AIR FORCE HANDBOOK 10-222, VOLUME 17

28 May 2015

RED HORSE QUARRY AND PIT OPERATIONS

DEPARTMENT OF THE AIR FORCE

BY ORDER OF THE SECRETARY OF THE AIR FORCE

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This handbook addresses equipment, procedures and safety information related to RED HORSE quarry and pit operations. It highlights quarry and pit site selection processes; rock drilling equipment and patterns; crushing, screening, and hauling operations, and quarry blast design. This publication applies to all Air Force active duty, Air Force Reserve Command (AFRC), and Air National Guard (ANG) RED HORSE units. It supports Air Force Instruction (AFI) 10-209, *RED HORSE Program.* Refer recommended changes and questions about this publication to the Office of Primary Responsibility (OPR) using the AF Form 847, *Recommendation for Change of Publication*; route AF Form 847s from the field through the appropriate functional chain of command and Major Command (MAJCOM) publications/forms managers. Ensure that all records created as a result of processes prescribed in this publication are maintained in accordance with (IAW) Air Force Manual (AFMAN) 33-363, *Management of Records*, and disposed of IAW the Air Force Records Disposition Schedule (RDS) in the Air Force Records Information Management System (AFRIMS). The use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force. This publication is nondirective; however, directive language is sometimes used to improve readability.

Chapter 1

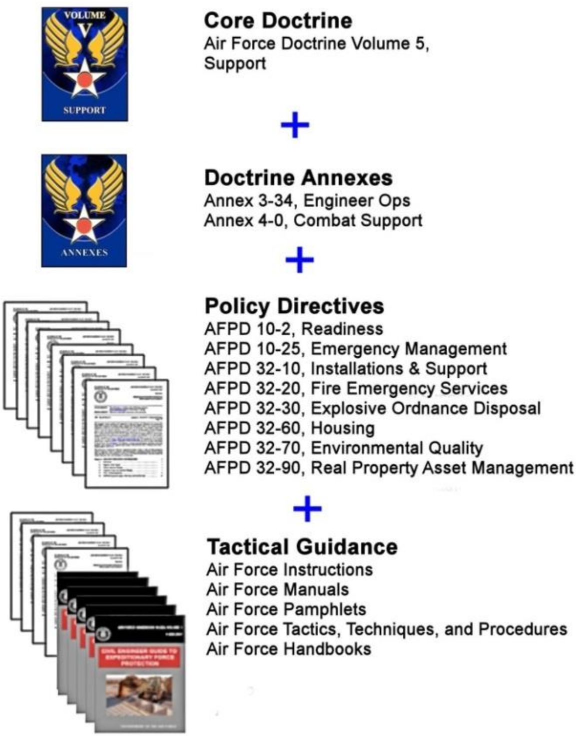
INTRODUCTION

1.1. General Information. RED HORSE units provide civil engineer special capabilities anywhere in the world. These unique capabilities include building roads, helicopter pads, taxiway ramps, and even large-scal**e** operational airfields. Expeditionary operations like these require high quality concrete, asphalt, base course, and surfacing and fill material to complete. These materials sometimes cannot be purchased in sufficient quantities, or at all, within a reasonable distance of the work site. When that situation occurs, RED HORSE can move quickly to stand-up quarry and pit operations to provide the needed construction materials (**Figure 1.1**). Our focus here is to provide an overview of the processes, materials, and heavy equipment used during RED HORSE quarry and pit operations. This publication is nondirective. It does not replace information contained in technical orders (T.O.) or other mandatory instructions vital for quarry and pit operations, therefore users must refer to applicable directives and required guidance for comprehensive information addressing the selection and operation of quarries and pits.

Figure 1.1. RED HORSE Quarry Operation.

1.2. Scope. The information in this handbook relates to tactics, techniques, and procedures (TTPs) use by civil engineers in supporting precepts outlined in Air Force Doctrine Volume 5, *Support* and Air Force Doctrine Annex (AFDA) 3-34, *Engineer Operations*. It also supports implementation of Air Force Policy Directive (AFPD) 10-2, *Readiness*, AFI 10-209, *RED HORSE Program*, and AFMAN 10-903, *Quarry Operations*. This association is illustrated in **Figure 1.2**, CE doctrine, policies, and guidance.

Figure 1.2. Core Doctrine and CE Policies and Guidance.



1.3. Roles and Responsibilities. RED HORSE Squadrons (RHS) perform quarry and pit operations in support of peacetime and contingency operations. To that end, selected RED HORSE and Prime BEEF personnel are trained to perform all aspects of quarry and pit operations, including blasting operations (**Figure 1.3**). The 820th RHS at Nellis AFB, Nevada, is the lead training unit for quarry operations and has responsibility for training CE personnel in quarry and pit operations. Units may schedule personnel for quarry and other training through the AFCEC CE Contingency Training SharePoint site at https://afcec-portal.lackland.af.mil/sites/CECT/SitePages/Home.aspx.

Figure 1.3. Blaster Training in Support of Quarry Operations.

1.4. Safety. Like any other engineer operation that involves the use of heavy equipment, understanding and observing safety requirements during quarry and pit operations prevents injuries and saves lives. It is everyone's responsibility to adhere to all related safety protocols and precautions.

1.5. Additional Information. Several resources was used in the development of this handbook, including information from relevant T.O.s, AFMANs, Unified Facilities Criteria (UFC), commercial equipment manuals, RED HORSE quarry course materials, and other resources. This handbook provides a basic overview of Air Force quarry and pit operations. Personnel should refer to applicable T.O.s, manuals and other approved guidance before performing any quarry or pit operation. In addition, contact the Air Force Civil Engineer Center (AFCEC) Reach-Back Center (RBC) when looking for information not addressed in this publication or the references in **Attachment 1**. Contact the Reach-Back Center at 1-888-232-3721 (toll free), 1-850-283-6995 (comm), Defense Switched Network (DSN) 523-6995, or via email at AFCEC.rbc@us.af.mil.

IMPORTANT NOTE

This handbook provides general information ONLY. It does not replace policy documents, T.O.s, manuals, or any applicable mandatory procedures or instructions. Users must review applicable technical, safety, and policy references before performing actual quarry or pit operations.

Chapter 2

SITE SELECTION

2.1. General Information. Significant research and evaluation is usually done before a quarry or pit site is finally selected. The selection process helps ensure the expected quality and quantity of construction material can be obtained from the site. This chapter provides an overview of basic quarry and pit selection factors, however, users should refer to applicable technical orders and other relevant guidance for specific site selection procedures.

2.2. Selection Process. Quarries and pits are classified according to the type of material contained in them and the methods of obtaining the materials (**Table 2.1**). In general, a quarry is considered a facility that produces rock material for construction through blasting and cutting operations. Conversely, pits are facilities that produce earth or rock particles (soil) for construction by removal with earthmoving equipment. For many good reasons, it is usually more beneficial to use an existing quarry or pit capable of producing the required material, but when such sites are unavailable, other sources must be found. The site selection process involves both a *preliminary* and *field* reconnaissance.

Table 2.1. Quarry and Pit Classifications and Use.

Category	Material	Primary Use	Operation
Borrow pit	Soil, sand, and gravel	Subgrades, base course, or fill	Medium and light mechanical
Gravel pit	Gravel, coarse sand, and clay	Base course, surfacing, or fill	Medium and light mechanical
Alluvial gravel pit	Clean gravel and sand	Aggregate for concrete and mixes	Heavy mechanical crushing, screening, and washing

Table 2.1. (Continued)

Category	Material	Primary Use	Operation
Dump pit	Mine spoil, slag, and overburden	Recycling, surfacing, or aggregate	Heavy mechanical crushing, screening, and washing
Hard-rock quarry	Aggregate	Base course, surfacing, or aggregate for concrete and mixes	Heavy mechanical crushing, screening, and washing and drilling and blasting
Medium-rock quarry	Aggregate	Base course, surfacing, or fill	Heavy mechanical crushing, screening, and washing and drilling and blasting
Soft-rock quarry	Cement material	Base course and surfacing of roads and airfields	Medium and light mechanical

2.3. Preliminary Reconnaissance. The preliminary reconnaissance typically consists of studying information sources that provide clues to potential mining sites. These resources include intelligence reports, satellite images, geologic and topographical maps, and any other available material. However, topographical maps are the most common source for preliminary information and planning. Local inhabitants can also be a good source of information. A combination of all these resources should help narrow the list of potential sites to the best possible candidates.

2.3.1. **Intelligence Sources.** Intelligence reports from the Department of Defense (DOD) and other federal agencies may contain information on soil types, rock formations, and existing and potential quarry locations for a particular area. Information in these reports comes from various sources including reconnaissance personnel and units located in an area of interest. This information is especially useful prior to entering an area or sector.

2.3.2. **Maps and Charts.** Geologic, topographical, and agricultural soil maps are excellent resources for locating existing and potential quarries. Topographical maps indicate the location of streams, roads, hills, cliffs, and other pertinent terrain features (**Figure 2.1**). Geologic maps often contain information on existing quarries and pits, mining districts, haul roads, and surface geology including vegetation. Like topographical maps, they may also provide information on terrain elevation and drainage. The Department of Interior United States Geological Survey (USGS) maintains a large repository of map data and is a great resource for beginning preliminary reconnaissance.

Figure 2.1. Topographical Maps Indicate Terrain Features.

2.3.3. **Satellite Images and Aerial Photographs.** When used in conjunction with other information, satellite images and aerial photographs can help analyze surface features including the location of quarries, pits, and rock formations. Imagery from the command's installation geospatial information and services (IGI&S) may also be useful in locating potential mining sites.

2.3.4. **Local Inhabitants.** Local people, particularly surveyors, engineers, miners, contractors, and quarrymen, can provide useful data on local geology and possible engineering problems. In addition, farmers are usually a good source of information because they are very familiar with local land conditions.

2.4. Field Reconnaissance. Following preliminary reconnaissance assessment, a field reconnaissance at the potential quarry or pit site is used to verify initial research and obtain additional information on the quality and quantity of construction material, and other factors that may affect excavation operations (**Figure 2.2**). If checking an existing quarry or pit that has been abandoned, determine why it was no longer being used (i.e., project completed, excessive water, quality of material, etc.). Engineers should maintain meticulous records during the field investigation because the information will likely influence the final site selection. Include any pertinent data annotated on geologic and topographical maps, geospatial information systems (GIS) overlays, or aerial imagery used during the investigation. Field reconnaissance techniques can include *boring*, *probing*, *drilling*, and *excavating*. Field reconnaissance should be conducted IAW American Society for Testing and Materials (ASTM) D5434, *Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock* as well as ASTM D420, *Standard Guide to Site Characterization for Engineering, Design, and Construction Purposes*. If the quarry will produce aggregates for concrete pavements, fine and coarse aggregate should be tested separately in accordance to ASTM C 1260 if possible. If the expansion is 0.08 percent or more in 28 days then mitigation measure are required. If the quarry will produce aggregates for concrete pavements, fine and coarse aggregate should be tested separately in accordance to ASTM C 1260.

Figure 2.2. Field Reconnaissance Confirms Site Data.

2.4.1. **Boring.** Boring is accomplished either mechanically or by hand. It consists of drilling, cutting, sinking, or enlarging a vertical hole in the earth's surface deep enough to provide desired information. Boring should be conducted IAW ASTM D1452, *Standard Practice for Soil Exploration and Sampling by Auger Borings*.

2.4.2. **Probing.** Probing is also accomplished either mechanically or by hand. It involves driving a steel rod through the ground's surface while observing the penetration resistance. The probing depth is limited to the length of the probe rod. For expedient field characterization, probing is most often accomplished utilizing a Dynamic Cone Penetrometer.

2.4.3. **Drilling.** Drilling involves the cutting and recovery of core samples. It is similar to boring except that drilling forces residue into a tube that is brought to the surface. Core drilling allows the encountered strata to be sampled, tested, and observed. A jackhammer can be used for shallow drilling. Drilling should be conducted IAW ASTM D2113 *Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation*. Maintaining proper drilling logs is not only critical for initial field reconnaissance, but provides invaluable information for follow-on blasting efforts.

2.4.4. **Excavating.** Excavating is an expedient method of site testing. Vertically excavating test pits and trenches exposes the subsurface materials and allows for in-place examination. Excavating is a reliable way to determine the occurrence, composition, distribution, structure, and stability of material deposits. While constructing test pits, care should be taken to not to disturb the soil of underlying layers for sampling purposes. Test pits should be a minimum of 1 meter by 1 meter square and stepped to the appropriate depth, as governed by the exploration. Shoring may be required if test pits are constructed over ten feet in depth.

2.5. Site Selection and Associated Factors. Several factors effect site selection and subsequent quarry and pit operations. These factors include the type, quality and quantity of construction materials, ground and surface water conditions, overburden, utilities, security, type of equipment, personnel training and qualification, communications, etc. These and other factors are addressed below.

2.5.1**. Quarry Materials (Rocks).** Understanding the basic geology of rocks is essential to evaluate potential quarry sites. Construction materials excavated from quarries may include various forms and classifications of rocks. The type of rock present and their specific engineering properties will determine site suitability. In general, rock shall be described using the following parameters (at a minimum): rock type, color, textural characteristics such as grain size and crystalline matrix, bedding thickness, bedding attitude (degree or angle of dip, strike direction, etc.), hardness, and any supplementary descriptions such as broken, fractured, jointed, weathered, water-stained, etc.

2.5.1.1. *Rock Classifications and Properties.* Rocks are generally classified into three categories: igneous, sedimentary, and metamorphic. These rocks are usually composed of several different minerals. For example, granite is a granular igneous rock composed primarily of quartz and potassium feldspar, but portions of other minerals will likely be present. See **Table 2.2** for a list of common rock classifications and properties.

2.5.1.1.1. Igneous rocks were formed by the release and cooling of molten rock material from within the earth's mantle. However, the mineral and chemical composition, texture, and mode of occurrence of igneous rocks can vary greatly.

2.5.1.1.2. Sedimentary rock results from the consolidation of loose sediment that has accumulated in layers, either by mechanical, chemical, or organic means. Clastic rock consists of mechanically formed fragments of older rock transported from its source and deposited in water or from air or ice. Chemical rock (such as gypsum) formed by precipitation from solution. Organic rock (such as certain limestones) consists of the remains or secretions of plants or animals.

2.5.1.1.3. Metamorphic rock is any rock derived from preexisting rocks by mineralogical, chemical, or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the Earth's crust.

Table 2.2. Rock Classifications and Properties.

Igneous	Properties[2]
Granite  (Image Copyrighted 2004, see Note 1)	An igneous rock with an even texture. Granite is gray, pink, or red, with crushing strength ranging from 15,000 to 30,000 pounds per square inch. Unweathered granites are strong and durable rock suitable for bridge piers, sea walls, and foundations of buildings. Its chief defect is that when heated and chilled, the quartz and feldspar grains expand or contract at different rates sometimes causing the rock surface to crumble or peel.
Diorite 	Diorites are a family of rocks that resemble dark granite and found most often in sills, dikes, and small stocks. Unweathered diorites are strong and durable and have an average compressive strength of 28,000 pounds per square inch.
Gabbro 	Gabbro is a dark gray, green, or black granular rock similar in appearance to diorites. Like granite, gabbro is found in batholiths, but it also forms small stocks, dikes, sills, and volcanic necks. Gabbro which is a durable construction material for all purposes, has a high degree of compressive strength (average is 26,000 per square inch), and low absorbability. Gabbro is chiefly used for road materials.

Table 2.2. (Continued)

Felsites 	Felsites are a group of very dense, fine-grained, extrusive igneous rocks. They have dull, stony textures and are composed of quartz and feldspars. Colors range from light or medium gray to pink, brown, yellow, purplish, and light green. Weathering causes Felsites to become brown, rusty and crumble, eventually breaking down completely to become clay. Felsites are generally used as concrete aggregate.
Basalts  (Image Copyrighted 2006, see Note 1)	Basalts are a group of very dense fine-grained igneous rocks whose colors range from black to dark gray to green to purplish. All basalts contain a great deal of lime, magnesium, and iron. They are a fine-grained equivalent of Gabbro and are closely related to the andesites.
Sedimentary	**Properties**[2]
Limestone  (Image Copyrighted 2008, see Note 1)	Any rock that contains more than 50 percent calcium carbonate in the form of calcite is considered limestone. When pure, limestones are white or colored, but they are usually colored gray to black by carbon or stained buff, yellow, red, or brown by iron oxides. Crushed limestone is used in the manufacture of Portland cement.

Table 2.2. (Continued)

Dolomite  (Image Copyrighted 2006, see Note 1)	Sometimes similar in appearance and usage to limestone, dolomite is a calcium magnesium carbonate of varying proportions.
Chert and Flint  (Image Copyrighted 2005, see Note 1)	Siliceous sediments are usually found in limestone and shale. They are very hard and difficult to drill. Chert can be used as a satisfactory road material.
Rock Salt 	Rock salt is very abundant, soluble in water, and very soft. Rock salt deposits are of no value as a construction material.

Table 2.2. (Continued)

Conglomerate  (Image Copyrighted 2009, see Note 1)	Conglomerates are composed of cemented gravel of varying sizes.
Breccia  (Image Copyrighted 2008, see Note 1)	A variety of conglomerate, Breccia is composed of cemented angular fragments and may be used for road material if properly graded or crushed to size. It is usually susceptible to rapid weathering and consequent weakness.
Diamictite  (Image Copyrighted 2008, see Note 1)	Diamictite is a rock made up of poorly sorted rock fragments of various types and sizes and mixed with finer grained sedimentary material. It is normally a good source of material for earth dams and embankments, but usually not suitable for concrete and bituminous aggregates.

Table 2.2. (Continued)

Sandstone  (Image Copyrighted 2008, see Note 1)	Sandstone consists of small grains (1/16 millimeter to 2 millimeters) that have been cemented together to form rock. The color of sandstone depends on the nature of the cement. Iron oxides give the red, yellow, and brown shades. Sandstone that splits easily into even slabs is known as flagstone. Flagstone is commonly used as a decorative building material.
Siltstone  (Image Copyrighted 2007, see Note 1)	Siltstone is similar to sandstone, but composed mainly of cemented particles that are between 1/256 and 1/16 millimeter in diameter.
Shale 	Shales and clays are made up of clay minerals, various oxides, silica, fine particles of ordinary minerals, and a greater or lesser amount of colloidal and organic material.

Table 2.2. (Continued)

Metamorphic	Properties[2]
Gneiss  (Image Copyrighted 2008, see Note 1)	Gneiss is a banded rock of granite composition, containing quartz, feldspar, and mica. Their banded structure enables the rock to be split into essentially parallel surfaces allowing its use in the construction of tough walls and some road surfaces.
Schists  (Image Copyrighted 2006, see Note 1)	Schist has much finer texture than gneiss and possesses a well-marked cleavage. Unlike gneisses, their bands are mineralogically alike causing treacherous rock slips in quarries, rock cuts, and in tunnels if unsupported on steep or vertical faces.
Slate  (Image Copyrighted 2006, see Note 1)	Slate is a fine grained, hard, and dense rock. It splits easily into thin layers that cut across bedding planes. The most important feature of slate is its cleavage, which makes it valuable for roofing. Although not recommended, it can be used as a road material if necessary.

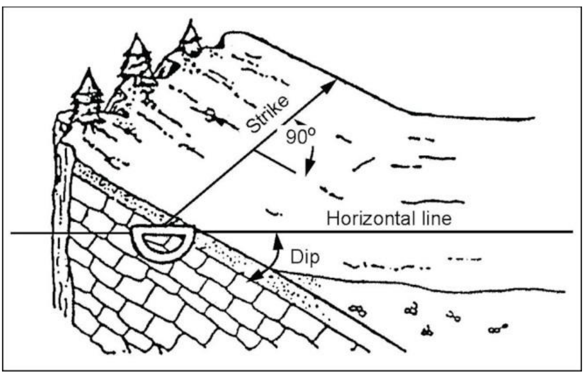
Table 2.2. (Continued)

Quartzite  (Image Copyrighted 2008, see Note 1)	Primarily, quartzite is metamorphosed sandstone. Other minerals are present as impurities and give the rock a pink, brownish, or red brick color. Similar in appearance to grainy limestone, quartzite is much harder. Quartzite is not used as building stone due to shattering during jointing, but when crushed, becomes good material for concrete work, railroad ballast, and roadwork.
Marble  (Image Copyrighted 2008, see Note 1)	Marble is the result of the metamorphism of limestone and dolomite. When crushed and used as an aggregate, marble has the same value as limestone.
Notes: 1. Image copyrighted by Andrew Alden, geology.about.com; used with Mr. Alden's permission. 2. In all cases, rock properties can and will vary significantly within the same rock grouping.	

2.5.1.2. *Rock Structure.* Rock structure refers to the natural arrangement or presentation of rock deposits. Understanding these structures is important to efficient rock excavation. Many rocks form in broad, flat layers called beds that stack up like layers of a cake. In some places, these rocks remain in their flat and level orientation. In other places, geological stresses tilt, bend and break these rock formations. The arrangement of rock structures are generally defined in terms of strike and dip, faults, folds, and joints. Each of these structures is briefly described below. Users should refer to applicable technical orders and manuals for detailed information.

2.5.1.2.1. Strike and Dip. Tilted and inclined rock beds are indicated by strike and dip lines on geologic maps. The *strike* is the line of intersection of an inclined layer of rock (geologic plane) with a horizontal plane (**Figure 2.3**). Engineers usually determine the strike orientation of an area during preliminary reconnaissance or when boring and excavating during field reconnaissance. The *dip* also provides insight into the rock structure of a particular area. The dip is the acute angle between the geologic plane and the horizontal plane. As illustrated in **Figure 2.3**, it is a vertical angle measured at right angles from the strike line. The strike and dip information can be used during quarry layout to optimize blasting and drilling efforts and minimize quarry overhang and slope instability.

Figure 2.3. Strike and Dip.



2.5.1.2.2. Faults and Folds. *Faults* are fractures in the rock structure that cause displacement of the rock parallel to the fracture plane (**Figure 2.4**). Faults are commonly recognized on rock outcrop surfaces by the relative displacement of strata on opposite sides of the fault plane. *Folds* are undulating (rising and falling) surface expressions caused by bending and crumpling of the rock structure. There are several basic types of folds, four of them as illustrated in **Figure 2.5**.

2.5.1.2.3. Joints. *Joints* are rock masses that fracture in such a way that there is little or no displacement parallel to the fractured surface (**Figure 2.6**). Joints influence the way the rock mass behaves when subjected to the stresses of construction. Joints may result from a number of processes, including deformation, expansion, and contraction.

Figure 2.4. Faulting and Fault Zones.

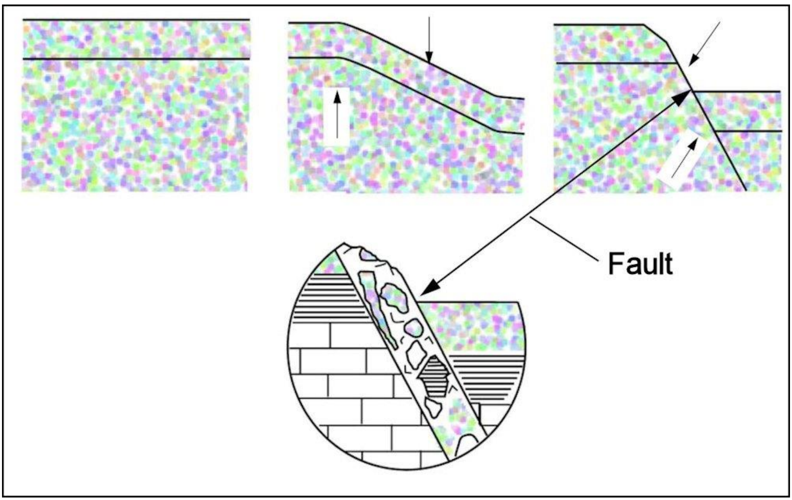


Figure 2.5. Common Folds.

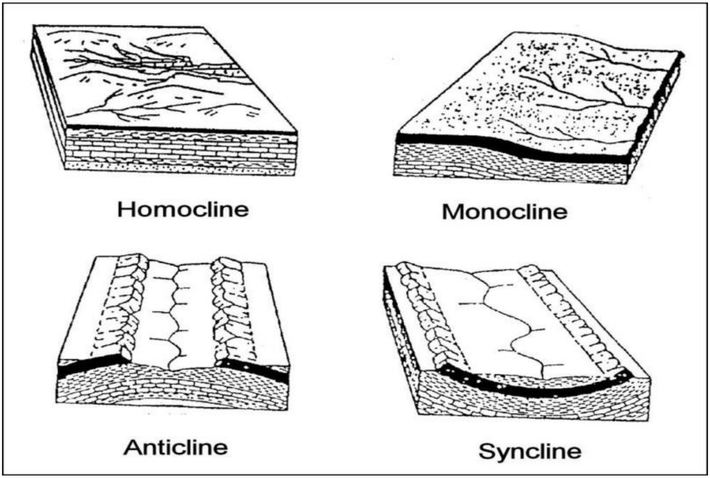
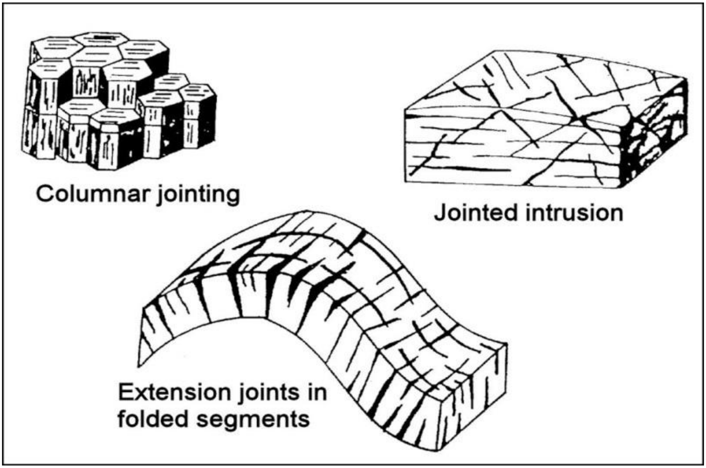


Figure 2.6. Jointing in Sedimentary and Igneous Rocks.



2.5.1.3. *Relative Hardness Factors.* Determining the hardness of rocks helps engineers identify certain minerals during field evaluations. Minerals can be extremely hard, very soft or anywhere in between. The following paragraphs highlight relative hardness factors relating to certain minerals and common objects. Generally, harder objects should be able to scratch softer objects. However, enough pressure must be applied to make the scratch, especially if objects are closely related on the hardness scale. Refer to AFMAN 10-903 for additional information on relative hardness factors.

2.5.1.4. *Mohs Scale of Relative Hardness*. In the early 1800s, mineralogist Friedrich Mohs developed a chart of relative hardness for various minerals. The Mohs Scale of Relative Hardness (**Table 2.3**) is still valid today. It lists the relative hardness of selected minerals from the hardest (#10-Diamond) to the softest (#1-Talc). For example, diamonds are harder than quartz, therefore diamonds will scratch quartz; quartz will scratch calcite; calcite will scratch gypsum; and so on.

Table 2.3. Mohs Scale of Relative Hardness.

Mineral	Relative Hardness
Diamond	10
Corundum	9
Topaz	8
Quartz	7
Feldspar	6
Apatite	5
Fluorite	4
Calcite	3
Gypsum	2
Talc	1

2.5.1.5. *Expedient Scale of Relative Hardness*. With the Mohs scale, mineral hardness is measured by the ability of one mineral to scratch another. However, in lieu of using a mineral to check another, common household items can be used if their relative hardness is known. The expedient scale (**Table 2.4**) provides the relative hardness of ordinary items such as a fingernail, copper penny, pocketknife blade, etc. The relative hardness of rocks is estimated by scratching it with the items listed in the expedient scale. For example, if a file scratches a rock, the rock's relative hardness is below 6.5 on the Mohs scale (softer than Quartz); if the rock scratches the file, the relative hardness of the rock is above 6.5; and if the rock scratches a pocketknife blade, but not the file, the rock's relative hardness is between 5.0 and 6.5.

Table 2.4. Expedient Scale of Relative Hardness.

Item	Relative Hardness	Scratch Reaction
Porcelain	7.0	Porcelain will scratch "quartz" and below.
Steel file	6.5	Steel file will scratch "feldspar" on down in the Mohs scale. Minerals above "feldspar" will scratch the file.
Pocket knife blade or nail	5.0	Pocketknife will scratch "apatite" and below.
Copper coin	3.0	Copper coin will scratch "calcite" and below.
Fingernail	2.5	Fingernail will scratch "gypsum" and below.

2.5.1.6. *Rock Construction Quality*. The physical and chemical properties of rocks determine how suitable they are for a particular construction need or project. Some rocks may be good aggregates for concrete or asphalt production, while others are more suited as a base course or subbase for road construction. Consequently, determining the quality of the available construction material is a key step during site selection. **Table 2.5** lists various rock types and their suitability for different construction requirements.

Table 2.5. Aggregate for Military Construction.

Classification	Rock Type	Use of Aggregates		Use as a Base Course or Subbase
		Concrete	Asphalt	
Igneous	Granite Gabbro-diorite Basalt Felsite	Fair–good* Excellent Excellent Poor*	Fair-good** Excellent Excellent Fair	Good Excellent Excellent Fair-good
Sedimentary	Conglomerate Sandstone Shale Limestone Dolomite Chert	Poor Poor-fair* Poor* Fair-good Good Poor*	Poor Poor-fair Poor Good — Poor	Poor Fair-good Poor Good — Poor-fair
Metamorphic	Gneiss Schist Slate Quartzite Marble	Good* Poor-fair* Poor Good* Fair	Good Poor-fair Poor Fair-good Fair	Good Poor-fair Poor Fair-good Fair
*Reacts (siliceous aggregate). These are known to have caused alkali-silica reaction (ASR) in the past. Some rock types that have not been identified as ASR susceptible can be susceptible if they contain the following minerals: Crisobalite, Strained quartz, Cryptocrystalline (or microcrystalline) quartz opal or volcanic glass (obsidian). **Anti-stripping agents should be used.				

2.5.1.7. *Rock Quantity and Weight.* Estimating the amount of rock material in a specific quarry is another important factor during site selection. The quarry should have enough material to sustain the anticipated operation. Rock quarry material is usually calculated in tons per cubic yard. Estimating the quantity of usable material can be accomplished by multiplying the average depth of the quarry face by the working area and then subtracting the overlying waste rock and overburden. **Table 2.6** lists estimated in-place weights and quantities for various types of rocks.

Table 2.6. Rock Quantity and Weight Estimates.

Classification	Rock Type	Pounds/ Cubic Foot	Cubic Feet/ Ton
Igneous	Granite	165	12.1
	Gabbro-diorite	183.5	10.9
	Basalt	178	11.2
	Felsite	166	12.0
Sedimentary	Conglomerate	163.5	12.2
	Sandstone	159	12.6
	Shale	134	14.9
	Limestone or Dolomite	167.5	11.9
	Chert	156	12.8
Metamorphic	Gneiss	171	11.7
	Schist	178	11.2
	Slate	175	11.4
	Quartzite	168	11.9
	Marble	164	12.2
Source: AFMAN 10-903.			
NOTE: Actual values in the field may vary up to 10% from the values shown here			

2.5.2. **Pit Materials (Earth and Rock Particles).** A wide variety of natural material can be extracted from pits and, thus, it is necessary to select the appropriate soil and location to match the intended product. For example, borrow pits may provide construction material suitable for select fill, surfacing or blending but are typically a poor source for high-quality base course. Similarly, an alluvial (deposited by water) pit can be a quality source of gravel and sand for paving aggregate but may also require crushing, screening and/or washing operations to meet specifications. Classification of the intended soil using the Unified Soil Classification System (USCS) is a simple, effective way to determine the expected engineering properties of the pit material. The individual solid particles in a soil have different sizes and shapes, and these characteristics have a significant effect on its engineering behavior. Natural materials from pits may include any combination of the following USCS particle sizes:

2.5.2.1. *Rock Fragments.* Particles larger than 3 inches (76.2 mm) are known as rock fragments (boulders and cobbles). Rock fragments must usually be crushed further for engineering applications.

2.5.2.2. *Gravels.* An unconsolidated, natural accumulation of typically rounded rock fragments resulting from erosion, consisting predominately of particles larger than sand such as boulders, cobbles, pebbles, granules, or any combination of these fragments. Gravels range in size from 4.76 to 76 millimeters.

2.5.2.3. *Sands.* Sands are unconsolidated or moderately consolidated sedimentary deposits consisting of medium-grained clastics. The material is most commonly composed of quartz. When the term sand is used without qualification, a siliceous composition is implied, but the particles may be of any mineral composition of rock or mineral fragments. Particle diameters range from 0.02 to 2 millimeters.

2.5.2.4. *Silts.* Silts are unconsolidated or moderately unconsolidated sedimentary deposits consisting essentially of fine-grained clastics. Silts range in diameter from 0.002 to 0.02 mm.

2.5.2.5. *Clays.* Clay is a naturally occurring material composed primarily of fine-grained minerals. These cohesive particles have diameters less than 0.074 millimeters and pass the U.S. standard sieve number 200.

2.5.3. Products. The following are typical products of quarry and pit materials:

2.5.3.1. *Pavement Aggregates.* Coarse aggregates (gravels) and fine aggregates (sands) are required for production of asphalt and concrete pavements.

2.5.3.1.1. Angularity, as measured by the percentage of fractured rock faces, is a critical component to the strength of asphalt. The interlocking friction of its aggregate provides asphalt's strength. Using non-angular (rounded) aggregates in asphalt will result in a low-strength mix vulnerable to rutting. However, the angularity of aggregate in concrete is not as important because aggregate primarily functions as filler inside the concrete. Using non-angular aggregates in concrete will result in lower concrete flexural strengths (for the same compressive strength) but increased workability.

2.5.3.1.2. The percentage of fine-grained soils, or "fines" in the aggregate required to meet specifications differ between asphalt and concrete. Asphalt mix designs typically specify from 3 to 6 percent fines in the combined gradation of the aggregate. Concrete mix designs typically have less than 2 percent fines in the combined aggregate gradation. Excessive fines coat the aggregate in concrete and reduce the bonding strength of the cement. The low amount of fines required in concrete usually necessitates an aggregate-washing operation.

2.5.3.2. *Base Courses.* An aggregate base course is usually required beneath both asphalt and concrete pavements.

2.5.3.2.1. The design strength of base course underlying asphalt typically depends on the angularity of the aggregate. A higher percentage of fractured faces results in an increased design strength. However, the angularity of the base course underlying concrete is not an important factor in concrete pavement design.

2.5.3.2.2. The percentage of fine-grained soils, or "fines", in base course underlying asphalt must be less than 8 percent. Excessive fines in base courses result in a significant loss of strength when wet. For base course underlying concrete, the fines specification is relaxed to less than 15 percent. Base course under concrete requires less strength due to the distribution of load across the concrete slab. Material requirements for airfield asphalt and concrete base courses can be found in UFC 03-260-02.

2.5.3.2.3. Before use as either an Aggregate Base Course (ABC) or a Graded-Crushed Aggregate Base Course (GCA), sand and gravel mixtures should be evaluated for suitability according to Unified Facilities Guide Specifications (UFGS) 32 11 23, *Aggregate and/or Graded-Crushed Aggregate Base Course*.

2.5.3.3. *Subbases*. Subbase materials consist of naturally occurring coarse-grained soils or blended and processed soils. Subbases are placed beneath a base course but above the subgrade (existing material) in an asphalt pavement system. The percentage of fines is required to be less than 15 percent. Material requirements for airfield subbases can be found in UFC 03-260-02.

2.5.3.4. *Aggregate Surface Courses.* An aggregate surface course is the top 6 inches of a pavement system without asphalt or concrete, such as an assault strip. Material used as a surface course must be cohesive enough to resist the abrasive action of surface wear. Therefore, the percentage of fines is required to be between 8 to 15 percent. See UFC 03-260-02 for additional material requirements for airfield aggregate surface courses.

2.5.4. **Groundwater and Surface Water.** Another important site selection factor, surface water and groundwater conditions at potential quarry and pit sites can affect anticipated mining operations. Field evaluations typically use test pits and borings to determine the approximate amount of groundwater and depth of the water table.

2.5.5. **Drainage.** While some gravel pits can be worked wet, most quarries and pits are usually worked in dry conditions; however, seepage and rainwater could fill subsurface quarries and pits, so the ability to drain off standing or surface water should be evaluated. Extensive drainage projects, such as diverting a stream or draining a lake, should only be undertaken in extreme cases when an emergency operation is necessary and when no other sites are available.

2.5.6. **Location and Roads.** Consider the location of the potential site. The quarry or pit operation should be as close as possible to the construction site and convenient to good routes of transportation. Loaded vehicles should move downhill whenever possible and the grades should not exceed ten percent.

2.5.7. **Overburden.** The amount of overburden can also influence the selection decision. Overburden is the barren rock material, either loose or consolidated, overlying a mineral deposit, which must be removed prior to mining. Sites containing quality materials with the least overburden are the most desirable.

2.5.8. **Equipment.** Heavy construction machinery like drilling, digging, hauling, scraping, crushing, and screening equipment is a necessary part of everyday life in an active quarry or pit operation (**Figure 2.7**). Therefore, equipment availability is an important factor during site selection. Whatever equipment is used, it should match the type and anticipated level of operation. For example, it may be inefficient to use big loaders with small dumps or small loaders with big crushers because the equipment is not suited for the task. See **Chapter 4** for additional information on heavy equipment used during quarry and pit operations.

Figure 2.7. Consider Heavy Equipment During Site Selection.

2.5.9. **Utilities.** Electrical and water utilities increase the operational efficiency of mining operations. Electricity for lighting is essential for efficient and safe operations. In addition to being a logistical benefit, the correct electrical voltage and frequency (hertz) provides a more reliable source of power for crushing and screening plant operations. Also, consider the power requirements for the utilities when planning for pit and quarry operations. In addition to being a logistical benefit, the correct electrical voltage and frequency (hertz) provides a more reliable source of power for crushing and screening plant operations. If prime power is available, less fuel may be required to keep crushing and screening equipment running, while lowering emissions. Clean water is vital for cleaning and maintaining equipment. It is also critical when aggregate must be washed for concrete and bituminous uses.

2.5.10. **Training.** While equipment is important, it takes skilled personnel to operate the equipment and produce the required material. Training is another key factor for quarry and pit operations. Having properly trained and qualified personnel helps to achieve production goals. Conversely, improper training increases the likelihood of accidents and slows production output. The RED HORSE quarry and pit operations training CE personnel receive is crucial to producing highly skilled crews needed for these operations.

2.5.11. **Security.** The ability to secure essential equipment items (including explosives) from theft and enemy action is an important concern. Protection might include fencing, lighting, guards, and concertina wire, etc.

2.5.12. **Communications.** Radio frequency transmitting (including citizen band radios, cellular telephones, AM and FM radios, radar, and television) communication devices can interfere with electrically initiated blasting operations and cause an undue hazard to personnel. Any communication devices utilized in a quarry or pit should be certified for use IAW Mine Safety and Health Administration (MSHA) or Department of Defense Standards, as appropriate.

2.6. Final Selection. Following completion of the field reconnaissance, engineer planners should have most, if not all of the information needed to finish their analysis and make the final site selections. The preplanning research, preliminary and field reconnaissance, and tactical considerations all provide planners with important data about potential quarry and pit site operations. Specifically, the quantity and quality of the minerals anticipated, location information, potential site layout factors, equipment, and personnel required to operate the site, and possible challenges to quarry or pit production (**Figure 2.8**). During the final analysis, the preferred or best sites should eventually become clear. For additional information on quarry and pit site selection, refer to AFMAN 10-903.

Figure 2.8. Analyzing Site Selection Data.

Chapter 3

SITE LAYOUT AND DEVELOPMENT

3.1. General Information. The ultimate goal of RED HORSE quarry and pit operations is to produce the greatest amount of quality material, in the least amount of time, with the minimum amount of effort. Effective site layout and development helps satisfy that goal (**Figure 3.1**). This chapter provides an overview of basic quarry and pit layout and development. However, users should refer to applicable T.O.s and manuals for specific quarry and pit layout procedures.

Figure 3.1. Effective Site Layout leads to Efficient Production.

3.2. Layout Planning. Quarry and pit layout involves planning the dimensions and arrangement of the quarry or pit, the shape and orientation of supporting roads, and the location and positioning of large support equipment (crushers, screening plants, etc.). The type of quarry or pit will also influence the eventual layout. After the layout has been determined, an operational plan should be prepared to address quarry or pit development, excavation operations, specific handling material, and crushing and screening operations. Additionally, a training plan should be developed in order to ensure all personnel working at the quarry or pit is given orientation training. The training should include an introduction to the work environment; the authority and responsibility of supervisors; proper ways to enter and leave the quarry or pit; transportation; communications; emergency evacuation procedures; barricading procedures; hazard recognition; accident prevention; emergency medical procedures; and health and safety aspects of assigned tasks IAW with MSHA Standards.

3.3. Quarry Layout Factors.

3.3.1. **Quarry Types.** Quarries may consist of hard, medium or soft rock. The three basic types of quarries are *hillside*, *subsurface*, and *terrain*.

3.3.1.1. Hillside quarries are constructed in rock that is part of the structural geology of a hill (**Figure 3.2**).

3.3.1.2. A subsurface quarry is one that is opened below the level of the surrounding terrain (**Figure 3.3**).

3.3.1.3. A terrain quarry is a temporary operation in which the existing terrain is lowered or leveled (such as the excavation of a roadway through a rock formation). Since this handbook focuses on the production of construction materials, only hillside and subsurface quarries are addressed. **Table 3.1** lists the advantages and disadvantages of hillside and subsurface quarries.

Figure 3.2. Hillside Quarry.

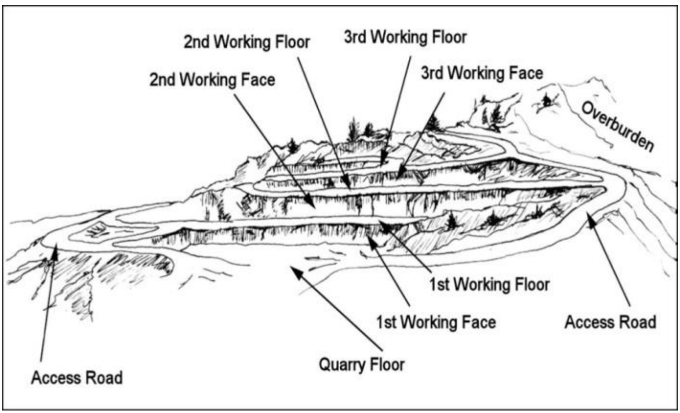


Figure 3.3. Subsurface Quarry.

Table 3.1. Quarry Advantages and Disadvantages.

Hillside Quarry	
Advantages	**Disadvantages**
• Natural drainage and gravity effecting the material flow from the quarry face	• Removal of overburden • Grade or steepness of haul roads • Highly visible operations • Noise radiating from the site • Susceptibility to severe weather • Necessity of bench operations
Subsurface Quarry	
• Masked from view • Less noise • Provides some protection from severe weather	• Removal of material (overburden /aggregate) below grade and disposition above grade • Does not naturally drain

3.3.2. **Quarry Dimensions.** Before beginning a quarry operation, the quarry boundaries should be marked. There are a number of factors that will determine these dimensions: the amount of material required, land boundaries, and the proximity of inhabited structures that could receive damage during blasting operations.

3.3.2.1. *Material Required*. The amount of material required for RED HORSE construction projects generally determines the size quarry needed. When calculating material requirements, you should include an appropriate safety margin for unforeseen changes in rock quality, voids, the presence of water, and other conditions. There are different methods to calculate the quantity of rock material in a quarry. One method is described in **paragraph 2.5.1.7**.

3.3.2.2. *Land Boundaries*. Whether in a large or small area, land boundaries can ultimately affect the dimensions of potential quarries. Ignoring boundaries or conducting excavation beyond allowable land boundaries could be costly to the government or produce other consequences and should be avoided.

3.3.2.3. *Proximity of Inhabited Structures*. When quarry operations involve blasting, the proximity of inhabited structures may also affect quarry dimensions. When determining required separation distances for inhabited structures, operators must consult AFMAN 91-201 and other applicable guidance.

3.3.3. **Drainage.** The quarry floor should slope away from the quarry face so water does not accumulate in the working area. Try to eliminate excess water by natural drainage since pumping can be a costly alternative. For hillside quarries, natural drainage is a significant benefit. However, in the case of subsurface quarries, if natural drainage or sumps are not an option, removing excess water by pumping may be necessary.

3.4. Pit Layout Factors.

3.4.1. **Pit Types.** Similar to quarries, the type of pit affects the eventual site layout. As addressed in **Chapter 2**, pits generally fall into four categories; borrow, gravel, alluvial gravel, and miscellaneous gravel or dump pits. This section addresses layout of two major pit categories—borrow and gravel pits.

3.4.1.1. Borrow pits generally provide unconsolidated earth (dirt, sand, etc.) for fill, surfacing or blending material.

3.4.1.2. Conversely, gravel pits usually provide unconsolidated rock particles (gravel, thick-grained sand, and clay) for surfacing secondary roads, base courses for roads, taxiways, and runways and as aggregate in concrete and asphalt construction. While unconsolidated earth or rock particles can usually be removed from pits without blasting, in some cases, this material may be too consolidated and require blasting to remove.

3.4.2. **Pit Dimensions.** Determining the working dimensions of the area to be developed is fundamental to pit layout. Area boundaries or limits should be sufficient for planned excavation methods, equipment positioning and maneuvering, placement of overburden, and supporting structures. When determining pit layout and dimensions, consider the following:

- Is the pit on a slope or on level terrain?
- Is the pit worked wet or dry?
- What excavation method will be used (scrapers, excavators, bulldozers, front-end loaders, etc.)?
- Where will additional equipment (loading, crushing, screening or washing equipment) be located?

3.4.3. **Drainage.** Although some pits can be worked wet or dry (alluvial pits), borrow pits should always be worked in dry conditions. Adequate drainage to eliminate surface and seepage water is an essential part of borrow pit operation. While natural drainage is always best, if water cannot be drained by gravity, some type of pumping or drainage sump operation will be required. If sumps are used, locate them away from working areas and traffic.

3.4.4. **Loading Ramps.** Loading ramps are constructed to load excavated material into trucks and other hauling units with earthmoving equipment, specifically when sufficient loading equipment (i.e., front-end loader or excavator) is not available to perform the task. They are also used to maximize loading output for large earthmoving jobs. When constructing loading ramps, they should be located as close as possible to the excavated material to limit the push distance to hauling equipment.

3.4.4.1. *Type of Ramps*. There are several different types of loading ramps and the following should be considered when planning their construction:

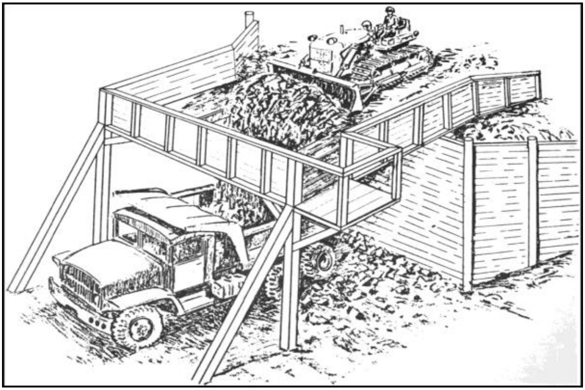
- What material will be loaded?
- How will material be placed in the ramp?
- How hauling equipment will enter and depart from the ramp?

3.4.4.1.1. Chute Ramps. Considered the simplest type of loading ramp (**Figure 3.4**), when constructed, the chute should allow the loading operator to see hauling equipment being loaded.

Figure 3.4. Simple Chute Loading Ramp.

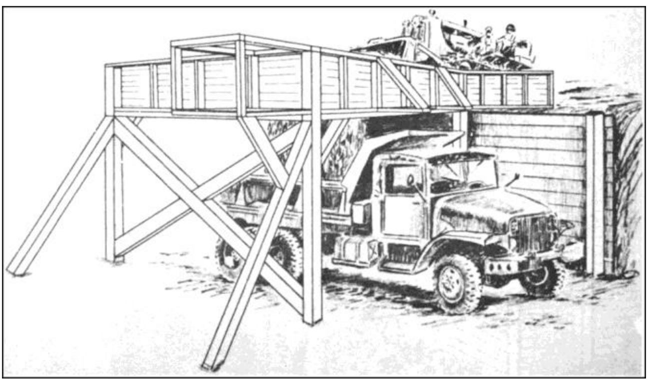
3.4.4.1.2. Single-End Trap Ramp (Truck Back In). This style ramp is best used to load small quantities of material (**Figure 3.5**). It can be constructed in a minimum amount of time with very few materials. It only requires one bulldozer for operation, and is best suited for bank excavation. A small area should be excavated to accommodate the rear end of trucks. When large quantities are desired and sufficient equipment and trucks are available, the ramp can be widened to allow loading of multiple trucks.

Figure 3.5. Single-End Trap Ramp (Truck Back In).



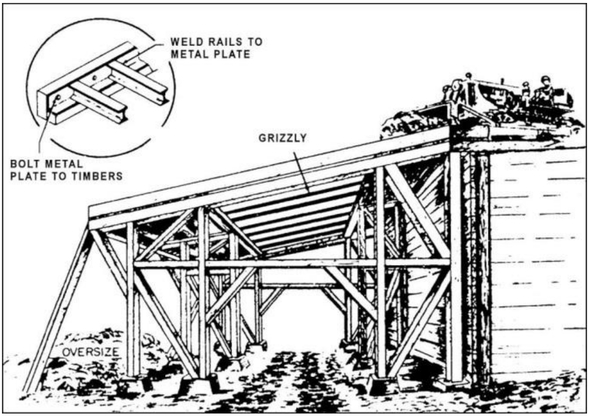
3.4.4.1.3. Single-End Trap Ramp (Truck Drive Through). This ramp is similar to the back-in type, but allows for closer control of truck loading and better traffic flow and circulation (**Figure 3.6**). It also requires more building materials and a much stronger design and construction.

Figure 3.6. Single-End Trap Ramp (Truck Drive Through).



3.4.4.1.4. Single-End Trap Ramp with Grizzly. This ramp is useful when a grizzly (**Figure 3.7**) is required to remove rocks, limps, or fines from excavated material. The grizzly should be constructed of heavy wire mesh or steel planking. **Note:** The grizzly may be adapted to or combined with any other type of loading ramp.

Figure 3.7. Single-End Trap Ramp with Grizzly.



3.4.4.1.5. Double-End Trap Ramp (Truck Drive Through). The double-end trap ramp allows material to be loaded from two sides and permits simultaneous operation of two faces, provided two-way traffic is properly supervised (**Figure 3.8**). It requires more construction effort than the previous ramps and is difficult to drain. However, this type of loading ramp is capable of being operated with dozers, graders, or tractor-drawn scrapers. Additionally, double loading can be done by lengthening the loading ramp similar to the overhead-with ramp type addressed in the next paragraph.

3.4.4.1.6. Double-End Trap Ramp (Overhead with Ramps). This type ramp is a modification of the double-end type above. It allows two trucks to be loaded simultaneously (**Figure 3.9**). Although this ramp is more complicated to construct than previously addressed ramps, it has the flexibility to permit single or double loading.

Figure 3.8. Double-End Trap Ramp (Truck Drive Through).

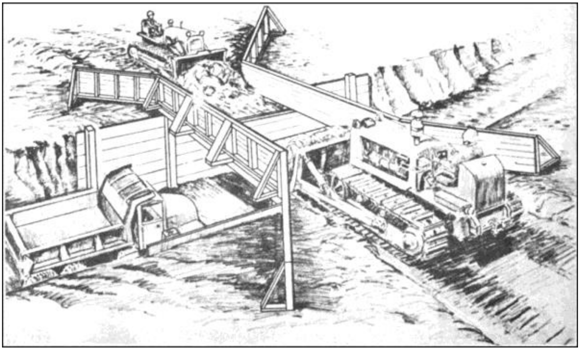
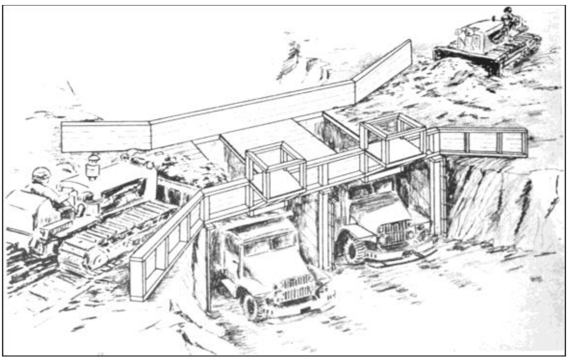


Figure 3.9. Double-End Trap Ramp (Overhead with Ramps).



3.4.4.2. *Ramp Design*. Loading ramps should be designed to allow maximum visual capability by the loading operator from his or her operating position. The operator should be able to see the loading ramp and the equipment being loaded.

3.4.4.2.1. Strength. The most common error in the construction of loading ramps is inadequate strength. Ramps must be designed to support the weight of the bulldozer, plus an impact factor of 50%, and 20 tons of material. Pay particular attention to cross and sway bracing.

3.4.4.2.2. Walls, Wingwalls, and Floors. Ramps must have walls, wingwalls, and a floor. All walls should be well braced and high enough to prevent spillage. Cover deck flooring with material to prevent damage from dozer cleats. Using 12 inches of excavated material should be enough to prevent dozer cleats from tearing up the flooring. When constructing traps in ramp flooring, traps should be centered over the truck bed and smaller than the smallest equipment bed to be loaded. Larger traps waste material over the sides of the truck and require more work to keep truck roadway clear of spillage. When the back-in loading ramp is used, a stopblock should be installed for the rear wheels of trucks.

3.4.4.2.3. Columns. Design columns with braces ("dead men" or "Harvey earth" anchors) to prevent columns from sliding or shifting. Columns beneath the loading ramp should be spaced wide enough apart to permit a grader or dozer blade to pass through when clearing spillage from the roadway.

3.4.4.3. *Location and Number of Loading Ramps*. Ramps should be located as close to the material to be loaded as possible. The number of ramps should be based on the number of haul vehicles you have and the rate material is needed.

3.5. Additional Quarry and Pit Layout Factors.

3.5.1. **Supporting Roads.** Access and haul roads to, from and within the site are part of the supporting road structure. The shape and orientation of these roads are usually a key factor in site layout. How well the roads are planned or currently configured can directly impact quarry or pit efficiency and safety. Below are some basic considerations for supporting roads:

- Roads should be planned so heavy equipment can safely enter, exit and maneuver around the site. Additional maneuver area may be needed for oversized equipment, such as scrapers and large rock dumps (**Figure 3.10**) so they can negotiate turns and other areas.

- Haul roads to quarries should be surfaced with crushed rock, and kept drained to reduce the amount of road maintenance required. Roads to and from pits should be graded and compacted to reduce rolling resistance for both tracked and wheeled vehicles.

- Control dust on quarry and pit hauls roads by applying water, geotextiles, asphalt, or road oil; do not use waste oil.
- Roads should follow the shortest and easiest route available. Try to stay within the 10% uphill and downhill grade.
- Design curves for safe negotiation at 20 mph.
- Consider the potential advantage of establishing driving on the left-hand side of roads so the operator can see the edge of the road.
- Keep haul roads and work areas in good shape.

Figure 3.10. Rock Dump Equipment.

3.5.2**. Position of Large Equipment.** Determining where to position large quarry and pit equipment is important when planning site layout. The location of rock crushers, screening and washing plants, and other equipment will ultimately have an effect on efficiency and safety. If blasting operations are involved, AFMAN 91-201 separation distant requirements also apply.

3.5.2.1. Rock crushers and screening plants should be located on stable ground of sufficient size to accommodate the plant and related equipment (conveyors and generators), stockpiles of crushed rock, and loading operations. Consider locating rock crushing, screening and washing plants near excavation sites (but far enough away, so quarry blasting operations do not endanger plants and their operating crews). If crushing and screening plants are within proximity to excavations, it provides two key benefits; minimizes haul time, and reduces wear and overall usage on haul trucks.

3.5.2.2. Equipment maintenance facilities should be sited in a suitable location with easy access near quarry operations. However, to avoid having to relocate facilities later, they should not be placed in an area of future excavation.

3.5.3. **Heavy Equipment Considerations.** When developing quarries or pits, engineers should consider the planned use and safe operation of heavy equipment within the site. Heavy equipment for quarry and pit operations may include dump trucks, excavators, bulldozers, scrapers, loaders and other large equipment (**Figure 3.11**). See **Chapter 4** for a review of heavy equipment.

Figure 3.11. Loader Stockpiling Fine Crushed Rock.

3.5.4. **Stockpiling.** When using heavy equipment to stockpile aggregate, exercise extreme care to avoid rollovers. Also, be aware that different size aggregates in a material being stockpiled have a tendency to separate from each other...this is called segregation. If you work the material too much, segregation takes place with larger particles rolling to the bottom of the pile. To avoid this, build your stockpile in layers to make sure it maintains a uniform gradation.

3.6. Quarry and Pit Development.

3.6.1. **Overburden Removal.** Sometimes a significant amount of waste material or overburden (top soil, humus, and waste rock) can cover quarries and pits. Consequently, engineers consider overburden thickness and the effort it would take to remove it as part of the site analysis. Stripping the overburden (and sometimes vegetation) can be as large an operation as excavating the material itself. If the overburden thickness exceeds 15 feet or is more than *one-third* of the useable material, it may not be prudent to excavate at that particular site. Below are other considerations relating to overburden.

3.6.1.1. An important aspect for removing the overburden is the location of the spoil pile. If the overburden is not intended to be recycled, used for fill, or restored, it should be cleared of the areas planned for future use. This reduces the need to handle the material a second time. If the overburden will be recycled, it should be located at a site that allows for the most efficient operation. Strive to separate and stockpile topsoil for future reclamation.

3.6.1.2. Overburden should be moved back from the quarry rim or face a minimum of 50 feet for safety reasons. Ensure overburden location will not interfere with natural drainage.

3.6.1.3. Overburden can be removed with various pieces of equipment, including bulldozers, scrapers, loaders, and trucks.

3.6.2. **Excavation.**

3.6.2.1. *Quarry Excavation*. The quarry working face should be oriented to minimize the undesirable influences of the rock mass being excavated. Excavate the quarry in the same direction of the strike, so the quarry face is perpendicular to the strike of the inclined rock layers (**Figure 3.12**). This orientation is especially important where rocks are steeply inclined because it optimizes drilling and blasting efforts by creating a vertical or near-vertical rock face after each blast.

3.6.2.1.1. Quarries may be worked parallel to the strike direction in instances where the rocks are not steeply inclined, but drilling and blasting will prove to be more difficult. As illustrated in **Figure 3.13**, if the rocks dip away from the excavation, overhang and oversized rocks are likely. If the rocks dip toward the excavation, problems with slope instability and toeing may result.

Figure 3.12. Quarry Face Running Perpendicular to Strike.

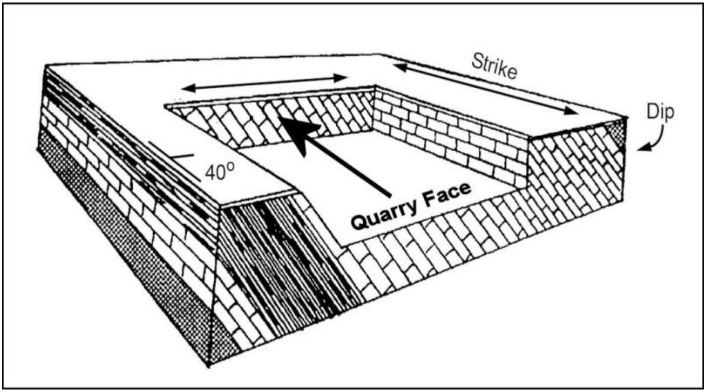
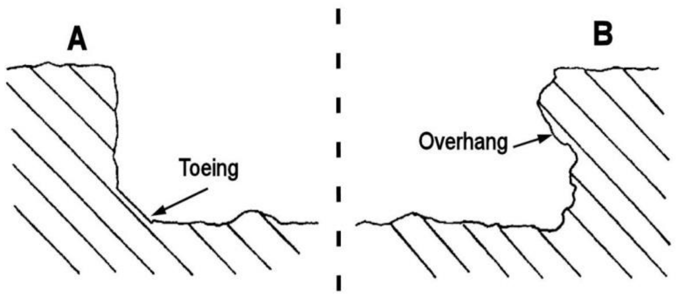


Figure 3.13. Quarry Face Running Parallel to Strike.



NOTE: Stability at A, because it lies on the plane of rock movement, will cause rock to slide towards the toe. Stability at B, because of overhang, will cause rock to fall straight down.

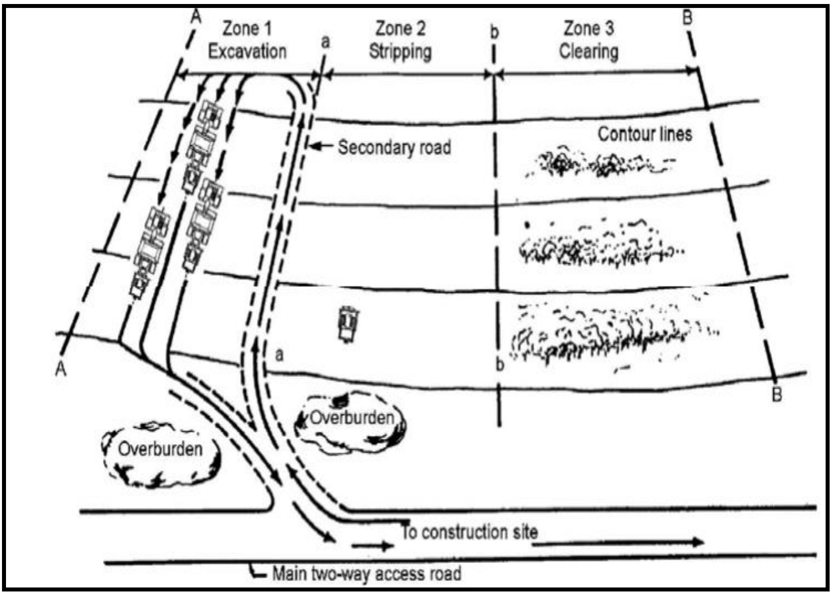
3.6.2.1.2. The quarry bench height is often referred to as the height of the working face of the quarry where mineral deposits are mined. More specifically though, it is the vertical distance from the top of a bench to the floor of the quarry (**Figure 3.14**) or top of the next lower bench, if a lower bench is present. The bench height of the quarry must be determined during the initial layout phase. Several factors can influence eventually bench height, including *loading equipment*, *geologic conditions*, and *drilling equipment*.

- Loading Equipment. Relatively lower bench heights are preferred where front-end loaders are used to load blasted rock.
- Geologic Conditions. Where layers of undesirable material occur within a deposit, plan benches so that the undesirable and desirable materials can be excavated separately to prevent contamination.
- Drilling Equipment. If the length of drill steel is limited, the maximum bench height will be limited to the drill steel length (in feet) minus the amount of subdrilling (in feet).

Figure 3.14. Bench Height.

3.6.2.2. *Scraper-Operated Pit Excavation*. When motorized scrapers are used to excavate materials, pits are often divided into zones and at right angles to ground contours for efficiency (**Figure 3.15**). By arranging the pit into zones, removing overburden and excavation can be performed at the same time. For example, Zone 1 overburden is stripped before excavation starts, then Zone 2 is stripped while Zone 1 excavation continues, then Zone 3 and so on. Aligning the zones at right angles to the ground contours allows scrapers to excavate materials downhill, thereby obtaining the maximum load and for ease in loading.

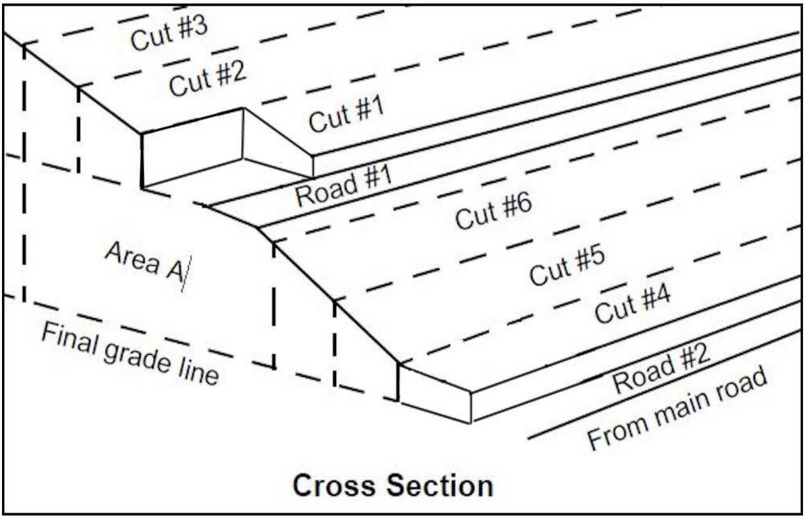
Figure 3.15. Layout of Scraper-Operated Pits.



3.6.2.3. *Hillside Pit Excavation*. Hillside pits are often excavated using front-end loaders or hydraulic excavators and trucks. Hillside deposits can be excavated from the top of the hill, at the toe or bottom of the hill, or both simultaneously. As a result, the arrangement of hillside pits can vary significantly.

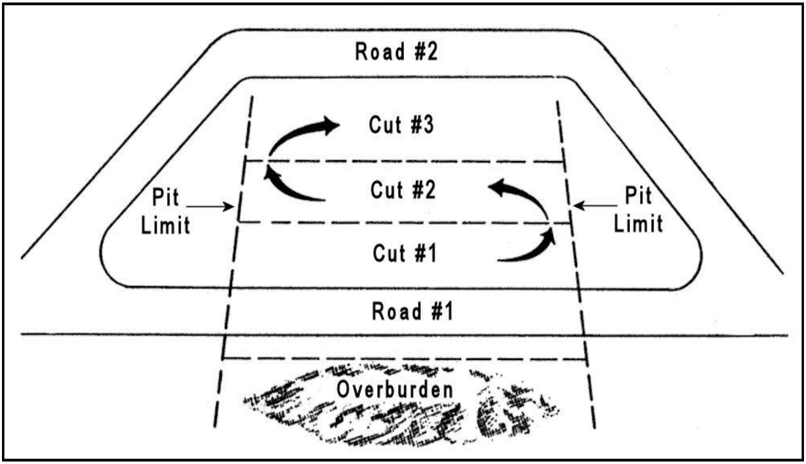
3.6.2.3.1. Illustrated in **Figure 3.16** is one method of excavating from the top of a hill. After the area is cleared and overburden removed, deposits are excavated by making successive bench cuts parallel to the terrain's contour lines. To improve equipment movement, trucks can use the first cut as a road. Once the top of the hill is excavated, crews can move down the hillside and continue excavation to the final grade from road #2.

Figure 3.16. Excavation from the Top of a Hill.



3.6.2.3.2. When starting excavation from the toe or bottom of the hill, a road is usually cut and leveled with a bulldozer along the base of the hill as illustrated in **Figure 3.17**. Excavation starts from the road and cuts into the hill until the excavator is clear of the road. Trucks can use the first cut while the second cut is being excavated. When the excavator has advanced into the hill to a point where the maximum working face height is reached, bulldoze a second road above the cut and start a new bench. When the second face reaches a maximum height, start a third bench, and so on.

Figure 3.17. Excavation from the Toe of a Hill.



3.6.2.4. *Horizontal Subsurface Pit Excavation*. Subsurface pits are created when excavating material from below level terrain. These pits are commonly excavated using a circular-bench method (large pits) or straight-bench method (narrow pits).

3.6.2.4.1. Large Pits. The circular-bench method illustrated in **Figure 3.18** is generally used for large pits where deposits are sufficiently large. First, the entire top level is excavated, and then the procedure is repeated, advancing one layer at a time until reaching the desired depth. The circular shape is created as the excavator makes successive cuts within the pit.

3.6.2.4.2. Narrow Pits. The straight-bench method (**Figure 3.19**) is sometimes used when the width of an area or site is too narrow for the circular-bench method; i.e., along an old streambed. Using this method, a hydraulic excavator or bulldozer digs the first cut to the desired height of working face. Then, excavation continues at this level until the cut is completed. Reverse the direction of the excavator and make a second cut beside the first. The first cut can be leveled with a bulldozer for truck travel.

Figure 3.18. Subsurface Pit Using the Circular-Bench Method.

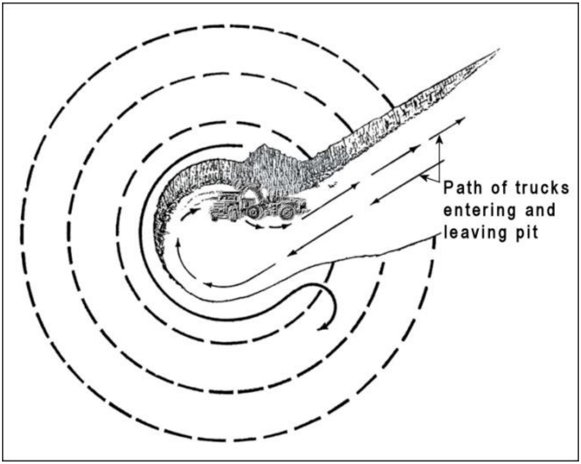
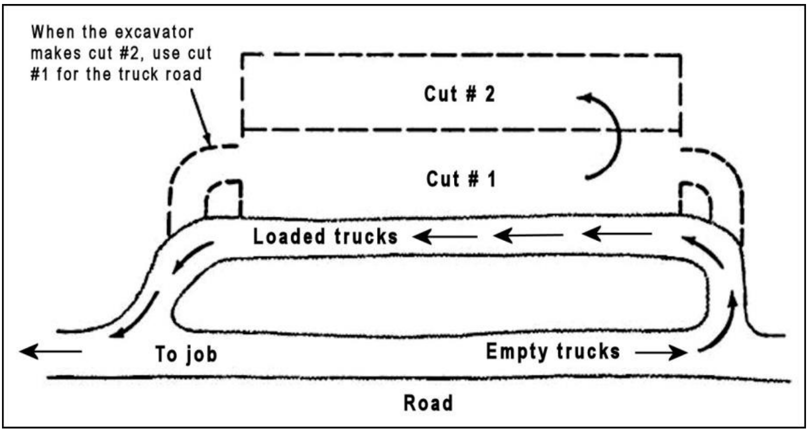


Figure 3.19. Subsurface Pit Using the Straight-Bench Method.



Chapter 4

EXCAVATION, LOADING AND HAULING EQUIPMENT

4.1. General Information. Productive quarry and pit operations rely on the proper employment, servicing and maintenance of heavy equipment. Excavators (**Figure 4.1**), front-end loaders, bulldozers, scrapers, dump trucks, and other machines are crucial to producing needed quantities of construction materials. In order to be effective and safe, the equipment must be maintained in good working condition and operated according to specific manufacturer operating and load limits.

Figure 4.1. Excavation Equipment.

4.2. Heavy Equipment. It is imperative that equipment selected for quarry and pit operations are sized to match; large hauling equipment is useless if loading equipment is too small for the task, and vice versa. In theory, heavy equipment used in quarry and pit operations are often grouped into categories; e.g., excavation, loading or hauling equipment. However, in practice, most of the equipment crosses the boundaries of these categories. For example, a hydraulic excavator is used primarily for excavation, but it can also be used to load dump trucks or crushers; scrapers are used to both excavate and haul material, and front-end loaders excavate and load material. In addition, equipment accessories and attachments can be installed on some heavy equipment to permit additional uses; i.e., grading, spreading, sweeping, lifting, or demolition. Bottom line, heavy equipment can often be used for multiple purposes; however, our focus is on equipment used for digging, loading and transporting soil, gravel and sand deposits for construction purposes. The following paragraphs describe heavy equipment used in quarry and pit operations. It is not all-inclusive and users should refer to appropriate T.O.s or manuals for information on specific equipment.

4.2.1. **Track Loaders.** Like the wheeled front-end loader, the track loader is used extensively in many quarry operations. Although, most often used for surface and subsurface excavation of soft and medium soils, they are also used to load excavated material into dump trucks, loading hoppers, and moving other construction materials. (**Figure 4.2**).

Figure 4.2. Loading Rocks with Track Loader.

4.2.2. **Excavators.** Excavators can move large quantities of earth or soil. They are sometimes referred to as large backhoes. These machines are also used for lifting and loading.

4.2.3. **Bulldozers.** Bulldozers are powerful wheeled or tracked machines used during quarry clearing and excavation operations (**Figure 4.3**). The bigger and more powerful heavy-duty dozers are typically used for deforestation, burden removal, and other large earth-moving operations, while medium-duty dozers are sometimes used for light clearing/excavation, stockpiling, haul road maintenance, or loading dump trucks via a loading ramp (**paragraph 3.4.4**).

Figure 4.3. Medium-Duty Bulldozer.

4.2.4. **Scrapers.** Scrapers can excavate and move earth short distances over relatively smooth areas. They consist of a bowl with a gate and bladed bottom. The blade scrapes up the earth as the bowl moves forward, forcing the excavated material into the bowl. Once filled, the gate is closed and the material is carried to the place of stockpile or disposal. Motorized scrapers (**Figure 4.4**) are the most efficient piece of equipment to move large amounts of material in the minimum amount of time.

Figure 4.4. Scraper.

4.2.5. **Dump Trucks.** Dump trucks (**Figure 4.5**) are the most common method to haul excavated materials. Typical design includes an open-top truck body that can be tilted to discharge its contents through an open tailgate. See **Chapter 5** for detailed information on articulated dump trucks or rock dumps.

4.2.6. **Front-End Loaders.** One of the most versatile pieces of excavation equipment, front-end loaders can be equipped to perform many tasks. The machine has a hydraulically operated shovel (or bucket) at the end of an articulated arm located at the front of the vehicle (**Figure 4.5**). Front-end loaders are used for both excavating and loading. Smaller models are usually equipped with a backhoe on the rear.

Figure 4.5. Wheeled Front-End Loader and Dump Truck.

4.2.7. **Water Trucks.** In functioning quarries and pits, water trucks are essential for controlling dust in and around aggregate operations. While nearly every aggregate operation (drilling, blasting, excavating, hauling, crushing, screening, etc.) produces dust particles, it is not feasible to use water trucks in every activity. However, applying water judicially in some locations can help control dust levels and minimize worker exposure (**Figure 4.6**). Water trucks are also used when compacting quarry roads and to wash dust and sand off equipment to improve operation and prolong their service life.

Figure 4.6. Water Truck.

4.3. Basic Hazards and Precautions. Quarry and pit work crews must be vigilant when using and working around heavy equipment. Inattentiveness can result in workers being trapped and crushed under heavy equipment. Understanding hazards and observing safety precautions are crucial to preventing injuries and saving lives. The following paragraphs list a few of the basic hazards and precautions associated with heavy equipment operations documented by the U. S. Department of Labor (DOL), Occupational Safety and Health Administration (OSHA). **Note:** According to OSHA, being struck by vehicles, heavy equipment and other objects is the top cause of injuries and second cause of deaths for construction workers.

4.3.1**. Hazards.** Although not all-inclusive, the following hazards are some of the most lethal associated with heavy equipment operations.

4.3.1.1. *Heavy equipment striking personnel or collision with other equipment:* Heavy equipment is often operated in close proximity to other heavy equipment and on-ground workers (**Figure 4.7**). Sometimes, changes in the path of the equipment or interactions between the heavy equipment and on-ground workers are not always coordinated—creating a potential safety challenge.

Figure 4.7. Close Working Proximity Creates Safety Challenge.

4.3.1.2. *Equipment rollovers:* Equipment rollovers can occur for a variety of reasons. Some examples include, operator losing position and going over a drop off, loads exceeding the capacity of the equipment, unbalanced loads, or one side of the equipment encountering loose ground or a depressed area.

4.3.1.3. *Obstructed view in backing:* Due to the size of the equipment, heavy equipment operators may have an obstructed view and blind spots while backing. Dirty or broken windows may also block operators' view of people or objects posing potential hazards.

4.3.1.4. *Caught between equipment and objects:* These incidents often involve on-ground workers getting pinched between heavy equipment and other fixed objects or crushed between the equipment. During quarry and pit operations, excavating, loading and hauling equipment operate in close proximity to each other and potential "pinch areas" can be created within the equipment's turning radius.

4.3.1.5. *Falling off equipment:* Injuries from falls can often be attributed to inattention, improper ingress or egress practices, unauthorized riding by workers, sudden turns or reversal of equipment, and failure to follow safety protocols (e.g. jumping out of the cab instead of coming down slowly).

4.3.1.6. *Runaway machines:* Runaway machines can occur when the wheels are not blocked upon parking or when operators are not able to control the equipment. Parking along a steep surface without proper blocks on the downgrade side of wheels can cause such a hazard.

4.3.1.7. *Excessive speed:* Heavy equipment is not designed for excessive speeds. However, if the equipment is not loaded, some operators may have a tendency to drive at higher than normal speeds causing hazards to on-foot workers and others on site.

4.3.2. **Precautions.** The following precautions address safety measures related to heavy equipment, including operator and on-ground worker safety.

4.3.2.1. *Vehicle Equipment and Maintenance.*

- Vehicles that are loaded from the top (e.g., dump trucks) must have cab shields or canopies to protect the operator while loading.
- Heavy equipment should have rollover protection and overhead protection from falling debris hazards as necessary.
- Seats for operators and workers should have operable seat belts and be firmly secured to the vehicle.
- All required safety equipment (e.g., backup alarms, horns, rearview mirrors, fire extinguishers, etc.) should be on vehicles.
- Vehicles must be checked at the beginning of each shift to ensure that parts, equipment, and accessories are in safe operating condition.
- Defective parts or equipment should be repaired or replaced prior to use.
- Load capacity or safety features of heavy equipment should not be modified without the manufacturer’s written approval.

CAUTION

Heavy equipment with missing, poorly functioning or non-functioning safety devices (e.g. backing signals, seat belts, lights, etc.) are unsafe to operate, and should not be used until devices are installed or repaired.

4.3.2.2. *Operators*.

- Operate only the equipment you are authorized and trained to operate.
- Adhere to equipment operating procedures/limits and observe safety precautions (no unsafe practices or horseplay).
- Be aware of blind spots and swing radius of excavation equipment.
- Do not move equipment without making positive visual contact with on-ground workers near the equipment.
- Wear all required and appropriate personal protective equipment (PPE), including hearing protection.
- Always wear seat belts when operating heavy equipment.
- Avoid potentially distracting activities (e.g., eating, drinking, adjusting non-critical vehicle controls, etc.) when operating equipment.
- Correct or report hazards to your supervisor.
- Do not operate vehicle in reverse with an obstructed rear view unless it has a reverse signal alarm that can be heard above ambient noise levels or you have a spotter to indicate it is safe to move.
- Do not overload haul equipment and ensure loads are balanced and contained within the vehicle.
- Remain with the vehicle when refueling and ensure ignition sources are at least 25 feet away from fueling area.

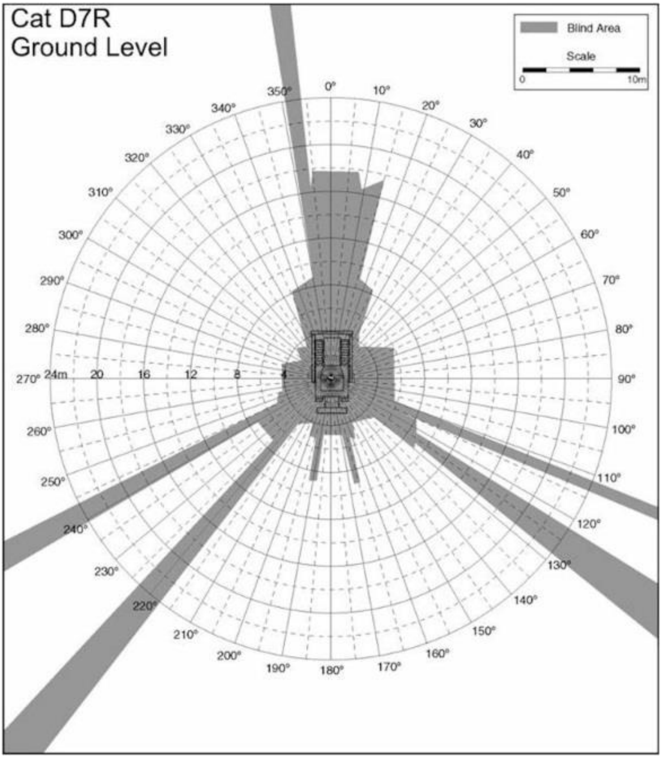
- Always face the vehicle and maintain three points of contact (1 foot/2 hands or 1 hand/2 feet) when getting on/off equipment.
- Use seats belts properly when operating/riding vehicle.
- Vehicle cabs should be free of unsecured tools or other loose items.
- To prevent slips and falls, maintain steps, walking platforms and other access areas on heavy equipment clear and as clean as possible.
- When exiting equipment, be sure to set the brake, place the transmission in appropriate parking position, and ground all attachments (if applicable). Improper parking can result in out-of-control and runaway equipment.

4.3.2.3. *On-Ground Workers.*

- Work defensively. Protect yourself at all times and observe safety precautions (no unsafe practices or horseplay).
- Workers should never place any part of their body, even for a moment, under any suspended load or elevated piece of equipment, including a raised loader or bucket.
- Never stand within the swing radius or path of moving components.
- Workers should never enter into the direct path of moving equipment or running equipment that may move unintentionally.
- Approach equipment only after making eye contact and signaling the operator; wait for the operator's clearance to approach.
- Never stand directly between wheels or on vehicle tracks when talking to the operator.
- Remember that equipment has blind spots and operators may not always be able to see on-ground workers, so workers should protect themselves by working defensively. For example, **Figure 4.8** is a diagram from the National Institute for Occupational Safety and Health (NIOSH),

showing the blind spots associated with the Cat D7R dozer. In the diagram, the front of the dozer is pointed down. This diagram is very similar to the blind spots associated with any dozer.

Figure 4.8. Blind Spots with the Cat D7R Bulldozer.



Chapter 5

ROCK DUMP EQUIPMENT

5.1. General Information. Articulated dump trucks (ADT), aka rock dumps, are extraordinary hauling machines designed to carry heavy loads and traverse difficult terrain more efficiently than standard dump trucks (**Figure 5.1**). Steep grades, uneven ground, and wet or muddy conditions presents little challenge for these huge machines. While there are many different types of ADTs, this chapter will address the basic features, characteristics and operational application of ADTs typically used during RED HORSE quarry and pit operations.

Figure 5.1. Articulated Dump Truck at Nellis AFB, Nevada (2009).

5.2. Features and Characteristics. Most ADTs range in size from those with roughly 20-ton payload capacity to the larger, monster trucks capable of hauling over 40 tons of material. While ADTs vary in size, their basic features and characteristics are very similar. Some of these features are addressed below.

5.2.1. **Comfort.** ADTs look rough and tough on the outside, but most have very comfortable operator stations that mimic the amenities of many passenger cars and trucks. Features like bi-level climate control, noise suppression cabs, ergonomically designed air-suspension seats, armrests and head restraints, tilt and telescoping steering wheels, state-of-the-art instrumentation, and even cup holders, are all common features for many ADT operator stations (**Figure 5.2**).

Figure 5.2. Typical ADT Operator Station.

5.2.2. **Visibility.** Nearly all ADTs provide the operator with good visibility; the sloped hood, wide front windshield, oversized side windows, central operator position, wide-angle mirrors, and other features contribute to better visibility.

5.2.3. **Drivability and Maneuverability.** Durable and responsive suspension systems, articulated frame design, and on-demand axle differential locks enhance the driving ease, safety, and maneuverability of large ADTs, such as the Volvo model shown in **Figure 5.3.**

Figure 5.3. Suspension and Frame Design Tackles Difficult Terrain.

5.2.4. **Safety.** Considerable safety features are incorporated into the design of all ADTs. These features provide additional safety for the operator and enhance situational awareness for personnel working on and around the machine. Typical safety elements may include the following:

- Roll Over Protection System (ROPS).
- Falling Object Protection System (FOPS).
- Rear Window Guard/Protective Grill.
- Slip-resistance Steps and Platforms.
- Handrails and Handholds.
- Retractable Seat Belts.
- Tinted Glass and Sun Visor.
- Windshield Wiper/Washers.
- Wide-angled and/or Heated Rearview Mirrors.
- Horn.
- Hazard and/or Beacon Lights.
- Work Lights.
- Back up/Reverse Alarm.
- Body Raised Alarm.
- Dump Body Lock.

5.2.5. **Safety Labels and Warning Plates.** Most ADTs have extensive safety notices placed in strategic locations on the vehicles. Truck operators, maintainers, and others working in close proximity to the vehicle should know and comply with these safety notices. Any missing or unreadable safety labels and plates should be replaced as soon as possible. As shown below, most safety notices refer to vehicle hazards that may present significant danger to personnel:

5.2.5.1. Crushing hazards.

- Beneath raised dump body and below axle housing.
- Between front and rear truck frames.
- Beneath raised cab.
- Caught in or under machinery.

5.2.5.2. High pressure hazards (i.e., pressurized fluids and gases).

- Near truck hydraulic system and suspension lines.
- Within air, oil, fuel and coolant systems.

5.2.5.3. Burn and fire hazards (i.e., hot surfaces/fluids and flammable liquids).

- Engine parts and engine coolant.
- Exhaust systems.
- Hydraulic system fluid and components.
- Fuel tank and lines.

5.2.5.4. Fall hazards.

- Near steps, ladders and platforms.
- Slippery surfaces,

5.2.5.5. Electric shock hazards.

- Battery and electrical system components and wires.

5.2.5.6. Explosion hazards.

- Battery (improper jump-start or exposure to flame).
- Tires (overheated or overinflated).
- Fuel and starter fluids.

5.2.6. **Specifications.** Dump truck specifications vary, depending on the size, make and model of a particular ADT. For example, engine power generally range between 265 to over 450 horsepower (hp), transmissions are mostly automatic with six forward and one reverse gear, and brake/retarder systems usually consists of park and secondary brakes, and auxiliary braking (e.g., automatic transmission retarder, engine vale brake, and exhaust brake). However, regardless of the manufacturer, ADTs of comparable size tend to have similar specifications. **Table 5.1** lists selected specifications for three, similar-sized rock dumps from well-known manufacturers.

Table 5.1. Truck Specifications.

Item	Caterpillar	John Deere	Volvo
Model Number	725	250D	A25F
Engine Model/ Gross power	C11/ 309 hp	6090/ 265 hp	D11H-B/ 315 hp
Transmission	Auto	Auto	Auto
Transmission Gears	6 Forward 1 Reverse	6 Forward 1 Reverse	6 Forward 2 Reverse
Fuel Tank Capacity	94 gallons	90 gallons	106 gallons
Engine Oil Capacity	11 gallons	6.7 gallons	10 gallons
Total Rated Payload	26 tons	25.6 tons	26.5 tons
Body Capacity (w/tailgate)	20 cu.	22.1 cu.	20.4 cu.
Turning Radius (outside)	23’8”	26’0”	26’7”
Length	32’6”	31’2”	33’6”
Height (body down)	11’3”	11’9”	11’3”
Width (excluding mirrors)	9’1”	9’3”	9’4”

5.3. Basic Operation. Rock dumps provide a flexible means to transport large quantities of aggregate material within quarries and pits to aggregate stockpiles and processing facilities; including crushing and screening plants, washing plants, and concrete and asphalt batch plants. Whatever the task, basic operation of the ADT is essentially the same. From initial start-up to final dumping of material, operators should follow procedures and safety precautions outlined in specific operator manuals and other approved guidance. Below are typical operating procedures for ADTs or rock dumps.

5.3.1. **Preoperational Check.** Operators should perform preoperational checks according to Preventive Maintenance Checks and Services (PMCS) requirements before operating ADTs. These checks may include the following:

5.3.1.1. Perform a walk-around inspection of the vehicle.

- Verify all required safety devices are installed (guards, shields, covers, handholds, seat belts, fire extinguishers, etc.) and required PPE is available and used.
- Look for obvious damage on the vehicle that may impair operations.
- Check the vehicle for oil, fluid, or water leaks. Wetness around seals, gaskets, fittings, or connections indicates leakage.
- Check for missing, defective or loose parts.
- Check belts for wear and tear.
- Check fluid levels (oil, fuel, coolant, hydraulics).
- Check air cleaner and service if necessary.
- Make sure all windows are clean and windshield wipers are in good condition.
- Check tires for defects (cuts, gouges, etc.) and under inflation.
- Check operator cab for cleanliness and damage. Verify seats and seatbelts functions properly.

WARNING

Heavy equipment with missing, poorly functioning or non-functioning safety devices (e.g. backing signals, seat belts, lights, etc.) are unsafe to operate, and should not be used until devices are installed or repaired.

5.3.2. **Start and Prepare to Operate the ADT.** Once PMCS is performed and needed repairs completed, the ADT should be started according to specific procedures in the operator manual. The following generic procedures are an example of typical start-up actions for many large dump trucks.

WARNING

Ensure no one is working on, underneath or in close proximity to the vehicle before staring the engine or driving the vehicle.

5.3.2.1. Climb into the ADT using available handrails, handholds, and steps.

5.3.2.2. Adjust the operator seat and rearview mirrors.

5.3.2.3. Fasten and adjust seatbelts.

5.3.2.4. Start the engine:

- Parking brake set to ON.
- Gearshift placed in NEUTRAL and DISENGAGE clutch.
- Activate engine start controls.

CAUTION

Stop the engine immediately if vibrating or making an excessive noise, or if oil pressure does not register or is not maintained at required psi.

5.3.2.5. Check Instrument Panel and Gauges (immediately after starting the engine, after reaching operating temperature, and at frequent intervals).

- Oil and air pressure gauges.
- Battery/generator indicator (should read in the green area).
- Air cleaner indicator (should not show red).
- Temperature gauge.
- Other gauges and warning indicators.

CAUTION

Stop the engine immediately if any gage readings (temperature, oil pressure, etc.) are out of range, failure to do so can damage engine.

5.3.2.6. Check interior and exterior lights for proper operation. If necessary, use a spotter to verify exterior lights are working.

5.3.2.7. Verify horn, back up and other warning devices are working.

5.3.2.8. Perform other starting procedures according to the operator manual.

5.3.3. **Operating the ADT.** After starting the ADT and verifying proper systems operation, select the correct driving gear range for the road conditions. Move out slowly and always be alert for personnel working near the ADT and changes in vehicle operation and road conditions. Other driving rules may include:

5.3.3.1. Remain seated with seatbelt fasten when operating the vehicle.

5.3.3.2. Keep the ADT under control at all times. Never operate beyond the vehicle's stated capacity and limits.

5.3.3.3. Travel with the body in the DOWN position.

5.3.3.4. Never raise the body of the ADT (even when empty) if someone is behind the vehicle.

5.3.3.5. Keep a safe distance away from the edge cliffs, ledges, terrain drop-offs and areas prone to slides.

5.3.3.6. When operating on hills, slopes or near water banks, or when crossing ditches or other challenging terrain, avoid placing the vehicle in a position where it may tip over.

5.3.3.7. When possible, work up and down slopes versus sideways. Ensure the proper gear range is selected before starting up or down grades.

5.3.3.8. Never coast the vehicle with the transmission in NEUTRAL or with the clutch depressed, it can cause overheating and damage to the transmission.

CAUTION

Do not "ride" the brake when going down a steep grade (pump the brakes); this could cause the brake linings to overheat.

5.3.3.9. Never allow additional riders in the ADT unless they are provided a seat with seatbelt and rollover protection.

5.3.3.10. Never leave or enter the cab while ADT is being loaded (**Figure 5.4**).

Figure 5.4. Loading ADT (John Deere Model 250D).

5.3.4. **Park and Shutdown.**

5.3.4.1. Park on a level surface whenever possible. If parking on a grade is required, block the vehicle to prevent movement.

5.3.4.2. Use caution when parking. Never operate the ADT in reverse gear with an obstructed view, unless it has an audible reverse alarm, or a spotter is used.

- Apply the service brakes to stop the vehicle, and then engage the parking brake.
- Shift the transmission to NEUTRAL and shutdown the engine according to procedures in the operator manual.

5.3.4.3. After vehicle shutdown, safely dismount the ADT using available handrails, handholds, and steps (**Figure 5.5**).

5.3.4.4. Remember to report any vehicle discrepancies or required repairs noted during ADT operation to the vehicle maintenance shop for resolution.

Figure 5.5. Use Steps, Handholds and Handrails to Dismount Safely.

Chapter 6

ROCK DRILLING EQUIPMENT

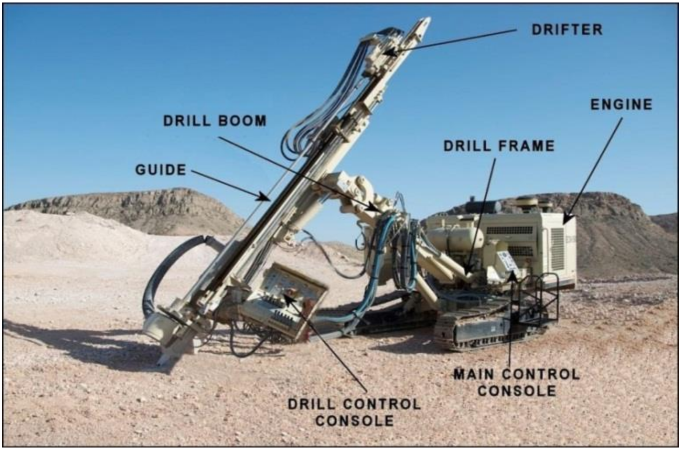
6.1. General Information. When quarry operations involve using explosives for rock excavation, drilling equipment is often used to bore blast holes into rock formations to place the explosives. Although, there are many types of rock drills, it is impractical to address each type and model in this handbook. The Atlas Copco ECM-590 rock drill (**Figure 6.1**) featured in this section is used by RED HORSE personnel at Nellis AFB, Nevada and has characteristics and operational features similar to other rock drills manufactured during the same period. This section provides basic information about the ECM-590 drill rig and how it supports RED HORSE quarry operations. Operators should refer to the applicable operator manual or T.O. for specific information and operation.

Figure 6.1. Atlas Copco ECM-590 Rock Drill.

6.2. Features and Characteristics. The ECM-590 rock drill is a track-mounted, self-contained impact drill, designed primarily for surface drilling and quarry operations. It is rugged and compact with simple, hydraulic controls, and is ideal for mining in rough terrain on remote sites where mobility and reliability are crucial.

6.2.1. **Major Components.** The rock drill has five major components as illustrated in **Figure 6.2**. They include the engine, drill frame, drifter, drill boom, and guide. Attached to the frame and guide are operator control consoles—the main control console and drill control console.

Figure 6.2. Major Components.



6.2.1.1. *Engine*. The power plant is a water-cooled, direct injection, turbo-charged, diesel fuel engine with an electric start and belt-driven alternator system. The engine drives the air compressor and hydraulic pump. It has fully integrated electronic controls and an EMERGENCY STOP switch.

6.2.1.2. *Drill Frame*. The drill frame supports the power pack assembly, which includes the compressor and hydraulic pump drive. The compressor provides free air delivery (FAD) or a working pressure to the system. The hydraulic pump drive converts mechanical force and motion into hydraulic power.

6.2.1.3. *Drifter*. The drifter is a hydraulically operated hammer drill that "drifts" along the drill guide or track. It moves up and down the guide by a feed motor and feed chain. The drifter has a hydraulically powered rotation motor that rotates the drill steel and bit while it hammers the bit into the rock. It is especially suitable for drilling vertical and angle blast holes in quarries. The ECM-590 is equipped with either an YH70 or an YH80A drifter. **Table 6.1** lists basic specifications, including blows per minute (BPM) for these model drifters.

Table 6.1. Basic Specifications for Drifters.

Drifter	YH70	YH80A
Weight	419 lbs.	463 lbs.
Rotation Speed	0-200 RPM	0-150 RPM
Impact Frequency	3000 BPM	2600 BPM
Hole Size	2.5 to 4 in.	3 to 4.5 in.

6.2.1.4. *Guide*. The drill guide is attached to the drill boom. It houses the hydraulically driven drifter and drill feed system. It guides drifter travel during drilling operations. The guide can be adjusted for vertical and dump angle drilling. Guide controls are located on the main and drill control consoles.

6.2.1.5. *Drill Boom*. The variable angle drill boom positions the drill over the drill location. The boom has a maximum horizontal swing of approximately 30 degrees right and 35 degrees left. The boom's maximum vertical movement is 51 degrees up and 15 degrees down. Boom controls are also located on the main and drill control consoles.

6.2.2. **Controls and Indicators.** The ECM-590 has two separate operator control consoles—the main control console and the drill control console. The main control console is located on the side frame near the engine (see **Figure 6.2)**. The drill control console is mounted on the drill guide for optimum operator visibility during drilling operations.

6.2.2.1. *Main Control Console*. The main control console contains the power switch and engine start button. As shown in **Figure 6.3**, the console also contains various engine gauges, switches, and fuses for the engine, indicators and accessories. Positioned on the left side of the main control console are the controls for boom and guide positioning (**Figure 6.4**). Additionally, tram control levers are located under the main control console.

Figure 6.3. Main Control Console.

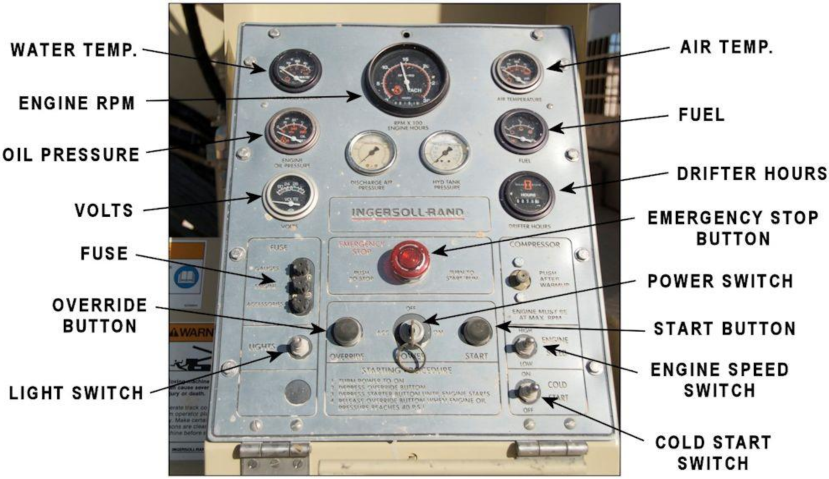
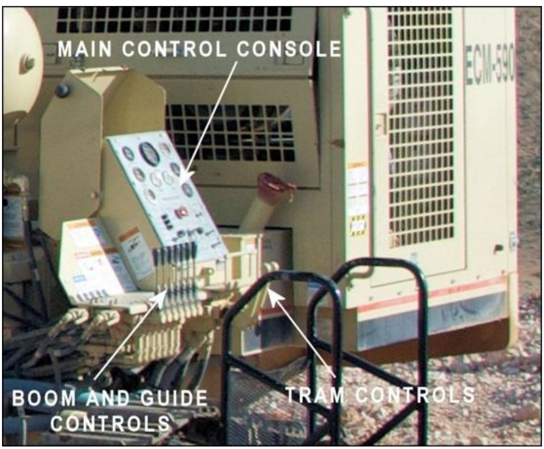


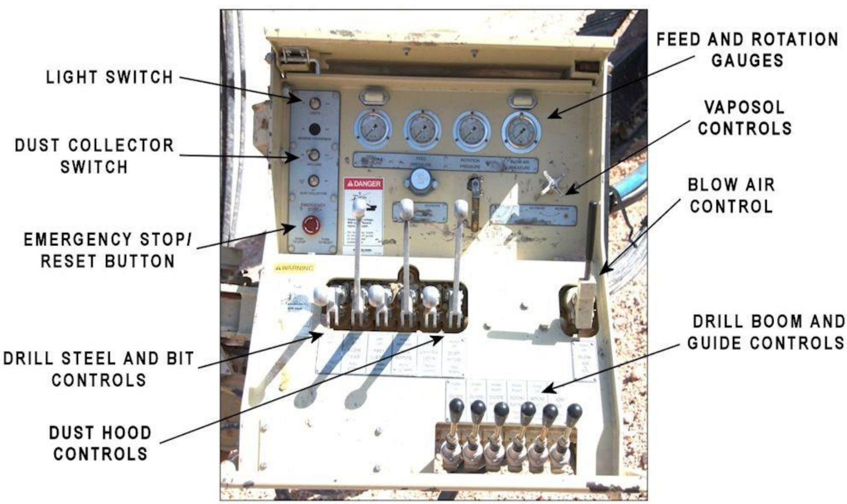
Figure 6.4. Drill Boom, Guide and Tram Controls.



6.2.2.2. *Drill Control Console*. The drill control console contains the second set of boom and guide controls (**Figure 6.5**); which directs boom swing, lift and extension, and guide extension, dump and swing. The drill control console also contains the following:

- Feed and rotation controls and gauges.
- Dust collector and Vaposol controls (dust control apparatus).
- Automatic rod changer controls.
- Emergency STOP button.
- Blow control lever and blow air pressure gauge.
- Dust collector hood.
- Centralizer control (assures proper drill steel alignment).

Figure 6.5. Drill Control Console.



6.2.3. **Specifications.** The specifications for ECM-590 rock drills vary based on when and where the drill was manufactured and the optional equipment included. **Table 6.2** lists a range of specifications for the ECM-590 rock drill.

Table 6.2. ECM-590 Rock Drill Specifications.

Shipping Dimensions and Weight:	
Width*	8 ft. to 8 ft. 7 in.
Height*	9 ft. 4 in. to 9 ft. 7 in.
Length*	19 ft. 5 in. to 29 ft. 4 in.
Weight*	23,500 lbs. to 24,500 lbs.
Engine:	
Horse Power*	215 hp to 220 hp
RPM	2350 rpm
Fluid Capacity:	
Fuel Tank	100 gal.
Hydraulic Tank	55 gal.
Engine Oil	23.2 qt.
Vaposol Tank	40 gal.
Compressor:	
Maximum Working Pressure	140 psig
Volume or FAD (free air delivery)	250 cfm
Boom and Guide	
Boom Extension*	30 in. to 48 in.
Hole Diameter Range*	2.5 in. to 4.5 in.
Drifter Travel*	14 ft. to 15 ft. 4 in.
Tram:	
Tram Speed (max)	2 mph
Ground Clearance	18 in.
*- Varies by model	

6.3. Operational Concepts and Safety. Effective and safe operation of the ECM-590 rock drill can be accomplished by following approved operating procedures and safety practices. Failure to do so could jeopardize the operation, your safety and the safety of others.

IMPORTANT NOTE

This section describes common operation and safety practices for the rock drill. Users must refer to the ECM-590 operating manual or applicable T.O. for specific operating procedures.

6.3.1. **Preoperational Checks.** Before operating the rock drill, operators should accomplish preoperational checks (**Figure 6.6**) and ensure required maintenance is accomplished and all protective and safety devices are in place before starting or moving the drill. Operators should also observe lockout/tagout procedures and other posted warnings.

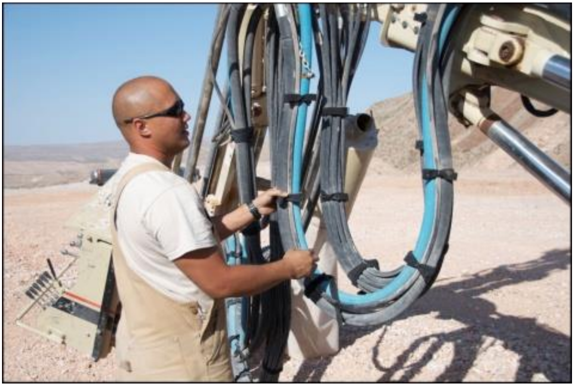
Figure 6.6. Preoperational Checks Enhance Operation and Safety.

6.3.1.1. Perform a complete walk-around inspection of the drill and correct any defects found during the inspection (**Figure 6.7**). Operators should verify:

- Required maintenance (including PMCS) has been accomplished.

- Instruction and safety labels are in place and legible.
- Operator consoles and gauges are not damaged.
- Pumps, motors, valves, hoses, connections, etc. are free of fluid leaks (fuel, oil, coolant, water).
- Fittings, bolts and connections are not loose or damaged.
- No missing parts or parts out of adjustment.
- Welds are not broken or cracked.
- Required safety devices (guards, shields, etc.) are installed.
- Operator's platform is clean and free from grease, oil and other items or tools that could cause a slip or fall.
- All required repairs have been made and lockout/tagout devices or warning tags properly removed.
- There is no visible damage that could impair operations.

Figure 6.7. Perform Thorough Preoperational Checks.



WARNING

Use extreme caution when handling, cleaning, or recharging batteries. Batteries give off flammable fumes that can explode. Do not smoke and always wear protective glasses when checking batteries. Keep open flames away.

6.3.1.2. Verify batteries and connections are serviceable.

- Battery posts and cables are free of corrosion.
- Terminal clamps are tight (loose wires can shock or cause fires).
- Caps are on all batteries.
- Batteries are charged with correct fluid levels.

WARNING

Use extreme caution and wear required protective clothing and equipment when checking or servicing fluids and high-pressure systems. Fluids may be hot or under pressure and can cause severe injury or death.

WARNING

Never fill fuel tank while the engine is running, when near an open flame, or while smoking. Fuel is very flammable and can explode easily. Always clean up spilled fuel.

CAUTION

Do not fill hydraulic tank with hydraulic cylinders extended. Excessive hydraulic oil can rupture the sealed hydraulic tank and cause injury or equipment damage.

6.3.1.3. Check required fluid levels, including the hydraulic oil, engine oil, coolant, fuel, and water. Replenish or refill as necessary.

6.3.1.4. Check fuel filter/water separator for signs of water and sediment. Drain water and sediment from filters and separators as necessary.

6.3.1.5. Verify warning lights, backup alarm and emergency stop controls are functioning.

6.3.1.6. Ensure discrepancies are corrected before starting and operating drill.

6.3.2. **Drill Operation.** Operators are the key to rock drilling operations and must avoid any practice or condition that compromises personnel safety or drill stability. Additionally, the drill should only be operated when all protective and safety devices, emergency shut off equipment, soundproofing elements and exhausts are in place and properly functioning.

6.3.2.1. *Start-Up.* The operator should check around the drill for any hazardous conditions or situations before starting the engine. Also, verify personnel working near the drill rig are wearing appropriate PPE (e.g. safety glasses, safety shoes, protective gloves, hearing protection, and a respirator if in dusty conditions).

- Start the engine from the operator's platform only. Use the power controls (**Figure 6.8**) on the main control console and follow engine start-up procedures on the panel (**Figure 6.9**) and in the operator's manual. Be prepared to push the EMERGENCY STOP button if a malfunction occurs.

- Check the indicators during startup procedures IAW the operating instructions. Verify controls and gauges are in good working order. If they are broken or damaged, replace them before operating the drill.

- Check the steering and lighting for proper function.

- Allow the engine to idle for a minimum of five minutes to allow for proper engine warm up before adjusting the engine speed switch to the HIGH position (**Figure 6.10**). Use the HIGH position when tramming the machine to different locations. Once at the desired location or when ready to start drilling, switch the engine speed to LOW. Load sensors will automatically regulate engine speed.

Figure 6.8. Engine Start and Emergency Stop Controls.

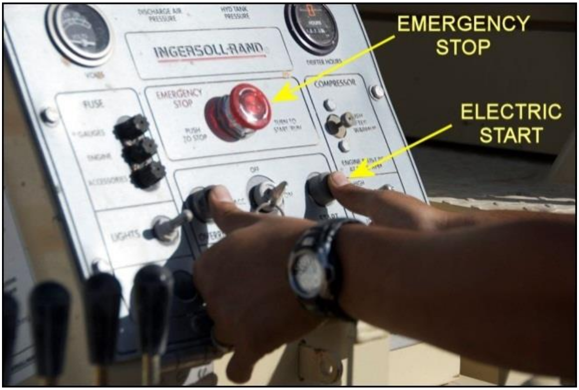


Figure 6.9. Engine Starting Procedures on Panel.

Figure 6.10. Engine Speed Switch.

6.3.2.2. *Moving the Drill.* Operators should use extreme caution when tramming the rock drill to other locations. When moving the drill:

- Make sure the drill rod is completely out of the hole before moving.
- Always verify the area around the drill is clear of personnel and obstacles.
- Secure drill rod and tools (lower the guide if moving a long distance).
- Verify the path of travel is clear.
- Turn lights ON during periods of poor visibility and darkness.
- Do not get on or off the drill while it is moving.
- Proceed slowly; be alert and use extreme caution when operating on hillsides or near ditches, gullies, holes, or obstructions where rollovers could occur.

6.3.2.3. *Positioning Drill for Operation*. The drill should be located a safe distance away from the edges of the quarry face, pit and slopes because the surface edges could crumble under the weight of the drill, causing personal injury or damage to the machine.

- Ensure the drill is situated on stable ground.
- Do not work near quarry faces, walls or benches that can collapse.
- Adjust the drill to the desired drill angle using the boom and guide controls.

6.3.2.4. *Drilling*. Safety should be a vital concern when starting to drill or setting the drill in motion. Operators should avoid any situation or operational mode that might jeopardize their safety or others.

- Ensure protective and safety devices are in place prior to drilling.
- Check that the dust hood seal is correctly sealing around the drill steel. **Note:** Change dust hood seal if damaged.
- Check the pickup hood and suction hoses for any blockages.
- Check the suction hose for sharp bends or crushed areas that can prevent it from supporting itself or blocking airflow.
- Turn dust collectors on and close oscillation controls.
- Follow drill procedures according to the operator manual. During cold weather, engage hydraulic controls slowly to avoid shock loading.
- While the drill is operating, personnel should not place any part of their bodies or clothing on or near any rotating machinery, gears, cables, or chains.
- Make periodic checks of the drill during operation. Listen for any unusual noises.
- Monitor feed chain vibration. Excessive chain vibration can cause the chain to come loose from the sprocket and damage the equipment.

6.3.2.5. *Parking and Normal Shutdown*. Whenever possible, park the drill on solid, level ground and away from the quarry face or other high wall before shutting the drill down for the day. Also, avoid parking the drill under an overhang or other location vulnerable to cave-ins.

- Relieve all pressures in the systems and place all controls in neutral or park position before leaving the drill.
- Position the engine speed control to LOW and allow the engine to idle for five minutes to cool down.
- Turn the engine key switch to OFF, remove the key and secure the drill from inadvertent movement.

6.3.2.6. *Emergency Shutdown*. To perform an immediate shutdown of the drill in an emergency, push the EMERGENCY STOP button located either at the main control console or the drill control console (see **Figure 6.5** and **Figure 6.8)**.

6.3.2.7. *Transporting Drill on a Truck or Trailer*. Before transporting the drill on a truck or trailer (**Figure 6.11**), make sure the machine has been shut down and configured according to the operator manual. Basic precautions include:

Figure 6.11. ECM-590 Prepared for Transport.

- Secure all drill rods and tools.
- Attach chains and binders to secure the machine to the truck or trailer. Refer to the operator manual to locate proper lifting points.
- Ensure there is sufficient clearance when crossing underpasses, bridges and tunnels, or under overhead lines (consider the drill's height, width, weight and length).

6.3.2.8. *Maintaining the Drill*. The drill should be kept in good working condition according to procedures in the operator manual. **Note:** Unauthorized modifications to the machine may impair function and/or safety and could impact machine service life. Drill operators should:

- Ensure required maintenance (including prestart checks) is performed.
- Never operate the machine with loose, worn, or broken parts.
- Avoid operational modes or conditions that could damage the machine.
- Make sure all safety devices, including shields are installed and functioning properly.
- Look out for leaking or broken hydraulic lines and air hoses.

Chapter 7

BLAST DESIGN

7.1. General Information. Whenever RED HORSE teams use explosives during quarry mining operations, blast design (including blast calculations and blasthole drilling) is carefully planned so the desired amount of material is produced with each calculated blast. While this section does not address blasting procedures or requirements, it does provide an overview of important factors related to blast design.

IMPORTANT NOTE

This section provides general information ONLY. It does not replace any policy documents, T.O.s and manuals, or any applicable mandatory procedures or instructions. Users must review applicable technical, safety, and policy references before performing any drilling, blasting, or related explosives tasks.

7.2. Design Considerations. The cut refers to the width and depth of material separated from the quarry bench in any single blast. When designing cuts for aggregate production, the goal of the head blaster and driller should be to provide the optimum amount of material to support rock crushing or other aggregate processing operations between blasts. Although imprecise, the cut design should get as close to your objective as possible. If adjustments are necessary, make one change at a time—so you know how the change influences the results. Head blasters must work closely with drillers to follow the cut design because it delineates both explosives and drilling requirements for blast holes.

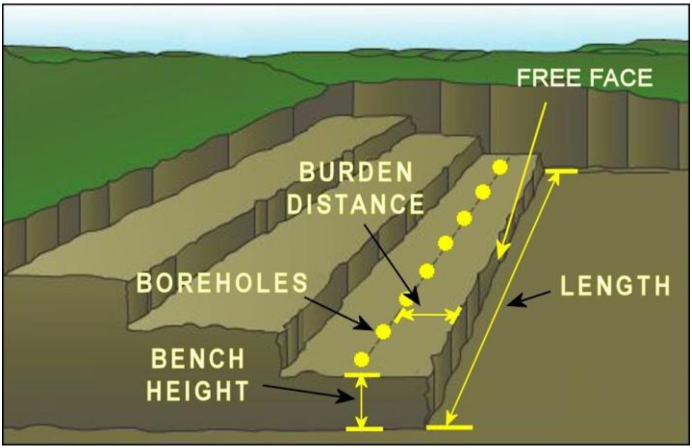
7.2.1. The volume of the cut should be equal to the *bench height* x the *length* x the *width* (**Figure 7.1**); which equates to the material expected to be dislodged by the blast. These factors are defined below:

7.2.1.1. *Bench height*. The bench height is the distance between the top of the bench to the quarry floor (or lower level). Sometimes the type of drilling, excavation or loading equipment used, existing ground elevation, or other physical or geologic conditions determines the height of the bench.

7.2.1.2. *Cut length*. The cut length is the total length (including spacing) of a row of blast holes measured perpendicular to the burden and parallel to the free face.

7.2.1.3. *Burden distance (width)*. One of the most important dimensions in cut design, the burden distance is normally the distance from the blast hole to the free face of the bench or excavation. However, underlying rock conditions could affect the burden distance and direction.

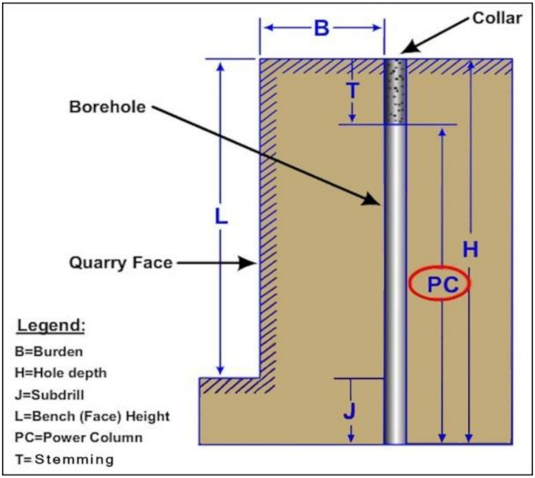
Figure 7.1. Cut Volume Equals Bench Height, Width and Length.



7.3. Blasthole Drilling. Rock drills are used extensively during quarry mining operations to bore blast holes. Drills equipped with sectional drill steels (each 10 or 12 feet long), are used to reach the hole depth required by the cut design. Factors that impact blast hole drilling include; the planned use of explosives, loading and hauling equipment, and geologic features (cracks, joints, etc.) of the rock formation. Other fundamental aspects of drilling blast holes include hole *configuration*, *depth*, *angle*, *spacing*, and *patterns*.

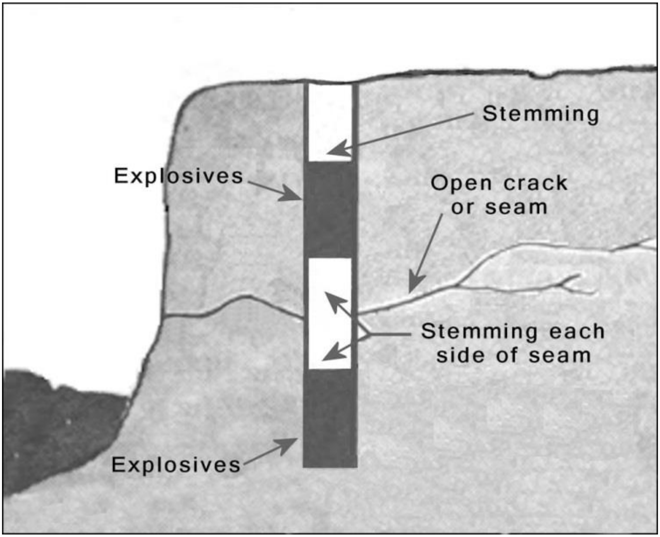
7.3.1. **Configuration.** By design, blast holes pressurize instantly when confined explosives detonate. The high, gas energy output of these explosions produce significant rock-breaking power. Although very simplistic, blast holes can be drilled and configured to produce specific results. The angle and depth of the hole, type of stemming or the type, size and placement of explosives within the hole can all influence final blast results. **Figure 7.2** illustrates the basic configuration of a vertical blast hole drilled adjacent to a quarry face. It consists of the powder column (PC), stemming (T), and subdrill (J). The vertical hole is the most economical and easiest to load. In the illustration, the existing quarry face can be removed and a new face is easily developed.

Figure 7.2. Vertical Blast Hole (Typical Configuration).



7.3.1.1. *Stemming*. Material used to dam or plug the collar regions of blast holes to restrain or confine the energy of the explosion and limit the ejection of fly rock. It is also used to separate the explosives in deck loading operations and to fill spaces caused by voids or cracks (**Figure 7.3**). Stemming (T) should be made of noncombustible, inert materials such as, sized crushed stone, drill cuttings, sand, or clay material.

Figure 7.3. Stemming Fills Space Caused by Voids or Cracks.



7.3.1.2. *Powder Column*. The powder column (PC) is the portion of the blast hole minus the section used for stemming (T) material.

7.3.1.3. *Subdrill*. A portion of the blast hole (J) that is drilled below the planned grade or quarry floor. Subdrilling is used to soften the quarry floor and help keep it smooth and level. **Note:** To improve fragmentation, blasthole primer should not be placed in the subdrill.

7.3.2. **Depth.** The blasthole depth for vertical holes is usually equal to the height of the quarry face plus the subdrilling. In the case of a multiple-bench quarry, the hole depth is typically equal to the height of the bench height plus the subdrilling. Drill holes are normally subdrilled 2 to 3 feet below the quarry floor to ensure complete rock fragmentation between holes during blasting and to help keep the quarry floor level. Sometimes, backfilling will be necessary to create a suitable working floor after blasting.

7.3.3. **Angle.** Depending on the purpose of the cut, the angle of blast holes may be vertical, horizontal, or inclined. For example, **Figure 7.4** illustrates the use of both horizontal and vertical blast holes to establish a vertical face in a hillside quarry (toe cut). In other examples, inclined and vertical holes are used to establish a vertical face in a hillside quarry (**Figure 7.5**) and to cut a ramp for a subsurface quarry (**Figure 7.6**).

WARNING

Due to the increased danger of blowing fly rock and debris from the blast hole, additional care should be taken to ensure proper stemming of angled or horizontal blast holes.

Figure 7.4. Toe Cut Using Horizontal and Vertical Blast Holes.

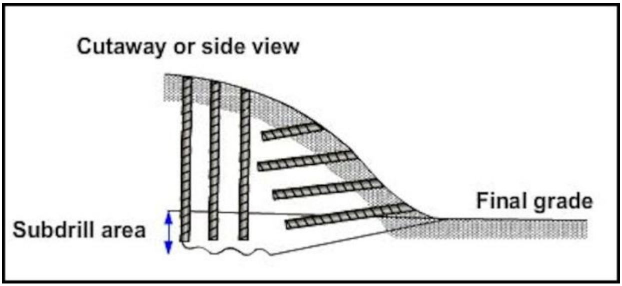


Figure 7.5. Establish Quarry Face with Inclined and Vertical Holes.

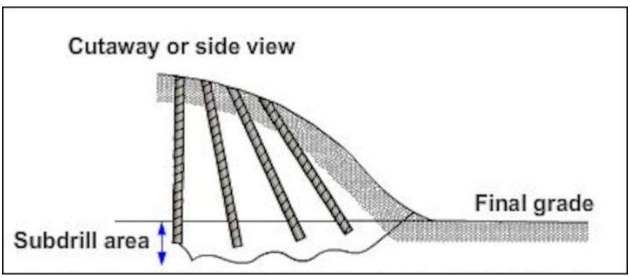
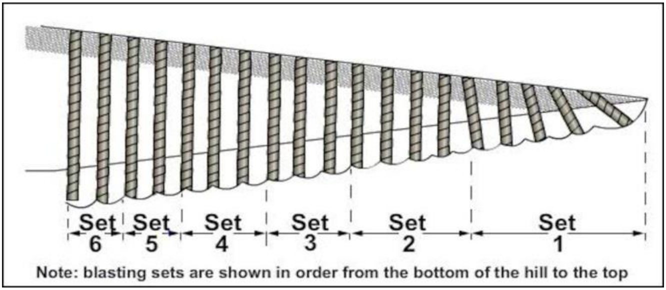
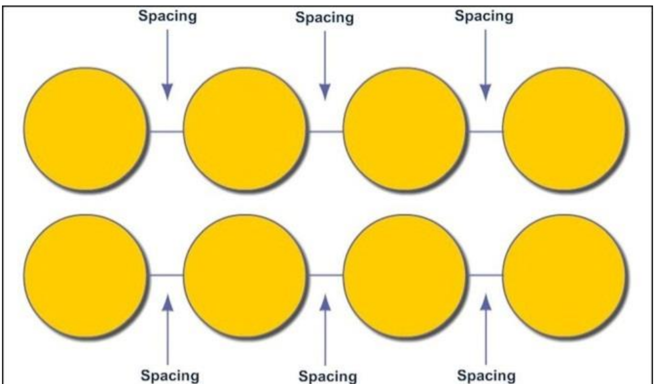


Figure 7.6. Excavating Ramp into a Subsurface Quarry.



7.3.4. **Spacing.** Spacing is the distance between blast holes in the same row; measured parallel to the free face (**Figure 7.7**). It is important to securing uniform rock breakage of suitable size. The spacing distance is usually not more than 1.5 to 2 times the burden distance and is not recommended to be less than the burden distance. Spacing distance less than burden distance can lead to fracture between holes causing propagation or blast hole cutoff and a misfire of individual holes. If spacing is too great, large unbroken boulders and a potential toe between holes could occur.

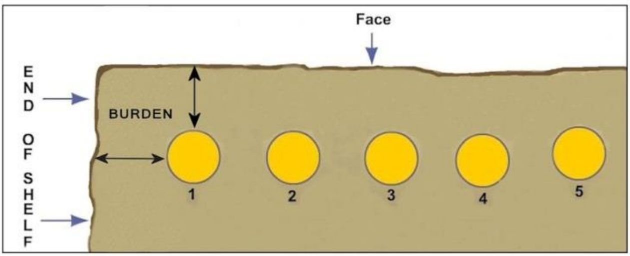
Figure 7.7. Hole Spacing.



7.3.5. **Drilling Patterns.** The drilling pattern is usually selected after determining the desired burden and hole spacing. The patterns used in quarry operations are single row and multiple-row. The drilling patterns are based on the blasting plan and are relevant to both vertical and inclined blast holes.

7.3.5.1. *Single Row*. The holes in the single-row pattern can be rigged for either simultaneous or delayed initiation. For simultaneous initiation, the spacing should be twice the burden for best fragmentation. If there is a front and side face, the hole nearest the open side should be drilled one burden distance from each face (**Figure 7.8**). For delayed initiation, more holes per width of the face may be required but fewer explosives may be needed and rock can be thrown in a desired direction.

Figure 7.8. Single-Row Drilling Pattern.



7.3.5.2. *Multiple-Row*. Multiple-row patterns are square, rectangular, and staggered. These patterns usually require delay caps or other delay devices. The square and rectangular patterns are the most commonly used.

- **Square.** In the square pattern (**Figure 7.9**), the burden/spacing ratio is 1:1. The holes in each row are aligned behind the holes in front of it.
- **Rectangular.** In the rectangular pattern (**Figure 7.10**), the burden is less than the spacing. The holes in each row are aligned behind the holes in front of it forming a rectangular.
- **Staggered.** In the staggered pattern (**Figure 7.11**), the burden and spacing may be equal. However, burden is more often the driving factor

rather than the spacing. The holes in alternate rows are in the middle of the spacing of the row in front of it. The staggered pattern usually requires extra holes to achieve a uniform bank on each end of the blast.

Figure 7.9. Square Drilling Pattern.

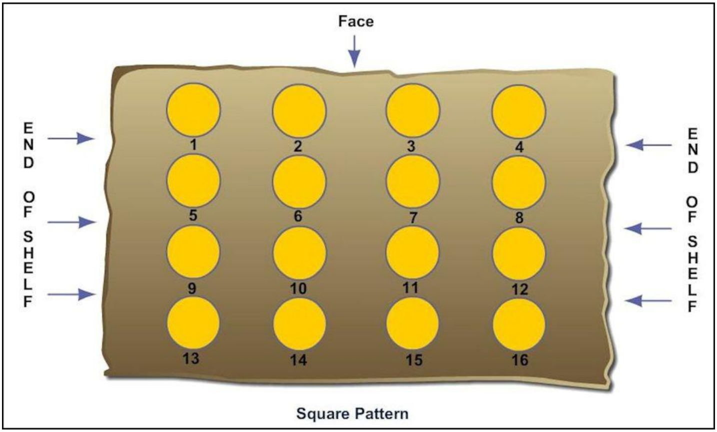


Figure 7.10. Rectangular Drilling Pattern.

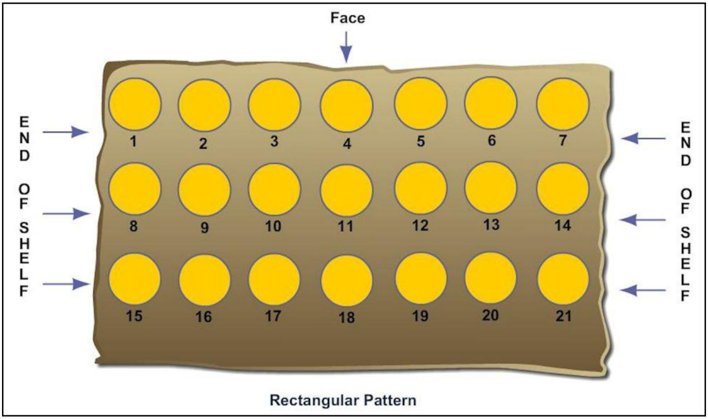
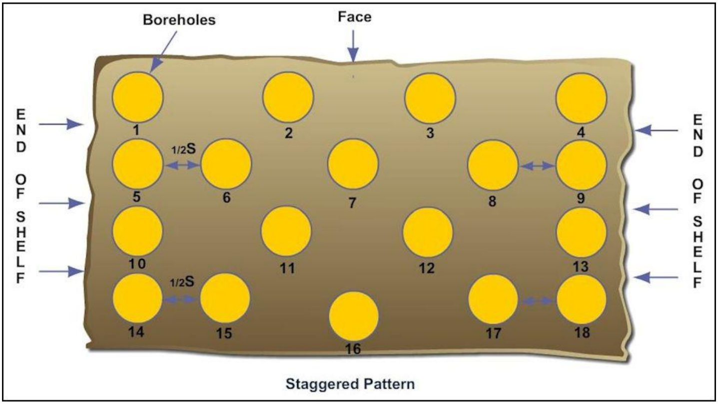


Figure 7.11. Staggered Drilling Pattern.



7.4. Drilling Log. Prior to drilling, a drilling log should be prepared following a visual inspection of the quarry's face and bench. The drilling log provides the drilling crew instructions and warnings about each hole (**Table 7.1**). All visible seams and cracks noted during the inspection should be incorporated into drill plans and listed in the drilling log. The log should include the following information:

- Drilling pattern.
- Hole number, size and depth.
- Location of actual or potential cracks, seams or any type of hole disruption.
- Observations and variations from proposed plans.

7.4.1. The drilling crew drills the pattern according to the log and records their observations and variations from the expected results. If joints or cracks are present, it could affect the drilling pattern. Heavily jointed rock formations often produce overbreak along joint planes during blasting. Bore holes should be drilled the "burden" distance from the crack.

Table 7.1. Drilling Log Example.

DRILLING LOG														
Head Driller: TSgt J. Federico												**Date:** 10 Jul 2014		
	Hole Number													
Depth	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***						
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
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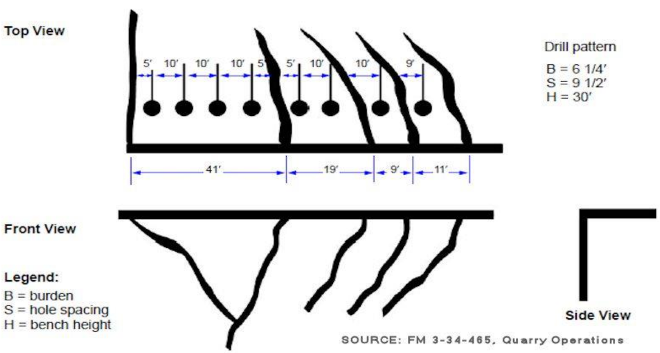
15														

Sketch of Drilling Pattern:



7.4.2. When the drilling log is completed, plans should be made for loading the boreholes based on the results of the drilling and the observations of the drilling crew.

Chapter 8

ROTARY IMPACT CRUSHER AND SCREENING PLANT

8.1. General Information. As their name suggests, rock crushers and screening plants break and separate (screen) rock material into the final desired aggregate product. There are many types and models of rock crushers and screening plants in existence. They include jaw, cone, and impact rotary type plants—both mobile and fixed site units. Some of the military plants have been around for years and may have undergone several modifications. Air Force CE has also begun purchasing more efficient, and sometimes smaller, mobile units for contingencies and future operations (**Figure 8.1**). Therefore, it is likely you may encounter different types during your tour of duty. While this chapter illustrates only the rotary type crusher and screening plant, certain systems and operational concepts addressed here are similar to other types and models and are therefore beneficial to your understanding of how these systems work. However, users must refer to the applicable T.O. or operator manual for detailed technical and safety information for their specific model.

Figure 8.1. Loading New Crusher for Airlift to AOR.

8.2. Description. The Rotary Impact Crusher and Screening Plant delivers rock crushing and screening capabilities. The plant shown in **Figure 8.2** has an overall height of 13 feet 6 inches and a weight of 106,000 lbs. A 272 horsepower diesel engine and a 75 kW generator power this older model plant. However, newer models come with a 325-HP diesel engine and 100 kW generators. The plant can process a high volume of virtually any aggregate or common recyclable feed material.

Figure 8.2. Rotary Impact Crusher and Screening Plant.

8.3. Components. The components of the crushing and screening plant are critical to the production of aggregate materials for concrete and asphalt production. The major parts of this plant consist of the items addressed below:

8.3.1. *Hopper and Feeder Assembly*. The hopper and feeder assembly consists primarily of the hopper and a vibrating grizzly feeder (**Figure 8.3**). The hopper holds the material while the vibrating grizzly feeder separates and sends any material larger than one and one-half inches to the impactor for crushing. Materials smaller than 1-1/2 inches is permitted to pass through the grizzly bars to the conveyor belts below.

WARNING

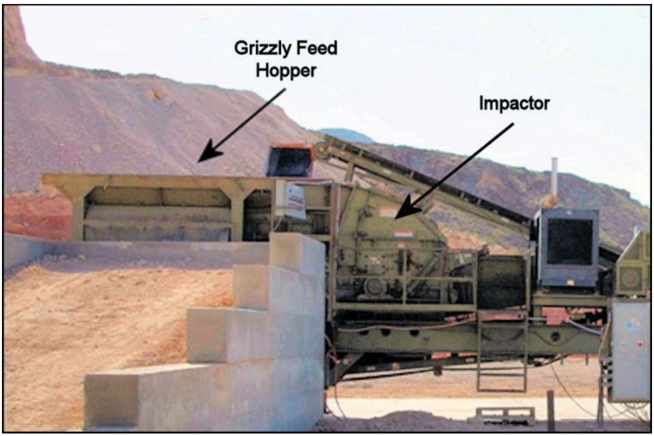
Never allow workers to position themselves directly over the intake of an impactor while it is actively crushing rock.

WARNING

Due to the risk of aggregate falling off a conveyor, Type II impact resistant hard hats must be worn at all times while the crusher is in operation.

8.3.2. *Impactor*. The Impactor is a combination Primary and Secondary crusher that is suitable for both recycling and aggregate applications (**Figure 8.3**). It is capable of processing a variety of sized materials by using the wide range of settings and adjustments of the primary and secondary curtains. The impactor has three main parts: Housing, Rotor and Curtains.

Figure 8.3. Hopper and Feeder Assembly.



WARNING

The impact crusher cannot stop immediately due to forces required to crush concrete and stone, it could take 15 minutes for the impactor's rotor to come to a stop.

8.3.2.1. The Housing holds the material while it is being crushed. It can be opened using hydraulics or an auxiliary engine when performing inspections or maintenance (**Figure 8.4)**. Wear plates line the inside of the housing and are periodically rotated and replaced according to wear. To meet environmental standards, the housing also has built-in spray heads to control dust.

Figure 8.4. Using Hydraulics to Raise Impactor Housing.

8.3.2.2. The rotor, which is driven by belts from the engine, spins approximately 60 miles per hour. It holds three blow bars that break up the material. In essence, the blow bars are hammers that provide blunt-force impact to the stone, concrete, or other materials being processed. See **Figure 8.5** for an illustration of this process.

8.3.2.3. The primary curtain; which is "gravity hung," also help to break the material into what is called "final product plus 4 inches." This means that material passing the primary curtain is not the finished product size and will generally be sized to "4-inches plus." The secondary curtain, which is "hydraulically adjusted," breaks the material into its final product size.

8.3.3. *Engine and Generator*. The engine is diesel-powered. It drives the rotor and runs the generator assembly. The generator runs off the diesel engine and provides 480 volts AC power to the main control panel (**Figure 8.6**).

Figure 8.5. Illustration of Impactor Crushing Process.

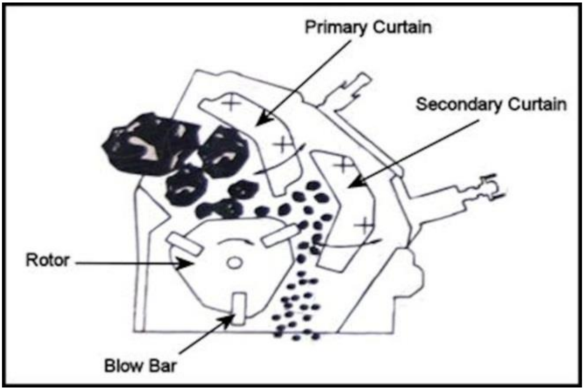
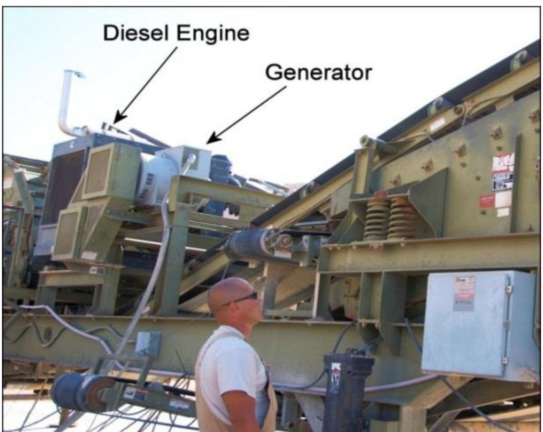


Figure 8.6. Engine and Generator.



8.3.4. *Main Control Panel*. The main control panel (**Figure 8.7**) has the start and stop buttons to operate the unit, however, the impactor, engine, and generator operate independently from the electrically controlled motors. In addition to all the start and stop buttons, the main control panel also has three additional starters and outlets for auxiliary equipment such as additional radial stacking conveyors. Auxiliary equipment is plugged into the designated outlet on the control cabinet as shown in **Figure 8.8**.

8.3.5. *Remote Operator Panel*. The remote operator's panel is mounted on the operator's platform near the feed hopper (**Figure 8.9**). The operator can control all electric motors from this panel. Motors are started from the furthest material handling point in sequence back to the feed hopper. As a safety precaution, if a motor stops during production, all the motors from that motor back to the feed hopper also stop. This helps to clear material from the crusher and limit the amount of material that piles up at the stopping point. The emergency stop button shown in **Figure 8.10** stops the operation of all electric motors.

Figure 8.7. Main Control Panel.

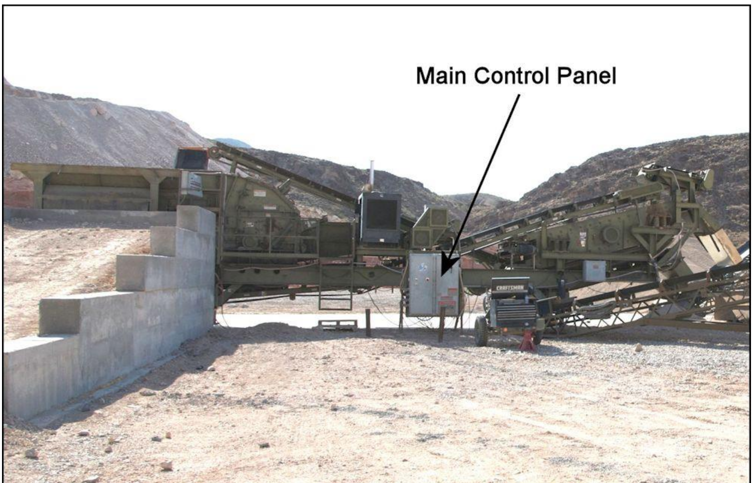


Figure 8.8. Auxiliary Outlets on Main Control Cabinet.

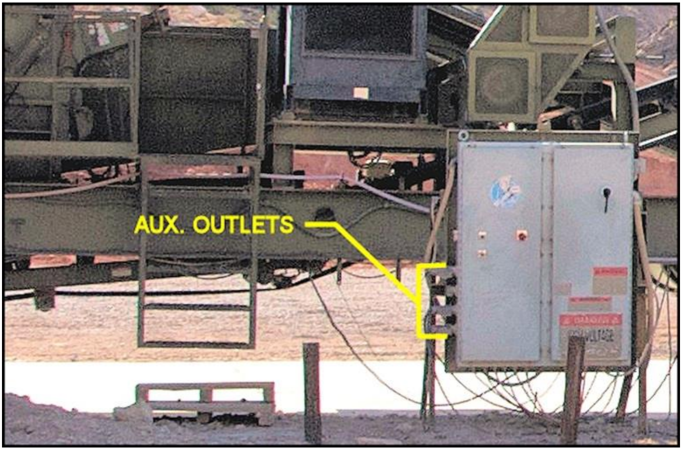


Figure 8.9. Location of Remote Operator Panel.

Figure 8.10. Emergency Stop on Remote Operator Panel.

8.3.6. *Conveyors*. Electric-powered conveyors belts are a prominent feature of the crusher and screening plant. Several conveyors are shown in **Figure 8.11**. They are used to move aggregate materials throughout the plant and consist of the grizzly cross conveyor, discharge conveyor, lower cross conveyor, upper cross conveyor, fines conveyor and the return conveyor. The grizzly cross conveyor collects material that is small enough to pass through the grizzly bars and discharges it from the crusher system or moves it to the primary discharge conveyor. The primary discharge conveyor moves material from the impactor to the screens for separation and discharge into the appropriate aggregate stockpile using the upper, lower, and fines conveyor. The return conveyor is used to return oversized material to the impactor for re-crushing.

8.3.7. *Screens*. The screens are designed to separate crushed aggregate material into two, final product-sized materials. There are two screens, a large screen on the top deck and a smaller one on the lower deck (**Figure 8.12**). Material that is too large to pass through the large screen can be returned to the impactor or discharged as a third product. A fourth product can also be obtained by using the material that passed through the grizzly bars prior to the crushing process.

Figure 8.11. Conveyors.

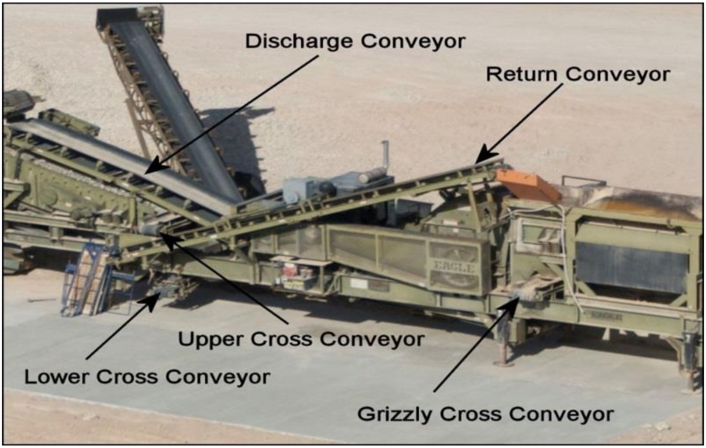
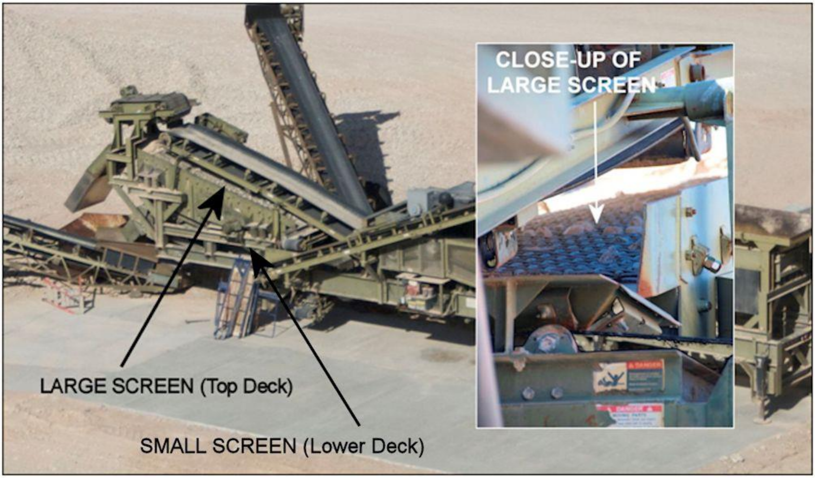


Figure 8.12. Screens.



8.3.8. *Magnetic Separator*. The magnetic separator is designed for recycling crushed concrete with rebar reinforcement. The separator is an electro-magnet that energizes the lower portion of the belt (**Figure 8.13**). When the metal from the crushed material is picked up it is carried along the lower portion of the belt then released and falls out of the crusher system. The metal is removed to prevent screen blockage and contamination of the product.

8.3.9. *Radial Stackers*. As its name indicates, the stacker's function is to stack or stockpile bulk material that has been processed through the crushing and screening plant (**Figure 8.13**). Stackers are equipped with a heavy-duty frame construction, supports, and axles and can be manually raised and lowered. The stacker's electric motor drive is pre-wired with 100 to 150 feet of power cable as shown in **Figure 8.14**. The cable is usually plugged into one of the auxiliary outlets on the main control panel.

Figure 8.13. Magnetic Separator and Radial Stackers.

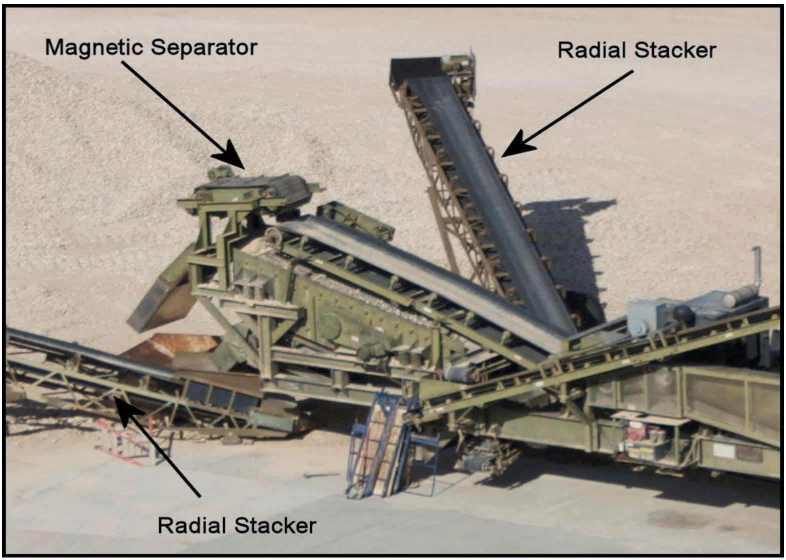


Figure 8.14. Radial Stacker Power Cable.

8.4. Operational Safety. Every major part of the crusher and screening plant is involved in aggregate production. Anyone near the machine should observe all safety precautions when the unit is operating. The operator should begin each shift with a detailed safety briefing and the work crew should have/wear appropriate protective equipment (see paragraph 8.4.3). The crushing and screening process begins when stone is initially dropped into the grizzly feed hopper, and continues through the feed box assembly and into the impactor for crushing. From the impactor, the material is screened and discharged onto the appropriate stockpile via conveyors. Rocks that are too large to pass through the screen can be discharged or sent back to the impactor for crushing via the return conveyor. Although this process may seem simple, it can be very hazardous, especially if individuals are not attentive. Take seriously any DANGER, WARNING, or CAUTION sign, they are critical to preventing injury. In addition, all protection guards and warning signs installed at the factory should not be changed, modified, or removed.

WARNING

NEVER attempt to remove jammed material while machinery is in operation. Shut down, isolate, and block all hazardous energy sources before performing machine maintenance.

8.4.1. **Moving Parts.** The operator is responsible for everyone working on or near the plant. He or she should look around before starting any equipment and ensure they know the location of all the workers. He or she must also be fully aware of the related dangers and the safety precautions that must be followed. Report any defective or unsafe situation to a supervisor. Obviously, since this equipment is made to crush concrete and large stones, careless operation or failure to follow hazard warnings could kill or severely injure personnel. In fact, any moving part can be dangerous, so never attempt to clean, lubricate, or adjust any part of the machine while it is in motion. The impactor is especially dangerous because it takes a while for it to stop when the drive is disengaged. Actually, it could take up to 15 minutes for the rotor to stop turning. Always use extreme caution around this component and follow all safety precautions.

8.4.2. **High Voltage.** The machine is very powerful with extremely high voltage currents, and unauthorized persons should stay clear of high voltage terminals, including those in the main control panel box. These general safety precautions cover the spectrum of plant operations, and it should be abundantly clear that you must observe these and all safety precautions—for your protection and the protection of others.

8.4.3. **Protective Equipment.** Just as important as adhering to general safety precautions, personnel must also wear personal protective equipment or PPE, like that listed below when operating the equipment. Depending on the environment, wear of additional equipment may also be necessary.

- Hardhat.
- Safety glasses.
- Ear protection.

- Safety boots.
- Dust mask.
- Gloves.
- Reflective Vest/Accessories.

8.5. Maintenance Activities. Good preoperational checks and a consistent daily, weekly, and general maintenance program are necessary to keep the machine's equipment in peak operational condition. Operators must also maintain a high level of safety awareness when performing inspection and maintenance actions. Below is a brief summary of operator maintenance activities.

WARNING

Do not clean, lubricate, or adjust any part of the machine while it is in motion. Personal injury or death could result from contact with moving parts.

8.5.1. **Preoperational Check.** These checks are essential to the overall crushing and screening operation and should be accomplished before starting the unit. First, ensure the plant is as level as possible because aggregate material will flow to the low side of an unleveled plant. This condition will result in uneven wear to the equipment, as well as a reduction in plant capacity. When necessary, the plant can be leveled using the gas-powered standard lift/leveling system. Other preoperational checks include verifying correct fluid levels for oil, fuel, and coolant; ensuring proper clutch engagement; checking the condition of conveyor belts and bearings, and the inside of the impactor for wear and damage. Required adjustments, repairs, and part replacement must be made prior to starting up the plant.

8.5.2. **Daily Maintenance.** Similar to preoperational checks, daily maintenance actions require that items like the engine oil, coolant, and conveyer belts be checked for wear and tear. In addition, operators should perform a walk-around visual inspection of all the sections of the unit. This is usually a good way to spot fluid or lubricant leaks and examine any bolted connections for looseness. In addition, dirt buildup should be removed when discovered. If the diesel engine air filter is dirty, compressed air can be used to clean it. In addition to basic daily maintenance, the screening plant also requires belt tensions be checked and corrected, protective guards be in place, and excess material build-up be removed from the feed box.

8.5.3. **Weekly Maintenance.** Weekly maintenance should include greasing the conveyor pulleys, bearings, and all the seals. In addition, the V-belts should be inspected for proper adjustment. Compressed air can be used to blow accumulated dust and foreign materials out of the diesel engine radiator to prevent the restriction of airflow. This helps prevent the engine's cooling system from overheating or automatically shutting down the engine. The level of the crusher and screening plant should be checked weekly and adjusted, as required. Weekly maintenance also requires inspection of the feed box liner for excessive wear.

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DCS/Logistics, Installations & Mission Support

Attachment 1

GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION

References

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Air Force Doctrine Volume 5, *Support*, 29 October 2013

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UFGS 32 11 23, *Aggregate and/or Graded-Crushed Aggregate Base Course*, August 2008

820th RHS, Explosive Demolition Training Reference Guide, April 2006

How to Read a Geologic Map, U.S. Geological Survey, 1997

Neuendorf, Klaus K.E., et al. (2005) *Glossary of Geology, Fifth Edition*. Alexandria, VA: American Geological Institute

Prescribed Forms

No prescribed forms are implemented in this publication.

Adopted Forms

AF Form 847, *Recommendation for Change of Publication.*

Abbreviations and Acronyms

ABC—Aggregate Base Course

ADT—Articulated Dump Truck

AFCAT—Air Force Catalogue

AFCEC—Air Force Civil Engineer Center

AFDD—Air Force Doctrine Document

AFH—Air Force Handbook

AFI—Air Force Instruction

AFMAN—Air Force Manual

AFPAM—Air Force Pamphlet

AFPD—Air Force Policy Directive

AFRC—Air Force Reserve Command

AFRIMS—Air Force Records Information Management System

ANG—Air National Guard

ASTM—American Society for Testing and Materials

BCE—Base Civil Engineer

BPM—Blows per minute

Cfm—Cubic feet per minute

CE—Civil Engineer

DOD—Department of Defense

DOL—Department of Labor

DSN—Defense Switched Network

FAD—Free air delivery

FOPS—Falling Object Protection System

Gal.—Gallon

GCA—Graded-Crushed Aggregate Base Course

GIS—Geospatial Information Systems

HP—Horsepower

HQ—Headquarters

IAW—In Accordance With

IGI&S—Installation Geospatial Information and Services

Lbs.—Pounds

MAJCOM—Major Command

MPH—Miles per hour

MSHA—Mine Safety and Health Administration

OPR—Office of Primary Responsibility

OSHA—Occupational Safety and Health Administration

PMCS—Preventive Maintenance Checks and Services

PPE—Personal Protective Equipment

Prime BEEF—Prime Base Engineer Emergency Force

PSI—Pounds per Square Inch

PSIG—Pounds per Square Inch Gauge

Qt.—Quart

RBC—Reach Back Center

RHS—RED HORSE Squadron

ROPS—Roll Over Protection System

RPM—Revolutions per minute

T.O.—Technical Order

TTP—Tactics, Techniques, and Procedures

UFC—Unified Facilities Criteria

UFGS—Unified Facilities Guide Specifications

USCS—Unified Soil Classification System

UTC—Unit Type Code

V—Volts

VAC—Volts Alternating Current

Terms

Air Force Civil Engineer Center (AFCEC)—A field operating agency (FOA) headquartered at Joint Base San Antonio-Lackland, Texas. The Readiness Directorate (AFCEC/CX) located at Tyndall Air Force Base, Florida provides readiness and emergency services support to the Air Force civil engineer community through technical information and standardized methodology, enabling civil engineers worldwide to execute their expeditionary combat support and emergency services missions safely, effectively and efficiently.

Aggregate—A mineral material, such as sand, gravel, shells, slag, broken stone or combinations thereof, with which cement or bituminous material is mixed to form a mortar or concrete. Fine aggregate is material that will pass a 1/4-inch screen. Coarse aggregate is material that will not pass a 1/4-inch screen.

Asphalt—A complex compound of various hydrocarbons, part of which are oxygenated. Related in origin to petroleum, it is brown or brownish black in color and is also called mineral pitch.

Base Course—The first soil layer underneath a pavement.

Blast Hole—A drilled or bored hole in rock used for placing explosives to blast rock during quarry mining excavation.

Blasting—Detonating explosives in a borehole to produce rock fragments.

Borehole—A hole drilled or bored into the earth; as blast hole.

Burden—This is the area measured from the free face to the first row of holes - also the distance between rows parallel to the face.

Deck Loading—Placing several explosive charges in boreholes separated from each other by stemming.

Face—Rock surface to be blasted.

Humus—Brown or black complex and varying material formed by the partial decomposition of vegetable or animal matter; the organic portion of soil.

Inclined Holes—Boreholes drilled at angles of 10^{o} to 40^{o} to the vertical.

Muck Pile—Broken rock or ore from the previous blast.

Overburden—The waste that overlies the good stone in a quarry (top soil, brush & trees, etc.); worthless surface material covering a body of useful mineral.

Powder—Generic term for all explosives and blasting agents.

Pit—A site from which material can be removed generally without blasting.

Quarry—A site where open excavations are made for the purpose of removing rock usually by drilling, cutting or blasting.

Spacing—Distance in feet between boreholes in a row measured perpendicular to the burden and parallel to the free face.

Subdrilling—Drilling boreholes below the planned grade lines or below quarry floor level.

Stemming—Crushed stone, dirt or drill cuttings used to plug the unloaded portion of a blast hole.

Tamping—Compacting a cartridge or column of cartridges with a wooden or non-sparking tamping stick.

Tramming—Moving or propelling a self-powered tracked drill rig.

Attachment 2

ENGINEER REACHBACK AND OTHER USEFUL LINKS

Table A2.1. Useful Organizational and Product Links.

Useful Links
Air Force Civil Engineer Center (AFCEC), http://www.afcec.af.mil/
Whole Building Design Guide (WBDG), http://www.wbdg.org/
Unified Facilities Criteria (UFC), http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4
Unified Facilities Guide Specifications (UFGS) http://www.wbdg.org/ccb/browse_cat.php?c=3
Air Force Engineering Technical Letters (AFETL), http://www.wbdg.org/ccb/browse_cat.php?o=33&c=125
Construction Criteria Base (CCB)—Whole Build Design Guide (WBDG), http://www.wbdg.org/ccb
U. S. Geological Survey (USGS), Maps, Imagery and Publications, http://www.usgs.gov/pubprod/
Air Force Publications and Forms, http://www.e-publishing.af.mil/
DOD Issuances (Publications, Directives, Guides, Etc.), http://www.dtic.mil/whs/directives/
USACE Engineer Research and Development Center, http://www.erdc.usace.army.mil/
On-Line Conversion Applications, http://www.onlineconversion.com and http://www.metricconversion.ws