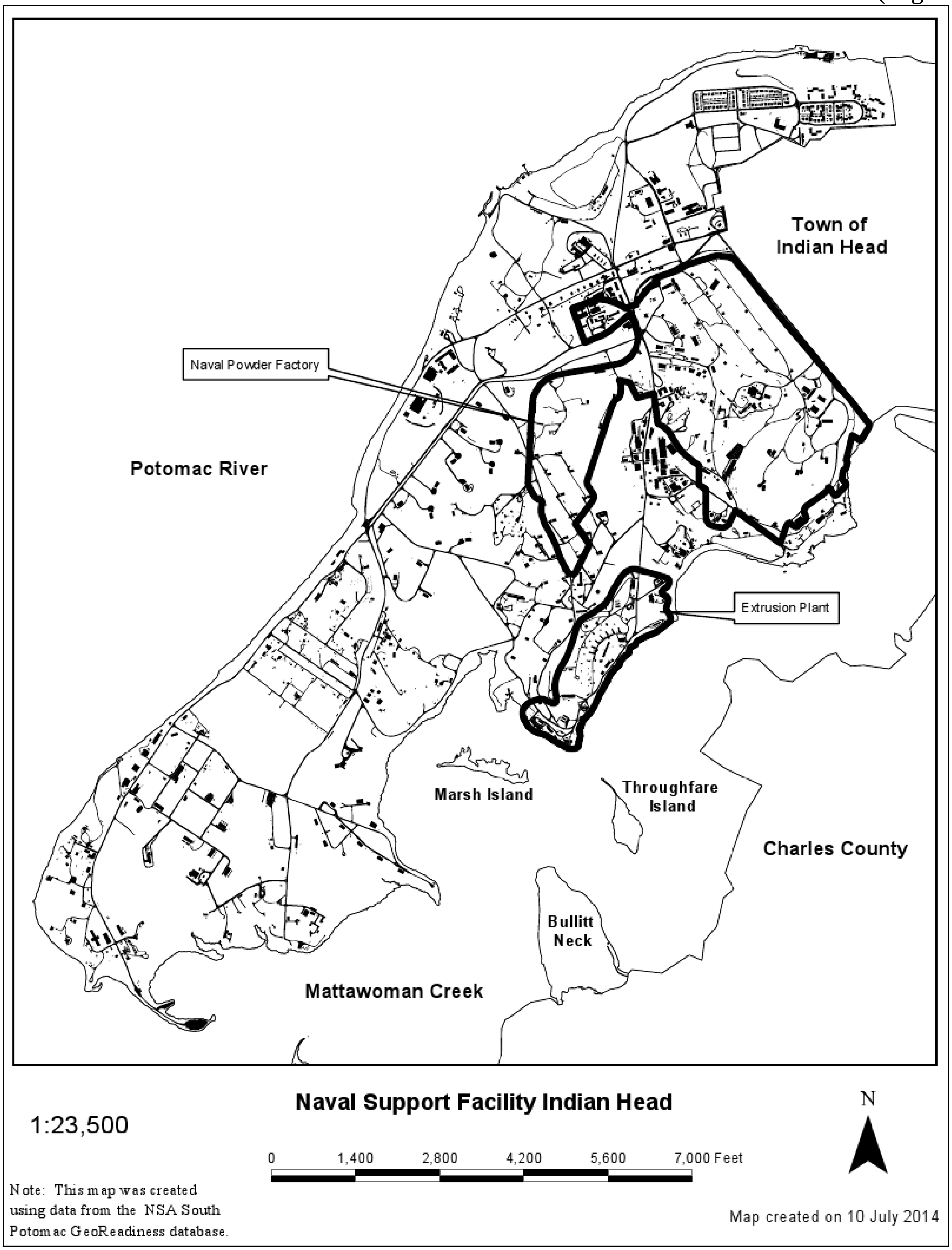
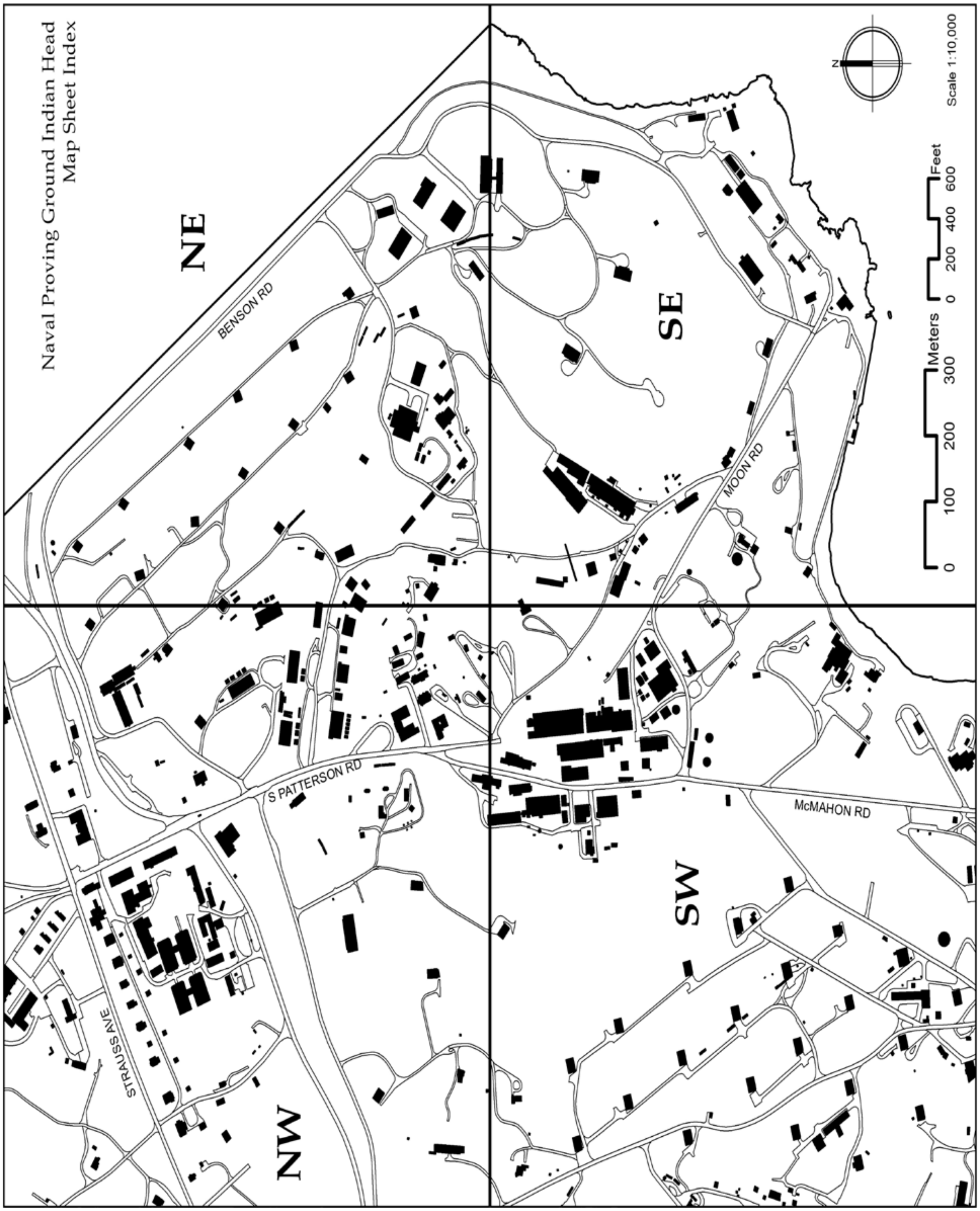


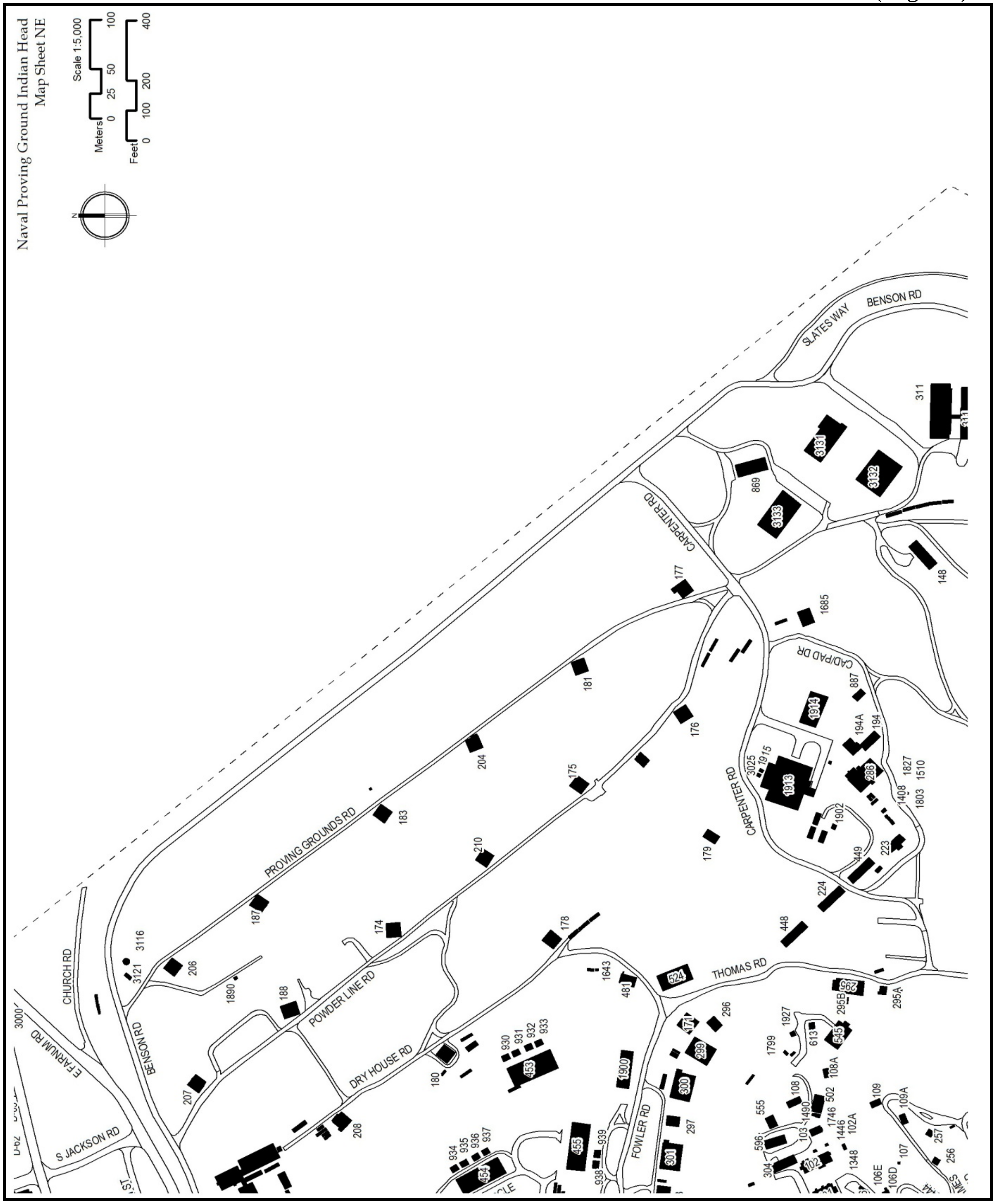
USGS 7.5-Minute Quadrangle Map, Indian Head, MD-VA 1966 (Photorevised 1978)



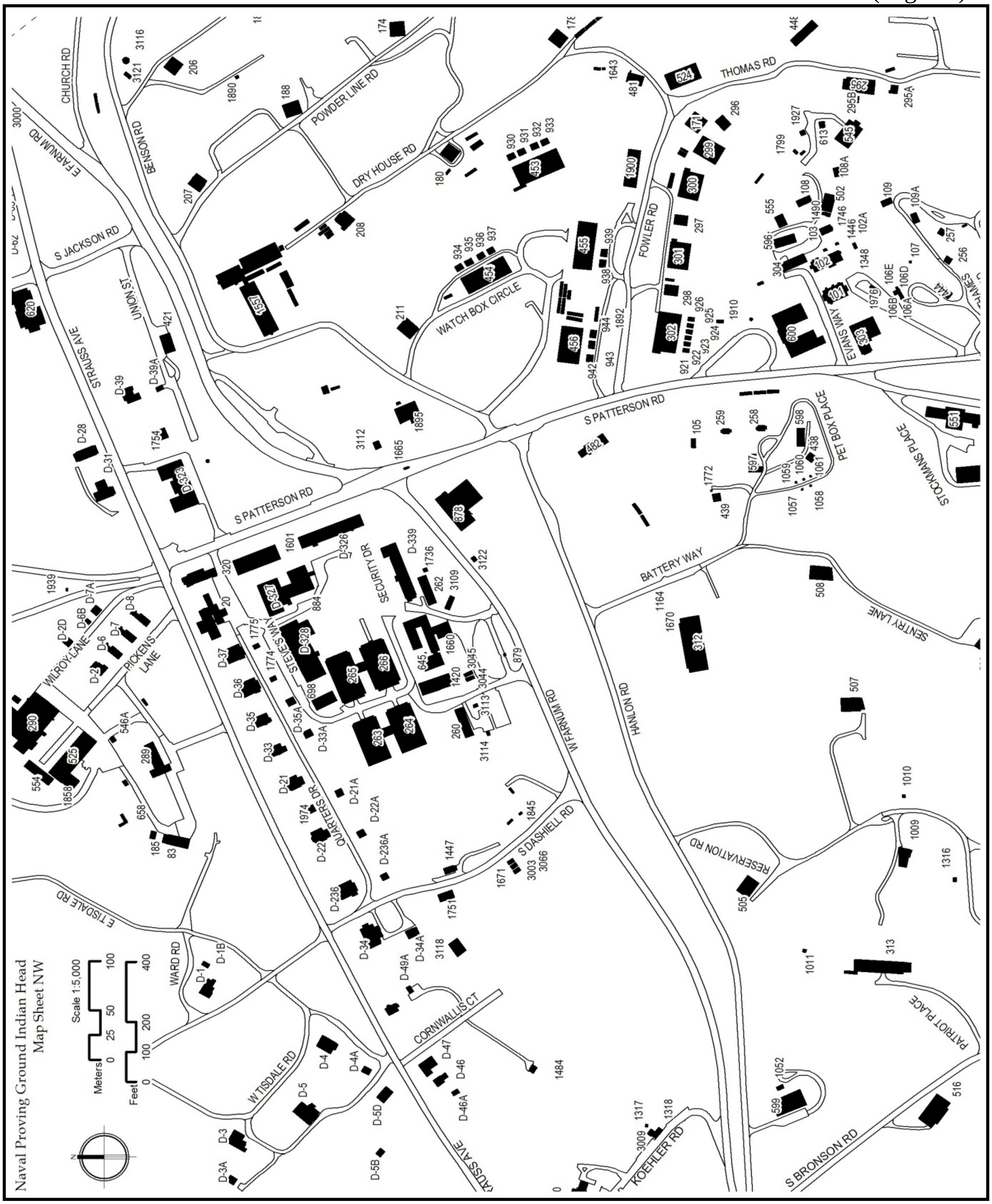
Naval Powder Factory and Extrusion Plant Areas, 2009



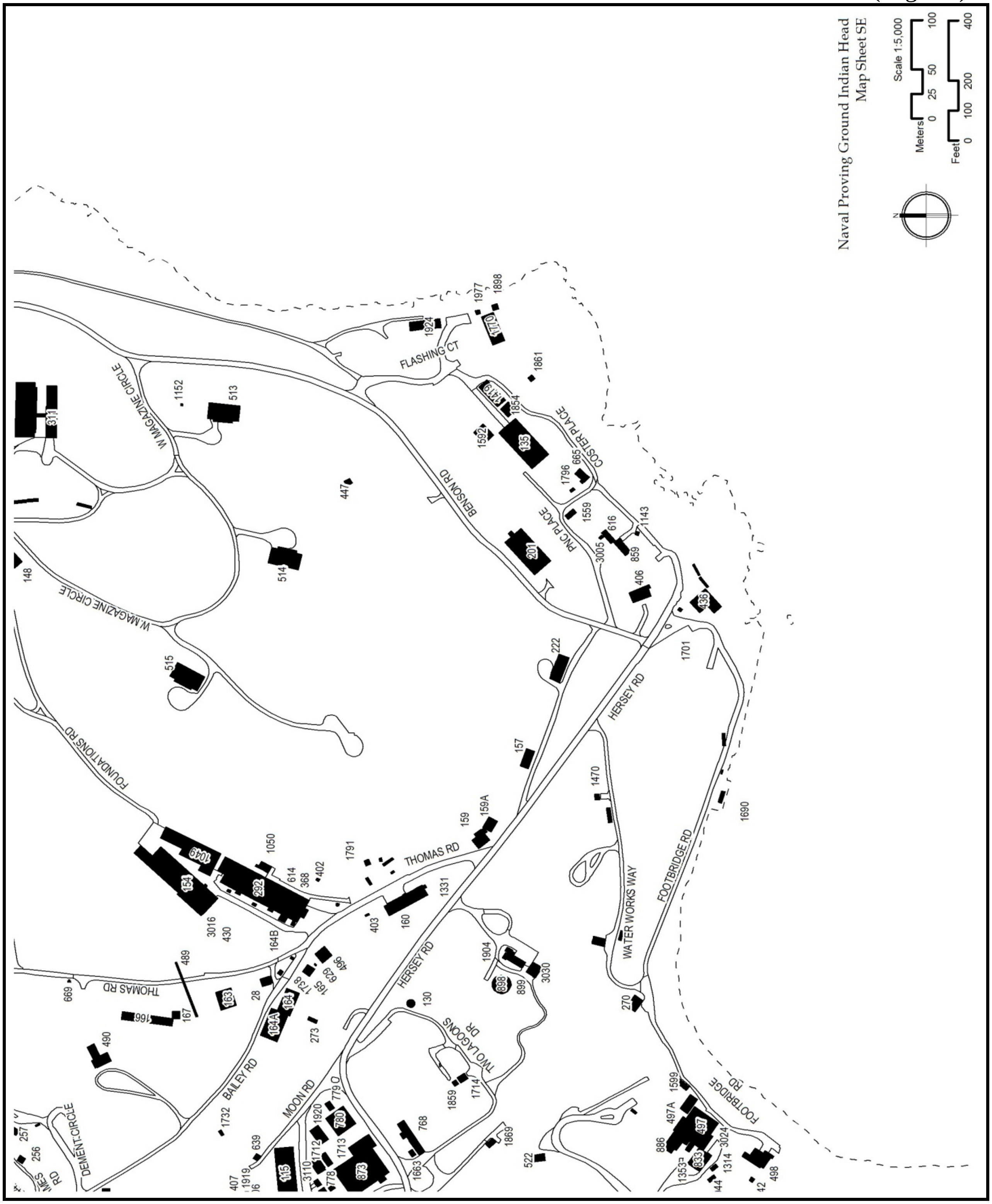
Naval Powder Factory Area



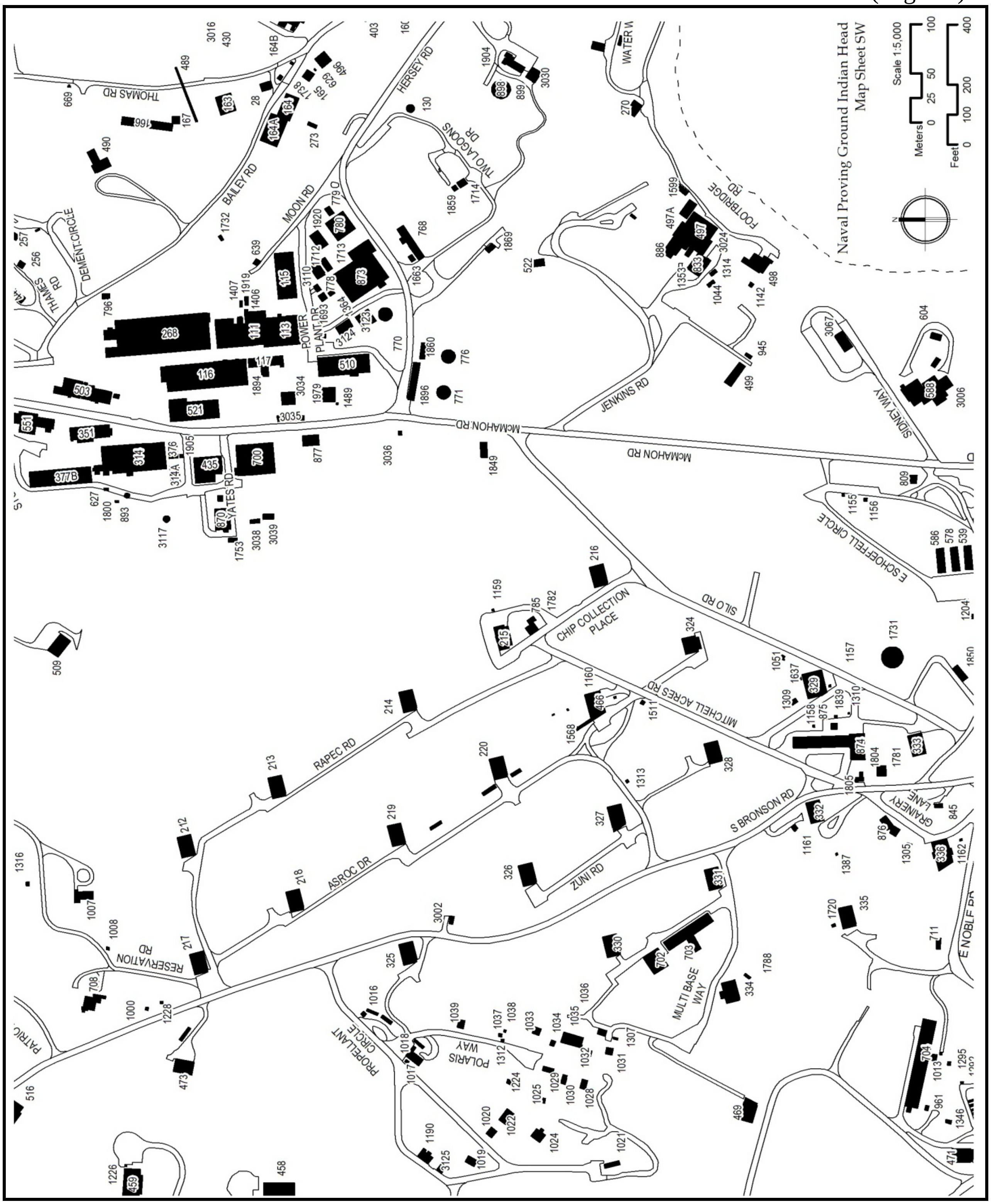
Naval Powder Factory Area, Northeast Quadrant



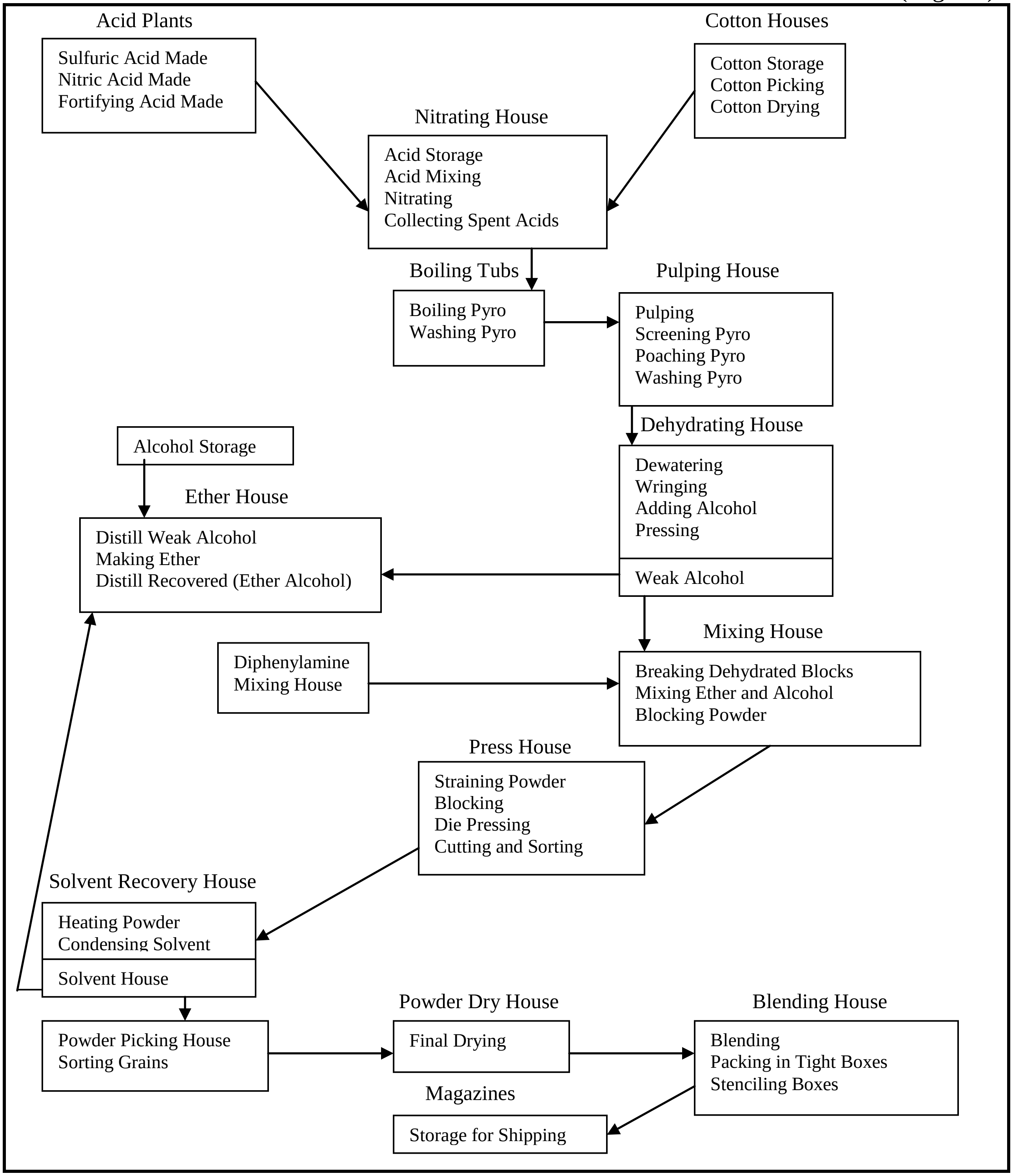
Naval Powder Factory Area, Northwest Quadrant



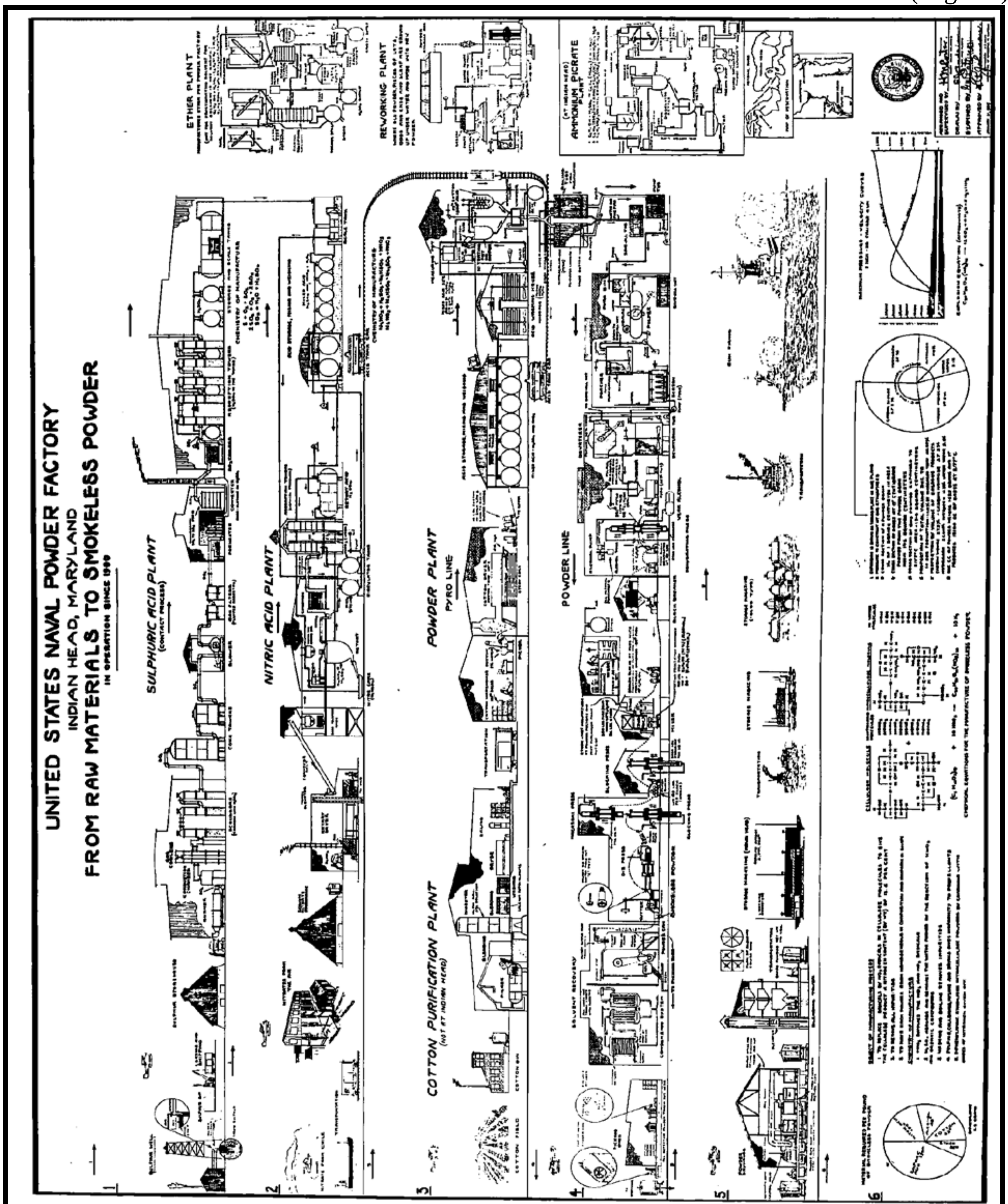
Naval Powder Factory Area, Southeast Quadrant



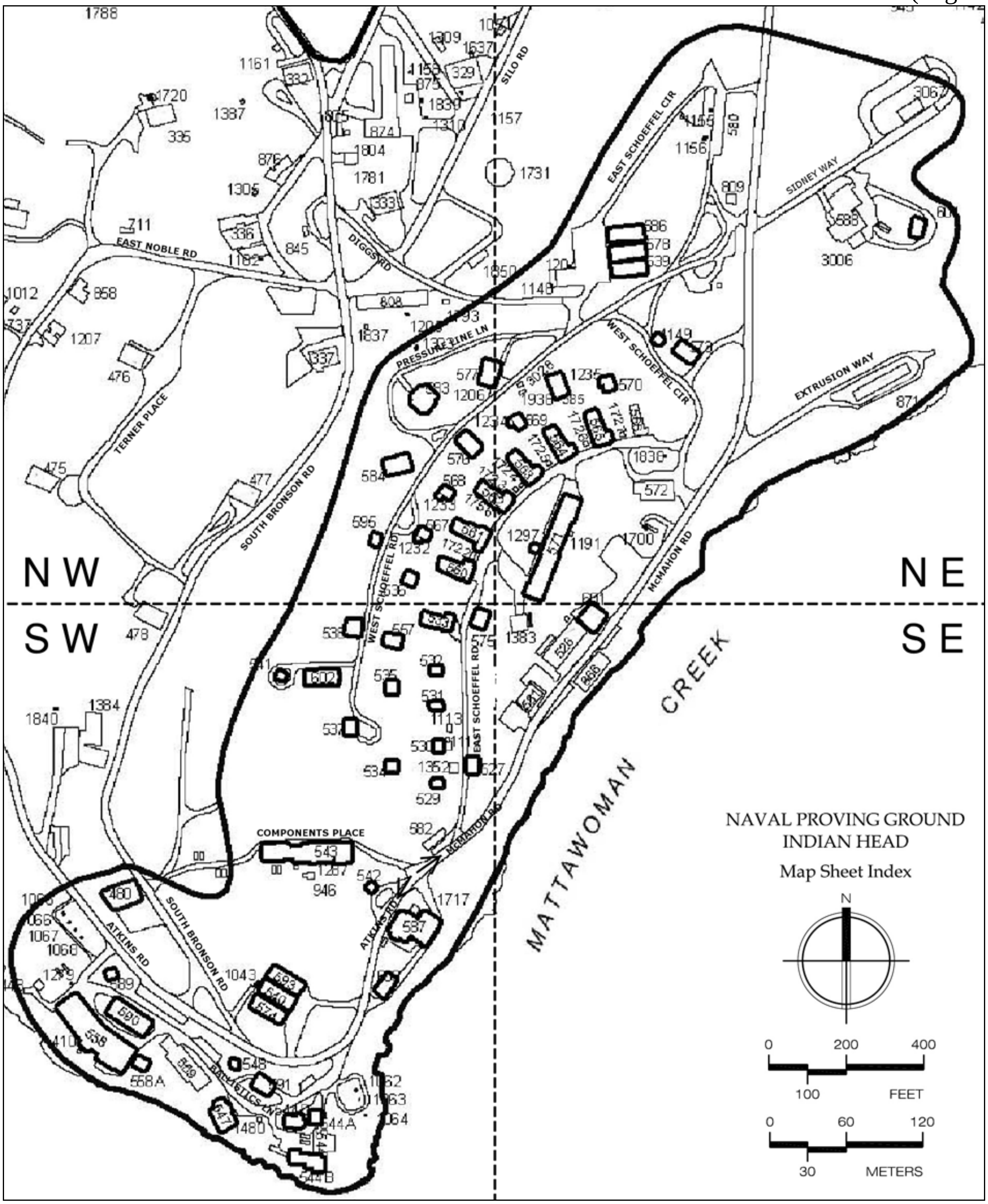
Naval Powder Factory Area, Southwest Quadrant



Powder Factory Flow Sheet (Indian Head Facilities Engineering Archives – Department of the Navy)



Flow Chart – From Raw Material to Smokeless Powder (Indian Head Facilities Engineering Archives – Department of the Navy)



Map of the Indian Head Extrusion Plant Area, Indian Head, Maryland

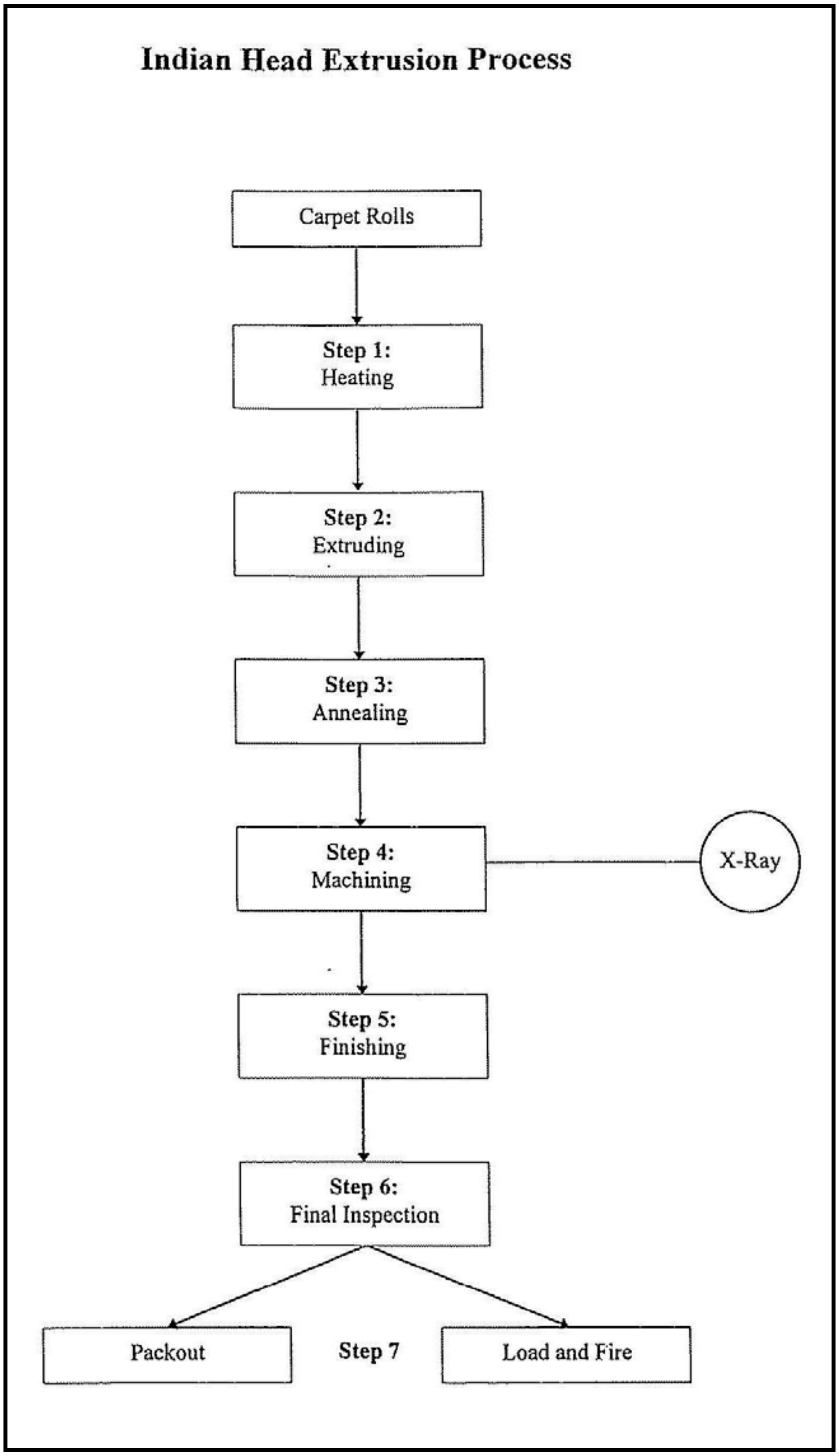
Buildings Associated with the Extrusion Plant and Small Motor Test Area

Building No.	**Construction Date**	**Use as of 2010**	**Historic Use**
480	1943	Dryhouse	Dryhouse
526	1943	Extrusion Plant Office	Extrusion Plant Office and Change Building
527	1943	Mix Control Building	Control Building No. 1
528	1943	Storage Building	Control Building No. 2
529	1943	Press House No. 1	Press House No. 1
530	1943	Fluorocarbon Mix Building	Press House No. 2
531	1943	Press House No. 2	Press House No. 3
532	1943	Press House No. 3	Press House No. 4
533	1943	Real Time X-ray Facility	Press and Control House
534	1943	Soaking Oven	Preheating Building No. 1
535	1943	Soaking Oven	Preheating Building No. 2
536	1943	Heating Oven Building No. 3	Preheating Building No. 3
537	1943	Fluorocarbon Weighting Building	Rolling and Weighting Building
538	1943	Charge Preparation Building No. 2	Rolling and Weighting Building
539	1943	Magazine	Import Magazine
540	1943	Magazine	Export magazine
541	1943	Magazine	Daily Storage Magazine
542	1943	Magazine	Daily Storage Magazine
543	1943	Multi-Bay Processing	Machining and Packing
544	1943	Ballistics Test Building	Ballistics Test Building
544 A	1944	Temperature Control	Oven Building
544 B	1944	Bomb Laboratory/Torpedo Workshop	Oven Building
544 C	1944	Bomb Laboratory/Torpedo Workshop	Loading Room
544 D	1944	Electronic Physical Laboratory	Shop and Storage
547	1944	Ballistics Test Building	Ballistics Bomb Building
548	1943	Magazine	Ballistics Bomb Magazine
557	1944	High Frequency Pre-heater House	Electronic Heating Building No. 1
558	1944	Ballistics Testing Building	Ballistics Test Building
558 A	1944	Temperature Conditioning Building	Oven Bay Annex
560	1943	Press House No. 6	Press House No.6
561	1943	Press House No. 7	Press House No. 7
562	1943	Press House No. 8	Press House No.8

Building No.	**Construction Date**	**Use as of 2010**	**Historic Use**
563	1943	Press House No. 9	Press House No. 9
564	1943	Press House No. 10	Press House No. 10
565	1943	Press House No. 11	Press House No. 11
566	1943	Press House No. 12	Press House No. 12
567	1944	Preheating Oven No. 4	Preheating Oven No. 4
568	1944	Preheating Oven No. 5	Preheating Oven No. 5
569	1944	Preheating Oven No. 6	Preheating Oven No. 6
570	1944	Preheating Oven No. 7	Preheating Oven No. 7
571	1943	Machine Building No. 2	Machine Building No. 2
572	1945	Rocket Loading Building	Finishing Building
573	1943	Magazine	Conditioning Storage Magazine (7-day storage)
574	1944	Magazine	Conditioning Storage Magazine (7-day storage)
575	1944	Maintenance Shop	Maintenance Shop
576	1944	Hi-frequency Pre-heating Building	Electronic Heater Building No. 2
577	1944	Charge Preparation Building No. 4	Charge Rolling Building
578	1944	Magazine	Import Magazine
579	1944	Annealing Oven Building	Annealing Oven Building
580	1944	Motor Loading Building	Double Base Powder Packing Building
581	1944	Extrusion Division Office Building	Die Shop
582	1944	Test Office/Metallurgy Laboratory	Box Shed
583	1944	Magazine	Ready Service Magazine
584	1945	Charge Preparation Building No. 3	Charge Rolling Building
585	1945	Hi-Frequency Pre-heating House	Electronic Heater Building
586	1944	Magazine	Import Magazine
587	1944	Gauge Calibrating Building	X-ray Building No. 1
588	1944	Motor Loading Building	X-ray Building No. 2
589	1944	Magazine	Primer Magazine
590	1945	Retail Outlet No. 7	Storage building for Inert Components
591	1944	Power Distribution Building	Power Distribution Building
593	1944	Magazine	Export Magazine
595	1944	Toilet Building	Toilet building
601	1945	Change House	Change House

Building No.	**Construction Date**	**Use as of 2010**	**Historic Use**
602	1945	Motor Loading House	Powder Cutting Building
603	1945	Operating Building	Temperature Condition Building
604	1945	Magazine	Cooling Magazine
611	1945	Change House and Lunchroom	Temporary Office
844	1949	Storage Warehouse	Box Washing and Testing Shed
1149	1941	Heater House	Heater House
1232	1943	Attendant Shed	Attendant Shed
1233	1943	Attendant Shed	Attendant Shed
1234	1943	Attendant Shed	Attendant Shed
1235	1943	Attendant Shed	Attendant Shed
1297	1943	Inert Storage	Inert Storage
1301	1940	Transformer Station	Transformer Station

Extrusion Plant and Small Motor Test Area Buildings and Structures Constructed Between 1940 and 1949 (Buildings in **bold** were photo documented for this report)



Extrusion Plant Manufacturing Process (Goodwin 1998:101)