BY ORDER OF THE SECRETARY OF THE AIR FORCE

AIR FORCE PAMPHLET 10-219, VOLUME 4
1 APRIL 1997
Operations

RAPID RUNWAY REPAIR OPERATIONS

This volume in this pamphlet series describes the Air Force Engineer's role in conducting expedient repairs to airfield operating surfaces following an enemy air attack. In addition to detailed information on actual rapid runway repair (RRR) techniques, it also contains procedural information on related activities such as damage assessment, minimum operating strip (MOS) selection, repair quality criteria (RQC) and airfield marking. This volume is of particular importance to unit-level engineers in preparing their personnel to meet the wartime airfield recovery mission. This pamphlet series supports AFI 10-210, *Prime Base Engineer Emergency Force Program* and AFI 10-211, *Civil Engineer Contingency Response Planning*. Send comments and suggested improvements to HQ AFCESA/CEX, 139 Barnes Drive, Tyndall AFB FL 32403-5319. 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.

Paragraph

Certified by: HQ USAF/CE (Lt Col R. Turner)
OPR: HQ AFCESA/CEX (Mr Joseph Smith)
Pages: 227/Distribution: F

Chapter 3--Minimum Operating Strip (MOS) Selection Procedures

Chapter 4--Repair Quality Criteria (RQC)

Chapter 5--Rapid Runway Repair (RRR) Techniques

Figures

Tables

Attachments

Chapter 1

INTRODUCTION

> "An army may be likened to water, for just as flowing water avoids the heights and hastens to the lowlands, so an army avoids strength and strikes weakness"
>
> Sun Tzu, The Art of War, c. 500BC

1.1. References, Abbreviations, Acronyms, and Terms. References, abbreviations, acronyms, and terms used in this volume are listed in attachment 1.

1.2. Concept. The Air Force flies and fights from its air bases. However, it is at the air base that air power is most vulnerable. They can be most immediate and lucrative targets for an adversary. After all, it is by far more effective to destroy aircraft while they are on the ground than to hunt them in the air. From a practical perspective, it is reasonable to say that during some phase of a conventional conflict, repair of airfield pavement damage will be one of the civil engineer's primary wartime missions. It is a complex and difficult tasking that requires the total commitment of all involved to succeed. Proper preparation must be accomplished prior to the moment of need--for time will not be available during the conflict to accomplish meaningful training.

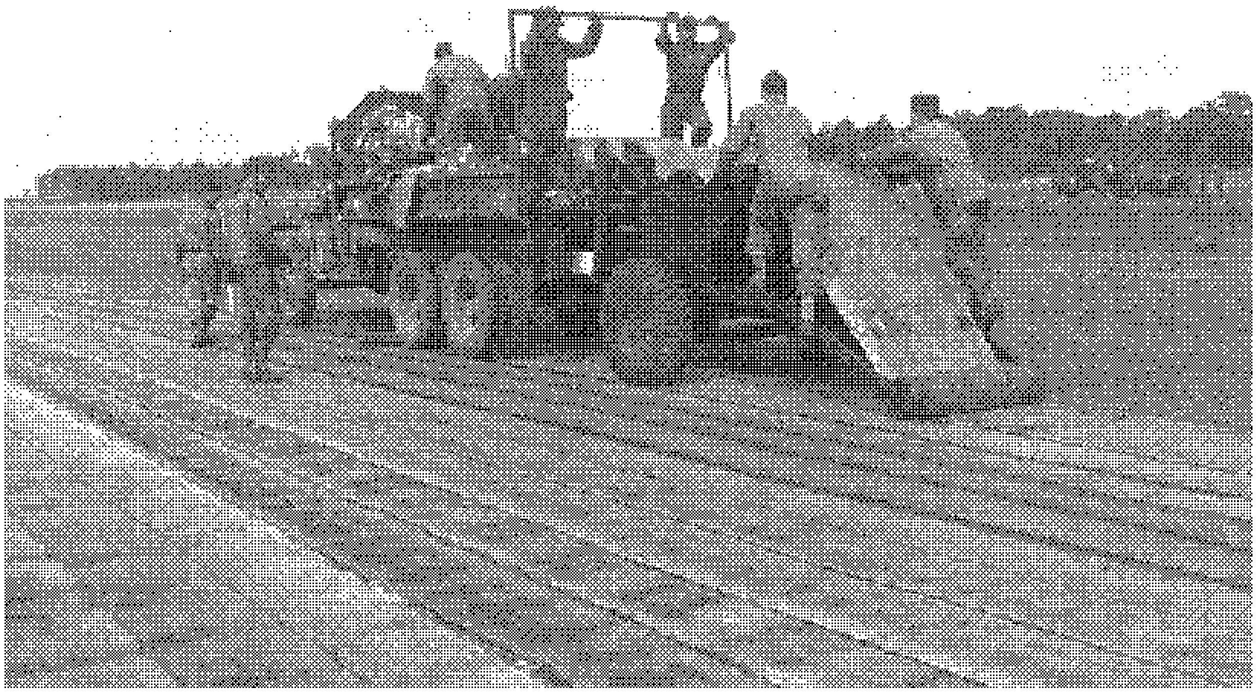
1.3. Background. American military leaders of World War II recognized the vital need for airfields to support operations in all theaters of operation. Many times this meant repairing enemy airfields or constructing new ones as quickly and close to the front as possible. To provide this level of support, Aviation Engineers experimented with several different types of runway materials. Some never proved feasible. For example, the attempt to construct a runway with wooden 2" x 4" landing mats was too costly and labor intensive. However, the engineers did develop several types of materials enabling them to provide expedient runways in just days or even hours. The three primary repair materials included: Pierced Steel Planking (PSP), Hessian Matting, and Square MeshTrack (SMT).

1.3.1. Pierced Steel Planking, also known as Marston Matting, was initially tested at Langley Field, Va., in 1940 and was in wide use even through the Korean War. The product proved to be very versatile. It was comparatively light, yet fairly rigid and very transportable. Its simple hook design on the plank edges made assembly a fast and relatively easy undertaking and minor replacement repairs usually ended up requiring only two men to accomplish. When major repairs were necessary, large sections of planking could actually be rolled up and removed and replaced as appropriate. A major drawback that eventually brought about its replacement was the development of drainage problems. The holes in the planking served to reduce weight but also resulted in an undesirable "pumping" action that caused rapid base course failures in wet climates such as Southeast Asia. By the end of World War II, enough PSP had been manufactured to construct nearly a thousand 150- x 5,000-foot runways (figure 1.1).

Figure 1.1. PSP Being Installed at Night by Men of the IX Engineer Command at an Air Base in Germany in 1945.

1.3.2. Hessian Matting, also known as Prefabricated Hessian Surfacing, was originally developed by the Canadian Army engineers. It was composed of bitumen impregnated Hessian cloth (a type of burlap) and was used primarily as a waterproof cover for the runway surface. With Hessian Matting, Engineers could construct an acceptable runway surface in a very short period. However, frequent maintenance requirements in aircraft braking and turning areas coupled with its generally brief longevity were the product's primary shortfalls. In addition, the material could not be placed when the grade was wet (figure 1.2).

Figure 1.2. Construction of a Hessian Mat Runway by Men of the 834th Engineer Aviation Battalion at Buchschwabach, Germany.

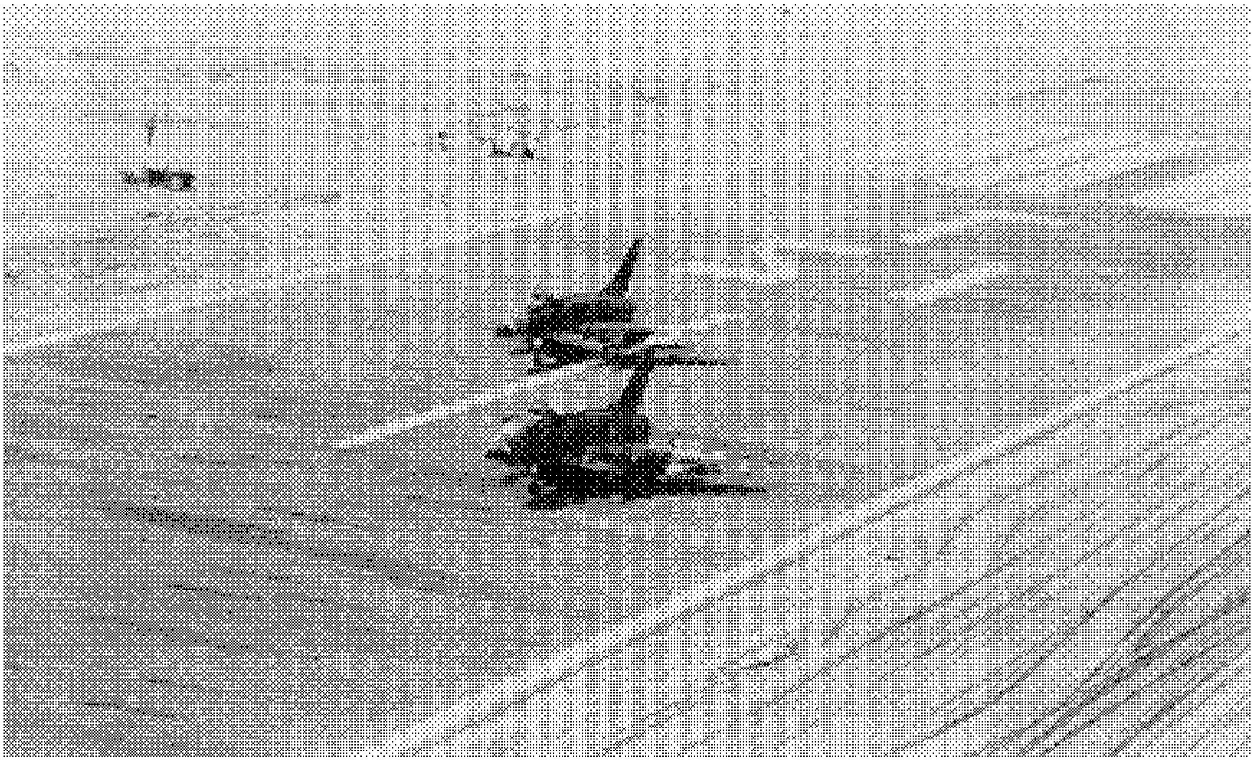


1.3.3. Square Mesh Track was specifically developed as an expedient temporary runway surfacing material in support of the invasion of Europe. During the invasion period engineers constructed nine SMT airfields, however these runways were limited to light and medium weight aircraft. As a primary runway surfacing material, Square Mesh Tracking received mixed reviews. It was light and highly mobile, but did not hold up well in the long haul. However, during the latter part of World War II, it had become rather common practice to employ Hessian Matting in conjunction with square mesh tracking and PSP. This "sandwich" product, though usually labor intensive, provided a much more durable runway platform where enemy air attack was least probable.

1.4. Post World War II. With the onset of the "Cold War" shortly after World War II, and the permanent posturing of Air Force units at overseas locations, construction of expedient airfields became the reality. Furthermore, with the addition of sophisticated fighter aircraft to the inventory, "ultra smooth" runway surfaces became an absolute must. No longer was there great interest in the expeditionary runway technology of the past. The day of earthen runways and expedient surfaces was gone. In its place was a burning need for expedient airfield repair technology--rapid runway repair (RRR). This was driven by the relatively close proximity of the potential enemy to our permanent platforms. AM-2 aluminum matting, precast concrete slab, and the folded fiberglass mat techniques are products of that need.

1.4.1. AM-2 matting became part of the Air Force inventory in 1965 and was primarily used for construction of expedient runways, parking aprons, and taxiways. At Tuy Hoa (figure 1.3), an entire 9,000-foot expedient runway and the extensive aircraft parking ramp at Phu Cat Air Bases in the Republic of South Vietnam were examples of AM-2 matting being used for these purposes. In the summer of 1975, the concept of using AM-2 material for bomb crater repairs was first tested at the Sky-10 testing facilities on Tyndall AFB. From these tests, the AM-2 crater repair procedures in use today were developed. Among the system's many strong points are portability and durability. Its major drawbacks include labor intensity and the transitional bounce that was created between the mat and the adjacent hard surface.

Figure 1.3. F-100s Landing on a Runway Constructed of AM-2 Matting at Tuy Hoa Air Base, Republic of South Vietnam.



1.4.2. In the early 1980s, HQ USAFE adopted the precast concrete slab repair technique (figure 1.4) as its primary RRR method. The procedure was already being used to a limited extent at that time by the then West German Air Force. The ample stocks of AM-2 matting postured throughout the command were designated as a backup system for the precast slab method or for use in taxiway repairs. At that time, the concrete slab repair system was the only fielded RRR technique that could, when correctly installed, provide a truly flush crater repair--a most desirable feature. However, the system did have two notable drawbacks: it was not very portable and was heavily dependent on specialized equipment. In October 1994, HQ USAFE officially discontinued employment of the precast concrete slab repair system. In its place they now use the folded fiberglass matting repair method as their primary RRR procedure.

1.4.3. In the late 1970s, HQ Air Force Engineer and Services Center (AFESC), now HQ Air Force Civil Engineer Support Agency (AFCESA), was working diligently at developing a synthetic matting system that would provide portability without the transitional roughness problems associated with AM-2 matting. Initial versions of their efforts were fielded in PACAF in August 1984 and were called Polyurethane Fiberglass Mats (PFMs). Unfortunately, these early PFMs products were not well received, mainly because of the storage and transport problems presented by their sheer bulk (figure 1.5). They were 50 x 60 feet in size, not foldable, and weighed approximately 1,500 pounds. However, work continued on the project and by February 1992, HQ AFCESA had perfected the folded fiberglass mat system that is the primary RRR method now employed Air Force-wide (figure 1.6). Without question, this is the most functional RRR system yet developed. However, it does have two weak points: it has the tendency to rut at a faster than desirable rate, and the elastomer hinges are susceptible to damage with heavy usage.

Figure 1.4. Precast Concrete Slab RRR Operation During June 1985 SALTY DEMO Exercise at Spangdahlem Air Base, Germany.

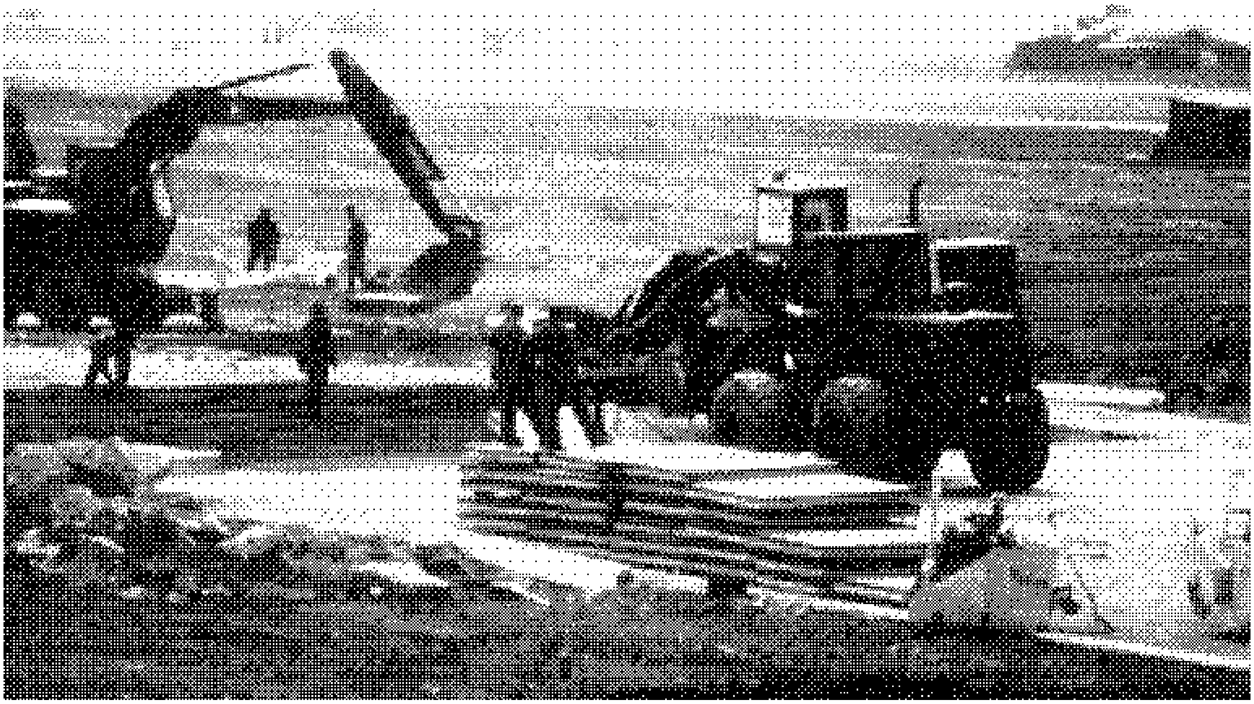


Figure 1.5. Polyurethane Fiberglass Mat (PFM) Being Transported to Storage Area.

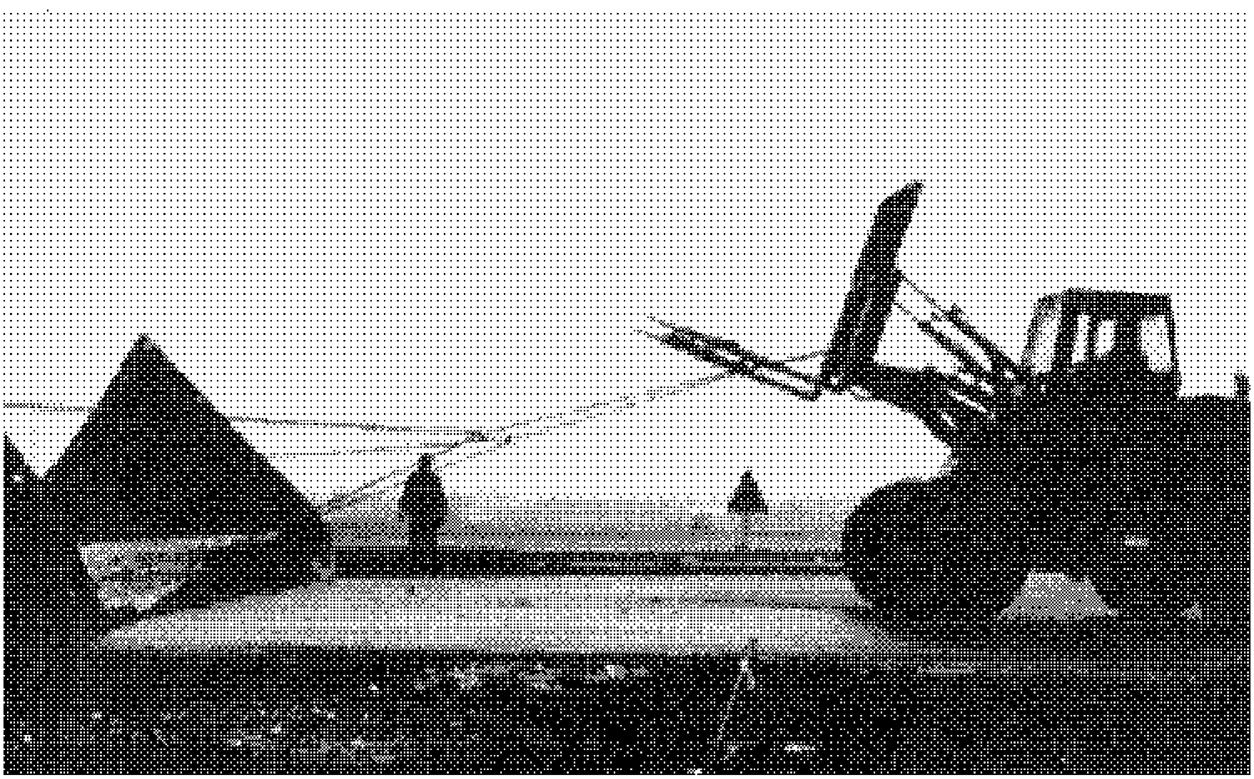
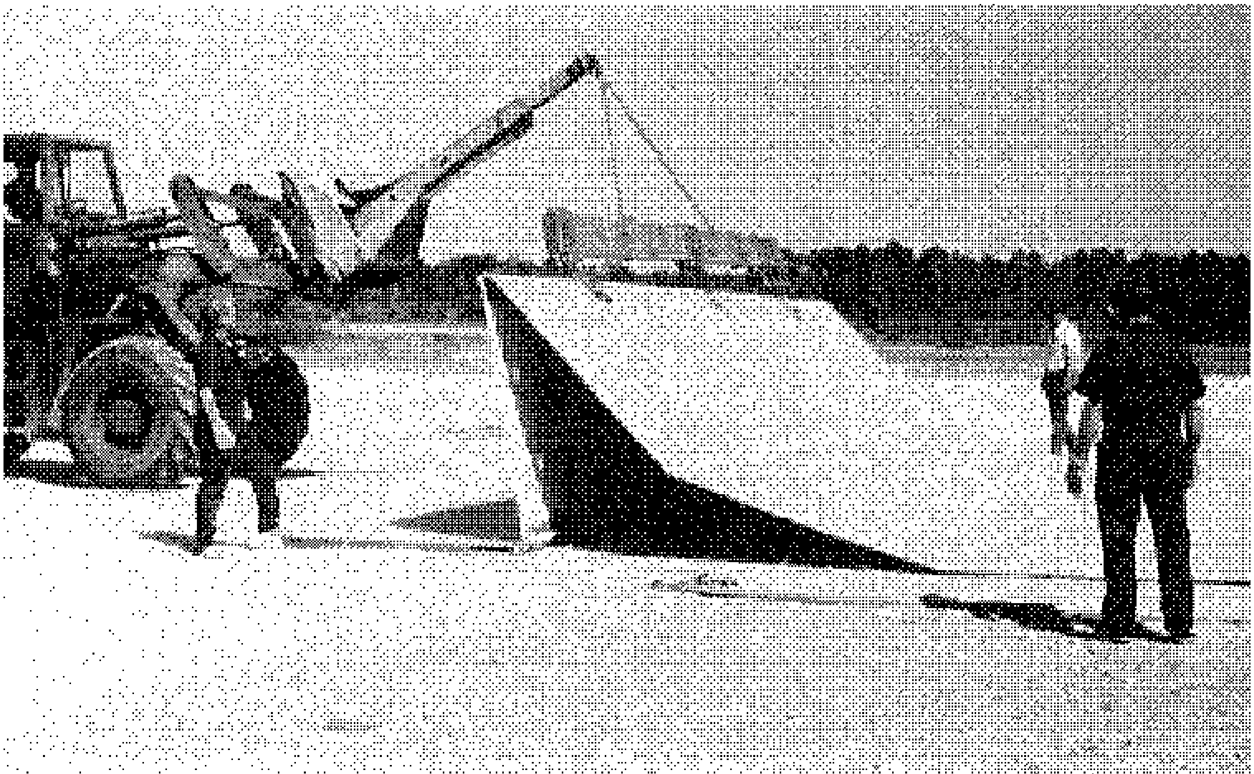


Figure 1.6. Early Version of Present-Day Folded Fiberglass Mat During Development at Tyndall AFB Test Facilities.



1.5. Scope. In the event of future hostilities, the United States Air Force will, as in the past, play a decisive role in defeating the aggressor. The flexibility, massive firepower, and speed of employment of our air forces are capabilities needed to win a future conflict. The overwhelming success enjoyed by Air Force from World War II through the Persian Gulf War amply demonstrated these features. To preserve these characteristics, however, we must maintain the relatively uninterrupted operation of our forward-based airfields through all stages of a conflict. During Desert Storm, allied air forces flew numerous sorties against Iraqi airfields, and in particular, airfield pavements. There is little reason to expect a capable enemy will not try to do likewise to us during a future conflict.

1.5.1. Fortunately we have never experienced a crippling air attack on one of our air bases in the recent past. Because of this, however, we have no real world RRR data base in terms of problems encountered, shortfalls experienced, or effort expended to draw from. This complicates the training situation in that training must be based on various assumptions, estimates, and subjective judgments. However, computer modeling techniques have indicated that given adequate equipment and personnel, current RRR procedures can meet the stringent parameters stipulated in various requirements documents and plans.

1.5.2. Obviously, the scope of airfield operating surface repair requirements will vary proportionally to the intensity of the attack. It could range from minor pavement disruption with minimal interference to aircraft operations to major airfield damage accompanied by complete shutdown of aircraft launch and recovery activity. It is this latter possibility that we must be prepared to handle swiftly and correctly. We should expect major airfield damage to include multiple bomb craters and numerous spall fields. In its most basic interpretation, the rapid runway repair mission is simply to overcome these multiple problems and provide an accessible and functional minimum airfield operating surface within a scant four hours. Though simplistic in outward appearance, it is a highly complex undertaking that may well have to be accomplished at night, in rain or snow, or even in a chemically contaminated environment. Achieving this lofty goal is what this volume is all about--repairing the airfield operating surface so that sortie generation can start as expeditiously as possible.

1.5.3. The following procedures are presented in this volume: damage assessment, minimum operating strip selection, repair quality criteria, rapid runway repair, and airfield marking. The material is presented in what may be expected to be its most common order of accomplishment. In addition, a number of attachments have also been included that serve to amplify some of the more intricate functions presented in a number of chapters.

Chapter 2

DAMAGE ASSESSMENT PROCEDURES

2.1. Introduction. From an engineering perspective, damage assessment activities are categorized into two distinct areas: rapid runway repair (RRR) damage assessment and facility and utility damage assessment. Resources permitting, both assessment operations should be conducted simultaneously and, depending on the situation at hand, may be of equal importance. Rapid runway repair assessments would include evaluation of damage involving runway surfaces, taxiway surfaces, and other facilities which directly support aircraft operations. Facility damage assessment includes assessment of damage to all other air base facilities and utility systems. For the purpose of this volume, we will limit our review to RRR assessment procedures. Facility damage assessment, which is conducted by teams referred to as damage assessment and response teams (DARTs), is presented in-depth in volume 3 of this series. Rapid runway repair damage assessment is the vital first step toward restoring an operational runway after an enemy attack. Since major recovery tasks cannot be started until damage assessment and minimum operating strip (MOS) selection are completed, speed and accuracy during damage assessment are essential. Dedicated RRR damage assessment teams (DATs) determine and report the location, types, and numbers of unexploded ordnance (UXO), and the location, types, and quantity of airfield pavement damage to the survival recovery center (SRC). A qualified team in the SRC, know as the MOS selection team, uses this information to select the MOS which must be cleared and repaired in order to launch and recover aircraft. In addition, this team must also take into consideration the damage requirements of the entire airfield operating surface, since such could plausibly impact aircraft generation. This entire airfield area is commonly referred to as the minimum airfield operating surface (MAOS). Simply put, the MAOS consists of a minimum operating strip and its supporting taxiways or access routes.

2.2. Overview. This chapter provides guidance for accomplishing RRR damage assessment operations. Organization, team composition, and equipment are described as well as assessment techniques and damage recording and reporting procedures.

2.3. General Information. During base recovery after attack (BRAAT), the survival recovery center is responsible to the wing operations center (WOC) for all base recovery and base support activities. It is manned by the support group commander and a recovery staff of essential organizations--such as civil engineer, which includes explosive ordnance disposal (EOD) and readiness--required to restore and provide base support functions.

2.3.1. Civil engineer functions performed in the SRC include directing damage assessment operations, recording and evaluating damage reports, plotting damage locations on airfield drawings, accomplishing MOS selection, developing repair plans, and directing recovery operations.

2.3.2. To shorten airfield restoration time, engineer damage assessment operations and explosive ordnance disposal/unexploded ordnance assessment operations will usually be accomplished jointly. Thus, the damage assessment team is organized to conduct ground assessments of UXO locations; pavement and navigational (NAVAID) damage; and aircraft arresting system condition, either on foot or from hardened vehicles.

2.4. Team Composition. A damage assessment team normally consists of one explosive ordnance disposal technician, one civil engineer specialist (usually an engineer technician), and one or more augmentees to assist in vehicle operation, recording information and communicating data to the SRC. Due to the length and width of the assessment areas, more than one DAT will usually be required. The exact number of teams necessary is a decision made by each base; however, three seems to be the norm. In general, the information presented in this manual regarding DAT team manning is based upon 1 lead and 2 follow team mobility augmentation. Each damage assessment team works to locate and identify UXO and pavement damage. Explosive ordnance disposal expertise is necessary to accurately identify and classify UXO, perform limited “render safe” procedures on selected ordnance, and oversee the activity in the hazardous UXO environment. However, as a general rule, “render safe” procedures are not performed unless two EOD members are present. The engineer member will determine the location and size of craters, camouflets, spall fields, and other airfield pavement damage. Normally, the ranking member will be the team chief. However, regardless of rank, the EOD technician is responsible for the team's movement where UXO exists. Field test results have proven that, with practice, the damage assessment teams can estimate short distances (less than 100 feet), crater diameters, and spall counts with acceptable accuracy without tape measurements.

2.5. Equipment. Equipment requirements of the DAT will depend on the means by which they will conduct damage assessment operations. For example, a team conducting damage assessment activities on foot will have different requirements than a team conducting assessment activities from a vehicle. In addition to chemical warfare defense ensembles, each team member may require certain equipment to perform a particular function. Explosive ordnance disposal personnel should reference appropriate operating instructions and technical orders to establish their required equipment. For the engineer member(s) of a DAT, the following is the recommended equipment that should have been assembled in the preattack phase:

2.5.1. Safety ropes for approaching an uncollapsed camouflet.

2.5.2. Data recording and reporting equipment to include base grid maps (both a crash grid map, 1":400', and an airfield pavement map with runway and station posts indicated, 1":100'), damage assessment forms, clipboards, writing implements, radios, and spare radio batteries.

2.5.3. Binoculars and night vision devices to improve detection capabilities.

2.5.4. Other equipment to enhance damage assessment includes explosion-proof, plastic-cased flashlights; nonmetallic measuring tapes; safety route boundary tapes; flags and UXO markers.

2.5.5. The damage assessment team should also develop a non-electronic reporting system (runner) and should include any additional items needed for this purpose in the equipment list.

2.6. Pavement Reference Marking System. For successful postattack communications, the damage assessment teams must be able to accurately locate the damage in relation to a reference system that the minimum operating strip selection team recognizes and understands. This reference system must be in place prior to the attack and be able to withstand the ravages of the onslaught. Furthermore, to achieve maximum effectiveness, the pavements reference system should be employed on all takeoff and landing (TOL) surfaces and their associated access routes.

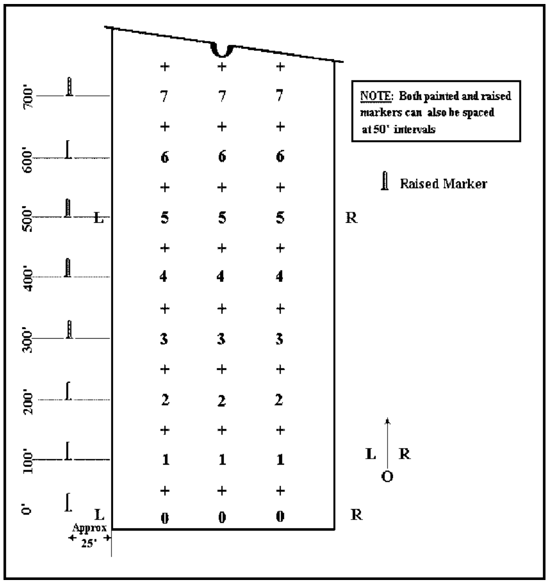
2.6.1. For each pavement surface, a zero point is established. With this reference system, damage and UXO can be located by identifying how far down the pavement they are from the zero point and how far right or left of the centerline they are. To eliminate the need for time consuming measurements, markers provide a visual cue which the DATs use to locate the damage and UXO. These markers are painted on the pavement surface at 50- or 100-foot intervals along the centerline and along each pavement edge, starting at the zero point. Additionally, raised markers are placed at 50- or 100-foot intervals at a distance of between 25 to 50 feet from edge of the pavement. This duplication and spacing away from the pavement edge helps ensure the reference system remains usable following an attack and actual recovery operations. Normally, placement of these raised markers is accomplished as part of preattack preparation and is included on the engineer damage control center (DCC) checklists. When using the pavement reference marking system, three basic rules need to be followed:

2.6.1.1. **Zero Point Rule.** For an airfield pavement section, the zero point is fixed. It does not switch from one end of the pavement to the other. The zero point is usually established at the runway threshold at which normal aircraft operations occur.

2.6.1.2. **Centerline Rule.** All distances along the length of the pavement section are measured along the centerline from the zero point for that pavement.

2.6.1.3. **Right/Left Rule.** Right and left of the centerline are determined as the DAT faces down the centerline of the pavement and moving away from the zero point. Figure 2.1 illustrates a typical pavement reference marking system and how the three basic rules are employed.

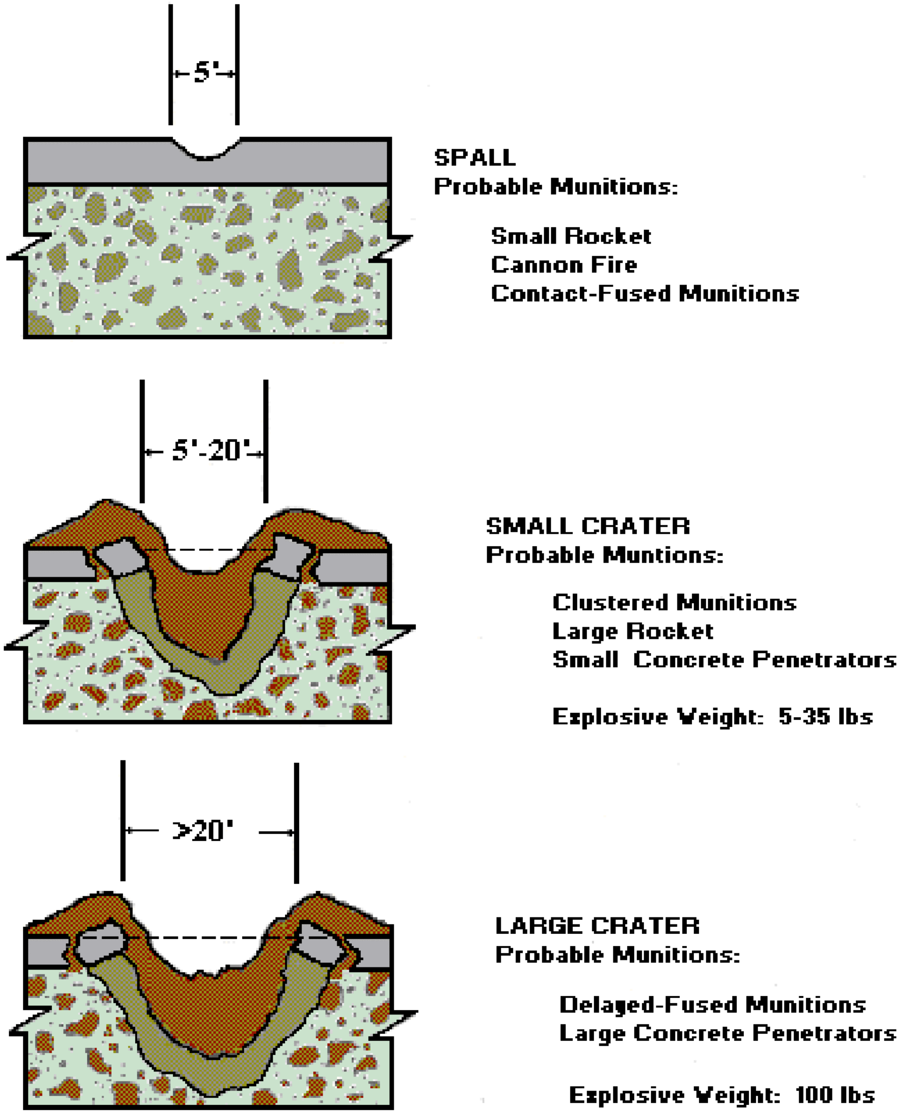
Figure 2.1. Typical Pavement Reference Marking System.



2.7. Damage Assessment Data. During damage assessment, DATs must gather two types of information--location of pavement damage caused by bombs, cannon fire; etc., and UXO data. The UXO data needed should include information regarding type, location and number. Unexploded ordnance that may influence aircraft operations must be accurately located, reported, and recorded in sufficient detail for the SRC explosive ordnance disposal representative to determine the risk to aircraft operations. Include the following information in the report: location, quantity, size, shape, color, distinctive markings, and fuze type and condition. All UXO within 300 feet of repair operations or aircraft operating surfaces must be identified. Holes of entry for subsurface UXO and camouflet craters must also be reported. Thus, scaled drawings must show sufficient adjacent area to include a 300-foot UXO radius-of-effect zone for paved surfaces and crater mat assembly areas.

2.7.1. Pavement damage (figure 2.2) to potential candidate MOSs will also be recorded on the same scaled drawings as the UXO reports. ***NOTE:*** Figure 2.2 shows limitations associated with each possible class of pavement damage. However, for DAT reporting purpose a crater has a sole identification of "C". This added information has been provided for those who are interested in seeing pictorial the limitations associated with each class of pavement damage.

Figure 2.2. Types of Pavement Damage.

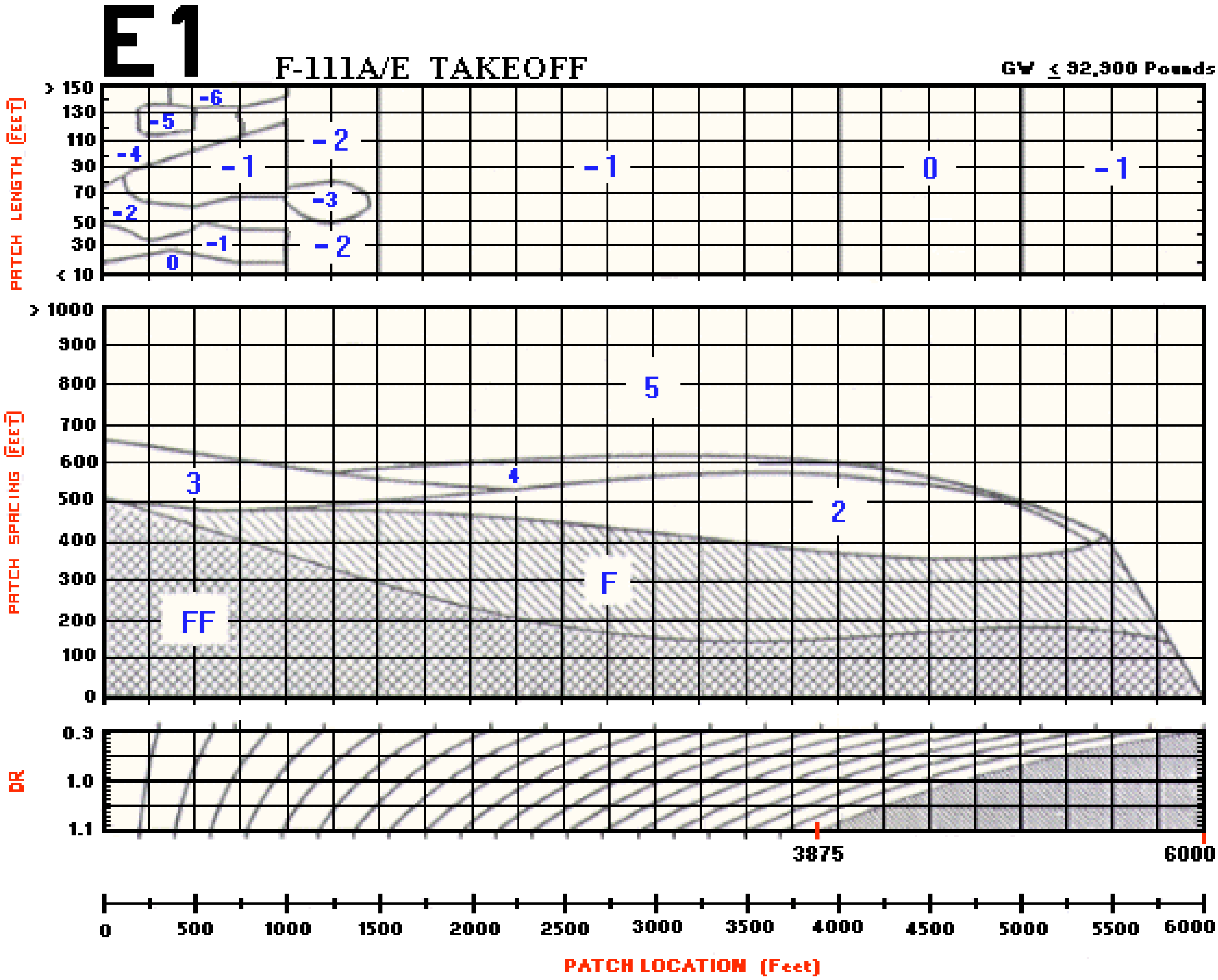


2.7.2. The following information should be included in each DAT report: damage type (crater, single spall, spall field, etc.); location (by grid coordinates or in relation to known reference markers); size (crater diameter, spall field dimensions, etc.); and number (of spalls in a field).

2.8. Assessment Technique. Current BRAAT planning is based on a two-phased damage assessment activity: Phase I--initial reconnaissance and Phase II--detailed damage assessment. In Phase I, an initial gross assessment is made from pre-positioned locations around the airfield. These locations are usually splinter protected and often elevated to afford clear visibility. From these advantage points, trained personnel can quickly locate areas of UXO and pavement damage on the airfield. The results of the preliminary survey helps the SRC to quickly direct the DATs to those areas requiring detailed damage assessment. In Phase II, where detailed damage assessment is conducted, the damage assessment teams follow a predetermined SRC-directed travel route from their staging location to their area of responsibility. Under the direction of the SRC, the DATs report the level of damage along these travel routes. Detailed damage assessment requires more accurate locating of damage than the initial reconnaissance because these reports are the basis for MOS selection.

2.9. Initial Reconnaissance (Phase I). The purpose of Phase I, initial reconnaissance is to quickly assess the postattack environment in order to identify the areas of pavement damage (figure 2.3).

Figure 2.3. Initial Reconnaissance.



2.9.1. Precise damage locations or measurements are not expected because most of the Phase I observations are made at some distance from the damaged area. The initial reconnaissance should be made from preselected observation posts by personnel trained in damage and pattern recognition. Examples of observation posts are the control tower, air base point defense positions, aircraft shelters, or other specific airfield vantage points. When hostilities are imminent, personnel will be assigned to those observation posts. After the attack, these individuals make visual observations and report the size and location of all damage as quickly and accurately as possible. Reporting procedures will depend on preattack instructions and available communications. Some observers may report directly to the SRC, while others report to their organizational control center. For example, security police observers may report directly to the security police base defense operations center, which would then relay the damage report to the SRC.

2.9.2. For any UXO threatening the launch and recovery surfaces, the individuals should attempt to provide information regarding the size, location, color, condition, etc., of the munition. Also, the extent of damaged pavement areas should be reported. From these observations and the resulting initial reports, pavement areas showing promise as possible MOSs may become readily apparent. However, if such is not the case, the SRC will direct DATs to assigned areas to conduct detailed damage assessment. Obviously, much time can be saved if the initial reports are thorough and informative enough to avoid DATs having to seek MOS candidates by area.

2.10. Detailed Reconnaissance (Phase II). Phase II damage assessment will be extremely hazardous and may be time consuming, depending on the level of damage. Since the extent of potential damage is most likely an unknown, several damage assessment teams (usually up to three teams) are designated prior to an attack and dispersed to protected locations on the base. Dispersal is important to ensure these personnel are available following an attack to conduct the vital first step in establishing an operational airfield runway. Immediately after an attack, the SRC relays damage assessment instructions to each DAT. This message is normally transmitted by radio and will include initial reconnaissance information, any changes to assigned damage assessment routes, and any special instructions necessary to define the task at hand. Damage assessment team travel routes are normally identified in advance during preattack planning. These preplanned routes ensure DATs do not waste time by assessing the same area. If appropriate, the SRC can modify the routes based upon the incoming initial assessment information. Since the primary purpose of airfield damage assessment is to ascertain the status and repair requirements associated with airfield pavement surfaces, the preplanned routes (and any successive modifications by the SRC) should take the DATs from their personnel shelters to the RRR staging area and then to the airfield areas. This approach ensures RRR teams have a relatively safe and clear path from their dispersed locations to the staging area and subsequent entry to damaged airfield locations. Logically, to achieve this outcome, the DATs must be sheltered close to where the RRR teams are and have their RRR equipment dispersed in locations with easy access to the DAT routes. These are not difficult feats to achieve, but they do entail some degree of preplanning.

2.10.1. The success of the damage assessment operation depends on dedicated communication links and strict communication procedures to ensure accurate transmission of damage information. The current concept calls for separate EOD and CE radio nets for transmission of this information. The EOD and CE representative on each DAT will transmit UXO and damage information to the SRC. With several DATs as well as other CE and EOD personnel around the base passing information to the command post over these radio nets, the potential for confusion is great. Clear, concise radio transmissions using strict radio discipline are essential. Unnecessary keying of the mike, transmission of unorganized thoughts, and interruption of other transmissions will necessitate repeat transmissions resulting in delay of MOS selection and start of repair operations. While radio communication is quick and generally effective, it does have the drawback of being jammed or intercepted. Until better communications are developed and fielded, "work-arounds" to these problems need to be addressed. About the only alternative now available is the use of a runner system. While the use of runners will lengthen the time required to pass information to the SRC, it will still get the job done.

2.10.2. Detailed reconnaissance may be conducted using two possible damage assessment techniques--manual or vehicular. Both require substantial civil engineer support.

2.10.3. Under the manual damage assessment system (MDAS), the runway-taxiway surface is surveyed by damage assessment teams on foot (figure 2.4). Damage assessment team members walk specified areas of the runway, identifying and locating UXO and damage to pavement and support systems. Normally, this is accomplished by using the pavement reference marking system. However, if possible, measurements should be made by pacing distances from known runway or taxiway locations, by estimating crater dimensions, and by visually determining UXO identifying features. In addition, the team should specify whether there is adequate pavement around taxiway damage to allow taxing aircraft to avoid the damage so repairs could be delayed to a more opportune time. Although the MDAS is the most accurate damage assessment method, it is extremely time consuming and exposes DAT members to UXO fragmentation and blast hazards. Actions of the individual team members are outlined in the following paragraphs.

Figure 2.4. Damage Assessment Team on Runway.

2.10.4. As addressed earlier, the EOD expert is responsible for the overall definition of safe travel routes through hazardous areas. The EOD member assigns areas or lanes of responsibility to each of the augmentees. As the team progresses through its area of responsibility, the EOD representative assists the augmentees in the proper identification of UXO and relays pertinent information to the SRC.

2.10.5. The civil engineer team member has the overall responsibility for damage assessment. The damage assessor will usually be an engineer technician and may be assisted in damage location and recording by one or more augmenters. However, as stated earlier, in areas of extreme bomb damage, the EOD representative typically takes charge of the damage assessment team to ensure all pertinent information is gathered, recorded, and relayed back to the SRC.

2.10.6. Augmenters are responsible for following the safe routes identified by the EOD member and identifying all pavement damage and UXO locations in the assigned area. Any identification problems are reported to the EOD or CE representative for resolution. Augmentees may also assist the EOD and CE members in transmitting information to the SRC. If a runner system must be implemented because of communications difficulties, the augmenters is usually called upon to serve as runners.

2.10.7. Following behind the DATs, the nuclear-biological-chemical (NBC) team samples the area for the presence of chemical or biological contamination. If contaminants are detected, the information is recorded and relayed to the SRC.

2.11. Vehicle Damage Assessment System (VDAS). Where the MDAS is a slow and hazardous damage assessment method, the VDAS offers increased speed and protection to the DAT. Ideally, with the VDAS, armored vehicles are used to transport the DATs between UXO and crater locations while providing protection from UXO blast and fragmentation effects. These benefits are not provided without some cost to system effectiveness. Visibility from inside the vehicle is restricted by the armor protection. This means the DATs must locate and identify UXO and damage from greater distances using binoculars. This limitation contributes to errors in reporting the size, position, and identification of UXO or damage. The accuracy of this method will vary from person to person. Observation distance, weather conditions, time of observation (night or day) and other human factors such as fatigue and fear will also affect the accuracy.

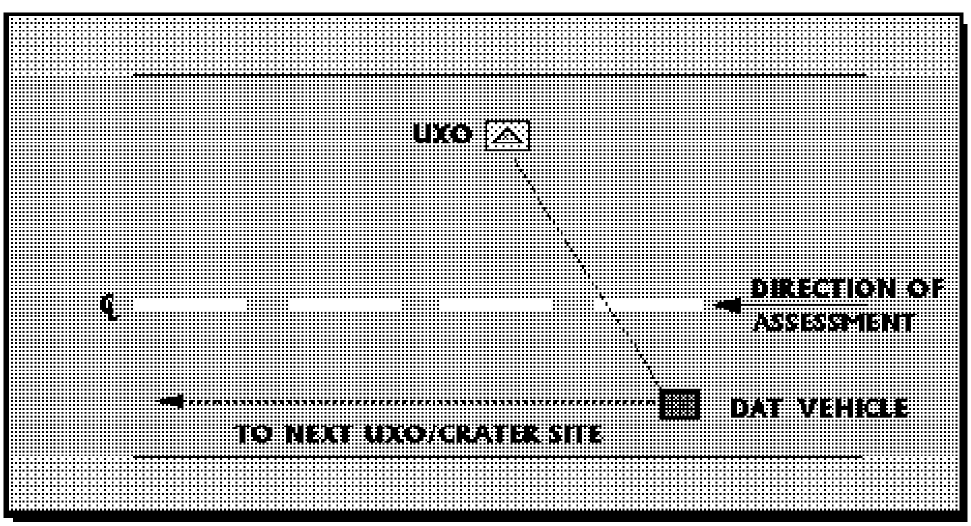
2.11.1. **Hardened Vehicles**. Hardened vehicles, such as the M113A2 armored personnel carrier and the up-armored HMMWV (figure 2.5), will provide protection from the UXO environment. If a hardened vehicle is not available, other possible substitutes include dump trucks, or a hardened rapid runway repair vehicle. Pickup trucks and similar vehicles do not provide the same measure of protection as do hardened vehicles; however, these vehicles may be reinforced with sand bags, plexiglass, plywood, etc. The DAT composition for the VDAS will vary with vehicle capacity, but should generally be the same as the MDAS team composition discussed earlier. As is the case with a MDAS team, the EOD experts are responsible for identifying UXO and safest travel routes. The civil engineer expert is responsible for identifying the damage to airfield pavements, airfield lighting, aircraft arresting system, utility systems, etc. Augmentation personnel will assist the other team members as needed and usually are trained to serve as the vehicle operator for the team.

Figure 2.5. Up-Armored HMMWV.

2.11.2. **VDAT General Guidelines.** Some general guidelines for vehicle-based damaged assessment are as follows. The best travel route will normally be along the pavement centerline. This route gives equal visibility to both sides of the runway and allows DAT personnel to visually sweep the area with binoculars forward and to the sides of the vehicle. Obviously, a meandering path may have to be taken to avoid UXO or pavement damage. When this is necessary, the DAT must be careful not to miss damage or UXO on the side of the runway. Because the vehicle is used for protection, the damage assessors should remain inside except for extreme cases where remaining in the vehicle would gravely hamper the assessment effort. An example of such would be a scenario where the extreme level of damage has destroyed the pavement reference system. In this case, the assessors would have to estimate the distance from the nearest remaining reference marker to assure the required accuracy. Specific procedures for vehicle-based damage assessment of various types of UXO and damage are detailed in the following paragraphs.

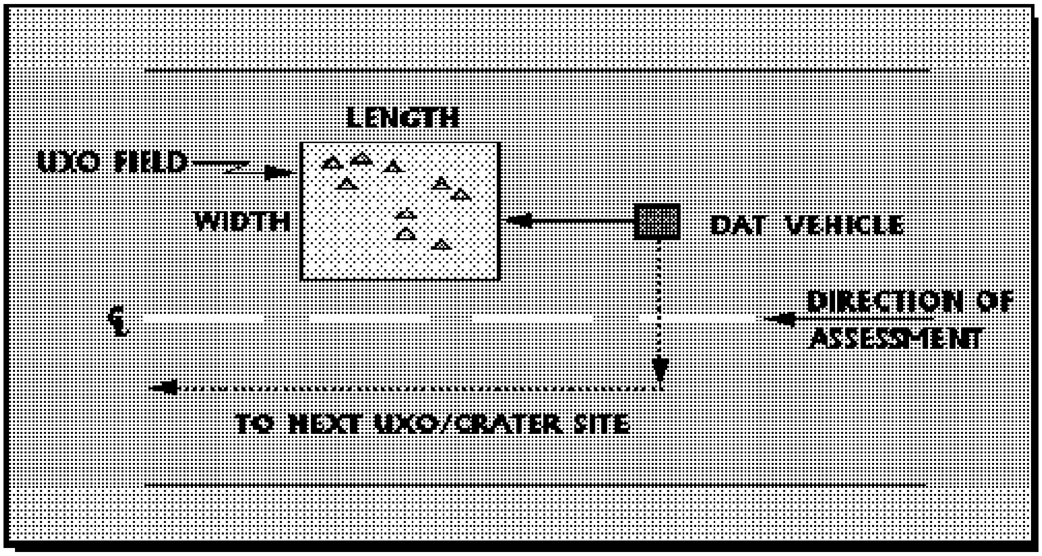
2.11.3. **Large UXO.** When the DAT sights a large UXO on the runway surface, the damage assessment vehicle will move off the runway centerline and approach on the far runway shoulder edge (figure 2.6). The DAT will then stop and record as much of the following information as possible: location, number, shape, color, weight, markings, coordinates, and estimated render safe time.

Figure 2.6. Single UXO Assessment.



2.11.4. **UXO Field.** When the DAT sights a bomblet or group of bomblets they should approach the closest ordnance (figure 2.7) at a safe distance and record the following information: number, shape, location, field width, field length, color, markings, and render-safe time. When this information is recorded and reported to the SRC, the DAT should drive past the field in such a manner so as to provide the maximum standoff distance between the UXO field boundaries and the team.

Figure 2.7. UXO Field Assessment.

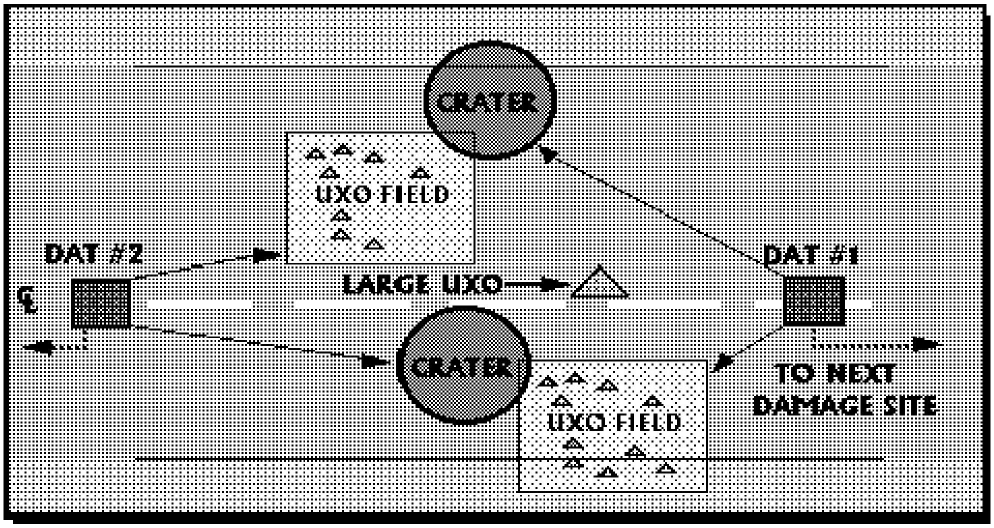


2.11.5. **Bomb Crater/Camouflet.** When bomb craters or camouflets are detected during vehicular damage assessment, the DAT should approach the area with caution. If the area appears to be free of UXO, move as close to the crater as possible for damage assessment. Coordinates for the center of each crater and the apparent crater diameter will be recorded. If a camouflet is discovered, its coordinates and the size of the entry hole will be recorded. Data on craters, UXO, and camouflets will be immediately relayed to the SRC. This immediate reporting procedure not only aids in hastening the MOS selection process but also serves to keep the SRC staff aware of the team's position on a frequent basis.

2.11.6. **Spalls.** Spall fields are similar to bomb craters in that they too should be carefully examined from a distance for the presence of UXO. If no UXO is sighted, the DAT should move the vehicle into the area and record the following information: coordinates of field location, starting point of the leading edge, field length, field width, and number of spalls. Because spalls are not highly visible even at close range, spall counts and field dimensions may be difficult to determine, especially since spalls are likely to be covered with debris.

2.11.7. **Multiple Ordnance/Damage Sites.** It is also possible that a DAT may encounter a situation where damage and UXO presence are so severe that they prevent continuation of the planned assessment run. Before attempting a circuitous route to reach the other side of the blocked area, the DAT should inform the SRC of the situation. The SRC may see a pattern developing, based on the damage reported, which allows adjustment of travel routes and have a different DAT finish assessing the affected pavement area (figure 2.8). In this type of situation, both DATs would assess damage from their respective sides of the blockage and report their findings back to the SRC. The SRC, in turn, would plot a composite of the area and, in all likelihood, develop a reasonably accurate picture of the damage sustained.

Figure 2.8. Multiple UXO/Damage Assessment.

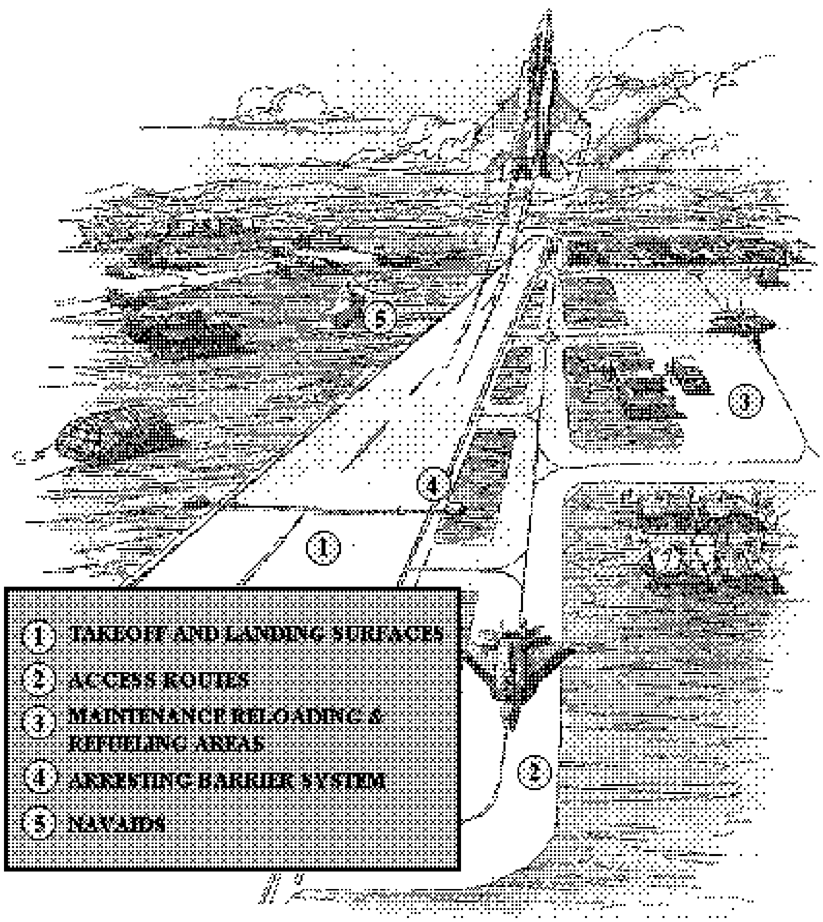


2.11.8. **Damage Recording and Reporting.** As the damage is assessed, it must be recorded and immediately reported to the SRC for damage plotting and MOS selection. The speed of reporting depends on the complete understanding of the information being relayed and strict adherence to radio discipline by both SRC and DAT personnel. A written list of the reported damage should be kept by each DAT and provided to the SRC for verification purposes upon their return.

2.12. Priorities. As mentioned earlier, DAT travel routes are normally predetermined in that they will start at the DAT personnel shelters, move to the RRR staging area, and then head toward the more critical aircraft pavements. These routes are updated or altered as required based on initial damage assessment reports. Generally, the SRC will have selected DAT travel routes so that the airfield is surveyed in the following priority (figure 2.9):

- Takeoff and Landing Surfaces. This includes runways, alternate launch and recovery surfaces, and taxiway segments that are long enough to permit aircraft launch and recovery.
- Access pavements to launch and recovery surfaces.
- Aircraft maintenance, rearming, and refueling areas.
- Aircraft arresting systems.
- NAVAIDS.
- Aircraft shelters and parking areas.
- Other SRC specified locations.

Figure 2.9. Critical Airfield Areas to be Surveyed.



2.13. Locating Damage. To determine the damage location when it is off the takeoff and landing surfaces and access routes, use the crash grid map coordinates. Most civil engineer personnel are familiar with the crash grid reference system. It is very useful for locating problems any place on base, especially when the precise location is not critical. Simply put, it is a base map with a grid overlay shown--usually in a 1:4,800 scale. It may also be used as a fallback system for TOL surface damage assessment at those locations, such as a collocated operating base, where a pavement reference marking system may not exist.

2.14. Recording and Reporting Damage. Each damage item is recorded as shown in figure 2.10 and is reported as a series of letters and numbers. A plot of these damage items on a 150-foot wide runway is shown in figure 2.11. Each plotting item is as follows:

Figure 2.10. Recording/Reporting Procedure.

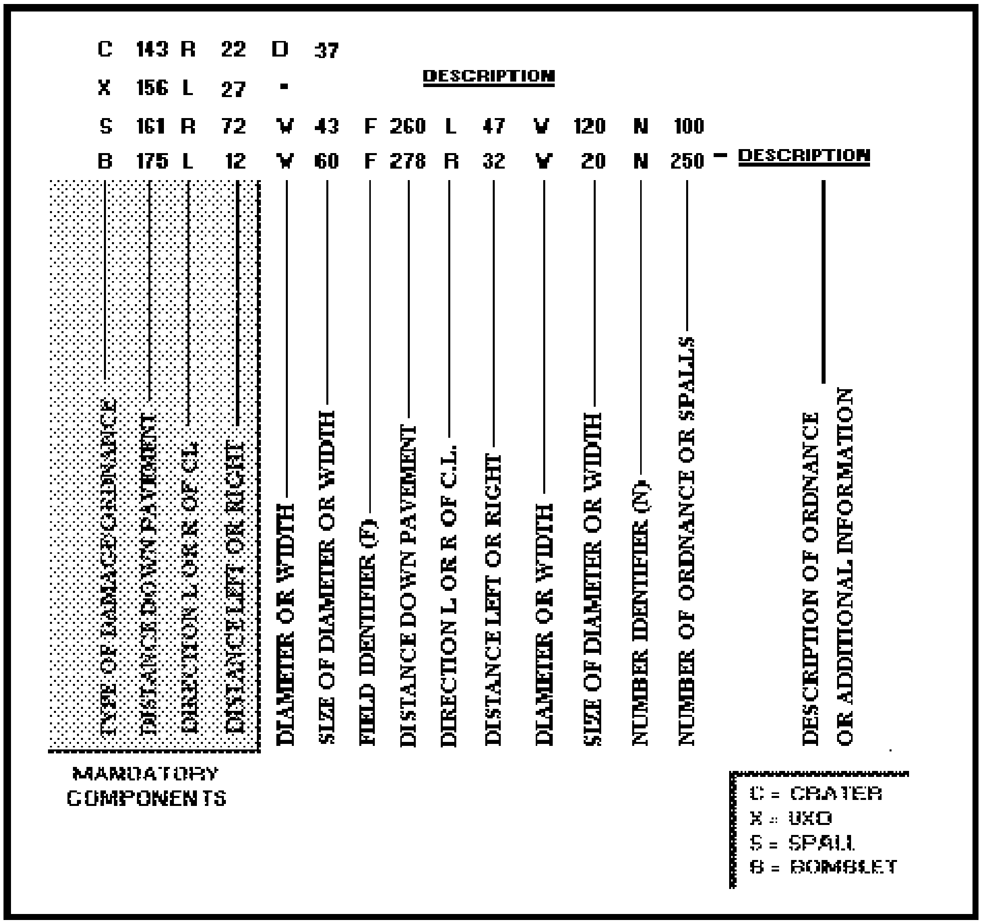
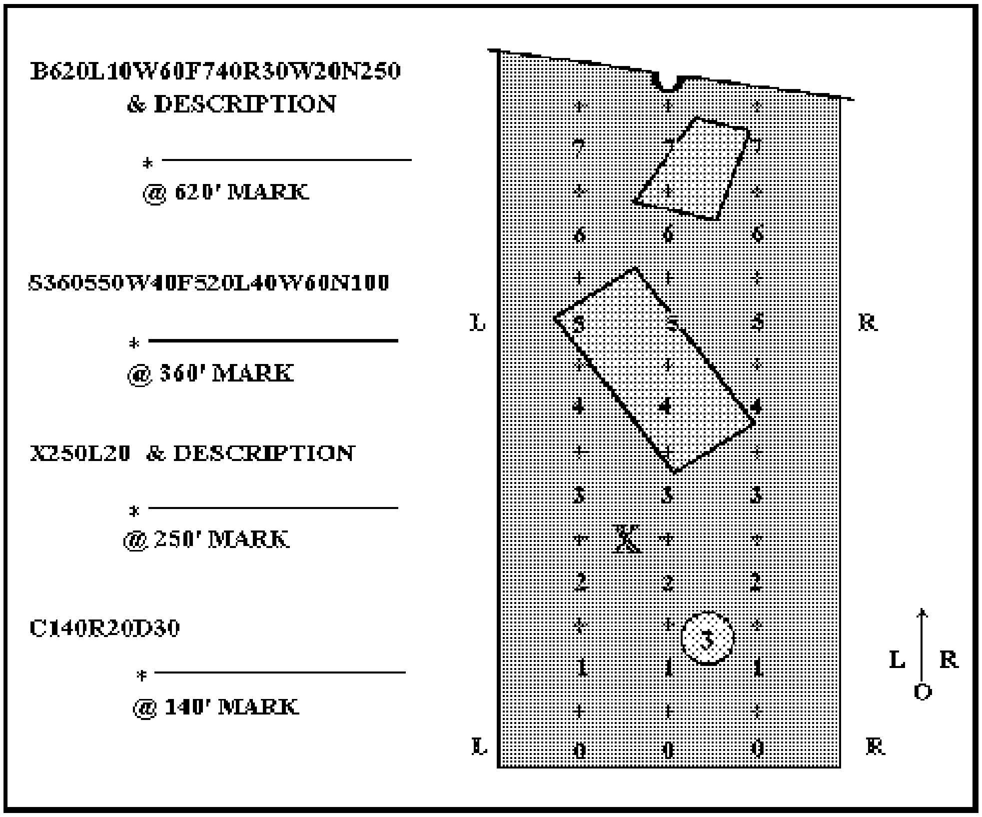


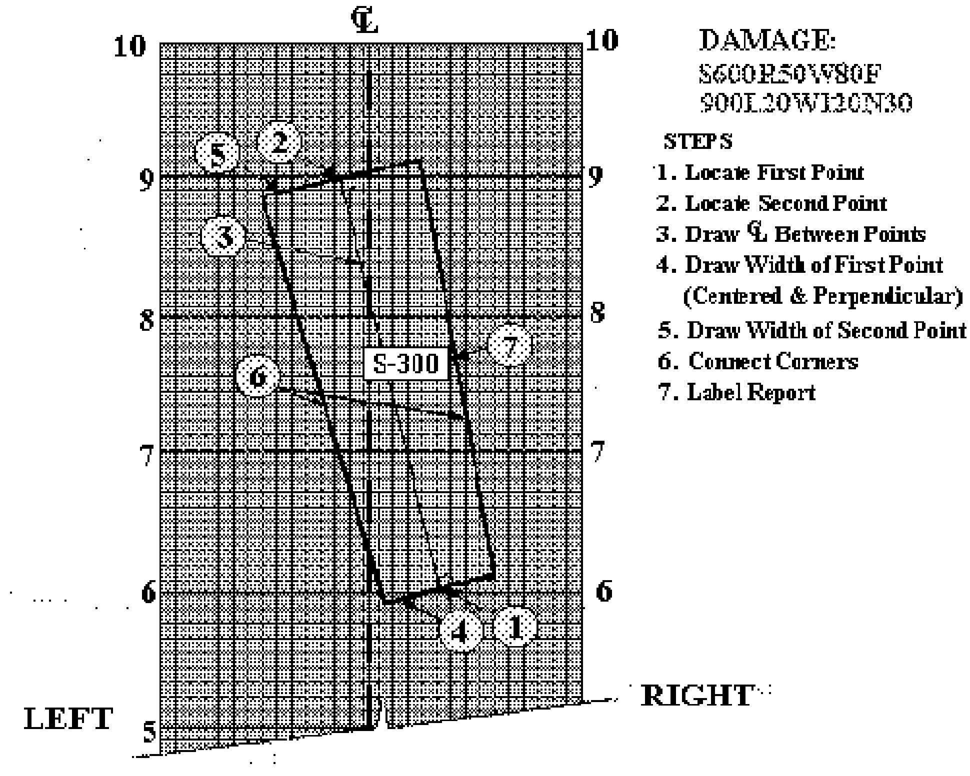
Figure 2.11. Data Report and Plot of Damage.



2.14.1. **Type of Damage or Ordnance.** The damage or ordnance type is entered here, using a letter coding such as "C" for crater, "X" for UXO, "S" for spall, and "B" for bomblet.
2.14.2. **Distance Down Pavement.** The distance from the zero pavement reference marker point to the center of the crater, UXO, or to the closest leading edge of the spall or bomblet field.
2.14.3. **Direction L or R of Centerline.** "L" stands for left, "R" stands for right. They denote the direction from the pavement centerline to the damage/UXO center point.
2.14.4. **Distance Left or Right.** This is the numerical distance expressed in feet.
2.14.5. **Diameter or Width.** For craters, enter the letter "D". For spall or bomblet fields, enter the letter "W".
2.14.6. **Size of Diameter or Width.** The numerical estimation of the apparent diameter or field width for that point along the pavement.
2.14.7. **Field Identifier.** If required, enter the letter "F" to alert the SRC that the following information completes the description of the spall or bomblet field. The next group of alphanumerics after "F" stand for the same as above and describe the second side of the field.
2.14.8. **Number Identifier (N).** The letter "N" alerts the SRC that the field identifier is completed and that the next number is the number of spalls or bomblets.
2.14.9. **Number of Bomblets or Spalls.** The numerical estimate of the number of bomblets or spalls in the field previously identified.
2.14.10. **Description.** Used to convey any additional information that would be helpful in accurately identifying the pavement damage or ordnance (i.e. color, shape, bands, size, features, etc.).

2.15. Double Point Damage Plotting Steps. Once the information identified by the damage assessment teams is forwarded to the SRC, it must be correctly plotted in order to determine its impact on the MOS selection process. Normally, for spalls and bomblets a process called double point plotting is used. The steps involved in conducting double point plotting are as shown below and in figure 2.12. Additional information regarding damage plotting and specific considerations applied during the MOS selection procedure are presented in chapter 3 of this pamphlet.

Figure 2.12. Double Point Damage Plotting.



2.15.1. **Step 1.** Identify specific type of damage (usually spalls or bomblets).
2.15.2. **Step 2.** Determine distance down the runway for first point, left or right of centerline, distance left or right and locate point.
2.15.3. **Step 3.** Determine distance down the runway for second point, left or right of the centerline, distance left or right and locate point.
2.15.4. **Step 4.** Construct centerline of field by connecting first and second points.
2.15.5. **Step 5.** Draw first point width, centered and perpendicular to the centerline of the two points.
2.15.6. **Step 6.** Draw second point width, centered and perpendicular to the centerline of the two points.
2.15.7. **Step 7.** Connect corners of end lines.
2.15.8. **Step 8**. Label the report.

2.16. Chapter Summary. Damage assessment forms the foundation for prompt and effective base recovery actions. Two primary types of teams that involve civil engineers are used in this activity. DATs, controlled by the SRC, concentrate on airfield pavement damage assessment so that rapid runway repair teams can provide a minimum operating strip and access taxiways for combat aircraft as quickly as possible. On the other hand, teams called DARTs are controlled by the engineer damage control center and respond to damage assessment requirements associated with base facilities and utilities. If effective damage assessments are to be realized, both DATs and DARTs must be comprised of qualified, experienced personnel; be provided adequate communications, transport, and protective equipment; and be completely knowledgeable of damage assessment procedures. In addition, a pavement reference marking system, used to identify the locations of damage and UXO on airfield pavements, must be employed if the airfield damage assessment process is to be within the required accuracy. The success of subsequent RRR activities to a large degree hinge upon the accuracy of the damage assessment teams efforts.

Chapter 3

MINIMUM OPERATING STRIP (MOS) SELECTION PROCEDURES

3.1. Introduction. If an enemy attacks an air base, the commander's immediate problem is to launch and recover mission aircraft as soon as possible after the attack. The base civil engineer must recommend the "best" airfield surfaces to repair--those that require the least repair time but still provide adequate launch and recovery surfaces for mission aircraft. The launch and recovery surface selected for repair is called the minimum operating strip (MOS). The MOS is the area from which aircraft actually takeoff and land. For fighter aircraft the MOS is nominally 5,000 feet by 50 feet, although its actual dimensions vary with aircraft type and weights as well as environment. When a MOS is combined with access taxiways from aircraft staging areas such as shelters and parking ramps, the entire area becomes the minimum airfield operating surface (MAOS). Most of the information presented in this chapter will focus upon MOS considerations. However, be aware that a MOS cannot be selected without a full appreciation of the extent of damage throughout the entire MAOS. For example, if an ideal MOS is identified that involves a minimum repair effort, finding acceptable access routes to that location should also be taken into account. If necessary, transitional taxiway routes may have to be constructed, assuming that the tradeoff in resource expenditure justify such. In addition, repair quality criteria (RQC) should be considered as part of the selection process. This is not to imply that the MOS selection team will include RQC calculations as part of their MOS selection process. Rather, it means that the team should be familiar enough with the RQC process to be able to indirectly apply fundamental RQC requisites when seeking the best MOS candidates. Confusion can often be avoided between the closely related acronyms MOS and MAOS, if you do not become a "definition purist". When used to describe situations, both term frequently overlap one another. Keep these points in mind as you progress in this chapter.

3.1.1. **Engineer Activities.** When an airfield is attacked, engineer personnel will respond with four kinds of activities:

3.1.1.1. Damage assessment.

3.1.1.2. Identification of candidate minimum operating strips.

3.1.1.3. Safing and disposal of explosive ordnance.

3.1.1.4. Repair of bomb damage.

3.1.2. **Event Order.** Damage assessment, covered in the preceding chapter, provides information about the location and extent of damage to the surfaces of the airfield. The wing operations center (WOC) provides other information on operational requirements and expected operating conditions following the attack. Using all this information, the MOS selection team locates potential operating strips to be repaired and recommends MOS candidates to the commander. After a specific MOS is approved by the wing commander, the survival recovery center (SRC) commander directs the explosive ordnance disposal teams work on the areas designated to be cleared. Finally, the rapid runway repair (RRR) teams move in to repair craters and spalls, clear debris, repair airfield collateral damage, and mark the MOS location. These activities are discussed in depth in subsequent chapters of this document. Since much of the success of the MOS selection procedure depends on advance training, personnel should be thoroughly prepared. All engineer SRC and damage control center (DCC) team members must be familiar with MOS selection procedure and understand each of its phases. Suggested MOS selection kit contents are outlined in paragraph 3.8 of this volume.

3.2. Overview. This chapter serves as a guide for personnel who must choose candidate minimum operating strips. Divided into two major parts, the chapter provides a broad picture of the MOS candidate selection process, to include concept of operations, team organization, sequence of the selection steps, and characteristics of a good MOS. The second major part of this chapter contains detailed procedures for MOS selection. An illustrated example of MOS selection is also presented. Common MOS selection terms are contained in attachment 1 (Terms Explained).

3.3. Concept of Operations. The current base recovery after attack (BRAAT) concept calls for a primary and an alternate survival recovery center (SRC). Both of these SRCs will have a MOS selection team assigned and will simultaneously perform MOS selection. This provides a double check on proposed MOS candidates and allows smooth transfer of control in the event that the primary SRC is incapacitated.

3.3.1. The MOS selection team will receive the damage and unexploded ordnance (UXO) information provided by the damage assessment teams (DATs) and identify acceptable MOSs. In the primary SRC a civil engineer representative will record data items, such as crater and spall damage. Similarly, the EOD representative in the primary SRC, using a different radio frequency, will record UXO type, location, and fuze data. Airfield damage and UXO locations will be plotted on the MOS selection map. In the alternate SRC, these same data are recorded by the civil engineer representatives and plotted on their equivalent MOS selection map. The wing operations center provides other information on operational requirements such as expected weather conditions, aircraft loads, desired MOS length and width, and arresting barrier requirements. As data are received, MOS selection procedures are conducted so that when the last DAT reports are received, the MOS candidate selection process is nearing completion. When a candidate MOS is identified, it is recommended to the wing commander for approval. It is also a good idea to have a couple of alternate MOS possibilities available in case previously unknown operational requirements surface which impact the suitability of the originally recommended MOS.

3.3.2. After the MOS has been selected by the wing commander, the BCE will direct the damage control center to prepare to relocate the RRR equipment from the dispersed locations to the appropriate staging area and make all necessary final arrangement in preparation to commence the necessary airfield reconstitution. At the same time, the SRC commander will direct EOD personnel to begin the safing, removal, and/or the "leave alone" UXO activities. This will invoke the employment of EOD teams for render-safe procedures and clearing submunitions from the MOS and other areas of repair. Once RRR activities are underway, primary and alternate MOS selection teams will commence repair quality criteria (RQC) calculations for the chosen MOS. It should be noted that the sequencing of the aforementioned activities is not cardinal. Many situations may develop that will necessitate adjustments. For example, it is plausible that a delay in the actual decision of which MOS to repair may allow the MOS selection team sufficient time to conduct RQC calculations on all MOS candidates beforehand. On the other hand, a route used from one of the RRR dispersal areas may encumbered by UXO problems resulting in a noticeable delay before that equipment will be available to contribute toward the recovery effort. Flexibility is essential to success of any complex undertaking and RRR is by no means an exception.

3.3.3. In addition to repairing the pavement damage, civil engineer personnel will mark the MOS, install the airfield lighting system, and, if necessary, install a mobile aircraft arresting barrier. Minimum operating strip marking is normally required prior to launching sorties. However, installing the barrier and lighting systems may be accomplished after air operations have begun, providing initial operations are in daylight hours and takeoff and landings can be accomplished without a barrier. Both of these provisos require approval of the WOC.

3.4. Team Composition. The MOS selection team is comprised, as a minimum, of two personnel--one of which should be an engineer assistant (AFS 3E5X1). The second team member serves as a radio operator and data recorder, while the engineer assistant acts as a data plotter. The EOD representative in the SRC supports the two civil engineer personnel by receiving and recording EOD related data from the DATs and providing technical expertise on how UXO information should be displayed on the airfield maps. Both the primary and alternate SRCs will be staffed with similar teams. Table 3.1 provides further details on the SRC team's composition, skill requirements, and responsibilities. Be aware that the manning shown in table 3.1 and figure A2.2 represent an ideal arrangement. Local situations many dictate a number of other manning configurations. ***NOTE:*** Additional information regarding the composition of the SRC team, of which the MOS selection team is a component, is outlined in paragraph 5.8.1 of AFPAM 10-219, volume 1.

3.5. MOS Selection Activity Sequencing. On declaration of alert, the MOS selection team members report to the primary and alternate SRCs. Once assembled, the team requests operational requirements and expected operating conditions from the WOC. The WOC also decides whether the MOS must support aircraft operations in one or two directions, depending on the wind directions expected. The MOS selection team also checks to ensure all necessary charts, maps, templates, etc., are readily available; conducts communications checks with the DCC and DATs, and verifies status of engineer equipment, materials, and supplies.

3.5.1. After an attack, the MOS candidate selection process begins as the team receives damage reports in the SRC. Damage to pavement surfaces and locations of UXO are plotted on scaled airfield maps. Damage assessment teams report craters by center coordinates and apparent diameter. Craters are drawn on airfield maps as circles whose diameters represent estimated repair diameters, which are twice the apparent diameters. Unexploded ordnance are identified with an "**X**". Spall and bomblet fields are also reported by identifying the field perimeters and approximate number of ordnance or spalls involved in each designated area.

3.5.2. Once the UXO and damage are plotted and the MOS requirements determined, the MOS selection team has two tasks, parts of which may proceed simultaneously: (1) identify potential MOS locations and, (2) identify access routes. One easy and expedient way of locating candidate MOSs is to fabricate a transparent template beforehand to the size (scale) of the required MOS. Once this is done, simply move the template over the map's surface until a promising MOS is located. Ideally, access/egress routes to and from the MOS must permit aircraft to taxi from each of the shelter areas to one end of the MOS and, after landing, allow taxiing from the other end of the MOS back to the shelter areas. Obviously, pertinent taxiway damage must be repaired before aircraft can be launched. Consequently, taxiway damage should be part of the DAT evaluation procedure before MOS candidate selection can be finalized. However, usually this action is not accomplished until after the DATs have completed their MOS evaluation. Initial searches by the SRC staff for candidate MOSs should consider those that have the same centerline as the runway, and if at all possible, are at either end of the original runway. Other selection considerations of consequence include looking for a MOS that can maximize the use of existing NAVigational AIDS (NAVAIDS), provide pilots a familiar runway centerline and threshold, minimize MOS painting/blackout, speed UXO clearance (on/off pavement operations), and possibly permit use of the existing aircraft arresting system.

Table 3.1. SRC Team Organization.

POSITION	NUMBER OF PERSONNEL	AIR FORCE SPECIALTY	REQUIRED SKILLS	RESPONSIBILITIES
BCE	1	32E3		Overseer
Team Chief	1	32E3 or 3E5X1	Know MOS candidate selection criteria and RQC procedures.	
Plotter	1	3E5X1		Plot data, select candidate MOSs, and calculate RQC
CE Radio Operator	2	3E9X1	Radio ops and data recorder	Receive/record data; assist with MOS selection
SUPPORT PERSONNEL				
EOD Tech	1	3E8X1	Radio operations, data recorder, and technical EOD expertise	Receive/record data; provide technical advice
DATs	3	3E5X1	Know airfield marking system, crater and spall damage assessment procedures. Also, be able to perform utility, facility, and NAVAID damage evaluations.	Assess pavement and supporting airfield systems damage and provide such data to the SRC.
	1	3E8X1	UXO identification	Provide EOD input to SRC.
	1	Augmenter	Vehicle operation and damage and UXO recording procedures.	Operate the DAT vehicle and develop a "hard copy" report of information provided to SRC.

3.5.3. When a sufficient search has been conducted and the team has identified and evaluated the most promising MOS candidates, normally the MOS(s) with the least amount of repairs required, they are reported to the commander. At this time, the commander should also be briefed on the status of repair resources, expected time to first aircraft sortie generation and any operational limitation associated with each potential MOS. After the MOS is selected and EOD operations and RRR begin, the MOS selection team updates the plotting map as new recovery operation data are received by the SRC.
3.5.4. Additionally, once the MOS has been selected and RRR efforts begin, the MOS selection team performs RQC calculations. At one time when use of AM-2 matting was the primary method of runway crater repair, great attention had to be paid to the spacings and smoothness of repairs prior to selection of the MOS. However, now that the folded fiberglass mat technique, considered a flush repair, is used on damaged runway surfaces, the impact of spacing and smoothness has eased considerably. Repair quality criteria calculations provide the allowable tolerances for crater repairs in terms of how far out from a perfect flush repair an actual repair can be and still be acceptable for aircraft traffic.

3.6. MOS Characteristics. Simply stated, the goal of MOS candidate selection is to locate the best available MOS that can be repaired in the least amount of time. A good MOS has many characteristics, the ranking of which will depend upon the situation at a particular base that is attacked. Consequently, the MOS selection process must be flexible to identify the best option under a wide variety of circumstances. As a general rule, a good MOS will allow rapid restoration of launch and recovery capability. With either of the two currently approved RRR techniques, crater repair is a lengthy process. Thus, initially it is important to repair no more damage than necessary. This is the reason that it is worthwhile waiting for completion of RRR damage assessment before finalizing MOS selection. The MOS selection procedure is designed to choose a runway that is comparatively low in crater and spall damage. Repair time, therefore, is saved at the cost of initial delay caused by accurately identifying and plotting damage and selecting a MOS. While in the majority of cases the MOS with the least damage will be selected, this may not always be the situation--other consequential considerations could come into play.
3.6.1. **Resource Limitations.** A RRR team's capability may be hampered by resource shortages and equipment deficiencies.

If there are notable limitations, the MOS selection team should consider them when choosing candidates. As reconnaissance reports are received in the SRC, the selection team must make a conscious decision to monitor the status of RRR equipment and materials and keep this information in mind during the MOS selection process. Engineer personnel in the alternate SRC and DCC should also monitor equipment and material status as a cross-check for accuracy. As airfield damage assessment nears completion, a quick verification on equipment and material status between all control centers should be accomplished to ensure the most current data are being considered.

3.6.2. **Sortie Capability.** Aircraft should be able to get to and from the MOS quickly. If you select a MOS without regard to sortie generation capability, aircraft operations could be restricted after MOS repair. The launch or recovery (LOR) status of an airfield measures sortie generation capability, independent of variables such as mission time, aircraft attrition, and origin of aircraft (aircraft may launch at one air base and be recovered at another). A few examples of how various restrictions can reduce LOR capabilities are shown in table 3.2. The highlighted example in table 3.2 shows that a MOS with two access taxiways that requires an aircraft to backtrack more than 2,000 feet will have a LOR capability of only 50%. Additional explanations of other common LOR restrictions are described below.

3.6.2.1. **LOR Status.** The LOR status of a MOS is the total number of launches and recoveries the surface can handle per unit time compared to the number that could be handled by the same undamaged airfield. A LOR status of 100 percent simply means that the MOS and its access route(s) are not restricting sortie capacity. Even if its LOR status is substantially less than 100 percent, this does not necessarily mean that the MOS is limiting sortie capability. Normal operations may not use the entire capability, and other factors in the base status after an attack may be even more limiting.

3.6.2.2. **MOS Location.** A MOS may be located on the main runway, on a parallel taxiway, or even on an alternate launch and recovery surface on or off base. The MOS location affects LOR status in various ways by limiting access and egress, by limiting air traffic control, or by restricting the flight approach of aircraft.

Table 3.2. MOS Launch or Recovery (LOR) Capability.

Two Access Taxi ways	One Access Taxi way	Taxi Backtrack Greater Than 1,000 Ft.	Taxi Backtrack Greater Than 2,000 Ft.	Barrier Engage-ment With Each Aircraft	Air Traffic Control Equipment Not Functional	Relative LOR Capa-bility
X						100%
X				X		34%
X				X	X	25%
X		X				60%
X			**X**			**50%**
	X					40%
	X			X		27%
	X			X	X	19%

3.6.2.2.1. **Air Traffic Control Limitations.** The availability of NAVAIDS to control air traffic can significantly improve the launch and recovery capability of a MOS. NAVAIDS provide pilots with the information necessary to locate the air base and the operating strip efficiently. NAVAIDS are also necessary to support operations when visibility is poor (including foul weather and nighttime).

3.6.2.2.1.1. **Location Consequences.** Location of the MOS has no effect on visual NAVAIDS such as emergency runway and airstrip lighting systems, since all these are portable and can be installed wherever the MOS is located. However, location of the MOS does affect the use of nonvisual aids. If there are no nonvisual NAVAIDS, aircraft can be recovered only when weather conditions are good.

3.6.2.2.1.2. **Minimum NAVAID Requirements.** The minimum NAVAID requirements for a MOS are tactical air navigation (TACAN)--a radio transmitter emitting 360 degrees, which the pilot uses to locate the airfield; and ground control approach (GCA)--a system which guides the aircraft onto a particular strip. The TACAN for the airfield will support any MOS, regardless of its location on the field. Ground control approach support can be provided to a MOS so long as neither the MOS threshold or departure is located within 3,000 feet of the original runway threshold of any GCA-supported runway. If a MOS was selected on an airfield surface that did not meet this criterion, or if the TACAN or GCA facilities were damaged in the attack, LOR status could be degraded by as much as 25 percent. If both systems were inoperable, landing capacity would be reduced by as much as 50 percent. If a MOS falls outside the air traffic control range and portable equipment is unavailable or takes a long time to set up, the MOS selection team should be aware that LOR status may be further degraded.

3.6.2.2.2. **Access/Egress Limitations.** Inadequate access or egress forces aircraft to taxi on the MOS, which results in excessive runway occupancy. At least two access routes are desired, preferably one at each end of the MOS. More limited access/egress may reduce LOR rates. Some of the more common access route limitations include:

3.6.2.2.2.1. **Cul-de-Sac.** The term cul-de-sac refers to the limiting factor whereby a taxiway access route requires an aircraft to taxi back on the MOS before takeoff or after landing.

3.6.2.2.2.2. **Only One Access Route.** A MOS with a single access route requires aircraft to taxi the length of the MOS before takeoff or after landing.

3.6.2.2.2.3. **Taxi Distance.** Selecting a MOS that is located off base or has a long taxiway route will reduce LOR capability and time to first launch. In addition, overheating of brakes could mean higher maintenance problems, and taxiing aircraft will spend more time in an exposed, vulnerable condition.

3.6.2.2.3. **Arresting Barrier Limitations.** Operational requirements, landing with battle damage, shorter than desired landing surface, wet or icy conditions, or other emergencies may dictate arrested landings. Normally, the mobile aircraft arresting system (MAAS) is used for wartime support of MOSs, since the probability of an in-place system being serviceable after an attack and in the correct place is low. The MAAS is capable of an aborted takeoff or arrested landing every 3-5 minutes. If an existing arresting barrier remains functional, is located longitudinally correct on the MOS, and is situated within the crater free restrictions, its pendant must span the MOS properly to prevent an aircraft from being pulled to one side or the other after engagement. Generally, an existing arresting barrier will perform effectively if it is engaged at a location along the pendant which is up to 50% of one-half the original runway width either side of the original runway centerline. Regardless, of whether a MAAS or an in-place system is operated, the compulsory use of an arresting system will reduce LOR status due to the time involved in barrier recycling operations.

3.6.2.2.4. **Other LOR Factors.** Many other variables outside the control of the MOS selection team affect LOR status. A few examples include aircraft maintenance, fueling, arming, and pilot briefings.

3.6.2.3. **Limitation Examples.** Table 3.2 gives the LOR capability of a MOS for various access limitations. Use it to help identify the impact your MOS candidate choice has on sortie capacity. As was addressed earlier, inadequate access forces the aircraft to taxi the length of the MOS, which results in excessive runway occupancy time. If taxiway repairs can be made while aircraft are using the MOS, you will probably recommend that the strip be declared operational after one access route is repaired. However, it may be that craters are located such that safety considerations preclude repairs to access taxiways during operations. In this case, your briefing to the wing commander should point out the tradeoff between increased LOR status and decreased recovery time. The commander can decide what percentage of full launch and recovery capacity is immediately required.

3.6.3. **Low Probable Aircraft Damage**. In spite of an earnest effort, the repaired MOS will most likely not be as smooth as the original runway. Restoring the surface to its original condition is too time consuming. However, if the repairs are too rough, damage to aircraft structures and strut systems may result. The acceptable roughness of a MOS depends upon many factors: type of aircraft using it, aircraft weight and configuration, and weather. Given these conditions, acceptable roughness for a particular repair depends upon location of the repair, the aircraft operation (takeoff or landing), and the velocity of the aircraft as it transverses that repair. Each of these factors is included as part of RQC addressed in detail in the next chapter of this document. However, a couple of key considerations are worthwhile discussing now since they substantially impact MOS operational characteristics.

3.6.3.1. **Density Ratio (DR).** Density ratio, a relationship between air temperature and altitude, gives a measure of aircraft performance. For high DRs (on cool days), aircraft performance will be good; during takeoffs and landings, the aircraft will accelerate quickly, achieve high velocity and lift in a relatively short distance. Consequently, a MOS may be shorter when the DR is high. How quick an aircraft accelerates, decelerates, and generates lift are factors regarding how rough of a crater repair an aircraft can tolerate. These factors are taken into account during RQC calculations.

3.6.3.2. **Repair Spacing.** Another item to consider is the distance between repairs on the MOS. To avoid over-stressing the aircraft, vibrations caused by encountering a crater repair must be allowed to dampen before the craft encounters another crater repair. Selecting a MOS with craters spaced far apart will increase the amount of time available for damping the vibrations and usually decrease the need for high quality repair.

3.6.4. **Expansion Capability.** The MOS is an expedient operating surface, selected to support a specific combination of aircraft under specific conditions. A larger operating surface, or one that can be rapidly expanded, is always highly desirable.

In some situations, the commander may choose to delay initial recovery in order to provide a more flexible MOS. The MOS selection team should keep these factors in mind as it searches for a candidate MOS. Avoid boxing-in the MOS with large craters at both ends. If an expansion option with equivalent or slightly longer repair time is available, that option should be included in the briefing to the wing commander. Also, be aware that expansion of a MOS may affect the repair qualities required. If you are planning on later MOS expansion, you may want to make the initial RQC calculations adequate to support both the initial and expanded MOSs.

3.7. MOS Selection Procedures.

3.7.1. **General Information.** This section is a guide for personnel who must select candidate minimum operating strips. As stated earlier, selection of the minimum operating strip normally takes place in the survival recovery center. The MOS selection team consists of a minimum of two persons (two engineers) trained in the selection procedures and familiar with working with damage assessment teams on the airfield.

3.7.2. **Preparation Steps.** If you are a member of a MOS selection team, you will need to know what preparation takes place before MOS candidate search begins. You will also need to understand what the elements of the "MOS selection kit" are and how to use them. And, you will need to thoroughly understand what happens in each of the four phases of the procedure for selecting the MOS following an attack.

3.8. MOS Selection Kit.

3.8.1. Each civil engineer squadron at a main operating base (MOB) overseas and a Continental United States (CONUS) unit with a deployment docket should develop a MOS selection kit. As a minimum, a kit should include the items listed below. Transparency material, markers, pens/pencils, and circle templates should be obtained either through local purchases or normal supply channels.

- Transparent material for making MOS templates, e.g., clear acetate or Plexiglas.
- Plotting board.
- Critical resources charts.
- Transparent circle templates with decimal units matching the airfield map scale.
- Repair quality criteria Technical Order (T.O. 35E2-4-1).
- Markers, pens, and pencils.
- Damage reporting/recording forms.

3.8.2. In addition to the items above, the following additional MOS selection kit augmentation items must be available at each MOB or deployment location for MOS selection team use:

- Base map - 1:4800 scale (1" = 400').
- Airfield map - 1:1200 (1" = 100') scale with the runway identifier and station marker posts indicated.
- Plotting board.

3.9. MOS Selection Phases. MOS selection is accomplished in four phases: (1) Alert status preparation--gathering the team equipment and basic information for use during MOS selection; (2) plotting the damage and searching for candidate MOSs and access/egress routes; (3) evaluating candidate MOSs; and (4) recommending a MOS to the commander.

3.9.1. **Phase 1--Alert Status Preparation.** After declaration of an alert condition, MOS selection personnel report to their assigned BRAAT duty position to acquire information on MOS dimensions, aircraft types and missions, direction of takeoff and landing, weather conditions, and possible use of an aircraft arresting barrier. This information should be recorded on the airfield map where it can easily be seen by the entire SRC staff. The information should also be relayed to the alternate SRC and the DCC by the primary survival recovery center MOS selection team and posted on the repair quality criteria (RQC) worksheet 1. ***NOTE*****:** RQC Instructional Guideline Steps 1 and 2 can be accomplished during the preattack period.

3.9.1.1. **MOS Dimensions.** The WOC will determine the dimension of the MOS it needs following an attack. These dimensions will be based on the known requirements of aircraft expected to use the MOS, mission objectives, weather, aircraft performance, and environmental conditions. After obtaining the MOS dimensions, make the MOS template to create a "picture" of the MOS in the same scale as the airfield map. ***NOTE:*** As a general rule, the dimensions of a basic MOS for fighter aircraft is considered to be 50' X 5,000'. However, a number of factors such as weather conditions, can necessitate that a larger MOS width or length is desirable. Consequentially, do not be surprised if a wing commander insists upon greater MOS dimensions.

3.9.1.2. **Aircraft Requirements.** Ask the WOC to provide the operational requirements for the MOS to be selected, i.e., what type(s) of aircraft will use the landing surface, and will each type be landing only, taking off only, or both. Under certain circumstances, an evacuation strip may be required. Evacuation is a minimum gross-weight takeoff, and requires a minimal amount of pavement. ***NOTE:*** Post this information on RQC Worksheet 1.

3.9.1.2.1. **Aircraft Braking**. For certain aircraft, a decision must be made to whether the aircraft will brake during landing. The trade-off here is that when braking is allowed, less pavement is required, but repairs must be smoother. If braking is not allowed, a rougher repair quality may be acceptable, but a longer MOS is required.

3.9.1.2.2. **Aircraft Barrier.** For fighter aircraft equipped with arresting hooks, the possibility exists for using a barrier when landing. This is only an option if your base has a mobile aircraft arresting system available, or if the installed arresting systems and sufficient surrounding pavement remain undamaged. In wet and especially in icy conditions, the barrier substantially reduces the amount of pavement required to land. If a system is available and wet or icy conditions are expected, plan on using it to retrieve fighter aircraft.

3.9.1.3. **Weather Conditions.** Consult the WOC or base weather regarding present and forecasted (48 hour) weather conditions. Of the weather forecasted, always use the most critical in your computations. In wet and icy conditions, most aircraft will require more than 5,000 feet to land. An arresting system may be needed to recover aircraft when insufficient cleared pavement is available. Furthermore, weather information must be updated as actual conditions change. The three main weather indicators are runway condition reading (RCR), runway surface condition (RSC), and density ratio (DR). Each will be discussed in detail in the next chapter.

3.9.1.4. **Uni/Bidirectional MOS.** A MOS can be used for unidirectional (takeoff and landing in only one direction) or bidirectional (takeoff and landing in both directions) operations. Repairs in landing zones will usually require higher repair quality criteria. Ask the WOC for the directional requirements (compass heading) for the MOS. Wind conditions also affect the direction requirement, since it is desirable for aircraft to takeoff with a head wind. If high changeable winds are expected, a bidirectional MOS may be required.

3.9.1.5. **Taxiway Widths.** MOS selection by its very nature concentrates on determining desirable MOS characteristics. Taxi access to the MOS must not be forgotten, however, and data on taxiway requirements should also be gathered early in the selection process. Of primary concern is the width that taxiways must be to adequately support the various types of aircraft expected to be using the MOS. Table 3.3 provides minimally acceptable taxiway widths for common aircraft. Choose the largest width from those which apply to aircraft that will be using the MOS. Also, request data from the WOC regarding aircraft turning radius requirements. Consider the problems presented if an aircraft should breakdown in a taxiway that is too narrow to allow it to be turned around. Though not a “show stopper”, this information should be part of the evaluation process. Supply the DATs with this information so that they can judge whether access routes are open or require repair. Also, do not forget to pass the same information to the alternate SRC and the DCC.

Table 3.3. Taxiway Criteria.

AIRCRAFT	REPAIRED WIDTH (FEET)
F-15	25
F-16	25
A-10	25
A-7	25
F-111	25
C-130	30
C-141	50
C-5A	60
DC-10	60
B-747	60

3.9.2. **Phase 2--Plotting the Damage and Searching for Candidate MOSs.** Selection of candidate MOSs is based primarily on the data provided by DATs. However, the data is gathered under adverse conditions and is not precisely measured; therefore, it may include some amount of error. Initial detailed airfield damage information comes into the SRC from the DAT reports. The radio operators log it on an appropriate form and plotters subsequently annotate the base map accordingly. The goal should be to have MOS candidate selection completed within 30 minutes after the last damage assessment reports on the potential LOR pavement surfaces are received. However, much of the work can proceed while damage assessment reports are being received.

3.9.2.1. **Plotting.** When the DATs assessing the pavement surfaces start to report in, use markers and the circle templates to plot the damage on the 1:1200 (1" = 100') scale airfield map.

3.9.2.1.1. **Craters.** The most critical damage data are the location and size of craters. The circle template used for crater plotting should have a decimal scale, e.g., an 0.40-inch circle will represent a 40-foot circle on the 1:1200 scale airfield map. The apparent crater diameter called in by the DATs should be doubled when plotted to represent the approximate required repair diameter. The apparent diameter should be noted inside the circle. The actual repair diameter will depend on how much upheaval lip has to be removed during the actual repair process. This obviously will be unknown until the RRR crews perform their upheaval measurements. However, the doubling of the apparent diameter gives a reasonable approximation and allows some room for both plotting and assessment error.

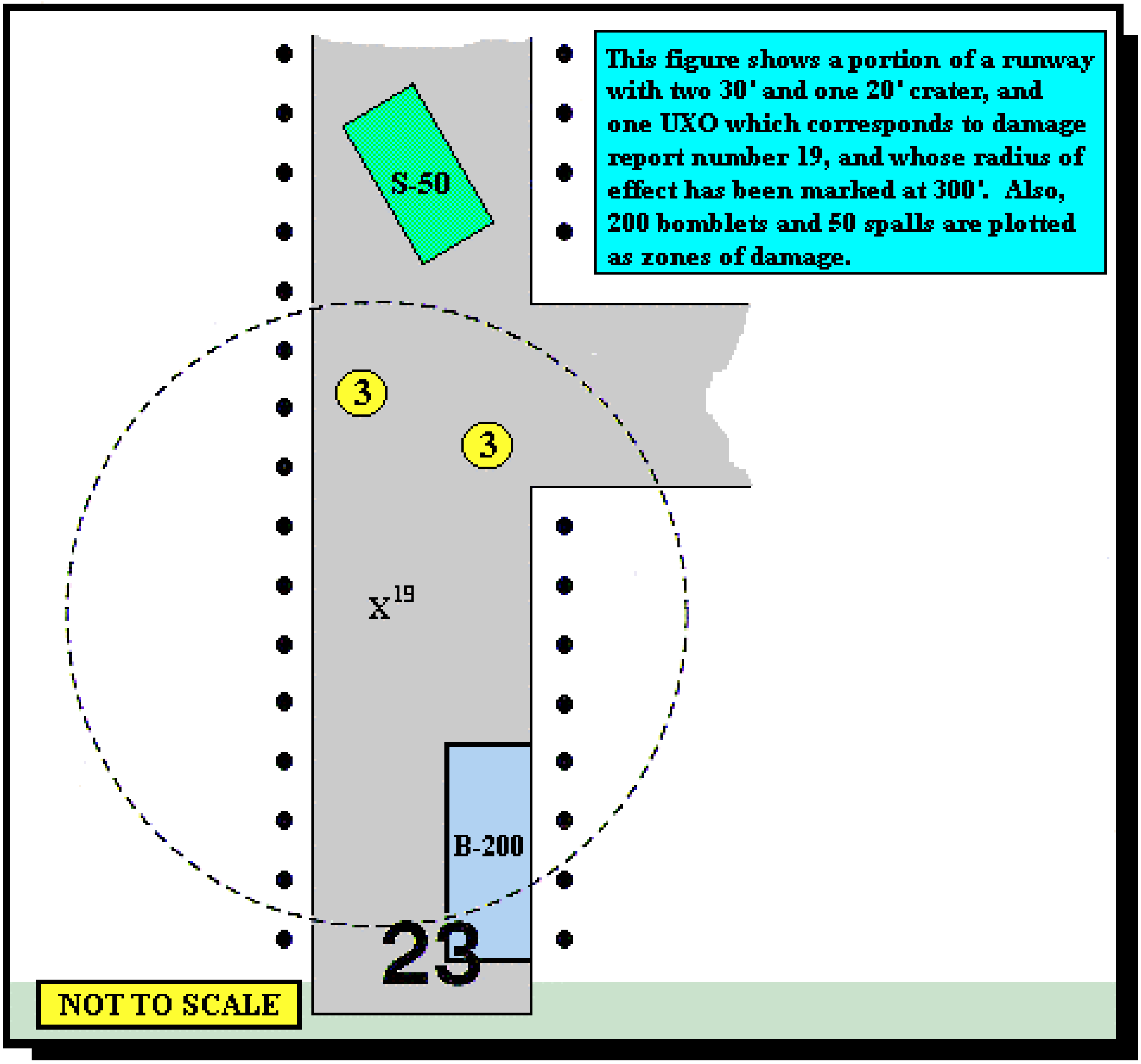
3.9.2.1.2. **Spalls and Bomblets.** A spall or bomblet field is shown on the airfield map by marking its perimeter and noting the approximate number of spalls to be repaired or bomblets to be removed. Bomblet and spall field counts are estimates and probably will not be exact, a factor to consider during the determination of a recovery time. Spall and bomblet fields, however, normally are not as difficult as craters to repair/replace in terms of searching for candidate MOSs.

3.9.2.1.3. **Utility Damage.** Utility damage affecting MOS selection must also be plotted. Examples include damaged petroleum, oil, and lubricant (POL) lines; airfield lighting; water lines; or electrical lines. Utility damage is especially critical when it occurs near runways and taxiways, since it could lead to pavement washout or deterioration or present a serious hazard to aircraft maintenance crews and firefighters.

3.9.2.1.4. **UXO.** Individual large unexploded ordnance should be marked with reasonable precision on the airfield map. They should also be cross-referenced with the EOD incident list. Exact position of an UXO is not critical, due to the large radius of effect upon detonation. Once an UXO is plotted, the EOD representative should determine the radius of effect on the airfield map. Depending upon what areas are covered by this radius, the prioritization of EOD recovery actions could be influenced.

3.9.2.1.5. **Other.** During plotting, you should also assess potential access/egress routes using the required taxiway width as determined in Phase 1. As mentioned earlier, access/egress to both ends of the MOS is an important factor when it comes to sortie capacity. A single access route could cut your launch and recovery capacity to 40 percent or lower. If damage is high, operations may begin with one access route; another route can be cleared as repair teams are freed. This strategy is particularly good if repairs to the second access route can be made while the MOS is in use. Figure 3.1 shows an example of various types of damage plotted on the runway.

Figure 3.1. Example of Damage Plots.



3.9.2.2. **MOS Candidate Selection Considerations**. The primary aim of MOS selection is to identify the best launch and recovery strip candidates for recommendation to the wing commander. As was addressed previously, a MOS template representing the required dimensions can be moved around the airfield map to quickly identify possible locations. However, always remember to initially check for MOSs that have the same centerline as the runway and begin or terminate at the threshold of the existing runway. If the same centerline cannot be used, the selected MOS must be parallel to the centerline of the runway. Skewed MOSs are not desirable and should be used only as a last resort when no other option is available. Other prime considerations in the selection process include:

3.9.2.2.1. **Craters and Spalls.** How many and what size are the craters? Likewise, how many spall repairs are there? A MOS involving the least number and smallest size craters and spalls will probably be the most attractive option. Start by avoiding areas with dense clumps of damage. Remember that the DATs may not be reporting the damage accurately. Damage assessment reports are only “best” estimates made under difficult circumstances; they could easily be off by several feet. However, there is some leeway, since the craters are plotted to represent repaired rather than apparent diameter. Nevertheless, if possible, it is best to avoid butting the MOS right up against the edge of plotted craters. These craters may not be exactly where you think they are. Also, attempt to find a MOS that does not have craters in the landing (touchdown) zones--roughly the first and last 1,000 feet of the strip. Besides requiring a higher quality of repair, craters in these areas will demand considerable maintenance since the landing zones receive the most abuse from aircraft traffic.

3.9.2.2.2. **MOS Access.** Always look for a MOS with good taxiway access/egress. Search for candidates with routes by which aircraft from shelters can readily taxi to and from both the takeoff and landing ends of the MOS. Access routes are best when positioned close to each end of the MOS.

3.9.2.2.3. **Expansion Potential.** The commander may opt for a MOS that requires a somewhat longer repair time if it can be readily expanded to support additional aircraft or poorer weather conditions. Always look for a MOS that is longer and wider than the minimum requirement provided by the WOC. Do not forget the possibility of using parallel taxiways as a primary MOS.

3.9.2.2.4. **UXO.** Are there any large buried bombs that will require careful excavation or bomblet fields that exclude a candidate MOS from consideration? Are bomblets mixed with crater debris, making clearance too slow? Will an in-place deflagration of an UXO make the MOS candidate option worse? A deflagration is an accelerated burn-out of explosive material within an item of ordnance. This situation is usually caused by an EOD technician hitting the munition with a rifle round. The resulting reaction (deflagration) is normally less destructive than that caused by allowing the ordnance to detonate--but some damage to the pavement surface will usually result.

3.9.2.2.5. **Resource Limitations.** Consider any limitations in resources that might impinge upon a repair effort. For example, if the stocks of spall repair material have been depleted, a MOS with few spalls will be at a premium. Likewise, if RRR equipment has been damaged, the impact on repair techniques and time must also be taken into consideration.

3.9.2.2.6. **MOS Identification.** Once candidate MOSs are selected, the threshold and departure ends and edges should be bracketed ([ ])on the airfield map. The MOS threshold is designated at the lowest numbered pavement/raised reference marker (see chapter 2, paragraph 2.6: “zero point rule”). Conversely, the MOS departure is indicated by the highest numbered pavement/raised reference marker. Be sure to coordinate the designation of the MOS threshold with the WOC.

3.9.2.2.7. **Other Factors.** MOS selection requires a compromise of all the aforementioned considerations. For this reason, the SRC staff must have an intimate knowledge of RRR procedures, capabilities of the repair teams and availability of all of the RRR assets and materials. The SRC staff must also have a basic understanding of operational requirements in terms of weather, NAVAID support, and aircraft operating characteristics. The SRC staff must be able to discuss all the tradeoffs knowledgeably and effectively with the BCE and the wing commander so the best repair plan is selected. Table 3.4 provides a MOS selection checklist highlighting a few of both the desirable and undesirable MOS features. Good MOS selection is a skill which must be acquired through training and operational readiness exercises. In the next procedure phase, candidate MOSs will be evaluated based on time for repair and assessment of various operational limitations. During MOS candidate selection the SRC staff will have time to evaluate only a few MOS candidates. The MOS selection team must have practiced enough to know the trade-offs without stopping to figure them out.

Table 3.4. MOS Selection Checklist.

1. Are MOSs available that are on the centerline and at either end of the original runway? 2. Crater and spall repairs—how many and what size? A MOS location that involves the least number and smallest size craters and spalls is usually the most attractive option. 3. Are there MOSs that are longer or wider than WOC requirements, but do not require additional repairs? 4. Are there MOSs that have expansion potential, yet require limited additional repairs? 5. UXO: a. Are there any UXO or bomblet fields that exclude a candidate MOS from further consideration (large buried bombs that will require excavation)? b. Will in-place detonation make the option worse? c. Are bomblets so heavily mixed with crater debris that clearance will be too slow? d. Has the time delay for start of crater repair necessitated by UXO clearance been estimated? 6. Have the shortest access routes been chosen consistent with the degree of repairs required? 7. Are access/egress routes positioned close to the end of the MOS? At least two routes are desired, with minimal MOS back-taxiing requirements. 8. Existing MOS: a. Is there an existing MOS? b. Is it still operable? c. Can it be made operable with minimal repair and marking? 9. Can a MOS be made operable by altering operational requirements (types of aircraft expected to use the MOS, gross weights, use of arresting barrier, unidirectional versus bidirectional operations, etc.)? The director of operations (DO) or supervisor of flying (SOF) must be consulted and the wing commander must be made aware of the possibilities. 10. Arresting Barrier: a. Is an arresting barrier required for operations? b. Is there a MOS candidate that includes an in-place arresting barrier? Is the candidate MOS centered sufficiently with the barrier pendant to permit proper barrier operation?

c. Is there sufficient crater free pavement on both sides of the barrier?
d. Is a MAAS available?

11. How well trained are the RRR teams? Can they meet the nominal 6-12 craters in 4 hours criterion?
12. What is the condition of the troops (fatigue, morale, attrition, etc.)?
13. What is the current condition of the RRR equipment?
14. What is the Nuclear-Biological-Chemical (NBC) state?
15. What are the environmental factors (weather, lighting, etc.)?
16. What is the possibility of reattack?
17. Navigational Aids:
    a. Will the MOS location allow the use of existing NAVAIDS?
    b. Are NAVAIDS needed?
    c. Are existing NAVAIDS operational?

DESIRABLE MOS SELECTION ASPECTS

1. Crater locations on the MOS that facilitate repair in pairs rather than an equivalent number of single repairs may be desirable to reduce crater repair times. However, RQC will normally be more restrictive for closely spaced craters.
2. A MOS that is aligned on the existing centerline to reduce marking time and take advantage of surviving NAVAIDS.
3. A MOS that has one end (either threshold or departure) situated on the threshold of the original runway.
4. A MOS that can utilize an existing in-place arresting barrier system.
5. Craters which are located close to material stockpiles.
6. A MOS with access/egress routes at each end.
7. A MOS with a minimal number of crater repair locations.
8. A MOS with dimensions longer and wider than the nominal 5,000' by 50'.

UNDESIRABLE MOS SELECTION ASPECTS

1. Craters located so close together that there is no clear working space around them.
2. Combination of craters, spalls, and UXO that are in excess of what a full RRR team can handle in a 4-hour time frame.
3. Craters within the first and last 1,000 feet of the MOS (these are the takeoff/landing touchdown zones, and RQC for repairs in these zones are more restrictive).
4. Boxed-in MOS, one that has large craters situated at the ends that limit expansion potential.
5. Craters in either an aircraft arresting barrier's cable approach or fixed tape sweep areas.
6. Only one access route with no potential of developing a second route.

3.9.3. **Phase 3--Evaluating a Candidate MOS.** Once the candidate MOSs have been identified, several factors must be considered before making the final selection. Many of these are somewhat subjective, therefore demand a wide experience base on the part of the engineer members of the SRC staff.

3.9.3.1. **Engineering Repair Times.** Equipment availability must be a prime consideration when selecting MOS candidates. Both vehicular and equipment availability directly impact upon a RRR team's crater repair times, regardless of operator expertise. Three equipment packages (R-1, R-2, and R-3) have been developed to specifically sustain RRR requirements. Each package supports a defined crater repair requirement. For example, the R-1 set will only provide enough vehicles and equipment so that three 50-foot (large) bomb craters can be repaired within a 4-hour period; whereas, an R-3 set will provide enough assets to allow a properly manned team to repair a total of 12 large craters within the same 4-hour time limit. Details regarding RRR equipment sets are outlined in chapter 5 and attachment 8 of this volume. If your RRR team has been training consistently, the data presented in table 3.5 should provide reasonable crater repair time estimates. If not, your estimate will have to be adjusted to be more subjective. Field tests have shown that an untrained team will normally require at least twice as much time to perform RRR as compared to what is illustrated in the table. Times obtained during training exercises may also prove helpful in estimating actual repair times required by your team. However, take into consideration that normally time estimates from training situations involve conditions that are much better than those that will be faced in a wartime environment. Furthermore, you will need to temper your estimates with the following considerations. Most of these factors will lengthen the RRR process to various degrees.

Table 3.5. Estimated Crater Repair Times For a Dual Crater Repair.

APPARENT DIAMETER	REPAIR TIME FIRST CRATER	ADDITIONAL TIME FOR SECOND CRATER	TOTAL REPAIR TIME FOR BOTH CRATERS
5-20 feet >20 feet	65 minutes 155 minutes	35 minutes 65 minutes	100 minutes 220 minutes
***NOTE*:** Times reflected are for both AM-2 and folded fiberglass mat repairs conducted under ideal environmental conditions with a complete vehicle/equipment complement utilized by a highly trained and capable RRR team. Estimates do not include travel times to the repair locations.			

3.9.3.1.1. What is the physical and mental condition of RRR team members? Are the troops fresh or have they been subjected to previous attacks and subsequent RRR operations?

3.9.3.1.2. What attrition has taken place? How many personnel have been lost or vehicles damaged?

3.9.3.1.3. What type of repairs are to be performed? Field experience has shown what AM-2 repairs tend to go faster than folded fiberglass mat repairs due to less stringent quality requirements.

3.9.3.1.4. What is the current or expected NBC status? Will the RRR crews have to wear portions or all of their ground crew ensembles during repair activities?

3.9.3.1.5. What are the environmental factors that will be present during repair? Will it be hot, cold, dark, wet, etc.?

3.9.3.1.6. What is the possibility of a reattack and what will be the time lapse? This type of information could be vital in deciding whether or not to repair an expanded MOS or stick with the minimum requirements.

3.9.3.1.7. How experienced are the DAT members at estimating crater sizes and locations? An inexperienced team could be providing data that are prone to recurring errors.

3.9.3.2. **EOD Time Estimates.** The SRC EOD representative will estimate the EOD clearance time for candidate MOSs. In addition, this individual will decide which EOD activities must be completed before RRR can begin and estimate "safing" times for each UXO. The EOD technician will also estimate the time needed for in-place UXO deflagration and/or bomblet field removal from the MOS and UXO clearance on routes from RRR dispersal sites to the MOS. The input from the EOD representative is critical to MOS selection and evaluation. It is entirely possible that the MOS with the least work for engineers could be negated by extensive EOD safing and clearing requirements.

3.9.3.3. **NAVAIDS.** The availability of NAVAIDS must be considered. If NAVAIDS are inoperative, what will it take to put them back in service? Are mobile NAVAID units available and can they be installed quickly by on-base communications personnel? If NAVAIDS will be out of service for an extended period, other factors may become more important. For example, two access taxiways to the MOS rather than only one may be required, thereby speeding ground flow of aircraft to compensate, to some extent, for the loss of air traffic control abilities.

3.9.3.4. **LOR Capability.** The MOS candidate selection team must assess any LOR limitations pertaining to each MOS candidate. Using the LOR table and the base layout map, the team must evaluate the various trade-offs associated with numbers of access taxiways, availability of arresting barriers, aircraft traffic flow, fueling and maintenance locations, etc.

3.9.3.5. **Collateral Damage Repairs.** Damage to in-place barriers, airfield lighting, vicinity utility lines, and NAVAIDS may have to be repaired before a MOS can become operational. Therefore, repair times for these systems involved with a particular candidate MOS must be considered. Some collateral damage may affect all possible MOS selections, for example, when an airfield lighting vault has been destroyed. Other collateral damage may affect only a few of the possible MOS candidates, i.e., a ruptured POL line crossing under the pavement at 1,000 feet from the south end of the runway. Repairing collateral damage will normally not be an overriding, time-critical factor, since crews other than RRR teams will be assigned to repair collateral damage. However, the MOS selection team must analyze all collateral damage for its potential impact on MOS selection.

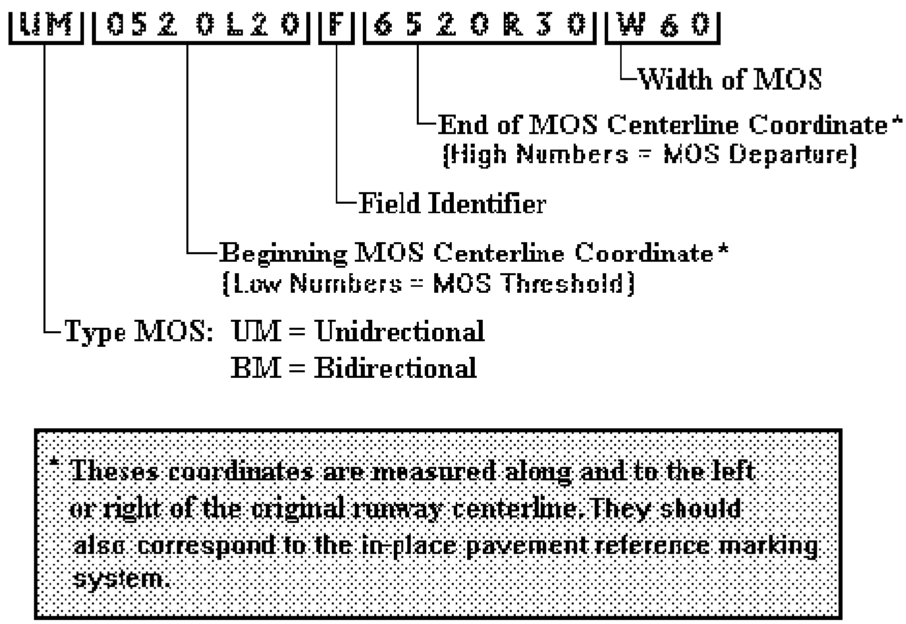
3.9.3.6. **Other Factors.** As part of the evaluation process, MOSs identified by the alternate SRC are also reviewed, particularly if they differ from the ones developed by the team in the primary center. This action provides a "check and balance" capability for MOS selection, thereby lessening the possibility that important factors have been overlooked. In addition, both the DCC and its alternate are also transcribing damage reports provided by the DATs and plotting candidate MOSs. By using this “cross-feeding” approach, the DCC can become aware of the true extent of the airfield damage incurred and attain a realistic insight to the extent of the RRR effort they will have to mount.

3.9.4. **Phase 4--Recommending MOS Candidates to the Commander.** In the last phase of the MOS selection procedure, the MOS selection team chief checks the work of the team and briefs the commander and BCE on the candidates.

3.9.4.1. **Presenting Options.** The MOS selection team chief recommends one or more candidate MOSs, estimates the comparative recovery times, and describes the advantages and disadvantages of each selection. The commander may request more information, such as an estimate of the time needed to expand a given MOS. In any case, the commander will be required to select a MOS on the basis of the data provided, while at the same time considering many factors that are hard to quantify. All decisions have some risk. Even with precise information, a less-than-the-best MOS may be selected. The MOS selection team's job is to provide an accurate and timely summary of necessary information to the commander, whose job it is to define what "best" means in a given situation.

3.9.4.2. **Commencement of Activities.** Once the commander has selected a particular MOS to repair, the BCE will advise the DCC so RRR teams can be dispatched. At the same time the SRC will direct the EOD technician to dispatch the UXO safing and bomb removal teams to clear the RRR team's route to the MOS and the MOS itself of munitions. The SRC staff also provides the details of the selected MOS to the DCC and alternate SRC. Besides the basics such as length, width, and location of the MOS; information on aircraft turning radii, access/egress route width, sweeping width, time frames for ancillary equipment installation, e.g., airfield lighting, etc., must be provided. The method of identifying the basic information pertaining to a selected MOS is shown in figure 3.2. The SRC and DCC staffs must ensure sufficient communications has taken place between them so recovery instructions and requirements are clearly and totally understood. As airfield recovery progresses, the MOS selection team calculates RQC for the MOS repairs, monitors the repair process, and updates the appropriate maps and charts to indicate the airfield's current condition. ***NOTE*:** When forwarding MOS information to the DCC, it is important to include data to indicate the direction of travel for a unidirectional MOS. The best method for doing such is to include the compass heading. For example, on a 06-24 runway the indication would be either "heading 060" or "heading 240" degrees.

Figure 3.2. MOS Identification Coordinates.



3.10. Review of MOS Selection Steps. The following is an abbreviated step-by-step review of the primary steps that members of the MOS selection team should take prior and during the selection process.

3.10.1. Verify availability of all necessary MOS selection maps, documents, materials, and equipment.

3.10.2. Obtain information from WOC on aircraft requirements, MOS dimensions, taxiway dimensions, operational parameters, weather, NAVAID and arresting barrier requirements, etc.

3.10.3. Construct a MOS template to the prescribed measurements provided by the WOC. Be sure that the template is made in the same scale as the airfield maps used to plot the damage.

3.10.4. Inform DATs of required MOS and taxiway dimensions and pertinent operational needs so that they can apply this data during their assessment process.

3.10.5. Record and plot damages and UXO data on airfield map.

3.10.6. Select candidate MOSs to include access and egress routes.

3.10.7. Evaluate candidate MOSs in terms of repair times, LOR capabilities, and collateral damage impacts.

3.10.8. Recommend one or more candidate MOSs to the wing commander, report the comparative recovery times, and describe advantages and disadvantages of various courses of action.

3.10.9. Relay commander's decision on MOS to DCC/alternate SRC

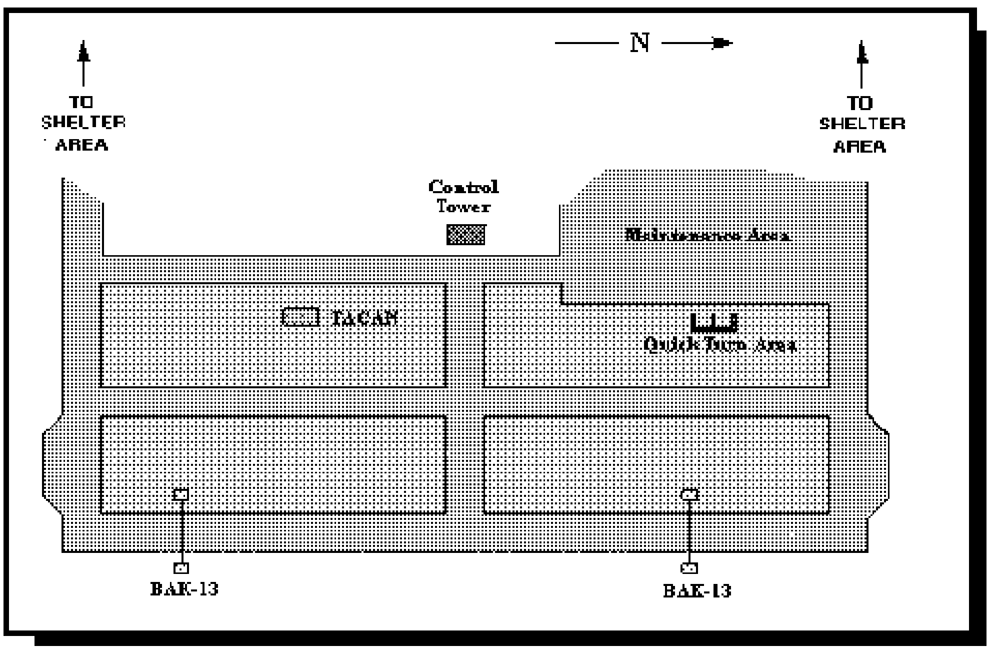
3.10.10. Have DCC dispatch RRR crews to relocate from there dispersed locations to the staging site.

3.10.11. Release RRR crew from staging area to the MOS after sufficient EOD safing/clearing operations have commenced.
3.10.12. Perform RQC calculations and monitor progress of recovery efforts.

3.11. Situation Example. The following situation example is presented to allow you to walk-through some of the thought processes involved in the MOS selection process. It is overly simplified, but outlines a few of the MOS selection considerations that will probably be encountered in an actual postattack environment.

3.12. Circumstance. U.S. forces are deployed to a theater operating location. The base runway measures 9,000 by 200 feet with three access taxiways (figure 3.3). In-place aircraft arresting barriers are located 1,000 feet from each end of the runway and airfield lighting exists. One mobile aircraft arresting system is in WRM storage on base. One lead and two follow Prime BEEF teams are in-place and an R-3 rapid runway repair set is available. Considerable quantities of AM-2 matting are available, but due to heavy structural damage to a storage facility, folded fiberglass mat quantities are available to repair only three craters. Training records reflect that a typical RRR crew has had training in both methods of RRR; however, such a crew will require a minimum of 4 hours to perform a two crater repair using the fiberglass mat technique. The base has just experienced an initial attack.

Figure 3.3. Airbase Layout.



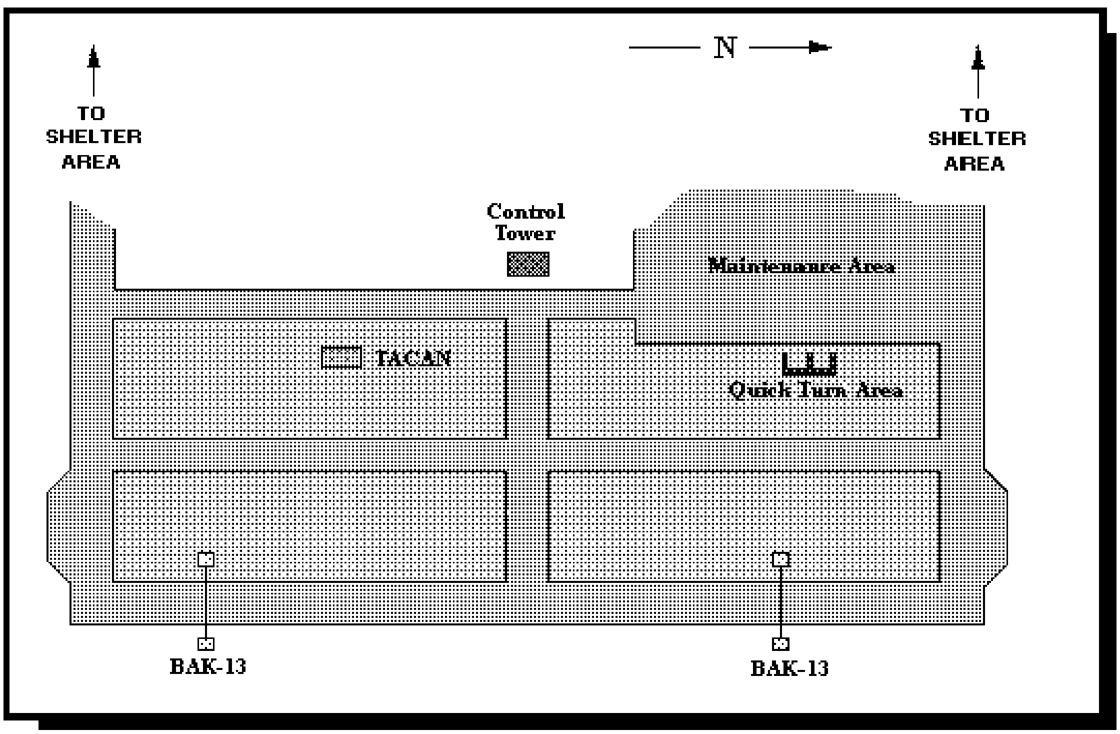
3.13. Phase I - Alert Status Preparation.
3.13.1. **Preattack Actions.** Prior to the attack, the wing operations center informed the SRC of the following:
3.13.1.1. MOS dimensions of at least 4,980' by 50' are required to support the fighter aircraft deployed to this location.
3.13.1.2. Support of cargo or other wide-body aircraft is not an initial consideration.
3.13.1.3. The use of an arresting barrier is highly desirable.
3.13.1.4. The weather is expected to be fair for an extended period, therefore, rain or ice should not be a limiting factor.
3.13.1.5. A bidirectional MOS is desired.
3.13.1.6. Access/egress route width needs to be at least 25 feet.
3.13.1.7. Maximum use of combat quick turn areas will be made.
3.13.1.8. Eventual expansion of the MOS (width and length) should be a consideration since resupply will be by air.
3.13.2. **Preparatory Steps.** Also, prior to the attack the SRC engineer staff ensured they had all appropriate equipment, materials, maps, and documents necessary. Once the WOC identified the required size of the minimum operating strip, the MOS selection team made a template to correspond in scale to the desired criteria. All MOS selection related data was written on the airfield map and also relayed to the alternate SRC and DCC. Engineer information pertaining to RRR capabilities, material availability, and personnel and equipment status was updated and verified. Lastly, a radio check was accomplished to ensure communication with the DATs.

3.14. Phase 2--Plotting Damage and Searching for a Candidate MOS.
3.14.1. **Plotting Procedures.** As the DATs report airfield pavements damage, the information is plotted on the airfield map.

Figure 3.4 lists the runway pavements damage the DATs encountered on their survey. Additional damage information reported by the DARTs, DATs, and other base personnel that could impact launch and recovery operations are listed below:

- Substantial structural damage to the airfield lighting vault.
- Aircraft quick turn area appears intact.
- A POL line crossing under the north taxiway is ruptured.
- Roads from the ammunition storage area appear passable.
- South taxiway is cratered in six locations.
- A sizable bomblet field is near the center of the parallel taxiway.
- The TACAN facility is destroyed.
- Both BAK-13 barriers are severely damaged.
- The parallel taxiway is heavily cratered and spalled at the 2,000' and 6,000' points.

Figure 3.4. Runway Damage Listing.



C1215R20D35	C3210L72D40	C5546L0D20
C161R42D20	X3513L17	C7065R50D25
C2420L40D35	C3756L66D35	C7500L46D30
B2500L10W50F2670L60W70N100	C3900L16D35	C8310L63D35
C2910R50D35	C4700R70D30	S8390R10W50F8540L20W70N150
X3069L38	C4980L68D20	

3.14.2. **Information Cross-Checking.** Figure 3.5 depicts the locations of the airfield related damage. With this information plotted, the MOS selection team now attempts to find candidate MOSs that fulfill the operational requirement. The selection team uses the MOS template to identify potential candidates. Engineer representatives in the alternate SRC and, if the situation permits, the DCC also perform the MOS candidate search. Information is continually cross-fed between these command centers both for operational continuity purposes and also as a cross-check on MOS selection accuracy and options. Many MOS candidates are possible, three of which are shown in figure 3.6.

Figure 3.5. Damage Plot.

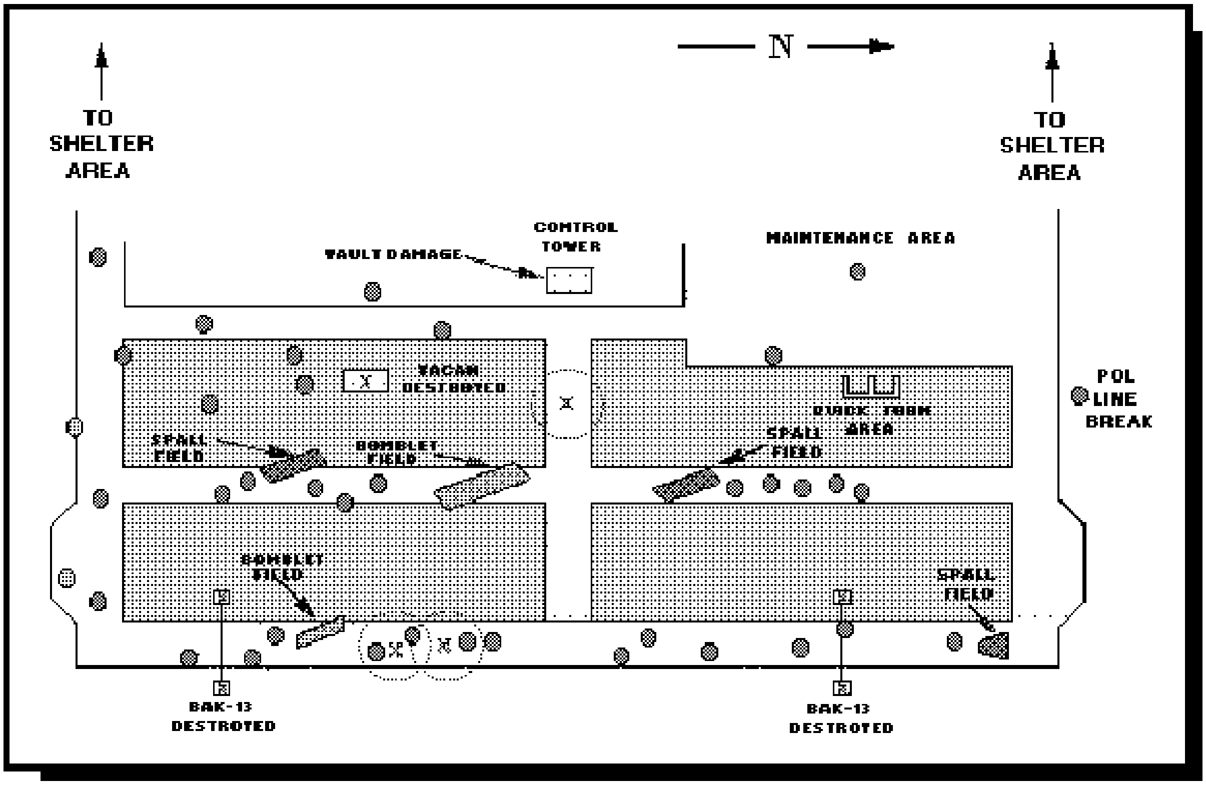
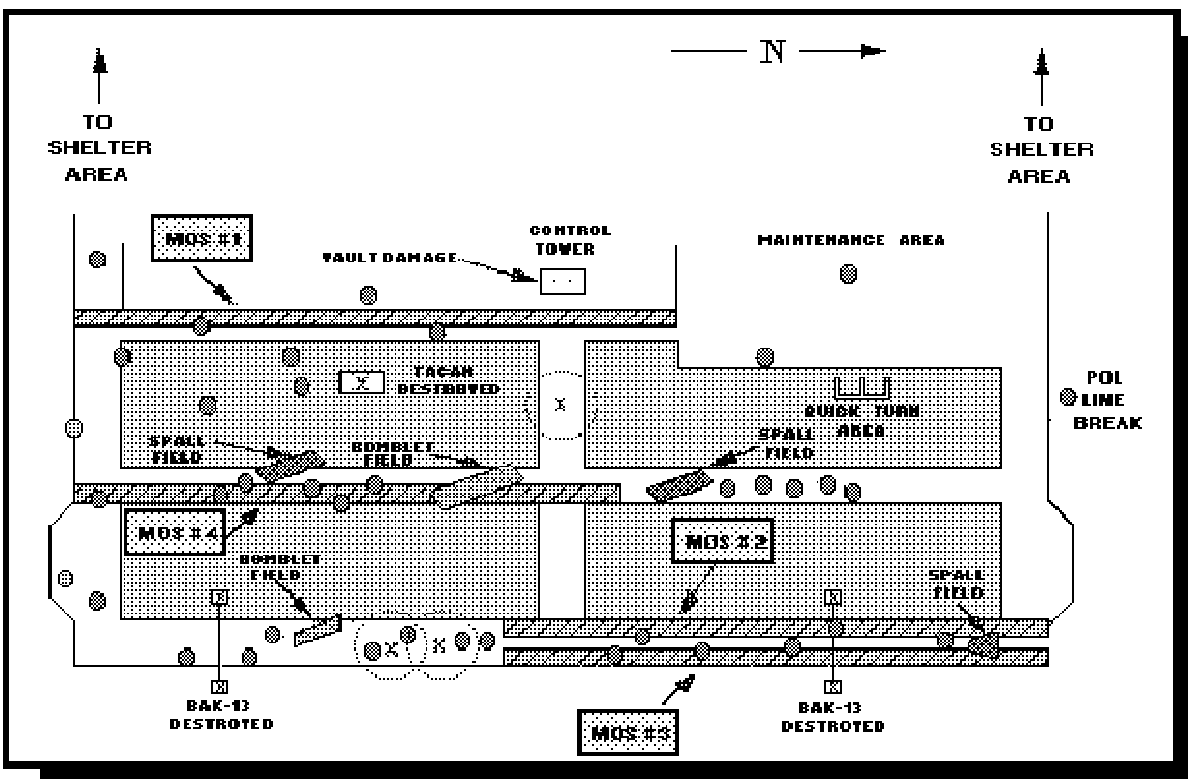


Figure 3.6. Candidate MOSs.



3.15. Phase 3--Evaluating a Candidate MOS. Once candidate MOSs have been identified, each must be evaluated to determine the best choice for support of launch and recovery operations. Each of the chosen MOSs in our example meet the length and width criteria, yet each have differing characteristics.

3.15.1. **MOS Candidate #1**. This MOS is part of a connecting taxiway. It has access from both ends and requires repair of only two craters in addition to those on any access routes. One of the two craters on MOS #1 is within the first 1,000' of pavement; this usually will require a high quality repair. Bidirectional use of this MOS is possible. Sufficient undamaged pavement along this MOS exists to enable installation of the MAAS in a crater free area, if necessary. For night operations an airfield lighting set will have to be installed. Access to the quick turn area is available without extensive maneuvering of aircraft. Primary drawbacks of this MOS are its proximity to structures (control tower) which poses a flying safety hazard and its nearness to the aircraft maintenance area, which limits expandability and could hinder aircraft taxi flow due to aircraft congestion. Explosive ordnance disposal UXO safing and bomb removal prior to establishment of this MOS appear to be minimal, since bomblet fields do not present immediate problems. The number of craters to be repaired does not appear to be excessive. Folded fiberglass mat repairs would be performed on the MOS and AM-2 repairs on access routes. Time frames for engineer repair efforts should be approximately 4-5 hours.

3.15.2. **MOS Candidate #2.** This MOS is located on the western edge of the original runway. Like MOS #1, it has access and egress routes, sufficient undamaged pavement for MAAS installation, bidirectional capability, and relatively easy access to and from the quick turn area. On the other hand, it requires the repair of three craters on the MOS surface itself plus those on the access routes and a portion of a spall field. Additionally, two of the three craters on the MOS are within 1,000 feet of each threshold, which usually results in higher RQC requirements. Near term expandability is limited due to additional craters and a bomblet field south of the MOS. For a south to north takeoff some back-taxiing on the MOS is necessary, since the southern access route intersects the MOS at about the 500 foot mark. One UXO on the south end access route must be safed and the POL line adjacent to the north access route, as a minimum, must be isolated. Using folded fiberglass mats for the MOS crater repairs and AM-2 matting for taxiway craters, the time frame for repair should also be in the neighborhood of 4-5 hours. Ample resources exist in terms of manpower, materials, and equipment to meet this time estimate.

3.15.3. **MOS Candidate #3**. This MOS is located on the eastern edge of the original runway. Similar to MOSs #1 and #2, it has access and egress routes, adequate clear pavement for arresting barrier installation and a bidirectional capability. However, there is a little problem with access to the quick turn area. Like MOS #1, it only requires repair of two MOS craters, does not have to rely on back-taxiing, and has a crater located in the first 1,000 feet from its south end. It, however, shares with MOS #2 the requirements for UXO safing and POL line isolation or repair on or along the access routes. Unlike the other two MOSs, it offers an expandability feature. By repairing one more crater and removing two UXOs and the bomblet field, an additional 2,300 feet of MOS length can be gained. The repair time estimate should be similar to both of the other MOSs.

3.15.4. **Candidate Comparisons.** Comparing the three MOS candidates, MOS #3 seems to provide the preferred solution. Repair time estimates are equal among all MOSs and MOS #3 offers expandability and less aircraft taxi traffic flow interference with the maintenance area.

3.16. Phase 4--Recommending a MOS to the Commander. Based on the evaluation of all three candidates, MOS #3 would be briefed to the wing commander as the selection of choice. MOS #1 would be the alternative if an option was asked for by the commander.

3.17. Chapter Summary. MOS selection is a critical phase of the total effort required to establish a launch and recovery surface for aircraft. To those involved, it can be time consuming, confusing and somewhat complicated if not practiced often. As indicated earlier, the selection process is not an exact science. But top quality personnel that are properly organized and trained can do the job in an effective manner. The need for high competency in and thorough understanding of the MOS candidate selection process cannot be over emphasized. The speed with which MOS candidate search and selection must be accomplished, coupled with the pressures and confusion of a postattack situation will not permit methodical, detailed, step-by-step evaluations of airfield pavement conditions. Minimum operating strip selection must be second nature to the selection team and the only way to gain this degree of efficiency is through constant, repetitive, realistic training. Remember, the mission of the entire air base after an attack is hostage to MOS selection. All principles involved in MOS selection must be prepared to perform this process rapidly and accurately--nothing less is acceptable.

Chapter 4

REPAIR QUALITY CRITERIA

4.1. Introduction. While today's modern aircraft are multi-capable, versatile, and extremely lethal in a combat environment, they are nevertheless highly dependent upon an airfield operating surface which must be in “near perfect” condition. This is primarily because the landing gear configurations of most aircraft are highly intolerant of pavement irregularities. Historically, aircraft designers have traded-off landing gear upgrades and undercarriage strengthening for decreased weight and improved avionics and weapons carrying capacities to increase the combat functions of aircraft. This sensitivity to the condition of airfield operating surfaces makes the rapid runway repair (RRR) task more difficult in that we must not only be attuned to the time it takes to accomplish repairs but also capable of accomplishing high quality repairs. These two features often tend to oppose each other and can only be made to mesh if sufficient training and preattack preparation are performed. Included in this training and preparation are the physical tasks of RRR, minimum operating strip (MOS) selection, and the subject of this chapter--the determination of repair quality criteria (RQC).

4.2. Overview. In this chapter we will discuss the procedural aspects of determining repair quality criteria for MOS crater repairs in a wartime situation. Included will be the purpose of RQC, the use of various charts and tables associated with RQC development, the interface between RQC and MOS selection, and the general concept of operations and timing of RQC activities. Although this chapter will address the details of RQC calculations and provide an example based on the MOS chosen in the previous chapter on MOS selection, you must obtain a copy of Technical Order (T.O.) 35E2-4-1, *Repair Quality Criteria System For Rapid Runway Repair*, before you can train RQC procedures fully. The T.O. contains additional aircraft related charts which are not provided in this volume due to their quantity. The T.O. also contains additional examples which can be used for training purposes.

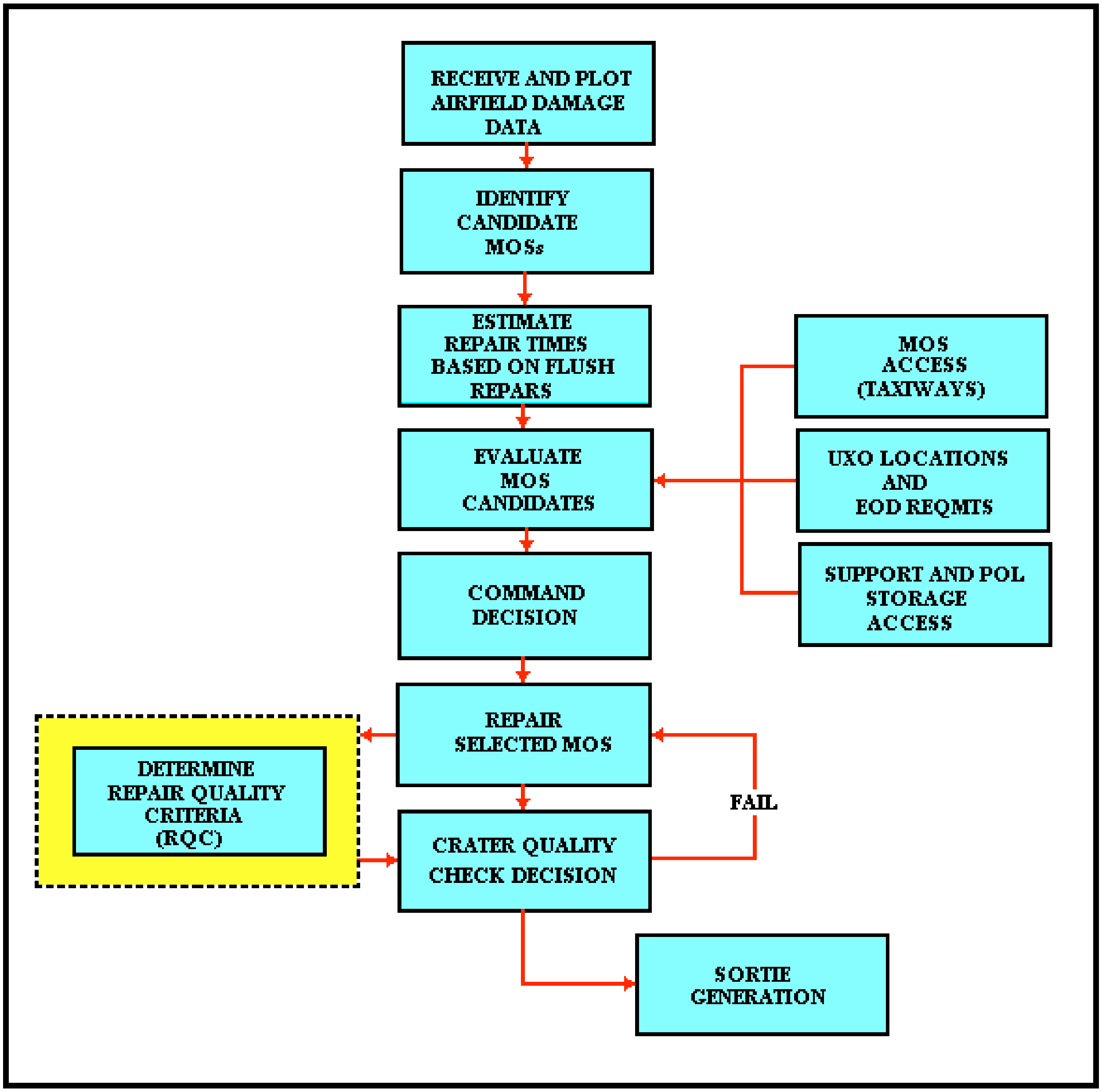
4.3. Purpose. The purpose of repair quality criteria is to provide guidance to the wing command and control staff, the damage control center (DCC), and RRR crews regarding the suitability of wartime pavement repairs for aircraft launch and recovery operations. The criteria basically tells whether a crater repair is good enough to allow aircraft use.

4.3.1. Current USAF policy calls for repairing a minimum operating strip for aircraft operations after an airfield attack. Rapid runway repair teams will attempt to make all repairs flush with the adjacent undamaged pavement surface (plus or minus 3/4 of an inch) using primarily the folded fiberglass mat repair technique. However, such repairs are difficult to achieve due to hindrances like poor weather conditions, equipment failures, personnel attrition, or the presence of chemicals and unexploded ordnance. When flush repairs are not obtained by the RRR teams, RQC becomes extremely critical. The criteria answers crucial questions such as must nonflush repairs be upgraded, or can they be used as is? The criteria also provides information on when and if maintenance to repaired craters is necessary, due to the development of out-of-tolerance sagging.

4.3.2. Repair quality criteria calculations result in either an **F**, indicating a flush repair requirement, or a single number, expressed in inches, for each MOS crater repair. This number represents the maximum allowed height that a finished repair can have in relationship to adjacent undamaged pavement. Determining RQC for each repair is a critical step in the air base recovery process. Incorrect RQC can result in certification of an unacceptable runway surface as usable. Operations on improperly certified surfaces could damage aircraft and endanger personnel. Proper use of the RQC system provides a pass/fail assessment for expediently repaired pavement surfaces which alleviates the potential of certifying an unacceptable MOS.

4.4. Concept of Operations. Repair quality criteria determination is an integral part of the RRR process, paralleling to some extent, then following MOS selection activities. The MOS selection team in the primary survival recovery center (SRC), has the responsibility for RQC calculations. As a cross-check, engineer representatives in the alternate SRC should also perform the calculations. If it is locally determined that MOS selection will concurrently be performed by civil engineer damage control center personnel, they should act as another RQC safety check. Regardless of how many control centers perform RQC determinations, however, ultimately the responsibility rests with the primary SRC engineer staff. Figure 4.1 depicts how the RQC process typically interfaces with MOS selection and RRR activities. As a minimum, RQC calculations must be accomplished after the wing commander chooses the MOS to be repaired and again after MOS repairs are completed if crater locations, lengths and spacings have changed during the repair process. Crater changes are entirely probable since damage assessment inputs are field estimates rather than precise measurements. Ideally, however, RQC determinations should start as early as possible.

Figure 4.1. MOS Selection--RRR/RQC Interface.



4.5. Activities Sequencing. As mentioned in the previous chapter, one of the initial actions required with respect to MOS selection is to ensure the necessary maps, charts, materials, and equipment are available in all appropriate command posts prior to an attack situation. This is equally important with regard to RQC components. A copy of the RQC technical order and extra copies of all worksheets and aircraft charts must be available. As a basic necessity, a reasonable estimate on what aircraft charts to have would be to consider charts associated with any in-place aircraft and aircraft scheduled in via operations plan (OPLAN) force deployment lists.

4.5.1. Also, in the previous chapter on MOS selection, certain initial steps are to be taken once the alert level dictates command centers are to be fully activated. The MOS selection team in the SRC immediately begins to gather data from the wing operations center (WOC) such as types of aircraft to be operated, the need for an arresting barrier, anticipated weather conditions, desired MOS length, etc. Besides being used in MOS selection, these data also form the basis for RQC calculations. Therefore, it is doubly imperative that this information be obtained as soon as possible.

4.5.2. Once the initial information is obtained from the WOC, the survival recovery center MOS selection team should gather the applicable aircraft charts and start filling in the worksheets. Particular attention should be paid to the required MOS length and width. The WOC will provide required MOS dimensions based on knowledge of aircraft characteristics and operational requirements. While the MOS length is probably adequate, since it came from the Operations community, it is worthwhile to make a cross-check using the RQC aircraft charts. MOS length is greatly affected by weather and pavement surface conditions and whether takeoffs or landings of a particular aircraft are being considered. For planning purposes, a nominal MOS length has commonly been considered 50 feet by 5,000 feet, but these dimensions may not hold true for all situations, particularly if environmental conditions tend to be variable. Once all relevant information is obtained from the WOC, the MOS selection team should calculate required MOS lengths for both takeoffs and landings of all applicable aircraft. If disparities with dimensions provided by the WOC are found, these should be resolved before further MOS selection activities take place. Once a MOS length is agreed upon by the WOC and the SRC, the necessary MOS template can be made for use in the MOS selection process with the assurance that MOS length will be adequate. If this action is not accomplished, MOS selection and subsequent RRR efforts could be based on a MOS length that may be too short to meet all desired operational requirements. Rapid runway repair crews may then be faced with a situation of having to repair additional pavement damage beyond that originally planned. This obviously causes a delay in aircraft sortie generation. Once the initial information is received from the WOC and MOS length and width have been verified by the MOS selection team, all such data must be relayed to the alternate SRC and the DCC, if appropriate.

4.5.3. After attack damage has been plotted, candidate MOSs will be identified and a MOS selected. If SRC staffing and time permit, RQC calculations should be accomplished for the most promising MOS candidates at this time as well. This information will give an indication of the degree of accuracy needed during RRR operations. Although all MOS crater repair techniques are meant to yield flush repairs, unless a RRR team is well trained and competent, it could have difficulty in meeting the flush criteria in a responsive timeframe. All else being equal, it is often better to recommend MOS candidates having greater latitude of repair tolerance, thereby to some degree countering the inexperience of a RRR team. This is a situation where the BCE and his staff must have an in-depth knowledge of the capabilities of the RRR team in order to make sound operational recommendations to the command section.

4.5.4. Once the wing commander has selected the MOS for repair and the DCC has dispatched the RRR teams, the MOS selection team performs the mandatory portion of the RQC process. Using the initial data obtained from the WOC and the crater location, size, and spacing information pertaining to the chosen MOS, repair quality criteria calculations are performed. When completed they are compared with those obtained at the alternate SRC and the DCC (if applicable) as a cross-check for accuracy. As repairs progress and actual repair patch locations, lengths, and spacing are identified, the RRR team chief relays this information back to the DCC and SRC. Repair quality criteria calculations are then reaccomplished to see if criteria have been altered due to changes in actual crater locations, lengths, and spacings found during the repair process. The results of these calculation are provided to the RRR team chief. If crater repairs are within tolerance, the RRR team completes MOS cleanup and progresses to its next assigned tasking. If, however, repairs are not within tolerance, the wing commander is informed of the situation and a decision is made by the commander as to whether aircraft operations will be attempted under such conditions. If the decision is negative, the RRR team must reaccomplish the out-of-tolerance crater repairs until they are suitable for aircraft use, i.e., meet RQC tolerances.

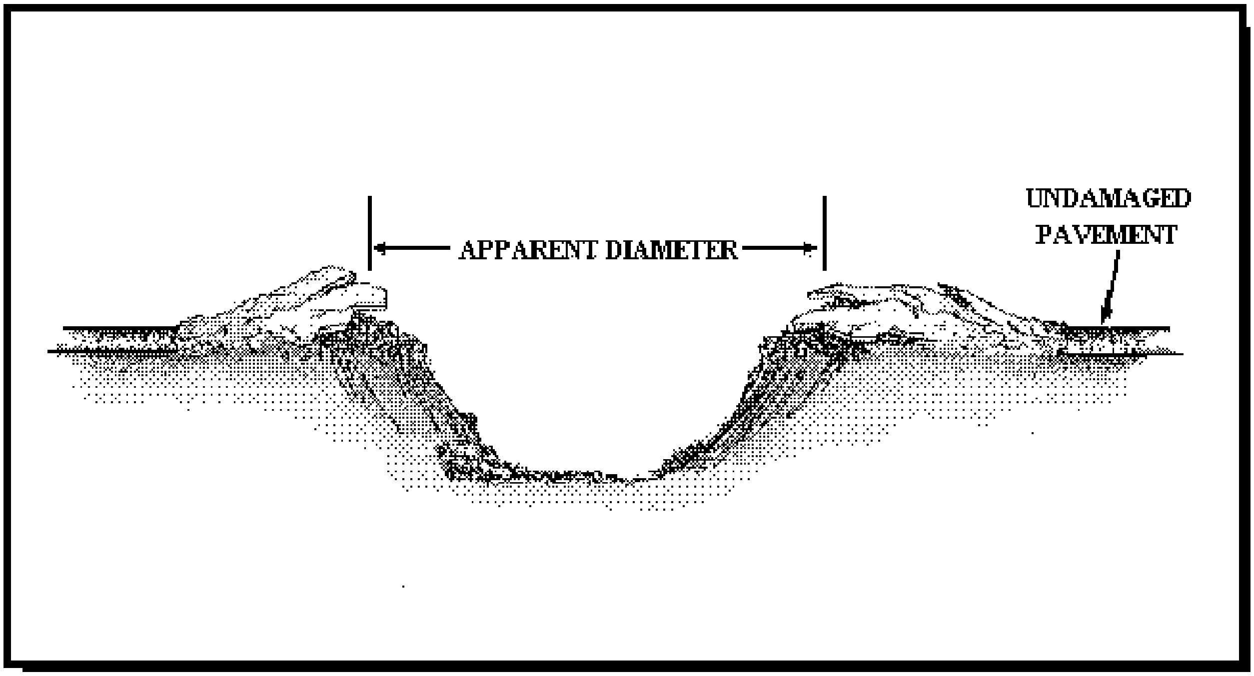
4.5.5. After repairs are complete and the MOS is usable, RQC calculations continue to apply for maintenance purposes. The tolerance measurements for each repair patch also provide information for maintenance purposes. With sustained aircraft use, the repaired craters on the MOS will most likely begin to settle. This settlement, called sag, could be just as damaging to aircraft landing gear as original crater repairs that are out-of-tolerance. Therefore, periodic checks of the repair patch quality on sag must be made to ensure their suitability for continued aircraft use. If a patch is found to be nearing an out-of-tolerance condition, an arrangement must be made with the airfield operations function to allow MOS downtime for crater repairs. It is also important to note changes in weather conditions. Wide temperature changes and precipitation will require RQC to be recalculated. According to the technical manual, MOS repairs that fall within a numbered area on the appropriate chart (0" to 6") are allowed to have a maximum 2" sag. However, craters that call for a flush (**F**) repair can have a maximum sag of only 3/4".

4.6. Repair Quality Criteria Procedures. In its most basic form, the RQC system is a set of charts and tables that allow quick and accurate determination of allowable crater repair roughness. Different aircraft can withstand varying levels of runway roughness. In addition, weather and runway conditions may affect an aircraft's performance and consequently, its tolerance to pavement irregularities. Furthermore, the type of aircraft operations also affect RQC, since different operations call for different procedures and aircraft configurations. All of these parameters are taken into account in the RQC system.

4.7. Terminology. An understanding of the terminology used in the RQC system is critical. The following are definitions for some of the more important terms common to the RQC process. It is imperative that all civil engineer command center personnel and RRR team leaders be thoroughly conversant with the meanings of these terms.

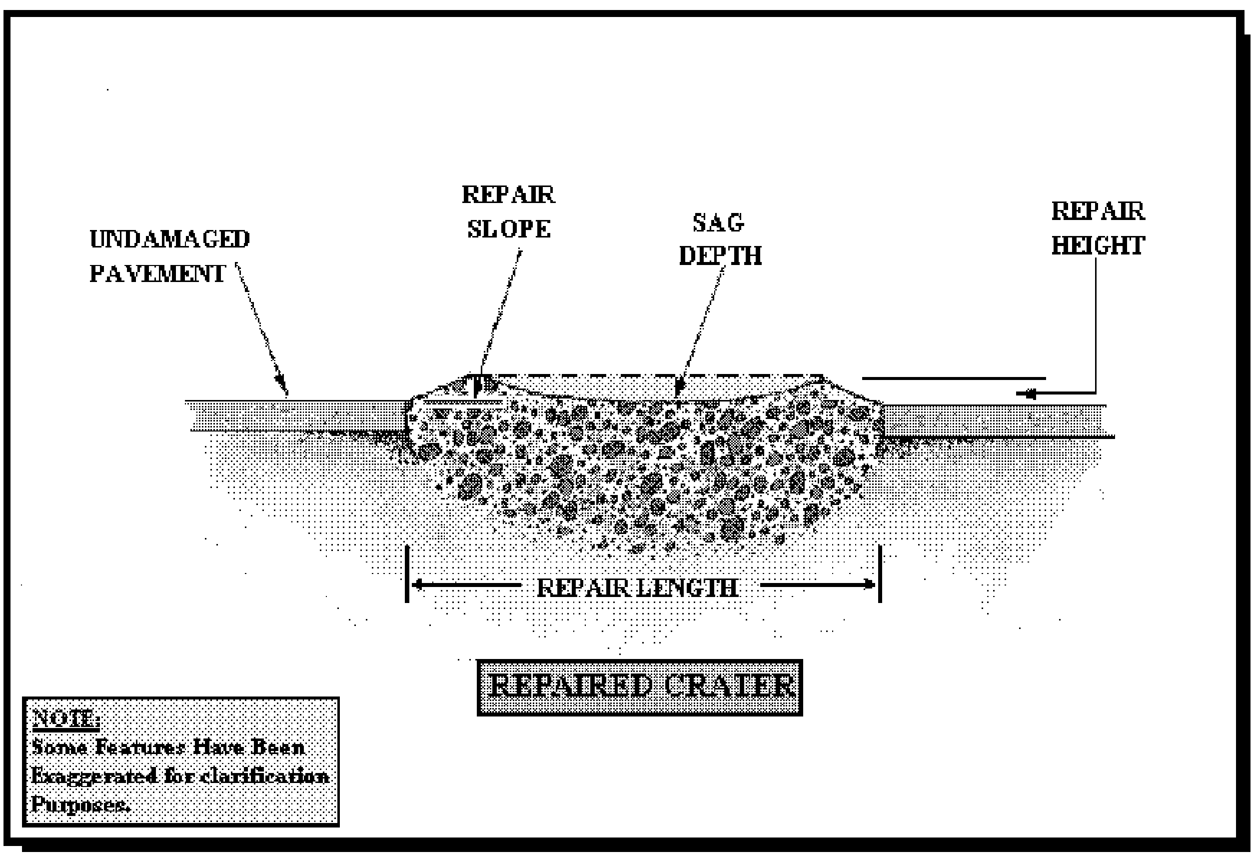
4.7.1. **Apparent Diameter.** The extent of visible damage associated with a crater (figure 4.2) measured from upheaved lip to upheaved lip. This is the information that is forwarded to the SRC by the DATs.

Figure 4.2. Apparent Crater Diameter.



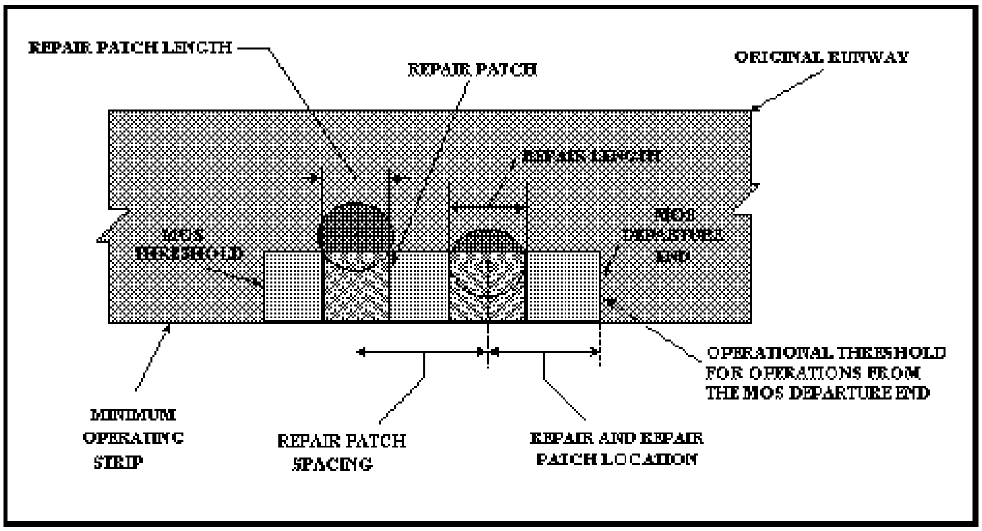
4.7.2. **Repair Length.** The length of a repaired crater, measured parallel to the MOS centerline, from undamaged pavement to undamaged pavement. Repair length is expressed in feet and is plotted as double the apparent diameter during the damage plotting portion of MOS selection (figure 4.3).

Figure 4.3. Repair Terminology.



4.7.3. **Repair Height.** The maximum height of the repair surface above the original undamaged surface (figure 4.3).
4.7.4. **Sag.** The maximum amount, in inches or fraction thereof, that a repair surface drops below the maximum repair height. Allowing sag permits a repair to degrade with aircraft traffic without requiring excessive maintenance during sortie generation. Allowable sag depths on RQC charts are constant (2.0 inches) for numbered repairs. Allowable sag depth for flush repairs is only 3/4 inch, since by definition flush means plus or minus 3/4 inch. These restrictions apply for each profile line overall portions of a repair surface (figure 4.3).
4.7.5. **MOS Threshold.** The MOS threshold is the starting point of the MOS (figure 4.4). It corresponds to the end of the MOS with the lowest numbered station marker on the pavement reference marking system.

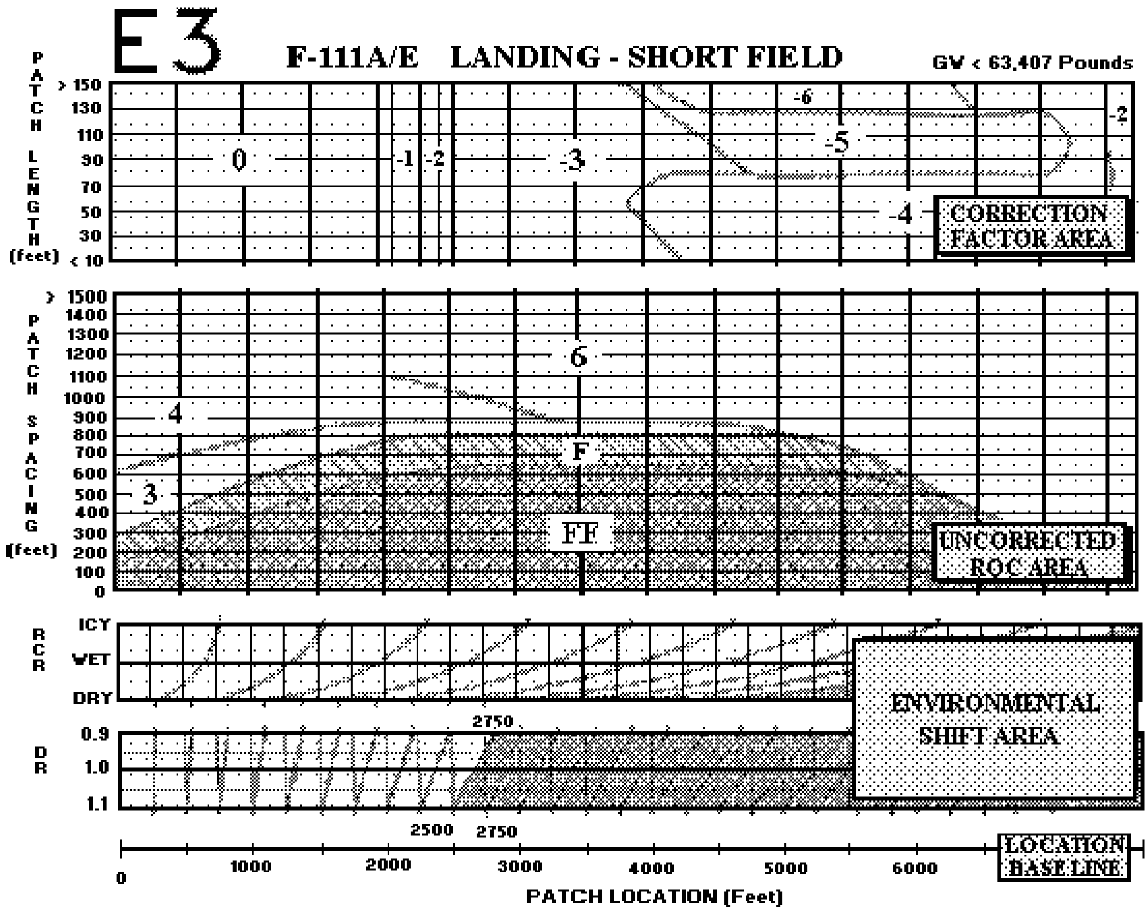
Figure 4.4. MOS Terminology.



4.7.6. **Departure End.** The departure end is opposite end of the MOS from the MOS threshold (figure 4.4). This point corresponds to the highest numbered station marker location on the selected MOS. All aircraft operations must begin at either the threshold or the departure end of the MOS.
4.7.7. **Operation Threshold.** The point on the MOS where aircraft begin their takeoff roll or touchdown on landing. For bidirectional operations, aircraft can operate from either the MOS threshold or the MOS departure, depending upon which direction aircraft will be flying when operations commence (figure 4.4). As will be described later in this chapter, bidirectional operations will require RQC calculations to be performed twice--once for operations starting from the MOS threshold and once for operations starting from the MOS departure end (typically driven by prevailing wind and given as runway headings).
4.7.8. **Repair Patch.** A repair patch is an area on the MOS that may include a single repair, part of a repair, or a combination of any number or parts of repairs. A repair patch is an area fixed as a single repair (figure 4.4).
4.7.9. **Repair Patch Location.** The location of a repair patch center relative to the operation threshold. The location is measured parallel to the MOS centerline and is expressed in feet (figure 4.4).
4.7.10. **Repair Patch Spacing.** Repair patch spacing is the distance from one repair patch center location to the next repair patch center location. Spacing is measured in feet parallel to the MOS centerline (figure 4.4).
4.7.11. **Repair Patch Length.** This is the length of a repair patch, measured parallel to the MOS centerline. Repair patch length is expressed in feet (figure 4.4).

4.8. RQC Chart Description. Technical Order 35E2-4-1 contains a number of different RQC charts designed to support various aircraft and operating situations. For example, chart E1 governs F-111A and F-111E aircraft during takeoff whereas chart E3 applies to F-111A/E aircraft during landing on short runways (short-field). Charts also exist for other variations like evacuation (the expedient departure with the lightest load possible). All RQC charts are divided into four major areas: location baseline, environmental shift area, uncorrected RQC area, and correction factor area. Figure 4.5 shows an example of a typical RQC chart.
4.8.1. **Location Baseline.** The location baseline is the starting point for RQC calculations. The baseline is at the bottom of an RQC chart. Marking the location of each crater repair on this line begins the RQC determination process. All locations are measured from the operation threshold.

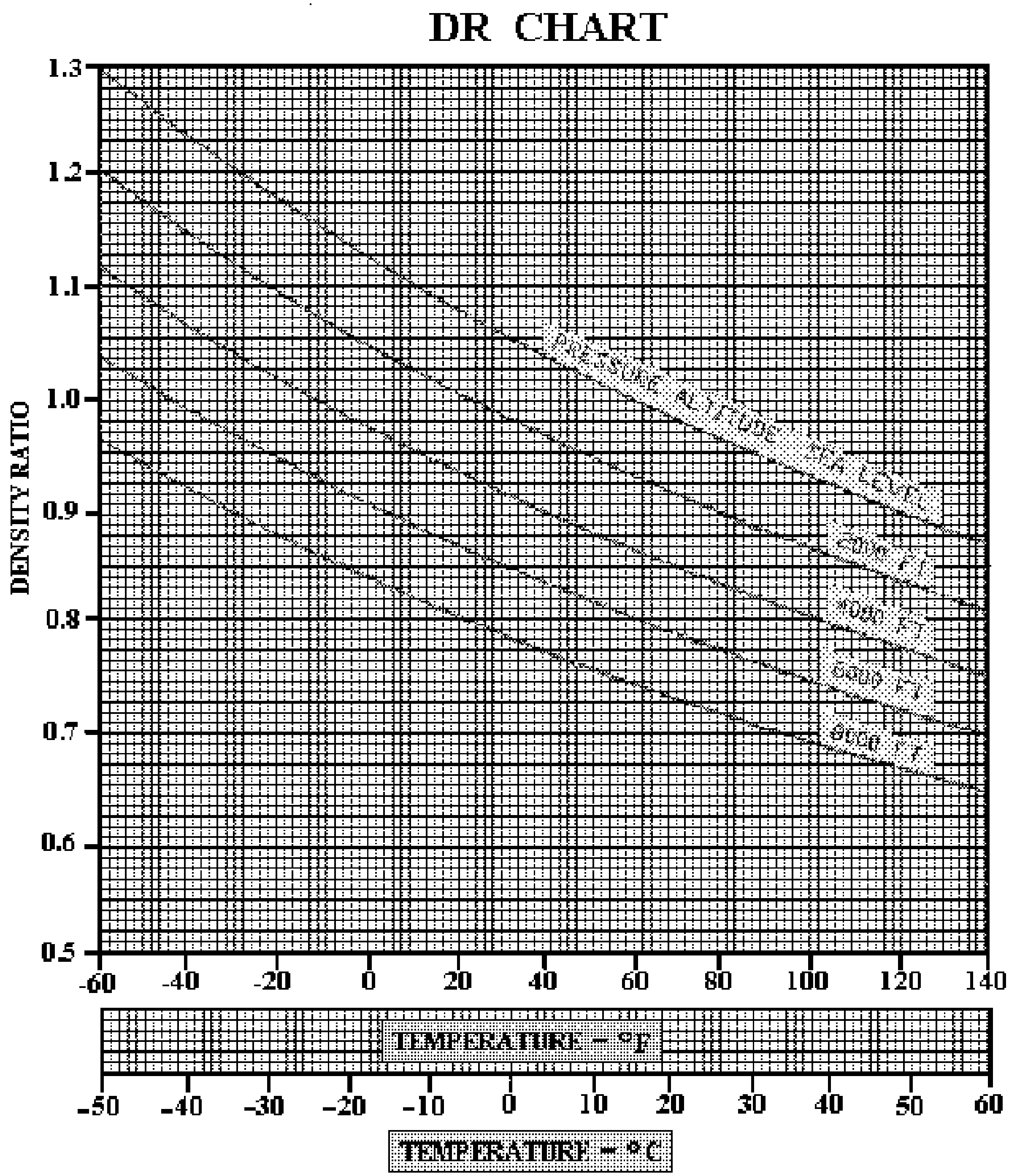
Figure 4.5. Example RQC Chart.



4.8.2. **Environmental Shift Area.** The environmental shift area includes the boxes above the baseline that compensates for aircraft performance changes under varying weather and runway surface conditions. These conditions are depicted using density ratio (DR), runway condition reading (RCR), and runway surface condition (RSC) numbers.

4.8.3. **Density Ratio (DR).** Density ratio is the relationship between air temperature and altitude which gives a measure of aircraft performance. On cool days the density ratio will be high and performance will be good. This means takeoff distances will be shorter. Ask base weather for the expected high temperature and pressure altitude. With these figures the DR can be found by using the chart shown in figure 4.6. Enter the chart with the temperature along the X-axis. From this temperature value, go vertically until the appropriate altitude line is reached. Then go horizontally to the Y-axis and read the DR value. For example, at 59 degrees Fahrenheit at sea level the DR value is 1.0. Note that as temperature and altitude increase, the DR value decreases. Density ratio affects all aircraft on takeoff and landing.

Figure 4.6. Density Ratio.



4.8.4. **Runway Condition Reading.** Runway condition reading affects the landing distance of aircraft by influencing wheel braking effectiveness. It can be measured as a specific number, but for purposes of RQC calculations it is subjectively expressed in terms of three choices: wet =12, dry =23, or icy =6.

4.8.5. **Runway Surface Condition.** Runway surface condition is a measure of the precipitation standing on the runway. It affects only multi-wheeled wide body aircraft during takeoff. Because of the large tire footprint area of cargo aircraft, precipitation can cause significant additional friction, resulting in a lengthening of the takeoff roll.

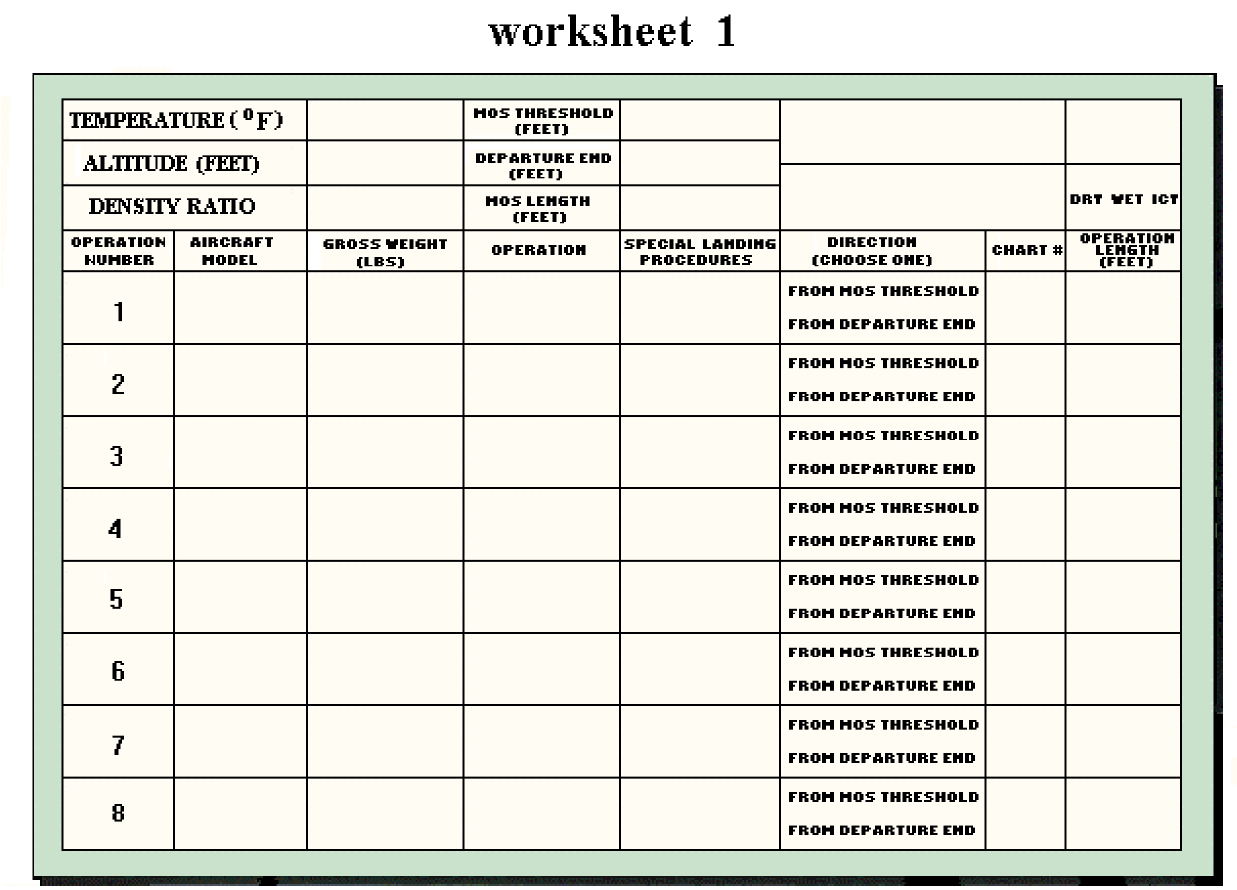
4.8.6. **Uncorrected RQC Area.** This area is located on the RQC chart just above the environmental shift area. It is used to assign an initial value for maximum repair height, based on patch spacing. For example, "**F**" means the repair must be flush; "**FF**" means the next repair down the MOS must also be flush. The areas identified by the numbers 1 through 6 reflect the maximum repair height in inches. As mentioned earlier, all numbered repair heights can allow a maximum sag of 2 inches. No sag is allowed with flush repairs beyond the + or - 3/4 of an inch normally accepted as part of flush repair criteria. These restrictions apply over all portions of a repair surface. The vertical axis on the RQC chart represents crater repair patch spacing. When a number is missing, like 5 is in the chart in figure 4.5, it means that the variance between numbers was too small to indicate.

4.8.7. **Correction Factor Area.** The correction factor area is at the top section of the RQC chart. It assigns a correction factor to the repair height, based on repair length. Here the vertical axis represents crater repair length. The correction factor is added to the uncorrected RQC to obtain the final required RQC. A quick look at figure 4.5 should tell you that the RQC for the F-111 A/E will never exceed 6 inches. The correction factor either reduces the repair quality height or has no affect. ***NOTE*:** No correction factor is allowed for "**F**" or "**FF**" repairs in the uncorrected RQC area. If, however, the correction factor is larger than the uncorrected RQC and the resultant RQC is negative, the RQC becomes "F".

4.9. Worksheets. Figures 4.7, 4.8, and 4.9 depict the three worksheets used in the RQC process. They are basically used sequentially for data collection as the RQC process progresses. The example that will be worked shortly will show you the details of how the forms are used; we will only briefly address the data that goes on the forms at this point.

4.9.1. **Worksheet 1 (figure 4.7).** This sheet (AFTO Form 71) is used to record much of the "given" data received from the WOC and base weather at the onset of the MOS selection and RQC determination processes. Information such as aircraft weights, weather, DR, operational parameters, required pavement lengths, and RQC chart numbers are entered.

Figure 4.7. RQC Worksheet 1.



worksheet 1

TEMPERATURE (°F)			MOS THRESHOLD (FEET)				
ALTITUDE (FEET)			DEPARTURE END (FEET)				
DENSITY RATIO			MOS LENGTH (FEET)				DRY WET ICY
OPERATION NUMBER	AIRCRAFT MODEL	GROSS WEIGHT (LBS)	OPERATION	SPECIAL LANDING PROCEDURES	DIRECTION (CHOOSE ONE)	CHART #	OPERATION LENGTH (FEET)
1					FROM MOS THRESHOLD FROM DEPARTURE END		
2					FROM MOS THRESHOLD FROM DEPARTURE END		
3					FROM MOS THRESHOLD FROM DEPARTURE END		
4					FROM MOS THRESHOLD FROM DEPARTURE END		
5					FROM MOS THRESHOLD FROM DEPARTURE END		
6					FROM MOS THRESHOLD FROM DEPARTURE END		
7					FROM MOS THRESHOLD FROM DEPARTURE END		
8					FROM MOS THRESHOLD FROM DEPARTURE END		

4.9.2. **Worksheet 2 (figure 4.8).** This sheet (AFTO Form 72) is used to record the repair patch locations, lengths and spacings, and calculate the RQC values obtained from the aircraft RQC charts.

Figure 4.8. RQC Worksheet 2.

WORKSHEET 2

MOS THRESHOLD (Ft)		OPERATION #					
DEPARTURE END (Ft)			FROM MOS THR.				
			FROM DEP. END				
MOS LENGTH (FEET)		OPERATION LENGTH					

CHART #	OP. #/ PATCH #	PATCH LOCATION (FEET)	PATCH LENGTH (FEET)	PATCH SPACING (FEET)	UNCORRECTED RQC	CORRECTION FACTOR	RQC

4.9.3. **Worksheet 3 (figure 4.9).** This sheet (AFTO Form 73) serves as a summary chart for the various crater repair RQC values and enables the determination of the final RQC requirements. It is most important when calculating RQC for bidirectional MOSs.

Figure 4.9. RQC Worksheet 3.

WORKSHEET 3

OPERATION DIRECTION	FROM MOS THRESHOLD														
OPERATION #	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH
SUMMARY															

OPERATION DIRECTION	FROM DEPARTURE END														
OPERATION #	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH
SUMMARY															
COMBINED															

4.10. Example. To illustrate the procedures for determining RQC, the MOS selection example from the previous chapter will be used as a baseline. The instructional guidelines in T.O. 35E2-4-1 also parallel what is presented in the example that follows.

4.10.1. Figure 4.10 shows the airfield map, plotted damage, and primary MOS candidate from the MOS example. Figure 4.11 provides an expanded picture of the MOS candidate itself. The following data are assumed to have been obtained from the WOC:

Figure 4.10. MOS Candidate.

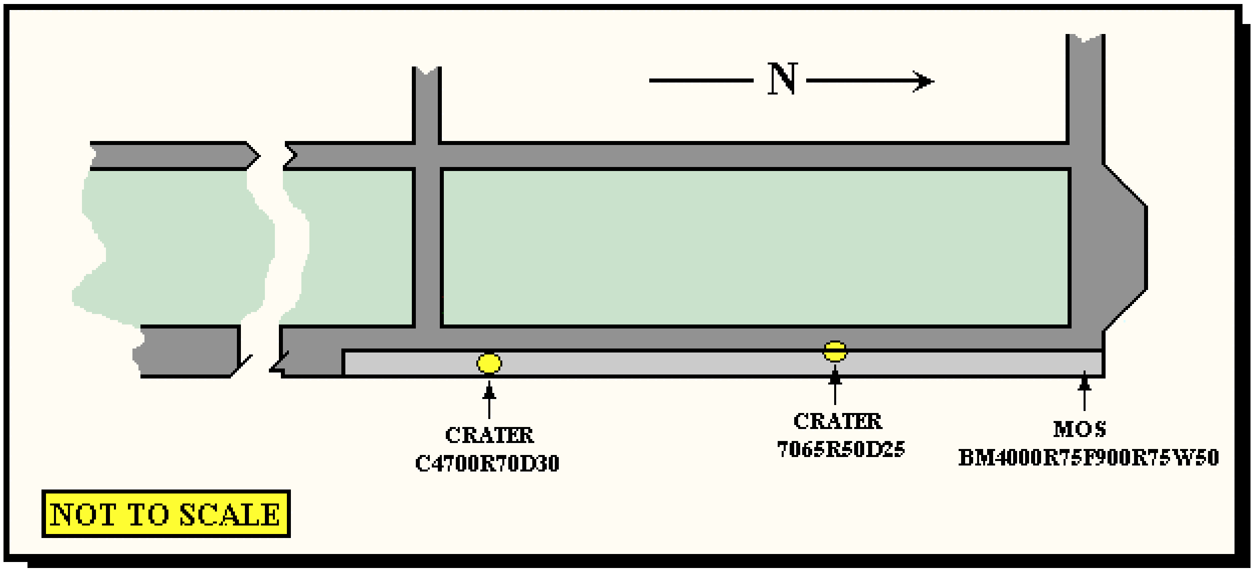
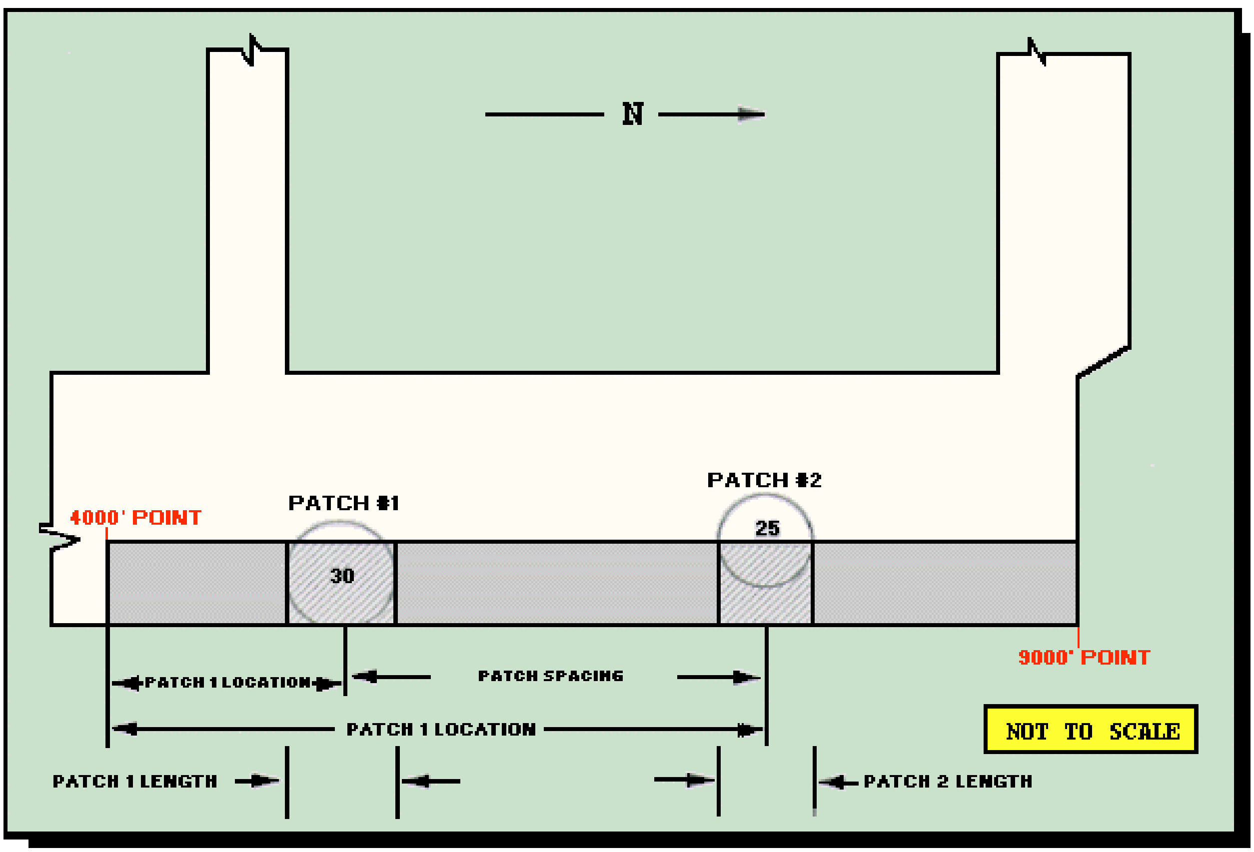


Figure 4.11. Expanded Picture of MOS.



4.10.1.1. Aircraft type--one squadron of F-111A aircraft. Cargo aircraft not a primary consideration.
4.10.1.2. Aircraft takeoff weight--90,000 lbs.
4.10.1.3. Aircraft landing weight--55,000 lbs.
4.10.1.4. Bidirectional operations desired.
4.10.1.5. Required MOS size--50 feet by 5,000 feet.
4.10.1.6. Sea level operations.
4.10.1.7. Weather--currently clear, long-range forecast clear, temperature high of 50 degrees Fahrenheit.

4.10.1.8. F-111A short field landing, minimum runway length procedures acceptable.
4.10.1.9. Evacuation requirements not probable.
4.10.1.10. Aircraft arresting barrier capability desirable but not mandatory at this time.
4.10.2. The above information is transposed onto worksheet 1 (figure 4.12). Because a bidirectional feature is desired, landings and takeoffs from both the MOS threshold end (operations 1 and 2) and the departure end (operations 3 and 4) are identified. Both variations must be addressed, since crater patches will be at different locations relative to aircraft roll, depending upon the direction of travel. In our example an aircraft traveling south to north (360 degree heading) on the MOS will reach crater patch number 1 before an aircraft traveling north to south (180 degree heading) will reach the same patch. This difference could influence RQC values resulting in the possibility that the same patch could have different values depending on the aircraft's travel direction. Investigate both situations to ensure the more stringent requirement is addressed.

Figure 4.12. WOC Data.

WORKSHEET 1

TEMPERATURE (°F)		50	MOS THRESHOLD (FEET)	4,000	RSC		0.0
ALTITUDE (FT)		Sea Level	DEPARTURE END (FEET)	9,000	RCR (CHOOSE ONE)		DRY WET ICY
DENSITY RATIO		1.02	MOS LENGTH (FEET)	5,000			
OPERATION NUMBER	AIRCRAFT MODEL	GROSS WEIGHT (LBS)	OPERATION	SPECIAL LANDING PROCEDURES	DIRECTION (CHOOSE ONE)	CHART #	OPERATION LENGTH (FEET)
1	F-111A	55,000	Landing	Short Field	FROM MOS THRESHOLD FROM DEPARTURE END		
2	F-111A	90,000	Takeoff	———	FROM MOS THRESHOLD FROM DEPARTURE END		
3	F-111A	55,000	Landing	Short Field	FROM MOS THRESHOLD FROM DEPARTURE END		
4	F-111A	90,000	Takeoff	———	FROM MOS THRESHOLD FROM DEPARTURE END		
5					FROM MOS THRESHOLD FROM DEPARTURE END		
6					FROM MOS THRESHOLD FROM DEPARTURE END		
7					FROM MOS THRESHOLD FROM DEPARTURE END		
8					FROM MOS THRESHOLD FROM DEPARTURE END		

4.10.3. The density ratio is determined using the density ratio chart (figure 4.6). A temperature of 50 degrees Fahrenheit and a sea level altitude equates to a DR of approximately 1.02. Since the weather is expected to remain dry for several days, the RCR will be considered "dry". This makes the RSC 0.0, since with dry weather there should be no standing water on the MOS.
4.10.4. The MOS threshold has been designated at the 4,000-foot point and the departure end at the 9,000-foot point corresponding to the desired 5,000-foot MOS required by the WOC. A cross-check on the adequacy of this length will be made shortly using the RQC aircraft charts.
4.10.5. Our next step is to determine what aircraft charts are needed. All such charts are contained in T.O. 35E2-4-1; therefore, we must have a copy of this T.O. readily available. Figure 4.13 provides a summary of some the available RQC aircraft charts. The summary indicates that for F-111A takeoffs, chart E1 is required (figure 4.14) and for F-111A short field landings, chart E3 is necessary (figure 4.15). These chart numbers are noted in the chart # column of worksheet 1 (figure 4.16). Because the WOC indicated a desire for the eventual installation of an aircraft arresting barrier, chart E4 is also gathered (figure 4.17). This chart will be used later as a check to see if the MOS that has been chosen can be properly fitted with an arresting system.

Figure 4.13. RQC Chart Summary.

TYPE AIRCRAFT	RQC CHART NUMBER	OPERATION	TYPE AIRCRAFT	RQC CHART NUMBER	OPERATION
F-15A/B	C1	TAKEOFF	F-111A/3	E1	TAKEOFF
	C2	LANDING-AEROBRAKING		E2	LANDING
	C3	LANDING-WHEEL BRAKING		E3	LANDING-SHORT FIELD
	C4	LANDING ARRESTMENT		E4	LANDING-ARRESTMENT
	C5	EVACUATION		E5	EVACUATION
F-15C/D	C6	TAKEOFF	C-5B	F1	TAKEOFF
	C7	LANDING-AEROBRAKING		F2	LANDING
	C8	LANDING-WHEEL BRAKING	C-130E/H	G1	TAKEOFF
	C9	LANDING ARRESTMENT		G2	LANDING
	C10	EVACUATION	C-141A/B	H1	HEAVY WEIGHT TAKEOFF
F-15E	C11	TAKEOFF	HEAVY	H2	HEAVY WEIGHT LANDING
	C12	LANDING	C-141A/B	I1	MEDIUM WEIGHT TAKEOFF
	C13	LANDING ARRESTMENT		L2	MEDIUM WEIGHT LANDING
	C14	EVACUATION	A-7D	J1	TAKEOFF
F-16A/B	D1	TAKEOFF		J2	LANDING
BLOCK	D2	LANDING		J3	LANDING-ARRESTMENT
	D3	LANDING-ARRESTMENT		J4	EVACUATION
	D4	EVACUATION	A-10A	K1	TAKEOFF
				K2	LANDING

Figure 4.14. F-111A/E Takeoff Chart.

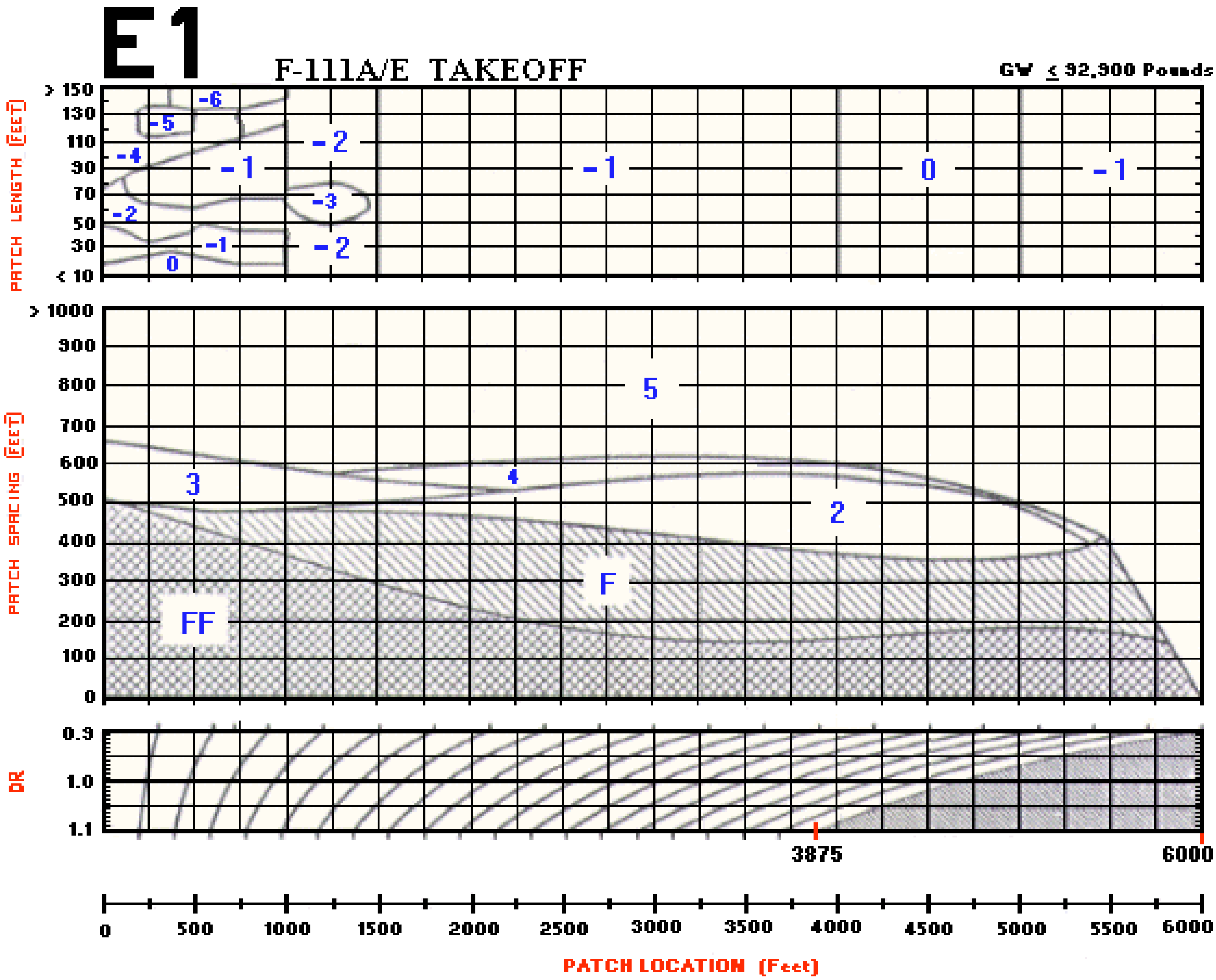


Figure 4.15. F-111A/E Short Field Landing Chart.

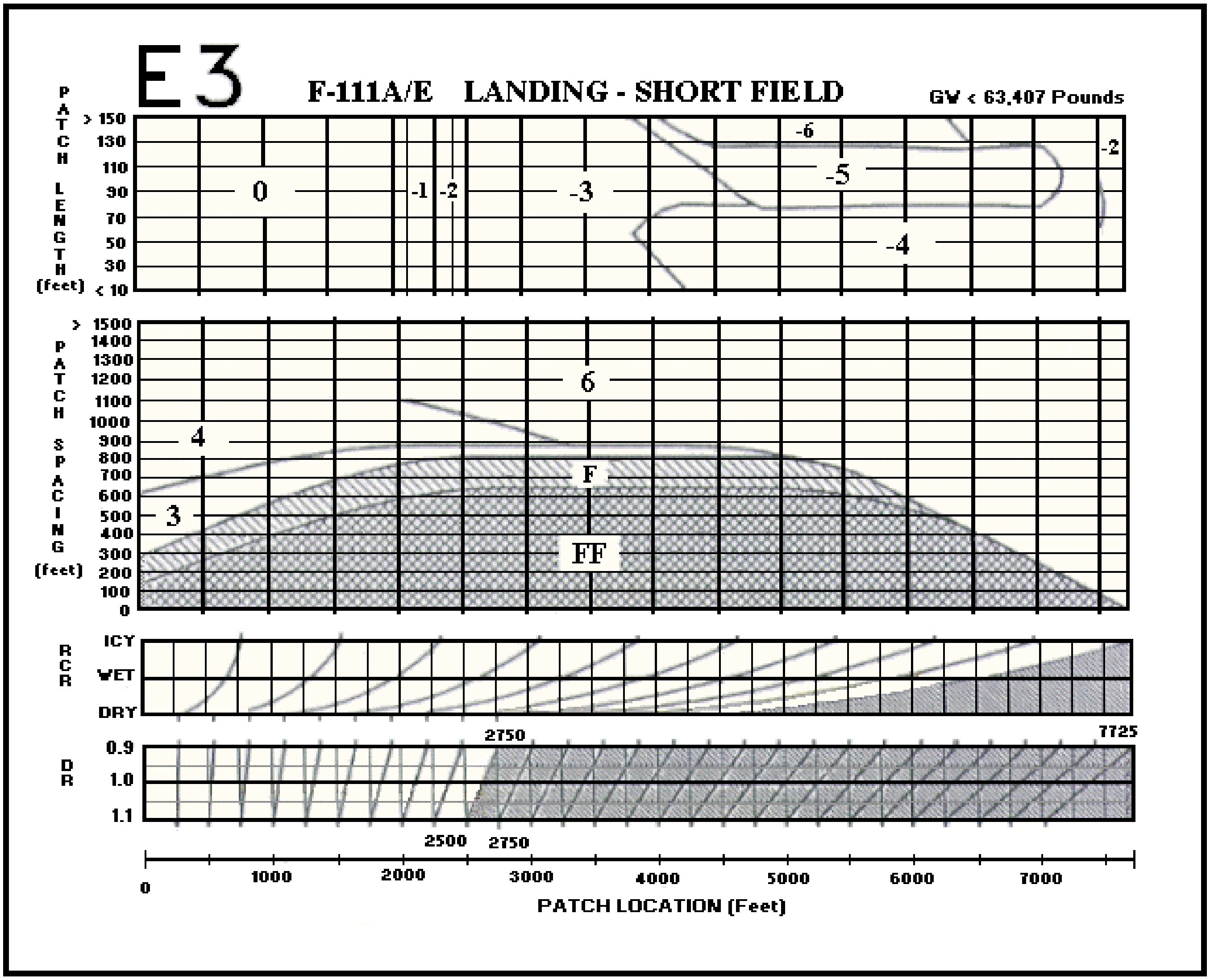


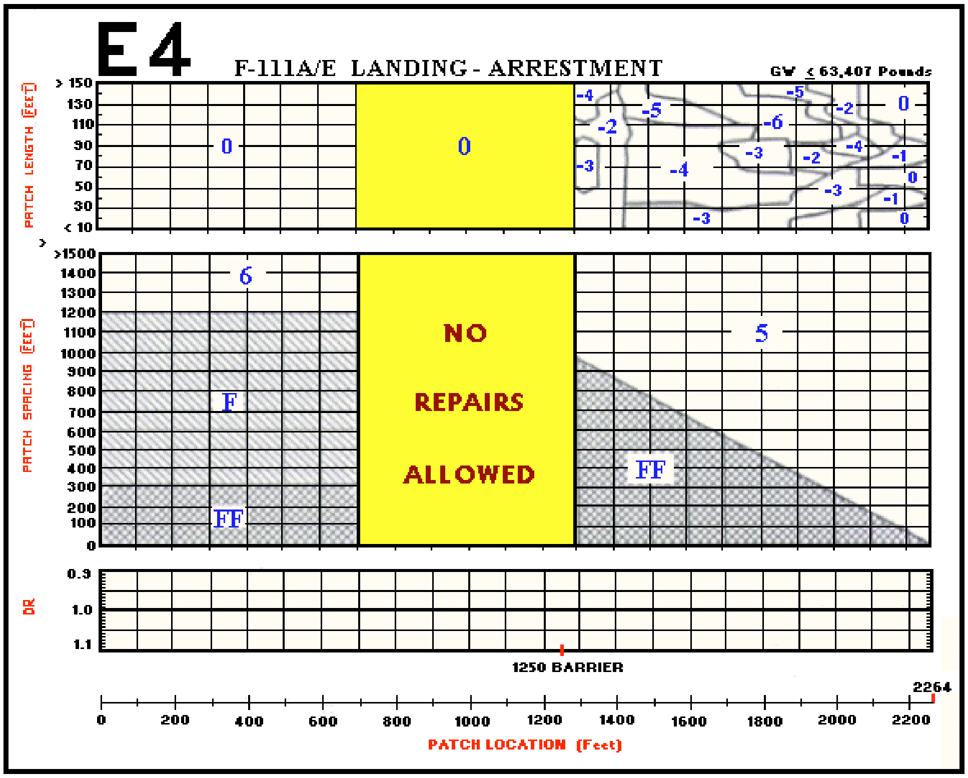
Figure 4.16. Worksheet 1, Chart # Column.

WORKSHEET 1

TEMPERATURE (°F)	50	MOS THRESHOLD (FEET)	4,000	RSC	0.0
ALTITUDE (FT)	Sea Level	DEPARTURE END (FEET)	9,000	RCR (CHOOSE ONE)	DRY WET ICY
DENSITY RATIO	1.02	MOS LENGTH (FEET)	5,000		

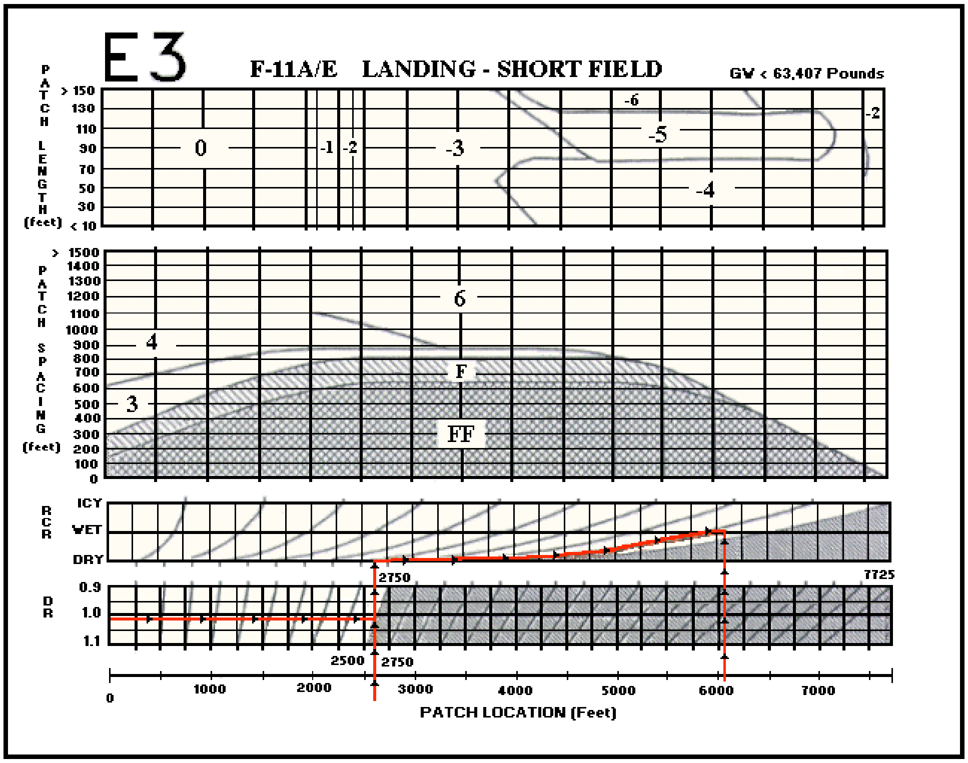
OPERATION NUMBER	AIRCRAFT MODEL	GROSS WEIGHT (LBS)	OPERATION	SPECIAL LANDING PROCEDURES	DIRECTION (CHOOSE ONE)	CHART #	OPERATION LENGTH (FEET)
1	F-111A	55,000	Landing	Short Field	FROM MOS THRESHOLD FROM DEPARTURE END	E-3	
2	F-111A	90,000	Takeoff	——	FROM MOS THRESHOLD FROM DEPARTURE END	E-1	
3	F-111A	55,000	Landing	Short Field	FROM MOS THRESHOLD FROM DEPARTURE END	E-3	
4	F-111A	90,000	Takeoff	——	FROM MOS THRESHOLD FROM DEPARTURE END	E-1	
5					FROM MOS THRESHOLD FROM DEPARTURE END		
6					FROM MOS THRESHOLD FROM DEPARTURE END		
7					FROM MOS THRESHOLD FROM DEPARTURE END		
8					FROM MOS THRESHOLD FROM DEPARTURE END		

Figure 4.17. F-111A/E Landing Arrestment Chart.



4.10.6. The data and charts gathered so far enable us to make determinations of operation lengths necessary for F-111A sortie generation from the selected MOS. Using chart E3 for short field landings, a horizontal line is drawn across the entire DR section corresponding to the DR value (1.02) which was recorded on worksheet 1. Now go back and find the point where the line intersects the shaded part of the DR section (figure 4.18). From this point of intersection, a vertical line is drawn up to the RCR section until it intersects the horizontal line representing "dry" conditions. Because no shift is caused by the RCR section under "dry" conditions, another vertical line is drawn from the RCR intersection point down to the location baseline. The reading at the intersection of this second vertical line and the location baseline is the operation length required for short field MOS landings. In our example this value is approximately 2,600 feet. This number is entered in the operation length column of worksheet 1 for both landing entries (operations 1 and 3). If, however, "wet" conditions were prevalent, the horizontal line on the RCR section representing "wet" conditions would have had to be used. In this case, a vertical line from the DR shaded area intersection would be drawn up to the bottom of the RCR section and then shifted to account for "wet" conditions. This shift would follow the guidelines proportionally from the bottom of the RCR section until the horizontal line representing "wet" conditions was reached. From this new intersection a vertical line would then be drawn down to the location baseline and the appropriate operation length read (approximately 6,125 feet). As would be expected, the new operation length under "wet" conditions would be considerably longer than that obtained when under "dry" conditions (i.e. braking is impacted). The dashed line on figure 4.18 illustrates the "wet" conditions case. In drawing the shift line from the bottom of the RCR chart up to the "wet" conditions horizontal line, it is important to stay between the guidelines in proportion to the starting location at the bottom of the RCR section.

Figure 4.18. F-111A/E Landing - Short Field Chart.



4.10.7. The determination of operation length for the takeoff of the F-111A is somewhat simpler, since no RCR section is contained on aircraft chart E1. A horizontal line is drawn across the DR section corresponding to the 1.02 DR value until it intersects the shaded area of the section. A vertical line is then dropped to the location baseline and a reading taken. For our example the operation length is 4,450 feet (figure 4.19). This number is entered in the operations length column of worksheet 1 for both takeoff entries (operations 2 and 4). Worksheet 1 is now complete (figure 4.20). Note that both the takeoff and landing operation lengths that were just determined were less than the 5,000-foot length requested by the WOC, therefore the 5,000-foot length is obviously adequate. If, however, takeoff or landing operation lengths were found to be greater than 5,000 feet, this information must be passed to the WOC since flight safety and mission effectiveness would be involved.

Figure 4.19. Showing Operation Length.

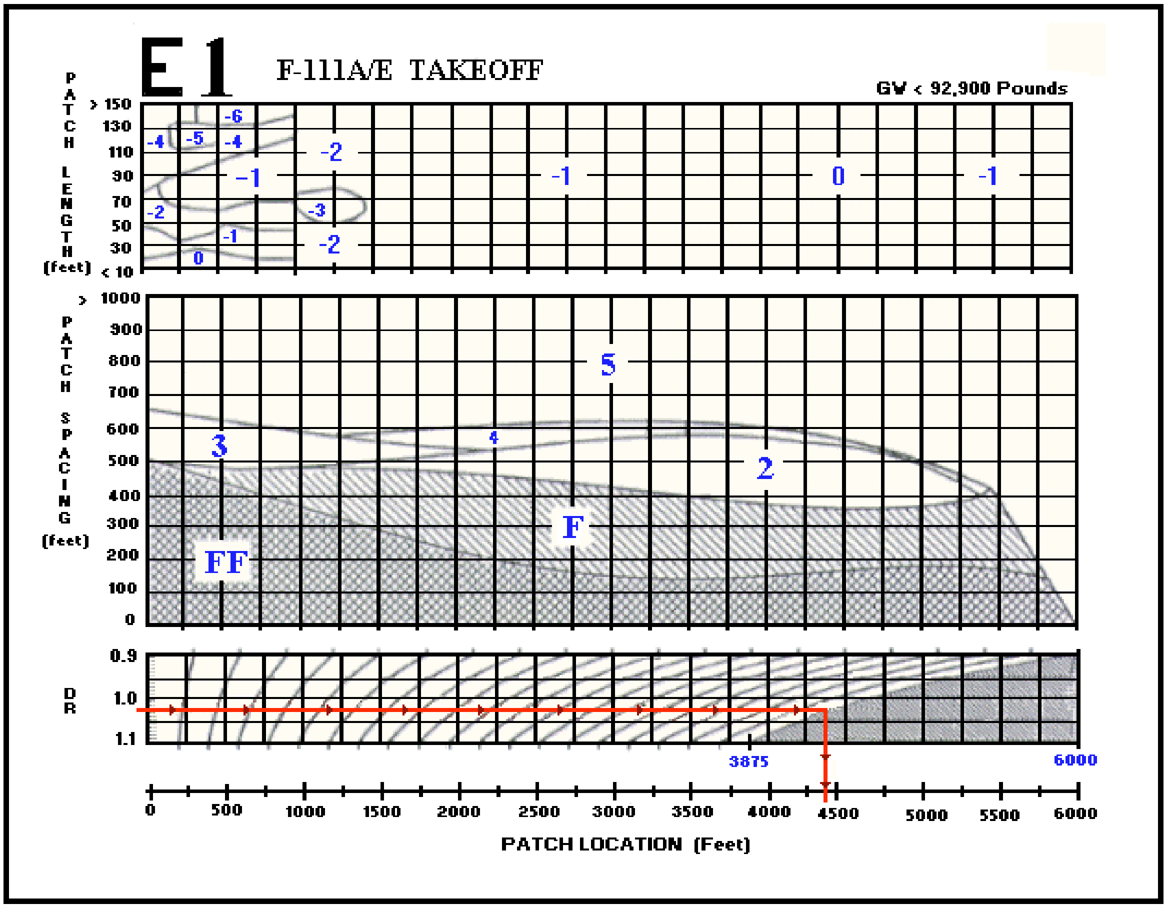


Figure 4.20. Worksheet 1 Complete.

WORKSHEET 1

TEMPERATURE (F)		50	MOS THRESHOLD (FEET)	4,000	RSC		0.0
ALTITUDE (FT)		*Sea Level*	DEPARTURE END (FEET)	9,000	RCR (CHOOSE ONE)		DRY WET ICY
DENSITY RATIO		1.02	MOS LENGTH (FEET)	5,000			
OPERATION NUMBER	AIRCRAFT MODEL	GROSS WEIGHT (LBS)	OPERATION	SPECIAL LANDING PROCEDURES	DIRECTION (CHOOSE ONE)	CHART #	OPERATION LENGTH (FEET)
1	F-111A	55,000	*Landing*	*Short Field*	FROM MOS THRESHOLD / FROM DEPARTURE END	E-3	2,600
2	F-111A	90,000	*Takeoff*	———	FROM MOS THRESHOLD / FROM DEPARTURE END	E-1	4,450
3	F-111A	55,000	*Landing*	*Short Field*	FROM MOS THRESHOLD / FROM DEPARTURE END	E-3	2,600
4	F-111A	90,000	*Takeoff*	———	FROM MOS THRESHOLD / FROM DEPARTURE END	E-1	4,450
5					FROM MOS THRESHOLD / FROM DEPARTURE END		
6					FROM MOS THRESHOLD / FROM DEPARTURE END		
7					FROM MOS THRESHOLD / FROM DEPARTURE END		
8					FROM MOS THRESHOLD / FROM DEPARTURE END		

4.10.8. The next steps in the RQC process involve defining the repair patches and identifying the repair patch locations, lengths, and spacing. The graphics work to support these activities should be accomplished on the same air base maps in the SRC and DCC that airfield damages are plotted on. To define the repair patches, the following actions are taken:

4.10.8.1. For each repair at least partially on the MOS, draw lines perpendicular to the sides of the MOS on both sides of each crater.

4.10.8.2. Shade the areas on the MOS between the lines for each repair.

4.10.8.3. Number each crater consecutively starting from the MOS threshold.

4.10.9. Figure 4.11 depicts the repair patch definition for the two craters on the MOS in our example. Two points pertaining to repair patch definition need to be mentioned before we move on. First, if two or more shaded areas are within 25 feet of each other, treat them as one large repair patch. Secondly, for bidirectional MOSs, RQC will be determined from both directions and the operation threshold will shift from one end of the MOS to the other. The crater numbers, however, do not change when the RQC from the other direction is calculated. Once a patch is numbered, it will retain that number throughout the RQC process.

4.10.10. Once the repair patches are numbered, patch locations, lengths, and spacing are determined; worksheet 2 is used to record all of this data and the MOS plotting board should also be updated accordingly. Since, in our example, RQC is being determined for bidirectional operations, repair patch distances will have to be calculated from both ends of the selected MOS. Figure 4.21 depicts the data for a south to north (360 degree heading) flying operations. The first step is to draw double lines, perpendicular to the sides of the MOS, indicating the operation threshold and operation length. This length corresponds to the operation length determined earlier using the aircraft charts, not necessarily the desired MOS length. Then record the operation number and patch number on worksheet 2 for each patch within the two sets of double lines. For a south to north (360 degree heading) direction the landing operation would include patch 1 and the takeoff operation would include patches 1 and 2. The center of each repair patch is determined next--this corresponds to the station location of the crater reported during damage assessment operations. Patch 1 center is at the 4,700-foot point and patch 2 center is at the 7,065-foot point. Subtracting the operation threshold location point (4,000 feet) from the patch center locations provides the patch locations on the MOS. Repair patch spacing is determined by calculating the distances between the centers of adjacent patches going in the direction of aircraft travel (i.e., patch 1 to patch 2, patch 2 to patch 3, etc). When the last patch within the operation length is reached, the maximum value on the patch spacing axis on the uncorrected RQC area of the applicable aircraft chart is used as the spacing distance. In our example the repair patch spacing between patch 1 and patch 2 is 2,365 feet and the maximum value on the patch spacing axis is 1,000 feet on the E1 chart and 1,500 feet on the E3 aircraft chart. Patch length is twice the apparent diameter as reported by the damage assessment teams. Remember from the MOS selection chapter, this was the dimension used when plotting craters on the airfield map. When two patches overlap or are within 25 feet of each other, a composite length must be calculated. In our example, however, the repair patches are individual, measuring 60' (patch 1) and 50' (patch 2). Figure 4.22 depicts the above data for landings and takeoffs under a south to north (360 degree heading) flying operation. ***NOTE:*** Another way for determining patch spacing distance being taught at the Air Force Institute of Technology for the last patch on an operation follows: Finding the "maximum value on the patch spacing axis on the uncorrected RQC area of the applicable aircraft chart" becomes quite cumbersome when dealing with several aircraft and a bi-directional MOS. Instead, insert the infinity symbol (∞) and go to the top of the Uncorrected RQC portion of the chart.

Figure 4.21. South to North Flying Operations (360 degree heading).

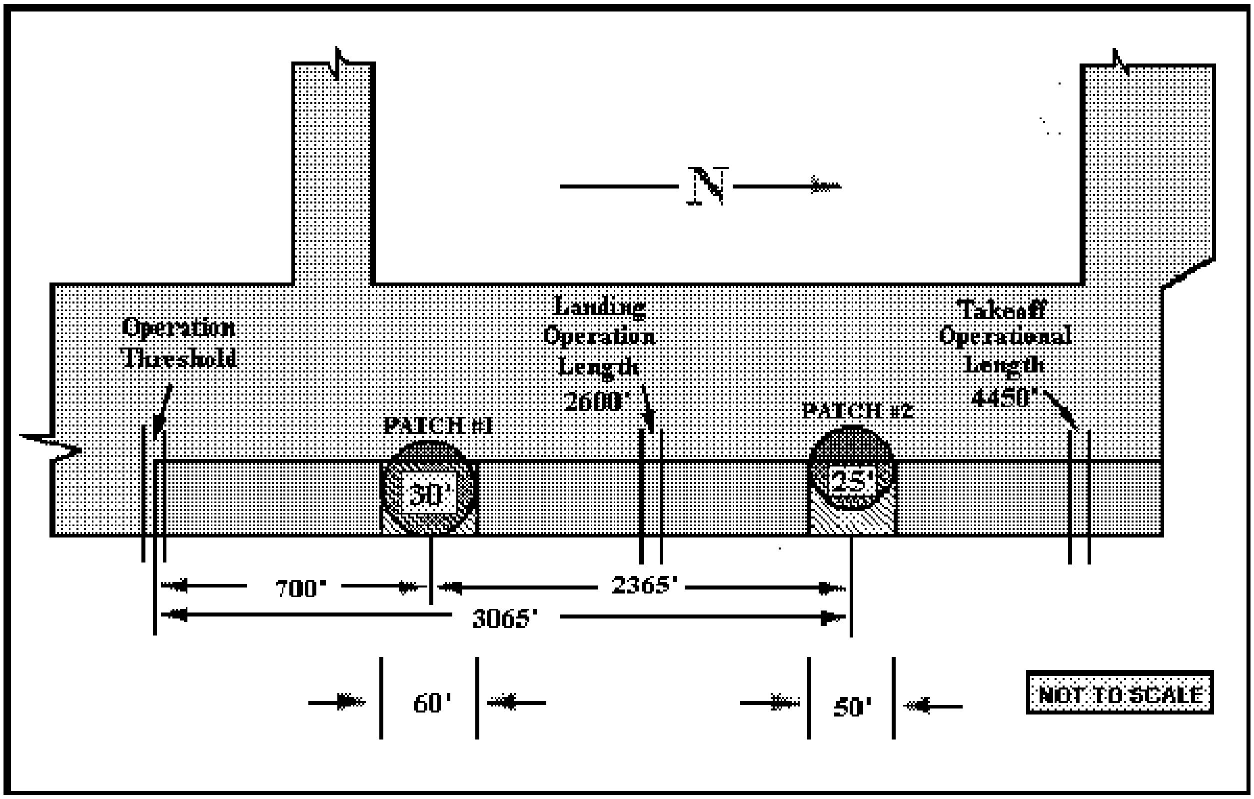


Figure 4.22. South to North Landing/Takeoff Data (360 degree heading).

WORKSHEET 2

MOS THRESHOLD (Ft)	4000	OPERATION #		1	2		
DEPARTURE END (Ft)	9000		FROM MOS THR.	X	X		
			FROM DEP. END				
MOS LENGTH (FEET)	5000	OPERATION LENGTH		2600	4450		

CHART #	OP. #/ PATCH #	PATCH LOCATION (FEET)	PATCH LENGTH (FEET)	PATCH SPACING (FEET)	UNCORRECTED RQC	CORRECTION FACTOR	RQC
E3	1/1	700	60	1500			
E1	2/1	700	60	2365			
	2/2	3065	50	1000			

4.10.11. Because a bidirectional operation is being considered, the same data as above must be determined for a north to south (180 degree heading) flying operation. Figure 4.23 shows the dimensions for this situation and figure 4.24 illustrates the resulting entries on worksheet 2. The data that has been gathered on patch distances and spacing enables us to make a quick check on the feasibility of an arresting barrier installation. RQC chart E4 (figure 4.17) indicates that at least 2,264 feet of pavement length is required for an arrested F-111 landing. Of equal importance is the need for having a substantial amount of undamaged pavement available prior to the barrier location. The RQC chart shows approximately 550 feet of undamaged pavement; however, at least 1,000 feet is desired by Air Combat Command. This distance allows a fighter aircraft to "stabilize" its movement prior to engaging the barrier cable. This harmonics dampening is critical if the aircraft tailhook is to function properly. While not indicated on the aircraft chart, the tape sweep of the barrier must also be considered. The tape sweep area runs about 1,000 feet past the barrier location. It follows then, if a bidirectional operation is to be pursued, at least 1,000 feet on both sides of the barrier location must contain undamaged pavement and a total operation length of 2,264 feet is necessary. From our calculations there is approximately 2,310 feet between the edges of repair patches 1 and 2; therefore, barrier installation and its subsequent operation would be recommended. A change in the landing threshold locations may be necessary, however, and this will have to be a decision made by the wing command element.

Figure 4.23. North to South Flying Operation (180 degree heading).

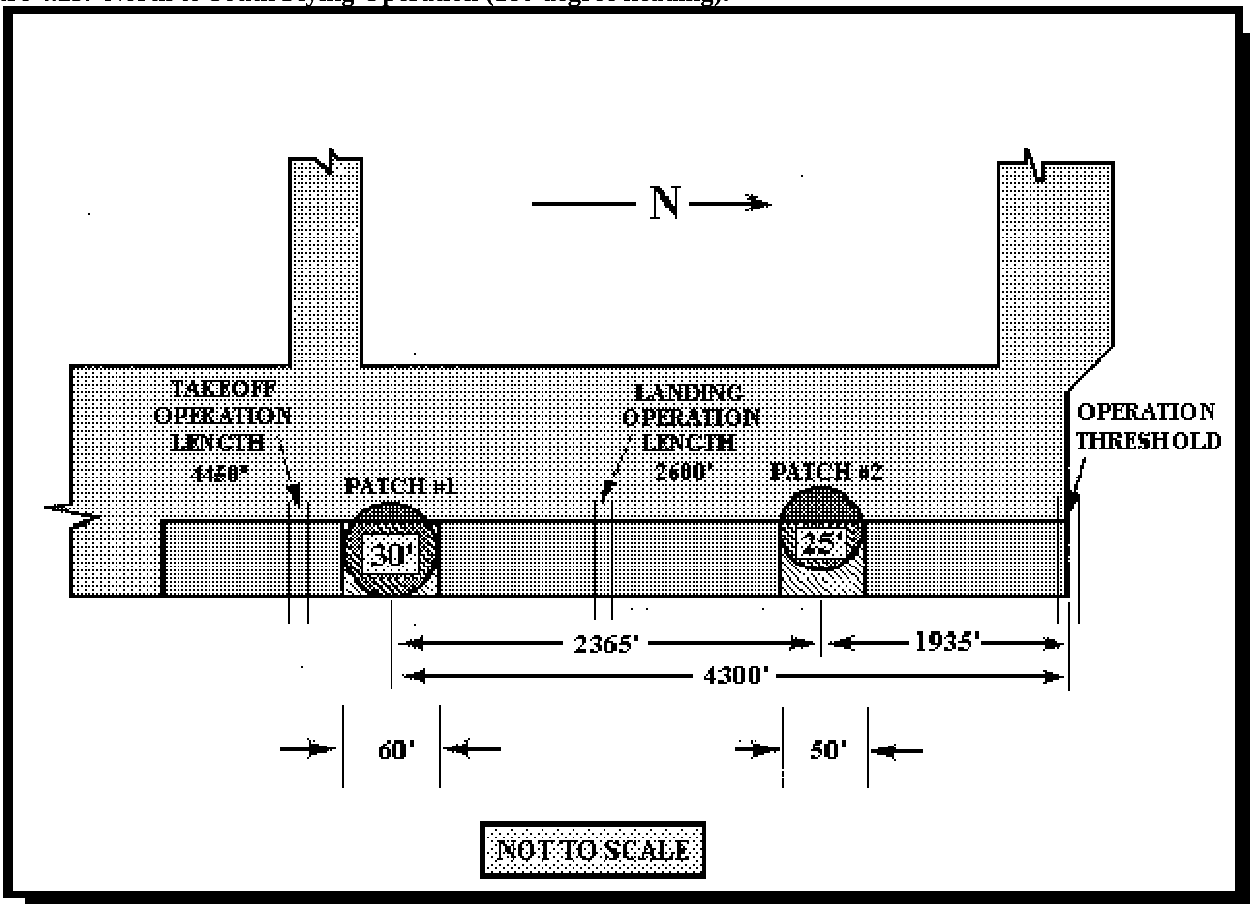


Figure 4.24. North to South Landing/Takeoff Data (180 degree heading).

WORKSHEET 2

MOS THRESHOLD (Ft)	4000	OPERATION #		1	2	3	4
DEPARTURE END (Ft)	9000		FROM MOS THR.	X	X		
			FROM DEP. END			X	X
MOS LENGTH (FEET)	5000	OPERATION LENGTH		2600	4450	2600	4450

CHART #	OP. #/ PATCH #	PATCH LOCATION (FEET)	PATCH LENGTH (FEET)	PATCH SPACING (FEET)	UNCORRECTED RQC	CORRECTION FACTOR	RQC
E3	1/1	700	60	1500			
E1	2/1	700	60	2365			
	2/2	3065	50	1000			
E3	3/2	1935	50	1600			
E1	4/1	4300	60	1000			
	4/2	1935	50	2365			

4.10.12. The dimensional data obtained so far allows determination of the RQC for all repair patches for each individual aircraft operation over the selected MOS. Beginning first with the landing operation from the south to north (360 degree heading) direction, the patch lengths, locations, and spacings are marked on the E3 aircraft chart (figure 4.25). If the value for any length or spacing is greater than the maximum or less than the minimum shown on the RQC aircraft chart, the maximum or minimum dimension on the chart will be marked. The DR and RCR values should also be marked on the chart and horizontal lines drawn as was done during the operation length determinations. As can be seen, only one repair patch is encountered within the operation length for short field landings, namely patch 1 at the 700-foot point. From the 700-foot mark on the patch location line at the bottom of the RQC aircraft chart, a vertical line is drawn until it intersects with the DR value line on the DR portion of the chart. The guidelines on the DR chart are then followed proportionally until the top of the DR portion of the chart is reached. From that point a vertical line is again drawn until it intersects the current RCR value (dry) on the RCR portion of the chart. The guidelines are once again followed proportionally to the top of the RCR section. From this point a vertical line is drawn through the two remaining sections to the top of the RQC chart itself. The line that has been drawn is then labeled operation 1/patch 1. Now a horizontal line is drawn from the patch spacing value (1,500 feet) on the uncorrected RQC area of the chart until it intersects the vertical line previously drawn and a reading is taken. In this case the value is 6, and this figure is entered into the uncorrected RQC column of worksheet 2 for operation 1 (figure 4.26). The last step for operation 1 involves determining the correction factor for the uncorrected RQC value just obtained. Using the correction area portion of the chart, a horizontal line is drawn from the patch length value (60') until it intersects with the vertical line drawn earlier. The value obtained at this intersection represents a number which must be added to the uncorrected RQC value determined in the previous step. In the case of this example the correction value is zero (0). The correction value and the resulting addition of this number and the uncorrected RQC are entered in the appropriate columns of worksheet 2 (figure 4.26). Note that all correction values are either zero or negative numbers. This means that the maximum value ever obtained for a final repair patch RQC will never be greater than six (6). RQC calculations for operation 1 are now complete; however, similar calculations must also be made for operations 2, 3, and 4.

Figure 4.25. Patch Lengths, Locations, and Spacings Marked.

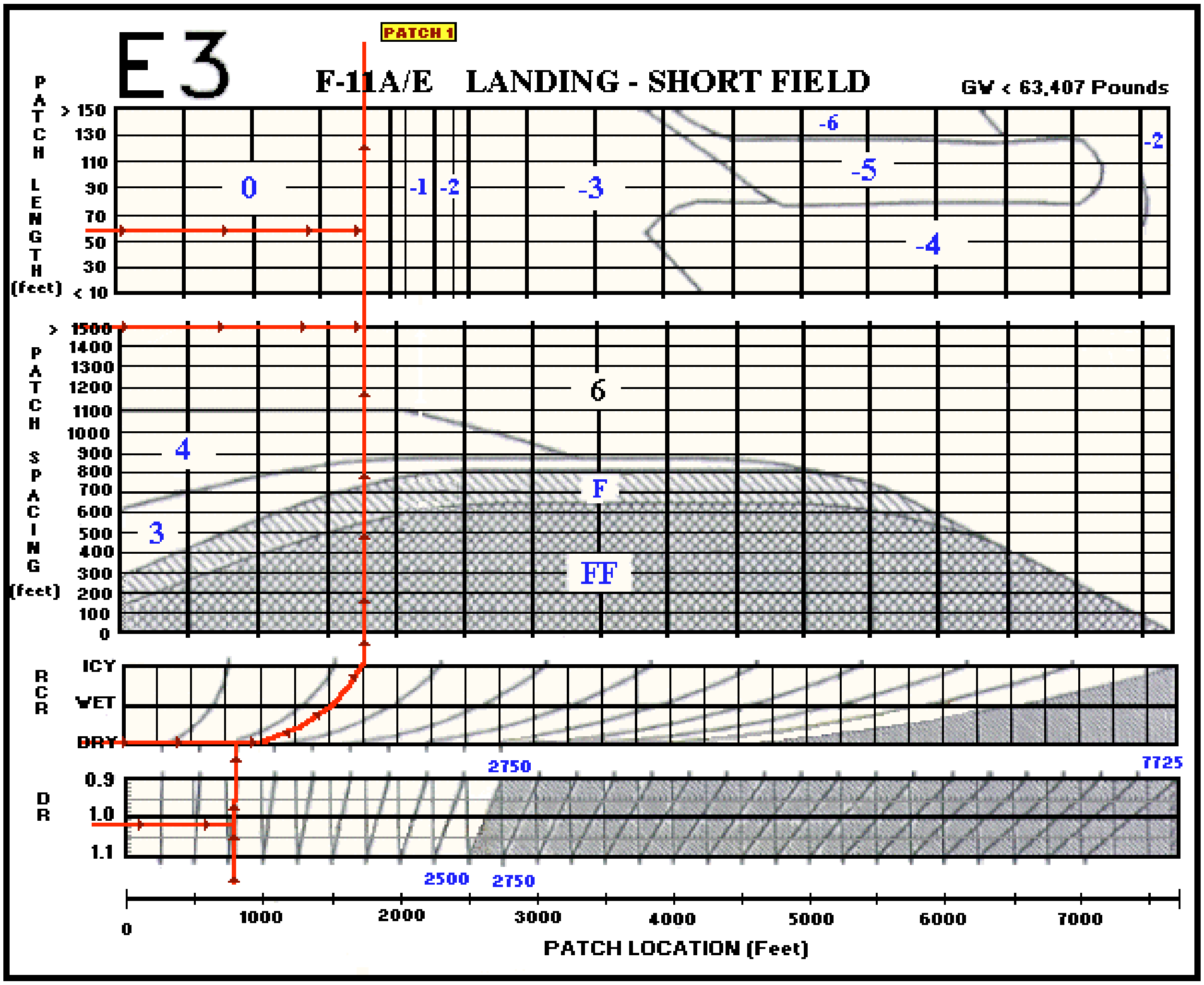


Figure 4.26. RQC Values.

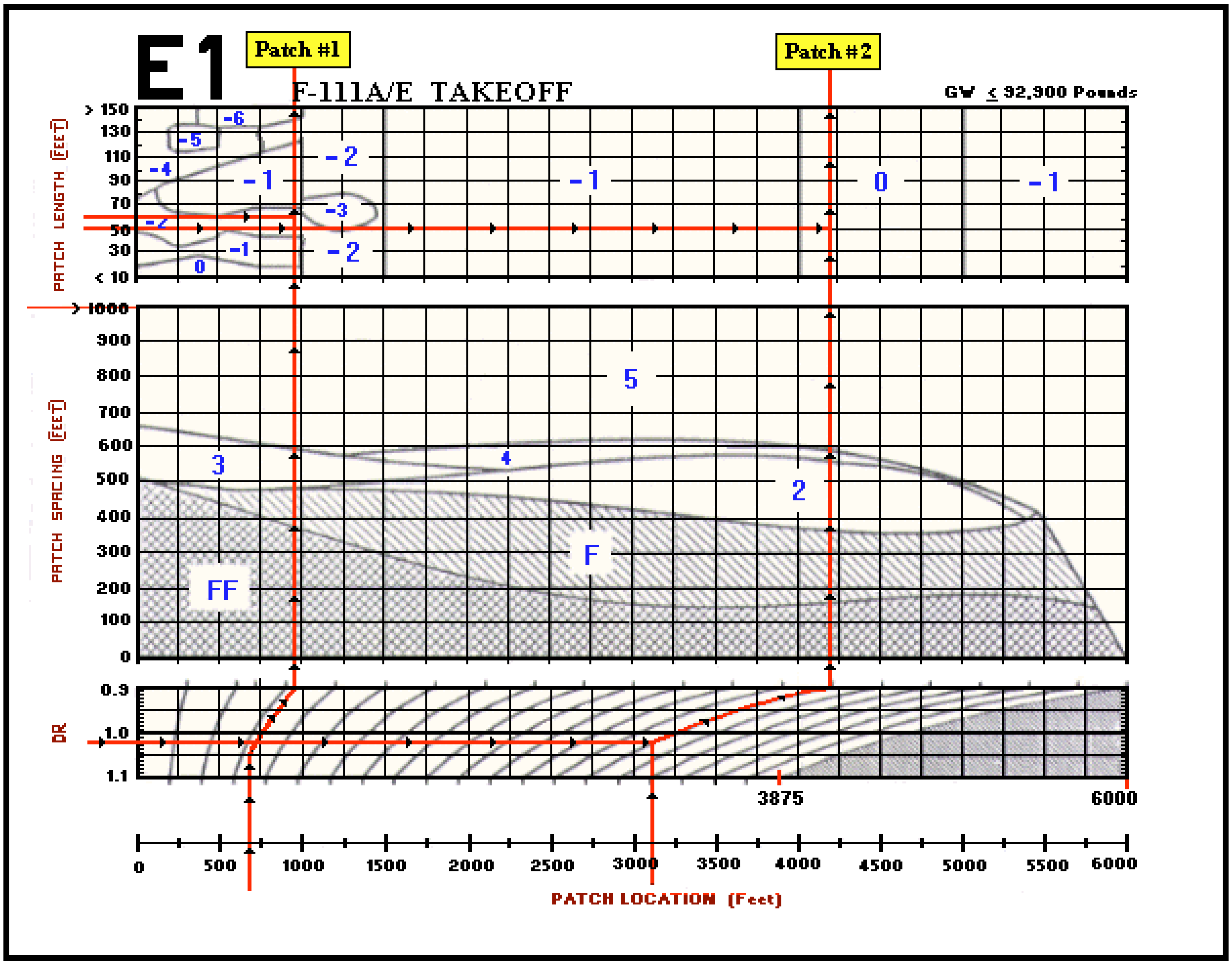
WORKSHEET 2

MOS THRESHOLD (Ft)	4000	OPERATION #		1	2	3	4
DEPARTURE END (Ft)	9000		FROM MOS THR.	X	X		
			FROM DEP. END			X	X
MOS LENGTH (FEET)	5000	OPERATION LENGTH		2600	4450	2600	4450

CHART #	OP. #/ PATCH #	PATCH LOCATION (FEET)	PATCH LENGTH (FEET)	PATCH SPACING (FEET)	UNCORRECTED RQC	CORRECTION FACTOR	RQC
E3	1/1	700	60	1500	6	0	6
E1	2/1	700	60	2365	5	-2	3
	2/2	3065	50	1000	5	0	5
E3	3/2	1935	50	1600			
E1	4/1	4300	60	1000			
	4/2	1935	50	2365			

4.10.13. Operation 2 is a bit more complex than operation 1, since two repair patches are within the operation length and RQC must be developed for both. Using the E1 F-111 takeoff chart, the repair patch locations, patch spacings, patch lengths, and DR value are marked accordingly (figure 4.27). Since this aircraft chart has no RCR section, the RCR value is ignored. Starting first with patch 1 at the 700-foot point, a vertical line is drawn until it intersects with the DR value. The guidelines are then followed proportionally to the top of the DR section. From this point a vertical line is again drawn to the top of the RQC aircraft chart and the resulting line marked as operation 2/patch 1. The same procedures are followed for patch 2 starting at the 3,065-foot point. When both vertical lines are completed, the uncorrected RQC values for each repair patch are determined. Starting at the 1,000-foot point of the patch spacing axis, a horizontal line is drawn intersecting the vertical lines of both patches 1 and 2. The 1,000-foot point is used for both patches since the distance between patches 1 and 2 is 2,365 feet and patch 2 is the last patch in the operation length. Both of these situations mean the maximum value on the patch spacing axis is used. The readings obtained at both intersections are 5, and worksheet 2 is annotated accordingly. Moving up to the correction factor area, horizontal lines are drawn from the repair patch lengths until they intersect with the appropriate vertical lines. The horizontal line from the 50' point is drawn to the patch 2 vertical line and the line from the 60' point is drawn to intersect the vertical line for patch 1. The readings are -2 for patch 1 and 0 for patch 2. These two readings are added to the applicable uncorrected RQC values for the patches and worksheet 2 is then updated. The resulting RQC values for patches 1 and 2 are 3" and 5", respectively (figure 4.26).

Figure 4.27. Patch Repair Locations, Spacings, Lengths and DR Markings.



4.10.14. Operations 3 and 4 pertain to the north to south (180 degree heading) component of our bidirectional flying operation. The RQC determinations for landing and takeoff operations are shown in figures 4.28 and 4.29 respectively. The resulting worksheet 2 entries are depicted in figure 4.30.

Figure 4.28. RQC Landing Determinations.

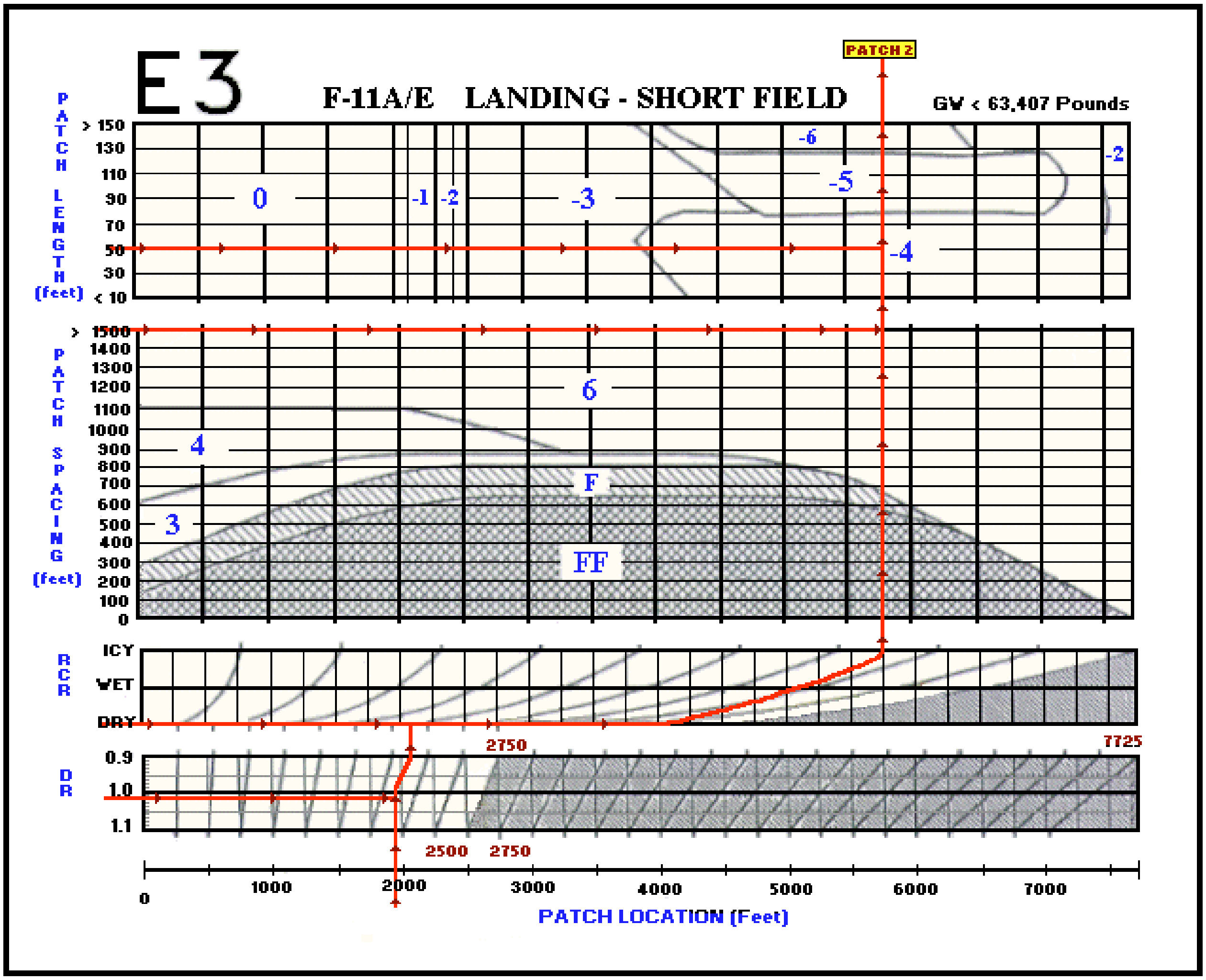


Figure 4.29. RQC Takeoff Determinations.

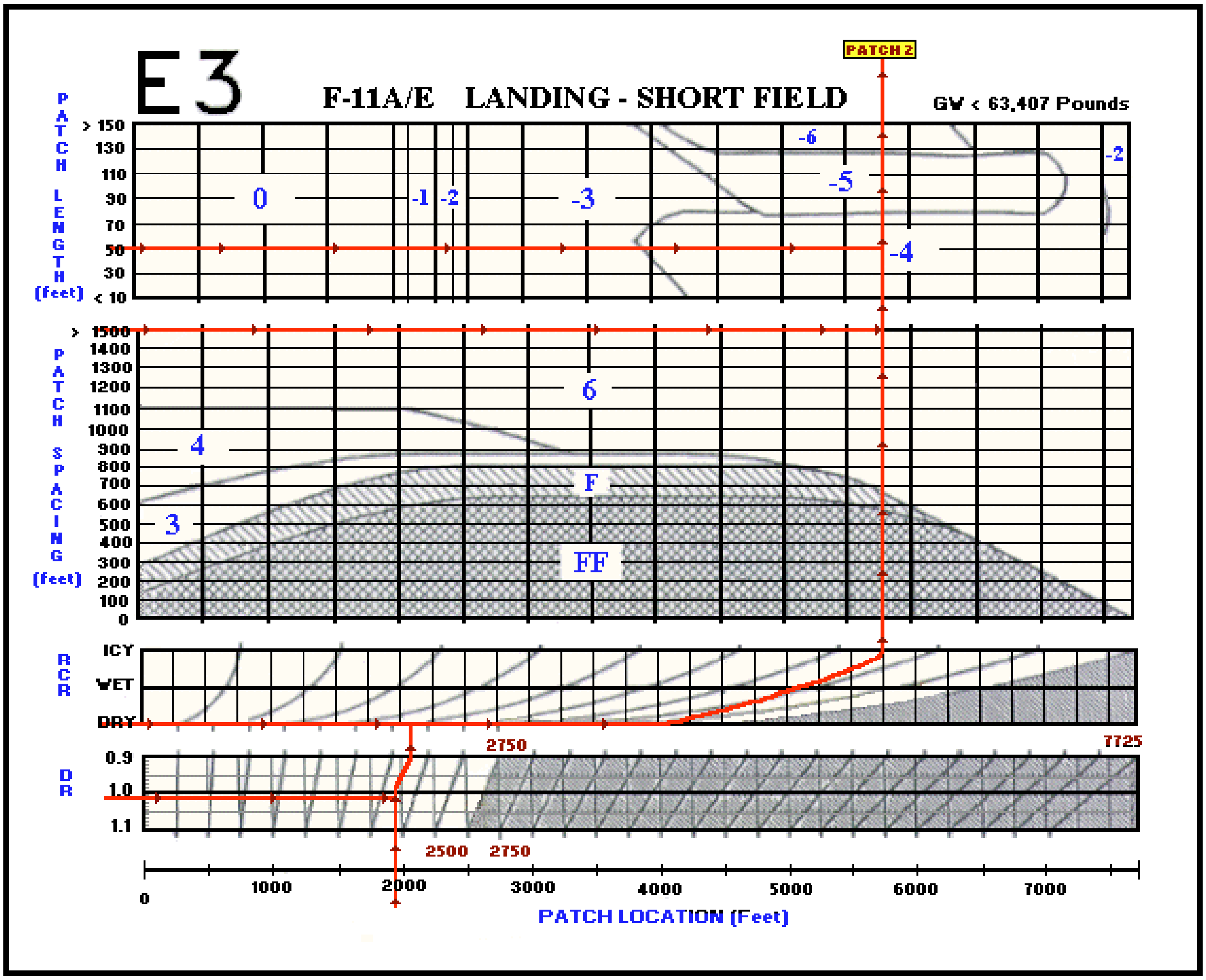


Figure 4.30. RQC Entries Worksheet 2.

WORKSHEET 2

MOS THRESHOLD (Ft)	4000	OPERATION #		1	2	3	4
DEPARTURE END (Ft)	9000		FROM MOS THR.	X	X		
			FROM DEP. END			X	X
MOS LENGTH (FEET)	5000	OPERATION LENGTH		2600	4450	2600	4450

CHART #	OP. #/ PATCH #	PATCH LOCATION (FEET)	PATCH LENGTH (FEET)	PATCH SPACING (FEET)	UNCORRECTED RQC	CORRECTION FACTOR	RQC
E3	1/1	700	60	1500	6	0	6
E1	2/1	700	60	2365	5	-2	3
	2/2	3065	50	1000	5	0	5
E3	3/2	1935	50	1600	6	-4	2
E1	4/2	4300	60	1000	5	-1	4
	4/1	1935	50	2365	5	-1	4

4.10.15. As is readily apparent, both patches 1 and 2 have differing RQC values depending on mode and direction of operation. Our final step is to summarize these values and determine which one governs the overall situation for each patch. Worksheet 3 is used for this purpose. Data from worksheet 2 are entered on this form; operations from the MOS threshold end (south to north 360 degree heading in our example) go on the top part of the form, those from the departure end go on the bottom part of the form (figure 4.31). Once these figures are entered, fill in the summary lines by comparing the RQC values for each individual patch and select the most stringent one (the lowest) as the summary value. While our example did not have one, an "**F**" value is lower than any numeric value. Once this step is complete, compare the summary values for each repair patch and enter the most stringent one of these in the "combined" line on worksheet 3. The RQC values on the "combined" line of worksheet 3 represent the level of quality that the RRR crews have to meet for each repair patch during RRR operations. In our example, 2" RQC is the lowest figure obtained. This means that a repair patch with this value can have a +2" variation and still be acceptable. Remember, the sag for any numbered repair (RQC#) can never exceed 2 inches.

Figure 4.31. RQC Summary.

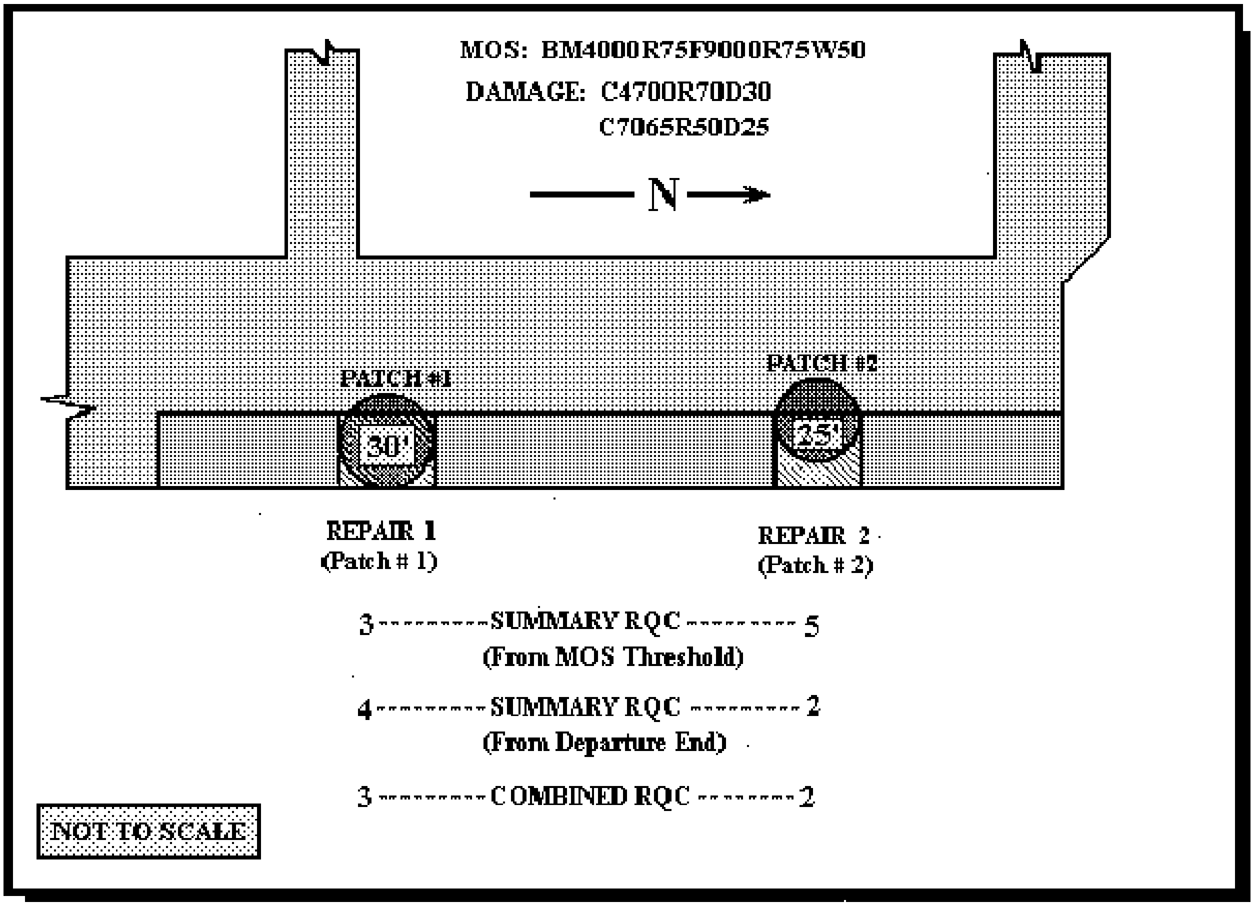
WORKSHEET 3

OPERATION DIRECTION	FROM MOS THRESHOLD														
OPERATION #	PATCH 1	PATCH 2	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH
1 (F-111 LANDING)	6	–													
2 (F-111 TAKEOFF)	3	5													
SUMMARY	3	5													

OPERATION DIRECTION	FROM DEPARTURE END														
OPERATION #	PATCH 1	PATCH 2	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH	PATCH
3 (F-111 LANDING)	–	2													
4 (F-111 TAKEOFF)	4	4													
SUMMARY	4	2													
COMBINED	3	2													

4.10.16. Once all RQC data have been determined, they must be presented to the BCE in a straightforward manner. Figure 4.32 illustrates one method of presenting this data using a MOS map. The RQC values for both MOS threshold and departure end operations are shown along with the combined values for each repair patch. In most cases the MOS will have already been chosen by the wing command element. This summary permits a quick way of informing the civil engineer command section of RQC requirements so they can be forwarded to the RRR crews expeditiously. If, however, the MOS candidates have not been presented to the wing command element, the RQC information can be used as an aid to MOS selection decision making. For example, the following factors could influence the wing commander's decision with respect to final MOS selection:

Figure 4.32. Summary RQC Data.



4.10.16.1. **Bidirectional Versus Unidirectional Operation.** In most cases, operating in an unidirectional mode will result in less stringent RQC values, which, in turn, could permit greater latitude in repair exactness. This is especially important if a RRR team is not thoroughly trained in a particular repair method. Assuming identical aircraft types and operations, an unidirectional MOS will usually have less restrictive RQC than a bidirectional MOS.

4.10.16.2. **Use of Aircraft Arresting Barriers.** In many situations, the landing of an aircraft will require more pavement length than takeoff--especially in wet or icy conditions. If an arresting barrier is available, the landing length can be shortened with an accompanying decrease in the RRR effort needed. Be sure, however, that sufficient undamaged pavement exists before planning on the use of a barrier. About 2,000 feet of pavement with no repair patches is necessary to use the barrier in a bidirectional mode.

4.10.16.3. **Displacing Operation Thresholds.** There may be occasions, particularly with bidirectional operations, when moving an operation threshold could decrease the RQC value for a repair patch. Look for the takeoff or landing operation that drives the lowest RQC value for a particular patch and see if moving the applicable threshold for that operation results in a less restrictive RQC value. Chances are the need for the repair patch will not be eliminated, but the degree of exactness will be lessened; thereby decreasing the potential for the repair to be out of tolerance once completed.

4.10.17. The previous paragraphs have addressed the "first round" determination of RQC values. As mentioned earlier, however, once repairs are completed and more accurate dimensions (repair lengths) are obtained, the RQC process must be repeated to ensure aircraft operations can proceed safely. This recomputation is extremely critical.

4.11. Final Considerations. As brought out early in this chapter, repair quality criteria determination is an integral part of the RRR base recovery effort and its importance cannot be overshadowed by the pace of recovery activities and pressures of the postattack environment. A single mistake in the RQC process can be catastrophic with respect to the aircraft sortie generation capability. Some key points and responsibilities deserve final mention.

4.11.1. A current copy of T.O. 35E2-4-1 must be readily available. Without this document RQC determination cannot be accomplished.

4.11.2. Specific personnel must be fully trained in RQC determination procedures. As a minimum all officers and engineer technicians (AFS 3E5X1) personnel should be capable of this task.

4.11.3. Training on RQC procedures must be extensive. Personnel must be able to perform RQC determinations without hesitation. There will be no time for practice or OJT during base recovery.
4.11.4. Rapid runway repair team chiefs must know and understand the importance of RQC determination. They must obtain and report accurate dimensions on repair patch sizes and locations as soon as they are available in the field. Furthermore, they must organize and use their resources in such a manner that the most critical repairs receive the most attention.
4.11.5. Senior civil engineer officers must be able to explain and defend the importance of RQC determinations to the base and wing command elements. This must be practiced in peacetime during training exercises; otherwise, it will be difficult to tell the commander that his/her aircraft cannot be flown during wartime due to the results obtained from a series of charts and dimensions.

4.12. Chapter Summary. This chapter has presented the concept and procedures for repair quality criteria determination. The RQC process forms the link between completed RRR efforts and the commencement of flying operations after an attack. As such, it must receive close attention from the command element of a civil engineer unit.
4.12.1. Once the MOS repair locations have been identified, rapid runway repair teams attempt to make flush repairs on MOS surfaces, but this level of preciseness is difficult to obtain under wartime conditions. The RQC process provides a method of determining the degree of tolerance allowed for each repair which will permit launch and recovery operations without aircraft damage. Repair quality criteria procedures account for differing aircraft characteristics; weather and pavement surface conditions; dimensions and spacings of repair areas; and the types of operations aircraft are expected to perform. The basic end result of RQC determinations is a value for each repair area, normally expressed in inches, which provides the RRR teams with pass/fail criteria to apply against their crater repair activities. These values can range from perfectly flush up to 6 inches above adjacent undamaged pavement surfaces. If completed crater repairs do not meet RQC values, the repairs must normally be reaccomplished before aircraft operations can commence.
4.12.2. Repair quality criteria determination provides a go/no go decision situation to the wing command structure. Accuracy in performing the RQC process is therefore critical, since faulty data could mistakenly delay aircraft launch or create extremely dangerous flying conditions. The appropriate engineer personnel responsible for RQC determination must be highly trained and capable of performing RQC calculations quickly and flawlessly.

Chapter 5

RAPID RUNWAY REPAIR (RRR) TECHNIQUES

5.1. Introduction. In the event of hostilities, the United States Air Force will play a decisive role in defeating the aggressor. The flexibility, massive firepower, and speed of employment of our air forces are capabilities needed to win a future conflict. The overwhelming success enjoyed by US Air Forces forces during the Iraq war amply demonstrated these features. To preserve these characteristics, however, we must maintain the relatively uninterrupted operation of our forward-based airfields through all stages of a conflict. During Desert Storm, allied air forces flew numerous sorties against Iraqi airfields and, in particular, airfield pavements during the initial portion of the Iraq war. There is little reason to expect a capable enemy will not try to do likewise to us, if the opportunity presents itself.
5.1.1. To ensure an airfield can quickly return to its operational role following an attack, a well organized rapid runway repair effort is essential. The need for effective RRR planning and training is discussed in volume 1 of this publication series. The value of the planning and training now becomes evident as the procedures are implemented during an actual attack.
5.1.2. When hostilities seem probable or imminent, RRR resources must be dispersed to protected locations on a base. Current requirements indicate that RRR assets will be dispersed to no less than three separate dispersal sites. Like items should be distributed to each of the different dispersal locations to improve the probability that some resources are available after an attack.
5.1.3. Immediately following an attack on an air base, damage assessors provide information about the location and extent of damage to the surfaces of the airfield. At the same time, the wing operations center (WOC) collects other information on operational requirements and expected operating conditions following the attack. Using all this information, the minimum operating strip (MOS) selection team selects the operating strip to be repaired. After approval of the MOS by the wing commander, explosive ordnance disposal (EOD) teams go to work on the areas designated to be cleared and the MOS selection team finalizes the repair quality criteria (RQC) for all repair patches on the MOS. Once sufficient UXO clearance has been provided, the RRR teams move to the MOS and taxiway repair locations and begin appropriate repair activities.

5.2. Overview. Preceding chapters have addressed damage assessment, selection of the MOS, and determination of repair quality criteria. This chapter lists the typical organizations and equipment required for RRR at theater bases, explains current crater repair systems, and shows the sequential repair steps common to all crater repair methods. Detailed procedures for crater repair using several types of fill material as well as step-by-step instructions covering the installation of the folded fiberglass mat (FFM) and AM-2 mat foreign object damage (FOD) covers have also been included. Crater repair methods are followed by procedures for spall repair and debris clearance. Individual crater repair methods are then shown in the context of the total runway repair concept of operations. Lastly, procedures for maintenance of expedient repairs are followed by a discussion of semi-permanent crater repair methods, a responsibility of the U.S. Army.

5.3. Concepts. The Air Force flies and fights from its air bases. However, it is at the air base that air power is most vulnerable. Under the right circumstances, air bases can be a most immediate and lucrative target for an adversary. After all, it is more effective to destroy aircraft while they are on the ground than to hunt them in the air. From a practical perspective, it is reasonable to say that during some phase of a conventional conflict, airfield pavement damage will be one of the civil engineer's primary wartime missions. Without question, repair of airfield damage can be a complex and difficult tasking that will require the total commitment of all involved in order to succeed. Proper preparation must be accomplished prior to the moment of need--time will not be available during a conflict to accomplish meaningful training.

5.3.1. **Expected Damage.** Obviously, the scope of airfield operating surface repair requirements will vary proportionally to the intensity of an attack. It could range from debris clearance with little, if any, pavement disruption to major airfield damage accompanied by complete shutdown of aircraft launch and recovery activity. It is this latter possibility that we must be prepared to handle swiftly and correctly. We should expect major airfield damage to include multiple bomb craters and numerous spall fields. Our mission is to overcome these multiple problems and provide an accessible and functional MOS within as short a time as possible. To add to the complexity of the task, we may be required to accomplish the work at night, in rain or snow, or even in a chemically contaminated environment.

5.3.2. **Multi-Skilling.** During wartime or contingency operations the scope and depth of engineer taskings will vary widely. We must have the flexibility within our units to be able to respond to these taskings at any time with sufficiently capable personnel. Historically, in previous conflicts there has seldom been an adequate number of engineers available to accomplish wartime support requirements. And, there is no reason to expect the situation to be any different in future conflicts. Within an engineer unit there are several different Air Force Specialties (AFSs) represented on our Prime BEEF teams and RED HORSE squadrons. Wartime tasks cannot be expected to mirror the skill mix of these units at all times; therefore, we must develop an inherent flexibility to cross AFS boundaries when faced with shortages of specific skills and sizable wartime requirements. In other words, there are no "union cards" in wartime and each of us must be able to perform tasks outside of our normal peacetime responsibilities if we are to properly support our combat forces. This need for multi-skilling is especially prevalent during RRR where many personnel are necessary to flesh-out the manning required for equipment operations.

5.3.3. **Wartime Command and Control.** Nothing has a more negative impact on a unit's capability to accomplish its mission than weak command and control. It can "rip the heart out" of an organization's motivation and esprit de corp. Simply put, without effective command and control nothing will work. The best trained and equipped RRR team will never reach its true potential if it is saddled with ineffective leadership. Command and control of an engineer team is a tough job, and it will be especially tough immediately following an attack on a base. Good leadership can contribute greatly towards overcoming training and resource shortfalls; unfortunately, the opposite is not true. For a unit to have strong command and control, individuals within the command structure must be completely knowledgeable and competent in their position--to accept anything else is unconscionable.

5.3.4. **Training.** The final item that needs to be addressed in this section concerns the training of engineer forces. Fortunately we have never experienced a crippling air attack on one of our air bases in the past 50 years. Because of this; however, we have no real world RRR database to fall back upon in terms of problems encountered, shortfalls experienced, or effort expended. This complicates the training situation in that training must be based on various assumptions, estimates, and subjective judgments. Computer modeling techniques have indicated that given adequate equipment and personnel, the RRR process can meet the stringent parameters stipulated in various requirements documents and plans. On the other hand, field tests and observations of training programs have been less positive. Shortfalls in leadership techniques, equipment operation capabilities, and basic knowledge of RRR procedures appear to be commonplace. These are the areas that we must concentrate on in our training programs. Such training cannot be accomplished solely in a classroom environment--extensive hands-on activities must be performed. Teamwork, skill proficiency, individual task accuracy, and overall operational responsiveness must be the key elements of this hands-on effort. The complexity and criticality of the RRR task demand that every unit establish and maintain a viable and aggressive RRR training program. This program must include the RRR aspects of all existing training avenues, namely, home station training, officer field education, regional equipment operator training site (REOTS), and special training site (STS) instruction.

5.4. Resource Requirements. Engineer forces require proper equipment and adequate personnel to achieve expedient repairs to war damaged airfield pavements. To fulfill this requirement, the Air Force has developed equipment sets for accomplishing airfield pavement repairs. Furthermore, Air Force Prime BEEF teams have been configured to provide sufficient numbers of personnel to adequately man these equipment sets. Training programs have also been adjusted to address the unique features of RRR operation and build multi-skilling capabilities within engineer units. The following paragraphs describe the equipment sets and provide recommendations on use of Prime BEEF forces for optimum manning.

5.5. RRR Equipment Sets. A RRR equipment set is a standardized set of equipment and vehicles that enable civil engineer forces to conduct RRR. At present there are three RRR sets that have been fielded. The sets are configured in a building-block manner to provide a designated crater repair capability.

5.5.1. **Basic (R-1) RRR Set.** The basic set was developed by the Air Force to provide an expedient bomb damage repair capability to theater air bases. When originally configured, the equipment in this set supported the repair of three 50-foot bomb craters with AM-2 matting within a 4-hour period. The R-1 set also supports the folded fiberglass mat method using the same criterion. The basic RRR set is currently in place at most high-threat theater main operating bases (MOBs). The components of the current vehicle and equipment sets are shown in table 5.1. Equipment item-by-item listings are shown in attachment 8, *Rapid Runway Repair (RRR) Equipment/Components/Kits.*

Table 5.1. R-1 Vehicle and Equipment Set.

VEHICLES	QUANTITY
Excavator	3
Grader	3
Dozer (T-7)	3
Front-End Loader (4-cy)	6
Front-End Loader (2.5-cy)	3
Vibratory Roller	3
Dump Truck (8-cy)	8
Dump Truck (5-ton)	4
Tractor (7.5-ton)	3
Tractor (10-ton)	3
Trailer (22-ton)	3
Trailer (60-ton)	3
Vacuum Sweeper	2
Tractor Mounted Sweeper (RRR)	2
Paint Machine (Part of MOSMS)	2
HMMWV	2
RRR Trailer	3
1,500-Gallon Water Truck	3
Dolly Converter (8-ton)	3
Basic RRR Equipment Support Kit	1
Basic RRR Airfield Lighting Kit	1
AM-2 RRR FOD Cover Kit	*3/6/9
AM-2 Support Kit	*1/2
Folded Fiberglass Mat FOD Cover Kit (Kit-A)	1
Folded Fiberglass Mat FOD Cover Kit (Kit-B)—Anchoring Systems	2
Spall Repair Kit	4
Minimum Operating Strip Marking System (MOSMS)	1
*** *NOTE:*** The specific quantities needed at a given MOB will depend upon the perceived threat. An R-3 requirement will dictate additional equipment as compared to what is provided for either an R-2 or R-1 set. Specific item details are shown in attachment 8, *Rapid Runway Repair (RRR) Equipment/ Component/Kits.*	

5.5.2. **Supplemental (R-2) Set.** The R-2 set contains additional vehicles and equipment which are additive to the R-1 set. The combined R-1 and R-2 sets give a unit the capability to form six crater repair teams (three on the MOS and three on taxiways), each able to repair one crater in 4 hours. Thus, the R-1/R-2 combination permits the repair of six craters in 4 hours. Table 5.2 shows the R-2 vehicle and equipment additives.

Table 5.2. R-2 Vehicle and Equipment Set Additives.

VEHICLES	QUANTITIES
Excavator	3
Front-End Loader (4-cy)	3
Front-End Loader (2.5-cy)	3
Vibratory Roller	3
Dump Truck (8-cy)	7
HMMWV	4
RRR Trailer	3
TOTAL VEHICLE REQUIREMENT:	**26**
EQUIPMENT ITEMS	**QUANTITIES**
Floodlight/Generator Set	6
Generator Set (Diesel)	1

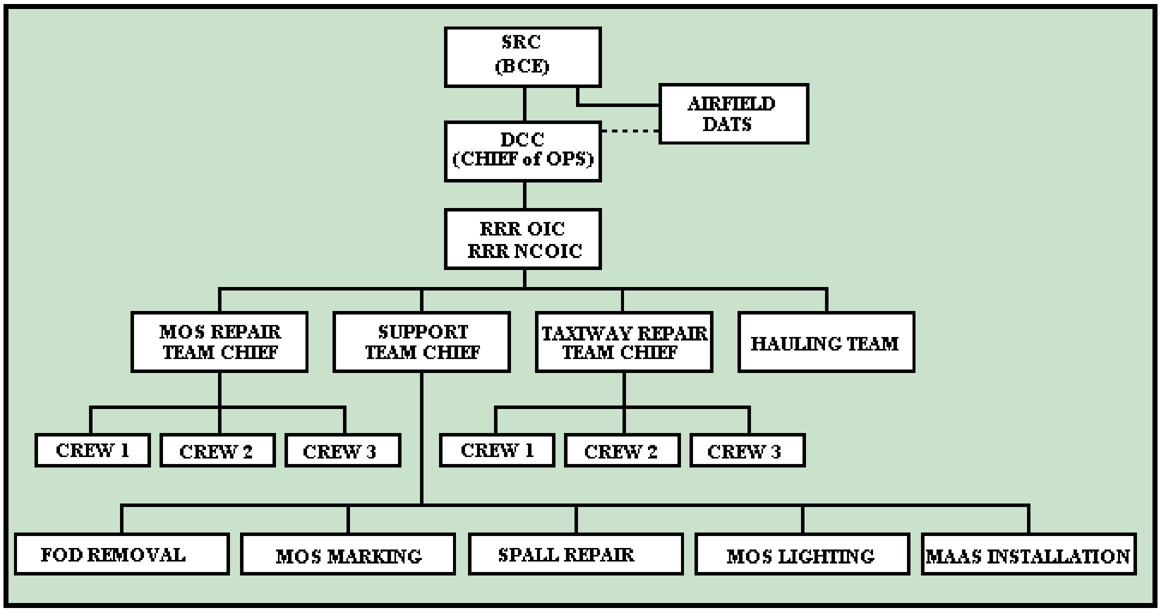
5.5.3. **Supplemental (R-3) Set.** The R-3 set provides yet more vehicles, enabling six crater repair teams (three on the MOS and three on taxiways) to repair two craters each, or a total of 12 craters within 4 hours. Only a few theater main operating bases have the R-3 package in-place, since current threat scenarios indicate a limited requirement for this configuration. Table 5.3 shows the R-3 additive assets complement.

Table 5.3. R-3 Vehicle Set Additives.

VEHICLES	QUANTITIES
Front-End Loader (4-cy)	4
Dump Truck (8-cy)	7
Vacuum Sweeper	2
Dirt Sweeper (RRR)	5
TOTAL VEHICULAR REQUIREMENT:	**18**
ADDITIONAL EQUIPMENT ITEM	**QUANTITY**
Floodlight/Generator Set	6

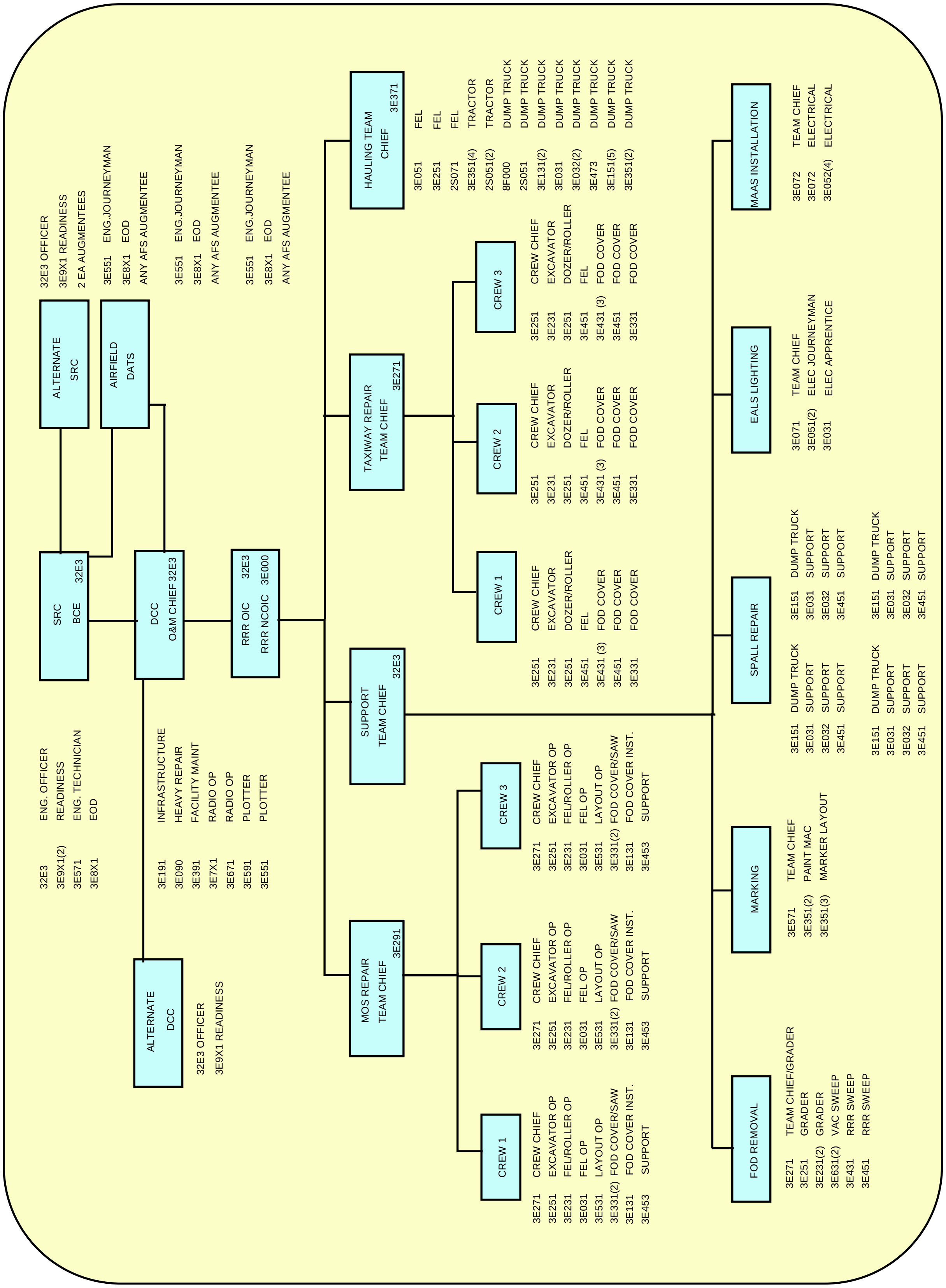
5.6. Personnel. Figure 5.1 illustrates a typical RRR organization predicated on the use of the combined R-1 and R-2 equipment and vehicle packages. The areas that fall under the control of the support team chief; specifically FOD removal, MOS marking, spall repair and airfield lighting system and arresting barrier installation; will be addressed in detail in later chapters of this volume.

Figure 5.1. Typical RRR (R-2 or R-3 Set) Organization.



5.6.1. In a situation that dictates the use of the full R-1 through R-3 equipment and vehicle packages, present Prime BEEF planning and force employment concepts envision that one 132-person lead team (UTC 4F9E5) and two 61-person follow teams (UTC 4F9E7) be used. While the full 196-person engineer complement of these UTCs will not be employed solely in the RRR role, a majority of the personnel will be dedicated to this tasking. Normal exclusions include individuals involved in command center (SRC/DCC), damage assessment, facility/utility recovery activities, and firefighting functions. Figure 5.2 depicts an example of how this multi-Prime BEEF team configuration could be organized to satisfy a six-crater RRR requirement employing only an R-1 and R-2 set. In particular, it illustrates the RRR team configuration using folded fiberglass mats for both MOS and taxiway repairs. However, employing this same configuration, AM-2 matting could be used on the taxiways instead attaining satisfactory results within the same 4-hour time constraint (see attachment 7 for AM-2 patch fabrication checklist). Because of the multi-skilling features of our training programs, many AFS combinations are possible. In this example, 36 individuals remain untasked (primarily in the utilities areas) that could be used to support utility/facility damage recovery identified by the damage assessment and response teams (DARTs). However, when it comes to RRR, one discipline where latitude is notoriously limited is construction equipment operators (3E2X1). This is one field where the RRR command and control functions must be fully aware of the capabilities and limitations of their personnel in order to realize optimization of the resource.

Figure 5.2. Typical RRR (R-2/R-3 Set) Organization Using Folded Fiberglass Mats for Both MOS &Taxiway Crater Repairs.



5.6.2. When theater intelligence indicates that the anticipated threat will entail repairing twelve or more craters, an R-3 set will be required and team manning must be increased by about 20 personnel--mainly for equipment operation purposes. With an R-3 set and proper manning, each crater crew is expected to repair two craters within the same maximum 4-hour time frame. However, if the conflict situation results in a less than six crater repair requirement, various subsets of these configurations should be employed. For the most part this simply involves decreasing the number of crater repair crews and proportionally downsizing the personnel strength of the hauling team. As a general rule of thumb for planning purposes, adequate manning of an R-1 set requires approximately 100 personnel, while an R-1/R-2 combination requires approximately 125 personnel, and an R-1/R-2/R-3 combination requires approximately 140 personnel. When it comes to RRR, the consequences of inadequate training cannot be over emphasized. An ill-prepared RRR team properly manned and equipped will have great difficulty accomplishing their mission within the mandated 4-hour time requirement. Furthermore, keep in mind that these figures are only for the RRR team; additional personnel will be required for fleshing-out command and control centers as well as manning the various airfield and base proper damage assessment teams. Details regarding additional team manning requirements are presented in volume 1, chapter 5 of this pamphlet series.

5.7. Crater Repair. Modern fighter aircraft require strong, smooth runway surfaces for takeoff and landing. After an air attack, runways and taxiways must be repaired to a standard that allows operations to be resumed with minimal risk to the aircraft. Since the folded fiberglass mat repair method can be accomplished in a flush manner, this method is the primary one used for MOS repairs. Because the AM-2 matting method inherently has a 1.5-inch rise due to the thickness of the matting, AM-2 repairs are normally relegated to taxiways where aircraft speeds are much slower and less aircraft damage is liable to result.

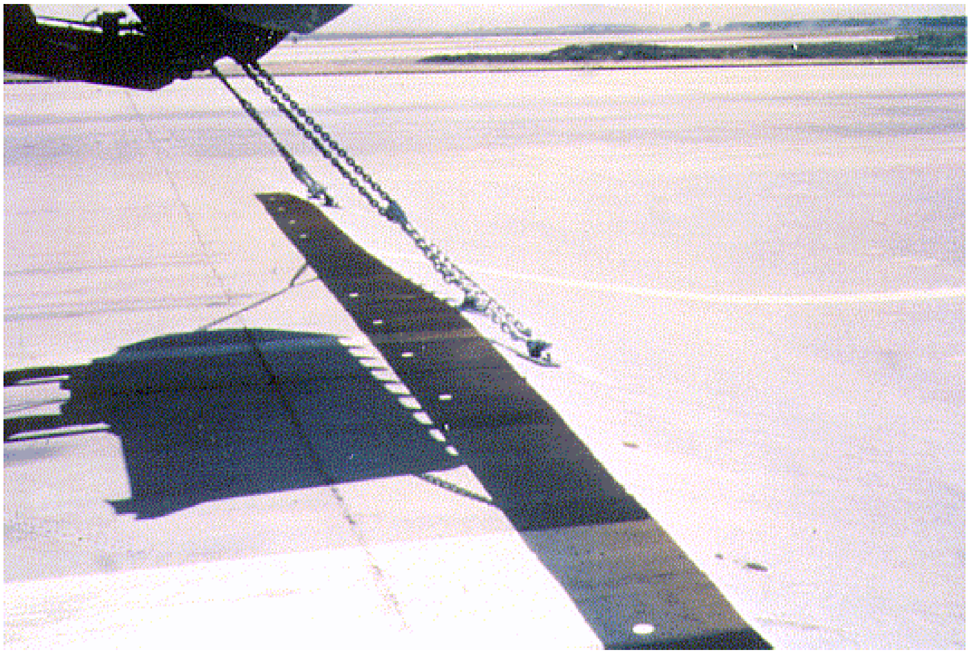
5.8. Types of Crater Repair. Each of the two repair systems mentioned above essentially require the same basic crater preparation prior to installing the repair surface. These steps include a simple survey to determine the extent of upheave, removal of unsound pavement and upheave, backfilling with debris and/or rock, leveling and compaction of crushed stone fill material, and lastly, placement and anchoring of the FOD cover.

5.8.1 **AM-2 Mat.** AM-2 aluminum matting is hand-assembled and anchored over the crater which was prepared with a layer of crushed stone. This repair surface is the most manpower intensive of the two primary RRR techniques (figure 5.3).

Figure 5.3. AM-2 Mat Repair Method.

5.8.2. **Folded Fiberglass Mat.** The second repair method to be discussed is the FFM. This procedure, which is currently the primary MOS repair method, involves the installation of an anchored FFM over a crater which was prepared with a layer of well-compacted crushed stone. Crater preparation is essentially identical to that used with the AM-2 matting system. Again, this is the principle method of RRR employed for MOS repairs at overseas MOBs (figure 5.4). Procedural detail regarding FFM installation are provided in Technical Manual T.O. 35E2-3-1.

Figure 5.4. FFM Repair Method.



5.9. Expedient MOS Layout. After an airfield attack involving runway damage, frequently a minimum operating strip with associated supportive markings must be established. As a result, regardless of the rapid runway repair method employed, the first activity in the actual on-scene repair effort is usually MOS layout. In its most basic concept, MOS layout takes the operating strip coordinates that were determined and approved in the survival recovery center (SRC)--and physically transposes those coordinates to the proposed MOS on the damaged airfield. This activity provides a visual cue of work tasks and assignments to the numerous work crews involved in an airfield recovery undertaking. As a minimum, this typically entails functions such as the establishment of new centerline and operating strip boundaries. Though a relatively straightforward procedure, when required, MOS layout is crucial to the overall RRR effort. It is germane to a number of key activities, such as MOS marking and mobile aircraft arresting system (MAAS) and emergency airfield lighting system (EALS) installation. Procedural details regarding MOS layout are provided in Technical Manual T.O. 35E2-6-1.

5.9.1. **MOS Layout Taskings.** MOS layout is accomplished in its entirety by members of the MOS marking team and usually involves location identification or layout of the following:

- MOS Threshold
- MOS Centerline
- "T" Clear Zones
- MAAS
- Precision Approach Path Indicators (PAPI)
- Edge, Distance-To-Go (DTG), and Aircraft Arresting System Markers
- Approach Lighting
- Taxiway Identification

5.9.2. **EOD Interface.** Explosive ordnance disposal support is critical to the entire RRR effort and specifically MOS layout. The SRC must ensure that the EOD team responsible for airfield ordnance clearance and safing are aware of the total EOD requirement. As a minimum, EOD personnel must sequentially clear and safe the entire MOS to include 100 feet out from all edges and the first 1,500 feet of overruns. For obvious safety reasons, MOS layout activities will normally not start until the EOD teams have completed unexploded ordnance (UXO) safing procedures on a specific portion of the MOS. The amount of surface to be cleared hinges to a great degree upon the munition(s) involved, but approximately 2,000 linear feet is not unusual.

5.9.3. **Visibility.** To assure that the layout work is both highly visible and readily apparent to all personnel working on the MOS, brightly colored traffic cones are normally used for marking purposes. However, though less effective, paint markings or a combination of cones and paint marking may be used when traffic cones are either not available or their numbers are limited.

5.9.4. **Chain of Command.** All necessary plotting data will be provided to the MOS marking team by the RRR support team chief through the damage control center (DCC). As with most of civil engineer recovery efforts, the DCC receives its direction from the SRC. However, much of the flight operations requirements that impact the locations of items, such as the MAAS and PAPI, will be provided to the senior engineer representative in the SRC by the wing operations center.

5.9.5. **Crew Composition.** The MOS layout crew is composed of four of the six members assigned to the MOS marking team. However, since exact plotting may be required, the layout crew should be headed by an engineer technician (AFS 3E5X1). Details of the various MOS layout activities are outlined below. Each activity has been presented in what is considered to be its most logical order of precedence. But, be aware that the situation at hand can readily dictate any number of variations to this sequence.

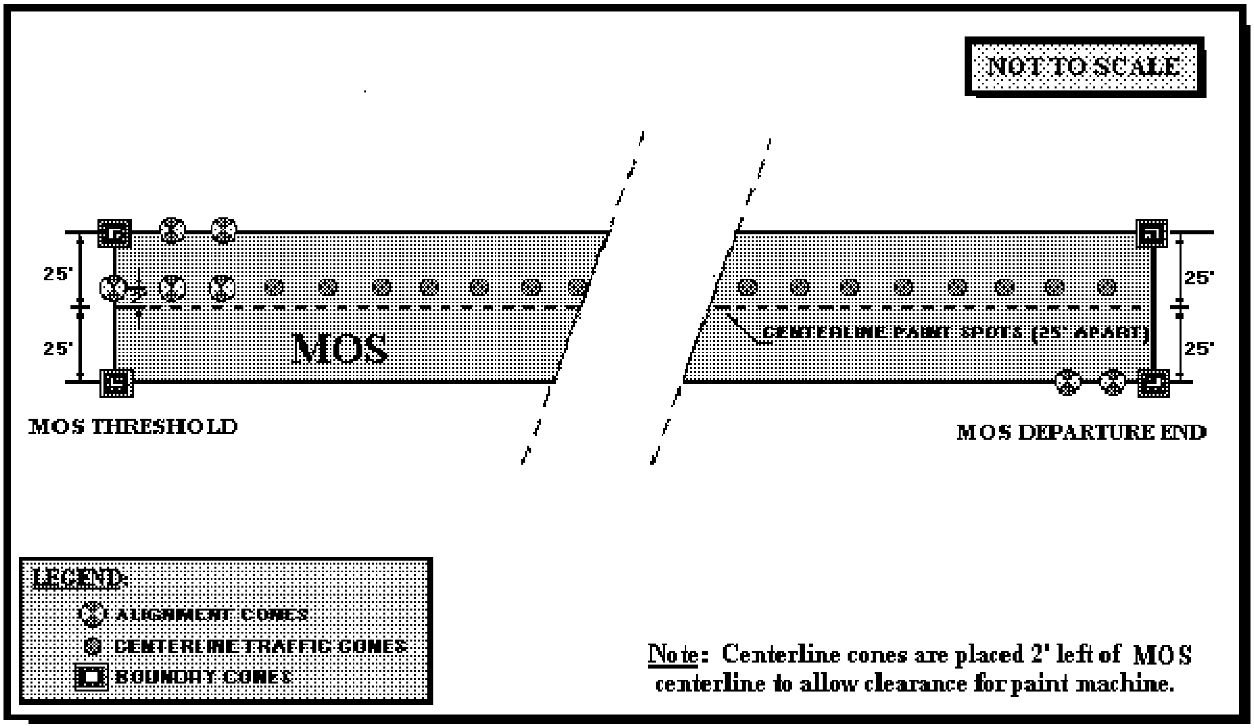
5.9.6. **MOS Threshold Layout.** During the RRR team's stay at the staging area, the DCC will provide pertinent MOS layout data, such as the starting point, width, and length. Once the SRC has received clearance from the on-scene EOD team for MOS access, the DCC will direct the RRR team chief to start MOS layout. At this point, the four-person MOS layout crew will immediately leave the RRR staging area with a vehicle (preferably a 1.5-ton cargo truck) and an ample supply of traffic cones and edge markers to accomplish all of the respective required layout activities. The two remaining MOS marking team members will remain at the staging area in order to prepare the paint machine for the later striping operation. As shown below, a typical 50' x 5,000' MOS with two arresting systems will require 68 traffic cones and 88 edge markers (plus 4 and 3 cones, respectively, for each "T" clear zone and taxiway intersection)--see table 5.4.

Table 5.4. MOS Layout Equipment Requirements.

TRAFFIC CONES	EDGE MARKERS
4 Threshold/Departure (Corner Markers) 4 Edge Marker Alignment 3 Centerline Alignment 23 Centerline 8 MAAS (4 per system) 12 PAPI (6 per location) 14 Approach Lights 4 per "T" Clear Zone 3 per Taxiway Intersection	48 Sides of MOS 40 Threshold/Departure Ends

5.9.7. **MOS Outer Boundaries.** Using the runway station markers (if available) and the layout information provided by the DCC, the MOS layout crew will locate and place a traffic cone at each corner of the threshold in order to define the MOS boundaries. In the example shown in figure 5.5, on a 50-foot wide MOS, each corner threshold (boundary) cone is positioned 25 feet from the intended new centerline opposite from one another. On a wider MOS, this distance would be adjusted accordingly. At the conclusion of centerline layout, the crew will also place two cones in the exact same manner at the MOS departure end (the end opposite to the threshold) in order to define the outer boundary limits there as well.

Figure 5.5. MOS Layout.



5.9.8. **Centerline Alignment.** Immediately after the corner cones have been correctly installed at the threshold (approach) end of the runway, the MOS layout crew will place three centerline alignment cones in the following manner:

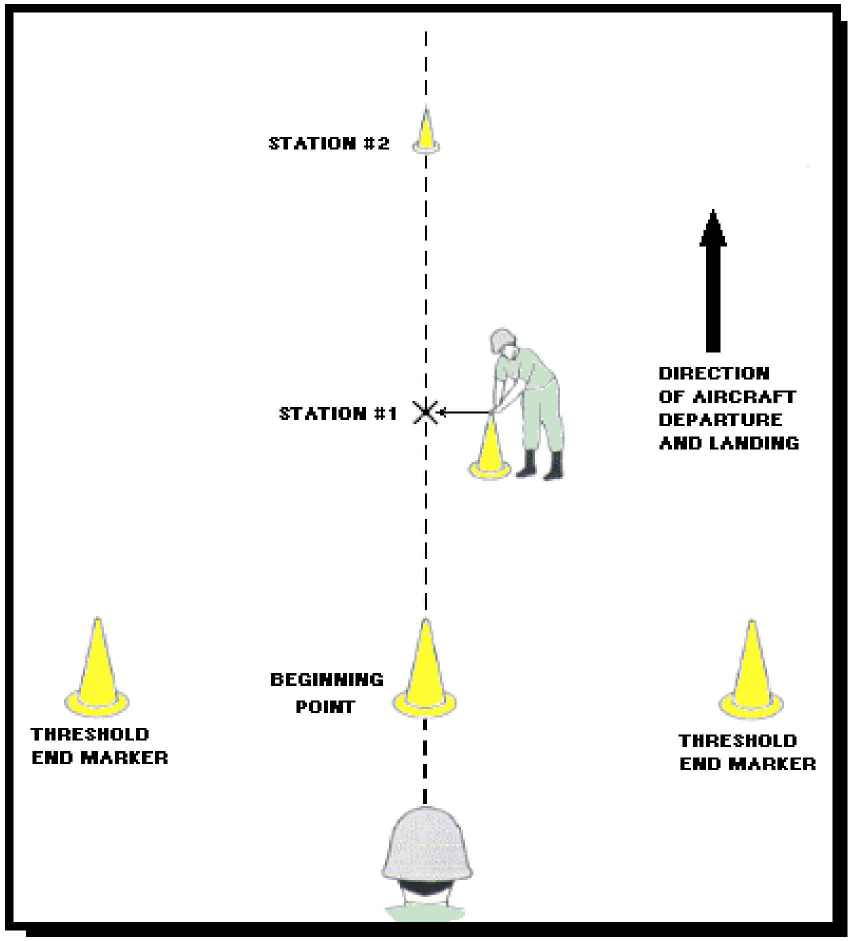
5.9.8.1. **Step One.** With the original runway centerline as a point of reference, the first alignment cone will be placed at the starting point of the new MOS centerline. For example, typically, the MOS location details provided by the DCC will position the new centerline a given distance to either side of the original airfield centerline. This beginning point and all subsequent cone placements (stations) should be placed 2 feet to the left side of the intended new centerline in order to provide room for the paint striping machine operation which will occur later in the RRR recovery effort. As will become apparent later in the text, it is essential that the placement of this first cone be as precise as possible.

5.9.8.2. **Step Two.** Once the beginning point centerline alignment cone has been positioned, one layout crew member should remain at this location to hold the end of a measuring tape. A second member will then run out the tape 200 feet to locate the next point farther down the MOS where another alignment traffic cone will be placed--this is station one. With the possible exception of the final cone located on the departure end of the MOS, all centerline stations are situated at 200-foot intervals. At this time, do not be concerned about the alignment of the cone at station one; any required adjustment will be made during step four. Simultaneously, with locating station one, the vehicle operator and the one remaining crew member will move with the vehicle from the beginning point to station one. ***NOTE:*** If the pavement reference marking system is still recognizable, it should prove useful during the MOS layout steps as reference points.

5.9.8.3. **Step Three.** At this time, the person located at the beginning point will release the end of the tape so that it can be used to determine the location of station two. During this step, the crew member that moved to station one with the vehicle places an alignment cone at this location and then holds the end of the measuring tape while the other crew member repeats the procedure in step two in order to find the location of station two. Once this location has been ascertained, the vehicle operator will relocate to station two with the vehicle. Here he/she will assist in obtaining as precise a positioning of the cone as possible by using the same methods that were applied when determining the placement of the cone at the beginning point. It cannot be overemphasized how critical it is that centerline alignment cones one and three are positioned as precisely as possible! The correctness of all subsequent cone placements hinges upon the accuracy of these initial markers.

5.9.8.4. **Step Four.** At this juncture, there are three cones positioned at 200-foot intervals on the new MOS spanning a length of 400 feet. However, only two of the three cones, those placed at the beginning point and station two, are accurately positioned. The next logical step is to assure that the positioning of the cone situated at station one is also correct. To do this, the crew member that stayed at the beginning point will provide any necessary adjustments to the crew member located at station one by using the line-of-sight technique. This involves forming an imaginary line between the first and third alignment cones as shown in figure 5.6. Once this imaginary line is established, alignment of the station one cone simply entails directing the individual at that location to move the cone in or out accordingly. Of course, hand signals employed in this alignment process must be worked out in advance.

Figure 5.6. Line-of-Sight Method.



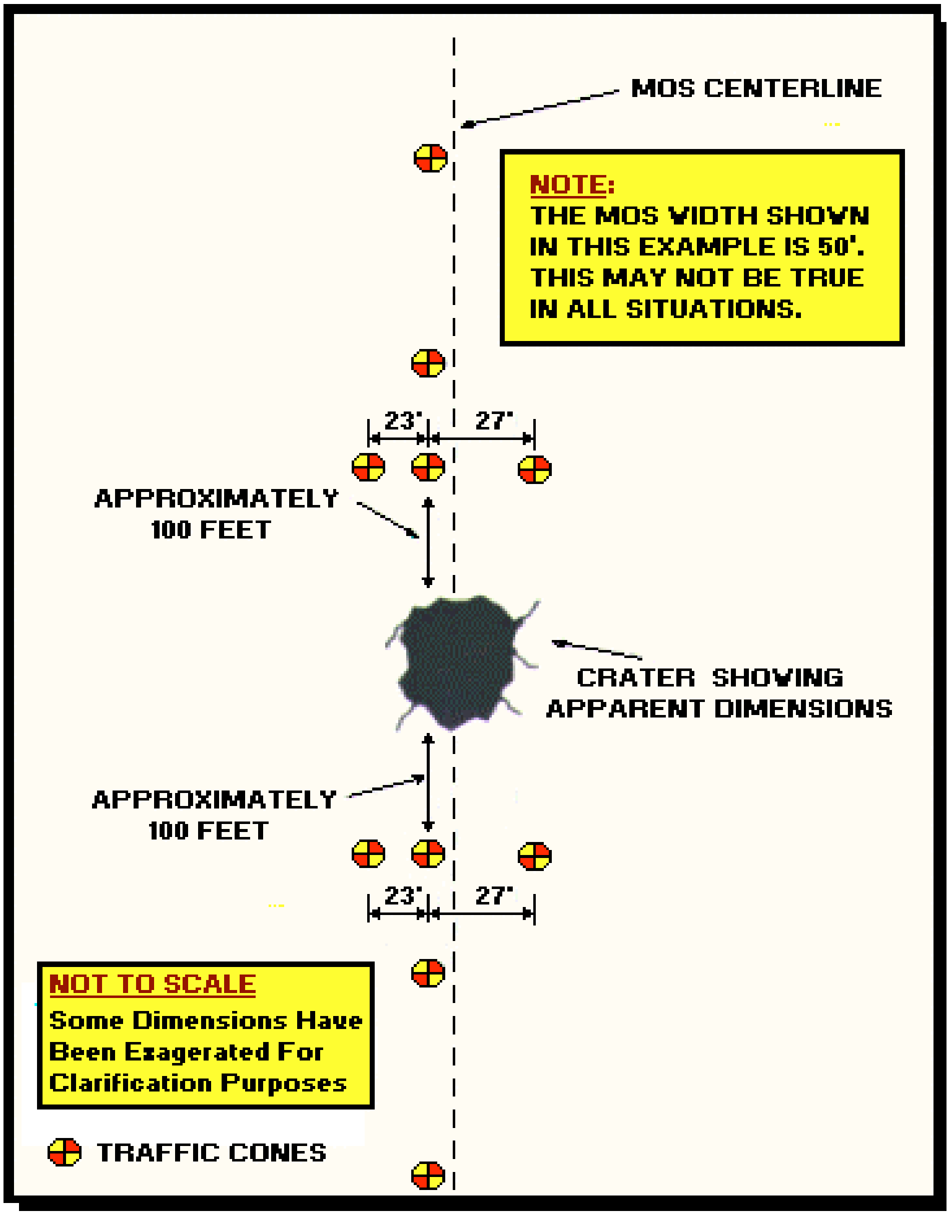
5.9.9. **Edge Marker Alignment.** The next procedure is to install edge marker alignment cones on the threshold end of the MOS. To do this, the crew will position two additional alignment cones with 200-foot separations on the left side of the MOS as seen when facing the departure end. Here, too, it is essential that care be taken to assure as accurate a placement as possible. As shown in figure 5.6, when properly positioned, each of these cones will be aligned with the corner cone and either the station one or two centerline alignment cone. Once positioned, these cones will serve as the benchmark for later edge marker placements, the details of which will be discussed later in this chapter. An added advantage of early installation of these alignment cones is that they can also serve as a reference point for a possible early edge light installation, if such should become necessary.

5.9.10. **Centerline Layout.** At this time, there are seven traffic cones configured on the MOS. Two indicate the outer MOS boundaries, three show the alignment of the centerline, and two serve as position guides for the future placement of edge markers. It is now time to accomplish the centerline layout. To do this, return to the last centerline alignment cone's location, station two. Centerline layout procedures for a MOS that is parallel with the original runway are straightforward. From station two forward, the one crew member with a vehicle should start placing cones along the remainder of the MOS at 200-foot intervals. Now that the benchmark (three centerline alignment cones) has been established, all subsequent cone installation distances will be estimated rather than measured. The remaining two crew members will serve as aligners by progressing on foot down the MOS adjusting each station cone they encounter using the previously explained line-of-sight technique. The separation distance (number of stations) used by the people involved in the sighting-in process varies with the individual; however, field experience has shown that a maximum comfortable operating range is normally no more than five stations or 1,000 feet. In this phase of the layout process, speed is more critical then accuracy. That is not to say that accuracy is unimportant, because it is. However, there is an acceptable degree of latitude for the use of approximations in centerline layout. During this operation, spending extensive time to assure that all measurements are precise is unnecessary. Under combat conditions, normally there is not the time nor the need to spend the effort to obtain precise measurements in this part of the MOS marking process. A variation of plus or minus 5% in actual cone distance placement will have little, if any, impact on the overall centerline marking effort. Experience has shown that this degree of accuracy is easily obtainable with a moderate amount of prior training and actual hands-on practice. However, for such training to be as realistic as possible, both day and night layout operations must be conducted. This incremental movement and alignment procedure just described will be repeated until all of the centerline cones have been placed. An exception will occur when a crater interferes with actual cone placement. In such situations, a "T" clear zone will have to be formed; the procedures of which will be discussed shortly in this section. As brought out earlier, once the centerline layout has been accomplished, both the corners and edge marker alignment cones must now be placed at the departure end of the MOS. To accomplish this use the same procedures applied to the threshold end, however, place the new edge marker alignment cones on the left side of the MOS when facing the threshold--opposite of those installed earlier (see figure 5.5).

5.9.11. **Skewed Centerline.** Until recently, developing a skewed centerline MOS was an acceptable alternate procedure. However, with recent changes in the threat analysis and considering potential complications presented by this procedure, development of skewed MOSs is no longer considered a necessary or needed procedure.

5.9.12. **"T" Clear Zone Setting.** When a crater is encountered during centerline layout, a clear zone uninhibited by traffic cones is required so heavy repair equipment can move about freely in the area during repair operations. Yet, some visual cue is required to determine where the new centerline will be. This is accomplished by using traffic cones to form an open area called a "T" clear zone approximately 100 feet from either side of the crater (see figure 5.7). These clear zones can be established either during the actual centerline layout process or immediately afterwards. However, the preferred method is to identify them as they are encountered. This is because often the EOD clearance process will not always allow timely access to the entire MOS; yet, during this delay frequently some craters are located in an UXO cleared area where repair work can actually begin. The procedures for developing a "T" clear zone are as follows:

Figure 5.7. "T" Clear Zone.



5.9.12.1. First, no less than 100 feet from the leading edge of the crater, set a centerline cone. Next, perpendicular to the centerline, set another cone on each side of the centerline approximately half the distance of the required MOS width. Do not forget to consider the 2-foot offset required to allow room for the painting operation. That is why in our example in figure 5.7, one cone is shown 23 feet and the other 27 feet from the planned centerline.

5.9.12.2. Once the leading side of the crater has been properly marked, repeat the process on the crater's trailing edge. Even though there is a break in the centerline layout, always try to keep the 200-foot spacing interval intact. As a result, a "T" clear zone could be spaced anywhere from 100 to 200 feet from a crater's edge.

5.9.12.3. After a "T" clear zone has been established, continue with the centerline marking procedures until either another crater is encountered or the entire MOS centerline has been laid out.

5.9.13. **MAAS Location.** After an aerial bombardment, the probability that the permanently installed aircraft barrier system of the base will be either functional or properly situated on the new MOS is highly remote at best. On the other hand, the air operations staff's need for an arresting barrier will undoubtedly be very high. Under most circumstances, an arresting system must be in place for the possible engagement of high-speed fighter aircraft returning to the base with battle damage and other emergencies. This is where the MAAS comes into play. It was specifically designed to fulfill the need for an expedient aircraft recovery system which is capable of high-cycle arrestment (up to 20 aircraft engagements per hour) of arresting hook-equipped tactical aircraft on bomb damaged surfaces. The MAAS is a self-contained system that can be installed in less than 40 minutes by a crew of six trained personnel on either a concrete, asphalt, or soil surface. Additional details regarding specific applications and capabilities of this system are discussed in length in T.O. 35E8-2-10-1.

5.9.13.1. **Original System Limitations.** The original MAAS was configured and intended to be used primarily for BRAAT. This operation scenario allowed for only unidirectional engagements and did not provide for both approach and departure end engagements. Furthermore, since the trailers were installed 7.5 feet from the runway edge, the relatively narrow cross-runway span did not allow for wide-body aircraft operations--an undesirable limitation.

5.9.13.2. **System Upgrades.** Since the MAAS is essentially a trailer-mounted BAK-12, these initial system limitations could be overcome. Making the system bidirectional simply involved adding 12 additional cruciform stakes (per trailer) and extending the tape run out from 900 feet to 1,200 feet. Furthermore, by also adding a lightweight fair-lead beam similar to those used with the BAK-12 for expeditionary, semi-permanent, and permanent installations, the trailer could be set back as much as 200 feet from the runway edge, thus allowing the room required for wide-body aircraft operations.

5.9.14. **MAAS Location Determination Procedures.** The actual decision as to whether a MAAS is or is not required will be determined by the senior commander located in the WOC. The location, engagement direction, along with other pertinent flight operational requirements, will be passed on to the support staff in the SRC.

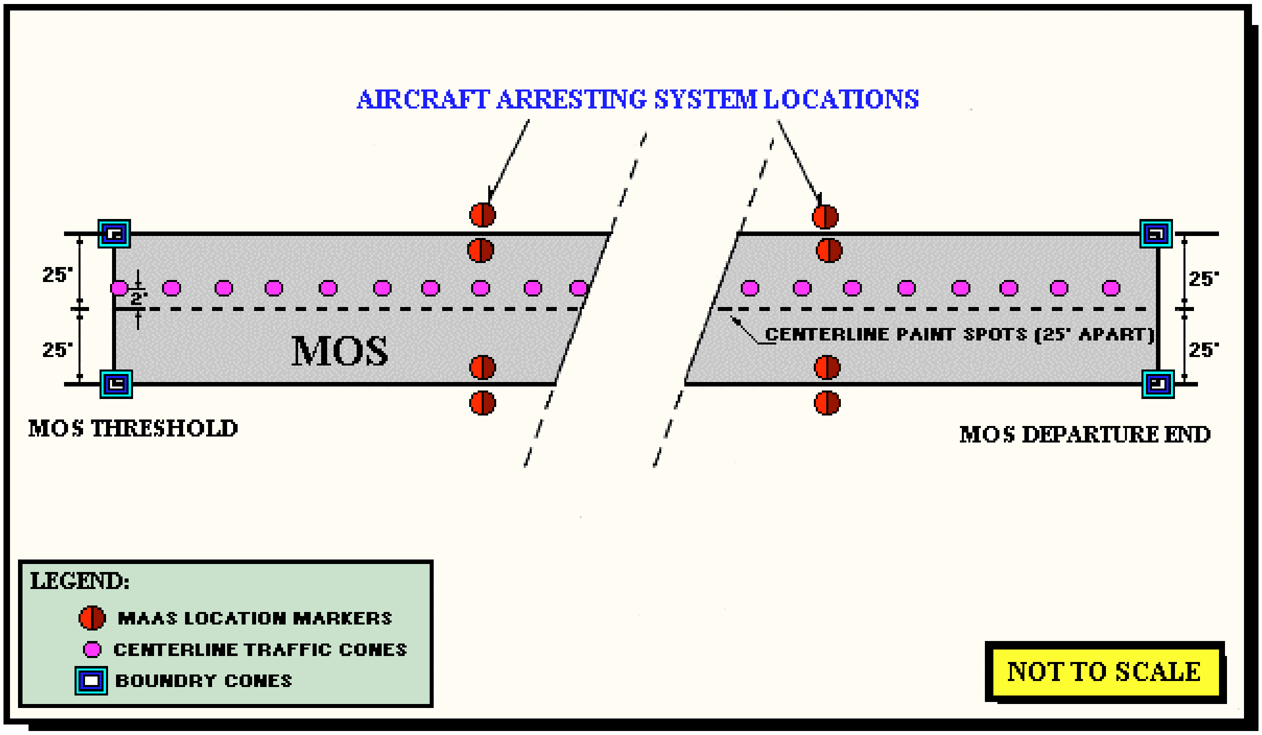
5.9.14.1. **Step One.** Once it has been determined that an aircraft arresting system will be required, the engineer function in the SRC will determine the exact positioning of the MAAS on the approved MOS. Mobile aircraft arresting system positioning will be influenced by a number of factors. A few of the more consequential ones include what type of aircraft are involved, whether the MOS will be bidirectional or unidirectional, and where crater repairs are located.

5.9.14.2. **Step Two.** Once the exact MAAS location has been plotted on the SRC airfield grid map, that information (coordinates) will then be passed to the DCC.

5.9.14.3. **Step Three.** The DCC will then annotate its grid map accordingly and relay the data to the RRR OIC who must assure this information is passed on through the RRR support team chief to the MOS layout crew.

5.9.15. **MAAS Layout Procedures.** The MOS layout crew will identify each MAAS location by the placement of four large traffic cones; two on each side of the operating surface. Specifically, one cone will be placed on the outer boundaries on each side of the MOS, with the second cone situated about 3 feet beyond the first (see figure 5.8). MAAS location identification is normally done after the actual centerline layout activity has been completed. However, keep in mind that the general goal is to have the actual barrier installation start within 1.5 hours after access to the runway surface has been given. Also, be aware that as with most other RRR functions, flexibility is essential if we are to react in a timely fashion to the situation at hand. Consequently, it is plausible that under certain circumstances the MAAS location may have to be identified earlier in the scheme of things. One such case would be if UXO problems delay access to other areas of the minimum operating surface, but not to the actual mobile aircraft arresting system's location. In this case, mark the barrier system's location so that the MAAS installation crew can start the installation rather than have them just sit idly by.

Figure 5.8. MAAS Location.



5.9.16. **Precision Approach Path Indicators (PAPI).** The EALS abbreviated PAPI system provides the aircraft pilot with approach slope information for a safe descent (figure 5.9). Like the Visual Approach Slope Indicator (VASI) system, the PAPI employs four units, two at each end of the MOS. At no time will a PAPI unit be placed closer than 50 feet from the edge of the paved surface. In addition, each pair of units will be separated by a 20-foot space and will normally be positioned approximately 950 feet from both the threshold and departure ends of the MOS (see figure 5.10). However, the actual PAPI locations in relation to the end of the MOS can vary since its installation site is predicated upon the MOS length and desired aircraft touchdown location. As is the case with most other directional information, specifics regarding PAPI location requirements will be provided by the WOC through the SRC. This information is usually given to the RRR team chief while the MOS marking team is either sheltered or in the staging area. Like most other airfield support functions, both PAPI locations must be identified by traffic cones so that the installation team; in this case the airfield (EALS) lighting crew will know where to install the units. However, to avoid confusion, since there are a number of other traffic cones positioned throughout the airfield area, stack two cones on top of each other between 50 and 60 feet from the edge of the MOS. This will indicate the PAPI module location that is situated nearest to the operating surface. Next, place an additional single traffic cone 20 feet farther from the MOS and each of the stacked cones to indicate the positioning of the other PAPI module.

Figure 5.9. Typical PAPI Light.

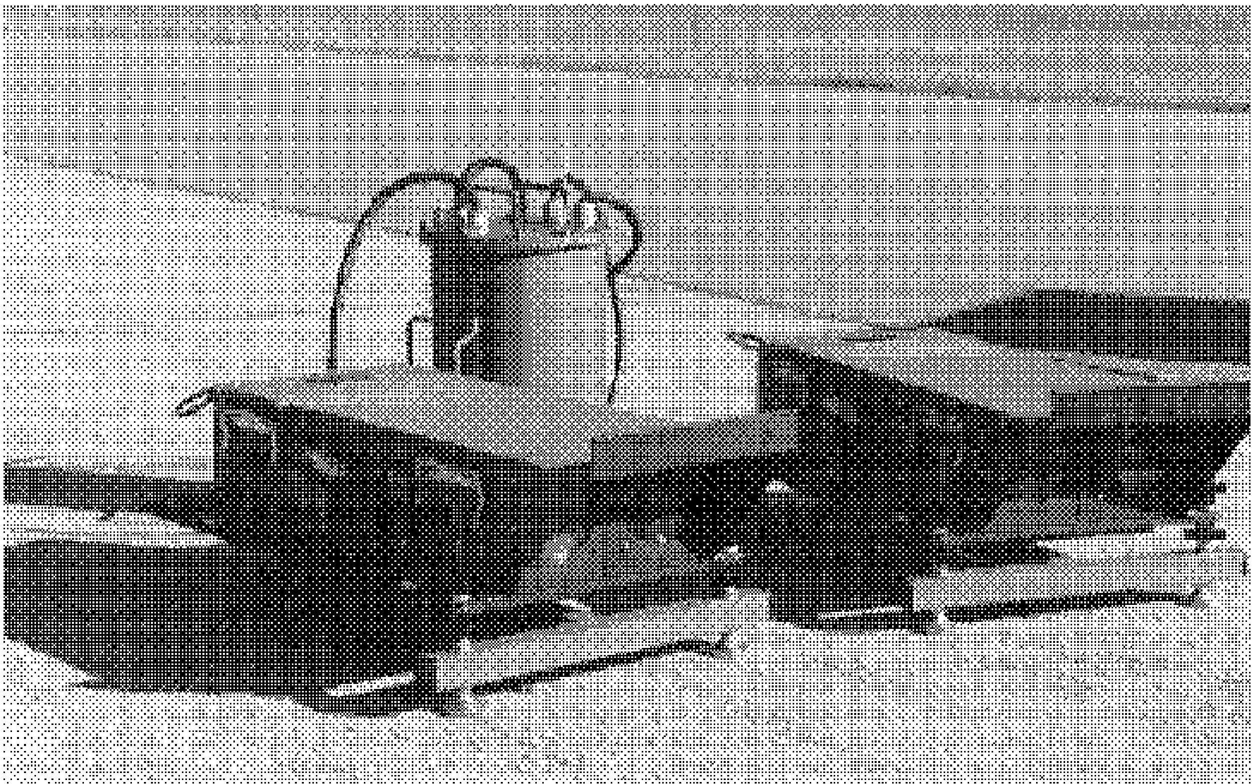
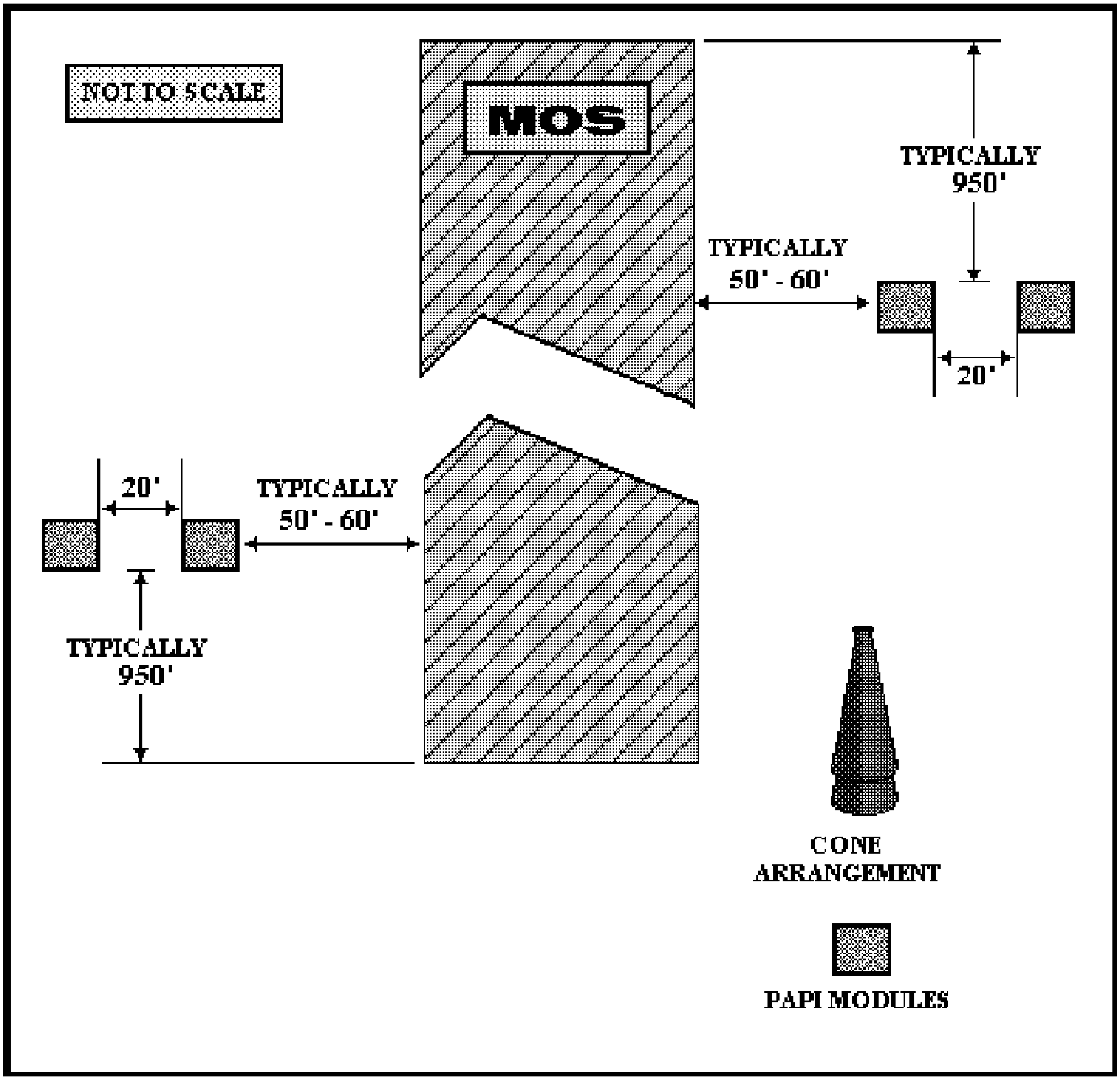


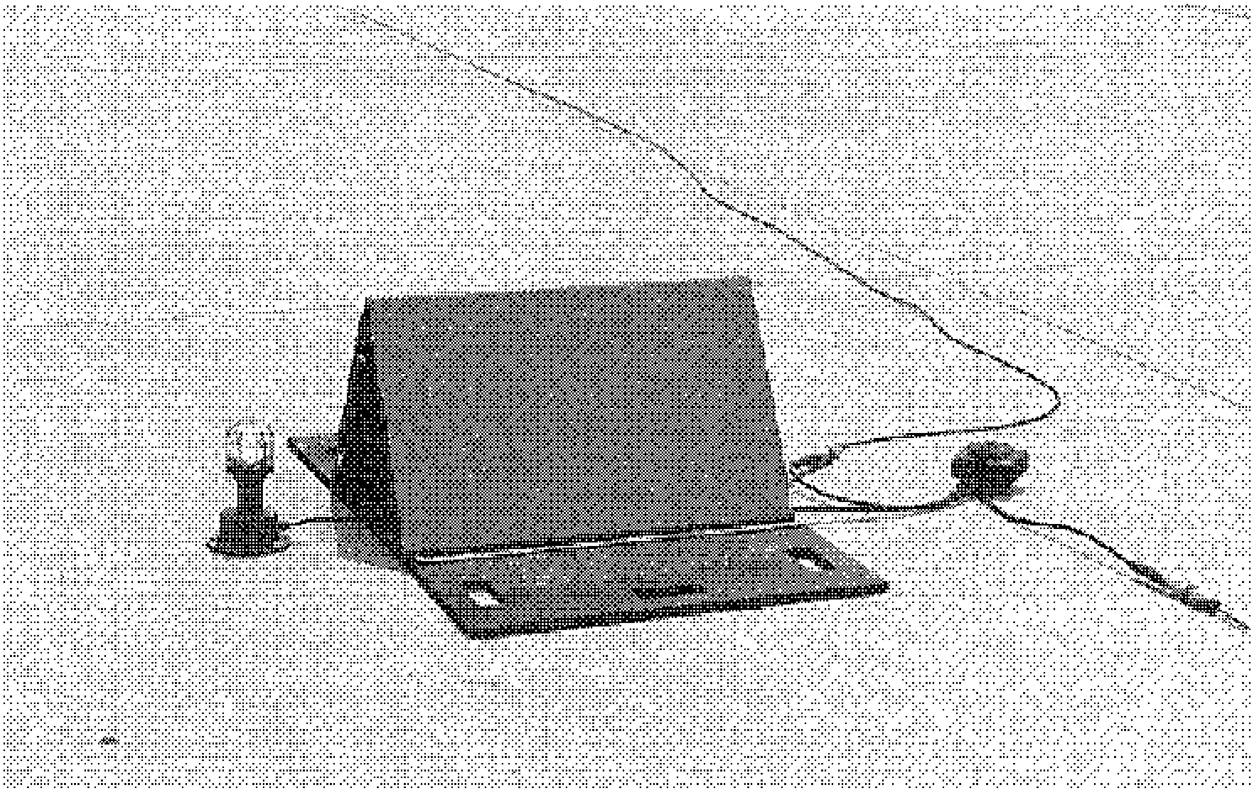
Figure 5.10. Abbreviated PAPI Lighting Scheme.



5.9.17. **Edge, DTG, and Aircraft Arresting Barrier Markers.** These markers are all normally installed as one operation. However, for the purpose of clarification, each will be addressed separately in this chapter.

5.9.18. **Edge Marker Placement.** Edge markers are used to indicate the outer boundaries of the MOS and can also prove helpful in the installation of an emergency airfield lighting set since the spacing requirements of both EALS lighting fixtures and edge markers are the same (200 feet). However, as with the centerline layout, exact measurements are not critical. Whenever possible, actual edge markers rather than traffic cones should be used (see figure 5.11). One notable exception is in crater repair areas. In such instances, large traffic cones may be more visible and less likely to be disturbed than the standard edge markers. The following is the recommended standard edge marker layout procedure:

Figure 5.11. EALS Edge Marker and Light Fixture.



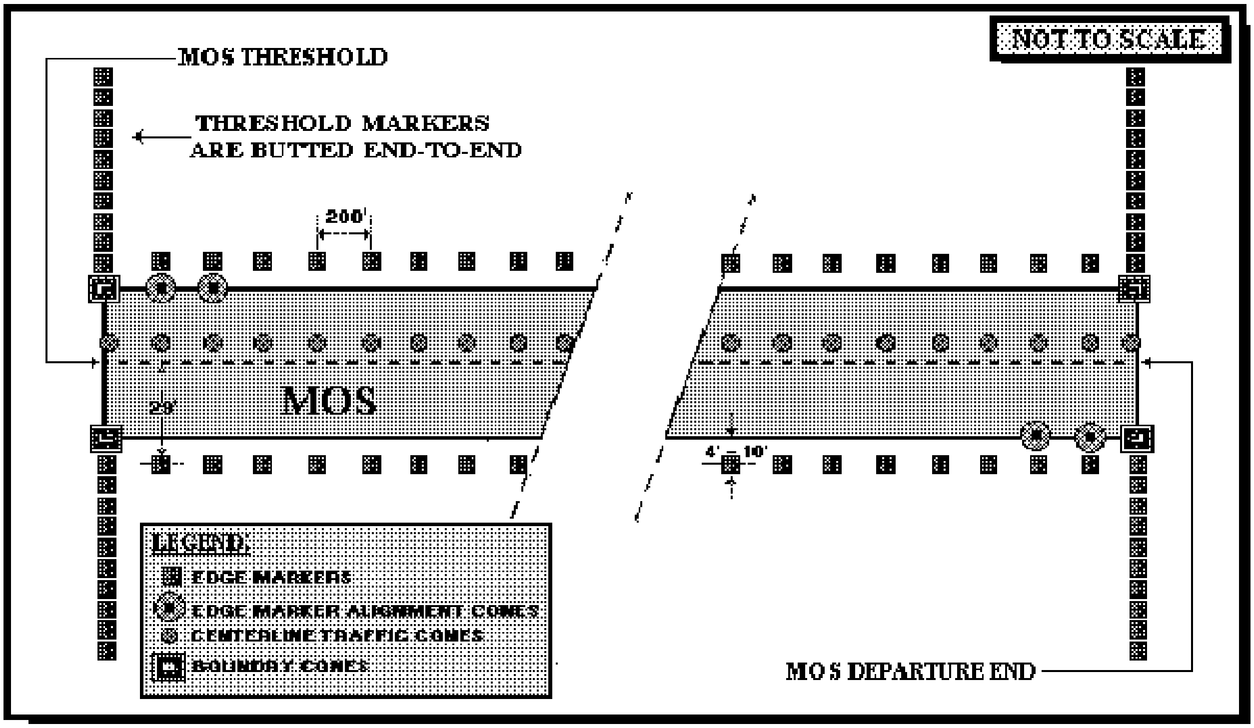
5.9.18.1. **Step One.** Drop off one of the MOS layout crew members with 20 edge markers at the MOS threshold. This person will assemble and place ten markers on each side of the threshold butted end-to-end. Position the marker which is closest to the MOS so that its length is parallel to and 4 to 10 feet off the MOS. Once the threshold markers have been placed in position, this individual will then walk up the MOS and join the remainder of the crew that are assembling edge markers and installing them along the side of the MOS.

5.9.18.2. **Step Two.** After the crew member has been dropped off for the purpose of threshold edge marker layout, the remaining three layout crew members will proceed with placement of edge markers along one side of the MOS. Which side is accomplished first is inconsequential. Two crew members will use a measuring tape or pace off a location perpendicular with the centerline which is half the width of the MOS plus 4 to 10 feet. In our example (figure 5.12), this is 29 feet because we elected to place the edge markers 4 feet from the edge of the MOS. The first edge marker should then be in-line with the both the second centerline and the first edge marker alignment cones--all of which were placed during the first part of the MOS centerline layout activity. Using this approach, the centerline cones can be used as a guide for all subsequent horizontal edge marker placements since, like the EALS fixtures, the spacing requirement of both are identical--200 feet. If the EALS edge lighting is installed ahead of the edge markers, edge markers will be placed 1-foot to the outside of the lights away from the MOS centerline.

5.9.18.3. **Step Three.** Once the first edge marker has been positioned, place the next two markers in the same manner. As was the case with the first marker, both of these will also be installed so as to be in-line with a centerline cone and an associated edge marker alignment cone.

5.9.18.4. **Step Four.** At this time there are three edge markers positioned at 200-foot intervals along the edge of the new MOS, all of which should be in acceptable alignment. As occurred with the centerline layout procedure, once the first three edge markers are correctly installed, they serve as the benchmark for all remaining marker positioning. From this point forward, the vehicle and two crew members should move with the placement effort down the MOS stopping at a point in-line with each centerline cone in order to fabricate and place an edge marker. Another crew member will remain a distance behind the installation effort in order to direct the subsequent alignment of these markers using the line-of-sight method discussed earlier. This incremental movement and alignment procedure will be repeated until all of the edge markers have been placed on one side of the MOS.

Figure 5.12. Edge Marker Layout.

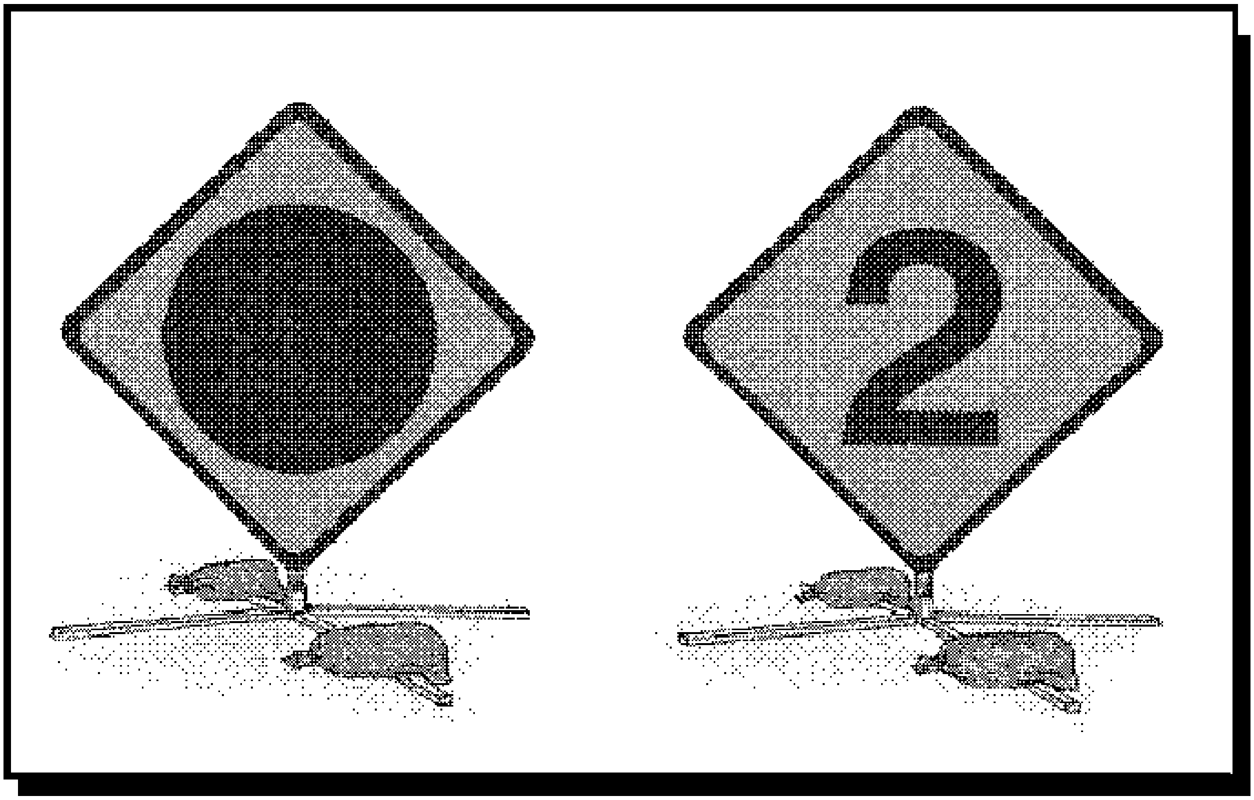


5.9.18.5 **Step Five.** Once all the edge markers have been properly positioned on one side of the MOS, edge markers will also have to be installed at the departure end of the MOS in the same fashion as was accomplished at the threshold. Again, drop off one of the crew members with 20 edge markers at the departure end. As was the case during the threshold edge marker effort (step one), once this person has completed placing the departure edge markers, he/she will join the remainder of the crew to assist with the remaining side edge marker installations. The remaining three crew members will then start placing edge markers down the other side of the MOS using the same procedures that were employed for the first side. As an added precaution, conduct a quick "eyeball" perpendicular alignment verification approximately every 2,000 feet during the operation to assure that the edge markers on each side of the MOS are in relatively close alignment with each other. ***NOTE:*** The edge markers situated in the MAAS tape swing (approximately two to five markers per direction) may have to be removed to avoid their destruction during a barrier engagement**.**

5.9.18.6. **Range of Accuracy.** As was addressed earlier during the MOS centerline layout procedure, the person who is performing the line-of-sight procedure will have to gradually change his/her position as the distance makes it difficult for him/her to determine proper alignment. When this actually occurs will vary from individual-to-individual, but field experience has shown that a maximum comfortable operating range is normally about 1,000 feet or five markers.

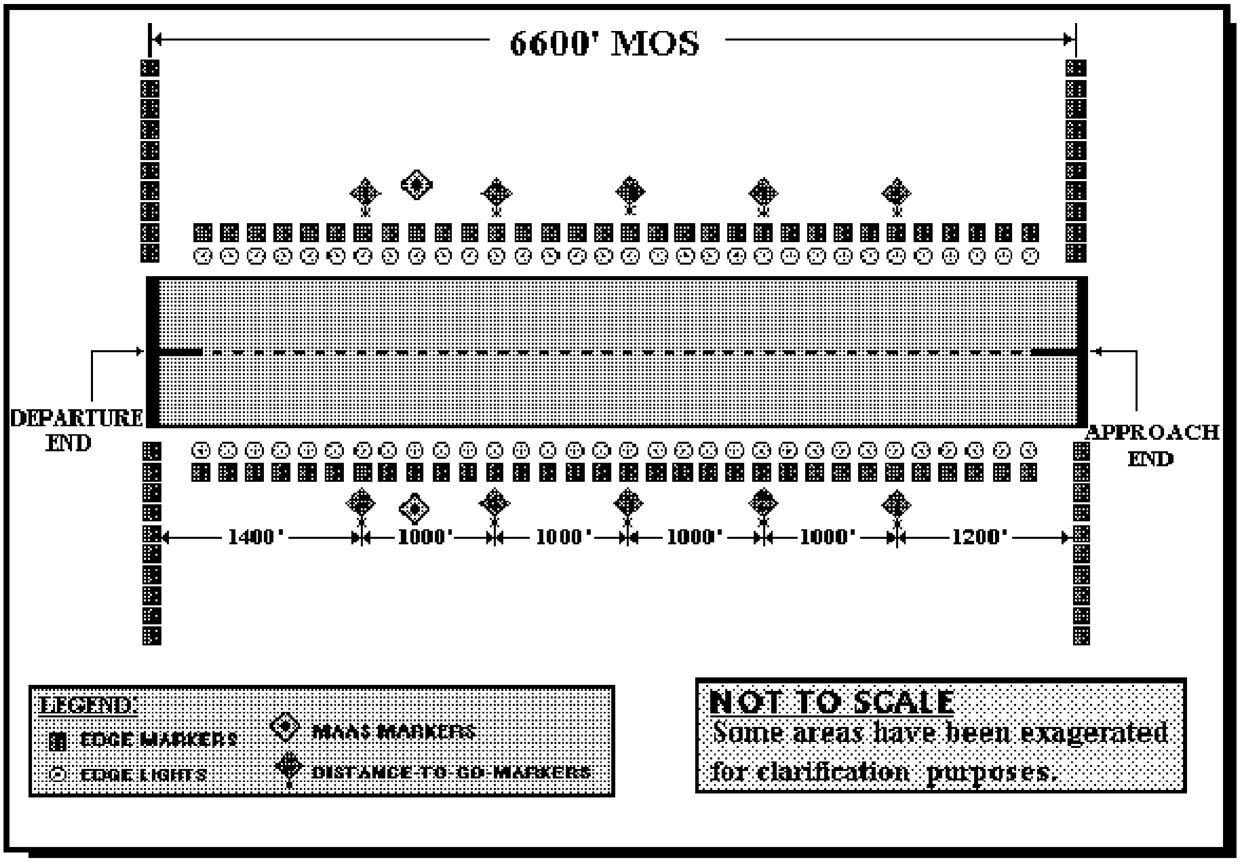
5.9.19. **Distance-To-Go Markers (DTG).** As a time saver, DTG markers are normally put in place during the edge marker installation activity. These markers, which are spaced at 1,000-foot intervals, are employed to inform a pilot of the amount of paved surface that remains as he/she progresses down a runway. They are free standing diamond shaped units composed mainly of a light fabric that requires them to be secured in place at the base by sandbags. When installed, they display a 38-inch high black single digit number on a bright orange background with a 2-inch black border (see figure 5.13). Distance-to-go markers are always situated so that pilots read the numbers on the right side of the MOS. When placing DTG markers, use the centerline cones as your measurement points. Each DTG marker should be placed about 25 feet off of the MOS to assure that it does not interfere with flying operations. Time allowing, use a tape measure; otherwise, pace off the distance. Once all of the DTG markers have been positioned on one side of the MOS, repeat the process on the opposite side. As indicated in figure 5.14, DTG markers are always placed directly across from each other.

Figure 5.13. Aircraft Arresting System and DTG Markers.



5.9.19.1. **Irregular MOS Lengths.** A prime concern when a MOS length is not in a multiple of 1,000 feet is that the DTG marker installations may end up not being placed directly opposite of each other on the operating strip. A simple way to avoid this problem is to distribute half of the extra distance which is less than 1,000 feet between each end of the MOS. Once this is done, the first DTG marker should then be positioned so as to align with the nearest edge light. Thereafter, all subsequent DTG marker installations will be based upon the standard 1,000-foot interval. Keeping in mind that edge lights are spaced at 200-foot intervals, it is very probable that the DTG markers at the threshold end of the MOS will be at a different distance from the closest markers at the departure end. This is graphically shown in the 6,600-foot MOS depicted in figure 5.14 where the DTG markers at the threshold end are 200 feet nearer to the end of the MOS than those positioned on the departure end. In this example, 600 feet is divided equally between both ends; however, one end must be adjusted to coincide with the 200-foot spacings of the edge lighting scheme. In situations where additional distance is available at one end of the MOS, it is usually better to add this space to the departure end to allow the pilot an added measure of safety. Details regarding where these offset DTG markers will be positioned on a MOS will be provided to the MOS layout crew by the DCC.

Figure 5.14. Distance-to-Go Marking Scheme.



5.9.19.2. **Precautions.** Since DTG markers are situated well off of the MOS, special care must be taken to avoid UXO that may be hidden in the debris from the enemy attack. This is especially so when there is a possibility that small anti-personnel devices have been used by the enemy. These small bomblets can be very difficult to locate, yet lethal when disturbed. As a result, DTG marker placement must not begin until EOD has checked and cleared access to the work area.

5.9.20. **Aircraft Arresting System Markers.** As was brought out earlier in the chapter, aircraft arresting barrier markers are also normally installed during the edge marker installation activity. These markers are used to inform a pilot of exactly where the airfield arresting systems are configured on the MOS. On a MOS that has two arresting systems in-place, four markers are installed--two at each system location. Each marker is situated 25 feet off the MOS edge, in-line with the barrier pendent cable, and directly opposite of each other. Aircraft arresting system markers are very similar in design to the DTG markers discussed previously; also requiring stabilization with sandbags. They are free standing, diamond shaped (48 inches on each side) units with a bright orange background, a 2-inch border, and a 40-inch centered black circle. The installation procedure for these markers is rather straightforward. When the MOS layout team reaches a MAAS location, they simply temporarily stop their edge marker installation process in order to fabricate and install two aircraft arresting system markers. As was the case with the DTG markers, these indicators must be placed so that pilots can see the black dots on the right side of the MOS, in the direction of aircraft travel.

5.9.21. **Approach Lighting.** The EALS approach lighting system is composed of two types of lights: incandescent and strobe. Approach lights are intended to assist the pilot in locating and aligning the aircraft with the airfield at night.

5.9.21.1. **Incandescent System.** The incandescent approach lighting system is composed of eight lights, four for each end of the MOS. In the EALS system the same light fixtures that are employed as edge markers are also used as incandescent approach lights (see figure 5.15). In addition, all components of the approach light, with the exception of the lens and lamp, are identical to and interchangeable with the threshold/end and taxiway lights. Approach lights are installed on 200-foot intervals extending outward from both the MOS threshold and departure ends. As shown in figure 5.16, they are aligned with the actual MOS centerline, not the traffic cones which are positioned 2 feet off-center to allow room for the striping machine operation.

Figure 5.15. EALS Incandescent Light Fixture.

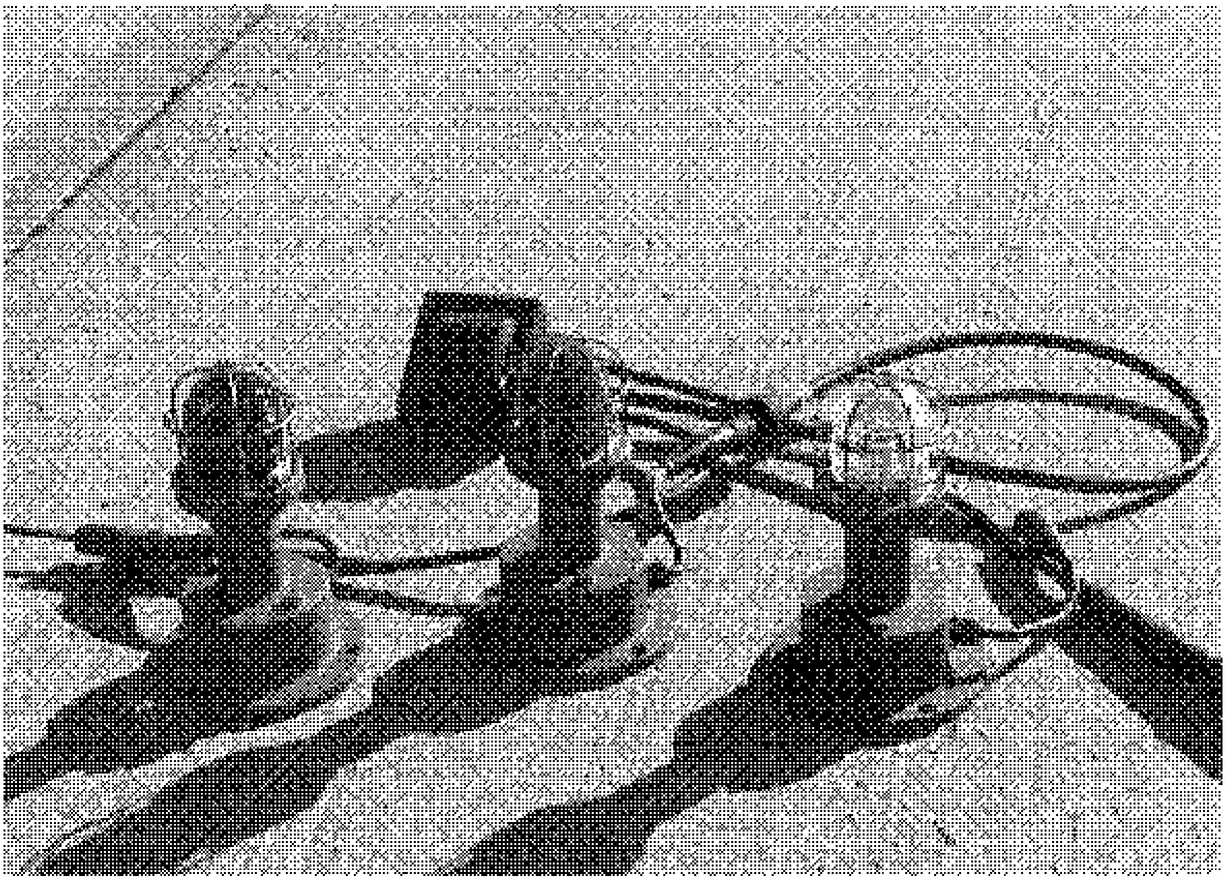
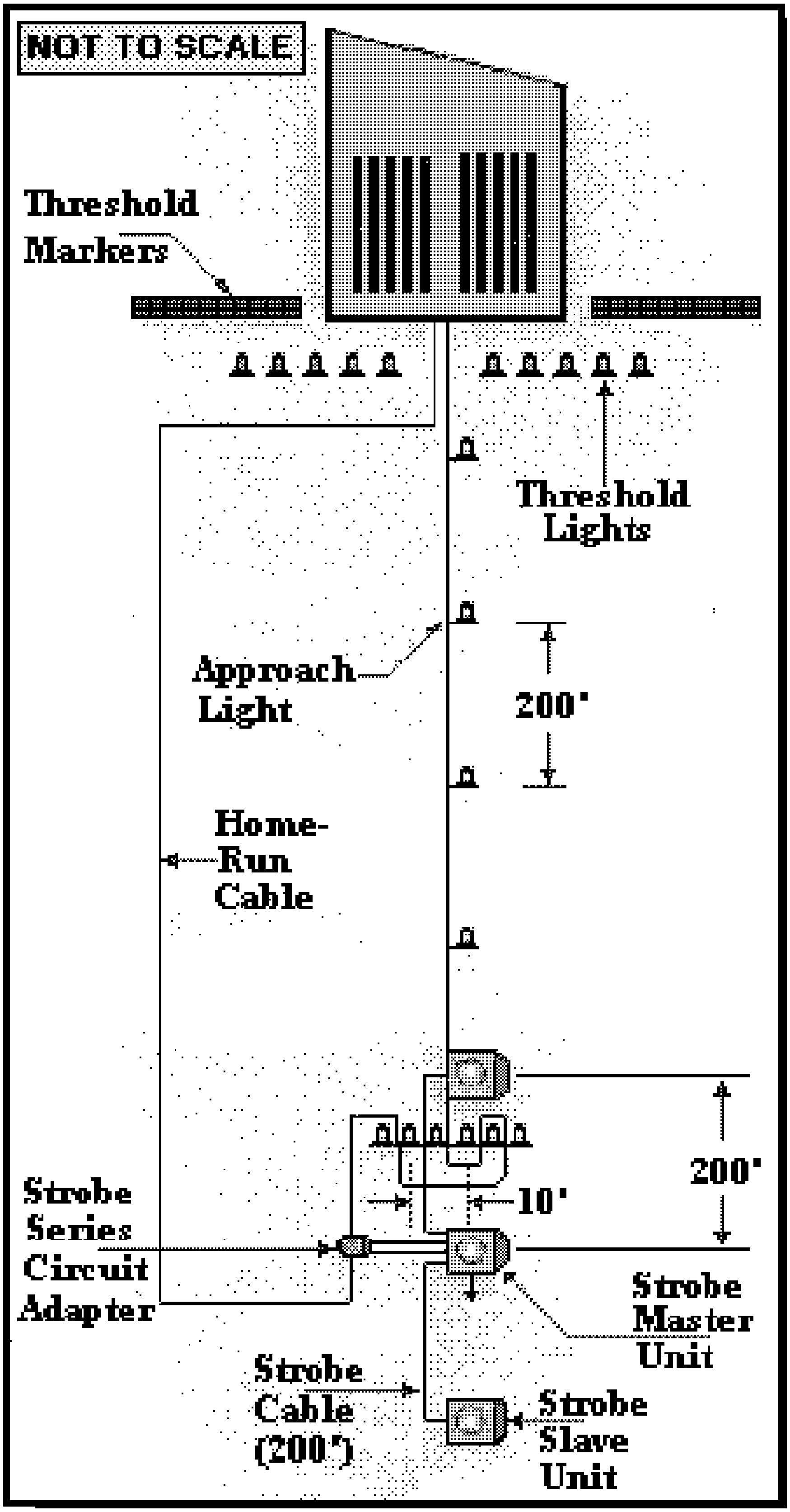
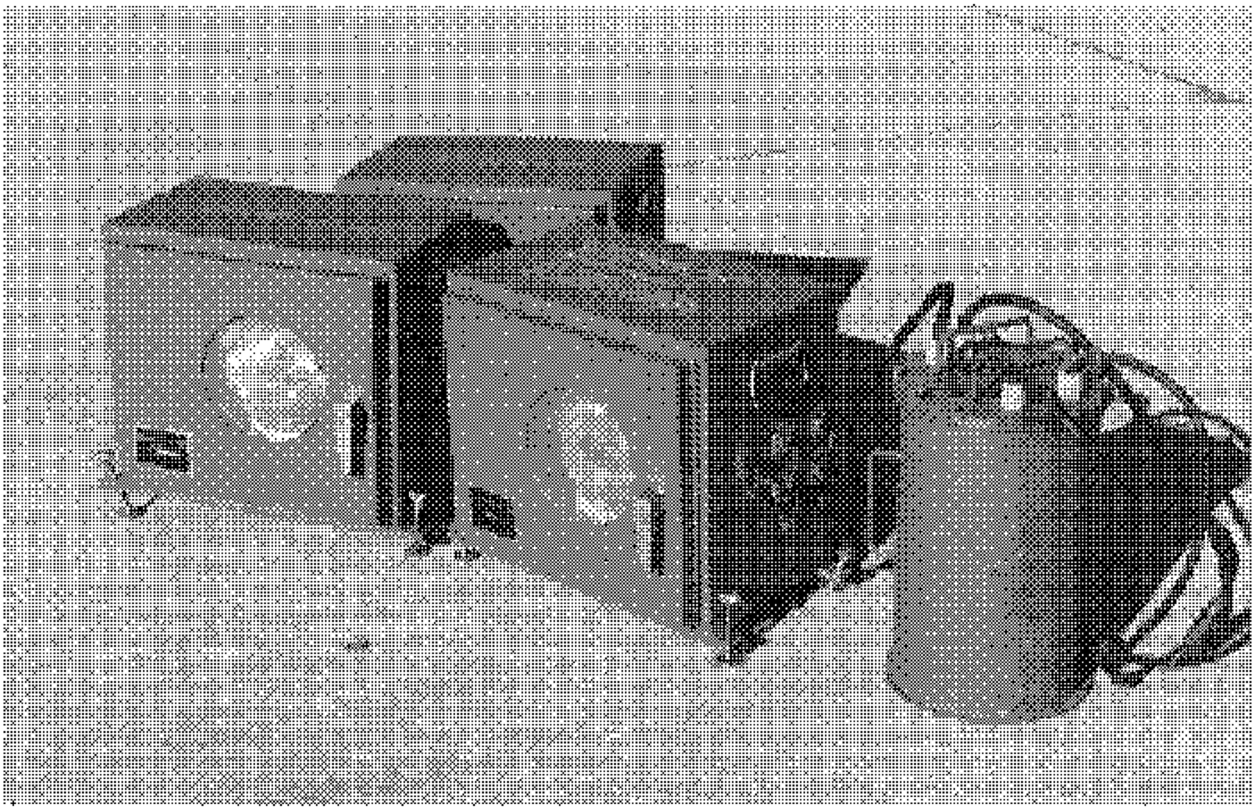


Figure 5.16. EALS Approach Lighting Scheme.



5.9.21.2. **Strobe System.** Strobe lights help the pilot locate the MOS centerline under conditions of reduced visibility such as cloud overcast, fog, and rain. As brought out previously, the EALS approach lighting system also includes strobe flashers (figure 5.17). There are a total of six strobe flasher units involved in the setup, three for each end of the MOS. Once correctly installed, a 200-foot separation will exist between each unit. When energized, each strobe will flash in sequence starting at the unit positioned outermost from the runway threshold. As with the incandescent approach lights, strobe lights are also placed on the extended MOS centerline. As depicted in figure 5.16, the first strobe unit is placed 200 feet from the farthest (last) incandescent approach fixture--1,000 feet from the MOS threshold.

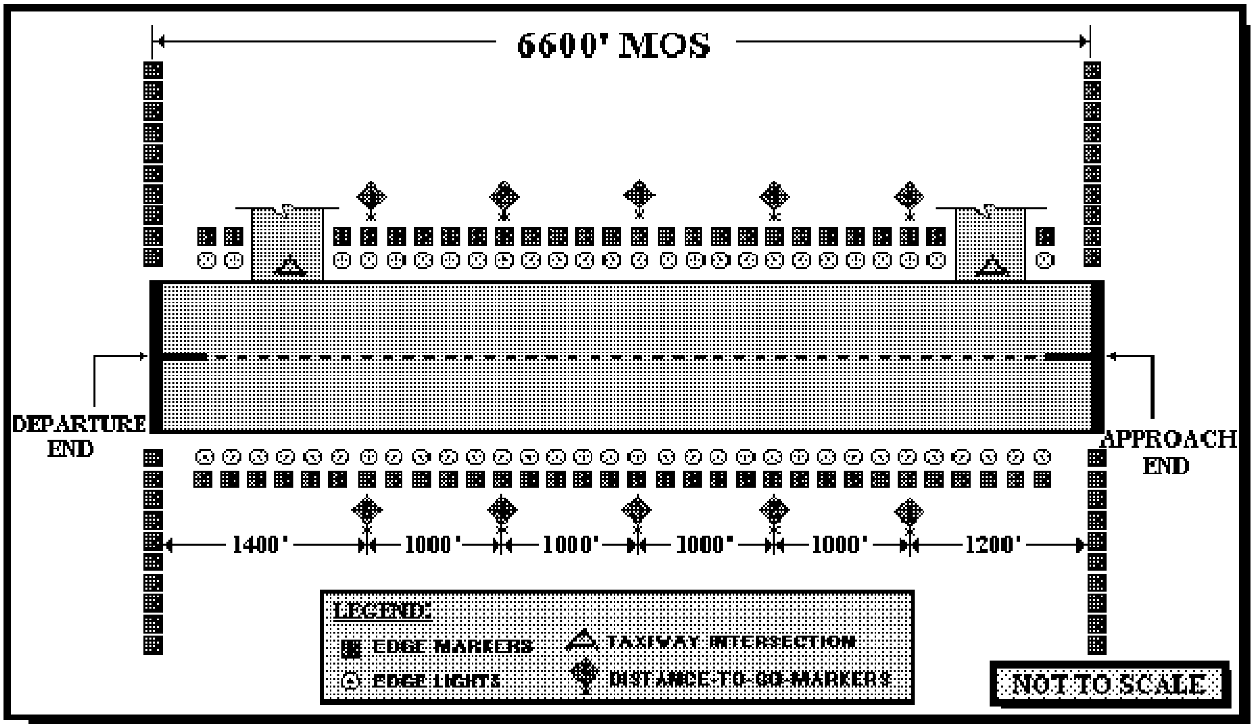
Figure 5.17. EALS Strobe Light Fixtures and Circuit Adapter Unit.



5.9.21.3. **Layout Procedure.** Actual installation of both the incandescent and strobe approach lighting systems usually does not take place until late in the RRR recovery effort. As a norm, EOD personnel will initially focus their UXO clearance effort on the actual MOS surface and adjacent 100 feet of peripheral surface. Areas, such as overruns, normally do not receive attention until the MOS itself has been attended to. As such, actual layout of approach lighting may well not occur until late in the airfield recovery effort. In fact, it is highly probable that it will be one of the last activities accomplished by either the MOS layout or EALS crews. Once EOD clearance to the area is given, approach lighting layout procedures are rather straight forward and easy. It simply entails the placement of 14 traffic cones, seven at each end of the MOS. Using the MOS threshold as a benchmark, place seven cones in an outward line at 200-foot intervals. Use the line-of-sight technique to assure that all seven of the cones are reasonably aligned with the MOS centerline. If a bidirectional MOS is to be used, once the approach light locations have been identified as the threshold, repeat the layout process at the departure end of the operating strip as well.

5.9.22. **Taxiway Identification.** It is essential to identify all usable access taxiways at the junction point with the MOS so that the airfield lighting crew will know where to install cable protectors to safeguard the airfield lighting system cabling. This is accomplished by simply placing three traffic cones configured as a triangle at each intersection as shown in figure 5.18.

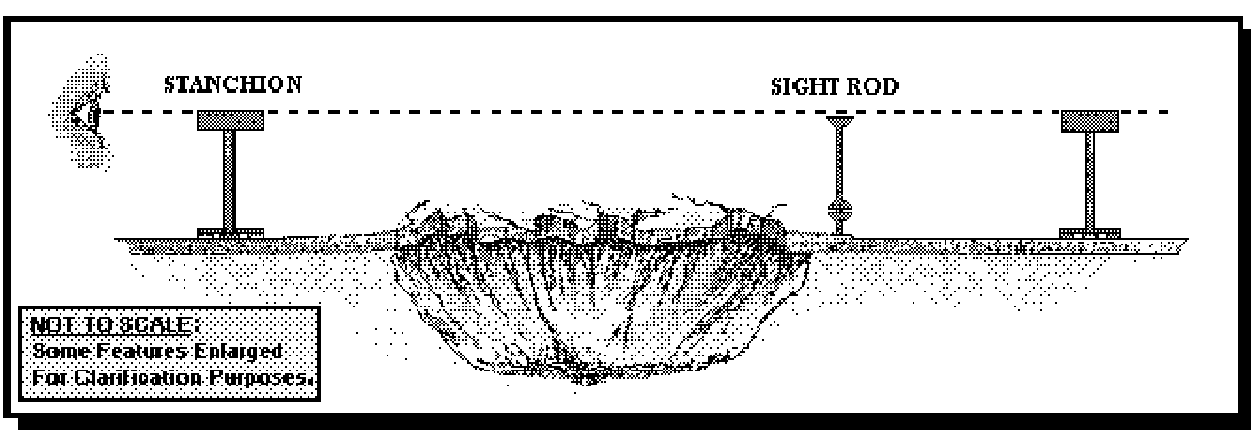
Figure 5.18. Taxiway Identification.



5.10. Determination of Upheaval. The determination of how much upheaved pavement must be removed at the start of a crater repair is accomplished by a process called crater profile measurement (CPM). The same process is used after repairs are complete to see if repairs have been performed within the tolerances specified by the repair quality criteria discussed in the previous chapter. Crater profile measurement will also be employed at various times while the repair is being trafficked by aircraft in order to determine if crater maintenance is necessary do to base course sag. As can be seen, CPM is an integral part of any RRR technique. It is of paramount importance that engineering command and control personnel know the exact extent of the upheaval damage as well as the quality of a completed repair effort. Without this information, RRR repairs will be relegated to "seat of the pants guesswork" and aircraft sortie generation damage is almost a certainty. ***NOTE*****:** Procedural details regarding CPM are provided in T.O. 35E2-5-1.

5.10.1. **Crater Profile Measurement.** Crater profile measurement is a relatively simple process relying on a visual line-of-sight technique (figure 5.19). The procedure is normally started immediately after the first front-end loaders on scene clears debris away from the area around the crater. The only equipment needed is a pair of "T" stanchions built according to the technical manual, a sight rod, and pavement marking material such as chalk or paint. As is the case in most surveying type activities, a minimum of two people are required to perform the process. However, by employing three people, the process can be noticeably accelerated. Measurement of the amount of upheaval to be removed is accomplished by adhering to the following steps.

Figure 5.19. Line-of-Sight Technique.



5.10.2. **Step One.** Set a stanchion on each side of the crater on a line which passes approximately through the center of the crater. Stanchions must be on sound pavement (not on any upheaval), positioned at least ten paces (approximately 25 feet) beyond the crater lip, and be situated parallel to the direction of future aircraft traffic. After the stanchions are properly positioned, the top of each (the "T" portion) should be level. Once the stanchions have been properly positioned and leveled, upheaval identification can commence.

5.10.3. **Step Two.** One of the two-man crew acts as the sight man while the other acts as the rod man. The sight man stands approximately 4 to 5 feet behind one of the stanchions and sights a line along the upper edge of both stanchions. The rod man holds the rod vertical while moving it horizontally on a line between the stanchions, stopping every 2 to 3 feet for an upheaval assessment. All measurements should start on obvious upheaval and move in a direction away from the crater toward one of the stanchions (figure 5.20). The upheaval start point is found when the single triangular target on the rod drops below the line-of-sight. Mark the pavement with chalk or paint about 1-foot further out from this upheaval start point (figure 5.21). This ensures that all of the upheaval has been included. Next, the rod man walks around to the opposite side of the crater and repeats this process there. At this point, there are two upheaval markings opposite each other on the pavement surface.

5.10.4. **Step Three.** Now that the crater is divided in half, completely mark all of the upheaval on one side--one crater half. To do this, position both stanchions approximately 4 to 5 feet toward one crater side, and repeat steps one and two. Again, start the measurements on obvious upheaval, locate the spot where upheaval is first detectable, and move away from the crater 1 or 2 feet from this point. Mark this location, as mentioned previously, to indicate the point where pavement is to be removed. Next, move to the opposite position on that half of the crater, and mark the beginning of the upheaval there on the same profile. Again, move the stanchions another 4 or 5 feet laterally from the crater to the next profile line and repeat steps one and two. Continue this process, moving laterally away from the crater centerline until the farthest edge of the upheaval is found. The upheaval measurement crew then moves to the other half of the crater and repeats the above steps until all upheaval is marked (figure 5.22). **NOTE:** The reason that only half of the crater's upheaval is marked at one time is so that the identification process does not delay the start of actual heaved lip removal operations. Once the first half of the crater has been completely marked, the excavator can begin breaking the upheaval in the marked area while the upheaval check is underway on the remaining portion (half) of the crater.

Figure 5.20. Sight Rod Movement.

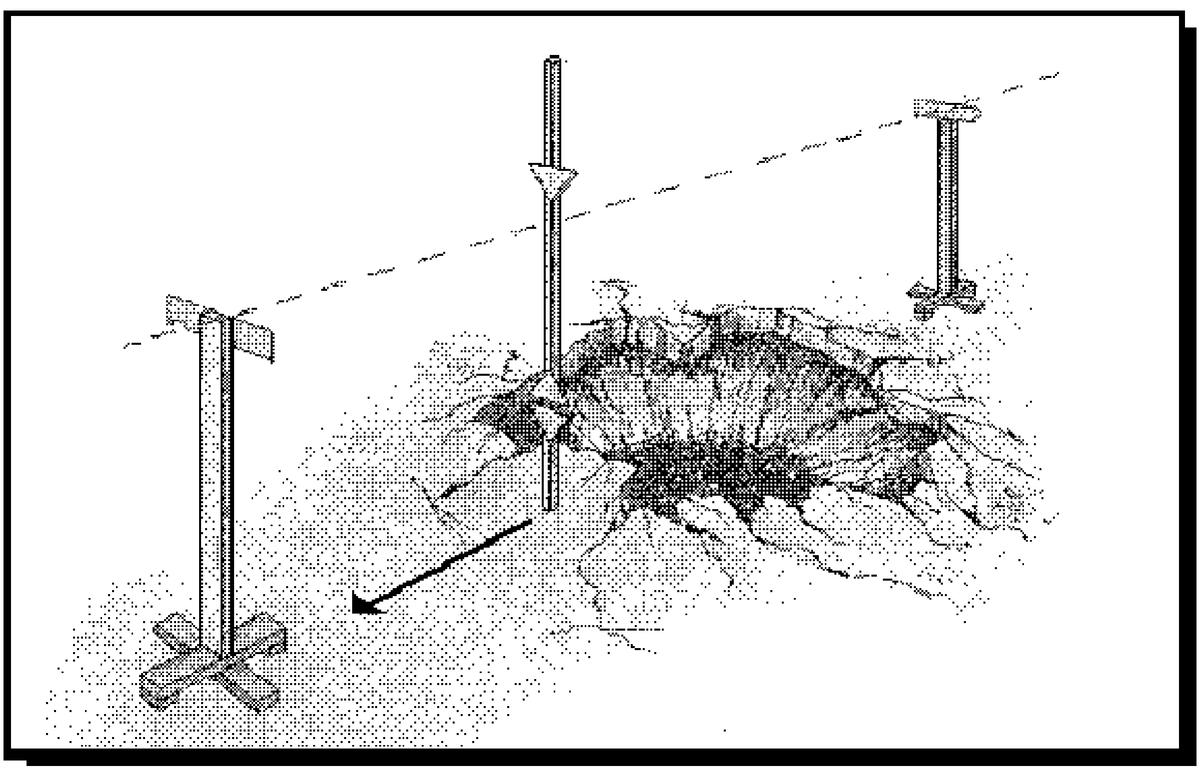
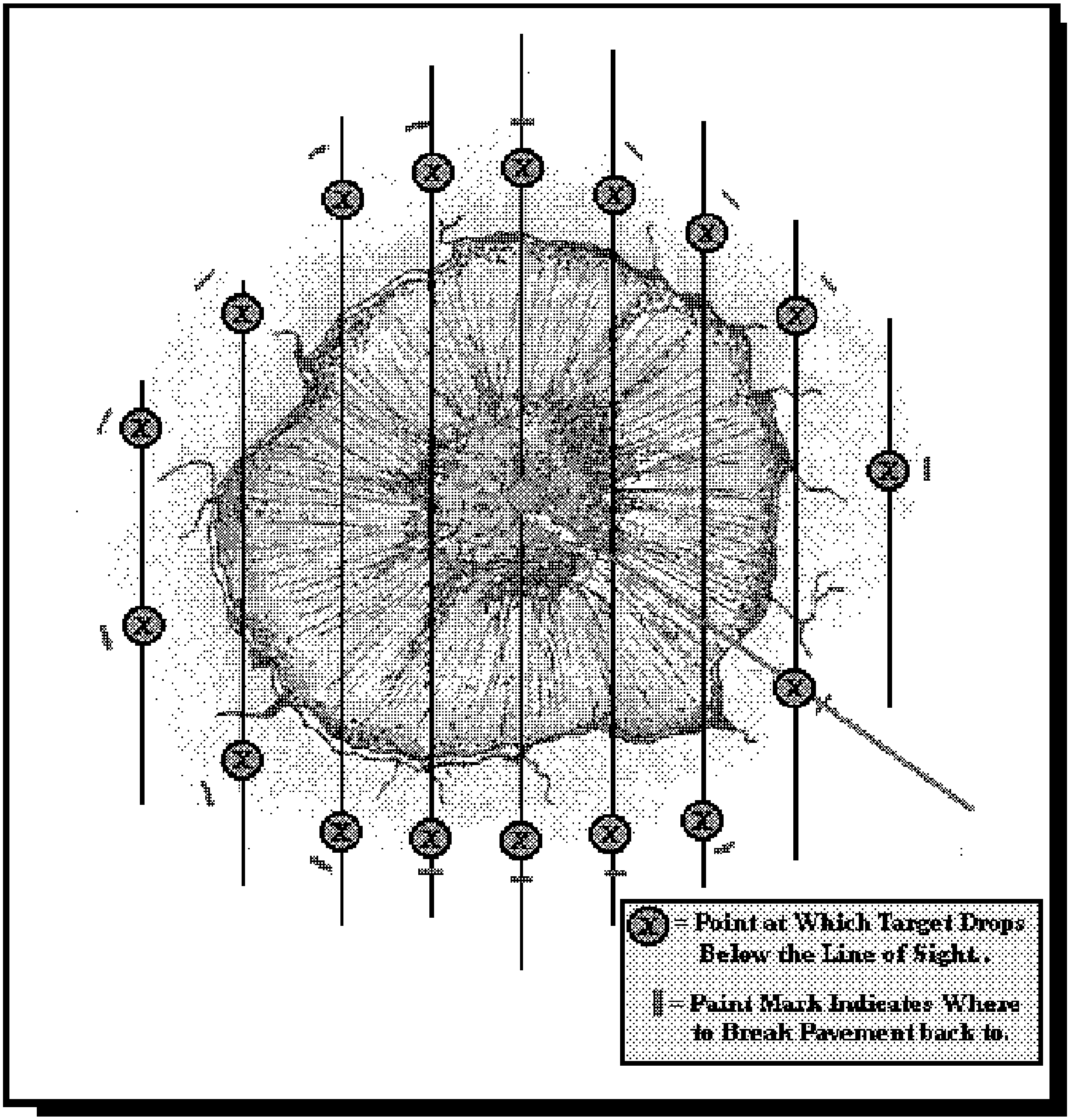
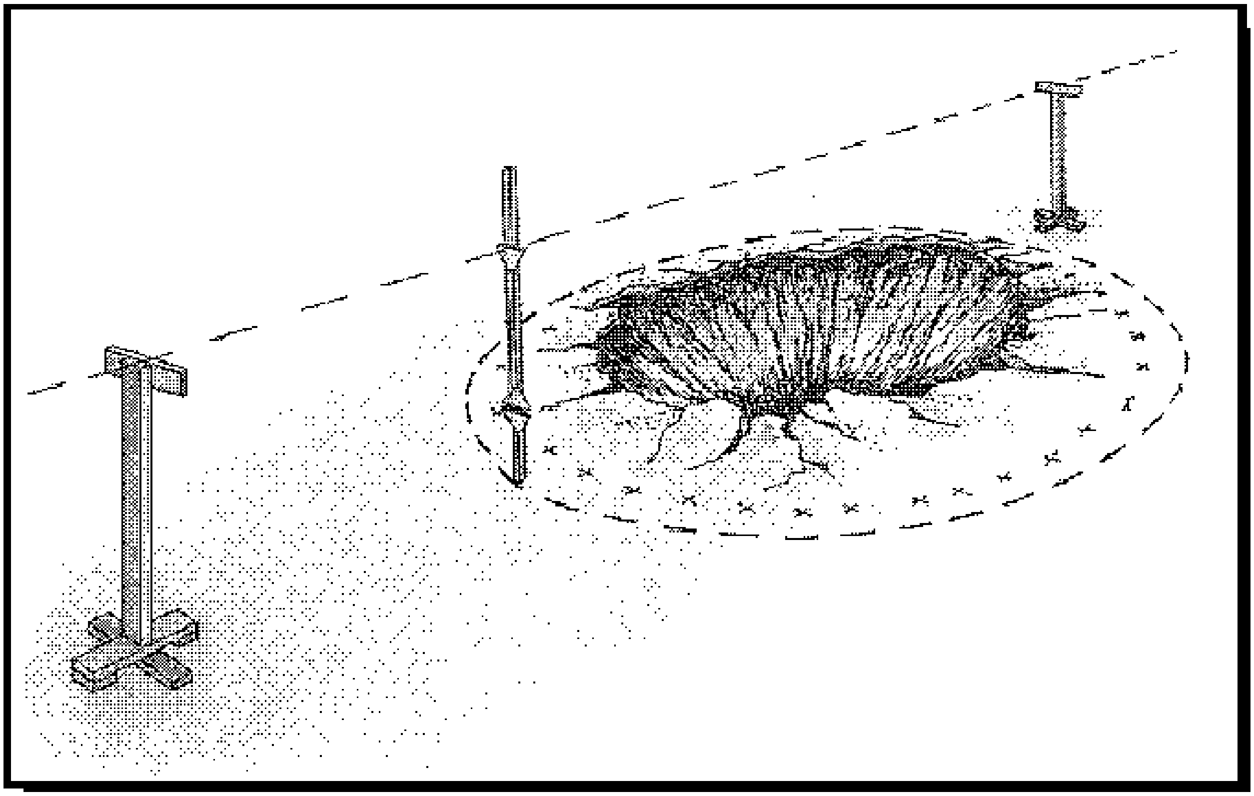


Figure 5.21. Marking Beginning of Upheaval.



5.10.5. **Step Four.** Outline the total upheaval requirement around the crater by connecting all of the upheaval marks, using spray paint or chalk (figure 5.22). Again, if you have marked your readings correctly, this outline should fall 1 to 2 feet outside the point where the upheaval was initially identified.

Figure 5.22. Total Upheaval Requirement.

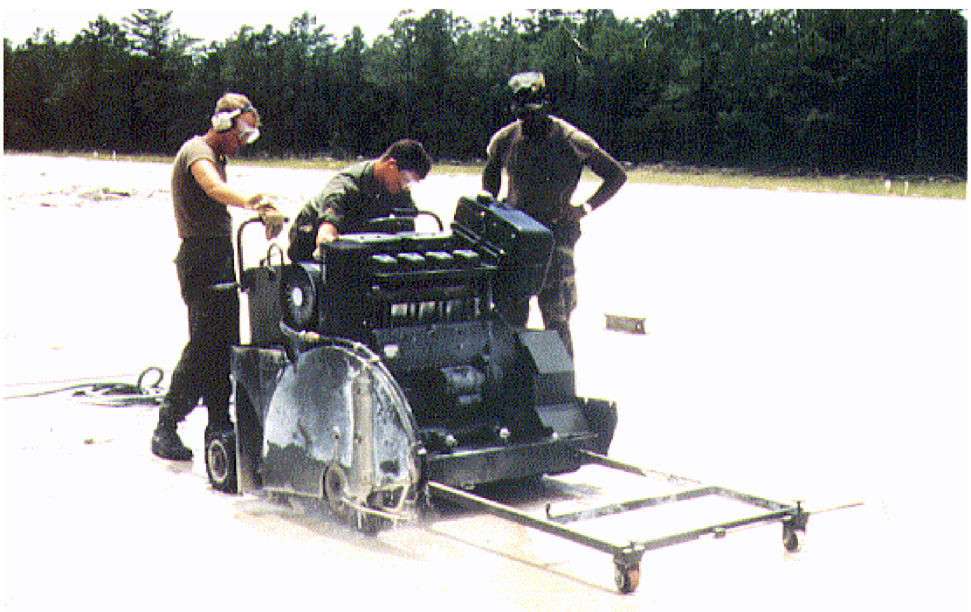


5.11. Removal of Upheaval. With the extent of upheaval determined, the next step in the RRR process is the removal of unsound and upheaved pavement. Unsound pavement is pavement that has been damaged to the point where there is a reasonable possibility that it might break apart under traffic and present a FOD problem. Since the AM-2 and FFM repairs are compatible with irregularly shaped craters, the pattern of upheaval breakout is not critical.

5.11.1. **Removal Activities.** Since no specific pattern is required using this method, the excavator moves around the crater breaking the pavement into smaller pieces back to the upheaval removal markings. At the same time 4 yd^3 front-end loaders flip out and remove the upheaval. If the jackhammer action is not necessary or is completed quickly, the excavator with bucket attachment is used to assist the loaders in the removal activity. The important point here is not to let the excavator stand idle--use the equipment as much as possible. Upheaval removal is a close quarters activity and safety must be stressed (figure 5.23). Be creative; equipment attrition may dictate changes in methods--do not get locked into an "only one way to do it" approach. For example, the dozer can be used effectively to break upheaval from below and push it to the edge of the crater, providing a large crater is being repaired. Also, if the excavator is down, time spent pre-cutting the area to be removed with the high-speed concrete cutting saws may actually reduce the time otherwise required for subsequent upheaval removal (figure 5.24). However, operation of the high-speed concrete cutting saw is tricky and requires extensive hands-on experience to become proficient. As the upheaval is removed from the crater, it is pushed off of the MOS, normally by front-end loaders. Here again, however, a dozer or the excavator using its blade can assist if either is available. The removed pavement pieces should be pushed at least 25 feet off of the MOS surface and not be piled any higher than 3 feet. Think ahead during this operation. If possible, push the broken pavement completely off the original runway or taxiway surfaces and clear of lighting fixtures. Eventually, you will probably have to open as much of the existing airfield surface as possible or establish a new MOS, if subsequent attacks occur. You do not want to have to move the same debris twice in order to open these pavement surfaces for aircraft use. Additionally, moving this material completely off airfield pavements decreases the FOD potential and removes major obstacles to aircraft flow, particularly during landing operations. However, be aware of possible UXO problems when moving debris away from the immediacy of the MOS proper. ***NOTE:*** The concrete cutting system was originally procured to support the now obsolete concrete slab repair method. However, the system has been retained as part of the R-1 set in order to provide flexibility in the heaved lip (upheaval) removal process.

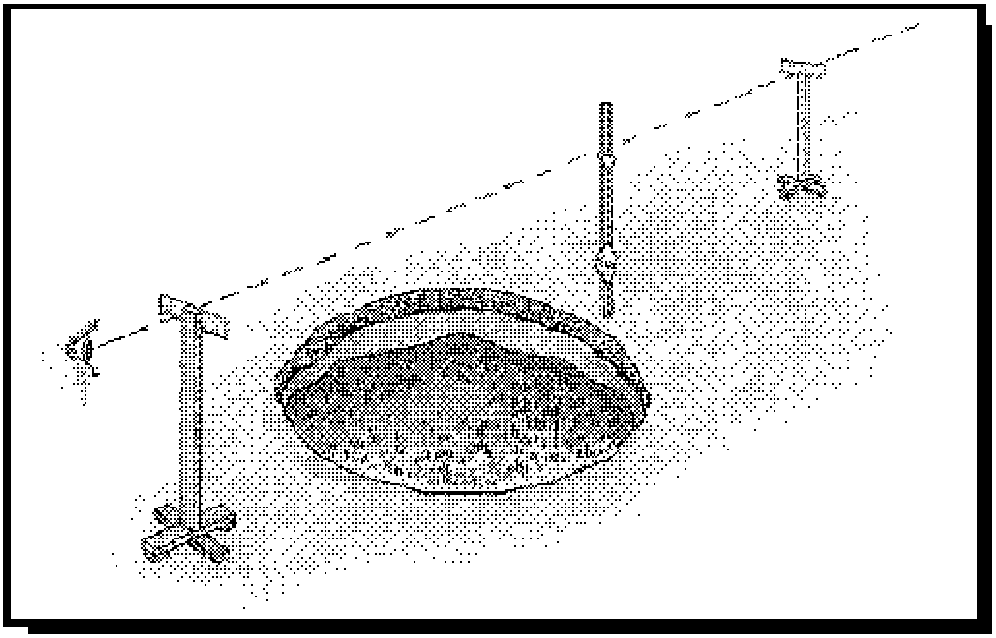
Figure 5.23. Upheaval Removal.

Figure 5.24. Concrete Cutting Saw Operation.



5.11.2. **Intermediate Profile Measurement.** The last stage in the upheaval removal process involves what is basically an accuracy check. Profile readings are taken to see whether all necessary upheaved pavement has been removed. If it has not, it is much easier to correct this situation now than trying to do it once repairs are almost complete. When all of the identified pavement upheaval has been removed from the crater, the area around the crater edge is checked to ensure that it is truly flush. The stanchions used for the initial crater profile measurements are again setup on both sides of the crater, parallel to the flow of aircraft traffic, and across the point to be checked. The sight rod is placed on the newly formed crater lip (figure 5.25). The upheave has been sufficiently removed if the single triangular target is below the line-of-sight, across the upper edge of the stanchions. A sufficient number of points, at least five or six, on each side of the crater must be checked to ensure that all upheaval has been removed. If the single target is above the line-of-sight, identify and remove all of the pavement that is out of tolerance.

Figure 5.25. Intermediate Profile Measurement.



5.12. Delivery of Repair Materials and Equipment. After an enemy attack, repair materials and equipment will have to be delivered to the damaged runway and taxiways before RRR operations can begin. The chaos common to any postattack environment requires close coordination between the hauling team NCOIC and the crew chiefs of the crater repair crews. This prevents delivery of excess materials to one repair area while another area is left without adequate repair supplies. It is up to the RRR OIC and NCOIC to oversee this entire delivery operation, making adjustments as necessary to ensure a steady progression of RRR activities. The RRR delivery operation is a major tasking in logistics flow, more dependent on organization and timing than ability to operate specific pieces of equipment in a prescribed manner. Repair teams, equipment, and materials were dispersed to several locations prior to the attack. These assets must now be brought from dispersal sites and properly combined and configured to perform the RRR operation. Transport vehicles, repair materials, and equipment are not always collocated during dispersal. If this is the case, trucks or other transport vehicles must be moved to the material stockpile locations and loaded before these assets can be moved to the damaged areas on the airfield pavements. After loading, the vehicles proceed to the damaged pavements using a designated haul route, off-load their supplies, and return to stockpile areas for resupply.

5.12.1. **Assembly.** After an airfield attack, airfield damage assessment teams are dispatched by the SRC to gather information for MOS selection purposes. Between the time these teams are dispatched and the final selection of the MOS is made, RRR crews must assemble; assess their equipment and material status; and prepare for movement to the repair sites. It is at this time that repair crews are normally formed and the convoy order of march is established. If vehicles for some reason are attrited, adjustments must be made predicated on how long the vehicle will be out of service, its importance to the flow of RRR activities, and what other “work-arounds” may be available.

5.12.2. **Loading.** The complexity of the loading operation will depend on the type of materials and equipment to be loaded and their stockpile or dispersal locations. For example, crushed stone and ballast rock loading operations will require the support of front-end loaders or similar equipment to place these materials into dump trucks. Bulldozers and other tracked vehicles may have to be loaded onto flatbed trailers for transport, if they are located a significant distance from the runway. AM-2 matting and folded fiberglass matting, and the various component kits will all require fork lift support for loading onto tractor trailer units. To the maximum extent possible, repair materials and equipment should be loaded prior to the attack and dispersed in this fashion. For example, the initial loads of crushed stone should be placed in several dump trucks and the folded fiberglass and AM-2 materials matting should be loaded onto tractor trailers.

5.12.3. **Establishment of a Haul Route.** Establishment of a good haul route at the very beginning of the RRR operation is essential to avoid traffic congestion and to ensure rapid movement of trucks and equipment between locations. The haul route should be selected as soon as possible after initial damage assessment. The haul route is normally designated by the DCC or the OIC of the RRR operation based on the location of pavement damage and UXO situation. The route must be known by all drivers and they must be warned not to deviate from it unless forced to by subsequent attacks or similar emergencies. A good haul route will have the following characteristics:

5.12.3.1. Be wide enough for two trucks or heavy equipment to pass one another.

5.12.3.2. If possible, a one-way travel circuit.

5.12.3.3. Be connected to all crater repair sites. This is required in case one of the stockpile sites is depleted and the supply of materials must be shifted to another stockpile location. This also allows command and control and vehicle maintenance personnel access to all repair and stockpile locations.

5.12.4. **Off the Line of the MOS.** Foreign object damage clearance and sweeping is seriously hindered by unnecessary vehicles on the MOS, and the cleared area can too easily be contaminated by muddy tires or a spilled load of stone. Equipment that is not in use must be parked out of the immediate areas of activity. However, be ever aware of potential hidden UXO--never move equipment outside of the EOD cleared zone without proper clearance.

5.12.5. **Debris Clearance.** Haul route clearance is the first priority of the crater repair operation. All front-end loader and grader operators should assist by traveling to their crater site with buckets and blades down in areas where debris is present. Where the debris is thick, front-end loaders should move debris to the side of the haul route, trying not to leave a thick, smooth, compacted layer which could be too deep for graders to remove.

5.12.6. **Traffic Congestion.** For ease of control, each repair team should deploy with all its equipment so equipment items do not become separated from the team. However, serious congestion occurs around the crater if equipment waiting to start work is parked in places that hinder other phases of the repair operation. On balance, it is recommended that teams move with all their personnel and equipment, but that equipment not required at a particular time be moved off of the MOS and parked about 100 feet away from the crater. Dump trucks can be a main cause of congestion along the haul route and around craters. If they must park to await an opportunity to dump their load, they should not get in the way of other trucks or equipment. It might be better to have the trucks discharge their loads near the crater repair area, so as to not delay the total delivery activity. This stockpiling approach can pay dividends in time saved when craters are extensively dispersed. However, normally, being able to dump fill directly into the crater is the best procedure, if the situation allows such. Regardless of the approach taken, it is the crater crew chief's responsibility to take steps to regulate vehicular traffic around his/her immediate operations area.

5.12.7. **Precise Identification of Runway Locations.** Without a system for identifying locations on the runway, misunderstandings between the DCC and crews are bound to occur. The hauling team drivers will have difficulty finding the right crater to deliver their load. As a result, frustrated crater crew chiefs may "hijack" passing trucks, and the team at the far end of the MOS will be seriously delayed while waiting for crater fill materials to be delivered. The marker posts set out on the grass adjacent to the runway just before the start of hostilities serve as more than just location stations for the damage assessment teams. They also can be used as identifiers for delivery locations for the hauling team (see chapter 2 of this volume). In addition to the runway reference marking system, it is also recommended that each crew chief wear a distinctive vest with a large number (1 to 6) on the back and front to identify the repair team designation (figure 5.26).

Figure 5.26. Raised Pavement Marker System Post.

5.12.8. **Off-Load Materials and Equipment.** Areas must be cleared around the craters for use as stockpile locations for folded fiberglass mats, AM-2 matting, and other materials. As a general rule, these areas must be cleared of debris.

5.12.8.1. Special areas must be identified and cleared for both AM-2 and folded fiberglass mat assembly. Unlike most other areas, these must be totally cleared and swept since even relatively small pieces of debris can interfere with mat assembly. One of the first tasks for the crater crew chiefs upon arrival at the repair site is to identify these stockpiling and assembly areas.

5.12.8.2. Delivery of material must continue until the crater crew chief determines that sufficient quantities are at the crater sites. Not all fill needs to be stockpiled nearby or at the crater's edge; some can be dumped directly into the crater void. If there is too much fill delivered to the crater, it can be pushed quickly to the runway edge; but, if there is not enough material the repair process can become delayed.

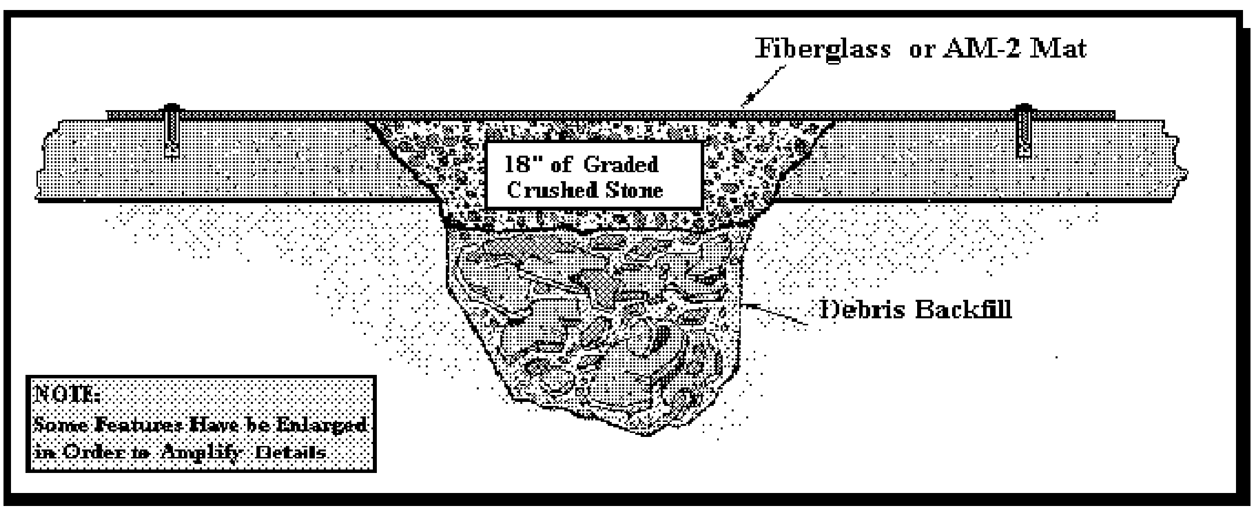
5.12.8.3. Dump truck tailgates should be unfastened by a "spotter" from the crater repair team as the truck backs up to deliver its load.

5.12.8.4. Dozers and other tracked vehicles should be unloaded from transporters as quickly as possible to reduce traffic congestion. Where to unload the dozer will be determined by each crater crew chief bases upon the situation at hand. The dozer operator should minimize pavement damage by driving the dozer along the grass beside the airfield pavement when moving between craters. Minimizing sharp turns and the use of street pads can also be helpful when a porus friction surface overlay of the runway surface is involved.

5.13. Filling the Crater. Now that the crater upheavals have been marked and removed, you must fill the crater to prepare it for placement of a final repair cover. The method used for filling the crater will primarily depend on ground conditions and fill material availability. The following paragraphs outline the most common methods for filling a crater.

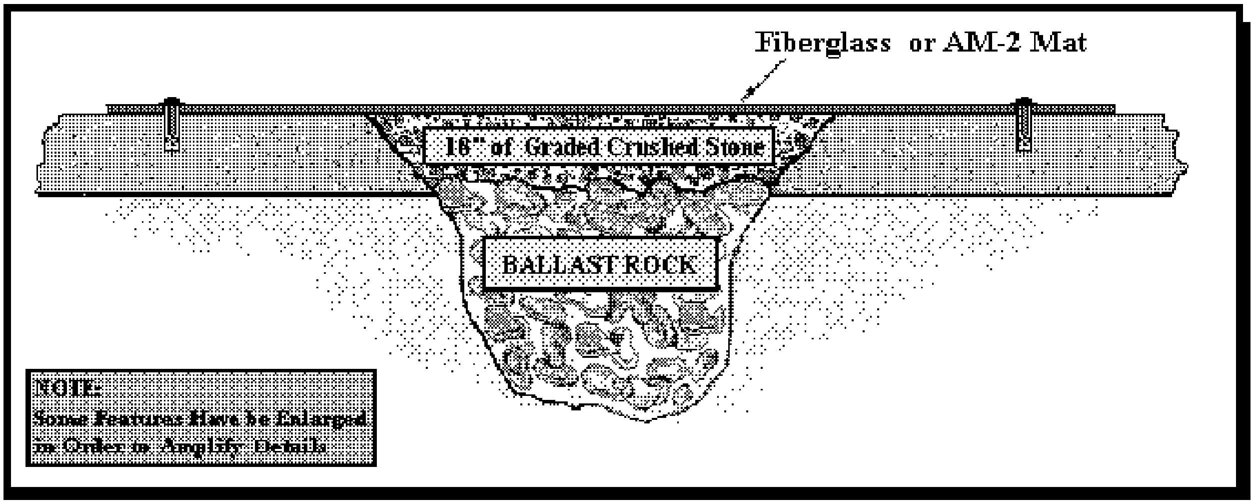
5.13.1. **Normal Crushed Stone.** The normal crushed stone repair procedure is shown in figure 5.27 and involves backfilling the crater with debris to a minimum of 18 inches from the pavement surface. Ejecta that is over 3 feet in diameter must be either broken into smaller dimensions or removed from the crater and pushed to the side. The crater is then overfilled by 3 inches with graded, crushed stone, which is then compacted with eight coverages of a 10-ton vibrating roller or two coverages of the excavator's compactor plate. After compaction, the repair is then leveled flush with the surrounding pavement. A folded fiberglass or AM-2 mat is towed over the repair and anchored to the pavement surface. This method assumes that the crater does not contain standing water, and that the debris backfill is reasonably firm. A minimum California Bearing Ratio (CBR) of three to five is assumed with respect to the load bearing capacity of the debris backfill.

Figure 5.27. Normal Crushed Stone Repair Method.



5.13.2. **Choked Ballast Rock.** When the crater contains water, or the debris is unsuitable for use as a backfill material, the crater is filled to a maximum of 18 inches of the pavement surface with ballast rock (figure 5.28). The crater is then overfilled by about 3 inches with a layer of graded, crushed stone which is compacted with eight coverages of a 10-ton vibrating roller and leveled flush with the surrounding pavement. A folded fiberglass or AM-2 mat is towed over the repair and anchored to the pavement surface. If a particularly soft or wet base course is encountered, a layer of geotextile 2000 material should be used for stabilization purposes. When placing the geotextile, the fabric must come up the sides of the crater and lay on the pavement on two sides to hold it in place. Once the geotextile layer is in position, dump trucks start to fill the crater with ballast rock. Dump truck rear tires are used to hold the geotextile in place during dumping operations. This arrangement also allows dumping to take place on two sides of the crater. Excess geotextile material should be cut off just prior to placement of crushed stone.

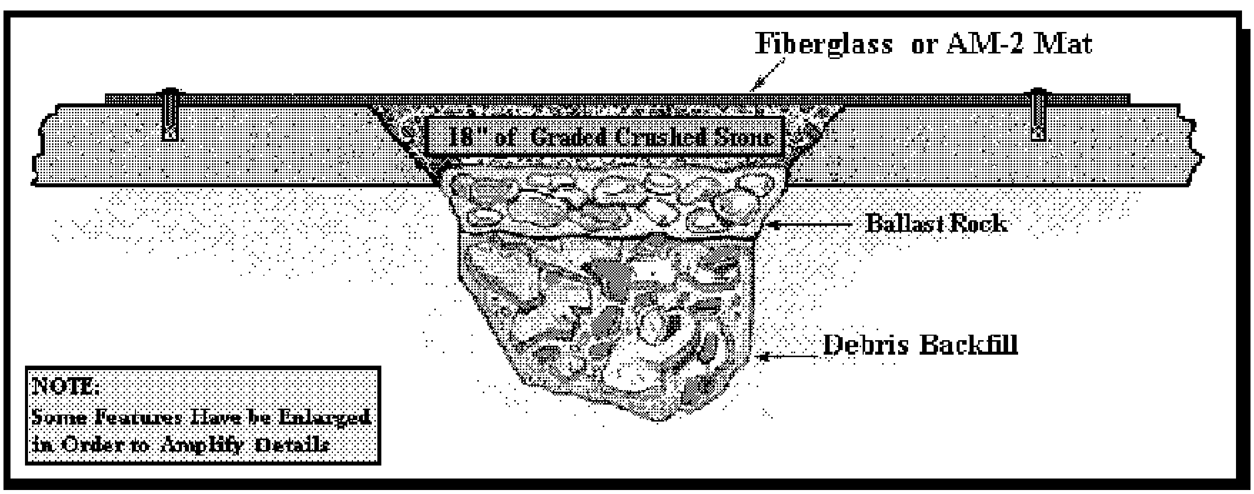
Figure 5.28. Choked Ballast Rock Repair Method.



5.13.3. **Choked Ballast Rock Over Debris.** If only a limited amount of usable debris is available for use in crater repairs, ballast rock can be used as substitute filler. As a general rule, ballast rock is cheaper than crushed stone. When using this method, the critical point is to leave enough space at the top of the crater so that a minimum layer of 18 inches of crushed stone can be installed (figure 5.29). This repair method should not be employed when there is water in the crater (see choke ballast rock repair method below). Also, ejecta pushed back into the crater must be less than three feet in diameter. All unusable debris should be pushed at least 25 feet off the MOS. For flight safety reasons, ejecta that is pushed off the MOS must never be piled higher than 3 feet. Procedures for this repair method are as follows:

- Fill the crater with as much acceptable debris as possible.
- Place ballast rock over the debris backfill leaving a minimum 18-inch void for crushed stone.
- Add a layer of graded crushed stone sufficient to overfill the crater by 3 inches.
- Compact the surface with eight coverages of a 10-ton vibrating roller.
- Grade surface leveled with the surrounding pavement.
- Cover with a folded fiberglass or AM-2 mat anchored to the pavement surface.

Figure 5.29. Choked Ballast Rock Over Debris.



5.13.4. **Filling Sequence.** The fill sequence for the normal crushed stone, choked ballast rock, and choked ballast rock over debris crater repair methods are listed below:

5.13.4.1. With the choked ballast rock over debris method, place as much acceptable debris in the crater as practical. Next fill the remaining space to within 18 inches of the adjacent sound pavement surface with ballast rock. Lastly, install a minimum of 18 inches of crushed stone.

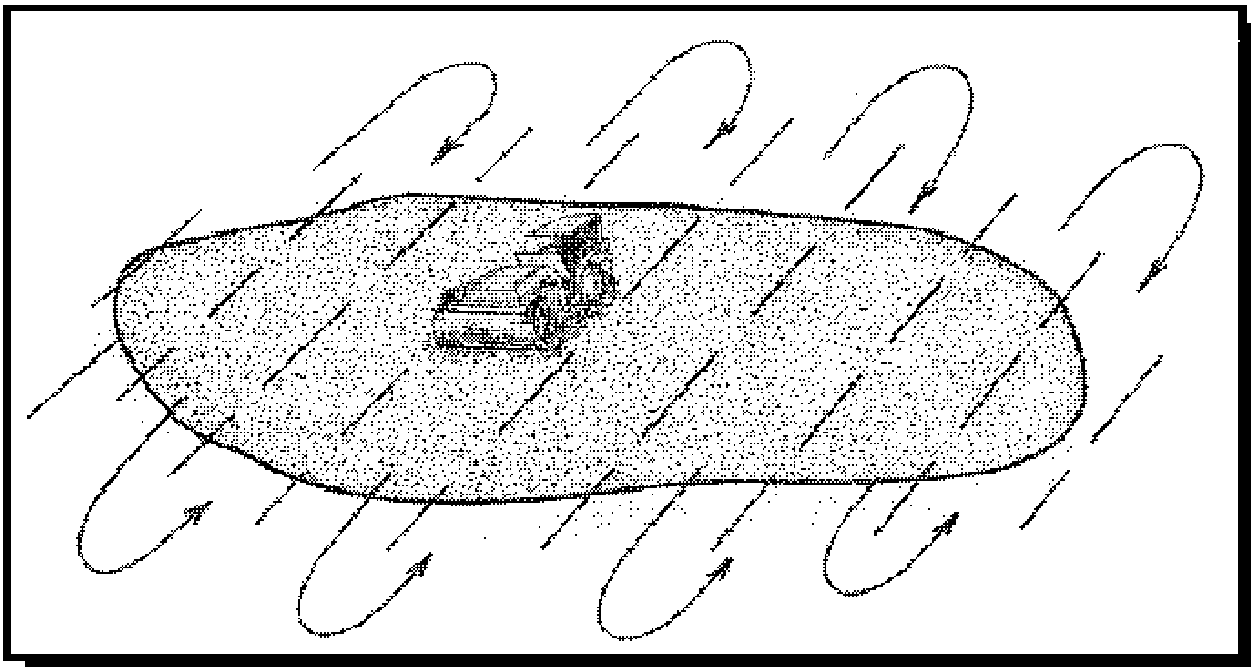
5.13.4.2. With the normal crushed stone method, fill the crater with debris to a minimum of 18 inches from the adjacent sound pavement surface. This allows for 18 inches of crushed stone to be used in the top layer of the repair.

5.13.4.3. With the choked ballast method, fill the crater with debris to a maximum of 18 inches from the adjacent sound pavement surface. The remaining void should then be filled with crushed stone. If there is water in the crater, install a layer of geotextile to enhance stabilization.

5.13.4.4. With all of the aforementioned methods, once the proper amount of base course material has be placed, overfill the crater with crushed stone about 3 inches above the pavement surface.

5.13.4.5. Compact the crushed stone surface with one pass (two coverages) of a 10-ton vibrating roller. One coverage means sufficient passes of the roller over the crater to cover every point on the crater once (figure 5.30).

Figure 5.30. Compaction of a Crushed Stone Repair.



5.13.4.6. Skim off surplus crushed stone to leave a dome 1.5 inches above the pavement surface. Ideally, use a grader for this purpose, however; if a grader is not available, the blade of the multifunction excavator can serve as an alternative.

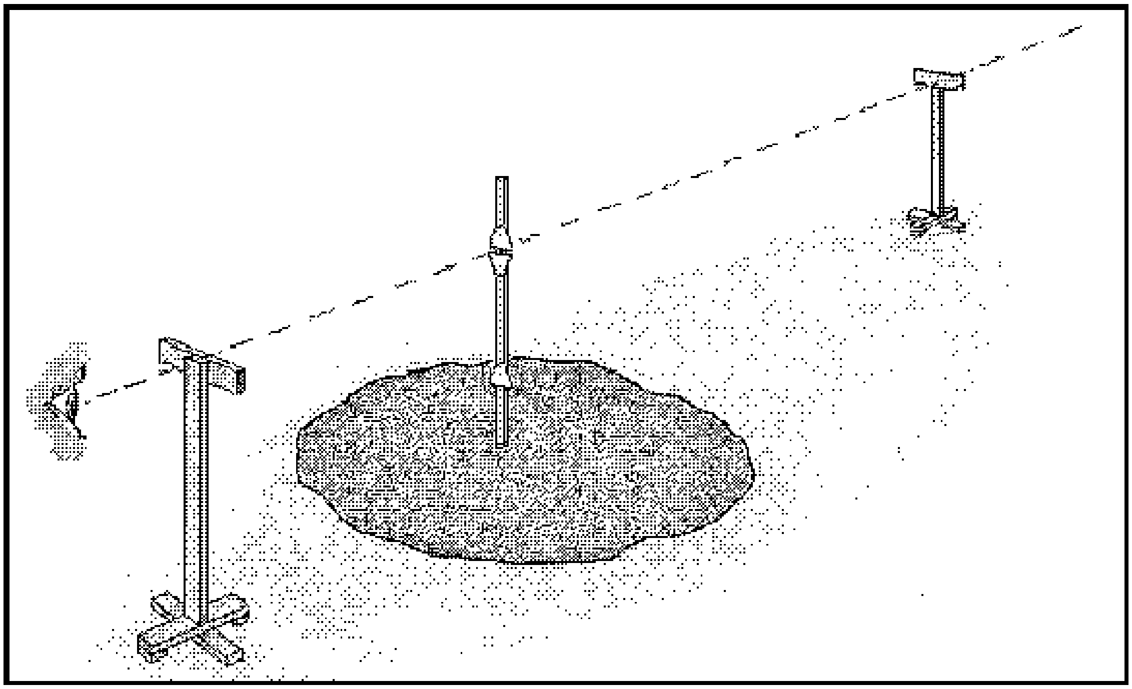
5.13.4.7. Make a second pass (two coverages) across the crater with a 10-ton vibrating roller.

5.13.4.8. Skim off surplus crushed stone to leave a surface flush with the surrounding pavement or adjusted to RQC requirements.

5.13.4.9. Conduct final two passes (four coverages) across the crater with a 10-ton vibrating roller. At the completion of these compactions, the total number of compactions provided will be four passes to equal eight coverages.

5.13.4.10. Before FOD cover installation, perform a final crater profile measurement, using the stanchions and sight rod to ensure that flushness has been maintained (figure 5.31).

Figure 5.31. Profile Measurement of Filled Crater.



5.13.5. **Small Crater Repair Procedures.** As indicated in chapter 2, a crater less than 20 feet in diameter is considered to be a small crater. Small craters will require some variations in the repair procedures as compared to that normally used for larger craters--ones with a diameter greater than 20 feet. Due to the limited amount of operating room associated with small craters, it is usually counter productive to attempt using most construction equipment within the crater itself. Experience has shown that the most effective approach is to relegate much of the repair effort to the skill of a competent excavator operator. Specific step-by-step procedures are outlined below. In the example presented, the crushed-stone over debris technique is being employed where a water problem does not exist. However, the basic steps presented still apply when other fill variations are used. As with large crater repairs, if standing water and a soft base course are a problem, use ballast rock and geotextile for stabilization purposes.

5.13.5.1. Use either the excavator or FEL to clear the debris from the immediate area and expose the upheaved pavement.

5.13.5.2. Utilizing the line-of-sight procedures identify the crater's heaved lip. ***NOTE*:** If the repairs are being conducted on a MOS, always initially attempt a flush repair. Repair quality criteria adjustments may prove more lenient later, but if such was not the case, you are still safe.

5.13.5.3. Use the excavator with the jackhammer attachment to breakup the previously identified upheaved pavement.

5.13.5.4. When the pavement has been sufficiently fractured, mount either the small or large bucket attachment on the excavator and commence with removal of broken pavement. If two excavators are being employed, the unit with the bucket attachment can start removal operations as soon as adequate safe operating clearance away from the excavator employing the jackhammer is available. This decision will be made on-scene by the crater chief.

5.13.5.5. Once the broken pavement has been removed, conduct an intermediate line-of-sight check to ensure that all of the upheaved pavement has indeed been removed. If the check proves that such is not the case, repeat the jackhammer and bucket procedures until only flush pavement remains.

5.13.5.6. After the remaining pavement has proven to be free of upheaval, backfill the crater with ejecta. However, there are two key points to keep in mind when backfilling either a small or large crater. First, do not place concrete pieces in the void that are more than 3 feet in diameter. Second, always leave a minimum of 18 inches for the placement of a crushed stone cap.

5.13.5.7. Once the proper amount of backfilling has been accomplished, the remaining steps are identical to a large crater repair. Start filling the remaining crater void with crushed stone until the repair is overfilled by approximately 3 inches. Next, conduct the necessary compaction and grade the surface so that the final grade is flush with the adjacent pavement. Lastly, accomplish a profile measurement of the filled crater and make adjustments as appropriate.

5.14. Covering the Crater. After the bomb crater has been filled and leveled, an appropriate cover or cap completes the repair process. The type of crater covering used will depend on the availability of material, the location of the crater, and quality of repair required. For example, the quality of repair for a crater located on an access taxiway may allow the use of an AM-2 mat, whereas a crater near the threshold on a MOS will most likely require a flush repair method--folded fiberglass mat. Details regarding accepted crater covering methods are outlined in the following paragraphs.

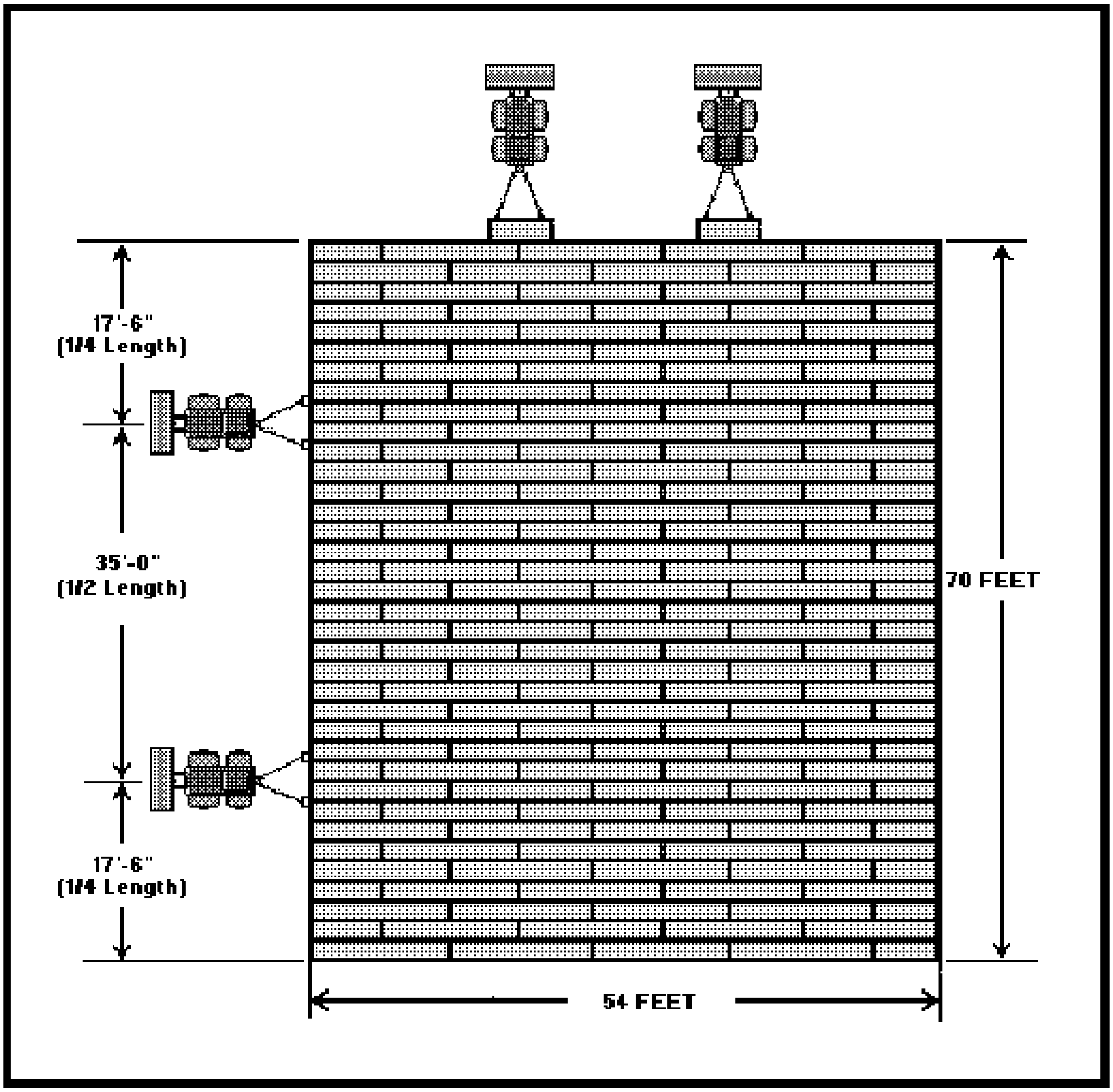
5.14.1. **Crushed Stone (Open).** This method leaves the repaired crater without a cover, relying on the compacted crushed stone fill material to provide an adequate takeoff and landing surface. When this method is employed, the compacting coverages by the vibrating roller must be greatly increased to at least 32 coverages. The open crushed stone method presents an increased likelihood of FOD and will require greater maintenance in the form of sweeping operations to reduce this problem. Consider this method of RRR as an "ace in the hole" when FOD cover materials have been exhausted. However, also be aware that this procedure is a choice of **last resort**. When using this procedure, the possibility of incurring aircraft landing system damage is great. Also, moisture content of the crushed stone will greatly affect the compaction results. Basically, crushed stone that is too wet will not compact regardless of the number of coverages applied.

5.14.2. **AM-2 Matting.** The AM-2 matting FOD cover technique has been in existence for almost 30 years. Once the mainstay of RRR operations, it has been primarily relegated to secondary use (taxiway repairs) due to landing system sensitivities of the more sophisticated aircraft now being fielded. It does still, however, represent an option for MOS crater repair if the FFM repair method cannot be used for some reason. A limited number of AM-2 aluminum mat kits are prepositioned at selected airfields overseas to cover crater repair. The size of a standard AM-2 patch is 54 feet wide by 77 feet, 6 inches long. Mat size can be reduced for small craters and increased for larger ones by simply decreasing or increasing the number of panels used. For example, when using AM-2 for taxiway repairs, a patch is usually only 30 feet by 60 feet, since taxing aircraft normally only require a 25-foot width. To this end, it may be worthwhile to configure some AM-2 bundles to support such activities. By doing this, time could be saved when actual taxiway crater repairs are required. Obviously, such modified bundles would have to be marked conspicuously to avoid possible confusion with these AM-2 bundles configured in the standard manner.

5.14.2.1. **Limitations.** AM-2 mat repairs are generally acceptable for fighter aircraft when spacing between the patches is large. However, they are generally considered to be inadequate for use with wide body aircraft. This limitation derives from the mat's inadequate anchoring system, narrow patch width, and susceptibility to separation during hard breaking and turning actions. On the other hand, AM-2 mats can be used to repair transport aircraft taxiways and aprons, provided that tight turns are not made over the mats.

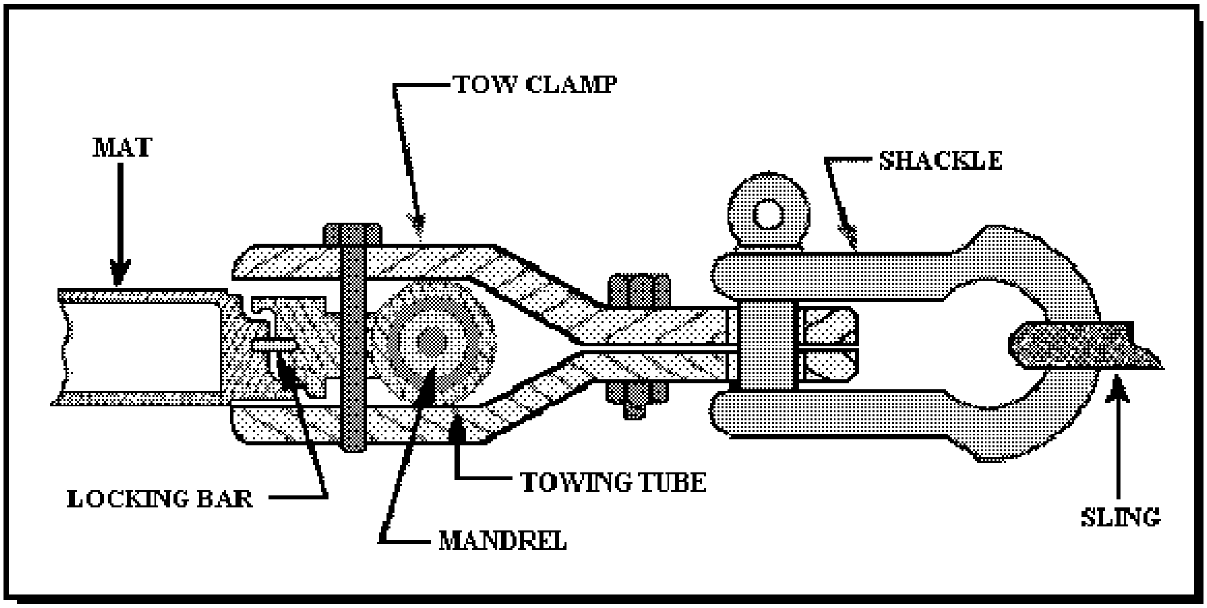
5.14.2.2. **Placement.** After the patch has been completely assembled (see assembly instructions in attachment 4) and the towing tubes attached and properly tightened, appropriate slings are affixed for towing the patch into position. The patch should normally only require pulling in one direction (perpendicular or parallel to the runway centerline). See figure 5.32 for towing clamp locations. During a conflict, time constraints will usually necessitate that mat assembly occur while the crater is being repaired. However, if time is of less consequence, e.g., on a taxiway pavement that is being repaired after launch and recovery pavements have been made serviceable, the patch can be assembled directly over the repaired crater. This eliminates the need for towing it into place.

Figure 5.32. Towing Clamp Locations.



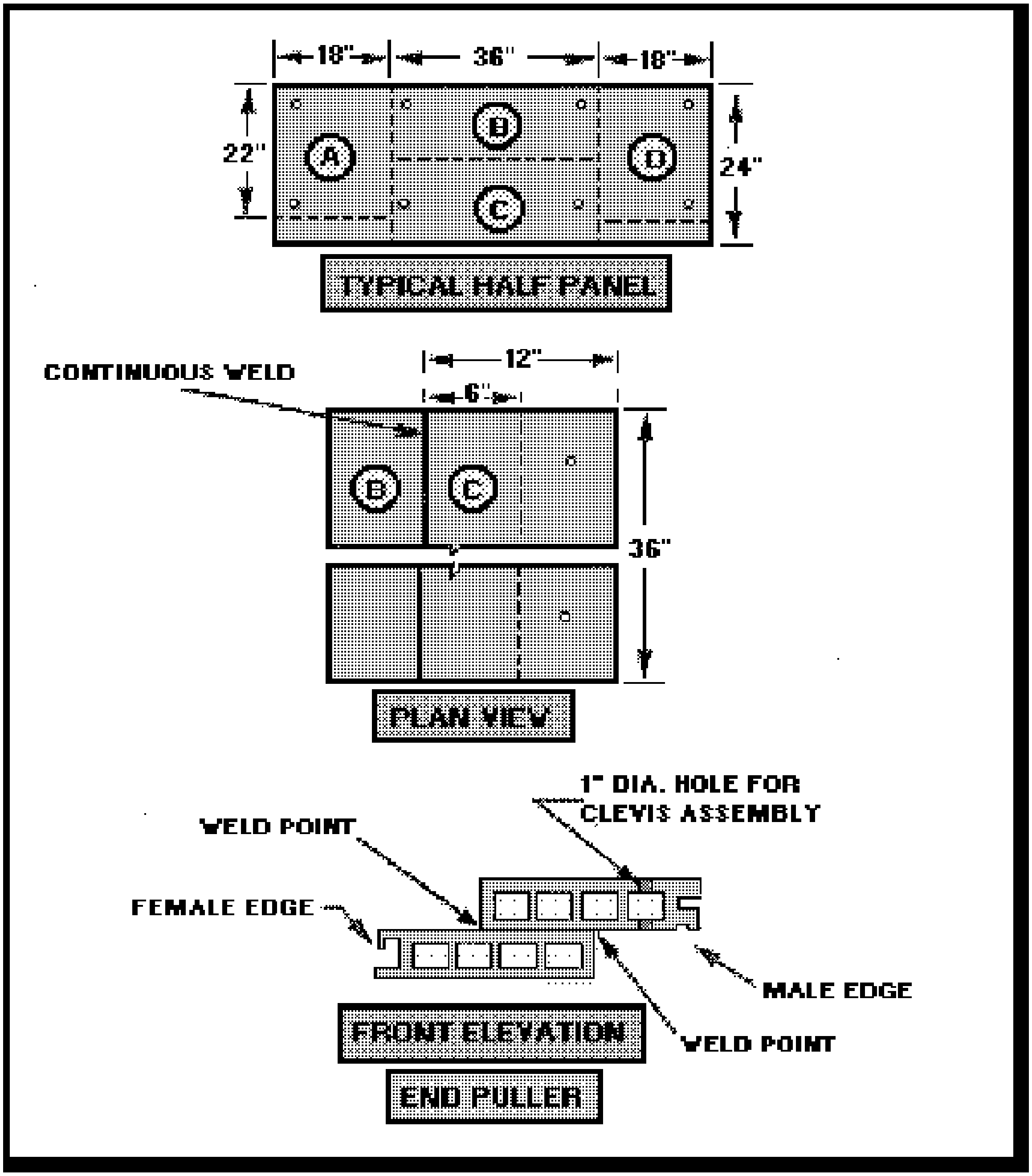
5.14.2.2.1. **Perpendicular Pull.** Use one harness. Two shackles are placed at each end of the sling, and a third, if used, connects the center of the sling to the towing vehicles. Connect four towing clamps to the towing tubes located nearest the crater. Place these so that the load will be distributed equally. Loosen the two short bolts on the clamp so that the clamp will slide over the tubes. Remove the long bolt in the clamp, align the threaded hole in the clamp with the threaded hole in the towing tube, and reinsert the long bolt (figure 5.33). Lastly, tighten all bolts.

Figure 5.33. Towing Clamp Fastened to Towing Tube.



5.14.2.2.2. **Parallel Pull.** Attach two end pullers at approximately the locations indicated in figure 5.32. End pullers are to be locally manufactured (see figure 5.34). To save time in anchoring the patch, place ramps on the assembled patch in approximate locations where they will ultimately be placed. Also, place the generator and air compressor on the assembled patch. Preposition extension cords, air hoses, drills, bolts, washers and nuts on the assembled patch. After towing clamps are in place, attach a shackle at each end of the sling and connect the center of the sling through a shackle connected to the towing vehicle. Finally, use two front-end loaders or one grader and tow the patch into place. If the patch is to be used on a MOS, its centerline must coincide with the MOS centerline. Make sure that the pull on each harness is equal; if the patch must be turned, attach one harness diagonally opposite to the other harness.

Figure 5.34. Recommended Design for End Pullers.



5.14.3. **Anchoring Procedures.** After the patch is correctly positioned, attach the ramps (figure 5.35). If the stops on the towing tube interfere with ramps' installation, loosen the towing tube end caps and revolve the stops away from the patch. During a parallel pull, no tow tubes are required and to save time ramps can be laid on the trailing edge before the pull. Start in the right corner (looking toward the centerline of the 54-foot width) of the patch to connect the first ramp. Do this at each end of the patch. Place the next ramp so that the holes in the overlapping plate are aligned with the threaded inserts on the ramp section just installed and fasten with flathead screws. Apply antiseizing compound to the screw threads before inserting the screw. Be sure to use a locking bar between each ramp and edge of the patch to properly align the ramps. Also, use locking bars between ramps and edges of panels to make sure that the panels are properly aligned (figure 5.36). After the ramps are placed and screwed together, use the ramp as a template to drill anchor holes in the pavement surface. The holes must penetrate at least 3 inches into concrete; they may be deeper in some surfaces depending upon the length of the bolts available. After each hole is drilled, use the blower (figure 5.37) to clean particles of dirt and water from the hole. Lag bolts and lead sulfur compound are then used to anchor the AM-2 mat to the airfield pavement. Using the melting pot included in the RRR component kit, melt the lead sulfur compound. Pour the melted lead sulfur compound into the hole until it is about three-quarters full. Then put the bolt into the hole, with the bolt head in the bottom of the hole, and with the nut and washer facing up (figure 5.38). The bolt should be threaded about three-quarters through the nut before it is inserted into the hole. Push the bolt into the hole until the nut and washer are flush with the ramp surface. Hold the bolt in place momentarily, until the lead sulfur compound has hardened (after about a 15-second set time); then tighten the nut until the ramp is pulled tight against the pavement. After the ramp is fully locked to the pavement, some of the bolts may protrude and require grinding. Great care must be taken to make sure that trailing edge ramps are flush with the pavement surface and securely fastened for aircraft takeoff conditions when afterburners are used.

Figure 5.35. Ramp Attachment.

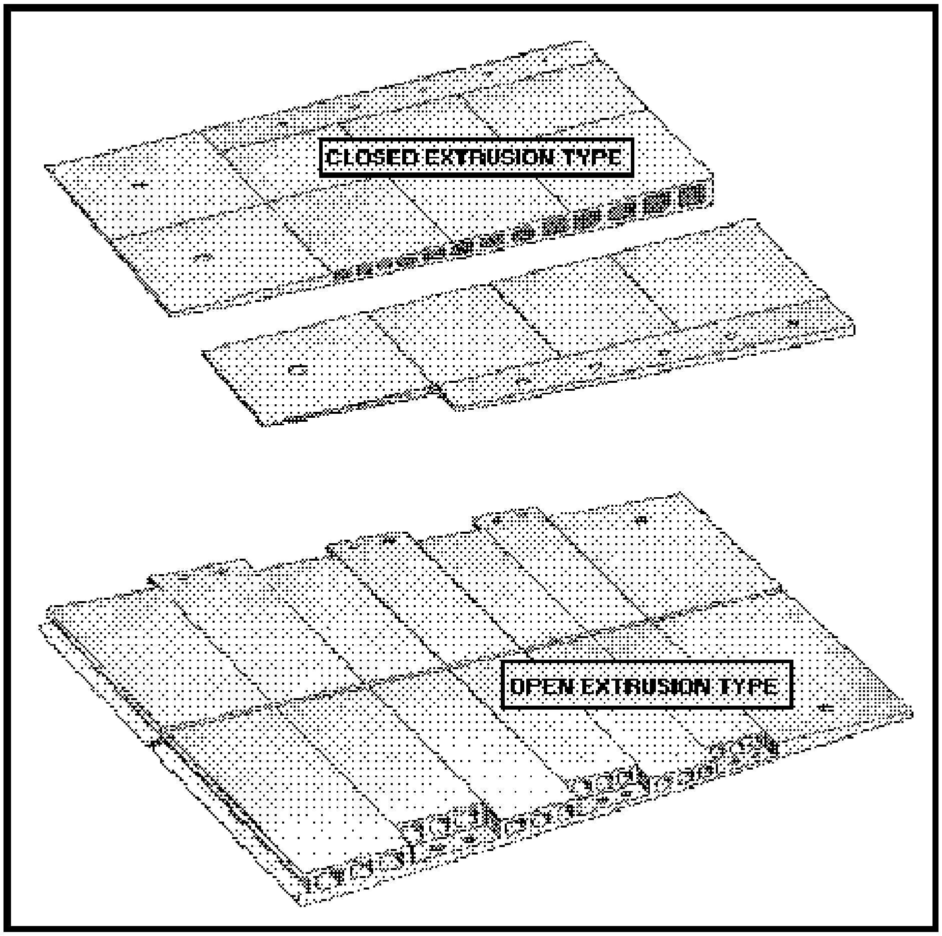


Figure 5.36. Use of Locking Bar.

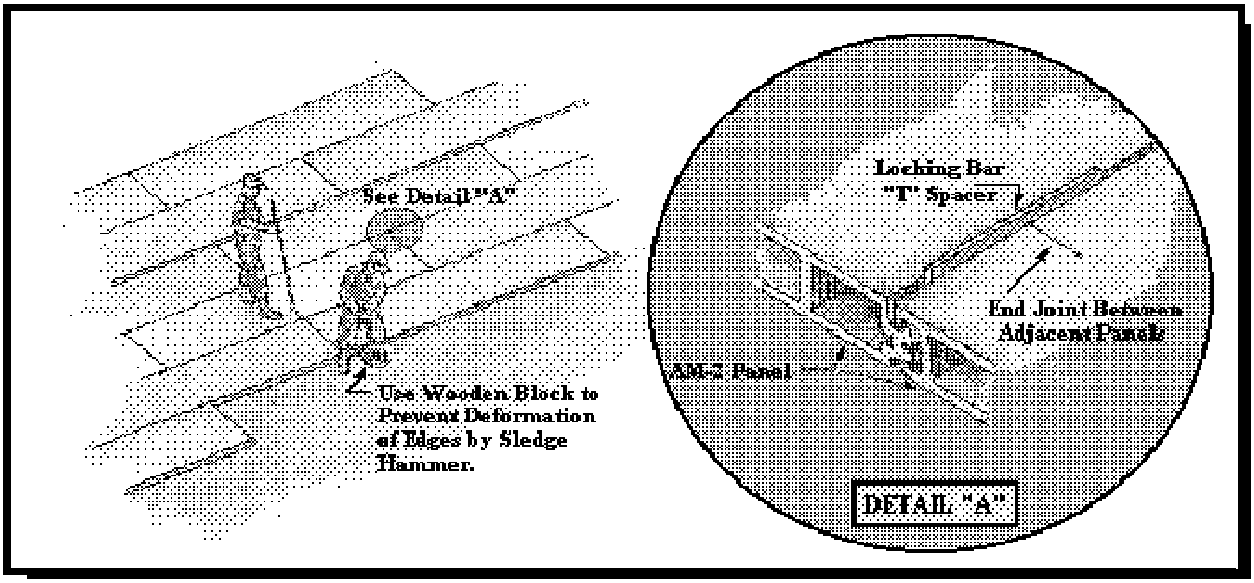


Figure 5.37. Standard Air Nozzle Modifications.

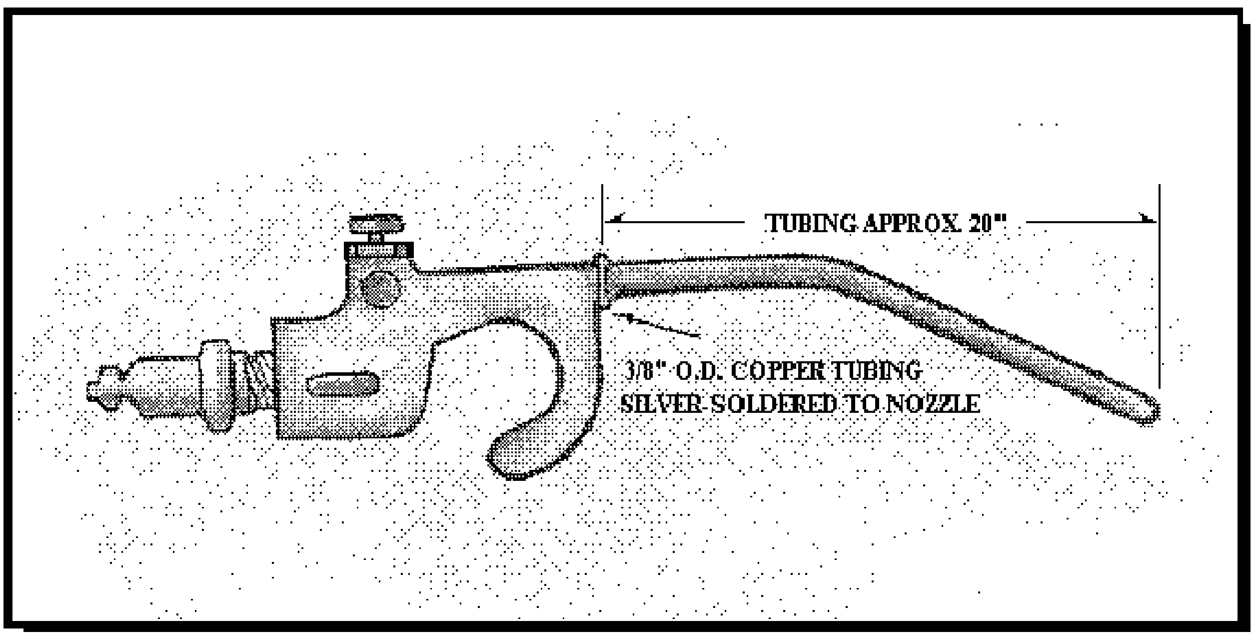
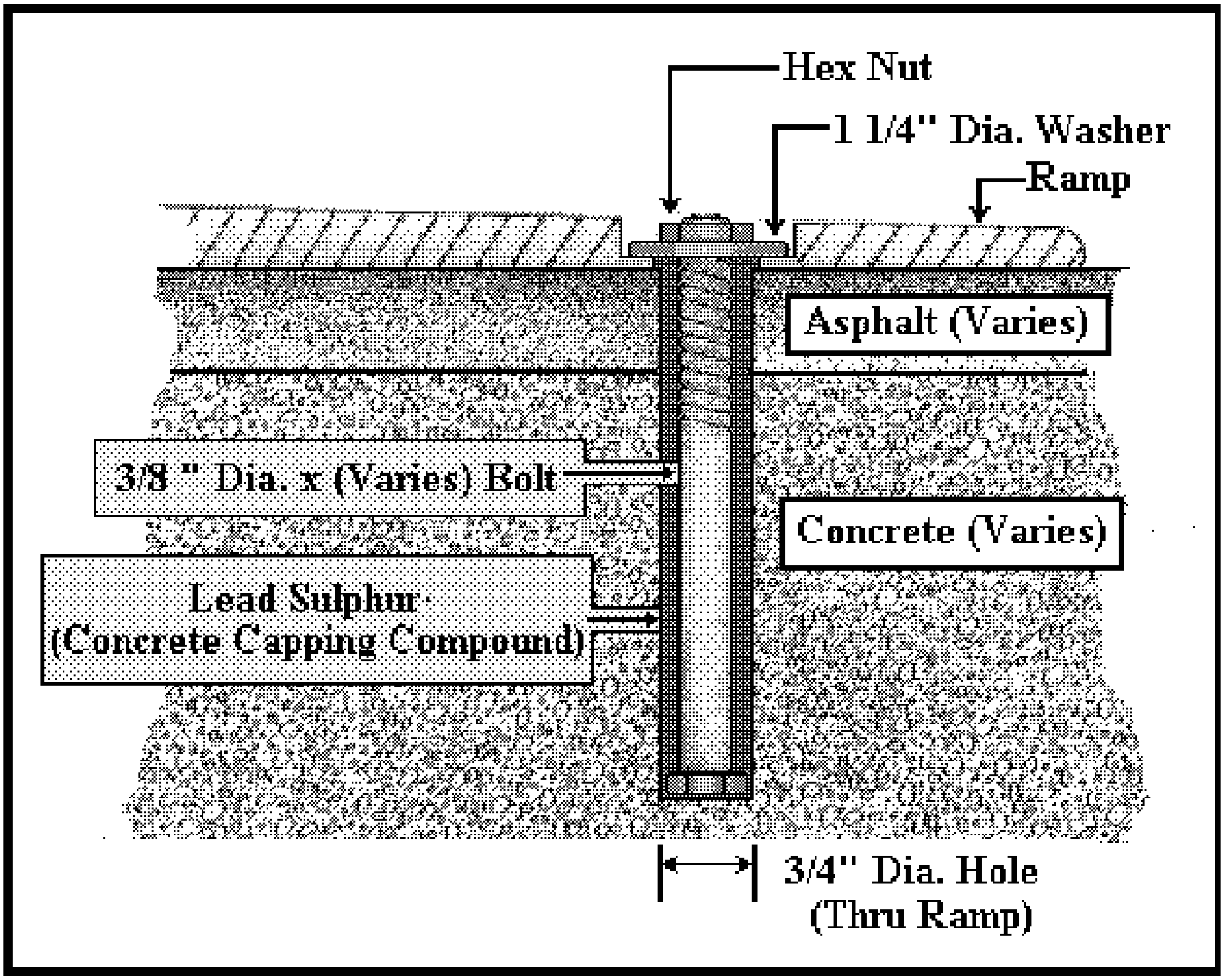


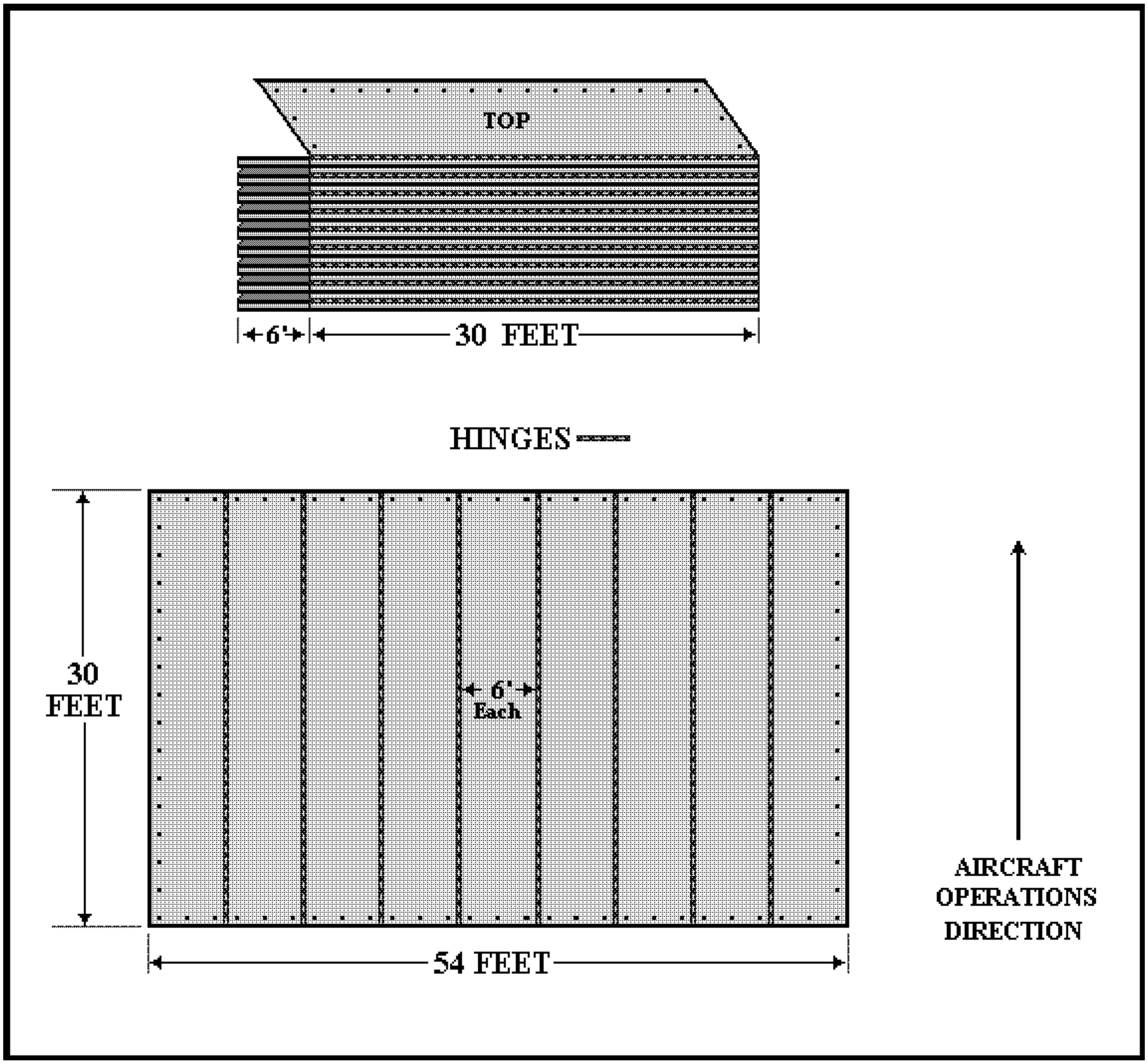
Figure 5.38. Mat Anchoring--Lead Sulfur Method.



5.14.4. **Folded Fiberglass Mat (FFM).** The folded fiberglass mat has several advantages; namely, it is air transportable, can be moved more easily by vehicle, can be positioned at greater distances from airfield pavement surfaces, and can be stored indoors out of the elements. The placement and anchoring procedures for the FFM are presented later in this pamphlet.

5.14.5. **Specifications.** A standard folded fiberglass mat weighs about 3,000 pounds and consists of nine fiberglass panels, each 6 feet wide, 30 feet long and about 3/8-inch thick. The panels are connected by elastomer hinges, approximately 3 inches wide. When folded, the mats are 6 feet wide, 30 feet long, and 8 to 10 inches thick. See figure 5.39 for illustrations of a folded and an unfolded mat. Besides the folded fiberglass mats themselves, this RRR system also includes joining panels and two mat support kits. The joining panels come in 24- and 30-foot lengths. One of each size is needed to connect two 30- by 54-foot mats together. The resulting 54-foot long by 60-foot wide mat is the normal size suitable for most crater repairs. If larger FOD covers are required, however, additional mats may be spliced together to form almost any size. Mat kit "A" contains all the necessary tools and hardware required to assemble, install, and maintain the system. Mat kit "B" contains the anchor systems required to attach the mat to a range of airfield pavement surfaces."

Figure 5.39. FFM Configuration.



5.14.6. **Placement.** Mats are loaded onto tractor-trailers at their storage locations and placed in dispersal prior to start of hostilities. Loading of the mats will require the use of two front-end loaders with fork attachments. After an attack and when the RRR team receives its order to proceed to the repair locations, the mats are transported to the repair sites. The RRR crater team chief selects a mat assembly area near the crater location and ensures the area is cleared and well swept. This area will have to be large enough to accommodate the unfolding of at least two mats and allow equipment operation around the mats. Care must also be taken to ensure the mat assembly operation does not interfere with the crater preparation activities. Once the assembly area is ready, the mats are unloaded and placed end-to-end about 4 feet apart, with the first panel top up and positioned so both mats unfold in the same direction. Unloading may be accomplished using either two front-end loaders with fork attachments or a single loader with a nylon strap sling (figure 5.40). If a sling is used, the loader simply lifts the mat slightly and the tractor-trailer drives out from underneath it. Once the mats are unloaded, they are unfolded in preparation of being joined together. The top panel of the mat is attached to a front-end loader or similar tow vehicle using nylon straps. This vehicle will slowly pull the mat open as it is being unfolded. A crew of at least four personnel or another front-end loader with forks is positioned on the opposite side of the mat to lift each successive panel as the mat is being pulled by the tow vehicle (figure 5.41). After the first mat is unfolded, a special step must be taken to counteract a potential FOD problem associated with mats that were procured from initial manufacturing programs. Field use indicates that resin flaking at the mat hinges occurs sometimes. To eliminate this FOD possibility, the vibratory roller makes one pass down each of the hinge locations and is followed by the broom sweeper. This simple operation normally loosens and removes the flaking material from the hinges. Once the vibratory roller and sweeper finish the first mat, they move to the second mat, which should have been unfolded by this time, and repeat the FOD elimination process. When the sweeping is complete, the mats are then ready to be joined together. The mats are aligned so that the 30-foot edges are even and the 54-foot edges to be joined are roughly parallel. One end of one of the 54-foot edges on one of the mats is then lifted and either the 24-foot or 30-foot section of the two piece joining panel set is slipped underneath the raised edge. The holes in the mat are aligned with the bushing holes in the joining panel and the mat lowered. The top joining bushings are then installed and hand tightened (figure 5.42). The process is repeated at the other end of 54-foot edge of the same mat using the remaining joining panel section. The second mat is then towed over to the first mat and one of the holes near the end of the second mat is aligned with its counterpart in the joining panel. Once this hole is aligned, a top bushing is installed. This point acts as a pivot around which the second mat is moved until all mat and joining panel holes match (figure 5.43). Top bushings are then installed and tightened using an impact wrench. After all the bushings in the second mat are completely tightened, all bushings in the first mat are then tightened with the impact wrench. The joined mats are now ready to be towed over the prepared crater. Before any towing operation actually commences, however, the crater crew chief must ensure the area between the mat assembly area and the prepared crater is completely swept. Any debris that is picked up under the mat as it is being towed to the crater could damage the matting or affect the smoothness of the repair. When the width of the MOS permits, the mat should be towed parallel to, and along side of the crater, aligning the joining panel with the center of the crater. With the hinges perpendicular to the tow direction, use a front-end loader or other vehicle to tow the mat over the crater. Position the mat so the hinges are parallel, or no more than five degrees off parallel, to the MOS centerline. Folded fiberglass mat fabrication procedures are outlined in T.O. 35E2-3-1.

Figure 5.40. Attaching Nylon Straps.

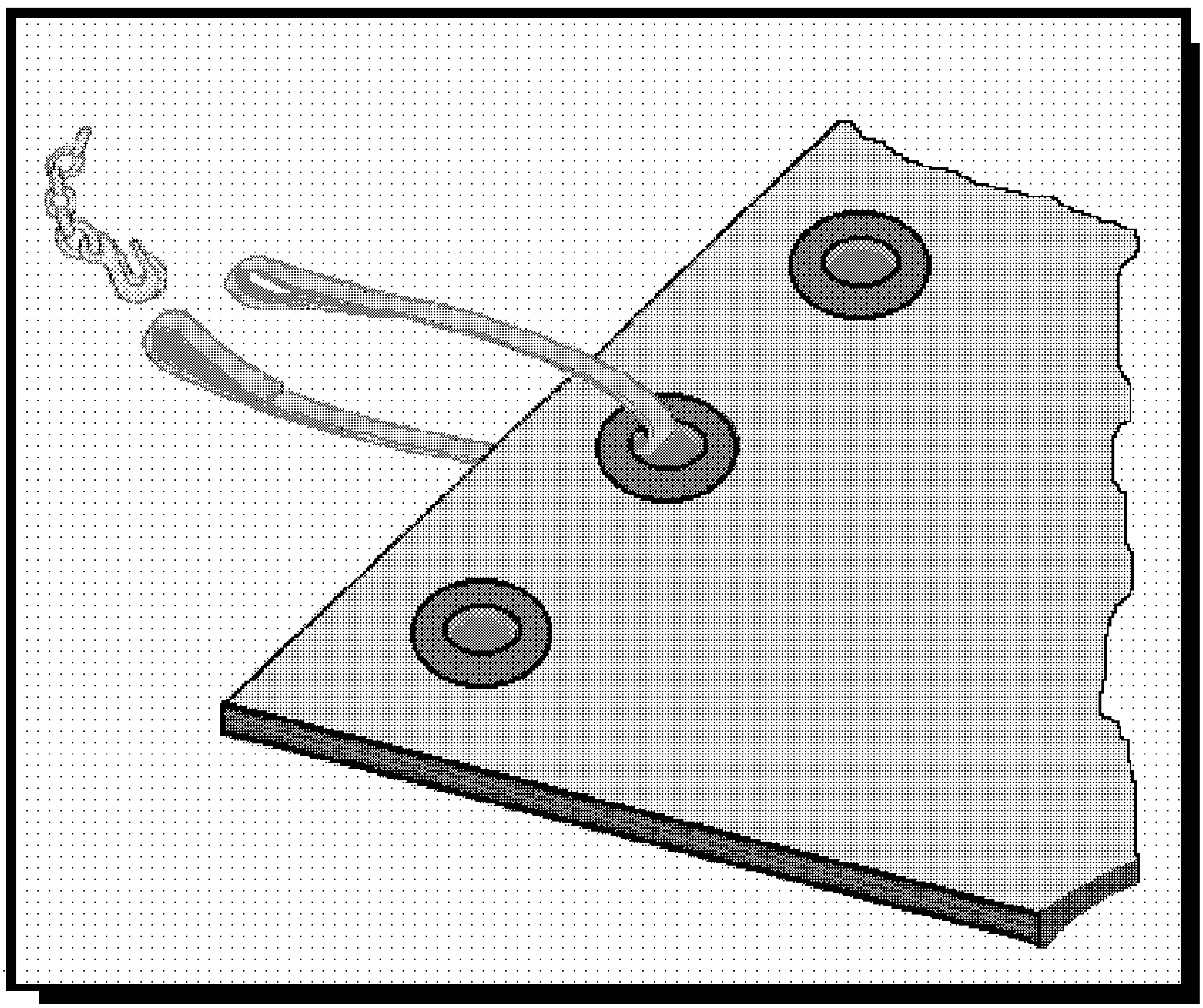


Figure 5.41. Mat Unfolding Procedure.

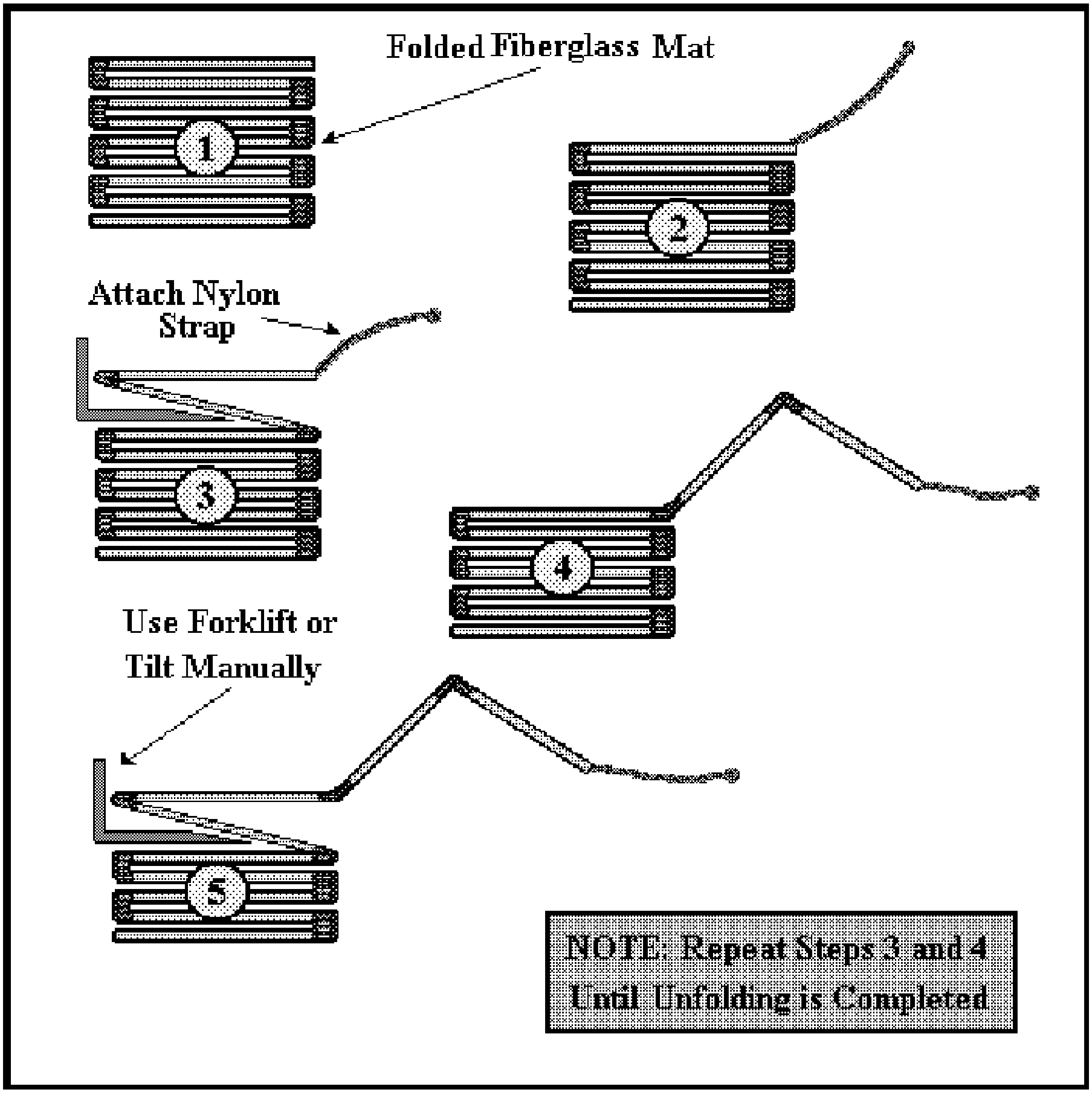

Folded Fiberglass Mat
1
2
Attach Nylon Strap
3
4
Use Forklift or Tilt Manually
5
NOTE: Repeat Steps 3 and 4 Until Unfolding is Completed

Figure 5.42. Joining Panel Attachment.

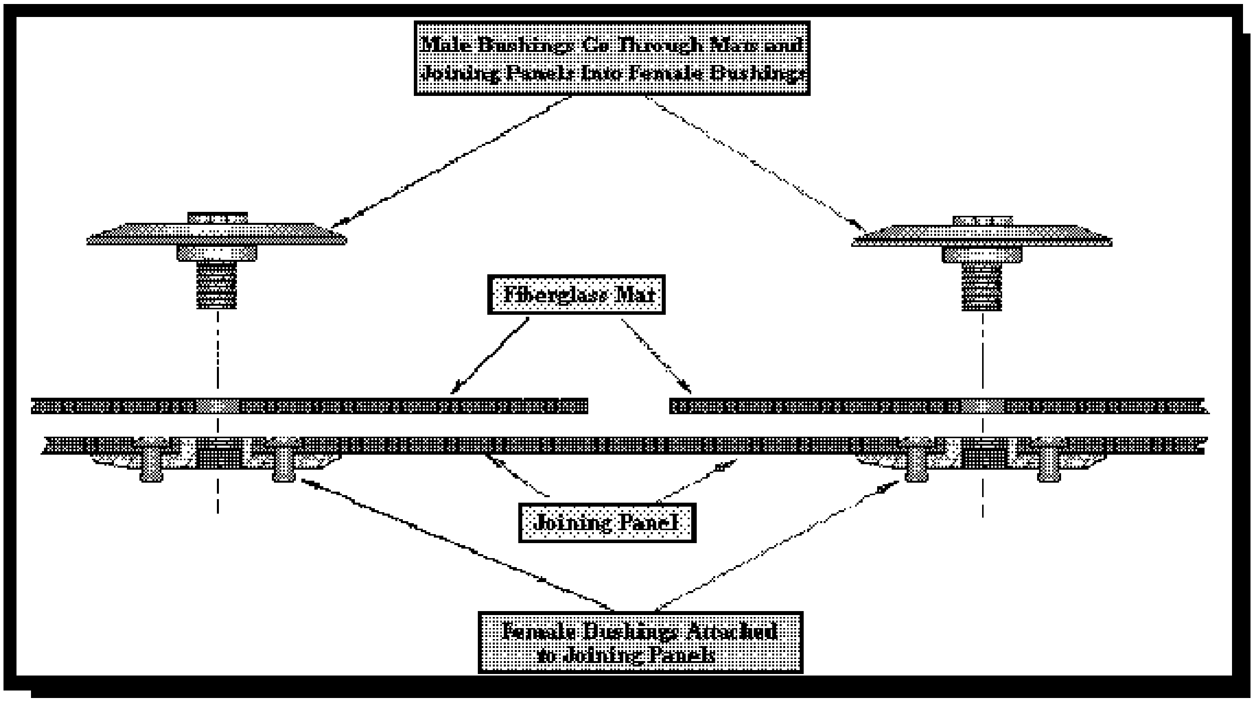
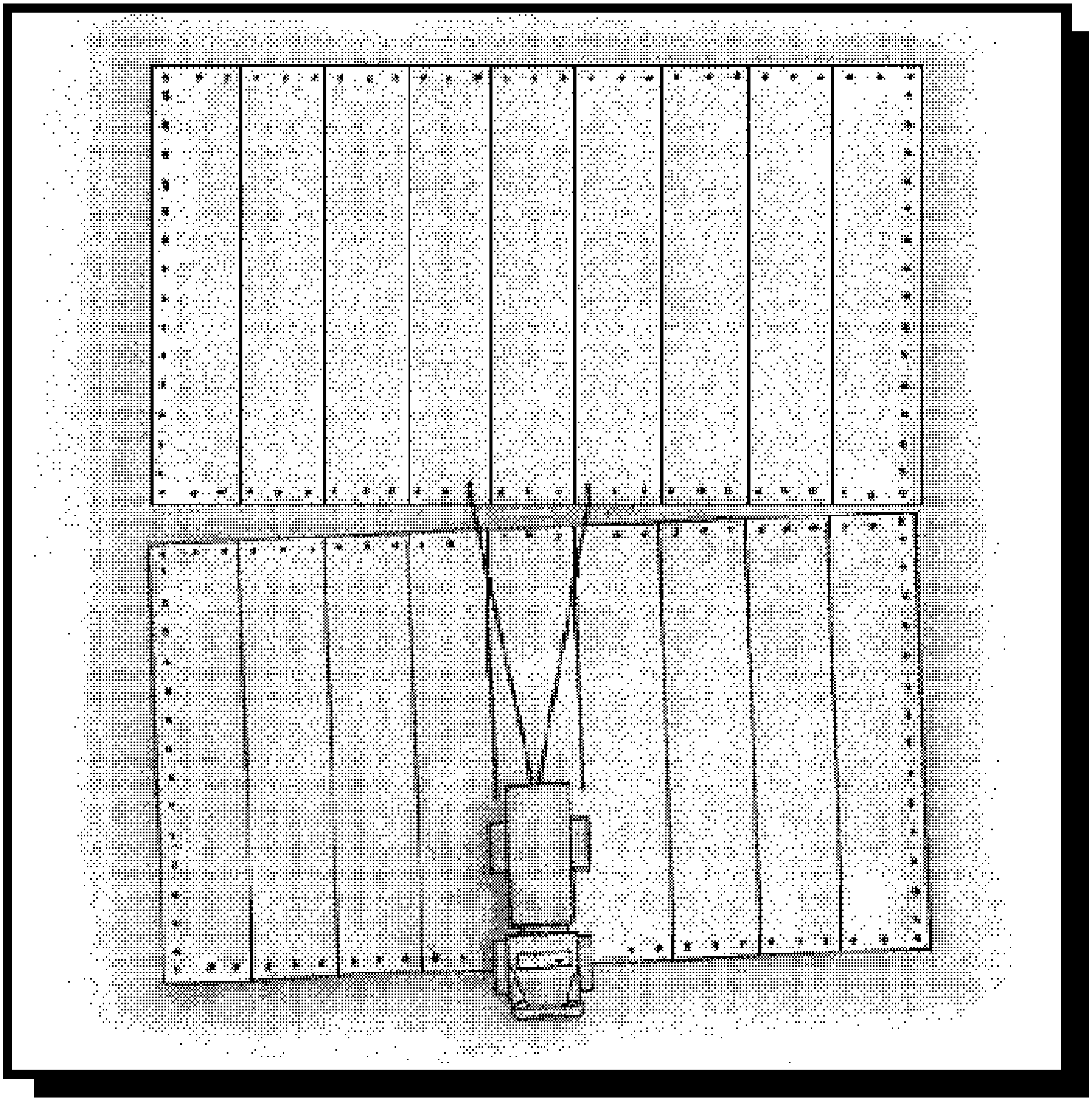


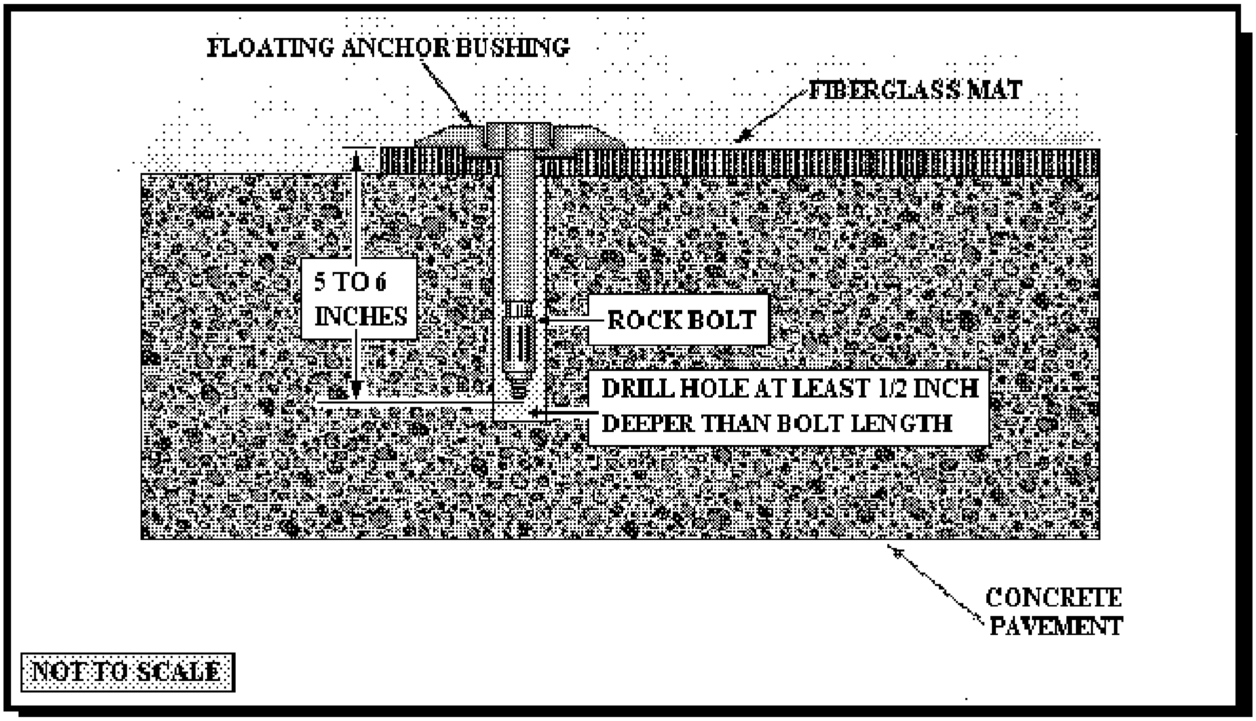
Figure 5.43. Joining Second Mat Using Pivot Point.



5.14.7. **Anchoring Methods.** Folded fiberglass mats are predrilled for anchoring bolts. The technique used to anchor a FFM will depend on the type of pavement surface. The normal anchoring system employs an expanding bolt for concrete and some asphalt over concrete pavements. For thicker asphalt pavements a 9.5-inch rock bolt with a polymer plug anchor is used. All three techniques involve a 4-inch bushing, through which the bolt passes, to hold down the mat. As is also the case with an AM-2 patch that requires pavement anchoring, FFMs are only anchored on the leading and trailing edges. FFM anchoring specifics follow:

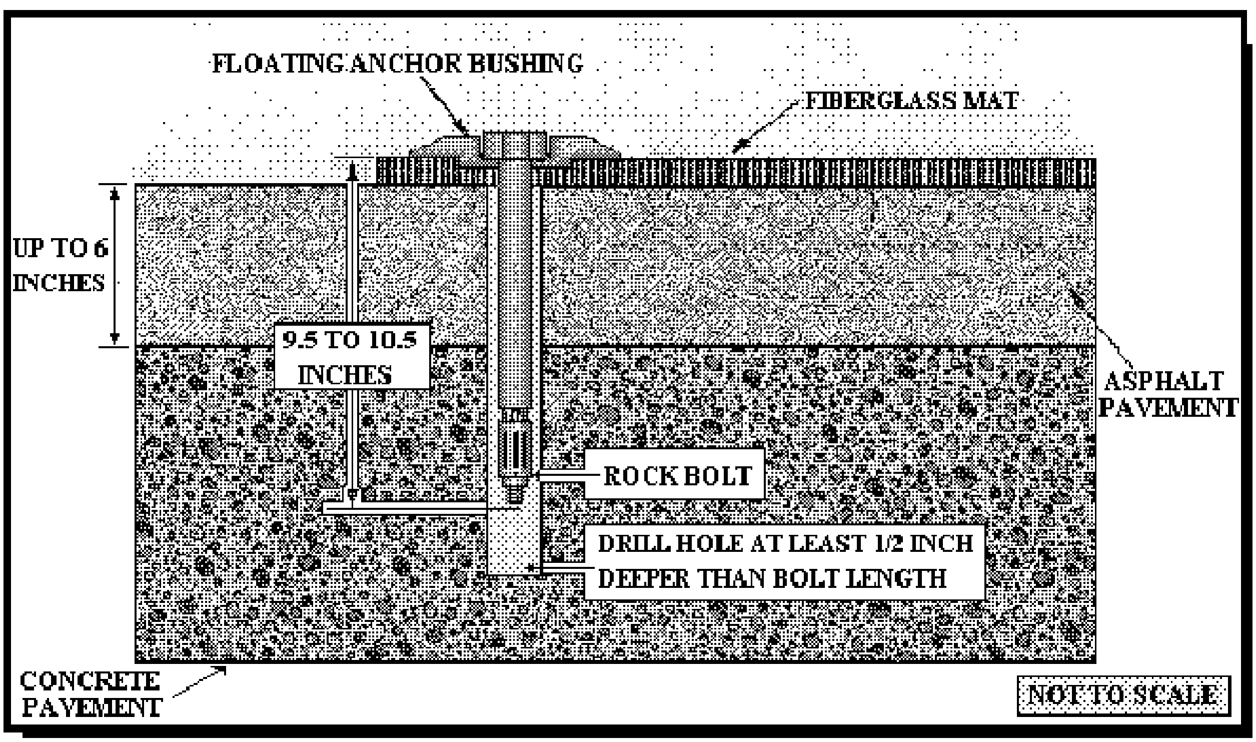
5.14.7.1. **Concrete Pavements.** The anchor for concrete pavements is normally a rock bolt, 5 to 6 inches long and 5/8- to 3/4-inch in diameter (figure 5.44). At each predrilled hole in the leading and trailing edges of the mat a hole, corresponding to the diameter of the bolt being used, is drilled into the pavement. The depth of the hole must be at least 1/2-inch longer than the length of the bolt. After the hole is cleaned out with compressed air, the bushing is put in position on the mat and the bolt inserted into the hole. The bolt is then tightened with the impact wrench.

Figure 5.44. Concrete Pavement Anchoring.



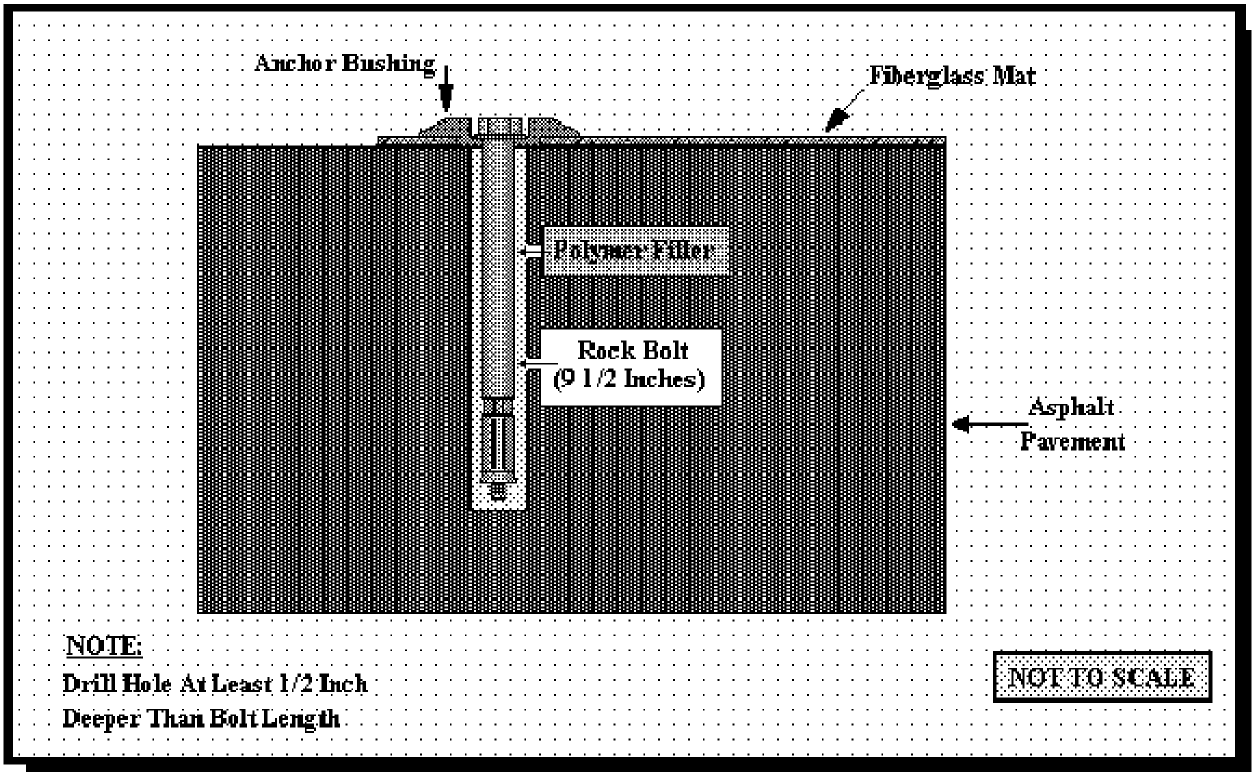
5.14.7.2. **Asphalt-Overlaid Concrete Pavements.** Asphalt-overlaid concrete usually entails about 6 inches of asphalt over an 8-inch thick concrete slab. The anchor for this type of pavement is a 9 1/2-inch long and 5/8- to 3/4-inch diameter rock bolt (figure 5.45). The procedures for installation are the same as those used for all-concrete pavements. The key factor in this installation is to ensure the bolt has been set deep enough into the concrete layer to provide a firm grip.

Figure 5.45. Asphalt-Overlaid Concrete Anchoring.



5.14.7.3. **Asphalt Pavements.** The anchoring system for asphalt pavement involves using 9 1/2-inch bolts with polymer plugs (figure 5.46). A 10-inch hole, 1 1/2-inch in diameter, is drilled at the center of each predrilled hole in the mat. A two-part resin polymer is mixed and poured into each hole to about a 1/2-inch below the surface of the pavement. An anchor bushing and bolt are then placed into each hole and pressed firmly against the mat. This method requires teamwork--the polymer will harden in about 3 minutes and you will probably not have the time to drill all the holes first before pouring the polymer. Drilling and setting bolts will have to be accomplished concurrently.

Figure 5.46. Asphalt Anchoring.



5.14.8. **Arresting Hook Operations Over FFM.** When FFM crater repairs are used on parts of the runway over which aircraft arresting hooks are to be dragged, special precautions must be taken to ensure that the arresting hook does not bite underneath the mat cover and tear it up. After the FFM has been bolted to the runway, form a 6- to 9-inch wide ramp, made from Silikal® or similar mixture, on the runway surface at both the leading and trailing edges of the mat. The intention of the ramps is to provide a relative smooth surface transition between the pavement and the mat. Basically, what you are trying to avoid is a sudden variation in surfaces that may cause the tailhook to bounce and thereby skip over the arrest barrier's cable. A horizontal gap of 1-inch should be left between the edges of the mat and ramps to allow the mat to be removed and replaced when maintenance of the crater repair is required. However, keep in mind that according to the RQC technical manual, repairs are not allowed for at least 550 feet in front of an aircraft arresting barriers--a 1,000 feet is desired by Air Combat Command. Consequently, the aforementioned situation can only occur during an emergency when the wing commander opts to allow repairs in an otherwise restricted portion of the MOS.

5.15. Sweeping the Crater Area. Regardless of what type of crater FOD cover is used, sweeping and clean up of the repair area is a mandatory final step. All equipment must be removed and either sent to other job sites or placed back into dispersal. Excess materials must be reclaimed or moved out of the immediate MOS area. The crater and its surrounding area must be thoroughly swept to eliminate the potential of FOD damage to aircraft which will be using the MOS immediately afterwards. Lastly, we must ensure that all debris resulting from the initial bombing attack and that generated from the crater preparation process is off of the total MAOS and does not present a hazard to flying operations or the functioning of aircraft arresting barriers and airfield lighting systems.

5.16. Repair Activity Sequencing. Although this chapter has looked at crater repair as an individual step-by-step process, if RRR is physically performed this way, recovery teams will never be capable of meeting the time frames dictated by the Operations community. To reduce RRR time, five basic requirements involving RRR team members need to be met. Each member of the RRR team must:

- Know his or her individual tasks and responsibilities.
- Be fully proficient in his or her individual tasks.
- Know how his or her tasks interface with the RRR process as a whole.
- Know the steps and sequencing of RRR activities (see checklists in attachments 5, 6, and 7).
- Receive extensive hands-on training and practice on the RRR process.

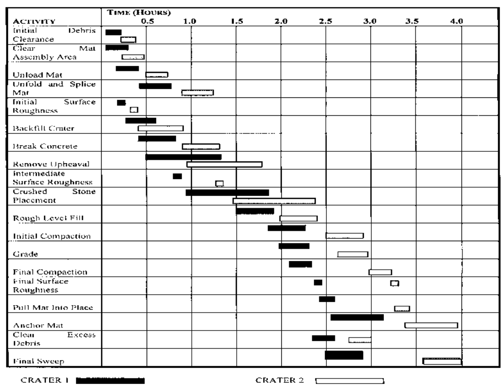
5.16.1. If these five requirements are satisfied, RRR time frames can be drastically shortened since people will anticipate their next actions, assist others without hesitation, and be able to do their jobs right the first time. To see how these requirements apply, let us look at the efforts involved in a dual crater repair.

5.16.2. As stated earlier, many of the RRR activities must overlap or can be performed concurrently to cut down on the time needed for RRR operations. Figure 5.47 graphically illustrate a two crater repair effort using folded fiberglass mats. When studying this figure, several instances where tasks overlap can be seen. If RRR team members know where and when these occur, they can respond accordingly and the RRR process will be accelerated. A few examples include:

- Transportation of folded fiberglass mats occurs while crater upheaval is being removed.
- Clearing areas for mat assembly occurs simultaneously with upheaval removal.
- Backfilling of craters starts before upheaval removal is completed.
- Grading and compacting of crushed stone can be concurrent events.
- Final clean up and debris clearance may begin before the folded fiberglass mat is fully anchored.

Figure 5.47. Dual Crater Folded Fiberglass Mat Repair.

FIBERGLASS MAT DUAL CRATER REPAIR
(TIME LINE)



5.16.3. These examples just relate to the repair of one of two craters assigned to a crater repair crew. However, about 80% of the time two craters will be worked concurrently. For a smooth operation, all RRR team members must thoroughly know the procedure and sequencing of RRR activities. These "knowns" must be mastered if the "unknowns" of wartime equipment losses and personnel attrition are to be faced with any degree of success.

5.17. Spall Repair. Spall damage should be expected after any conventional airfield attack. Spalls are generally defined as pavement surface damage that does not penetrate the base course and results in a damaged area up to 5 feet in diameter. They are most commonly caused by ordnance impact, e.g., strafing and bomblet detonation; bomb fragmentation impacts; and pavement ejecta. As a norm, spalls are easier to correct than crater damage, providing the numbers are not overwhelming. Silikal® polymer concrete is presently the material of preference for spall repair, but cold-mix asphalt or quick setting magnesium phosphate and portland cements can also be used, particularly when conducting training exercises. Due to the environmental problems and limited shelf life associated with Silikal®, extensive research is currently being conducted by HQ AFCESA and Wright Laboratory to identify a more environmentally friendly substitute. Much progress has been made in this effort, and just such a replacement should be selected in the near future. Specifics regarding Silikal's® environmental hazards are discussed in detail later in this section.

5.17.1. **Personnel Equipment Requirements.** For planning purposes, three spall repair teams consisting of four personnel each are usually established as part of the overall RRR team complement. This number of personnel is sized to respond to a potential requirement of repairing up to 400 spalls within the 4-hour RRR time frame. Obviously, if fewer spalls are encountered, the team sizing can be adjusted accordingly by the engineer command and control element.

5.17.2. **Equipment/Materials Requirements.** The equipment and materials generally needed for each spall repair team consist of the following:

- One 5-ton dump truck or similar vehicle.
- Portable radio.
- Protective masks.
- Mixers, tools, and materials appropriate to the type of repair product being used.
- Joint use of the RRR team jackhammer and compressor.

5.18. Silikal® Spall Repair Procedures. Silikal® is a polymer mortar comprised of a powder resin, powder hardener, liquid component, and a cold weather accelerator component. Once mixed, it remains workable for 5 to 10 minutes and sets in about 20 minutes. The cold weather accelerator should only be used at and below 32 degrees Fahrenheit. At higher temperatures it reduces the strength of the mortar. Gravel can be added up to the same weight as that of the powder component to increase the quantity of mortar. However, because Silikal® is sensitive to water, only dry aggregate should be used.

5.18.1. **Packaging.** One Silikal® R7-AF kit, which contains 80 units, is comprised of the following:

5.18.1.1. **R7-AF Powder Component.** This material is packaged in polyethylene bags and shipped in four 55-gallon fiber drums (20 bags per drum). Each bag, which is also used for mixing purposes, holds 32 pounds of powder component.

5.18.1.2. **Powder Hardener Component.** The hardener component is supplied in pint-size (500 ml) wide mouth plastic containers. Each unit contains 0.46 pounds (210 grams) of powder hardener component. It is packaged in 20 containers per cardboard box (one box per drum of R7-AF powder component).

5.18.1.3. **R7-AF Liquid Component.** This material is packaged in 5-gallon (19-liter) steel pails. There are eight pails per kit, or 0.5-gallon per 31-pound bag of R7-AF powder component.

5.18.1.4. **Cold Weather Accelerator.** This additive is packaged in sealed quart (1-liter) cans. Eight cans are supplied with each kit.

5.18.2. **Preparation, Mixing, and Placement Procedures.** The following steps are employed when conducting a Silikal® spall repair (see checklist included in attachment 6):

5.18.2.1. Remove loose dirt and unsound pavement from the spall. Small lumps of broken concrete debris are good bulk fillers for deep spalls.

5.18.2.2. If time permits, use the jackhammer in the RRR set to form 1-inch deep sides when a spall is shallow (smooth dish-shaped). This will serve to reduce the likelihood of the repair popping out under aircraft use.

5.18.2.3. Remove any standing water and, if possible, use the RRR compressor or leaf blower to air dry the spall.

5.18.2.4. Remove the 0.5-gallon plastic pitcher from a drum containing the R7-AF powder component.

5.18.2.5. Open the cardboard box containing the plastic bottles of powder hardener component and remove one bottle.

5.18.2.6. If the temperature is below freezing, also open the cardboard box containing the eight metal cans of cold weather accelerator. Open a can of accelerator and empty its contents into one 5-gallon pail of R7-AF liquid component. Close the pail and mix for 15-20 seconds by vigorously moving it back and forth.

5.18.2.7. Remove and open one plastic bag containing the R7-AF powder component from a fiber drum.

5.18.2.8. Empty the plastic bottle containing the powder hardener component into the 0.5-gallon pitcher.

5.18.2.9. Next, open the 5-gallon pail of R7-AF liquid component and measure out 0.5-gallon of liquid into the plastic pitcher containing powder hardener component. The powder hardener component will dissolve virtually instantaneously when mixed with R7-AF liquid component.

5.18.2.10. Now hold open the plastic bag containing the R7-AF powder component and empty the entire 0.5-gallon pitcher of liquid hardener mix into the bag (figure 5.48). Draw the top of the bag closed to force out any excess air on top of the material. Once you have removed most of the excess air, close the bag firmly with a twisting action.

Figure 5.48. Adding Silikal® Hardener Mix.

5.18.2.11. Next, vigorously knead and roll the contents, alternately picking up each corner to obtain a thorough blending. Continue this process until an even consistency is obtained. Mixing should take no longer than 15-30 seconds.

5.18.2.12. Now hold the mixing bag over the hole and split the bag open with a trowel. The Silikal® mix should pour out like a fluid. If it does not, there is either too much aggregate, or the Silikal®has begun to set because too much hardener was added. If such is the case, discard that bag and make a new mix.

5.18.2.13. Tamp the Silikal® into the spall and level off with a trowel or straight edge. The mixture should remain workable for 5 to 10 minutes (figure 5.49).

Figure 5.49. Leveling Silikal®.

5.18.3. **Clean Up.** Be sure to clean all tools before the Silikal® sets. Use the liquid hardener, acetone, methylene chloride, or trichloroethylene as a solvent. Dispose as toxic waste those containers which contained unused cold weather accelerator.

5.18.4. **Safety Precautions.** While Silikal® is an effective material for the spall repair process, it does present some significant safety problems which must be carefully addressed. Namely, it is toxic and flammable. Several safety precautions must be taken.

5.18.4.1. Wear protective equipment when performing mixing and placing activities. Of the four components included in Silikal®, the manufacturer's literature recognizes three as having hazard ratings of moderate, high, and extreme. The following protective equipment must be used:

5.18.4.1.1. An organic vapor chemical cartridge respirator. Two examples of such are the M17 Chemical Warfare (CW) series gas mask with M13A2 filter and the MCU-2P CW series gas mask with C2 canister.

5.18.4.1.2. Impervious neoprene gloves.

5.18.4.1.3. Splash proof goggles, if not wearing a full face respirator.

5.18.4.2. Use water from your canteen to immediately wash off any liquid component splashed onto the skin.

5.18.4.3. Do not wear contact lenses when using this product. If material does come in contact with your eyes, flush with plenty of water and get prompt medical attention.

5.18.4.4. Keep sparks and flames away from the highly inflammable liquid components. Have proper type extinguishers available during product use. During a fire, irritating or toxic gases may be present--firefighters should wear full protective clothing including self-contained breathing apparatus.

5.19. Cold Mix Products. Tests of a variety of cold mix materials for spall repair have resulted in limited success. A conventional cold mix asphalt, that which is used for peacetime day-to-day repairs, is suitable for small spalls up to 2 feet across and 6 inches deep. However, proprietary products such as Amalgapave, Wonder Patch, and Future Patch, can be used for both small spalls and large ones up to 5 feet in diameter. When using any of these products, a small tamper or plate compactor is required to initially tamp the cold mix into place, then the repair is compacted further with a vibratory roller.

5.19.1. **Cold Mix Repair Procedures.** The following steps are employed when conducting a cold mix spall repair:

5.19.1.1. Remove all loose debris and water from the spall. If possible, the hole should also be dried with compressed air to improve the bond between the cold mix and the existing pavement.

5.19.1.2. As addressed previously, small spalls of less than 2 feet across can be repaired using conventional cold mix asphalt.

Place the repair material in 2-inch layers, compacting each layer with a hand held plate compactor as you go. Continue this process until the spall is overfilled to stand 1 1/2-inch above the adjacent pavement surface. This overfill then will be further compacted to a flush finish by the vibratory roller.

5.19.1.3. If the spall to be repaired is 2 feet or more across, conventional asphalt should not be used. Instead, fill the hole to within 1-inch of the pavement surface with a well-graded stone. Be sure to compact the stone well. The better the compaction, the longer the repair will last. Next, top the repair with a 2 1/2-inch layer of Amalgapave, Wonder Patch, Future Patch, or other comparable item, and hand compact. As with the previous repair procedure, overfill the spall to stand 1 1/2-inch above the adjacent pavement surface. Again, this overfill will be further compacted to a flush finish by the vibratory roller.

5.19.1.4. Inspect and maintain cold mix repairs regularly. As a norm, cold mix repair should survive approximately 100 fighter passes before requiring maintenance.

5.19.2. **Cold Mix Drawbacks.** Although cold mix products will work for spall repair purposes, they have some drawbacks which affect their all-around capabilities. First, they tend to be difficult to work with in cold temperatures and will not bond well with adjacent pavement surfaces if these surfaces are cold or wet. Second, the shelf life of products is not particularly long. Lastly, frequent maintenance is normally required.

5.20. Quick-Set Concrete Repair Procedures. Quick setting cements are presently on the market which also can be used for spall repair. The most common type is magnesium phosphate cement.

5.21. Magnesium Phosphate Cement. Magnesium phosphate cements are inorganic compounds which can be used in a way similar to Portland cements. Some commercial names are Por-Rock, SET 45, FEB ASR-1, and Rapid Set Non-Shrink Multipurpose Grout. They are all water-based, can to some degree displace water from a wet spall, and bond well to wet or dry concrete or asphalt surfaces. The time that this type of cement remains workable depends greatly upon the temperature. Below freezing, it takes several hours to set, while at about 100 degrees Fahrenheit a flash set occurs within 30 seconds. Without the aid of accelerators or retarders, magnesium phosphate cements are usually usable over a temperature range of between 35 degrees to 75 degrees Fahrenheit. As a general rule, set times can be altered somewhat by using either high or low temperature additives or hot and cold water, as appropriate. Due to their lack of handling hazards and general ease of use, it is highly probable that in the near future a type of magnesium phosphate cement product will be identified as the spall repair product of choice to replace Silikal®.

5.21.1. **Magnesium Phosphate Repair Procedures.** The technique for using magnesium phosphate cement for spall repair is essentially the same as that used for Portland cement. However, due to its quick set time, it should be mixed in small mixers for only one to two minutes and then immediately discharged into the spall. Some procedural tips include:

5.21.1.1. Mix only the quantity you can use right away.

5.21.1.2. Once the 1 to 2 minute mixing time has been achieved, empty the mixer immediately even if you have no use for the material. Continued mixing does not stop the material from solidifying.

5.21.1.3. Extend material if necessary. Normally, a magnesium phosphate grout can be extended by approximately 50 percent by adding 1/4-inch to 3/4-inch sized gravel.

5.21.1.4. Frequently scrape or rinse hand tools and the mixer drum to prevent a buildup of hardened grout.

5.21.1.5. Do not dump surplus material onto the runway surface. It may require a jackhammer to remove the hardened material later.

5.21.1.6. Make sure that the spall is free of oil, grease, latence and debris.

5.21.2. **Magnesium Phosphate Cement Drawbacks.** Three drawbacks have been identified relative to this type of cement. First, it has a limited working period (particularly in hot weather) unless a retarder is used. Second, it releases high heat and a nontoxic ammonia odor as it is setting. But, both of these factors are easily managed, though they do not make the product very “user friendly.” However, the fact that tight restrictions are associated with the water/cement ratio is more consequential. The water/cement consistency (ratio) must be correct in order to achieve the desired end results. Specifically, if too much water is added, the patch will prematurely crack and chip under moderate aircraft trafficking; a most undesirable feature.

5.22. Debris Clearance. The peacetime standard of cleanliness for runways and taxiways requires that they be kept free of any debris that could cause FOD to aircraft. In wartime, the runway surfaces will be extensively covered with debris after each air attack, and no equipment available can rapidly clear the surface to peacetime standards. The USAF has a continuing research project which will determine how FOD is thrown into the air from a runway surface and how it damages the aircraft. The results should give a better understanding of the risks involved in operating aircraft from debris-strewn surfaces and may show that sweeping of certain sections of the runway is not an absolute operational requirement. In any case, the risk to aircraft being launched from a "dirty" runway is much less than if aircraft were caught in an air attack while sitting on the ramp, waiting for sweeping operations to be completed.

5.22.1. **Event Sequence.** Foreign object damage occurs in this sequence:

- Debris is lifted by tires or airflow from the ground into the air.

- Next, debris is carried along the flow lines of air passing through the engine or over the fuselage.
- Lastly, debris strikes the components of the engine or stores fixed to the outside of the aircraft.

5.22.2. **Clearance Procedures.** Using combinations of equipment in the RRR equipment sets, different standards of cleanliness can be achieved. Tests have shown that very little benefit is achieved by making more equipment coverages than the following recommendations:

5.22.2.1. The cleanest surface is achieved by making one “fast” (4-to-5 mph) sweep of the area with a grader, followed by two coverages with a vacuum sweeper traveling at 3.5- to 4-mph.

5.22.2.2. The next best standard of clearance is achieved by conducting one fast (4-to 5-mph) grader coverage followed by one coverage of the tractor with a front-mounted broom traveling at approximately 5.5 mph. These speeds are effective only if the debris is fairly dry. If, however, the debris is wet and sticky, a broom cannot produce a good clean surface.

5.22.2.3. A "dirtier" surface, because it has more large stones left on it, is produced by a "slow" (2-to 3-mph) grader coverage followed by a second, faster (3-to 5-mph) grader coverage.

5.23.2.4. The "dirtiest" surface, but fastest operation, is left by conducting one "fast" (4-to 5-mph) coverage with only a grader.

5.23. Clearing and Sweeping Recommendations. Recommendations for clearing and sweeping activities include:

5.23.1. Sweep all areas to be trafficked by aircraft even if debris appears minimal. It is essential to remove as much shrapnel as possible; even small pieces of sharp metal can cause severe tire damage.

5.23.2. Clear taxiways and a strip about 25 feet wide on both sides of the MOS with one fast grader coverage. Also make a single coverage about 15 feet wide with the grader down the center of what will be the overruns of the MOS to provide open access for airfield lighting placement. The length of this run will be dependent on the type of expedient lighting system available. A better standard of sweeping is required on parking aprons, and uphill sections of the taxiway where the aircraft needs to use more power and is therefore likely to suck up more debris. At these locations use a kick broom sweeper or second grader coverage.

5.23.3. Clear the first 300 feet of the MOS (the most critical area) with a vacuum sweeper.

5.23.4. Clear the next 800 feet of the MOS with a vacuum sweeper, if possible.

5.23.5. Clear the remainder of the MOS with the kick broom sweeper or by two coverages with the grader.

5.23.6. The above recommendations should be considered just that--recommendations. They are not the minimum requirements. If time and vehicles permit, as much FOD as possible should be removed from all airfield pavements that will be used for launch and recovery purposes. Rest assured that sweepers will be running continuously and we will be receiving never ending requests for sweeper support. Plan on making frequent trips to the MOS for FOD clean up--aircraft activity and winds will continually blow additional debris across the air strip. Once airfield pavement debris clearance is under control, you can expect to receive pressure to clean base thoroughfares that lead to the flightline from maintenance facilities, munitions storage areas, and POL storage sites.

5.24. Equipment Repair and Recovery Planning. Vehicular equipment will experience breakdowns in an operation of the magnitude of RRR. Planning for such an eventuality will avoid lengthy downtime which could seriously delay repair efforts. The transportation squadron should be petitioned to provide a minimum of two special purpose vehicle mechanics who are to be dedicated to RRR support operations. Where this support can be provided, the two-person team should be equipped with a mobile maintenance vehicle of some sort, a means of two-way radio communication (radio/cellular phone), tool boxes, and a supply of common replacement spare parts, and remain on the MAOS during the RRR operation to quickly repair equipment breakdowns. In addition, all front-end loaders and dozers should be equipped with towing straps to recover any equipment stuck in a crater or to remove any disabled vehicles from the MOS area.

5.25. Equipment Substitution. When a specific item of equipment does break down, do not let the RRR operation grind to a halt. There are many cases where other pieces of equipment may substitute and perform a task almost equally as well. Table 5.5 provides an equipment hierarchy illustrating what types of tasks various pieces of equipment can perform. The equipment items are listed in descending order of precedence. For example, for grading the primary vehicle to use would be the grader, followed by a front-end loader and then the excavator. The point to remember is there are alternatives. You are not locked into following a strict technical order or set of procedures. Use initiative, be innovative, and be flexible.

Table 5.5. Equipment Hierarchy.

CRATER PREPARATION	CRATER CLEARANCE	AGGREGATE HAULING
4 YD^3 Loader Excavator 2.5 YD^3 Loader Dozer	Loader Excavator Dozer Grader	Dump Truck Loader
GRADING	**COMPACTING**	**LOADING/HAULING**
Grader Loader Excavator	Roller Excavator	4 YD^3 Loader/w Fork Atch 2.5 YD^3 Loader/w Fork Atch Forklift (All Terrain)
SPALL CLEANING	**LEVELING**	**DEBRIS CLEARANCE**
Compressor Backpack Leaf Blower Vacuum Sweeper Vehicle Vacuum System	Grader Loader Excavator Dozer	Loader Grader Excavator Dozer

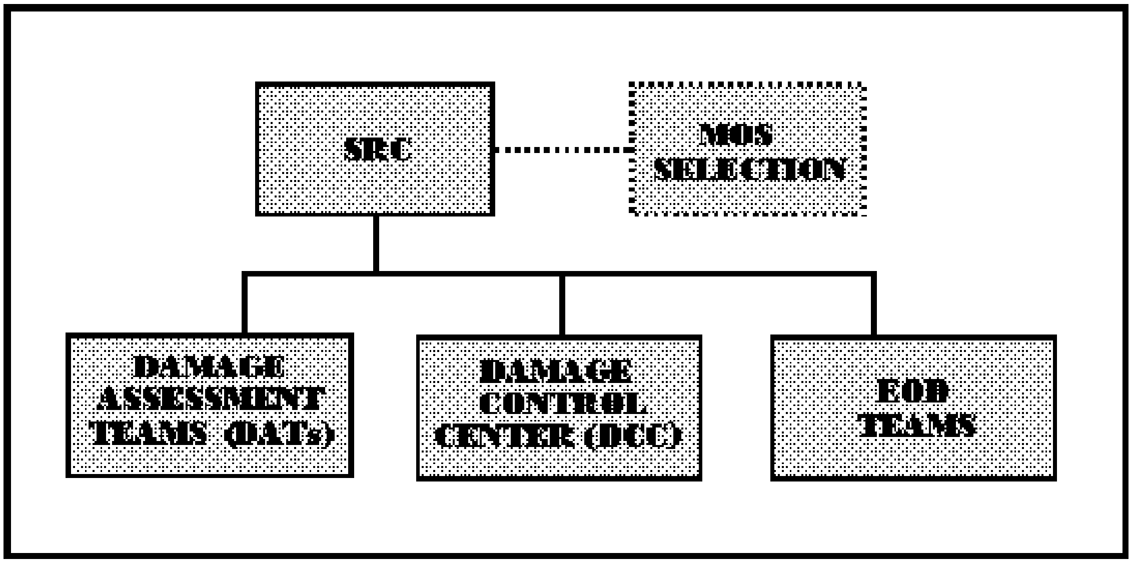
TRANSPORTING MATS	SWEEPING
Tractor/Trailer 4 YD^3 Loader 2.5 YD^3 Loader Excavator	Tractor Mounted Broom Sweeper Vacuum Sweeper Hand Broom

NOTE**:** Equipment under each heading is listed in descending order of precedence.

5.26. Runway Repair Concept of Operations. As described in the beginning of this chapter, there are various equipment sets to satisfy differing RRR requirements. Manpower requirements vary with the differing equipment sets. The acquisition and prepositioning of assets at any particular location are determined primarily by the enemy threat. Logically, if the aircraft are not sheltered, they will be the prime targets. If aircraft are sheltered, the runway becomes the prime targets. The closer the base is to an enemy front, the greater the probability of larger initial attacks and more frequent follow-on attacks. Despite these variables, a general concept of operations applies and is the subject of the following paragraphs. A detailed concept of operations is contained in attachment 2. For the purposes of the discussion in this chapter, we will assume that an R-3 RRR equipment set is available and one lead and two follow Prime BEEF teams are in place. The example outlined in paragraph 5.28 represents one of the more demanding scenarios with respect to wartime RRR operations. However, first let's briefly review the organizational structure and primary areas of responsibility associated with a typical RRR effort from an engineering perspective.

5.26.1. **Overall Organization.** Under the base recovery after attack (BRAAT) concept, the SRC is the hub of rapid runway repair activities. From the SRC the base commander, BCE (or designated representative), and other key support commanders or functional chiefs provide overall direction and guidance to the field forces accomplishing base recovery. In particular, the BCE passes SRC information and decisions to the civil engineering DCC. The MOS selection team is located in the SRC and the RRR damage assessment and EOD teams report to the SRC. The overall organizational concept for RRR operations is shown in figure 5.50.

Figure 5.50. RRR Organizational Concept.



5.26.2. **Engineer Organization.** The DCC is the focal point for engineer activities during base recovery. As was shown earlier in figure 5.1, the RRR team receives its direction from the DCC. The team functions under an area repair group concept wherein an essentially equal effort is applied to both MOS and access taxiway repair requirements. Three crater repair crews are designated for MOS support and another three crews are assigned to taxiway requirements. Each crew has the responsibility for the repair of a maximum of two craters. The hauling crew supports all six repair crews with fill and FOD cover deliveries. The support team accomplishes all the ancillary but equally important tasks of FOD removal, spall repair, airfield marking, and airfield lighting and arresting barrier installation. This entire operation is led by the RRR OIC and NCOIC.

5.27. Organization Responsibilities. During an actual airfield recovery situation many difficult decisions must be made quickly and accurately. Recognizing the need for decisive response to a wide variety of situations, the BRAAT concept calls for a standard organizational structure and assigns responsibility accordingly. Briefly summarized, these responsibilities are:

5.27.1. **Survival Recovery Center.** The SRC is responsible for managing overall installation recovery operations, including RRR. The BCE and engineer members of the MOS selection team are located in the SRC. During RRR operations, the SRC staff directs the airfield damage assessment effort, receives and plots damage and UXO data, and makes a MOS selection. The SRC then instructs the DCC to initiate RRR operations and orders EOD forces to begin UXO safing operations.

5.27.2. **Damage Assessment Teams.** Chapter 2 of this volume provides detailed information on the responsibilities of the DATs. Basically, the DATs receive direction from the SRC and report airfield damage and UXO data.

5.27.3. **MOS Selection Team.** Chapter 3 of this volume outlines procedures for selecting the MOS. The MOS selection team plots damage and UXO data received from the DATs, and after MOS selection is complete, continues to monitor and record damage repair and EOD progress. The MOS selection team also performs all repair quality criteria calculations as outlined in chapter 4 of this volume.

5.27.4. **Damage Control Center and RRR OIC.** The DCC is manned by key BCE supervisory personnel, and serves as the focal point for management of civil engineer recovery efforts. During the initial stages of damage assessment (from the advantage point of the DCC), the RRR OIC monitors the logging and plotting of all incoming damage and UXO data reported by the DATs. After the MOS has been selected, the SRC designates the location of the MOS, identifies the location of craters to be repaired, and designates which taxiways and access routes are to be cleared and repaired. Once this data has been received, the RRR OIC normally will join the RRR team at either their dispersed sites or staging area and outline specific duties and areas of responsibility. From this point on, the RRR OIC will usually remain on-scene and assume immediate control of the operation. If damages to be repaired are considerably different than those upon which RRR operations are preplanned, the RRR OIC alters team assignments as necessary. For example, the RRR OIC may have to shift a crater repair crew from the MOS to the access taxiways or perhaps release crews to other taskings if damages are lighter than expected. Much of the extent of this adjustment can be determined in the DCC prior to the RRR OIC leaving the control center. Once the overall scope of the RRR operation has been identified, the OIC directs crews to craters, designates haul routes to be cleared, and determines which stockpiles are to be used. In the DCC, plotters continue to update wall displays as repair progress reports are received. In addition, these plotters maintain the status of material usage, personnel casualties, and equipment losses. Display boards in the DCC should include, but not be limited, to the following:

5.27.4.1. Airfield map showing damage, crater identification numbers, planned or actual MOS and taxiing patterns, haul routes, and areas where work is in progress or completed. Tasking board listing each team's repair task, start time, and estimated completion time.

5.27.4.2. Equipment status indicating each team's equipment allocation and performance limitations due to breakdowns, malfunction, or war damage.

5.27.4.3. Material usage to show quantities of ballast rock, crushed stone, AM-2 mats, and FFMs remaining at each stockpile location.

5.27.5. **Support Team OIC and RRR NCOIC.** The support team OIC's primary responsibility is to ensure that the several crews assigned under him/her accomplish their taskings on time and correctly. While the crews themselves are not large, they are diverse in nature and somewhat specialized. Any one of them has the potential to delay launch and recovery operations if the performance of their portion of the RRR effort is lacking. This is particularly true of the FOD removal and spall repair teams. The support team OIC will have to act in a roving controller capacity during the entire RRR operation to ensure the support required from all his/her teams is being provided. Also having to serve as a roving controller is the RRR NCOIC. This individual must maintain close oversight of both the MOS and taxiway RRR operations and the associated hauling team support. This person's primary function is to act as an on-site problem solver and provide technical and control assistance to the RRR OIC. The RRR NCOIC must facilitate the coordination of requirements between all RRR crews to ensure slippages in repair progress are avoided.

5.27.6. **RRR Crater Crew Chiefs.** Crew chiefs carry out their task of managing the crater crew's operations and reporting progress to the RRR OIC. A sample of the type of progress information to be reported are shown in tables 5.6 and 5.7.

Table 5.6. Suggested Progress Report (Progrep) Format (AM2 Mat Repair).

FROM REPAIR TEAM NUMBER ________________

REFERENCE CRATER NUMBER ________________

Serial Example	Activity not sent over radio)	Time or % Complete
A	Time now	12:30
B	Started work (time)	12:05
C	Clear around crater (%)	100%
D	Removal upheaval (%)	10%
E	Stone in crater (%)	
F	Compaction (%)	
G	Final leveling (%)	
H	AM-2 patch assembly (%)	10
I	Sweeping (%)	
J	Mat in place (time)	
K	Patch anchoring (%)	
L	Estimated time of completion	15:00

Table 5.7. Suggested Progress Report (PROGREP) Format (Folded Fiberglass Mat Repair).

REFERENCE CRATER NUMBER ________________

Serial Example	Activity (not sent over radio)	Time or % Complete
A	Time now	12:30
B	Started work (time)	12:05
C	Clear around crater (%)	100%
D	Removal upheaval (%)	10%
E	Stone in crater (%)	
F	Compaction (%)	
G	Final leveling (%)	
H	Mat assembly (%)	10%
I	Sweeping (%)	
J	Mat in place (time)	
K	Mat anchoring (%)	
L	Estimated time of completion	15:00

FROM REPAIR TEAM NUMBER ________________

5.28. Sequence of Events. To address a sequence of events for RRR operations, a general scenario must be portrayed. In our case, we will begin at the point where all preattack actions have been completed, all command posts and control centers are functioning, dispersal requirements have been met, and personnel have been sheltered. The base has just been attacked and considerable damage has been sustained. Particularly hard hit were the runway, taxiways, and major aircraft parking areas. After the attack, personnel occupying observation posts and organizational units begin reporting damage, fires, and UXO sightings to the SRC. Reports confirm major damage to the airfield with numerous craters on the main runway, taxiways, aprons, and access routes from the aircraft shelters. Spalls are prevalent throughout the pavement system and UXO are in abundance.

5.28.1. **Locating a MOS.** Immediately following the attack, the SRC dispatches the airfield damage assessment teams to determine the extent and severity of damages to airfield operating surfaces. Based on initial damage reports from observers and base agencies, the SRC directs the DATs (using preplanned routes) to the least damaged areas of the airfield pavement complex to provide feedback on the size, type, and location of damage and UXO. At the same time designated RRR personnel make a quick inspection of RRR equipment and stockpiles reporting the results of their findings to the DCC where the RRR OIC is initially located. As reports from the DATs are received, the MOS selection team in the SRC and equivalent plotters in the DCC record and plot the damages sustained.

5.28.2. **Repair Time Estimates.** Repair time estimates and strategies must now be developed. UXO safing time estimates are obtained from the EOD representative on the SRC staff. Aircraft mission requirements are provided by the WOC and a cross-check of the MOS length requirement is made by the MOS selection team using repair quality criteria preattack procedures. In due course the full extent of the attack becomes apparent. The critically important decision at this juncture must now be made as to which areas of the airfield pavement surfaces require immediate repair to conduct aircraft generation. The MOS location will normally be that part on the airfield requiring the least amount of repair and disposal of unexploded ordnance yet, at the same time, meets the requirements for aircraft launch and recovery. This MOS must satisfy mission requirements for sustained operation and must be suitable for the type aircraft specified by the WOC.

5.28.3. **MOS Candidate Selection.** Shortly after receiving the last bit of relevant airfield damage information, the MOS selection team completes its determination of what possible MOS candidates exist. The best one is chosen for presentation to the wing command element. Upon approval of the MOS by the commander, EOD teams start UXO safing and removal actions and RRR personnel begin recovery efforts as soon as appropriate UXO clearance is afforded.

5.28.4. **Mobilizing Repair Forces and Materials.** The SRC informs the DCC of the details of the selected MOS and directs the commencement of RRR operations. The DCC, in turn, directs the RRR team. Since the RRR OIC is normally in the DCC during the MOS selection phase of the RRR operation and has the opportunity to observe as damage inputs are received and plotted, he/she should be fully aware of the overall RRR recovery requirement. With this knowledge in hand, the RRR OIC then takes on-scene control of the RRR operation, assigning tasks to the various RRR crater crews; designating travel routes of vehicles, equipment, and personnel from dispersal sites; and coordinating the efforts of the RRR crews, hauling crews, and support teams. Vehicles are moved from dispersal sites to a staging area in preparation for convoying to the repair sites, a last check of equipment is made, and the word is passed back to the DCC that the RRR teams are ready to proceed. Keep in mind, if the team can follow the same preplanned route(s) used by the DATs to the MOS, most apparent UXO hazards on such route(s) will have already been identified and the potential for incurring subsequent UXO damage should be noticeably reduced.

5.28.5. **Accomplishing RRR Operations.** When EOD teams have sufficiency cleared or safed any impinging munitions, the SRC clears the RRR forces for entry to the repair sites. As RRR teams convoy to their respective work areas the team's OIC and NCOIC conduct a quick final check of the MOS to ensure RRR operations can actually commence as planned. If circumstances that might invalidate MOS selection are identified, the OIC immediately should advise the DCC and inform the teams to hold position until the situation is reevaluated. Some conditions that might invalidate MOS selection include:

- Excessive damage.
- Too large a repair area.
- Unchecked broken fuel lines.
- Missed area-denial weapons.
- Damaged utility lines.

5.28.5.1. If no unforeseen problems are found, the RRR crews continue to convoy to each of the repair locations. Rapid runway repair crews travel to their sites in small, mixed increments so explosions, accidents, or contamination will not cripple the RRR effort through the loss of an entire crew. The vehicles contain "mixed loads" of people so all excavator operators or other highly trained personnel will not be attrited by one weapon. The vehicles are convoyed individually at no less than 60-second intervals. At the same time the crater repair crews are moving to their repair locations, crews from the support team, such as airfield lighting installation, arresting barrier installation, FOD removal, and spall repair are also transported.

5.28.5.2. Convoys are arranged so that the first group of personnel on the scene are those tasked with MOS layout. This MOS layout is accomplished in its entirety by members of the MOS marking team and usually involves location identification or layout of the following:

- MOS threshold layout
- MOS centerline
- "T" clear zones
- MAAS
- Distance-To-Go (DTG) Markers.
- Precision Approach Path Indicators (PAPI)
- Edge Markers
- MOS threshold lighting
- Approach lighting

5.28.5.3. As crater repair crews arrive at their work sites, they perform the repair operations following the detailed procedures outlined earlier in this chapter. It is up to the crater crew chiefs to ensure their repairs progress smoothly and rapidly and that no equipment stands idle. The team's OIC and NCOIC closely monitor the overall progress of the entire operation and make necessary adjustments as required. Flexibility, resourcefulness, and leadership ability will be required here.

5.28.6. **Installing the Aircraft Arresting Barrier.** Most airfield recovery situations will require the installation of a mobile arresting barrier, since it is likely the permanently installed systems are either damaged or located in an area that cannot serve MOS requirements. Details concerning barrier systems are addressed in volume 5 of this AFPAM series. If a barrier is necessary, its location will have been marked by MOS layout personnel prior to the arrival of the barrier installation team. Prior to initial movement of the RRR forces the support team chief ascertains from the team's OIC whether the barrier will be unidirectional or bidirectional. This information is passed to the barrier installation team chief. As soon as possible after the barrier location has been marked, the barrier installation team starts its efforts. If debris clearance is required at the installation site, the barrier team chief requests such assistance through the support team OIC. Once the barrier is installed, the barrier team chief checks the tape sweep area for cleanliness. If debris has to be moved out of the tape sweep area, this is also coordinated through the support team OIC. The barrier team chief retains the responsibility, however, for ensuring the tape sweep area is usable. He/she must not declare the barrier serviceable until the tape sweep area is completely clear of any object that could interfere with the arresting barrier operation and can certify that the installation is in accordance with the technical manual (T.O. 35E8-2-10-1). ***NOTE*****:** Barrier certification must be accomplished by a qualified power production (AFS 3E) technician.

5.28.7. **Installing Airfield Lighting.** Airfield lighting may not be important for daytime aircraft operations, but it is essential for nighttime flight. It is possible that restoration of the existing permanent lighting system may not be feasible, due to the extent of damage or location of existing lighting relative to the MOS. If this situation prevails, the lighting system included in the RRR support kit or an EALS has to be installed. Procedures for installing portable lighting systems, as well as guidance on salvaging the existing system, are provided in volume 5 of this pamphlet series.

5.28.7.1. In most cases, the question will be when to install the lighting system, not whether one is necessary. If considerable daylight will be available after all other RRR operations are anticipated to be complete, airfield lighting should not prove to be immediately critical to aircraft launch and recovery efforts. On the other hand, if the onset of darkness is a factor, airfield lighting installation must be started as soon as possible. The RRR OIC will have to decide the timing for this operation based on inputs from the SRC and WOC and the situation at hand.

5.28.7.2. If it is necessary to install the lighting system concurrently with other RRR operations, the lighting installation team starts the task as soon as possible. Because the edges of the MOS may not be marked and considerable debris may be remaining in the area, final placement of the fixtures probably will not be possible when the team first starts its efforts. The cabling and fixtures can, however, be assembled 25 feet or so off of the probable MOS edges and moved into place once all major debris has been moved from the final installation area. Placement of the airfield lighting regulator and generator can also be accomplished early, but the support team OIC will have to arrange for the use of a forklift from the hauling team for this purpose if the RRR lighting kit rather than EALS is to be used--major EALS components are self-contained on a dedicated trailer. The support team OIC must also make a concerted effort to dovetail the heavier debris clearance activities with the lighting installation. Since access to the areas around craters that are being repaired will usually be limited, the airfield lighting team should initially concentrate its activities on other areas where availability is not hampered by either debris or equipment operations. Obviously, such decisions are on-scene judgments with the potential of involving unlimited variations. The basic point here is do not expect the airfield lighting team to be able to start at one end of the MOS and work to the other end without interruption--there usually will be too many other major activities ongoing on and around the MOS to allow this. While the support team OIC will have much coordination to do with respect to airfield lighting installation, the lighting installation team chief retains the primary responsibility for proper installation and performance of the system. This individual should not permit the installation team to leave the MOS area until the system is fully functional and correctly installed.

5.28.8. **Debris Removal.** Debris will be abundant and removal may well take considerable effort. Expect debris removal activities to continue throughout the entire RRR operation time frame. The debris removal equipment is responsible for clearing all areas of the MOS and access taxiways that are not in the immediate vicinity of crater operations. Areas immediately around the craters will be cleared by the crater repair teams but will require final sweeping by the FOD removal team when repairs have been finalized.

5.28.8.1. The debris removal equipment may be divided into separate teams each working an assigned area, or it may remain together, all working the same area at once. The support team OIC will decide the assignments, based on the size of the areas to be cleaned and the situation at the time.

5.28.8.2. First, the FOD removal team clears debris for a clean access route for vehicles to use while traveling between craters and while traveling to and from stockpiles or equipment storage areas. The team then starts clearing undamaged areas that do not contain spall fields. Since the spall repair operation creates debris, the debris clearance equipment waits until spall repair is completed in an area before cleaning spall fields. Debris should always be pushed at least 25 feet off of the MOS, and to avoid possible aircraft wing contact, never pile material more than 3 feet high. The support team OIC will have to oversee this operation closely since its timing impacts upon MOS marking, airfield lighting installation, and arresting barrier installation progress.

5.28.9. **Spall Repairs.** The support team OIC receives information relative to the scope and location of spall repair requirements from the RRR OIC at the onset of RRR operations. Based on this information the support team OIC determines the assignments of the spall repair crews. Unless a spall field is located near a crater where there is heavy debris, spalls should be easy to find. Spall crews initially start their repairs in these areas and move on to the debris covered area later. This approach allows time for the support team OIC to arrange for the necessary debris removal actions to take place. Debris covered spall fields are cleared by a single pass of either a grader, excavator, or front-end loader--the intent is to clear enough debris to enable easy identification of spall locations. Once all spalls are repaired, final clearing and sweeping actions are accomplished.

5.28.10. **Airfield Marking.** Marking of the MOS must normally be accomplished before aircraft launch and recovery operations commence. The MOS marking effort includes striping the MOS centerline and ends; placing edge, distance-to-go, and arresting barrier location markers; and obliterating existing paint markings that are no longer applicable. Undamaged sections of the selected MOS can be marked and old markings obliterated while repairs are ongoing in other areas. The support team OIC coordinates the MOS marking team's activities with those of the FOD removal team to ensure the marking team is not held up by a lack of cleared pavement. The goal of the MOS marking team is to have all MOS marking complete, except for that required over craters being repaired on the MOS centerline, by the time RRR operations are nearing completion. As RRR efforts come to an end, you want to be in a position where the MOS marking crew is waiting for the crater repair crews to finish, not vice versa. Detailed procedures on proper marking of the MOS are presented in chapter 6 of this volume.

5.28.11. **Moving Off the MOS.** The DCC, in coordination with the SRC, determines the next steps in the base recovery strategy while initial RRR efforts are underway. Upon completion of these initial RRR recovery tasks, the RRR OIC notifies the DCC of the situation and requests further instructions with respect to requirements for pavement repair operations. In all likelihood the recovery strategy will include numerous additional taskings for RRR team support. These could range from returning to dispersal locations in anticipation of follow-on attacks to continuation of pavement repair activities to expand airfield capabilities. Upon receipt of the applicable instructions, the RRR OIC dispatches the majority of the RRR team to its next series of taskings. A portion of the FOD removal team (primarily sweepers) is retained until the final inspection of the airfield pavements is accomplished. If no further sweeping is required, the remainder of the FOD removal team is released.

5.28.11.1. Before declaring the MOS open, the RRR OIC and NCOIC, along with the support team OIC inspect the MOS, taxiways, and access routes to ensure that:

- All craters have been repaired and meet RQC.
- AM-2 mats and/or FFMs are anchored in place.
- All necessary spalls have been repaired.
- Operating surfaces have been satisfactorily swept.
- Airfield lighting and arresting barrier, if required, are operational.
- Markings on the MOS and taxiways are completed and conflicting (old) markings have been obliterated.
- All tools, equipment, and unused components of AM-2 mats and FFMs have been removed from the operating surfaces.

5.29. Maintenance of RRR Repairs. Rapid runway repair crater and spall repairs are considered to be only temporary and require periodic inspection and maintenance. Whenever possible, observers should be posted near the MOS to observe deflection of crater repairs and to note the response of aircraft while passing over the repaired surfaces. Increased aircraft bounce will be an indication of deteriorating trafficability of the repair. Checks for rutting and sagging should be made after 10 to 20 aircraft passes. This interval can be extended to every 50 to 60 passes once initial settlement has occurred and confidence in the repairs has been gained. When any repaired crater has settled, rutted, or sagged by 2 inches (at its worst point) below the original flat surface of the repair, it must be releveled. An obvious exception would occur if a flush repair is required, in this situation the sag cannot exceed 3/4 of an inch. The inherent rigidity of folded fiberglass mats to bridge irregularities in the surface of the crushed stone layer beneath can result in inaccurate readings during RQC checks. Consequently, to ensure that the mat conforms to the shape of the stone surface beneath it, a vehicle should be parked on the mat while crater profile measurements are being taken. Surface roughness checks to determine the need for maintenance are identical to the repair quality criteria checks accomplished at the completion of the initial repairs. The same stanchions and sight rod are used. At least three profiles of each crater should be taken along obvious ruts or along equally spaced lines parallel to the existing runway centerline.

5.29.1. **Maintenance of AM-2 Mat Repairs.** The following steps should be conducted when performing maintenance actions on a failed crater repair involving an AM-2 FOD cover:

- Remove all of the nuts from the anchor bolts.
- Remove ramp units from both ends of the mat.
- Tow the AM-2 mat away from the crater.
- Grade off any high spots where the stone has been pushed up, fill ruts with additional crushed stone, and compact the surface.
- Check surface roughness to ensure that the repair surface is within tolerance.
- Cut off the tops of the old anchor bolts so that they are flush with the MOS surface.
- Tow the AM-2 mat over the crater. Replace the ramp units and drill new holes in the pavement for new anchor bolts. Offset the patch so that new holes are at least 6 inches from the original bolt holes.
- Reanchor the AM-2 mat to the pavement.

5.29.2. **Maintenance of FFM Repairs.** The following steps should be conducted when performing maintenance actions on failed crater repair involving a FFM foreign object damage protective cover:

- Remove all anchor bolts and bushings.
- Tow the FFM away from the crater.
- Grade off any high spots where the stone has been pushed up, fill ruts with additional crushed stone, and compact surface.
- Check surface roughness to ensure the repair surface is within tolerance.
- Tow FFM mat over the crater. Realign the mat so the holes in the mat are at least 6 inches from the original pavement bolt holes.
- Drill new holes in the pavement and reanchor the mat into position.

5.29.3. **Maintenance of Spall Repairs.** The following steps should be conducted when performing spall maintenance actions:

- Remove loose spall repair material and other debris.

- Make a new spall repair using Silikal®, cold mix asphalt, or quick setting cement.

5.30. Semipermanent Crater Repair (Army) Responsibilities. Current Joint-Service regulations establish policies, responsibilities, and procedures for Army troop construction support to the Air Force. In the context of postattack recovery, the Army is responsible for rehabilitation and repair of Air Force bases and facilities beyond the immediate emergency recovery requirement of the Air Force. The Army, in accordance with Joint-Service regulations, provides the requisite manpower and equipment, as well as the necessary materials, to meet Air Force specifications.

5.30.1. U.S. Army engineer units perform Air Force construction tasks on a general support or direct support basis. The execution of large construction projects (for example, the construction of an entire runway system in a theater of operations) will normally be on a general support, that is project directives basis. When performing general support missions, Army engineers remain under Army command and operational control. In executing emergency rehabilitation, considered direct support, Army engineer units expect to receive detailed operational requirements from the supported Air Force commander.

5.30.2. In overseas theaters, specific in-place Army engineer battalions are assigned the responsibility of performing airfield damage recovery in support of the Air Force. At some of these locations, joint training is being conducted and command and control arrangements are being practiced. From a RRR perspective, when Army engineers provide postattack support, they will upgrade the Air Force's rapid crater repairs to a semipermanent quality normally using a "gravity-grout" repair method. Semipermanent quality is defined as a repair that is expected to last a minimum of 90 days without additional attention.

5.31. Gravity-Grout Repair Procedures. The gravity-grout repair method mentioned previously is a repair system employed by the Army engineers in support of Air Force airfields which results in a semipermanent quality crater repair. The major steps involved in this repair procedure are as follows:

5.31.1. Excavate the expedient crater repair to a depth of approximately 30 inches below the runway surface.

5.31.2. Twelve to 15 inches of well-graded stone is placed in the crater and compacted with a vibrating roller or plate compactor.

5.31.3. Two layers of polyethylene sheeting are placed over the compacted stone to stop cement group percolating down into the stone. The sheeting should be trimmed to fit the bottom of the hole, and not brought up the sides, as this would inhibit bonding to the existing pavement.

5.31.4. Dowel bars may be drilled into the existing pavement as a load transfer mechanism, time permitting.

5.31.5. The remaining crater void is filled to one-third of its depth (about 5 inches) with a Portland cement grout, containing 1.2 percent calcium chloride as an accelerator.

5.31.6. Three-inch "single-size" ballast rock is tipped into the liquefied grout and leveled with a front-end loader to about 1-inch below pavement surface level.

5.31.7. After leveling, the ballast stone is compacted with a vibrating roller.

5.31.8. Grouting is resumed to bring the surface of the repair up to pavement level.

5.31.9. Normally it takes approximately 8 hours of curing before the repair is ready to support fighter and transport aircraft traffic.

5.32. Chapter Summary. The airfield runway has always been a vulnerable target for enemy air attack. The widespread use of hardened aircraft shelters to protect aircraft on the ground has made the runway an even more desirable target of an enemy intent on dominating the sky. To counter this threat, civil engineer forces must be capable of completing rapid runway repair in the shortest time possible.

5.32.1. This chapter provided information and guidance on organization, equipment, materials, and methods for rapid runway repair. The chapter was designed to be used as a ready reference, as well as a guide when conducting training.

5.32.2. By using the material presented in this chapter; the technical data included in the Prime BEEF Home Station Training Courses of Study, Volume III; and the technical orders for folded fiberglass mat use (T.O. 35E- 2-3-1) and crushed stone crater repair (T.O. 35E-2-5-1); civil engineer units should be able to build a viable RRR home station training program.

Chapter 6

AIRFIELD MARKING PROCEDURES

6.1. Introduction. The marking of an airfield must adhere to precise guidelines. Air Force Instruction (AFI) 32-1042, *Standards for Marking Airfields*, outlines very specific requirements for marking airfield surfaces to conform with recognized standards for aircraft operations. While these markings are considered ideal under normal circumstances, it is unlikely that sufficient time will exist following an enemy attack to restore the markings to their original condition. Repair crews will be rapidly repairing craters and other attack damage. The marking team must be ready to apply expedient techniques that will mark the usable runway surface in the shortest possible time if combat aircraft are to be launched and recovered. Minimum operating strip marking system (MOSMS) procedures are outlined in T.O. 35E2-6-1.

6.2. Restrictions. The methods discussed in this chapter are intended for use during extreme emergencies, such as enemy attacks, to quickly restore a runway to some degree of usefulness. The techniques described must not be employed as replacements for standard runway markings during peacetime. Specifically, these expedient procedures and marking configurations should be employed only when marking a minimum operating strip (MOS) under base recovery after attack (BRAAT) conditions.

6.3. Chapter Overview. This chapter is concerned with expedient runway marking procedures for aircraft operations. The current MOS marking system concept as addressed includes descriptions of the various system components and discussions of preattack and postattack activities. The basic layouts for marking a MOS are illustrated. Marking procedures described include obliteration of existing conflicting markings; painting of new MOS markings; and placement of edge markers, distance-to-go markers, and aircraft arresting system markers. Also covered are marking procedures that may be required if a grass, dirt, or other unimproved landing strip is developed to support contingency operations. The final section of the chapter deals with the marking of obstructions, damaged areas, or other hazards that may have been caused by an attack.

6.4. MOS Marking System The dimensions of the MOS that will be repaired by rapid runway repair (RRR) crews will vary primarily according to the type of aircraft the base will support and the environmental conditions to be expected following an attack. Although the nominal MOS dimensions for fighter aircraft operations are 50- by 5,000-feet, the length and width of the selected MOS could be greater. The MOS marking crew complement of the RRR team must be flexible enough to be able to respond to any number of MOS marking requirements. The MOS marking system that this crew uses provides much of this flexibility. This system includes four major components: edge markers, distance-to-go markers, aircraft arresting system markers, and a paint striping system. Each of the components can be used separately or in combination with each other, depending upon the extent of need. They also can be installed in any order in case time does not permit the entire system to be installed all at once. The MOS marking system contains sufficient material and equipment to mark a 10,000-foot MOS. Although it is doubtful that a MOS of this length will ever be a requirement for support of fighter operations, a system with this capability provides material redundancy for shorter MOS needs and the potential for expansion to support aircraft that may require much longer landing and takeoff surfaces.

6.5. Edge Markers. An edge marker consists of a 30- by 48-inch, hard rubber baseplate and a polystyrene foam "A" frame with 30- by 20-inch sides that have orange colored reflective covers (figure 6.1). The two components are secured together by hook and loop fasteners. The MOS marking system contains 138 of these markers. Edge markers are placed to the sides of and in line with the threshold and departure end of the MOS as well as along the sides of the MOS at 200-foot intervals. The markers along the sides of the MOS are positioned 4 to 10 feet from the MOS edge, depending on site conditions (figure 6.2). As is typical of runway marking devices, the edge markers are frangible and tops can easily be replaced.

Figure 6.1. Edge Markers (Shown With Edge Light & Transformer Cable).

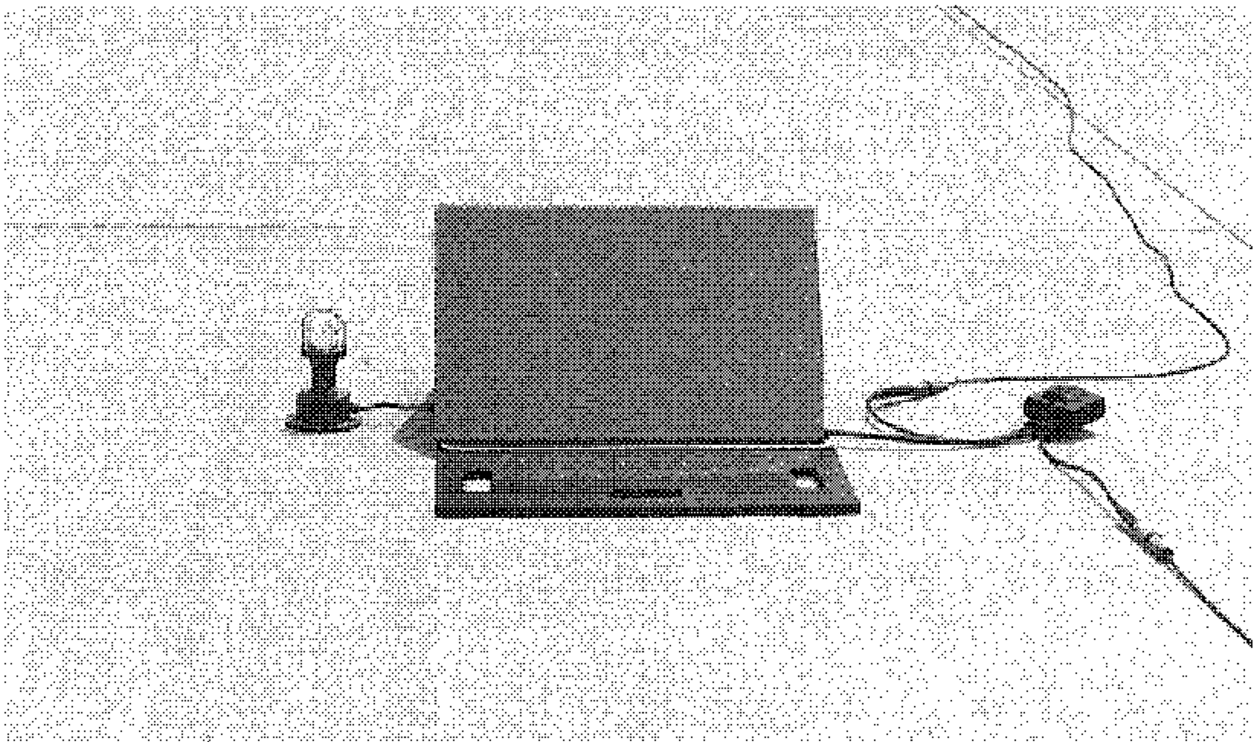
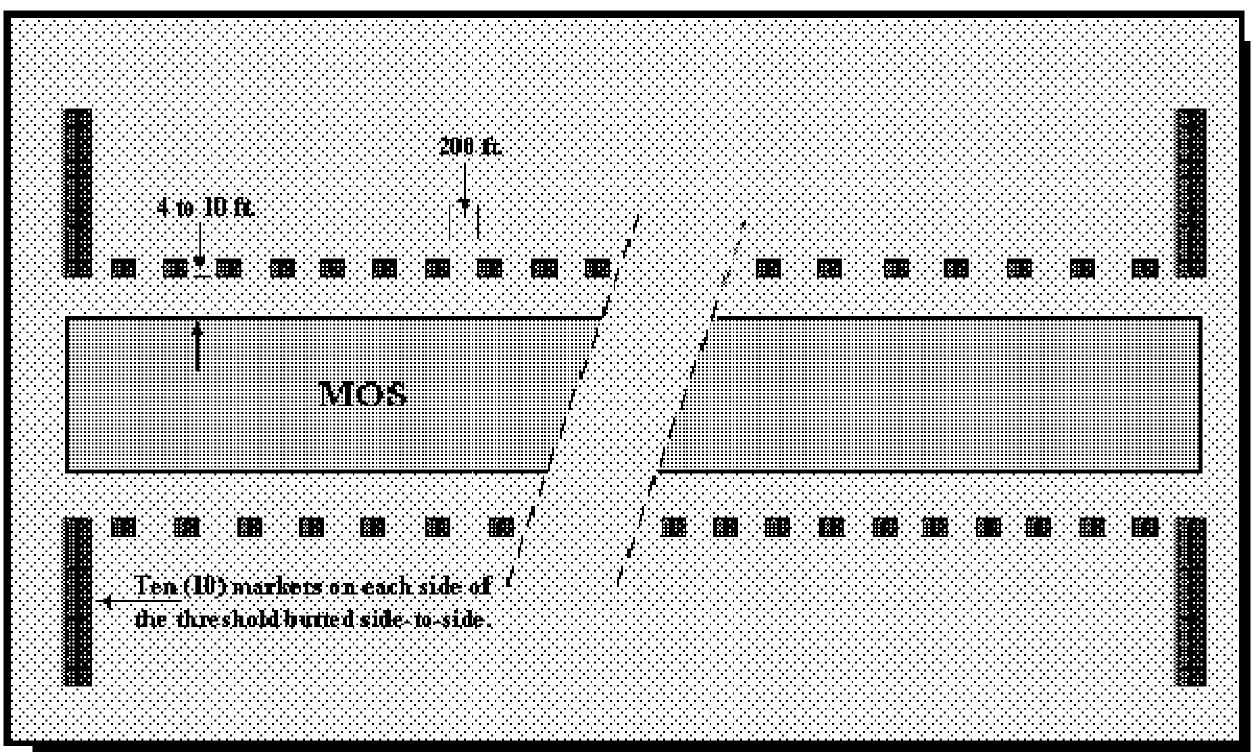
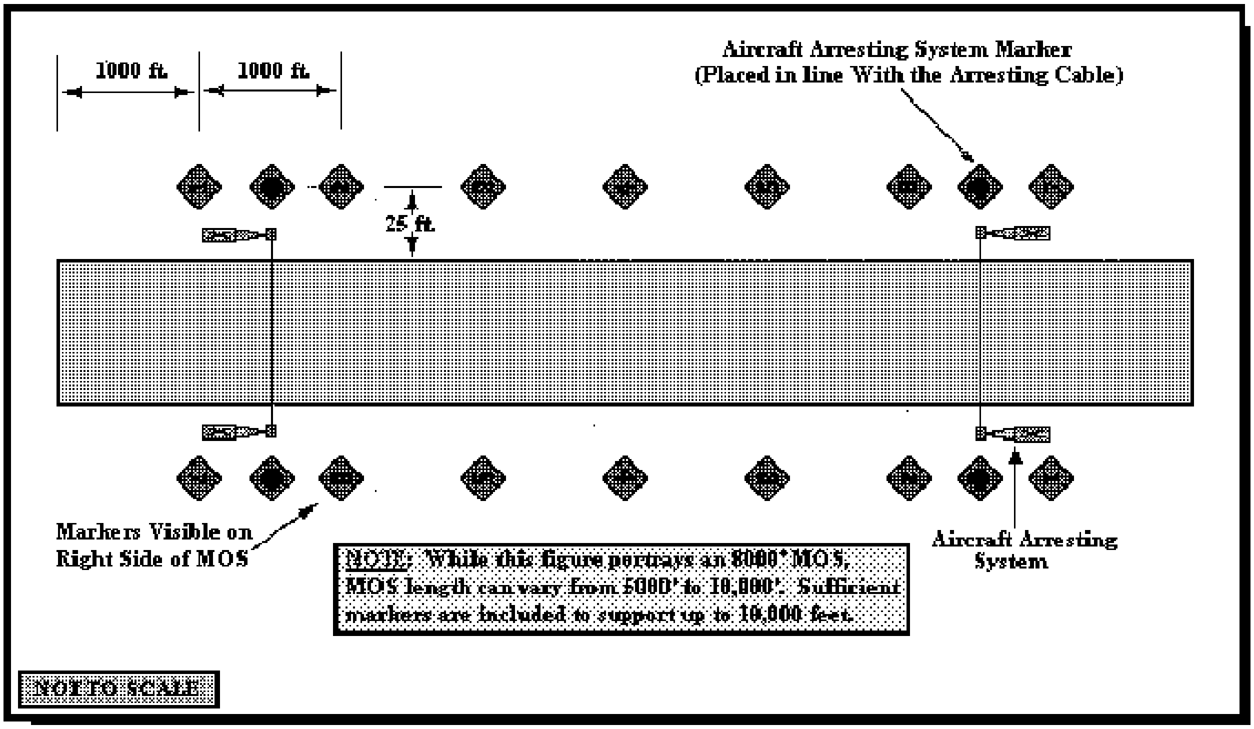


Figure 6.2. Edge Marker Placement.



6.6. Distance-To-Go Markers. Distance-to-go markers are 48-inch free standing, diamond shaped markers displaying single digit numbers on one side. Markers are placed 25 feet off the edge of the MOS and designate, in thousands of feet, the distance remaining to the end of the MOS (figure 6.3).

Figure 6.3. Aircraft Arresting System Marker and Distance-to-Go Marker Placement.



6.6.1. For unidirectional operations markers are placed only on one side of the MOS. For bidirectional operations markers are required on both sides of the MOS. The markers are turned so the pilots can read the numbers on the right side of the MOS in the direction of travel. The markers are stabilized by placing a minimum of one sandbag on each of two opposing legs. Sandbags are included as part of the MOS marking system. Eighteen distance-to-go markers are packaged in the MOS marking system; each packaged in its own individual carrying pouch.

6.6.2. Distance-to-go markers are 48 inches square and are colored bright orange. They have 2-inch black borders and 38-inch high, black numbers (figure 6.4). Assembly of the markers and their stands are depicted in figures 6.5, 6.6, and 6.7.

Figure 6.4. Distance-To-Go Markers.

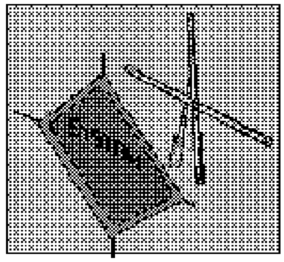
Figure 6.5. Initial Marker Assembly.

INITIAL MARKER ASSEMBLY INSTRUCTIONS

Sign-faces and crossbraces are shipped in separate cartons. Before you can use your System, these two pieces must be attached to one another as follows:

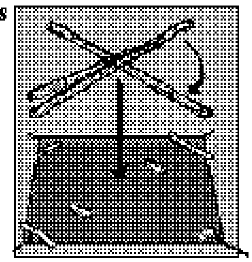
STEP 1:

Make sure you have both parts (sign-face and crossbrace)



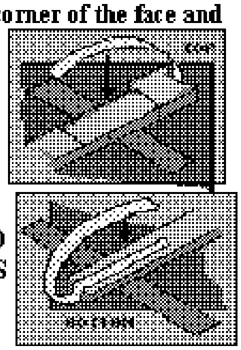
STEP 2:

Attach the two parts by first spreading the sign-face, face down, on the floor. Next, turn the crossbraces perpendicular to each other. Position the crossbrace over the sign-face with the crossbrace decals facing up. The crossbrace tip that does not have a rubber cap should be positioned at the bottom corner of the sign-face.



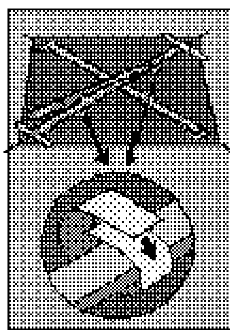
STEP 3:

With the crossbrace positioned carefully in the center of the sign-face, take the 1/2" Velcro strip on the top corner of the face and fold it back over the tip of the crossbrace -- pressing it down onto the Velcro strip on the crossbrace. Repeat this process to fasten the bottom corner. DO NOT FASTEN VELCRO SIDE STRAPS AT THIS TIME. Keep sign-face taut on the crossbrace, but be careful not to over strech it.



STEP 4:

Fasten the two interior Velcro straps around the vertical crossbrace.



THE SIGN-FACE IS NOW ATTACHED TO THE CROSSBRACE.

The assembled sign can be stored by turning the horizontal crossbrace parallel to the vertical one ... rolling the sign-face up around the crossbracing ... and securing it with the longer Velcro strap.

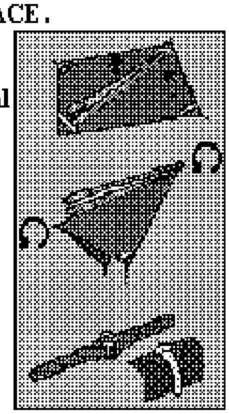


Figure 6.6. Marker Stand Assembly.

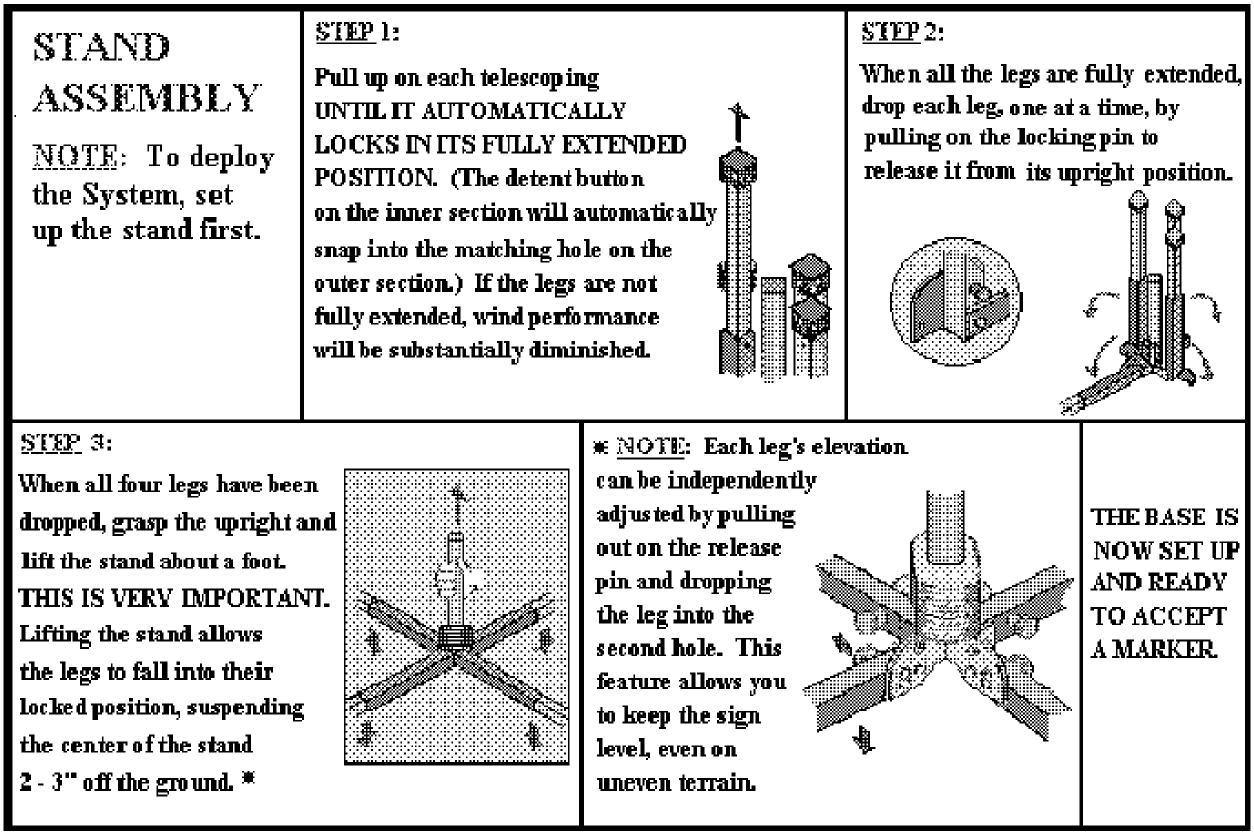
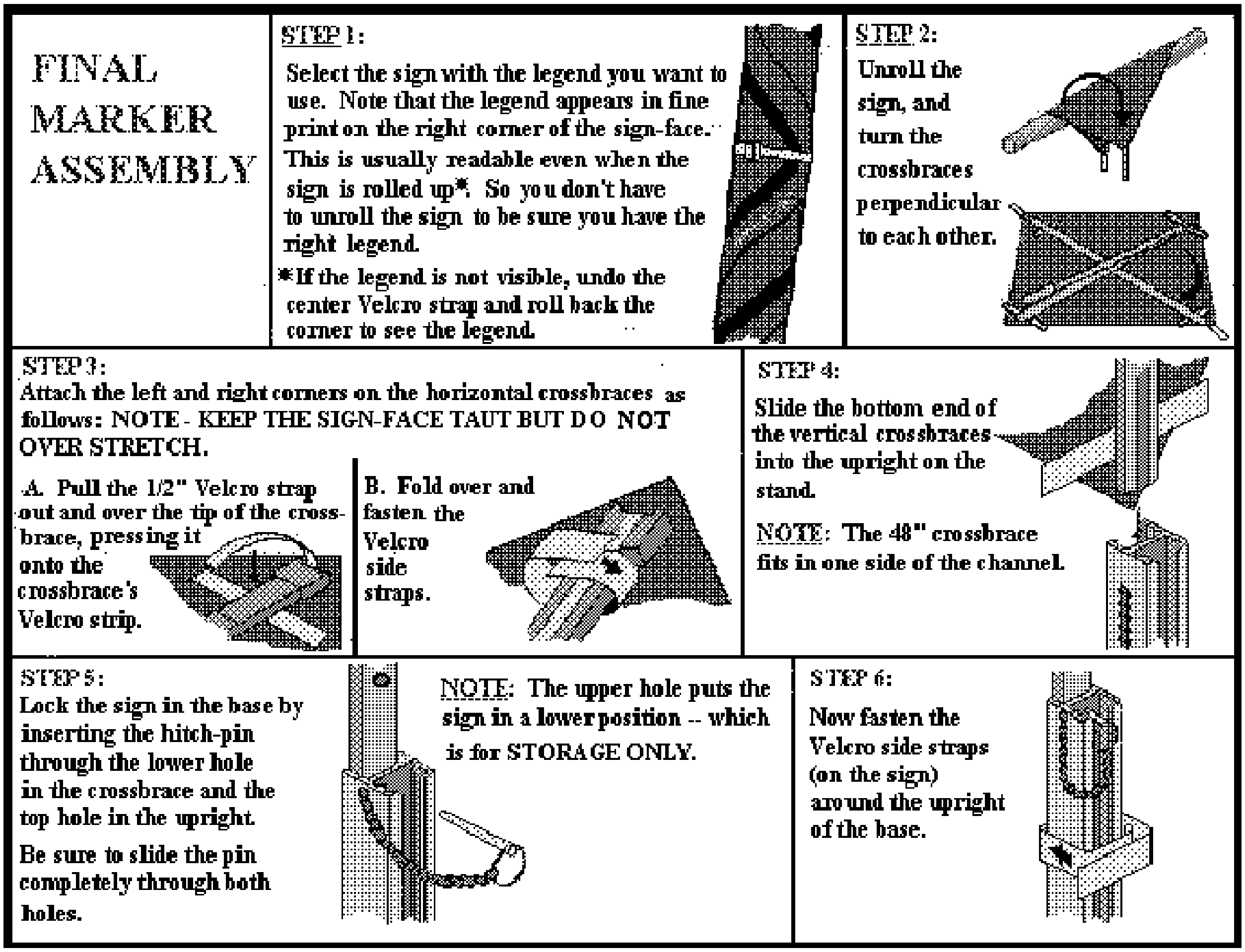
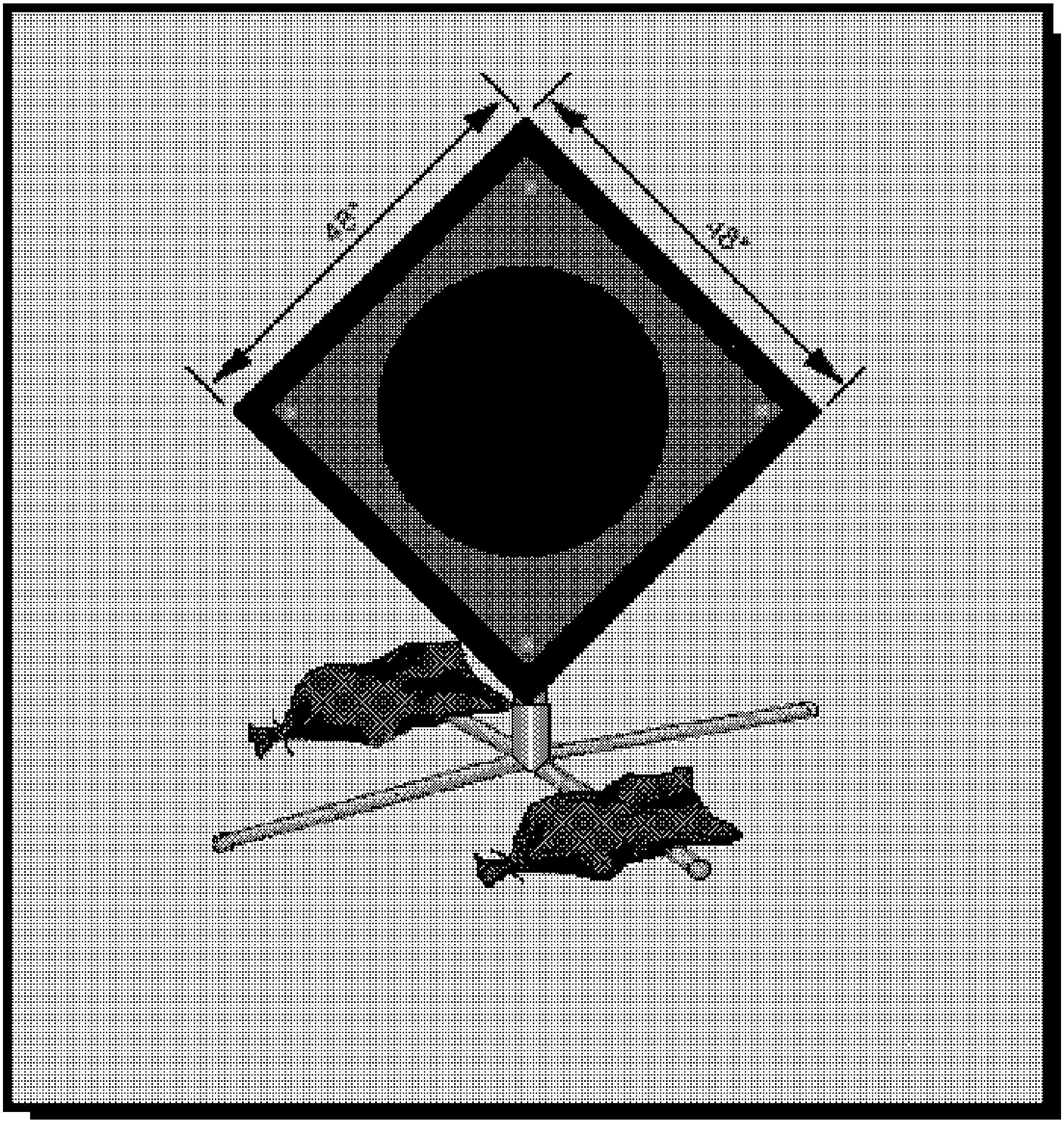


Figure 6.7. Final Marker Assembly.



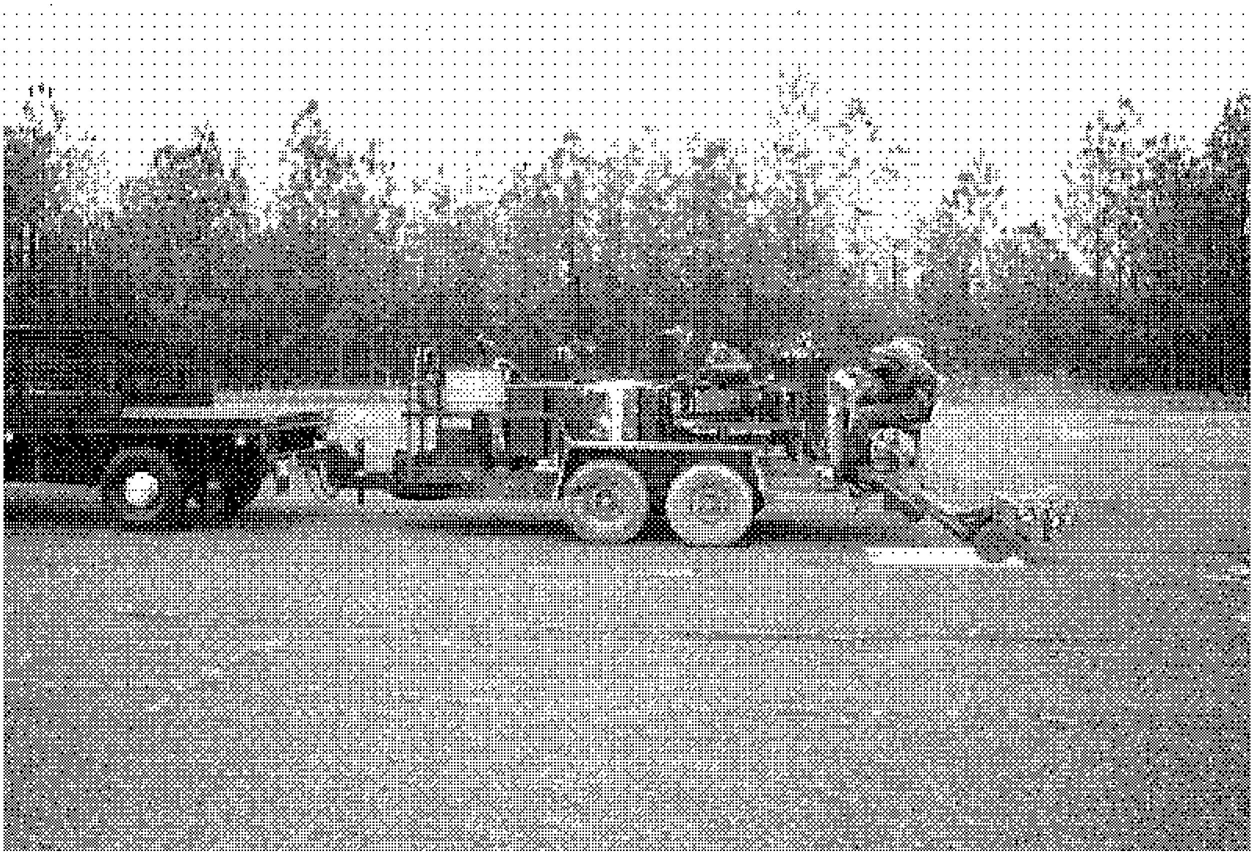
6.7. Aircraft Arresting System Markers. Aircraft arresting system markers are similar to distance-to-go markers. There are four aircraft arresting system markers in the MOS marking system. Two of these markers are placed on opposite sides of the MOS, 25 feet off the edge at each location of the aircraft arresting system, in line with the arresting cable (figure 6.3). The markers are diamond shaped, 48 inches on each side. Each side of the marker is identical with a bright orange background, a 2-inch black border, and a 40-inch black circle centered on the marker face (figure 6.8). The markers are stabilized by placing a minimum of one sandbag on each of two opposing legs. Assembly procedures for the aircraft arresting system markers are identical to that of the distance-to-go markers.

Figure 6.8. Aircraft Arresting System Marker.



6.8. Paint Striping System. Striping of the MOS is accomplished with a paint machine mounted on a trailer towed by a suitable vehicle (figure 6.9). The striping machine can also be removed from the trailer and mounted in the bed of a pick-up truck, if necessary. The paint machine can pump paint from two internal paint tanks or from paint drums placed on the front of the trailer. A diesel engine is used to drive a hydraulic pump, an alternator, and an air compressor. The hydraulic pump provides pressure that drives an airless paint pump. The paint is distributed through three paint guns that are mounted on a towed carriage. The air compressor pressurizes a cylindrical glass bead tank. Glass beads are fed from the tank to three bead guns also located on the towed carriage.

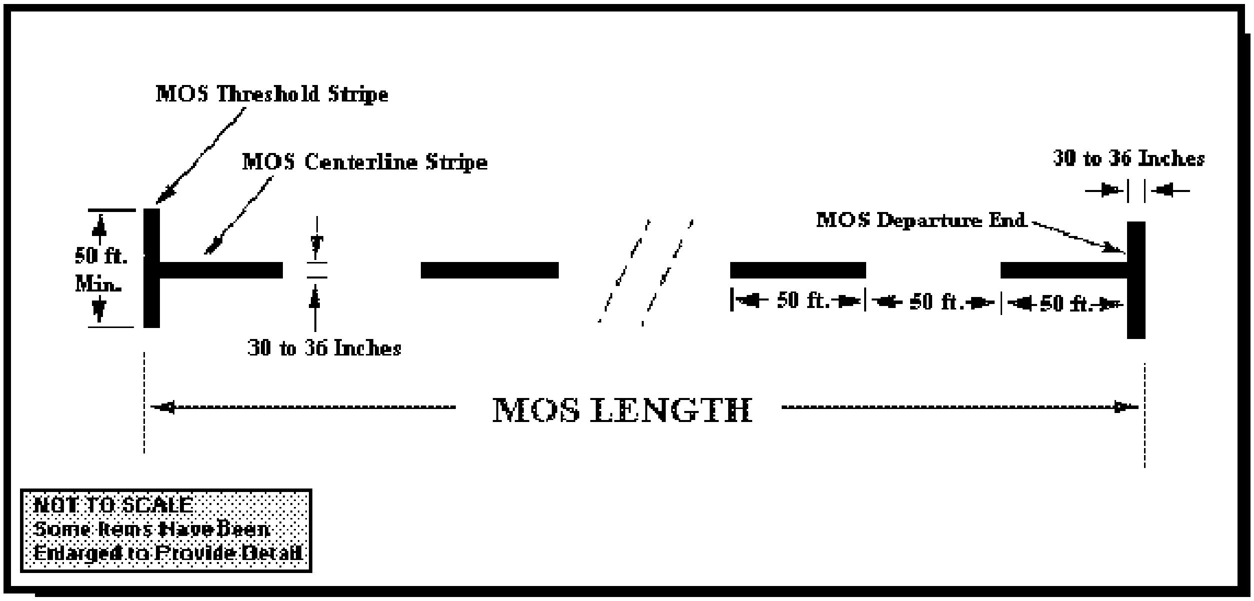
Figure 6.9. Paint Striping Machine.



6.8.1. **Striping Requirements.** MOS marking includes striping the MOS centerline, threshold end line and departure end lines, and obliterating any existing runway markings that could cause confusion to pilots. MOS striping requirements are depicted in figure 6.10. They include marking the full width of both ends of the MOS with a solid stripe and painting the centerline of the MOS with 50-foot stripes separated by 50-foot intervals. All markings are 30 to 36 inches wide. Fast drying white traffic paint with glass reflective beads is used. Obliteration of existing markings is accomplished using black traffic paint. The degree of obliteration required depends upon the location of the MOS with respect to the existing runway and taxiway pavements. For planning purposes the following obliteration priorities for existing markings on the MOS should be used:

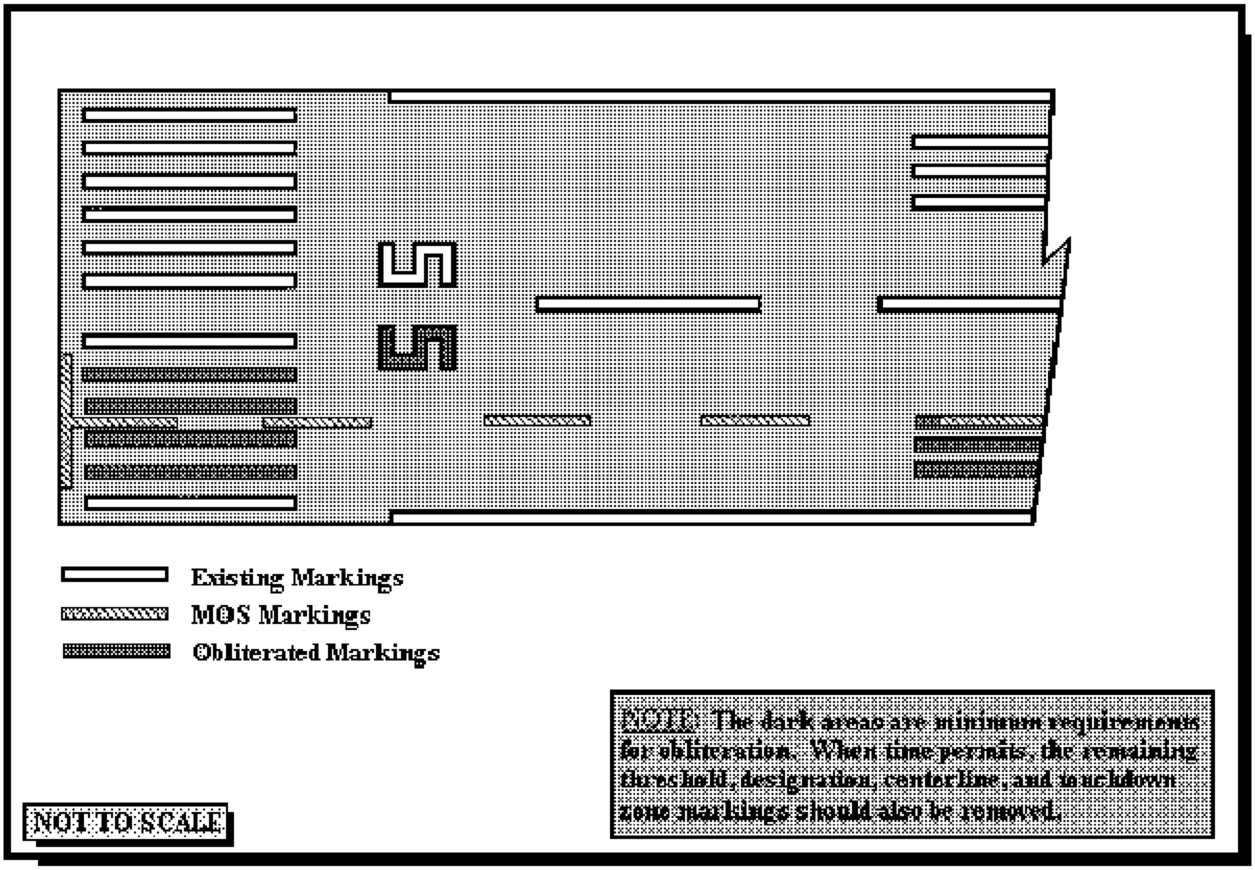
- Threshold markings
- Designation markings
- Centerline markings
- Aircraft arresting system markings
- Taxiway lead in/lead out line markings
- Touch down zone markings
- Fixed distance markings

Figure 6.10. MOS Striping.



6.8.2. **Marking Obliteration.** Figure 6.11 illustrates a typical example of old marking obliterations on a MOS. At the completion of MOS striping activities there should be no paint markings on the new MOS other than those shown in figure 6.10. If time permits, or after flying operations have resumed, further marking obliteration may be pursued, particularly in the approach zone of the airfield. The same priorities as above should be followed for obliteration of existing markings not on the new MOS. An alternative for blacking out these off-the-MOS markings is the use of a large "X" similar to the standard closed pavement marking. The primary purpose of blacking out these off-the-MOS markings is to preclude a pilot from mistaking them as part of a serviceable airfield pavement.

Figure 6.11. Marking Obliteration.



6.9. MOS Marking Procedures.

6.9.1. **Advanced Planning.** While the majority of time sensitive MOS marking activities will occur in the period immediately following an attack, many preattack actions must be accomplished to ensure postattack taskings can be met. For example, much advanced planning and training must be completed. Specifically:

6.9.1.1. MOS marking team members must be identified and trained. Sufficient personnel must be trained to ensure any losses from attrition can be overcome. Team members normally come from the structural and engineer technician career fields. As a minimum, team members must receive hands-on training on the operation of the paint striping machine and assembly of the edge and distance-to-go markers. Additionally, they also must be instructed on proper marker spacing and layout procedures and typical MOS painting requirements.

6.9.1.2. Vehicle support for the MOS marking team must be pre-identified. Minimum operating strip marking vehicles are not included as part of the RRR fleet; therefore, they must come from the other civil engineer or base assets. Procedures need to be established that will ensure the vehicles become immediately available upon reaching a pre-defined stage of Defense Readiness Condition (DEFCON) alert.

6.9.1.3. Dispersal locations for MOS marking materials and equipment must be identified in appropriate plans. Use a minimum of two separate sites with like sets of equipment going to each location. For example, place one-half of the distance-to-go and edge markers at one dispersal site and the other half of the markers at another.

6.9.1.4. Adequate stocks of paint and glass beads must be procured and stored. Sufficient white paint to complete a 10,000-foot MOS must be available along with enough black paint to obliterate at least one half of all existing runway markings. In addition to the paint and beads, a stock of thinner or solvent should be maintained to allow immediate clean up of the paint striping machine once MOS striping is completed.

6.9.1.5. Tools required for MOS marking must be gathered and stored with the MOS marking system components. Such tools include a 200-foot tape, shovels, and brooms. Sufficient numbers of empty sandbags should also be included with the tool sets.

6.9.2. **Preattack Activities.** In addition to the advance planning requirements, once preattack posturing commences, further preparatory activities for MOS marking systems are necessary. For example:

6.9.2.1. Two MOS marking vehicles must be obtained from the pre-determined vehicle fleet and properly fueled and checked.

6.9.2.2. MOS marking equipment, tools, and materials must be drawn from storage, unpacked, and separated for dispersal.

Besides the system components themselves, adequate quantities of marking paint and glass beads must be pulled from storage and loaded onto the MOS support vehicles. As the paint is drawn from storage, the drums should be agitated by rolling to mix the paint.

6.9.2.3. Adequate numbers of sandbags must be filled and loaded onto the MOS vehicles.

6.9.2.4. All personnel trained in MOS marking procedures should be assigned shelters along with other RRR team members. Care should be taken not to shelter all MOS marking trained personnel in the same location to preclude the loss of MOS marking capability if a shelter is seriously damaged during an attack. A primary MOS marking team (six personnel) must be specifically identified out of all those personnel trained in MOS marking procedures. One specific individual (preferably an engineer technician--AFS 3E571) must be designated as crew chief. The RRR support team OIC needs to be informed of the location and composition of the MOS marking team.

6.9.2.5. The MOS paint striping machine must be fueled and operationally checked.

6.9.2.6. When directed by the civil engineer damage control center (DCC), MOS marking system vehicles, equipment, and materials are placed in their assigned dispersal locations.

6.9.3. **Postattack Activities.** As with other RRR activities, the MOS marking team reacts in response to direction received from the DCC. Once the RRR OIC obtains the overall scope of the RRR requirement, MOS marking data are provided to the RRR support team OIC. Such data would include MOS location, length, and width; arresting barrier location; major areas of crater repair activity; haul route locations; and any potential hazards such as unexploded ordnance or bomblet fields. A sketch on a base map is ideal for this purpose. The RRR support team OIC briefs the MOS marking team chief (and other team members if possible) on the probable scope of the MOS marking effort and reiterates what must be accomplished in the way of MOS layout when the marking team arrives at the MOS area.

6.9.3.1. **Team Configuration.** Details regarding the sequencing and overall requirements for MOS layout are contained in chapter 5 and will only be highlighted here to provide a composite picture of the MOS marking team's activities. The six-person MOS marking team is normally configured into two crews which work concurrently. Two personnel are assigned paint striping requirements while the remaining four accomplish MOS layout and marker placement tasks. The engineer technician assigned to the MOS marking team leads the larger four-person crew.

6.9.3.2. **Layout and Placement Tasks.** When directed to commence airfield recovery operations by the DCC, the MOS marking team, as part of the full RRR complement, moves to the RRR staging area from its dispersal locations. The team then receives its instructions from the RRR support team OIC and reconfigures one of its supporting vehicles with the requisite number of traffic cones, edge markers, sandbags, etc. When clearance has been received to start airfield damage repair, the four-person crew immediately proceeds to the designated MOS area to perform MOS layout and marker placement tasks. The normal order of these tasks is as follows:

- MOS threshold layout (traffic cones).
- MOS centerline layout with "T" zones as necessary (traffic cones).
- Mobile aircraft arresting system (MAAS) location identification (traffic cones).
- Precision approach path indicator (PAPI) system location layout (traffic cones).
- Edge and distance-to-go markers.
- MAAS marker placement.
- Approach lighting location identification (traffic cones).

6.9.3.3. **Alignment Checks.** When all cones and markers have been placed, the MOS marking team crew chief checks the finished job to ensure alignment is reasonable, distance-to-go markers are sequenced correctly, and no unnecessary traffic cones, marker components, or carrying pouches have been left behind.

6.9.3.4. **Final Actions.** The final major task of the four-person crew is to remove any existing airfield marking signs that may pose problems relating to MOS acquisition and use by pilots. This normally involves removal of existing distance-to-go and aircraft arresting system location markers. The RRR support team OIC makes an on-scene determination of what markers should be dismantled. Once this determination is made, the airfield lighting or MAAS installation crew (whichever is most readily available at the time) is tasked to disconnect and dismantle the chosen markers. The four-person crew then removes these markers taking care not to damage them since, in all likelihood, they will eventually be reinstalled once semipermanent repairs are made to the airfield.

6.10. MOS Striping.

6.10.1. **Striping Machine Preparations.** The two-person MOS striping crew prepares the paint striping machine for centerline striping by loading white paint, black paint and glass beads into the appropriate tanks on the machine. Although not part of the paint striping machine, a 55-gallon drum should also be placed on the trailer and filled with water. The water is necessary to flush the system when paint colors are switched. The spray guns are adjusted to provide a 30- to 36-inch wide stripe and the controller mechanism on the machine is set to maintain the 50-foot stripe intervals. Assuming explosive ordnance disposal (EOD) personnel have cleared/safed all unexploded ordnance, it is likely that much of the MOS will be accessible for striping purposes and that crater repair actions will be concentrated in only two or three locations. The striping crew will have to work around these repair actions until they become available for marking near the end of the RRR time window. To a lesser extent, the striping team may also have to work around any major spall fields until spalls that interfere with striping requirements are repaired. The spall repair teams will normally repair these first and then move on to those spalls which do not conflict with MOS striping activities. The RRR support team OIC will have to ensure that the spall repair teams are aware of spall field areas that potentially conflict with MOS striping. This is easily done by instructing the spall repair teams to repair areas near and between the centerline marking cones or paint marks first. The RRR support team OIC must also instruct the foreign object damage (FOD) removal team to initially make a pass or two with sweepers (and grader if necessary) along the centerline location of the selected MOS.

6.10.2. **Painting Order.** Starting at one of the MOS ends (typically the threshold), the end stripe is first painted. Painting of the centerline is then accomplished using the traffic cones or paint marks placed earlier by the four-person crew as a centering guide. Areas where access is not possible, due to on-going repair efforts, are by-passed for the time being. Once as much of the centerline is striped as possible, the other end stripe is painted. For areas that may not be easily accessible with the paint machine, the paint wand provided with the machine is used. After centerline and end stripes are completed, the MOS striping crew picks up all centerline traffic cones (if used) that are no longer required as painting guides. **NOTE:** If time permits, consider painting the MOS ends after the centerline in order to avoid tracking fresh paint all over the area.

6.10.3. **Obliteration Steps.** When as much white painting is completed as practicable, black paint is used to obliterate any existing airfield markings that could interfere with aircraft operations or mislead pilots. The RRR support team OIC must ensure sufficient support from the FOD removal team is provided to uncover any existing painting that must be obliterated. When obliteration of existing markings on the MOS is completed and if time permits, the striping crew starts obliterating existing off-the-MOS markings that could interfere with landing approaches. Prioritization of what markings to remove was addressed earlier in this chapter. This off-the-MOS activity, however, should only be attempted if the areas are free from unexploded ordnance and little or no support is required from FOD removal team personnel.

6.10.4. **Deferred Areas.** As the MOS repairs near completion, the striping crew reloads white paint and glass beads, if necessary, into the machine. The RRR support team OIC must ensure the striping crew starts this activity in sufficient time to dovetail with repair completions. Once MOS repair areas become accessible, the striping crew proceeds to stripe those areas that were by-passed earlier. Although there should be relatively little striping to accomplish, care must be taken to maintain a reasonable approximation of the 50-foot spacing between stripes. At the completion of this last bit of centerline striping, the MOS striping crew picks up any remaining traffic cones in the area and leaves the MOS along with other members of the RRR team.

6.10.5. **Final Actions.** Immediately after leaving the airfield area, the MOS striping crew flushes and cleans the paint machine. This also includes removing all glass beads from the bead tank on the machine. If no further immediate need for airfield painting is identified, the paint striping machine is returned to storage or dispersal as determined by the DCC. In all likelihood, however, additional obliteration on the airfield will be needed along with new markings on access taxiways. Arrangements for these efforts are made by the DCC and for the most part will be driven by operational flying requirements.

6.10.6. **Other Considerations.** The preceding paragraphs indicate the application of white paint is performed before obliterating existing markings with black paint. Actually, the order of painting will be situation-specific. There could be occasions where black paint application might take precedence, e.g., the MOS being on the centerline of the original runway. The order of painting will be determined by the RRR support team OIC and provided to the MOS striping crew during the postattack briefing.

6.11. Marking of Unimproved Landing Strips. Under some conditions it may become necessary to use grass, dirt, or other unimproved landing strips for military operations (usually involving C-130 aircraft). When the area in use is large and relatively uniform, it may not be crucial to specifically define the limits of the landing area. Where the lateral and longitudinal limits of a runway do require visual definition, single markers are placed within 15 feet of the edge of the runway, and opposite each other on both sides of the runway at intervals not to exceed 300 feet. Double markers are provided on each side of the runway at both ends, and at 100 feet inward from the runway in the direction of landing. The outer of the two markers are located not more than 15 feet laterally from the inner row of markers. Detailed instructions for construction of these markers are covered in ETL 9401 (Engineering Technical Letter), dated 5 April 1994 and AFJMAN 32-1015.

6.12. Marking of Obstructions/Hazardous Areas. An extensive enemy attack on an air base is sure to damage airfield surfaces beyond what can quickly be repaired. Even after a MOS has been selected, repaired, and marked, damage will remain which could cause hazards to aircraft operating in and out of the airfield. Air Force Instruction 32-1042, Section G, outlines procedures that are to be used to identify pavements that are closed or hazardous to aircraft traffic. Although these procedures may not apply following an enemy attack, they do serve as excellent guides for the development of methods for marking hazardous pavements during emergencies.

6.12.1. **Closed Areas.** According to AFI 32-1042, closed runways, taxiways, and aprons are marked with a non-reflective yellow capital "**X**".

6.12.2. **Hazardous Areas.** Where a hazardous area, such as a bomb crater, exists in or adjacent to an active pavement that cannot be closed to aircraft traffic, the area should be outlined with markers and lights. At all corners and ends, dual markers and lights should be used. A single marker and light should be positioned every 50 feet or less between the corners. The markers may be either low (1-foot or less in height) or high (2 to 3 feet in height) profile barricades.

6.13. Summary. The need to quickly mark the minimum operating strip following an attack by hostile forces requires that expedient runway marking procedures be used. There is not time to restore the entire airfield to the standards required during peacetime operations. The markings restored should be the minimum necessary for aircraft operations to support the air base mission. The MOS marking system provides the basic components for establishing the minimum markings required for combat aircraft launch and recovery. The system includes MOS edge markers, distance-to-go markers, aircraft arresting system markers, and a pavement paint striping capability. Standard runway marking paints should be used and base civil engineering units must ensure an adequate stock of such paint is available. Any existing runway markings that could cause confusion regarding the location of the MOS must be obliterated. Field tests have shown that the entire marking system can be deployed well within the overall RRR time frame. However, such testing was performed under sterile, non-hostile conditions--expect and plan for delays.

6.13.1. **Unimproved Landing Strips.** The marking of unimproved landing strips will depend on the condition of the landing surface and the operational objectives of the aircraft which use the strip. Hazardous areas on or adjacent to active airfield pavements should be clearly marked to avoid accidents which could reduce the effectiveness of aircraft operations.

6.13.2. **Variation Considerations.** The information provided in this chapter is intended as general guidance for expedient marking of airfield surfaces. The specific tasks required to quickly mark a runway surface following an attack will vary with each situation. Use your experience and engineering knowledge to integrate these suggestions into an effective plan for the accomplishment of runway marking requirements.

EUGENE A. LUPIA, Maj General, USAF
The Civil Engineer

GLOSSARY OF REFERENCES, ABBREVIATIONS, ACRONYMS, AND TERMS

References

AFDD 42, *Civil Engineer*

AFI 10-208, *Continuity of Operations Plans*

AFI 10-209, *RED HORSE Program*

AFI 10-210, *Prime Base Engineer Emergency Force (BEEF) Program*

AFI 10-211, *Civil Engineer Contingency Response Planning*

AFI 10-404, *Base Support Planning*

AFI 25-101, *War Reserve Materiel (WRM) Program Guidance Procedures*

AFI 25-201, *Support Agreements Procedures*

AFI 32-1026, *Planning and Design of Airfields*

AFI 32-1042, *Standards for Marking Airfields*

AFI 32-3001, *Explosive Ordnance Disposal Program*

AFI 32-4001, *Disaster Preparedness Planning and Operations*

AFI 32-4007, *Camouflage, Concealment and Deception*

AFI 37-101, *War and Contingency Planning*

AFMAN 32-4005, *Personnel Protection and Attack Actions*

AFMAN 10-401, *USAF Operation Planning Process*

AFPAM 10-219, *Volume 1, Contingency and Disaster Planning*

AFPAM 10-219, *Volume 2, Preattack and Predisaster Preparations*

AFPAM 10-219, *Volume 3, Postattack and Postdisaster Procedures*

AFPAM 10-219, *Volume 5, Bare Base Conceptual Planning Guide*

AFPAM 10-219, *Volume 7, Expedient Construction Methods*

AFH 10-222, *Volume I, Guide To Bare Base Development*

AFH 10-222, *Volume II, Guide To Bare Base Assets*

AFJAM 32-1030, *Engineering Use of Geotextiles*

AFJPAM 32-8013, volume 1, *Planning and Design of Roads, Airfields and Heliports in Theater of Operations -Road Design*

AFJPAM 32-8013, volume 2, *Planning and Design of Roads, Airfields and Heliports in Theater of Operations - Airfield and Heliport Design*

Other References

TO 35E2-5-1	*Crushed-Stone Crater Repair and Line-Of-Sight Profile Measurement for Rapid Runway Repair*
TO 35E2-6-1	*Minimum Aircraft Operating Surface Marking System*
TO 35E8-2-10-1	*Arresting Systems, Aircraft, Mobile Model NO.A/M 32A-96 (MAAS)*
TO 35E2-4-1	*Repair Quality Criteria System for Rapid Runway Repair*
TO 35E2-3-1	*Folded Fiberglass Mats for Rapid Runway Repair*
TO 35F5-3-17-1	*Lighting System, Airfield, Emergency A/E82U-2*
TO 36C35-7-1	*Paint Stripping Set (AFI20 SET)*
TO 36Y27-5-1	*Concrete Cutting Saw Set (Model MSCRRR-01)*

Related Audiovisual Training References

PIN #	Program Title
30790	*Camouflage, Cover and Concealment (Two Parts)*
602413	*Constructing Fighting Positions, Part I*
602414	*Constructing Fighting Positions, Part II*
604725	*Hardening of Critical Facilities and Utilities*
606035	*Survive to Operate*
606039	*Protective Shelters*
606041	*Individual Protective Equipment*
608408	*Explosive Ordnance Reconnaissance, Part I*
608408	*Explosive Ordnance Reconnaissance, Part II*
608660	*Explosive Ordnance Reconnaissance*
609930	*Prime BEEF Wartime Command and Control*
609978	*Introduction to Resource Dispersal*
610384	*An Overview of the RRR Process*
610619	*Introduction to Fiberglass Mat Repair*
610735	*Introduction to AM-2 Method of RRR*
611348	*Introduction to Airfield Spall Repair*
611902	*Folded Fiberglass Mat Procedures*
611954	*Crushed Stone Crater Repair*
612714	*EOD Overview*
612819	*DP Overview*
612838	*Emergency Airfield Lighting System (EALS)*
613017	*Contingency Airfield Marking System*
613113	*Camouflage, Concealment and Deception*
613065	*Damage Assessment and Response Team (DART) Procedures*
613113	*Camouflage, Concealment and Deception*
613177	*Lightweight Screening System*

Allowance Standards References

AS 012	*Vehicles*
AS 156	*Air Base Operability and War Reserve Material Support Equipment*
AS 429	*RED HORSE and Prime BEEF/RIBS Teams*
AS 660	*Non-Weapons Systems Communications Requirements*

Abbreviations and Acronyms

ABO	Air Base Operability
AF	Air Force
AFB	Air Force Base
AFCESA	Air Force Civil Engineer Support Agency
AFH	Air Force Handbook
AFI	Air Force Instruction
AFJAM	Air Force Joint Manual
AFPAM	Air Force Pamphlet
AFS	Air Force Specialty
AS	Allowance Standard
BCE	Base Civil Engineer
BDOC	Base Defense Operations Center
BRAAT	Base Recovery After Attack
CAGE	Commercial and Government Entity
C^2	Command and Control
CE	Civil Engineer
COB	Collocated Operating Base
CONTEST	Contingency Testing
CONUS	Continental United States
CPM	Crater Profile Measurement
CSG	Combat Support Group
CW	Chemical Warfare
CWD	Chemical Warfare Defense
DART	Damage Assessment and Response Team
DAT	Damage Assessment Team
DCC	Damage Control Center
DEFCON	Defense Readiness Condition
DO	Director of Operations
DOD	Department of Defense
DP	Disaster Preparedness
DR	Density Ratio
DTG	Distance-To-Go
EALS	Emergency Airfield Lighting System
EAP	Emergency Action Procedures
EOD	Explosive Ordnance Disposal
EOR	Explosive Ordnance Reconnaissance
FEL	Front-end Loader
FFM	Folded Fiberglass Mat
FGM	Fiberglass Mat
FOD	Foreign Object Damage
GCA	Ground Control Approach
GCE	Ground Crew Ensemble
HMMWV	High Mobility Multipurpose Wheeled Vehicle
IPE	Individual Protective Equipment
JCS	Joint Chiefs of Staff
JSCP	Joint Strategic-Capabilities Plan
LOR	Launch or Recovery
LRC	Logistic Readiness Center
MAAS	Mobile Aircraft Arresting System
MAJCOM	Major Command
MAOS	Minimum Airfield Operating Surface
MDAS	Manual Damage Assessment System
MOB	Main Operating Base
MOS	Minimum Operating Strip
MRSP	Mobility Readiness Spares Package
NAVAIDS	Navigational Aids

NBC	Nuclear, Biological, and Chemical
NSN	National Stock Number
OCONUS	Overseas Continental US
OI	Operating Instruction
O&M	Operation and Maintenance
OPLAN	Operation Plan
OPR	Office of Primary Responsibility
PACAF	Pacific Air Forces
PAPI	Precision Approach Path Indicator
PFM	Polyurethane Fiberglass Mat
POL	Petroleum, Oils and Lubricants
Prime BEEF	Prime Base Engineer Emergency Force
PSP	Pierced Steel Planking
RCR	Runway Condition Reading
REOTS	Regional Equipment Operator Training Site
ROWPU	Reverse Osmosis Water Purification Unit
RQC	Repair Quality Criteria
RRR	Rapid Runway Repair
SCPS	Survivable Collective Protection System
SFES	Silver Flag Exercise Site
SMT	Square Mesh Track
SMUD	Standoff Munition Disrupter
SOF	Supervisor of Flying
SP	Security Police
SRC	Survival Recovery Center
STS	Special Training Site
SWA	Southwest Asia
TA	Table of Allowance (Obsolete Term--See AS)
TACAN	Tactical Air Navigation
TM	Technical Manual
TO	Technical Order
TOL	Takeoff and Landing
USAFE	United States Air Forces in Europe
UTC	Unit Type Code
UXO	Unexploded Ordnance
VASI	Visual Approach Slope Indicator
VDAS	Vehicle Damage Assessment System
WMP	War and Mobilization Plan
WOC	Wing Operations Center
WRM	War Reserve Materiel
WRSP	War Readiness Spares Package
WTS	Wartime Task Standard

Terms

NOTE: The acronyms and terms shown in this attachment may not always agree with what is presented in Joint Publication 1-02 (*DOD Dictionary*) or AFMAN 11-1 (*Air Force Glossary of Standardized Terms*). However, the acronyms and terms included are common to the engineering community as a whole.

Access Route. The route aircraft must take from the parking area/shelter to the MOS. Typically the route will meander to avoid damage. The time to clear or repair the access route is a consideration in MOS selection. The terms "transition path, taxiway, and transition route" are sometimes used to indicate an access route on a launch/recovery surface.

Air Base Operability (ABO). The integrated capability of an installation to defend against, survive the effects of, and recover from hostile action, thus supporting effective wartime employment of air power. Air base operability provides the sustained operational capability to wage war.

Alarm Black. An alert condition signifying that the attack is over, but that chemical agent contamination is possible. Personnel are cleared to leave the shelters, but they must wear chemical protective ensembles.

Area-Denial Weapons. Weapons designed to deny personnel access to an area. They usually are delayed-fusing munitions, such as mines or submunitions, that explode from time delay, disturbance, movement, or other such target activation.

Base Recovery After Attack (BRAAT). A theater concept of recovering a base after a conventional attack where resumption of flying operations is the first priority. Other recovery activities may be conducted concurrently; however, these activities must not impede the resumption of flying operations.

Camouflage. The use of natural or artificial material on personnel, objects, or tactical positions with the aim of confusing, misleading, or evading the enemy.

Camouflage, Concealment, And Deception. The use of concealment, disguise, and decoys to minimize the possibility of detecting or identifying troops, material, equipment, and installations. It includes taking advantage of the natural environment, as well as applying natural and artificial materials.

Camouflet. The resulting cavity in a deep underground burst when there is no rupture of the surface. Camouflets are considered to be a form of small crater.

Cannibalize. To remove serviceable parts from one item of equipment in order to install them on another item of equipment.

Chemical Monitoring. The continuous or periodic act of seeking to determine whether a chemical agent is present.

Chemical Warfare. All aspects of military operations involving the employment of lethal and incapacitating munitions/agents and the warning and protective measures associated with such offensive operations. Since riot control agents and herbicides are not considered to be chemical warfare agents, those two items will be referred to separately or under the broader term “chemical,” which will be used to include all types of chemical munitions/agents collectively. The term “chemical warfare weapons” may be used when it is desired to reflect both lethal and incapacitating munitions/agents of either chemical or biological origin--also called **CW**.

Chemical Warfare Defense. The methods, plans, and procedures involved in establishing and executing defensive measures against an attack involving chemical agents.

Collocated Operating Base (COB). A base, hosted by an ally, that can be used to beddown Air Force augmenting forces. COBs require civil engineering support to accommodate reception, beddown, launch, and recovery of USAF aircraft. A COB may be a main, standby, or limited base of the allies.

Collateral Protection. This is a term used to describe the level of protection provided by the Survivable Collective Protection System (SCPS). This method protects from weapon fragments, ground shock, and blast over pressures associated with the detonation of a 1000-pound general-purpose bomb at a miss distance of 21 feet. This includes a surface burst and a 14-foot depth of burial burst. This is the lowest level of protection to which chemical processing capability should be coupled.

Collective Protection Shelter. Shelter area which can provide protection from the effects of nuclear, biological, chemical, or conventional weapons for more than one individual.

Command And Control (C^2). The exercise of authority and direction by a properly designated commander over assigned forces in accomplishing the mission. Command and control functions are performed through an arrangement of personnel, equipment, communications, facilities, and procedures employed by a commander in planning, directing, coordinating, and controlling forces and operations in the accomplishment of the mission.

Continental United States (CONUS). United States territory, including the adjacent territorial waters, located within North America between Canada and Mexico.

Contingency. An emergency involving military forces caused by natural disasters, terrorists, subversives, or by required military operations. Due to the uncertainty of the situation, contingencies require plans, rapid response, and special procedures to ensure the safety and readiness of personnel, installations, and equipment.

Contingency Response Plan. A base civil engineer plan of action developed in anticipation of all types of contingencies, emergencies, and disasters.

Contingency Testing (CONTEST). An engineering evaluation program designed to assist commanders in assessing the individual knowledge level of Prime BEEF team members on contingency matters. Tests are structured into two categories: general knowledge and AFS specific.

Conventional Weapons. A weapon which is neither nuclear, biological, nor chemical.

Crater. The pit, depression, or cavity formed in the surface of the earth by an explosion. It may range from saucer shaped to conical, depending largely on the depth of burst. In the case of a deep underground burst, no rupture of the surface may occur. The resulting cavity is termed a camouflet.

Crater--Actual Diameter. The actual crater diameter is the diameter across the crater after the heaved pavement has been removed. In other words, the actual size of the required repair.

Crater--Apparent Diameter. The apparent crater diameter is the visible diameter of the crater, inside edge to inside edge, at the original surface level, prior to debris being removed. In actual practice, this can be measured from pavement edge to pavement edge. Apparent diameter is the information forwarded to the SRC by the damage assessment teams.

Crater--Large. Pavement damage from conventional weapons that penetrate or disturb the subgrade, resulting in a pavement damage area in excess of 20 feet in diameter.

Crater--Small. Similar to a large crater, except the pavement damage area is 20 feet or less in diameter.

Damage Assessment. The determination of the effect of attacks on targets (DOD). The process of identifying and locating damage and unexploded ordnance following an attack. Damage assessment activities generally are separated into two categories: airfield pavements and facility/utility.

Damage Assessment And Response Team. Teams formed from CE forces responsible for facility and utility damage assessment and isolating/safing damaged utility systems. These teams are assigned to the DCC.

Damage Control Center. The operations center established by the BCE to control and conduct postattack recovery operations with BCE forces. The DCC usually is headed by the BCE operations (O&M) chief and manned from the appropriate BCE Staff. Rapid runway repair and other BCE recovery operations are controlled from the DCC.

Debris. Material ejected from the crater including broken pavement and soil. Debris is sometimes usable as backfill material particularly for large crater repair, but for small crater or spall repair it is generally not advisable

Depot Maintenance. That maintenance performed on material requiring major overhaul or a complete rebuild of parts, assemblies, subassemblies, and end-items, including the manufacture of parts, modifications, testing, and reclamation as required. Depot maintenance serves to support lower categories of maintenance by providing technical assistance and performing that maintenance beyond their responsibility. Depot maintenance provides stocks of serviceable equipment by using more extensive facilities for repair than are available in lower level maintenance activities.

Direct Combat Support. Work essential to the direct support of combat operations in an overseas theater; that is, work which if not performed could cause immediate impairment to the Air Force combat capability.

Dispersal. Relocation of forces and assets for the purpose of increasing survivability.

Ejecta. The debris and other material ejected from a crater during detonation of a bomb.

Emergency Airfield Lighting System (EALS). A complete mobile airfield lighting system intended for postattack recovery and/or bare base beddown operations. It consists of preformed cables, runway edge and threshold lights, and anchors for either soil or pavement installation. It also includes approach lights, taxiway lights, strobe lights, and precision approach path indicators. The system is packaged, shipped, and stored unassembled.

Exercise. A military maneuver or simulated wartime operation involving planning, preparation, and execution. It is carried out for the purpose of training and evaluation. It may be a combined, joint, or single Service exercise, depending on participating organizations.

Explosive Ordnance (EO). All munitions containing explosives, nuclear fission or fusion materials and biological and chemical agents. This includes bombs and warheads; guided and ballistic missiles; artillery, mortar, rocket, and small arms ammunition; all mines, torpedoes and depth charges; demolition charges; pyrotechnics; clusters and dispensers; cartridge and propellant actuated devices; electro-explosive devices; clandestine and improvised explosive devices; and all similar or related items or components explosive in nature.

Explosive Ordnance Disposal (EOD). The detection, identification, on-site evaluation, rendering safe, recovery, and final disposal of unexploded explosive ordnance. It may also include explosive ordnance, which has become hazardous by damage or deterioration.

Explosive Ordnance Reconnaissance (EOR). Reconnaissance involving the investigation, detection, location, marking, initial identification, and reporting of suspected unexploded explosive ordnance.

Fall Back. Crater material which is ejected at such a high angle that it falls back into the crater. This material is characteristically loose, requiring either compaction or removal before repairs can be made.

Facility. A real property entity consisting of one or more of the following: a building, a structure, a utility system, pavement, and underlying land.

Fiberglass Mat (FGM). A large one-piece fiberglass mat (either 30-feet long by 54-feet wide or 60-feet long by 54-feet wide) used as a FOD cover over crater repairs. It is anchored to the runway surface only on the leading and trailing edges.

Folded Fiberglass Mat (FFM). A 30-foot long by 54-foot wide fiberglass mat made in 6-foot wide by 30-foot long panels with flexible joining hinges to allow folding for shipment. The mats are shipped in a 6-foot wide by 30-foot long stack.

Foreign Object Damage (FOD). Rags, pieces of paper, line, articles of clothing, nuts, bolts, or tools that, when misplaced or caught by air currents normally found around aircraft operations (jet blast, rotor or prop wash, engine intake), cause damage to aircraft systems or weapons or injury to personnel.

Ground Crew Ensemble (GCE). The total set of individual protective clothing that, when worn and fitted properly, will provide protection against threat chemical agents. It consists of charcoal undergarments, gloves, socks, mask, goggles, outer garments, hood, and boots. The GCE is part of Individual Protective Equipment (IPE).

Hardened Facility. A below-ground facility designed to resist nuclear weapon effects. These facilities have very high levels of protection. Examples are Minuteman and MX silos.

Harvest Eagle. A “nickname” given to a selected package of essential items of equipment and supplies required to support forces and personnel under bare base conditions. It is an air transportable housekeeping package designed to support activities deployed to remote areas where it is not feasible to preposition assets. Harvest Eagle sets are designed to support 550 personnel, are designated as WRM, and are maintained in a ready-to-deploy status.

Harvest Falcon. A “nickname” for an air transportable package of hardwall and softwall (tents) shelters and equipment required for base and personnel housekeeping and aircraft support in bare base conditions. Harvest Falcon operates under the concept to provide support for sustained wartime operations. It uses tents in lieu of hardwall shelters for most housekeeping (billets, kitchens, showers) support. Although Harvest Falcon could be deployed to support operations almost anywhere in the world (no freeze protection), the package was developed and sized to support operations in Southwest Asia (SWA).

Heaved Lip. See Pavement Upheaval.

Individual Protective Equipment (IPE). In nuclear, biological and chemical warfare, the personal clothing and equipment required to protect an individual from biological and chemical hazards and some nuclear effects.

Initial Reconnaissance. The initial, long-range damage assessment conducted from observation posts, control towers, airbase point defense positions, and other airfield vantage points.

Joint-Use WRM. WRM that can be used in daily operations, in accordance with maintenance and operational readiness parameters spelled out in the WRM directives.

Large Crater. See Crater--Large.

Launch/Recovery Surfaces (LOR). All pavement areas large enough for a MOS and suitable for launch/recovery of aircraft. Primary and secondary runways are potential MOS areas as well as aprons or taxiways of sufficient size and construction and free of airfield obstacles.

Magnesium Phosphate Cements. Magnesium phosphate cements are inorganic compounds which can be used in a way similar to Silikal® for spall repair. They are all water based, can displace water from a wet spall and bond well to wet or dry concrete or asphalt. Due to their lack of handling hazards and general ease of use, it is very likely that in the near term a magnesium phosphate cement product will be identified as the spall repair product of choice to replace Silikal®.

Main Operating Base (MOB). A base on which all essential buildings and facilities are erected. Total organizational and intermediate maintenance capability exists for assigned weapon systems. The intermediate maintenance capability may be expanded to support specific weapon systems deployed to the MOB

Minimum Airfield Operating Surface (MAOS). The combined requirement for airfield surfaces for both runway and access routes. For example, the MOS is part of the MAOS.

Minimum Operating Strip (MOS). The minimum operating strip is the smallest amount of area that must be repaired to launch and recover aircraft after an attack. Selection of this MOS will depend upon mission requirements, taxi access, resources available, and estimated time to repair. For fighter aircraft, the typically accepted dimensions are 5,000 feet long by 50 feet wide.

Mobile Aircraft Arresting System (MAAS). An aircraft arresting system mounted on two identical, four-wheeled towable trailers, one on each side of the runway. Each trailer serves as a storage and ground transportation and as a platform for securing the basic arresting gear components: BAK-12 energy absorber, pendent tape, tape connector, hook cable, rewind system, and cooling system. The MAAS can be anchored in concrete, asphalt, or soil in less than 1 hour and is capable of 20 arrested landings per hour. The MAAS is capable of bidirectional arrestment, but if configured for airfield survivability application (aborted takeoff and landing aircraft), is unidirectional.

Mobility Readiness Spares Package (MRSP). Spare parts designated for specific equipment. These parts are maintained in a ready status and are assembled in a flyaway-type container, to be deployable with a unit in minimum time. Routine peacetime usage is not allowed, except with specific authorization. The contents of the kits are normally high-consumption items that should enable a unit to operate the equipment at a forward location for a short time (usually 2 weeks to 30 days).

MOS Selection. The process of plotting damage and UXO locations on an airbase runway map and using this information to select a portion of the damaged runway which can be repaired most quickly to support aircraft operations.

Nuclear, Biological And Chemical (NBC) Defense. The methods, plans, procedures and training required to establish defense measures against the effects of attack by nuclear weapons, chemical and biological agents.

Operational Plans (OPLANS). An operation plan for the conduct of joint operations that can be used as a basis for development of an operation order (OPORD). An OPLAN identifies the forces and supplies required to execute the CINC’s Strategic Concept and a movement schedule of these resources to the theater of operation. The forces and supplies are identified in time-phased force deployment data (TPFDD) files. OPLANs will include all phases of the tasked operation. The plan is prepared with the appropriate annexes, appendixes, and TPFDD files as described in the Joint Operation Planning and Execution Systems manuals containing planning policies, procedures, and formats.

Operator Maintenance. That level of maintenance conducted on equipment, usually on-site, preventive in nature, and consisting of minor adjustments, and routine checking and servicing of fluid and pressure levels.

Pavement Upheaval. The vertical displacement of the airfield pavement around the edge of an explosion-produced crater. The pavement upheaval is within the crater damage diameter, but is outside the apparent crater diameter. In other words, it is that part of the pavement out of “flush” tolerance which is elevated above the adjacent undamaged surface.

Prime Base Engineer Emergency Force (BEEF). A Headquarters U.S. Air Force, MAJCOM, and base-level program that organizes civil engineering forces for worldwide direct and indirect combat support roles. It assigns civilian employees and military personnel to both peacetime real property maintenance and wartime engineering functions.

Rapid Runway Repair (RRR). The process of using construction equipment, tools, potable equipment, expendable supplies, and temporary surfacing materials to provide a minimum operating surface through expedient repair methods.

RED HORSE. Headquarters Air Force-controlled squadrons established to provide the Air Force with a highly mobile, self-sufficient, rapidly deployable civil engineering capability required in a potential theater of operations.

Rapid Runway Repair (RRR) Minikit. A rapid runway repair training program developed by HQ AFESC (now HQ AFESA) in 1989, the goal of which was to provide CONUS Prime BEEF teams with the means (equipment and vehicles) to effect a realistic home station RRR training program. The concept included both individual and team proficiency training. Each unit involved in the program received a training syllabus, and the vehicle and equipment packages necessary to conduct the required training. Package details are outlined in attachment 8 of this pamphlet. RRR Minikit authorizations are listed in AS 019 and 429.

Reverse Osmosis Water Purification Unit (ROWPU). A portable water purification device which uses a series of membranes to eliminate impurities. The ROWPU is capable of removing dissolved minerals--including salt.

Regional Equipment Operator Training Site (REOTS). A MAJCOM operated training site where individuals in the heavy equipment career field (AFS 3E2X1) receive extensive hands-on instruction on four equipment items which are essential to RRR (excavator, dozer, grader, and 4-cy loader).

RRR Damage Assessment Team (DAT). A team directed by the SRC used to identify and locate bomb damage and UXO following an attack. Their initial efforts are normally targeted towards the airfield proper; but can also be employed elsewhere as deemed necessary. The RRR DAT usually will consist of one civil engineering person, one EOD technician, and an augmentee. The RRR DAT should be equipped with an armored vehicle and communications enabling them to report their observations to the SRC. The RRR DAT must be accurate in their runway damage reports because this information is used in MOS selection.

RRR Set. A standardized set of equipment and vehicles provided to selected MOBs, enabling base civil engineering forces to conduct rapid runway repair. The sets are graduated in a building-block manner to provide the following crater-plus-spall-repair capability:

R-1. The basic set of vehicles, equipment, and materials to enable the BCE to form the RRR forces into three crater repair crews, each capable of repairing one crater in 4 hours.

R-2. Equipment and vehicles, that when added to the R-1 set, provide the capability to form mixed repair teams (three teams for the runway minimum operating strip; three teams for the taxiway), each capable of repairing one crater in 4 hours. Thus, R-2 equates to a capability for six crater repairs in 4 hours.

R-3. Additional equipment and vehicles, when added to the R-1 and R-2 sets, provide the capability for six crater repair teams to each repair two craters within 4 hours. Thus, R-3 equates to a capability for 12 craters repairs in a 4-hour period.

SALTY DEMO. A RRR demonstration conducted in Europe in May 1985 to evaluate the capability of currently accepted methods of RRR.

Semihardened Facility. This term refers to NATO semihardened criteria--a list of weapons at specific miss distances a structure is designed to resist. The list includes near misses of general-purpose bombs and direct hits of smaller munitions. A typical design is an above-ground structure with 65-cm thick reinforced concrete walls with spall plates, blast valves, and blast doors. Examples of semihardened facilities are aircraft shelters, squadron operations facilities, and POL truck shelters.

SILIKAL®. Silikal® is the registered trademark name of a quick-setting concrete used for spall repair. It is prepackaged in 20-pound plastic bags which also contain a can of pre-measured catalyst. The can is emptied into the bag with the concrete, mixed by shaking the bag, then poured into the spall directly from the bag. The Silikal® hardens in 20 to 30 minutes. Toxic fumes from the mix require the user to wear a protective face mask and gloves.

Silver Flag Exercise Sites (SFES). These are MAJCOM operated locations were Prime BEEF personnel in a number of core mobility team positions are certified in specific wartime/contingency skills.

Small Crater. See Crater--Small.

Spalls or Scabs. Pavement surface damage that does not penetrate the pavement base course and results in a pavement damage area that could typically be up to 5 feet in diameter.

Splinter Protection. This method protects from weapons fragments and small arms fire and also prevents magnification of the blast pressure from reflection off vertical surfaces. Examples of this method are sand-filled metal bins, earth berms, and modular concrete sections, i.e the Bitburg revetment. When coupled with dispersal, splinter protection can provide a relatively high degree of survivability for short- and long-term deployments.

Survivable Collective Protection System (SCPS). A semihardened shelter that provides protection from blast and chemical agents. It also provides a processing area to remove contaminated clothing; a toxic free area for rest and messing; and contains bunks, potable water, food, showers, and toilets.

Survival Recovery Center (SRC). A supplemental command post collocated with, or immediately adjacent to, the wing command post (WOC) to ensure expeditious resumption of flying operations after attack. The combat support group (CSG) commander directs SRC operations. The base civil engineer is a member of the SRC staff.

Transition Route. See Access Route.

Unexploded Explosive Ordnance. Explosive ordnance which has been primed, fused, armed or otherwise prepared for action, and which has been fired, dropped, launched, projected or placed in such a manner as to constitute a hazard to operations, installations, personnel or material and remains unexploded either by malfunction or design or for another cause.

Unimproved Surface. A takeoff and landing (TOL) surface that has not been improved through paving with asphalt, concrete, or other durable substance. For example, a grass or dirt landing strip.

Unit Type Code (UTC). A five-character alphanumeric code that uniquely identifies each type unit of the Armed Forces.

War and Mobilization Plan (WMP). Five volumes published to fulfill the U.S. Air Force requirement for a plan in support of the Joint Strategic-Capabilities Plan (JSCP) and DOD mobilization planning directives. Volume 1 is the Wartime Planning Guide, and Volume 3 is the unit type code description.

War Reserve Materiel (WRM). Materials required in addition to primary operating stocks and mobility equipment to attain the operational objectives in the scenarios authorized for sustainability planning in the defense planning guidance. Broad categories are: consumables associated with sortie generation (to include munitions, aircraft external fuel tanks, racks, adapters, and pylons); vehicles; 463L systems; material handling equipment; aircraft engines; bare base assets; individual clothing and equipment; munitions and subsistence.

Wartime Task Standard (WTS). Volume 10 of AFPAM 10-219 that outlines specific Prime BEEF and RED HORSE wartime team requirements. Listed taskings cover knowledge as well as actual performance standards. When used as a proficiency guide, the WTS can be very useful in assisting commanders in assessing the actual capability of their teams in specific areas.

Wing Operations Center (WOC). The operations center through which the wing commander controls the assigned and attached wing forces. It consists of vertical communications capability, status boards, operational schedules, the people necessary to track activity, and the commander's battle staff to assist in operational and support decisions.

CIVIL ENGINEERINGRAPID RUNWAY REPAIR
CONCEPT OF OPERATIONS (CONOPS)

A2.1. Introduction.

A2.1.1. **Overview.** If, during a conflict, USAF main operating bases (MOBs) sustain substantial runway and taxiway damage they must be recovered as quickly as possible to support tactical aircraft launch and recovery. The objective of the rapid runway repair (RRR) program is to provide the base civil engineer (BCE) with the materials, equipment, support, procedures, and trained manpower needed to identify and repair the minimum amount of pavement damage required for sortie generation in the least amount of time. This capability must be developed, fielded, and integrated into a BCE work force that immediately must make the transition from a peacetime mission of real property operation and maintenance to a wartime mission of base recovery after attack (BRAAT).

A2.1.2. **Purpose.** The purpose of this concept of operations is to layout the road map for RRR and to help the civil engineer (CE) community prepare its men and women to make that critical transition to a wartime mission. This concept will guide the organization in the equipage, training, and employment of those forces to ensure that they are prepared to fight, survive, and win by providing the infrastructure to support aircraft sortie generation.

A2.2. Implementation. This concept of operations provides guidance so civil engineers can organize and train in the most practical and realistic manner possible during peacetime in order to be capable of meeting the wartime mission requirements if and when called upon to do so.

A2.3. Scope. This concept of operations delineates the general guidance, broad policies, and interfaces that a BCE needs to effectively employ RRR forces following a conventional and chemical attack at a theater MOB. It provides a general understanding of the situation, identifies decisions and choices the BCE has to make, and provides logic and some rules of thumb to assist with those choices.

A2.3.1. This document is limited to recovery of a MOB or bare base in either USAFE, PACAF, or CENTAF. It does not include Continental United States (CONUS) bases, forward operating locations (FOLs); or allied collocated operating bases (COBs), where insufficient RRR assets exist or where host nation or contract assets are considered for base recovery.

A2.3.2. The BCE’s organic capability to repair a minimum operating strip (MOS) in the prescribed time depends on how well the base has prepared for the attack, i.e., with personnel, equipment, material, and training. However, the capability to conduct RRR in a postattack environment depends directly on satisfactory and timely completion of the prerequisite activities of damage assessment, MOS selection, and explosive ordnance disposal (EOD). Although these are all BRAAT-related actions, RRR is separate and distinct, done with different people, and does not commence until damage assessment and MOS selection are completed and the EOD teams have safed the immediate repair area. The critical phase of RRR starts when unexploded ordnance (UXO) have been cleared or safed at the repair area and ends when the MOS is ready to launch and recover aircraft. However, runway repair may continue after initial aircraft launch in order to enhance aircrew operations. This concept of operations is oriented toward the immediate phase of developing an initial postattack aircraft launch and recovery capability. The RRR discussed in this document is not to be confused with the permanent repairs accomplished with host nation, U.S. Army, or contract support.

A2.4. Mission.

A2.4.1. **General.** Following an attack, the commander’s first priority and the BCE’s primary mission is to rapidly restore and sustain an aircraft launch and recovery capability. The immediate goal of recovery operations is to provide only the minimum repair required for an initial capability for sustained operations. After the MOS is repaired initially, repair crews will continue to repair the minimum airfield operating surface (MAOS) (the MOS and access route(s) combined)) to eliminate attack-caused choke points, and to make flying operations safer. Semipermanent repairs will be performed later and are not considered in this concept.

A2.4.2. **Specific**. The BCE's mission is to provide a support force which is organized, equipped, and trained as a cohesive unit, capable of quickly making the transition from the peacetime base operations and maintenance role to the wartime role of recovery of an airbase that has been attacked with conventional and chemical weapons. The RRR system components must be responsive to the unique features of an individual base. For example, different pavement types often require different kinds of foreign object damage (FOD) cover anchors. The system also must be able to respond quickly and effectively in an intense postattack damage environment. The RRR capability at each MOB must be capable of meeting the threat presented to that specific base. At present, a worst case scenario would require the repair of 12 craters (for planning purposes, six on the MOS, six on the taxiways) and up to 400 airfield surface spalls per attack within the specified time. For the purpose of our discussion in this CONOPS, we will concentrate on the worst case situation. However, keep in mind, that a number of our deployment locations do have and will continue to have lesser RRR requirements. **NOTE:** A worse case scenario was identified in USAFE during the 1980s regarding the Warsaw Pact threat. To counter this threat, an R-3 set of vehicles and equipment was assembled to provide the capability to repair 12 craters within 4 hours. While this threat is thought to now rarely exist, the RRR equipment sets do, however. As a general policy, if a theater base possesses an R-set, it must be capable of properly performing the number of crater and spall repairs affiliated with the associated threat. Specific threats and R-set associations are described in paragraph A2.7.

A2.5. Environment.

A2.5.1. **Threat.** The RRR system was developed to deal with a threat consisting primarily of conventional general-purpose bombs; runway-cratering munitions; mines; anti-personnel sub-munitions; and other area-denial weapons, including chemical weapons delivered by aircraft or tactical missiles. Nuclear weapons are not considered in this scenario. Under a worst case situation, it is envisioned that the initial attack may be preceded by a period of increasing hostilities, providing at least several days of preattack preparation. Adequate warning permits commanders to disperse resources, beddown augmentation forces, shelter personnel, install armor, replenish stockpiles, expediently harden and conceal key resources, and generally, assume a more capable defensive posture. Conversely, history has shown that adequate warning may not always precede all attacks and that an immediate response may be required.

A2.5.2. **Damage.** Airfield surfaces, command and control centers, airbase repair resources, communication facilities, utilities, and sortie generation capability most likely will be among targets for damage and disruption during an air attack. Logically, after an attack, communications (both telephone and radio) may be severely degraded, and utilities may be cut, essentially leaving the base without electricity; water; and petroleum, oil, and lubricants (POL). Runways and taxiways may be cratered and covered with bomb-damage debris. Unexploded bombs, anti-disturbance and delayed-fuze mines, antipersonnel and area-denial sub-munitions, and chemical weapons may be interspersed with the debris. Wounded people may require attention. Figure A2.1 shows the number, location, and estimated average size of expected craters and spalls per attack that must be repaired to achieve a MAOS during a worst case situation.

Figure A2.1. Maximum MAOS RRR Requirements After an Attack.

NUMBER OF CRATERS: 12 CRATERS

LOCATION: 6 on MOS and 6 on TAXIWAY

SIZE: AVERAGE 35-FOOT (12 METER) DIAMETER

NUMBER OF SPALLS: 400 TOTAL

LOCATION: THROUGHOUT AIRFIELD (MAOS)

SIZE: AVERAGE, APPROXIMATELY 2-5 FEET

A2.6. Rapid Runway Repair Operations.

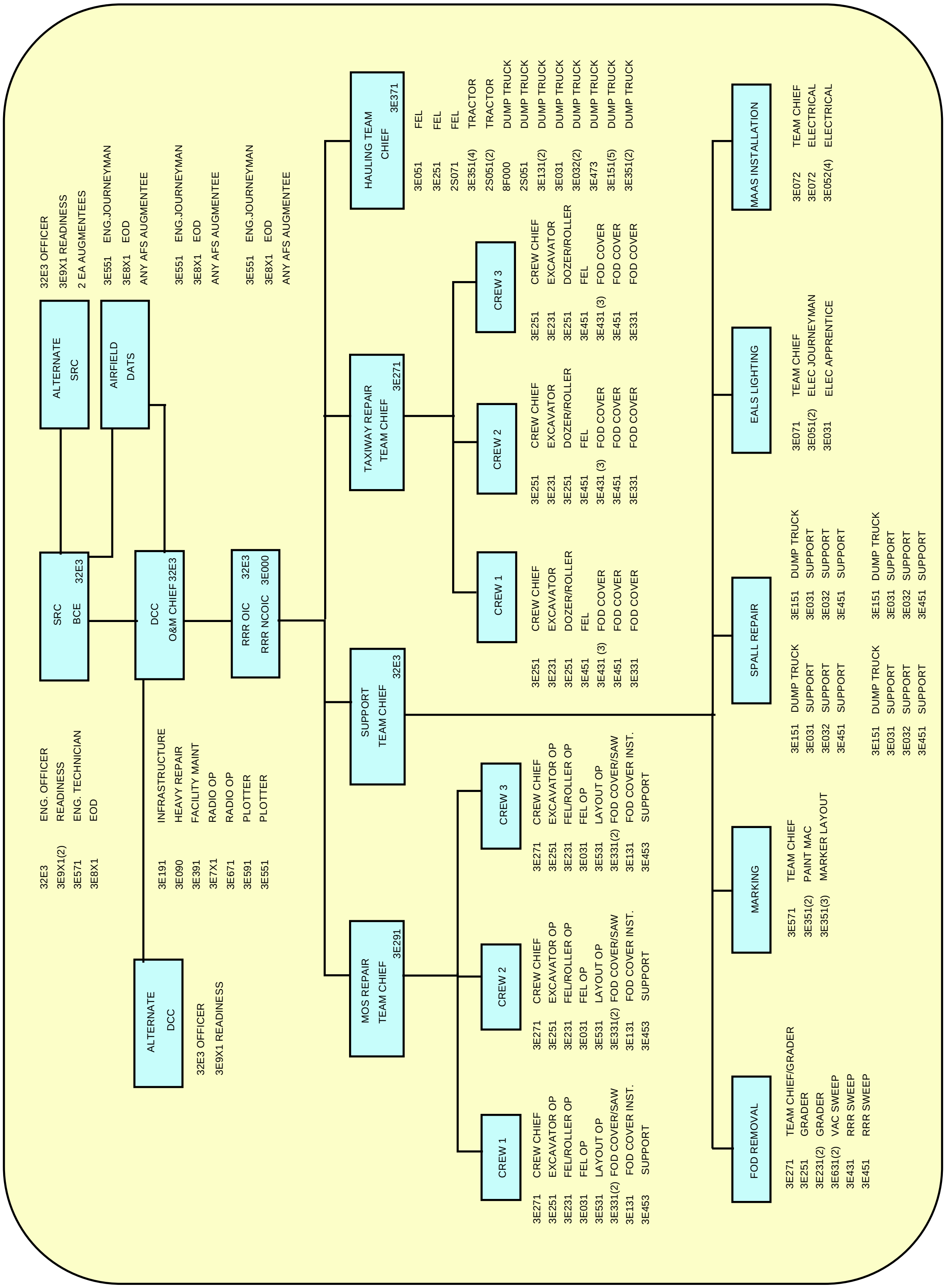
A2.6.1. **Forces.** During peacetime, the BCE's personnel and organization remain configured for daily base support functions, with periodic RRR training required in the fielded repair system. The wartime functional requirements are considerably different and require a different organizational personality. The civil engineer squadron (CES) must make the transition from the peacetime support organization of many diverse functions, capabilities, and specialties to a tightly-knit, smoothly functioning team, proficient in its wartime mission, able to work well under combat stress. The peacetime functions of fire and crash response, utilities repair, and structural repair continue after attack, but are modified significantly to accommodate the situation. Most other CE assets make the transition into a wartime organization to conduct airfield recovery. The ability to make this transition from the peacetime to the wartime organization is one of the critical factors in determining success. During peacetime, the BCE should organize and train assigned forces as integral RRR teams. However, the base-assigned CE forces normally will be insufficient to maintain a 24-hour-a-day RRR capability once the bases initiate a 12-on/12-off work schedule. Deploying CONUS forces augment these theater forces and jointly provide around-the-clock RRR operations.

A2.6.2. **Augmentation and Integration.** With the exception of mobile Prime Base Engineer Emergency Forces (BEEF) and RED HORSE units, most theater-assigned Air Force engineer personnel will be considered non-mobile during war and will be used to perform applicable wartime tasks. Host base engineer personnel may be augmented by deployed Prime BEEF and RED HORSE personnel, civilian and contractor personnel, host nation support, base military augmentees, and Army engineer personnel. Tasking will be carried out according to applicable operations plans (OPLANs).

A2.6.3. **Pre-hostilities.** During pre-hostilities when alert conditions reach a prescribed level, Prime BEEF mobility forces will begin to deploy from CONUS and Overseas Continental US (OCONUS) bases. Deploying mobility forces, although integral to theater in-place forces and responsible to the host base BCEs, should not be broken up, if possible. These forces organize, train, and deploy as a team. Unit integrity and cohesion are most important. If mobility forces are in place at a theater base before the initial attack, they would work side-by-side with the theater in-place force to recover the base. The host BCE will make the determination of assigning specific wartime recovery tasks, establishing separate operating shifts, and assigning personnel and responsibilities. The bottom line is that all deploying US CE mobility forces will be under the operational control of the host BCE.

A2.6.4. **Organization.** A suggested RRR organization is shown in figure A2.2. At a bare base location, this organization can be configured by deploying one each EOD and CES lead team and two CES follow teams. The remaining personnel are usually utilized for utilities and structures recovery and fire protection functions.

Figure A2.2. Suggested RRR Organization.



A2.7. Systems and Equipment. Present RRR functions and associated capabilities are depicted in figure A2.3. Rapid runway repair capability is best described in terms of the vehicle and equipment sets (R-sets) provided to the BCE for the RRR mission. The R-set concept is a stepped approach to fielding a RRR capability which builds from a small, basic RRR set into bigger sets capable of completing more crater repairs in the same time or less, until the worst case scenario requirements are met.

Figure A2.3. RRR Functions and Capabilities.

FUNCTION	PRESENT CAPABILITY
System	Rapid Runway Repair
Direction	AFI 10-211; AFPAM 10-219, Vol 4
Damage Assessment	Manual and Vehicular Damage Assessment
Training Locations	Home Station, REOTS, and Special Training Sites (STSs)
MOS Selection	Manual MOS Selection
Crater Preparation Vehicle Sets	R-1, R-2, and R-3 Sets
MOS Crater Cover	Folded Fiberglass Matting (AM-2 in an emergency)
Taxiway Crater Covers	AM-2 Matting
Spall Repair	Silikal®, Quick Setting Concrete, and Cold-Mix Asphalt
MOS Marking	MOS Marking System
Airfield Lighting	RRR Lighting Set and Emergency Airfield Lighting System (EALS)
Aircraft Arresting System	Mobile Aircraft Arresting System (MAAS)

A2.7.1. **R-Sets.** The minimum RRR package designed to deal with a possible air attack threat to an air base is the R-1 set. This set provides the vehicles, equipment, and material needed by a base to form three crater crews, each capable of repairing one crater in 4 hours. If the threat analysis for a given base indicates that an R-1 set capability is insufficient, additional vehicles and equipment should be obtained to bring the unit's RRR recovery package up to an R-2 set level. The R-2 set gives the base the capability to form six crater repair teams each able of repairing one crater in 4 hours. Consequently, an R-2 set provides a base the ability to repair six craters in 4 hours. However, if the enhanced R-2 set capability is still inadequate to meet the perceived threat, the base should posture an R-3 set. An R-3 set provides yet more vehicles and equipment, enabling six crater repair teams to repair two craters each, or 12 craters in 4 hours--the current maximum perceived threat situation.

A2.7.2. **R-Set Manning/Equipment.** Teams assigned with R-sets should be manned and equipped as depicted in tables A2.1, A2.2, and A2.3, respectively. The tables reflect only dedicated manning. For instance, folded fiberglass mat (FFM) personnel are used on both taxiways and the MOS; whereas, AM-2 mat personnel are usually employed only on taxiway and ramp repairs.

Table A2.1. Personnel Requirements.

TEAM	POSITION	R-1 SET	R-2 SET	R-3 SET
Command and Control (C^2)	RRR OIC	1	1	1
	RRR NCOIC	1	1	1
	Support Team OIC	0	1	1
MOS Crater Repair Crews (3 each)	Team Chief	1	1	1
	Crew Chief	3	3	3
	Excavator	3	3	3
	FEL	6	6	6
	Eng Asst. (3E5X1)	3	3	3
	MOS Layout Support	6	6	6
	Vibratory Roller	3	3	3
	FOD Cover (FFM)	6*	6*	6*
	Saw System (Optional)	6	6	6
	Water Truck (Optional)	3	3	3
	Dozer	3	0	0
Taxiway Crater Repair Crews (3 each)	Team Chief	0	1	1
	Crew Chief	0	3	3
	Excavator	0	3	3
	FEL	0	3	6
	FOD Cover (FFM/AM-2)	06/27	6/27	6/27
	Dozer/Vibratory Roller	0	3	3
Hauling Crew	Team Chief	1	1	1
	FEL	3	6	7
	Tractor	6	6	6
	Dump Truck	8	15	22
FOD Removal Crew	Grader	3	3	3
	Vacuum Sweeper	2	2	4
	RRR Kick-Broom	2	2	7
MOS Layout and Marking Crew	Paint Machine	2	2	2
	Support	4	4	4
Spall Repair Crews (4 each)	Dump Truck	4	4	4
	Support	12	12	12

*Only dedicated resources are reflected. Optimum crew size for installing FFM FOD covers is six (two dedicated to this task and four assigned to other tasks). As other tasks near completion, some personnel will be available to assist in FFM cover installation.

Table A2.2. Vehicle Assignments.

TEAM	VEHICLES	R-1 SET	R-2 SET	R-3 SET
RRR OIC	HMMWV	1	1	1
RRR NCOIC	HMMWV	1	1	1
Support Team OIC	HMMWV	0	1	1
MOS Team (3 crews)	HMMWV Excavator 2.5-Cubic Yard FEL 4-Cubic Yard FEL Dozer Vibratory Roller RRR Trailer Water Truck (optional)	0 3 3 3 3 3 3 3	1 3 3 3 0 3 3 3	1 3 3 3 0 3 3 3
Taxiway Team (3 Crews)	HMMWV Excavator 4-Cubic Yard FEL Dozer Vibratory Roller RRR Trailer	0 0 0 0 0 0	1 3 3 3 3 3	1 3 6 3 3 3
Hauling Crew	HMMWV 8-Cubic Yard Dump Trk 2.5-Cubic Yard FEL 4-Cubic Yard FEL 7.5-Ton Tractor 22-Ton Trailer 10-Ton Tractor 60-Ton Trailer	0 8 0 3 3 3 3 3	1 15 3 3 3 3 3 3	1 22 3 4 3 3 3 3
FOD Removal Crew	Grader Vacuum Sweeper Kick-Broom	3 2 2	3 2 2	3 4 7
MOS Layout and Marking Crew	Paint Machine 1.5-Ton Stake-Bed Truck	1 1	1 1	1 1
Spall Crew	1.5-Ton Stake-Bed Truck	4	4	4
NOTE: These figures are not cumulative.				

Table A2.3. RRR R-Set Configurations.

VEHICLES	R-1 SET	R-2 SET	R-3 SET
Excavator	3	3	
Grader	3		
Dozer (T-7)	3		
4-Cubic Yard FEL	6	3	
2.5-Cubic Yard FEL	3	3	
Vibratory Roller	3	3	
8-Cubic Yard Dump Truck	8	7	
5-Ton Dump Truck	4		
7.5-Ton Tractor	3		
10-Ton Tractor	3		
22-Ton Tilt Trailer	3		
60-Ton Trailer	3		
Vacuum Sweeper	2		2
Tractor Wheeled W/Front Mounted Broom	2		5
Paint Machine (Part of MOSMS)	2		
HMMWV	2	4	
RRR Trailer	3	3	
Dolly Converter (8-Ton)	3		
COMPONENT KITS	**R-1 SET**	**R-2 SET**	**R-3 SET**
Basic RRR Equipment Support Kit	1	2	
Basic RRR Airfield Lighting Set	1		
AM-2 RRR FOD Cover Kit	3	6	9
AM-2 Support Kit	1	2	
Folded Fiberglass Mat FOD Cover Kit (Kit-A)	1		
Folded Fiberglass Mat FOD Cover Kit (Kit-B)	2		
Spall Repair Kit	4		
MOSMS (Airfield Marking System)	1		
NOTE: These figures are cumulative and show what would be added to the previous set. For example, the R-2 set consists of six (6) excavators, including three (3) from the R-1 set and three (3) additional units added at the R-2 level. See attachment 8 for equipment kit/set details.			

A2.8. General Conditions. At the beginning of hostility buildup, when the airbases move to an increased alert posture, the host engineer forces will be limited to performing only essential base support services and life-sustaining activities, such as pre and postattack wartime tasks. The following factors should influence preattack planning:

A2.8.1. **Manning.** As a general rule, minimum of 200 USAF military engineers will be available at each overseas MOB in a near worst case war fighting scenario. If a worst case war fighting scenario developed, additional forces would be provided to ensure around-the-clock 12 craters in 4 hours capability. In fact, in a worst case situation, approximately 400 US Air Force military engineers would be required to perform all possible BRAAT activities.

A2.8.2. **The SRC and BRAAT.** The survival recovery center (SRC) directs and controls all BRAAT forces to support passive defense and recovery operations. All BRAAT activities will be directed by and through the SRC once the preattack posture is assumed.

A2.8.3. **Work Shifts.** Assigned and augmentation forces should be split to provide 24-hour-a-day, 7-day-a-week coverage, when practical. However, some subordinate commanders may set up appropriate rest cycles and shorter work shifts because of personnel having to wear the individual protective equipment (IPE) while working specific, high-stress, highly physical activities with high temperatures and humidity. When a chemical threat is envisioned, personnel should be organized into small groups and rotated to preclude a processing buildup at the collective protection shelters.

A2.8.4. **Personnel Shelters.** Personnel will be moved into their primary assigned collaterally protected shelters before the attack. After the attack, they should remain in these shelters during off duty (sleeping, eating, resting, etc.). Ideally, if either a chemical or biological threat is possible, survivable collective protection systems (SCPS-II), which are over pressured, filtered-air shelters, will be employed. Other over pressured shelters are also available and are touched upon in volume 2 of this series.
A2.8.5. **Materials/Equipment Stocks.** Sufficient RRR materials and equipment (R-sets) to complete airfield repair for the number of craters and spalls expected during the initial and subsequent attacks should be stockpiled. Each base will meet this requirement according to its respective threat analysis.
A2.8.6. **Unit Integrity.** Deploying engineer forces normally should retain unit integrity and be under the operational control of the host CE commander, regardless of rank. The host BCE then will assign work to his forces and to the deployed forces through the respective command channels.
A2.8.7. **Reattack.** Reattack with only a few minutes warning may occur during the recovery effort. Consequently, both training and planning actions should take this into consideration.
A2.8.8. **Personnel/Equipment Attrition.** Significant personnel and equipment attrition should be expected during the attack and postattack operation. After an attack, this attrition may result from area-denial weapons, antipersonnel bomblets, other UXO, chemical contamination, accidents, and reattack.
A2.8.9. **RRR Vehicle Set Repairs.** Rapid runway repair vehicle maintenance and repair during BRAAT should normally be limited to removal and replacement, since there is not a dedicated RRR fleet vehicle battle damage repair capability. As a general rule, vehicles with major malfunctions or battle damage requiring more than 1-hour to repair will be pushed off the MOS for later recovery, moved back to an equipment repair area, or used for cannibalization purposes.
A2.8.10. **Communication Equipment.** The host BCE's communications equipment will provide sufficient assets to accomplish the RRR mission. However, mobility forces should deploy with two-way radios to further enhance the RRR capability. When possible, the deployment team's radios should be adjusted to correspond to the frequency of the host. This may require reed replacement/adjustments. However, without such modifications, the usefulness of the deployed team's radios will be constrained and communication interaction between host and deployed personnel could be greatly impaired.

A2.9. Communications.
A2.9.1. **RRR Essential Communications.** The RRR officer in charge (OIC) and noncommissioned officer in charge (NCOIC) must maintain communications not only with the various RRR team chiefs, but also with the engineer damage control center (DCC).
A2.9.2. **Alternate Communication Forms.** Radio communication is the ideal method. However, due to any number of variables, radios may be partially or totally unusable. Therefore, some alternate form of communication, such as field phones, base phones, runners, etc., must be established to pass information, such as simple status reports, requests for essential services or supplies, and passing directions and guidance.
A2.9.3. **Damage Control Center.** Communications with the following essential primary and alternate agencies should be available to relay damage reconnaissance and to manage RRR activities from the engineering DCC:

- Survival recovery center.
- Fire operations center.
- Base defense operations center (BDOC).
- Logistic readiness center (LRC).
- Medical services.
- Sheltered engineer teams.
- Rapid runway repair operations.

A2.9.4. **Rapid Runway Repair.** Figure A2.4 illustrates the interface requirements of a typical RRR network. Table A2.4 serves as a quick visual reference of suggested RRR team radio requirements. This list is in no way intended to be cardinal. Rather, it is presented as general guide. Each unit should formulate their RRR communications requirements predicated upon the anticipated situation. Factors to consider when doing so include team experience, threat assessments, leadership expertise, and available equipment resources. Radio authorization levels are outlined in AS 660, *Non-Weapons Systems Communications Requirements*. For RRR purposes, the following minimum radio equipment is desired:

Figure A2.4. RRR Communication Requirements.

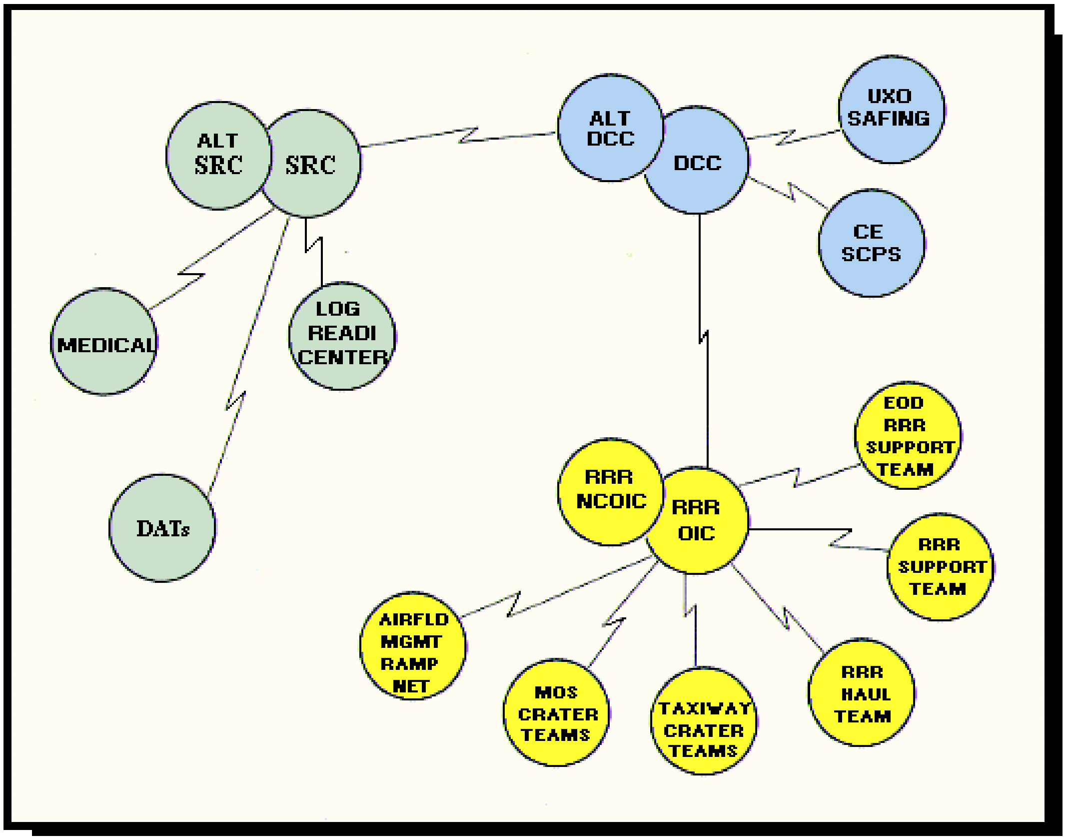


Table A2.4. Suggested RRR Team Radio Requirements*.

FUNCTION	REQUIREMENT
RRR OIC and NCOIC	Both a portable (hand held) and vehicle mounted, jam-resistant units.
MOS Repair Team Chief	Portable two-channel, jam-resistant unit.
Taxiway Repair Team Chief	Portable two-channel, jam-resistant unit.
Hauling Team Chief	Portable two-channel, jam-resistant unit.
Support Team OIC	Portable two-channel, jam-resistant unit.
MAAS Crew Leader	Single-channel, jam-resistant unit.
MOS Marking Team	Single-channel, jam-resistant unit.
Airfield Lighting Team	Single-channel, jam-resistant unit.
FOD Removal Team	Single-channel, jam-resistant unit.
Fill Site(s) Personnel	Single-channel, jam-resistant unit.
Equipment Operators (as required)**	Single-channel, jam-resistant unit.
NOTES: *Each RRR situation should be assessed individually. The above suggested radio requirements will most likely not prove ideal for every scenario. Make necessary adjustment accordingly. **Care must be taken to avoid having too many radios in use. Excess chatter on the frequency can only serve to create confusion and discord.	

A2.9.4.1. Both RRR OIC/NCOIC should have a portable (hand held) and vehicle-mounted, multichannel, jam-resistant (if available) FM radio for communications with engineering DCC and RRR teams.
A2.9.4.2. MOS crater team, taxiway crater team, haul team, support team mobile aircraft arresting system (MAAS), airfield lighting, FOD clearance, MOS marking, EOD RRR support team, and shelter managers should each have a portable (hand held), two-channel, jam-resistant (if available) FM radio for intercommunications.
A2.9.4.3. The airfield management and ramp net should have a single-channel, jam-resistant for contact with the RRR OIC/NCOIC.
A2.9.4.4. Equipment operators (sweepers, excavators, graders, paint machine, ordnance clearance equipment, dump trucks, stockpile loader, etc.) should be provided a single-channel, jam-resistant (if available) radio for contact with their respective team chief.

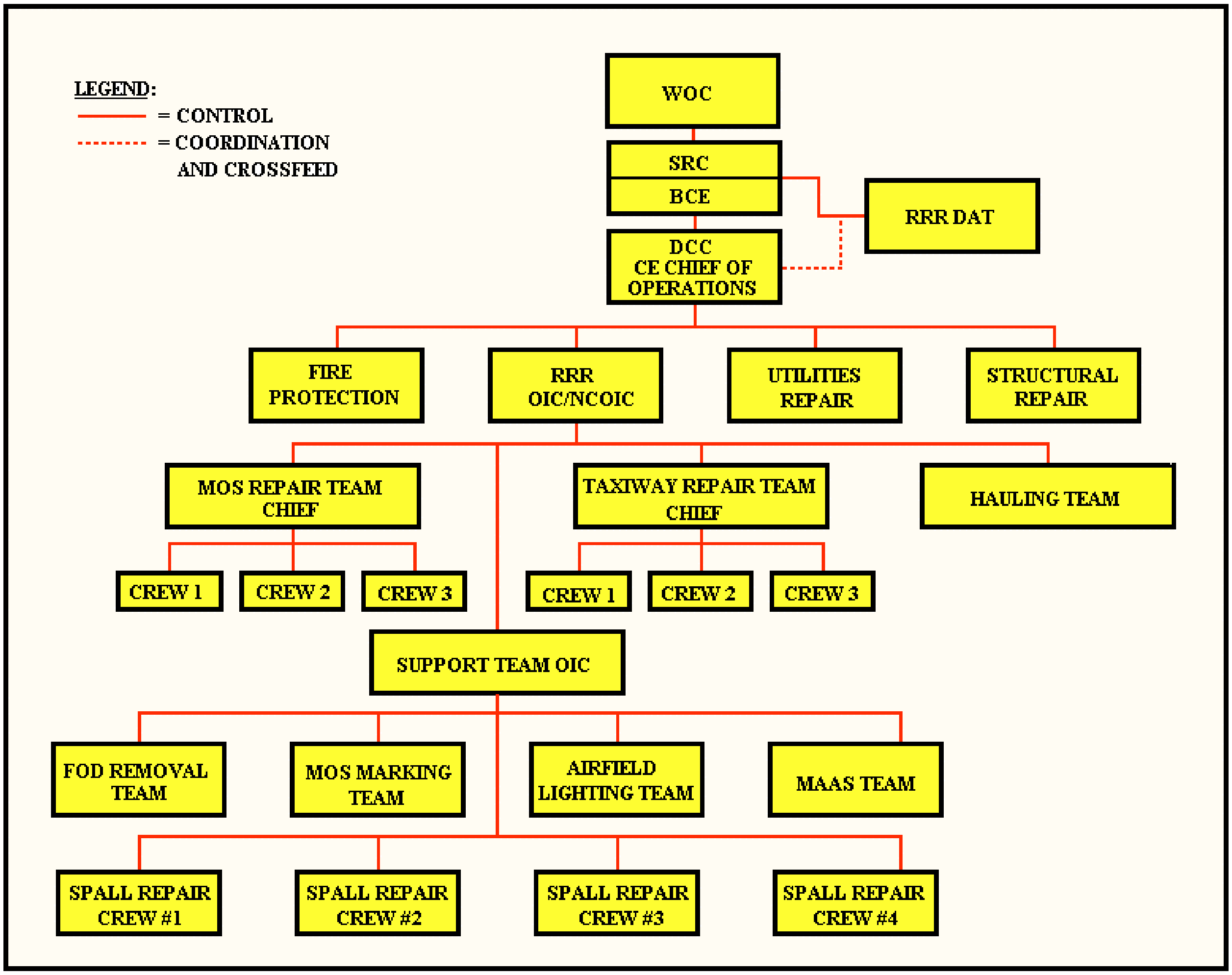
A2.10. Command and Control (C^2).

A2.10.1. **Organization.** All MOB assigned forces (in-place and deployed) are under the operational control of the local wing commander or equivalent. The wing commander controls assigned forces and all air base operability (ABO) operations through the wing operations center (WOC) using the battle staff and existing radio and telephone communications. The WOC monitors status and location of personnel, resources, communications, damage, and other factors impacting mission-capability.
A2.10.1.1. The SRC is established, in accordance with AFI 32-4001, *Disaster Preparedness Planning and Operations*, and AFI 10-212, *Air Base Operability Program*, specifically to direct ABO survivability and recovery operations. As addressed earlier, the SRC is the focal point for all BRAAT operations. It also provides command and control of most ABO forces to ensure continuity of operations during preattack, transattack, and postattack.
A2.10.1.2. The support group (SG) commander, or equivalent, directs activities in the SRC and coordinates the efforts of the supporting staff to collect, analyze, prioritize, display, and report information on the status of the base. The SRC, which is subordinate to the WOC, is the focal point for determining and tracking the extent of base damage. As damage inputs are received, the SRC staff then develops a recovery strategy for WOC approval, implements and directs the recovery activity, and monitors recovery progress. As an integral part of the WOC, the SRC actively coordinates with other WOC cells (logistics, operations, reports, etc.), and reports directly to the battle staff. The SRC usually is collocated with, or adjacent to, the WOC battle staff work area (Battle Cab) to allow the battle staff easy viewing of SRC displays. Without a close proximity arrangement with the WOC battle staff, the SRC will find it difficult to perform its BRAAT mission effectively.
A2.10.1.3. An alternate SRC is established at another facility (preferably, the alternate WOC) which affords at least the same degree of protection as the primary SRC. The alternate SRC will be manned to track and record information plotted at the primary SRC, so it will be capable of assuming the primary SRC functions with little or no notice.
A2.10.1.4. The SRC is responsible for determining the scope of damage; determining its impact on the base mission; and maintaining the status of personnel, casualties, and material resources. It develops a recovery strategy, directs recovery

actions, and tracks progress.

A2.10.1.5. The BCE, or equivalent, normally operates from the SRC. The engineering DCC, which is subordinate to the SRC (figure A2.5), is established in accordance with AFI 10-210 *Prime Base Engineer Emergency Force (BEEF) Program.* The DCC is usually headed by the squadron's chief of operations and normally controls all CE recovery activities. In other words, the recovery priorities and strategy are established in the SRC, then implemented, executed and controlled by the DCC.

Figure A2.5. BCE Organizational for Airfield Recovery Operation.



A2.10.2. **Survival Recovery Center Staff.** Once activated, the SRC constitutes the upper echelon of the organization for base recovery operations. The SRC staff composition may be established to fit local base requirements, but, generally, it will consist of representatives from the following functions:

- Base Civil Engineer or Senior Representative (EOD and Readiness).
- Security Police.
- Medical Services.
- Transportation.
- Communications.
- Personnel.

A2.10.3. **SRC Staff Functions.** At theater bases, the BRAAT concept of operations requires the BCE (or a senior designated representative) and members of the MOS selection team to be located in the SRC. Some of the primary SRC staff member responsibilities include:

A2.10.3.1. **SRC Commander.** As mentioned previously, normally, the SRC is managed by the support group (SG) commander, who is responsible for all SRC operations. Other senior SG officers serve on the staff and as director of the alternate SRC.

A2.10.3.2. **Civil Engineer Representatives.** The BCE or designated representative is the senior advisor to the SRC commander on engineering matters. From the SRC, the BCE provides direction to the RRR crews and DATs, directs facility and utility repair, and provides fire protection and crash rescue capability. As mentioned earlier, much of the BCE's direction is executed through the DCC staff. As a member of the SRC, the BCE is the command and control link between the SRC and the DCC. From the SRC, the BCE receives, reviews, and evaluates damage assessment reports, and assists the commander in developing and implementing the base recovery strategy. Other members of the civil engineer staff include:

A2.10.3.2.1. **Readiness Flight Officer.** This individual is responsible for oversight and administration of the SRC, coordinates activities of the remaining staff, and recommends priorities for emergency response forces. He/she advises the commander and battle staff on chemical warfare defense matters and exercises operational control of nuclear, biological, chemical (NBC) survey teams. This person is also responsible for monitoring activities of the shelter management and contamination control teams through their respective functional control centers.

A2.10.3.2.2. **Explosive Ordnance Disposal Representative.** The EOD representative controls the UXO safing teams' activities and advises the commander and battle staff on all matters concerning UXO.

A2.10.3.2.3. **SRC Controllers/Plotters.** To support SRC operations, controller/plotter positions are filled, as needed, according to AFI 10-212 and base Disaster Preparedness OPLAN 32-1. These individuals will both record, plot, and track attack damage inputs received from individuals and organizational control centers. They will also conduct MOS selection based upon inputs from damage assessment teams (DATs), weather and aircraft loading factors, and other mission data from the WOC.

A2.10.3.3. **Security Police Representative.** The security police representative coordinates airbase ground defense activities and manages base security issues through the base defense operations center.

A2.10.3.4. **Medical Representative.** The medical representative advises the commander and battle staff on all medical matters and casualty status.

A2.10.3.5. **Chief of Personnel.** The personnel representative maintains the status of personnel strengths--assigned, augmentation forces (on-station and forecasted) and casualties.

A2.10.4. **Command Post Resources.** Data requirements at the SRC and DCC (primary and alternate) that should be available include:

- BCE contingency response plan, including checklists.
- Charts to track personnel accountability.
- Charts depicting vehicle status, by category, such as snow removal, RRR, base recovery, damage assessment, EOD, etc., and special-purpose equipment, generators, water supplies, and materials.
- Base layout map (in acetate) to mark and track UXO, damage and contamination, location of remote stockpiles, dispersed personnel and equipment, and the location of recovery teams.
- MOS selection and repair quality criteria (RQC) kits.
- Base master plan tabs (C & G) showing location of utilities, drainage, etc.
- Base Disaster Preparedness Operations Plan.

A2.10.5. **Precedence of Command and Control.** Normally, the wing commander directs operations from the WOC. After the SRC is activated, the preattack and recovery operations are managed from this command cell. In the event of isolation, attrition, or loss of equipment, civil engineering and RRR command and control would pass as follows:

- SRC (BCE).
- Alternate SRC.
- DCC.
- Alternate DCC.
- Senior BCE Officer.
- RRR OIC.

A2.10.6. **Communication Loss With the Survival Recovery Center/Damage Control Center.** If the RRR OIC loses contact with the DCC and its alternate, it must be assumed that they either have been damaged beyond operational capability or have inoperative communications equipment. In either case, the OIC will attempt to verify the situation by dispatching a runner to check their status. Once verified, or until directed otherwise by competent authority, the RRR OIC will continue working toward providing a repaired MOS in the required time. Similarly, DATs and EOD teams must be trained in the command sequence to automatically report to the DCC if they lose contact with both the SRC and its alternate.

A2.11. RRR Procedures. The BCE should provide the necessary assets and trained personnel (with augmentation where and when required) to repair airfield surfaces and to restore limited aircraft operational capability. Although the following information is repetitious to some degree of what has been discussed elsewhere in this pamphlet, in being presented here as an overall objective rather than individual efforts. As a result, the totality of the RRR mission should become more apparent, since sequential steps, interfaces, and coordination required to conduct RRR in the BRAAT environment are outlined.

A2.11.1. **Required Postattack Activities.** Required activities in the postattack environment which directly affect airfield recovery include the following:

- Airfield Damage Assessment
- MOS Selection.
- UXO Safing and Removal.
- MOS Layout.
- Crater and Spall Repair.
- RQC Calculations.
- MAAS Installation.
- MAOS Clearing and Sweeping.
- MOS Marking.
- Airfield Lighting Installation.

A2.11.2. **Associated Taskings.** Associated taskings are discussed in attachment 3, *Sequential RRR Functions*. There they are presented as a sequential overview of the functions typically included in the recovery of a bomb-damaged airfield. The discussion in attachment 3 explains the kinds and relationships and functions that must be performed and presents a general description of those procedures. However, as has been stressed throughout this document, they are by no means cardinal; the situations at hand must dictate the appropriate response.

A2.11.2.1. Functional areas in postattack repair operations are similar for both the AM-2 mat and the folded fiberglass mat repair systems. However, procedures differ somewhat for each repair system.

A2.11.2.2. The AM-2 aluminum mat and folded fiberglass mat repair systems are currently the only approved and fielded RRR methods, though AM-2 will primarily used for taxiway repairs. Attachment 3 of this volume describes the general sequential procedure for postattack operations using both of these systems.

A2.12. Peacetime Planning and Actions.

A2.12.1. **Preattack Planning Phase.** This phase of recovery operations is very critical. Meticulous planning, realistic training, extensive checklists, pre-selected dispersal sites, hardened facilities/equipment, and other such planning measures will prepare BCE forces to perform quickly and efficiently during the subsequent phases.

A2.12.1.1. All preattack preparations, including RRR, must be listed, disseminated, and exercised properly. These tasks generally are listed in Major Command (MAJCOM)/base recovery directives/checklists, base/joint support plans, reception plans, medical wartime plans, and communications support plans. Such plans should be disseminated to the lowest level necessary to ensure rapid execution. The BCE's preattack planning efforts should be consolidated into the BCE Contingency Response Plan.

A2.12.1.2. As a norm, hostility buildup can be expected to provide several days warning during which the base should improve its defensive posture. However, to ensure not being caught off guard, a minimum alert preparation plan (short notice) should also be written, incorporated into the BCE Contingency Response Plan, implemented, and practiced. Specific reaction standards (times) should be established to measure satisfactory performance. Time will be of the essence. Commanders should use the "Task Accomplishment Times" shown in the Prime BEEF Wartime Task Standard (WTS) as their benchmarks for planning purposes, unless hands-on experience dictates otherwise.

A2.12.2. **Peacetime Actions.** During peacetime, at bases with defined threat probabilities, the BCE should accomplish the following actions:

A2.12.2.1. In conjunction with the BCE Contingency Response Plan and Emergency Action File checklists, develop specific checklists itemizing essential RRR actions for the preattack phase. These checklists, along with those provided by higher headquarters, should be implemented when directed by the WOC or SRC.

A2.12.2.2. Conduct integrated training in full chemical warfare defense (CWD) gear, so crews are proficient in the environment and are accustomed to working in full CWD equipment. To add realism, at least one integrated nighttime exercise should be conducted annually.

A2.12.2.3. Determine and preposition an adequate supply of needed repair materials, identify strategic locations for stockpiles, and establish several suitable alternative haul routes from these stockpiles to potential MOSs. The repair quantities of fill materials required will be dictated by theater and MAJCOM directives based upon the perceived threat. Repair materials should be located for rapid access to the expected repair areas. Aggregate should be stockpiled in the immediate vicinity of runways and taxiways to minimize haul times, yet separated far enough from each other to increase survivability. Pile heights and locations must be considered to comply with aircraft obstruction and clearance requirements. Access to buried utilities must be maintained. Stockpile locations must provide reasonable all-weather access and, when possible, should not require haul routes that use the MOS. Otherwise, trucks may track mud and, possibly, spill rocks and debris onto the MOS surface, complicating the runway and taxiway sweeping and clearing problems.

A2.12.2.4. Determine requirements, and preplan stockpiles of emergency water supplies, since normal base utilities may be disrupted during the attack. Water for drinking and personal hygiene should be pre-identified and available at the dispersal site or in protected areas, such as basements. After an attack that may include chemical weapons, unprotected base water must be considered unsafe for consumption until proven otherwise.

A2.12.2.5. Install an accurate and survivable runway reference marker system to be used by the DATs in reporting airfield damage and UXO, and by the MOS marking team for MOS layout.

A2.12.2.6. Plan for beddown and integration of augmentation forces.

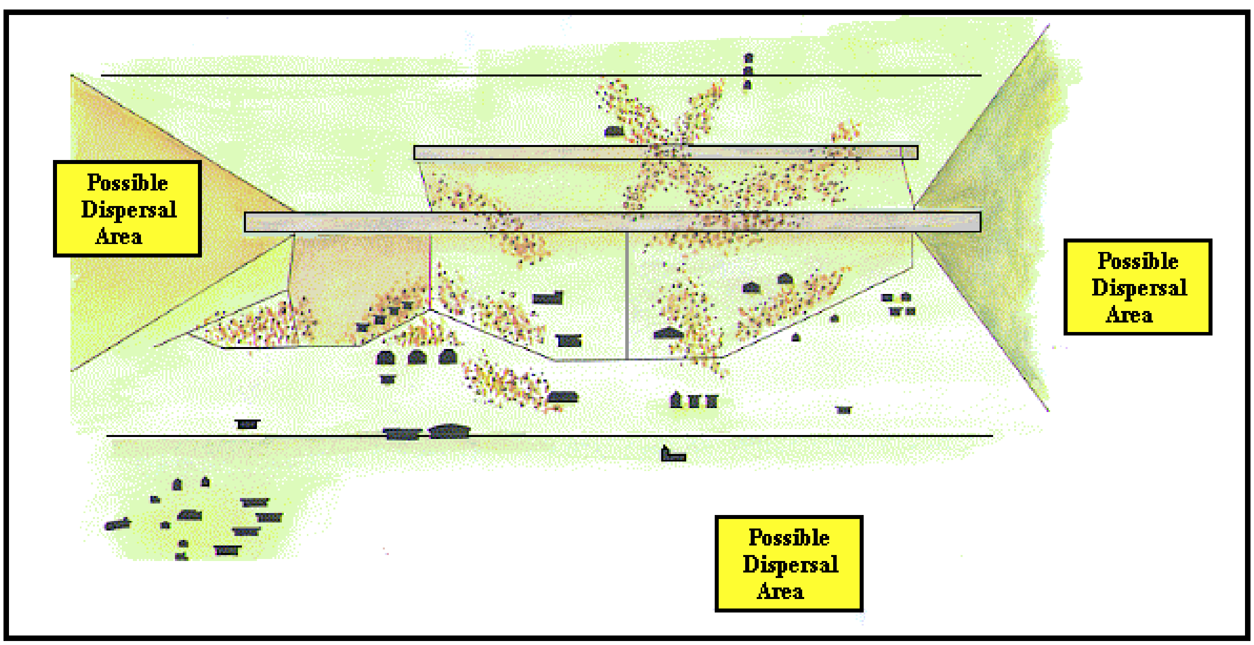
A2.12.2.7. Identify support requirements, such as transportation, from the shelters to the dispersed equipment locations, vehicle mechanics to assist in postattack vehicle repairs, and EOD personnel to stand by at the repair site for potential UXO safing. These requirements should be coordinated with appropriate tasking agencies, and incorporated into the BCE Contingency Response Plan.

A2.12.2.8. Determine suitable dispersal locations for RRR equipment, materials, and people. This may include programming collaterally protected personnel shelters; building berms; or modifying existing natural protection, such as ditches, hillsides, etc., into some means of splinter protection, and improving the surface and/or drainage to preclude a mud problem in a rainy season. In selecting these dispersal sites, consideration should be given to the proximity to possible targets, natural cover and concealment, security, access in inclement weather, etc.

A2.12.3. **Probable Targets.** There is no 100-percent method for determining bomb-impact areas, even from the offensive viewpoint. Although the impact points usually would be expected close to the runway and other high-value targets, it may be common to see bomb patterns 500 to 1,000 feet short or long, and occasional patterns and impacts even outside those ranges. Procedures and candidate locations for the disposal of safed UXO must also be identified.

A2.12.4. **SALTY DEMO.** Figure A2.6 is a rough composite of 25 replications of a simulated runway attack at Spangdahlem Air Base Germany, during the May 1985 Air Base Survivability Capability Demonstration (SALTY DEMO). Each dot represents a bomb impact. As shown, the center two thirds of the runway, 500 to 1,000 feet either side of that runway portion, and aircraft shelters received the heaviest concentration. A 90-degree cone extending off either end of the runway would appear to suffer the least number of impacts. Probable targets, other than the runway, include communication facilities, utility plants, POL areas, munitions storage, aircraft shelters and hangars, open aircraft, and headquarters buildings. Attack headings probably would be planned to coincide with secondary targets, so long or short rounds would inflict secondary damage. People, equipment, and materials normally should be dispersed at least 1,000 feet from probable primary fixed targets. Heaviest bomb groupings occur on the runway/alternate launch and recovery surfaces, aircraft shelters, and industrial areas. As shown in figure A2.6, the areas off the ends of the runway and the housing area are relatively clear of bomb impacts and may provide candidate dispersal areas.

Figure A2.6. Bomb Impact Dispersal Pattern (25 Replications of SALTY DEMO Attack One).



A2.12.5. **Dispersal Area Considerations.** General guidelines for selecting dispersal areas for equipment include:

A2.12.5.1. Dispersal areas should be at least 1,000 feet from anticipated targets and not in the 60-degree cone of an expected attack heading. Coordinate with the local intelligence section (wing director of operations) for the most likely targets and attack headings. The area off the runway may be safe, but care should be taken so the area is not in another attack pattern.

A2.12.5.2. When possible, sites that provide natural cover, such as trees, foliage, ditches, or hillsides, should be selected. Cover and concealment that blend with the background should be planned. Protection should be improved with drive-through trenches, berms, sandbags, etc.

A2.12.5.3. Sites that are accessible in inclement weather should be selected, and the effects of drainage, mud, icy inclines, or snow drifts should be considered.

A2.12.5.4. If the housing area is clear of occupants, dispersal into the housing area should also be considered. Equipment should be parked as close as possible to the sides of the buildings (preferably in the shadows) away from the flight line and industrial areas. Basements should be used for personnel protection. If feasible, a top-story window should be used for an observer with a radio to report to the DCC after an attack. However, care should be taken to provide as much splinter protection to that position as possible.

A2.12.6. **Personnel Dispersal Area Considerations.** General guidelines for selecting dispersal areas for personnel include:

A2.12.6.1. In general, location considerations used in sheltering the equipment from attack also should be applied when sheltering personnel. However, when sheltering personnel, the first option should be for a hardened, filtered-air, over pressure shelter, such as SCPS-II. If the SCPS-II is not available, the next option should be to wear the ground crew ensemble (GCE) inside a collaterally protected facility. If collateral protection is not available, personnel should don IPE and take shelter in places away from primary bomb impact areas, as depicted in figure A2.6. Expedient shelters would include trenches, berms, basements, behind buildings, under equipment, or other such splinter protection. During peacetime, personnel shelters should be assigned, communications capability between shelters and with the SRC/DCC should be installed, and postattack reporting procedures should be established and practiced.

A2.12.6.2. Once the crews are in GCE and the gear becomes contaminated, there is presently no way for people to partially remove individual pieces, such as the hood and mask for food intake, or the trousers for bodily functions. Water intake is possible through the water-intake port in the mask, but care must be taken to not break the mask seal. Rest or relief outside the contaminated clothing can take place only at a SCPS or at a processing facility with positive filtered airflow. In a CWD environment, there is not a threat-level requiring only a partial ensemble. The BCE's preattack planning should include the following:

- Total number of individual protective garments and masks assigned.
- Decontamination cycle and time requirements.
- Processing and decontamination responsibilities.
- Work/rest cycle--instead of 12-on/12-off, a 4-on/4-off or similar schedule may be required to provide sustained capability if temperature and humidity are excessive.

A2.12.6.3. Survey the area to determine several suitable alternative routes from the selected dispersal sites to potential staging areas.

A2.12.7. **Training**. Peacetime training should be comprehensive and thorough, and should be in accordance with existing training guidance. Contingency training requirements are outlined in the Prime BEEF Wartime Task Standard. During peacetime training, the BCE must be alert to all interfaces impacting RRR and must ensure that those functions and related training are standardized and thorough. An example of such an interface follows.

A2.12.7.1. Peacetime SRC training should include specific, consistent DAT procedures for damage assessment training. Concepts concerning how damage assessment would be conducted should be developed. This concept should include, but not be limited to, the following:

- Description of the team's function, collectively and individually.
- Performance requirements.
- Personnel sources and training responsibilities.
- Team chief identification.
- Team equipment identification.
- Training requirements.
- Reporting format.
- Procedures for "comm out," vehicle malfunction, attrition, and other contingencies.

A2.12.7.2. Actual hands-on SRC exercises should involve use of the following functions/activities:

- Runway reference marker system.
- Repair quality criteria system.
- MOS selection.

A2.12.7.3. Similar procedures should be developed for individuals from base organizations that will be acting as initial reconnaissance personnel immediately following an attack. Specific attention should be given to the scope and type of damages to be reported.

A2.13. Preattack Actions. During this phase, the base should make final preparations to survive an attack. When directed by higher headquarters, the wing commander, through the WOC, should initiate emergency action file (EAF) measures, such as:

- Activating the SRC.
- Implementing the base recall.
- Coordinating the evacuation and travel of noncombatants.
- Directing issue of field equipment, weapons, CWD equipment, rations, and individual equipment.
- Placing the base on wartime duty hours.

A2.13.1. **SRC Responsibilities.** The SRC is responsible for establishing alert postures and directing all combat support organizations to take appropriate action in coordination with the established alert posture. When activated, the SRC staff assemble and run the appropriate checklists, deploy the necessary teams and equipment, and generally, ensure that all recovery personnel and activities are ready to perform their BRAAT functions.

A2.13.2. **Damage Assessment Teams.** The DATs should establish contact with the SRC and report to their sheltered dispersal locations. Each team chief should ensure team equipment operability, account for team composition, and secure assigned vehicle and equipment near the each team's shelter.

A2.13.2. **EOD Personnel.** EOD personnel remain under the operational control of the BCE for BRAAT activities. The EOD team chief should brief team personnel, make EOD assignments to DATs, keep the SRC informed of EOD activities, and secure assigned vehicles and equipment near the team's sheltered dispersed areas.

A2.13.3. **BCE Preattack Actions.** At this point, the BCE's efforts should be directed toward protecting people, equipment, and vehicles, and to ensure that civil engineer resources are ready to start base recovery as soon as the attack is over. The BCE should establish a base of wartime operation; assemble, account for, brief, and disperse civil engineer people and equipment; prepare expedient hardening; ensure that communications equipment is in commission; and see that all personnel understand their jobs. The following actions are included:

A2.13.3.1. Execute the preattack checklists.

A2.13.3.2. Put personnel on appropriate shift schedules; establish duty hours and crew changeover procedures; move the off-duty personnel into the SCPS or assigned shelters to start their crew duty cycle; and plan for messing, rest, and relief, and for chemical contamination processing. As planned, RRR teams should be dispersed between shelters and transported so one shelter or vehicle loss will not eliminate an entire functional capability, e.g., all excavator operators or team chiefs should not be located in one shelter or vehicle.

A2.13.3.3. Issue all required individual protective equipment.

A2.13.3.4. Prepare RRR equipment and vehicles for recovery operations. Mount blades on designated vehicles, install armor, and check fluid levels. Identify emergency sources of water for refill and confirm travel routes from dispersal sites to the predesignated staging area.

A2.13.3.5. Beddown and integrate the augmenting RRR forces, if appropriate.

A2.13.3.6. Plan for building berms or similar structures at the preplanned UXO holding areas. Identify locations for shallow ditches at predetermined intervals along the aircraft operating surfaces. These ditches will be used as sub-munitions holding areas for EOD clearance operations. The purpose of these ditches is to get the munitions below grade; therefore, the ditches should not be more than approximately 1 to 2 feet deep, or more than 2 to 3 feet wide. Rather than digging trenches at this time, areas can be identified where trenches may be dug without cutting utility lines. Also, identify locations for possible construction of expedient trenches near the runway. These trenches would be used by RRR team members in the event they are caught by surprise on the area of the MOS by a no-notice follow-on attack and do not have sufficient time to reach a hardened shelter facility.

A2.13.3.7. Inspect stockpiles and haul routes. Ensure that adequate spall repair material and associated dry aggregate are available.

A2.13.3.8. Review plans for refueling and servicing equipment, on-site maintenance, and spare parts availability. Ensure that keys are left in vehicles and that spare keys are available.

A2.13.3.9. Review vehicle status board and discuss the consequences of any known equipment limiting factors (LIMFACs).

A2.13.3.10. Account for personnel, and ensure teams are fully manned.

A2.13.3.11. Ensure that communications equipment (two-way radios) are issued and checked for proper operation, and that an ample supply of spare batteries are available. If more than one frequency is to be used, make sure all involved understand the reasons for such. Also, make sure that the battery chargers function properly.

A2.13.3.12. If required, when the RRR crews have completed their preattack actions, have them assist other engineer recovery crews in such activities as utility isolation; hardening; sandbagging; camouflage, concealment, and deception; and beddown of arriving forces.

A2.13.3.13. Designate specific personnel to leave shelters immediately after the attack is over to obtain a "quick look" for status of RRR vehicles, stockpiles, and haul routes, and report their finding back to the DCC.

A2.13.3.14. Load dump trucks with appropriate fill material and water trucks as required.

A2.13.3.15. Load appropriate RRR matting kits and dozer (if required).

A2.13.3.16. Inventory and inspect the RRR airfield lighting set and MAAS.

A2.13.3.17. Coordinate with other support agencies providing services and assets to the RRR effort. This would include the vehicle maintenance teams to ensure that their stock levels are filled, mechanics are assigned, and vehicles are collocated with the RRR equipment.

A2.13.3.18. Arrange for fuel services to top-off all dispersed vehicles and equipment. At no time during a threat situation should RRR assets be left idle with their fuel tank less than one/half full.

A2.13.3.19. Plan for weapons issue and work party security based on the state of alert and the perceived threat.

A2.13.3.20. Move RRR sets and associated equipment to dispersal locations and shelter all personnel.

A2.13.3.21. Normally, the rapid runway repair OIC and NCOIC report to the DCC in order to observe damage plotting activities as they are received from the DATs. This will allow both the OIC and NCOIC to obtain first-hand knowledge of the true extent of damage to the MAOS; better preparing them to make on-scene decisions once the team is situated on the MOS.

A2.14. Transattack.

A2.14.1. **General.** The effort at this point is to ensure that all needed actions have been taken to rapidly place the base at a maximum level of protection to survive a full-scale attack employing conventional and chemical weapons. Standardized USAF attack alarm signals (based upon international agreements) are used at all high-threat area bases. The decision to declare a given attack alarm is made by the wing commander, based on an actual threat to the base, rather than on forecasted threats for large geographic areas. Information about the type and level of threat is obtained from intelligence reports, air defense radar, early warning systems, base NBC detection systems, individual reports, unit air traffic control organizations, security patrols, and civil/host nation agencies. Dissemination of the attack alarm is done by the installation warning system which incorporates voice, siren, and other audible signals, as well as visual signals to ensure that all personnel are warned promptly of attacks. The base is expected to receive at least a 5-minute warning before the attack. All personnel should don the IPE, according to MAJCOM and base instructions, go to the nearest or assigned shelters, or take cover under or behind the nearest expedient shelter and wait for the “all clear” signal (alarm black) with specific instructions.

A2.14.2. **BCE Transattack Actions.** Civil engineer personnel are well qualified to identify facility, utility, and pavement damage. Each RRR team, if not inside a SCPS or other such “blind” shelter, should appoint an observer to watch the attack (if a suitable and safe vantage point is available) and immediately report observed munitions, general-purpose, or sub-munitions damage to the DCC. This information will then be consolidated and passed on to the SRC for consideration. Such reports will assist the SRC in obtaining a quick picture of the postattack situation and will enable them to focus the EOD and damage assessment efforts. Although not equipped to test and respond to chemical contamination, the observers should watch for vapor-dispersing munitions and be especially watchful for animal reactions. If there are signs of birds dying or small animals having convulsions and becoming incapacitated, with no apparent wounds, it is likely that chemical agents are present.

A2.15. Postattack.

A2.15.1. **Goal.** The base effort at this time is oriented towards restoring an operational capability as soon as possible. The sole goal is to recover the base to support aircraft sortie generation and operations. Expedited action and repairs are essential, and personnel must be well trained and know ahead of time what to expect. The following information should serve as a guide toward obtaining that objective:

A2.15.2. **RRR Activities.** After an attack and the all clear has been declared (alarm black), the SRC ensures that the DATs and chemical agent reconnaissance teams conduct damage and contamination reconnaissance. Additionally, the DCC ensures CE damage assessment and response teams (DARTs) perform base critical facility and utility damage assessments following pre-planned assessment routes. Designated RRR personnel will accomplish a quick inspection of RRR equipment, stockpiles, and haul/transit routes, and will report the status to the RRR OIC or NCOIC in the DCC.

A2.15.2.1. Once the DATs are underway and have established communication with the SRC, the SRC and the DCC will record reported airfield damage. The DCC also will monitor DATs and DARTs for facility and utility damage. Base activities are responsible for conducting initial reconnaissance of assigned areas and reporting to the SRC or associated control centers. Each DAT should report damage to the SRC as often as required, but should initiate a radio call at intermediate, predetermined points so the SRC will know the team’s progress. Without this periodic radio contact, the SRC does not know the team’s status. In the event of “comm-out,” they should follow procedures established by the SRC. These procedures may involve using light or flare signals to the control tower or another designated observer, or dispatching a runner to the SRC (runners may be tasked from other base resources by the SRC). If the runner is the only means of communication, the SRC should establish relays and consider providing transportation. In such “comm-out” situations, procedures should be implemented whereby DAT reports are relayed from the SRC to the DCC. Otherwise extensive delays and confusion regarding RRR requirements may result. In the event of attrition, the SRC should be prepared to replace the

DAT team immediately; in the event of vehicle or communications failure, replacement equipment also should be dispatched immediately. The SRC should have a communications specialist with a vehicle and replacement radios on standby. If a vehicle is damaged and cannot be replaced, the team should proceed as directed by the SRC.

A2.15.2.2. The DATs must provide reasonably accurate data (crater and spall field location and size and UXO descriptions) to facilitate MOS selection and repair criteria determination, thereby expediting aircraft sortie generation. However, time is of essence. Consequently, detailed measurements are not normally appropriate. Actual versus estimated crater size adjustments accomplished by the MOS selection team during the MOS selection process should compensate for most variances.

A2.15.2.3. If during its assessment the DAT cannot proceed because of mine fields, area-denial weapons, target-activated munitions, etc., they will stop; advise the SRC and attempt to circumvent the area via an alternate route. They should then continue their assessment functions in a more permissive area and return to the denied area after UXO clearance/safing has been completed.

A2.15.2.4. When the DATs have completed their assigned area of responsibility, they will proceed as directed by the SRC. If not employed, the DATs should service and repair their vehicle to prepare for another attack. After task completion, DATs should return to their shelter, retaining team integrity, instead of scattering to assist in other functions. Once airfield requirements have been satisfied, it is highly probable that DATs will be directed to divert their attention to surveying non-MAOS areas on the base proper.

A2.15.2.5. As soon as the airfield surface damage picture starts coming into focus and available taxi routes and MOS sites become apparent, the SRC will direct EOD teams to specific areas to start clearing and safing heavy ordnance. Areas containing area-denial weapons will also be identified and cleared by the EOD personnel and equipment. Bomb-removal crews should begin clearing UXO as soon as the weapons are safed and marked. If an existing UXO holding area is not available, or is within the MOS clear zone, an appropriate area should be prepared at a reasonable separation distance from the MOS. As addressed earlier, these holding areas must coincide with prior planning so utilities are not damaged further, creating additional engineering problems.

A2.15.2.6. The DCC is usually headed by the Chief of Operations and manned with the production control staff and superintendents. Its primary function is to execute recovery operations for the civil engineer and provide the interface between the SRC and RRR forces.

A2.15.2.7. The DCC passes direction to the RRR OIC/NCOIC who, in turn, assigns work and coordinates the efforts of the MOS crews, taxiway crews, hauling team, and the support team.

A2.15.2.8. When the MOS has been identified and cleared for access, the OIC should conduct a quick on-scene check to ensure accuracy and validity. If circumstances that might invalidate MOS selection are identified, the OIC should immediately advise the DCC and hold the RRR crews until the situation is reevaluated. Some conditions that might invalidate a MOS selection include:

- Excessive upheaval.
- Too large a repair area.
- Unchecked broken fuel lines.
- Utility damage.
- Area-denial weapons.
- Craters in MAAS pendant sweep area.

A2.15.2.9. When conditions permit and SRC clearance is provided, RRR team members move from shelters to the dispersal locations where they conduct a final equipment inspection. When directed by the DCC, the team will next move from the dispersed locations over approved routes to the designated staging area situated near the runway.

A2.15.2.10. Rapid runway repair teams should travel to the staging area in small, mixed increments so explosions, accidents, or contamination will not cripple the total RRR effort through the loss of an entire team. The vehicles should have mixed loads of people, so all excavator operators or other highly trained people will not be attrited by one weapon detonation. Vehicles should be dispatched in no less than 60-second intervals.

A2.15.2.11. While at the staging area awaiting final clearance to access the repair locations, team chiefs should discuss final repair tactics with their team members. In addition, team chiefs should also review their checklists to ensure that they know the location and status of all materials, tools, and supplies. This is the time to make any necessary final adjustments.

A2.15.2.12. A dispersed vehicle maintenance vehicle, collocated with the RRR equipment, should be equipped with a bench stock of belts; hoses; quick-fix, high fail-rate items; and fire extinguishers, and should respond as directed by the RRR OIC/NCOIC. The bench stock also should include quick-disconnect hose splices and a large quantity of hydraulic fluid. An extra quantity of hydraulic fluid, sufficient to replenish all equipment tanks, should also be stored in the staging area.

A2.15.2.13. The RRR OIC/NCOIC should maintain status boards in their vehicles that display the following information:

- Preidentified routes from shelters, dispersal and staging areas; haul routes, airfield damage, crater locations and identified UXO locations; bomb disposal sites; the MOS (including airfield reference markers); and taxi routes. This information should be on an airfield grid reference map, and craters should be numbered for easy reference in reporting status of repair, maintenance, etc.
- Personnel and equipment status, showing personnel availability and casualties, and equipment status showing location,

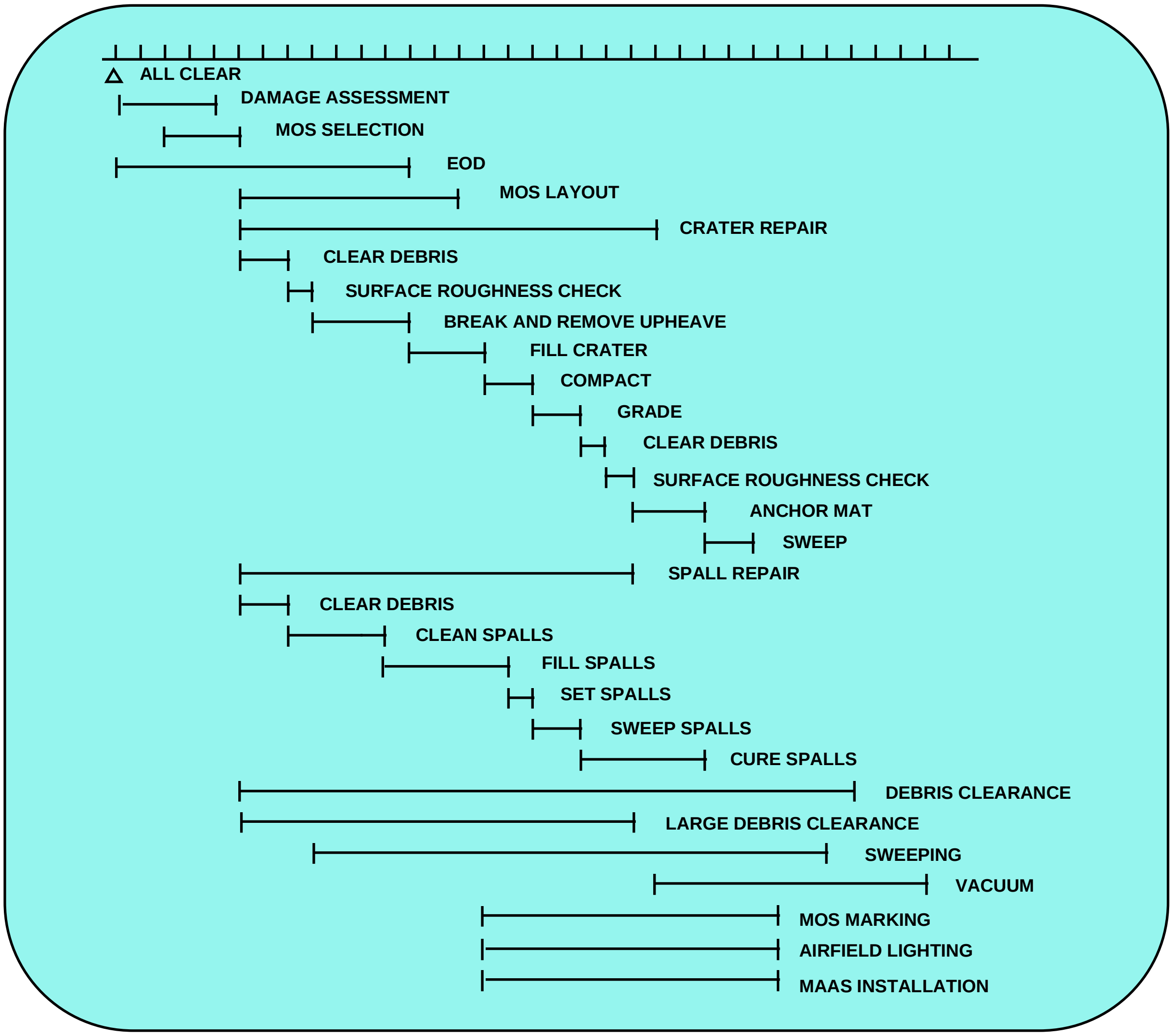
availability, etc.

- Crater repair status, showing directed repair quality, and tasking status indicating team assignments, start times, and estimated completion times.
- Limitation factors (LIMFACS) that might necessitate “work arounds”, e.g., shortages of key vehicle/equipment items and personnel. Other factors that may impinge upon repair times would include weather, an elevated water table, and a poorly trained RRR team.

A2.15.2.14. The UXO safing teams will be dispatched and controlled by the SRC. The EOD representative in the SRC will prioritize the ordnance to be safed; however, the UXO teams initially should be assigned to clear and safe the immediate crater repair area and access routes. When the EOD teams complete their work at MOS craters, they should begin clearing MOS approach and departure overruns, taxiways, access routes to and from fill sites, and other priority areas around the base, including 100 feet either side of the MOS outer edges. EOD teams also should clear areas for MAAS and airfield lighting equipment installation and expedient personnel trenches. **NOTE**: Local situations may justify a variance to this sequence. One such incidence would occur if the routes used by the dispersed RRR teams are encumbered by UXO. After all, the best RRR team is worthless if it cannot reach the repair area!

A2.15.2.15. Once the UXO are safed to an acceptable degree, approval will be given by the SRC for the RRR team to access the MOS repair area. At this point, the SRC, through the DCC, should have already passed on detailed information regarding repair requirements (crater sizes, locations, haul routes, etc.). Armed with this information, the RRR command and control functions have made actual team/work assignments. However, be aware that usually, initial clearance will not provide total MOS access, since UXO safing activities may still be underway. Consequently, it is plausible that only one or two crater crews may be able to initially commence work. This is where the RRR command structure must “earn their money” by making appropriate personnel and equipment adjustment in order to minimize delays. As shown in figure A2.7, many RRR activities overlap and can be accomplished simultaneously.

Figure A2.7. RRR Related Sequence of Events.



A2.15.2.16. Typically, the first RRR activity to take place is MOS layout. The MOS marking team should locate and mark the centerline, preferably with traffic cones. During the centerline identification process, "T" clear zones will also be designated, as appropriate. After the centerline has been identified, the team should measure and mark the edges and position edge markers to outline the MOS boundaries. The MOS marking team usually starts their layout effort as soon as the EOD team has progressed about 2,000 feet down the MOS. Normally, if utilizing a hardened vehicle, the marking team will maintain a 1,000-foot clearance behind the EOD team. However, if the MOS marking team is unprotected, they should extend that minimum clearance distance to at least 2,000 feet or as designated by the EOD team. Since time is of essence, when possible, actual crater repair activities should not be delayed while MOS marking is in progress. Specifically, debris clearing and heaved lip identification usually can both get underway in cleared areas without delay.

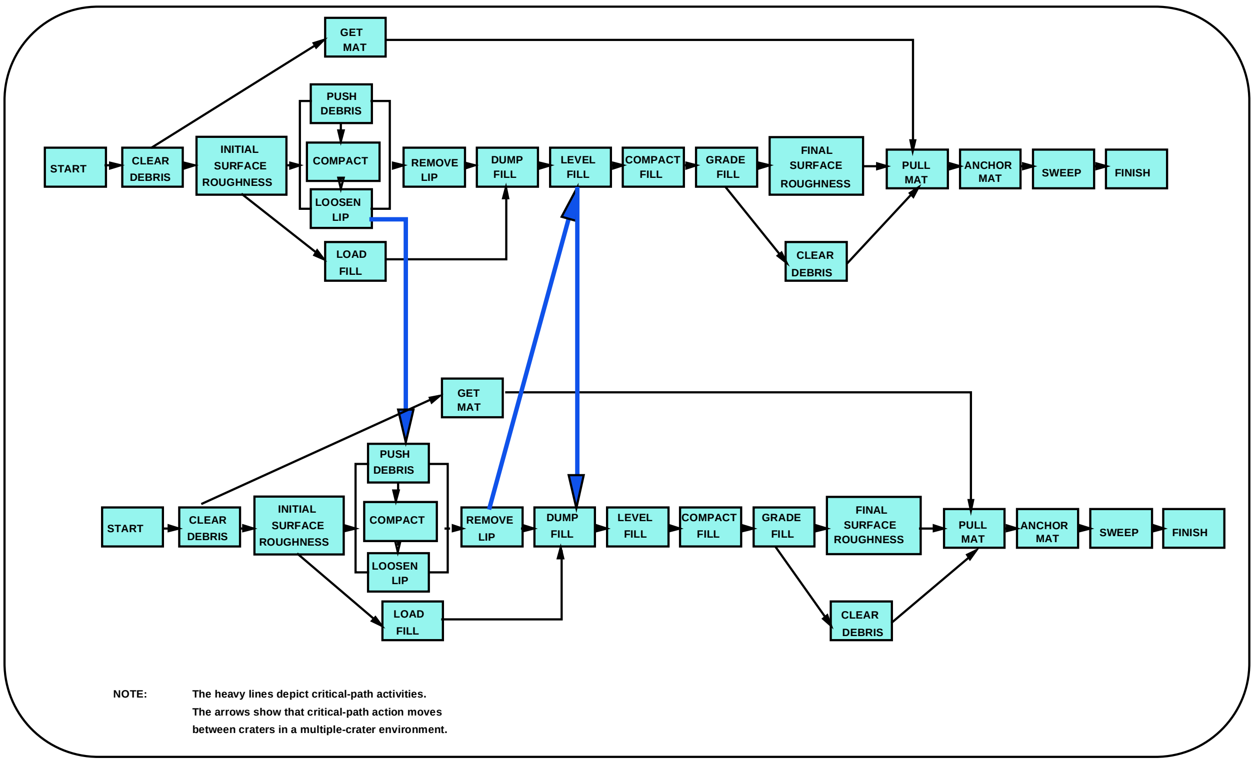
A2.15.2.17. Another important point to keep in mind is that without people the best planned RRR effort is useless. With this in mind, at the earliest opportunity, each repair crew chief should prepare an expedient personnel protection area off the side of the MOS for team members in the event of a "no notice" reattack. This protective area should be situated opposite the bomb-holding areas and at least 200 feet from the MOS itself. Again, as discussed previously, prior planning is essential so underground utilities are not damaged further by construction of this trenching.

A2.15.2.18. Any damaged lines found in the crater repair area should be reported to the DCC. If the broken utility line creates a hazard, the RRR crews may work in other areas until the hazard is eliminated. Otherwise, do not delay MOS crater repairs because of damaged utilities. If the utility is indeed mission-critical, undamaged sections on either side of the runway/taxiway craters may be located, and a bypass repair accomplished at a convenient time.

A2.15.2.19. **Repair Procedures.** Crater and spall repairs should be accomplished using the procedures outlined in this pamphlet and Technical Manual 35E2-5-1, *Crushed-Stone Crater Repair*. The following suggestions may enhance standardization and consistency:

A2.15.2.19.1. **Crater Repair.** As a general rule, during multiple crater repairs, minimize equipment idle time. If an item of equipment is finished with an activity at the first crater and is not needed immediately there for the next activity, the operator should proceed to a new location to begin another required activity. If communications are available, the equipment can be returned, if needed, to the first crater by signaling the operator. Under a "no communications" situation, an excavator, loader, and dozer operator must monitor the crater crew chief for direction. Obviously, the team chief must be thoroughly familiar with RRR critical path items, as shown on figure A2.8, and must ensure that they receive proper priority consideration. If, during the repair, an unexploded bomb or sub-munition is found in the crater repair area, the team chief should notify the OIC, who should in turn advise the SRC. In both instances, a UXO team should be promptly dispatched by the SRC to cope with the ordnance. Pending safing or removal actions, the crater crew would normally be diverted to other tasks. Once the situation has been corrected by EOD members, the crew can return to the site and continue their repair activities.

Figure A2.8. Critical Path Network for a Two Crater Repair.



A2.15.2.19.2. **Debris Clearance.** The debris clearance equipment is responsible for clearing all areas of the MAOS that are not in the immediate vicinity of crater operations. The equipment may be divided into a number of separate teams to work different areas, or remain together as a cohesive unit to work in one area at a time. The support team chief will decide the assignments, based on the size of the area and the situation at hand. First, the team should clear an access route for vehicles to use while traveling between craters and stockpiles or equipment storage areas. Next, the team should start clearing undamaged areas that do not contain spall fields. Since the spall repair operation creates debris, the debris clearance equipment should wait until spall repair is completed in an area before clearing spall fields. It is essential that all debris be pushed at least 25 feet off the MOS, and not piled more than 3 feet high.

A2.15.2.19.3. **Spall Repair.** When provided approval by the DCC following an attack, the spall repair teams should go to their dispersal areas and check the spall repair kits for damages and report their finding back to the DCC. After being properly cleared to do so, the spall repair team should convoy with the rest of the RRR team from the dispersal locations to the staging area. As with most RRR team job designations, specific task assignments are normally not made until the team reaches the staging location. This is simply because it is usually not until this point in time that the RRR OIC has the opportunity to brief all of the command and control personnel regarding damage particulars they are to cope with. As far as the spall repair team is concerned, in most cases, actual spall repair will begin before the debris clearance graders clear the area. Therefore, cones need to be placed, marking the spall field, so the debris clearance equipment, as well as other equipment, stays out of the spall field area being worked on. Unless the spall field is located near a crater where there is heavy debris, the spalls will be easy to find. In areas of heavy debris, a grader or front-end loader (FEL) should first conduct a quick clearing pass so spalls can be found. Since the spall repair operation by it self generates debris, final clearance of the field should not be performed until the spalls are repaired. As with most RRR activities, the actual approach that will be taken regarding spall repair activities will be predicated upon the situation at hand. Realistically speaking, the scenario variations are almost endless.

A2.15.2.20. **Clearing Sequence.** MOS sections, other than those near the craters, may be cleared while repairs are being conducted. Care must be taken to restrict traffic on swept sections to prevent debris from being tracked from surrounding unprepared surfaces, or rocks/gravel spilling from haul trucks.

A2.15.2.21. **MAAS Installation.** The RRR OIC should coordinate with the DCC on MAAS installation requirements. Debris clearance and UXO safing/clearing support will most likely be necessary. In order to have enough time for installation, the MAAS site must be determined not later than 2 hours after RRR operations commence. The following considerations must be included in any MAAS installation planning:

A2.15.2.21.1. **Personnel Requirements.** Six personnel, two of which must be electric power production specialists (AFS 3E0X2).

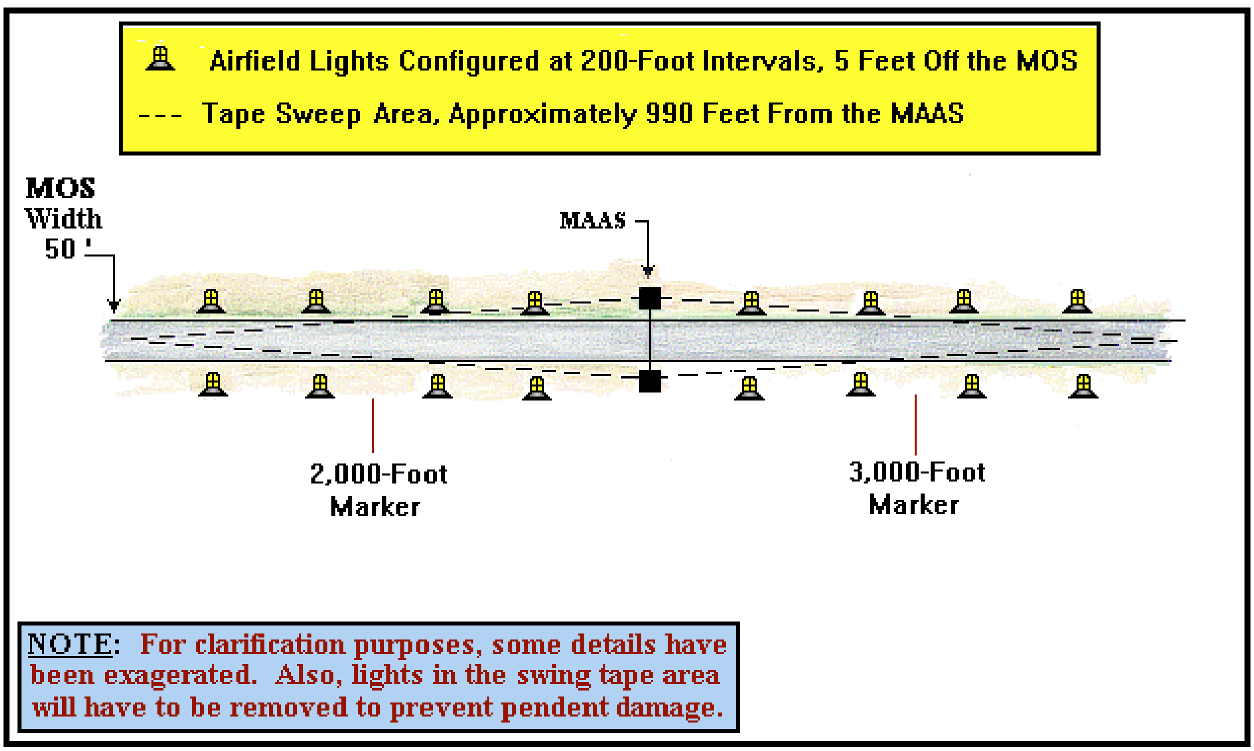
A2.15.2.21.2. **Equipment Requirements.** One truck with a pintle hook (4-wheel drive preferred).

A2.15.2.21.3. **Installation Time.** Time to install complete system--for a well trained team, installation should take less than 1-hour after arrival at the site.

A2.15.2.21.4. **Unit Size.** Each MAAS (one unit on each side of the runway) is 20 by 8.5 feet, and approximately 6 feet high.

A2.15.2.21.5. **RRR Interface.** As stated earlier, debris and UXO clearance equipment may be required to prepare each side of the MOS where the MAAS trailer should be positioned and anchored. In order to have UXO support available in a timely manner, MAAS requirements have to be presented to the UXO team chief early in the recovery effort. Otherwise, conflicting requirements may cause unacceptable delays. After determining the direction of possible engagements, all potential obstructions must be removed from the tape swing area, as shown on figure A2.9.

Figure A2.9. MAAS and Airfield Lighting Installation on a 5,000-Foot MOS.



A2.15.2.21.6. **Siting Considerations.** Although locating the MAAS on a paved surface would be ideal, it also can be situated on a soil surface. However, the MAAS should not be sited near a repaired crater where the crater cover could possibly cause an aircraft's tailhook to bounce over the arresting cable. Specifically, there cannot be crater repairs within 550 feet in front of the pendent (arresting cable). If the MOS is bidirectional, this 550-foot requirement will apply to both directions--possible reducing MOS candidates extensively. However, as addressed in chapter 4, be aware that a more stringent crater free requirement may be called for by the MAJCOM. According to the MAAS technical manual (T.O. 35E8-2-10-1), the following minimum surface areas are needed on either side of the MOS for anchoring purposes: asphalt--50 by 15 feet; concrete--35 by 15 feet; and soil--50 by 30 feet.

A2.15.2.21.7. **Barrier Cable/Tape.** Engagement cables come in 90- and 150-foot lengths. For a 50-foot wide MOS, the 90-foot cable would be used. The cable's center must be on the MOS centerline. Therefore, the MAAS units would be located 20 feet off the MOS edge. The tape and cable, when fully engaged, are dragged approximately 990 feet down the runway.

A2.15.2.22. **Airfield Lighting.** In order to avoid confusion, close coordination between the MOS marking and the airfield lighting crews is essential. The RRR OIC should consider the remaining daylight when planning airfield lighting installation, since flying operations can commence without it if sufficient daylight remains. Actual airfield lighting assembly can be ongoing during RRR crew operations; however, many problems can result from such an approach. If light assembly crews can wait until final MOS clearance is completed before beginning their operations, ease of operation would be enhanced and deconflicting activities would be reduced significantly. Two consequential examples of potential problems that can be brought about by attempting to install the system too early in the scheme of things include:

- Personnel attrition may be experienced, since the airfield lighting regulator, generator, and associated connecting cables are positioned very close to the fringes of the initial UXO cleared zone (EOD initially clears only 100 feet out from each side of the MOS).
- Debris clearing operations conflicts may develop, since the debris clearing zone extends well beyond the area where airfield lighting is actually installed. All MOS debris must be removed a minimum of 25 feet beyond each MOS edge.

A2.15.2.22.1. **Planning Factors.** Ideally, if the situation permits, light assembly and installation can be conducted simultaneously with aircraft takeoff and landing. However, regardless of when the system is installed, the following factors should be considered when planning an airfield lighting system installation:

- **Personnel Requirements.** Four people (at least two electrical systems personnel--AFS 3E0X1) are needed.
- **Equipment Requirements.** One 6-passenger (4 by 4) pickup truck with a pintle hook and one enclosed trailer containing the RRR airfield lighting set or emergency airfield lighting system (EALS).
- **RRR Interface.** When using the RRR airfield lighting set, a 2.5-yd^3 FEL with forks is needed to haul the larger regulator from its secured storage site to the airfield. Once the regulator is positioned, the FEL can be released for other purposes. Therefore, a FEL from the hauling team or from a crater repair team should be used, rather than dedicating one for just a 20-minute task. Also, several of the electrical systems personnel should be licensed on the FEL/forklift. If the EALS is employed, FEL augmentation is not required since the regulator is already mounted on its own trailer.
- **Configuration.** The lights are positioned 4 to 10 feet off the MOS edge. Lights in the MAAS tape swing area (approximately two to three lights per direction) may have to be removed to avoid tape damage and subsequent light fixture destruction during an engagement (see figure A2.9).
- **Anchoring.** There are two different types of light mounting systems. One uses a heavy plate which lies on the pavement, and the other involves employment of a bayonet devise, which is stuck into the ground. The one that is employed will depend upon the situation at hand.

A2.15.2.22.2. **Installation.** If the decision is to conduct an installation simultaneously with other RRR operations, the airfield lighting team can begin assembling the lights and cables approximately 25 to 75 feet off the MOS edge. Once the heavy debris clearance is done, the team then pulls the lights over to their operating location of between 4-10 feet off the MOS edge.

A2.15.2.23. **MOS Line Marking Obliteration.** Undamaged sections of the selected MOS can be marked and old markings that may serve to cause confusion can be obliterated while repairs are on-going in other areas. The goal here should be to have threshold and departure ends marked and the new centerline laid out and ready for painting by the time the last MOS crater (if on the centerline) is completed.

A2.15.2.24. When the assigned repairs have been completed and the quality of the repairs has been measured and found to be within RQC tolerances, the individual team chiefs should move their equipment and personnel off the MOS to the staging area and report this action to the RRR OIC. The equipment should be checked for damage and malfunctions, then serviced. The mobile vehicle maintenance teams should assist, as required, in repairing the vehicles and equipment and in preparing them for additional work.

A2.15.2.25. However, if a repair does not meet RQC, the SRC, in coordination with the wing deputy commander for operations (DO) or the supervisor of flying (SOF) should determine the impact of operating over an out-of-criteria repair. If it is determined that the repair is at a critical location, and the DO decides that the potential risk to aircraft operating over the repair is unacceptable, the SRC will direct the RRR OIC to reaccomplish the repair.

A2.15.2.26. Before completing repairs on the last crater, the SRC should have already determined if other craters on the runway need to be repaired. Normally, the immediate goal is to continue repairing craters that will both lengthen and widen the critical MOS (this operation must be coordinated closely with the DO and airfield management to preclude interference with flying activities). If additional expansion is to be accomplished, the SRC should inform the RRR OIC of these craters and their priority as early as possible in the repair effort so appropriate planning can be accomplished. The RRR OIC then will assign crater crews to these tasks as they become available.

A2.15.2.27. The SRC may direct that the RRR crews be returned to their shelters for messing, relief, and rest. Personnel should continue to wear full chemical protection equipment until the contamination survey teams determine that chemical contamination is not present. When not being worn, the non-contaminated CW equipment should be kept close at hand, in accordance with disaster preparedness instructions, so it is readily available in the event of another attack.

A2.15.2.28. During MOS repairs, equipment damaged to the point that it cannot be repaired in 1-hour or less should be towed or pushed to the cleared holding area, out of the way of repair operations. The RRR OIC should determine whether to repair the equipment or to set it aside and coordinate with the respective team chief to determine the consequences of replacement versus non replacement. Equipment damaged beyond repair can be returned to the heavy repair area, used for splinter protection in the staging area, employed as decoys and/or used for cannibalization.

A2.15.2.29. The RRR OIC will assign personnel to conduct periodic maintenance checks of the repairs after flying operations have started. Repair quality criteria checks for sag and rutting should be made, in accordance with T.O. 35E2-5-1 procedures--usual after 10 to 20 aircraft passes. **NOTE**: Checks may be made at longer intervals after initial settlement has occurred and confidence in the repairs is gained.

A2.15.2.30. Once airfield surfaces are repaired and the repairs are determined to be within acceptable tolerances, the construction equipment should be returned to dispersal areas, serviced, and prepared for the next attack. At that time, the crews should return to their shelters for food and rest if specialized equipment is not needed for rescue operations, or if a critical facility rehabilitation is not directed by the SRC.

A2.16. Reattack.

A2.16.1. **General.** In the event of reattack, the base reverts to preattack or transattack status, depending on the amount of warning provided. Non-contaminated IPE should be redonned, if previously removed. Time permitting, removed equipment should be returned to the preattack dispersal locations, and personnel returned to shelters. However, if time is short, equipment should be driven into ditches or behind buildings or other suitable locations to provide splinter protection. High-priority equipment should be protected by previously damaged or lower priority equipment, if ditches, berms, or buildings are not available.

A2.16.2. **Reattack Actions.** Once the reattack is over and the "alarm black" has been sounded, the following actions should be accomplished:

- Recheck the chemical protective gear.
- Re-institute damage assessment efforts.
- Check equipment status.
- Reassemble and reconstitute the RRR teams.
- Check and report casualties, equipment damage, and overall status to the SRC.
- Replace attrited people and equipment, and reorganize, as needed.
- Await direction from the SRC to restart repairs after validating damage data.

A2.16.2.1. If reattack occurs while repairs are in progress, the operators should take cover and protect their equipment. If given sufficient warning, they should attempt to move equipment back to the dispersal areas. If insufficient time is provided, operators should not attempt to reach the dispersal area and instead take shelter in an expedient personnel trench. As addressed earlier, real-time egress routes to the staging area and slit trenches should be planned in advance and should be cleared by EOD as time permits. All people must be briefed and trained in reattack procedures. After reattack, personnel should remain protected within full IPE until informed otherwise. The SRC again should begin the recovery operation, as required.

A2.16.2.2. If during reattack time does not permit the team to retreat to the original dispersal locations, the next choice should be to relocate the RRR assets back to the staging area. However, if only limited splinter protection is available at the staging area, highest priority protection should be given to excavators, spall repair equipment, paint machines, and other unique equipment. If splinter protection is not available, the vehicles should be dispersed randomly, away from the runway target area. As a general rule, there should be an approximate 300-foot separation between vehicles.

A2.16.2.3. Casualties at the repair site should be handled in accordance with existing direction and self aid buddy care (SABC) procedures. The team chief and OIC should coordinate with the DCC for replacement personnel.

A2.16.2.4. In the event of personnel attrition, the involved team chief should, whenever possible, ensure that the replacement individuals have the same Air Force Specialties (AFS) and skill levels as those of the attrited persons. Having experience in the same contingency positions is an obvious plus as well. The RRR OIC should have a personnel listing that shows each team member's AFS and multi-skilling capabilities. In addition, it would be advantageous to include remarks indicating individuals who also have additional unique capabilities, i.e. qualifications in other unrelated engineering AFSs. Equipment attrition should follow a replacement hierarchy, as indicated in figure table A2.5. For instance, if the function is grading, a grader is the desired equipment. However, if the grader is attrited, a FEL becomes the next best choice; if the FEL is unavailable, the excavator is the next alternative, etc.

A2.16.2.5. As would be expected, after reattack, the base reverts to postattack status. Damage must be assessed, UXO cleared, MOS selection validated or restarted (depending on the new damage) work assignments revised; and in general, the entire operation must be restarted. Unwarranted haste and proceeding without confirmed direction at this point will most likely result in a giant step backwards.

Table A2.5. Equipment Hierarchy.

CRATER PREPARATION	CRATER CLEARANCE	AGGREGATE HAULING
4-Cubic Yard Loader (FEL) Excavators 2.5-Cubic Yard Loader (FEL) Dozers	Loaders (FELs) Excavators Dozers Graders	Dump Trucks Loaders (FELs)
GRADING	**COMPACTING**	**LOADING/UNLOADING**
Graders Loaders (FEL) Excavators	Vibratory Roller Excavator	4-Cubic Yard Loader F/Latch 2.5-Cubic Yard Loader F/Latch Forklift
SPALL CLEANING	**LEVELING**	**DEBRIS CLEARANCE**
Compressor Backpack Leaf Blower Vacuum Sweeper Vehicle Vacuum System	Grader Loaders (FELs) Excavators Dozers	Loaders (FELs) Graders Excavators Dozers
TRANSPORTING FFM/AM-2 MATTING	**SWEEPING**	
Tractor/Trailers 4-Cubic Yard Loader (FEL) 2.5-Cubic Yard Loader (FEL) Excavators	Towed Kick Broom with Tractor Vacuum Sweeper Hand Brooms	
NOTE: Equipment under each heading is listed in descending order of precedence**.**		

A2.17. Support Requirements.

A2.17.1. **Logistics--General.** Essential materials, equipment, and energy resources must be available to support base recovery efforts. Procedures to attain minimum/maximum material levels are outlined in AFMAN 23-110, volume II, *USAF Supply Manual* and AFI 125-101, *War Reserve Materiel (WRM) Policy*. However, the basic philosophy is to maximize self sufficiency for a minimum of 7 days.

A2.17.1.1. Engineer support of contingency and wartime operations depends on WRM, both pre-stocked and pre-positioned. War reserve materials includes the base-level supply system plus:

- Station sets.
- Housekeeping sets.
- War consumables.
- Spare and repair kits.
- Air transportable housekeeping equipment and supplies.
- Petroleum, oil, and lubricants (POL).
- Rations.
- RRR kits (R-Sets).
- Aluminum airfield matting.
- Aircraft shelters and revetments.
- Airfield damage repair materials.
- Rapid utility repair kits (RURKs).
- Emergency airfield lighting sets (EALS).
- Mobile aircraft arresting systems (MAAS).

A2.17.1.2. Equipment and supplies required for recovery operations must be pre-positioned at each MOB, either as minimum stock levels or as separately stored items.

A2.17.1.3. Procedures for decreased work levels should be implemented during the initial contingency phase, since forces are expected to accomplish only emergency work during this period.

A2.17.1.4. CONUS Prime BEEF mobility squadrons and teams are manned and equipped in accordance with AFI 10-210 to provide rapid augmentation of theater base civil engineer forces, or, in combination with other teams at COBs, to form complete BCE organizations where none exist previously. While Prime BEEF forces are equipped with consolidated tool kits and individual equipment, they rely on the availability of in-place or pre-positioned theater equipment, vehicles, and supplies. Forces are deployed in accordance with appropriate plans, with initial emphasis on force beddown. Special attention is given to siting, operating, and maintaining Harvest Eagle and Harvest Falcon air transportable equipment at selected locations and to providing for aircraft launch and recovery operations. The unique capabilities of each Prime BEEF Unit Type Code (UTC) are reflected in AFI 10-210.

A2.17.2. **Peacetime Maintenance Concept.** The RRR system maintenance concept reflects the type of equipment being supported (off-the-shelf or modified construction industry equipment) and the expectation that the equipment will spend most of its service life in storage. The peacetime maintenance concept includes the following points:

A2.17.2.1. Equipment should be maintained within the current Air Force capability and support structure.

A2.17.2.2. Some RRR assets will be designated WRM. While in storage awaiting wartime use, this equipment will receive scheduled maintenance, as required. The WRM manager should provide custody of this equipment; the major command will determine specific maintenance responsibilities. Depot support will be available for major repairs, modifications, and time compliance technical orders (TCTOs). Support equipment and spares for WRM assets also may be designated WRM, and all assets may be checked periodically and used during readiness exercises and deployments. The joint-use WRM will be used, operated, and maintained in accordance with WRM procedures.

A2.17.2.3. For other items, maximum use should be made of available resources, and the majority of repairs will be accomplished at organizational and intermediate levels.

A2.17.2.4. The RRR system is comprised of both general-purpose and RRR-unique equipment. General-purpose equipment should be maintained using standard procedures. Support for unique equipment should maximize common maintenance skills. This approach applies to all maintenance levels.

A2.17.2.5. Rapid runway repair equipment should use common facilities and mobility procedures to the maximum extent possible.

A2.17.2.6. Peacetime maintenance will consist largely of scheduled inspections, with unscheduled repairs to clear discrepancies resulting from normal use, inspections, or exercises, and from implementation of TCTOs. Wartime maintenance is expected to consist only of mission-essential maintenance required to keep the equipment operating to support specific, intense operations.

A2.17.3. **Maintenance Levels.** The peacetime maintenance concept is structured into three maintenance levels:

A2.17.3.1. **Operator/Mobile Maintenance** (On Job Site/On Equipment)**.** In general, this maintenance will be restricted to before use, non-technical, preventive maintenance routines and preoperative checks. Operator maintenance functions will be limited to proper care and use, simple fault determination, inspection, cleaning, and servicing. More specifically, this type repair will consist of restoration and preventive maintenance, including cleaning, preserving, servicing, special inspections, lubricating, troubleshooting, corrosion control, and minor repairs not requiring disassembly of sub-assemblies. Additionally, this maintenance level should consist of fault diagnosis, removal and replacement of defective parts, and adjustments necessary to restore the equipment to an operational condition. Furthermore, a mobile maintenance capability should be established to ensure quick repairs of equipment and vehicles while operating away from the fixed maintenance shops. This mode is especially appropriate during postattack operations. Ideally, each RRR team needs a vehicle repair team (assigned by the transportation squadron), and a roving vehicle repair team should support the taxiway and spall repair equipment--this function should be formally tasked in the base recovery plan. These teams should maintain an on-board bench stock of high fail-rate items, plus belts, hoses, and hydraulic oil. The organizational maintenance goal is to keep on-line equipment operationally ready and to restore failed equipment to operational readiness.

A2.17.3.2. **Intermediate Maintenance** (On-Site/Off-Equipment). This level of maintenance will consist of corrective actions that are beyond the scope of the on-site/on-equipment functions. This category includes repairs requiring shop facilities, replacement or repair of major unit assemblies, parts fabrication, and providing such assistance to organizational maintenance effort, as required. For vehicles, this work is done at MOBs by the transportation squadron. The on-site/off-equipment maintenance goal is to achieve responsive support by locally accomplishing maintenance that is beyond the capability of the organizational maintenance activity. Scheduled and preventive maintenance requirements, beyond the scope of on-equipment maintenance, will be identified in the Inspection Requirements Manuals. Local commanders and their maintenance officers have the prerogative to increase the frequency and scope of scheduled maintenance requirements and are expected to exercise this prerogative when local conditions dictate. Base work centers will accomplish modification, installation, local manufacture, repair, test and calibration of peculiar support equipment not accomplished by the precision measurement equipment laboratory.

A2.17.3.3. **Depot Maintenance** (Off-Site/Off-Equipment). During peacetime, items requiring repair actions beyond the scope of intermediate maintenance should be identified and processed to depot or contractor repair facilities. Depot maintenance will not be considered during BRAAT operations.

A2.17.4. **Maintenance Skills.** Maintenance skills required to support RRR equipment will correspond to skills currently in use by transportation and civil engineer maintenance organizations. New skill requirements should be identified and reported as they become necessary.

A2.17.5. **Wartime Maintenance.** After the start of an attack against airfields, there may be three types of vehicle and equipment attrition: direct battle damage from the conventional weapons effects, mechanical failures, and accidents. The definition of battle damage repair for RRR equipment includes repairs and fixes for all incidents that occur during wartime employment of the RRR fleet. Some incidents are actual battle damage, random failures, operator errors, accidents, wear-out failures, or any combination thereof.

A2.17.5.1. During wartime operations, rapidly returning the airbase to an operational status necessitates that equipment be surged and supported beyond normal peacetime requirements. Rapid runway repair equipment is essential and must continue to operate for the conflict's duration. Maintenance shortcuts and expedient repair procedures should be developed to ensure maximum availability during critical operations. This wartime-essential maintenance may have to be performed by technicians wearing full IPE.

A2.17.5.2. Battle damage repair elements will use procedures for minimal repair and maintenance of equipment. This approach allows the operator or mechanic to exceed normal maintenance tolerances (outlined by manufacturing standards and applicable technical orders (T.O.s)) to maximize availability for runway and taxiway repair. Battle damage repair procedures will identify expedient actions needed to return damaged parts, components, or assemblies to full or acceptable degraded operating conditions in minimum time. These procedures include:

- Waiving inspection and compliance requirements.
- Installing components that can be modified to fit or be interchanged with other vehicle components.
- Using repair parts that serve a noncritical function elsewhere on the same vehicle for restoring a critical function.
- By passing noncritical components to restore basic functional capability.
- Using expeditious cannibalization procedures and parts installation.
- Fabricating parts from kits or from readily available materials.
- Using makeshift substitutes, where possible.
- Using substitute fuels, fluids, or lubricants.
- Developing mobility readiness spares package (MRSP) for RRR vehicles.

A2.17.5.3. Mobility readiness spares package assets would be dispersed throughout each MOB for survivability and ease of access to MOS repair areas where battle damage repairs would be performed.

A2.17.5.4. These battle damage repair procedures would permit vehicle operators or vehicle maintenance personnel to initiate repairs on-site where the failure occurs. Mobility and availability of tools and test equipment should be key elements of battle damage repair. Additionally, training to conduct battle damage repair procedures in a chemical agent environment is essential to the program's overall success.

A2.17.5.5. When an equipment item is damaged or fails during RRR operations, operators and maintenance specialists rapidly must determine the extent of damage. They must determine if the unit is repairable within the 1-hour time frame and the assets required to make the repair are available. The repair must be made on the spot or in the staging area. If the equipment piece is critical, the 1-hour repair time does not apply and the RRR OIC, in coordination with vehicle repair personnel, will decide whether to attempt repair at that time, or to push the equipment aside until it can be returned to the heavy-repair area.

A2.17.5.6. As addressed previously, this battle damage repair will be performed by a special mobile maintenance team equipped with vehicle mechanics, two-way radios, tools, test equipment, parts, and supplies. This mobile maintenance capability should be established at each MOB to ensure quick repairs of RRR equipment and vehicles during recovery operations. Ideally, each MOS team will be assigned a vehicle repair team. A separate roving team will support taxiway and spall repair. These teams should maintain an onboard bench stock of high fail-rate items, plus belts, hoses, and hydraulic oil. The organizational maintenance goal is to keep RRR equipment operationally ready and to restore failed equipment to an operational status as quickly as possible. A degraded operational capability will often be acceptable.

A2.17.6. **Storage/Service.** Storage, periodic inspection, and maintenance of RRR equipment and material should consist of a variety of methods. These methods will depend on whether the equipment is assigned to the CE squadron for daily use, for WRM or for joint (daily and WRM) use.

A2.17.6.1. Most RRR equipment will be stored in the open, but some unique pieces, such as the paint machine, should be provided with covered storage. Furthermore, some items such as runway paints and folded fiberglass mats require not only require covered protection, but also need environmentally controlled storage. Folded fiberglass mats require dry, covered storage to prevent deterioration from moisture and sunlight.

A2.17.6.2. A complete analysis of RRR equipment and material storage requirements should be conducted to optimize storage and the effective life of the system components. For the present, the BCE or WRM manager should use any technical directives, manufacturer's guidance, or best judgment (considering locally available storage resources), to determine how to best protect these valuable resources.

A2.17.7. **Supply Support.** Rapid runway repair supply provisioning can be determined after the level of repair for each RRR item is established. Supply support should be detailed later.

A2.17.8. **Technical Data.** Technical data (T.O.s or commercial manuals) should be provided to operate and maintain the RRR equipment and support equipment.
A2.17.9. **Support Equipment.** Support equipment requirements for RRR equipment are expected to be minimal and should be drawn from inventory, whenever possible.

A2.18. Support Agreements. During peacetime, the BCE will establish contingency support agreements with other base support functions. Each tasked and tasking organization must have a complete understanding of what is expected during RRR operations. These support arrangements should be exercised with the same frequency that integrated RRR is practiced. Furthermore, these agreements should be written into the Base Disaster Response and BCE Contingency Response plans as formal taskings and will include, but will not be limited to, the support functions listed below.
A2.18.1. **Transportation Squadron.**

- Movement of personnel.
- Postattack "Red Ball" mobile vehicle maintenance team with bench stock.
- Use of additional water trucks for preattack water storage.
- Replacement of attrited general-purpose vehicles.
- Unique maintenance/repair support requirements.

A2.18.2. **Services Squadron**. Field messing and billeting, as required.
A2.18.3. **Communication Squadron.** Emergency repair of nontactical radios.
A2.18.4. **Supply Squadron.**

- Emergency resupply efforts for vehicle and equipment parts.
- Emergency resupply of materials, local purchase and rentals.
- On-site refueling and servicing of RRR vehicles and equipment during repair operations.

A2.19. Survivability. Equipment hardening and protection is essential if the RRR forces are to survive and be effective in the postattack environment.
A2.19.1. **Hardening**. Wherever possible, vehicle and equipment hardening should be accomplished at the assembly line by specifying additional steel members and panel thicknesses, rather than by field modifications (additional thicknesses of steel plates).
A2.19.1.1. Where dual wartime and peacetime operations will be performed by an equipment item, all hardening, except for the cab area, should be done, to the maximum extent possible, on the assembly line. A unitary hardened cab can be provided as a single bolt-on item, as was done for the excavator. Such vehicle cab areas should be "human-engineered" for operators wearing IPE, and vehicle design criteria should include the possible use of easily decontaminated material or coating.
A2.19.1.2. As suggested previously, optimum hardening should be done on the assembly line. However, since existing equipment might not be replaced for many years, the BCE must devise methods to protect current resources. One method, bolt-on kits, is possible and may be used; in the meantime, the BCE should consider expedient hardening procedures. Such procedures would include covering exposed hoses with an armor wrap, for example, the Caterpillar® type XT6. Hoses should be modified to be routed inside the frame or behind solid metal plates, wherever possible. Where ventilation and movement are not critical, sandbags may be strapped on to protect critical components. However, before attempting any expedient hardening techniques, other than sandbag placement, first talk with the vehicle maintenance personnel. Otherwise, unacceptable maintenance access obstructions may result from your effort.
A2.19.2. **Facility and Equipment Protection**. Rapid runway repair assets should be protected by one or more of the following three survivability measures:
A2.19.2.1. **Blast and Fragmentation Protection.** The BCE should use earth berms, revetments, and/or terrain elevation changes to provide blast and fragment protection. Earth berms should be at least as high as the article being protected, should be constructed of native material or an equivalent, and should be seeded for erosion control. When metal bin revetments (Armco or B-1) are used, they should also be erected as high as the item they protect, filled with soil, and top sealed with concrete. Portable concrete slab revetments, such as Bitburg revetments, also can be used to provide temporary or permanent splinter protection. These should be produced locally. Wherever possible, earth berms should be built up along the outer facing of concrete revetments to provide additional mass and stability, as well as blast and fragmentation protection. If available, protective facilities should be located in areas where changes in terrain elevation can be used to provide blast and fragmentation protection. For example, vehicle parking areas or command bunkers can be cut into the face of a hillside, so material protection is formed on one to three sides. Revetting by construction methods would be required only on the remaining exposed areas. Having such protection in the staging area(s) is logical and pragmatic.
A2.19.2.1.1. **Dispersal.** Rapid runway repair assets should be removed from high-threat target areas to ensure that one weapon cannot knock out a non-replaceable group of RRR personnel, material, or vehicles. Wherever possible, similar RRR assets should be dispersed to a minimum of three widely separated locations. Bermed or unbermed vehicle parking areas should be limited to two or three vehicles. Fragment "kill" distances can be as far as 1,000 feet, depending on weapon size and fragment velocity and size, as well as on trajectory and terrain considerations. When siting dispersal locations, avoid

anticipated weapon-impact locations, as shown in figure A2.6.

A2.19.2.1.2. **Camouflage and Concealment.** Camouflage and concealment should be incorporated into protective facility design and siting, as well as into vehicle and equipment dispersal, when possible. Plans should include using wooded areas for dispersal locations, elevation changes to blend facility contours into surrounding terrain, earth and grass cover over facilities, liberal amounts of camouflage netting on both facilities and vehicles, and placing junked or heavily damaged vehicles as decoys in open areas, away from RRR organizational locations.

A2.19.2.1.3. **Reattack Protection.** Protection against enemy reattack should be provided for RRR personnel and equipment at repair locations in case a no-notice reattack occurs, and the force cannot relocate to its original protected dispersal location. “Dash-In-Dash-Out” facilities at multiple locations near runways and taxiways should be provided for the RRR force's protection during reattack. These facilities can consist of drive through revetments or excavated areas, combined with low revetments (equipment trenches) where airfield clearance criteria require a low-profile facility. Such facilities can withstand, at a minimum cost, blast and fragment effects from close-proximity, conventional ordnance detonations. Earth berming and camouflage netting should be combined with “dash-in-dash-out” facilities, to the maximum extent possible. Expedient personnel trenching near the runway will normally be accomplished after an attack has occurred. However, pre-identification of candidate sites is an absolute necessity to avoid causing possible utility line disruptions during their creation.

A2.20. Training. Mission success in all theaters of operation depends on the level of individual and unit training. Ideally, whenever possible, engineer personnel should train in the way they expect to fight, and their training should be comprehensive and realistic.

A2.20.1. **General.** Engineer personnel must train for wartime construction and maintenance and must learn to be innovative because of potential shortages of supplies, equipment, and manpower. Their training should stress flexibility and multi-skilling capabilities to offset the effects of casualties and unforeseen situations, i.e., training in contingency engineering skills, as well as in their duty Air Force Specialty. Integrated exercises should tax their physical and mental limits to build stamina, to minimize wartime trauma, and to acquaint them with the friction of war. Engineer personnel should be prepared for a variety of missions in all kinds of weather and climates, throughout the spectrum of warfare, from low-intensity conflict to theater conventional war, in a chemical environment.

A2.20.2. **Major Deployment Requirements.** In-place BCE assets at MOBs in USAFE and PACAF are expected to be manned with sufficient personnel to accomplish all wartime responsibilities on a two-shift basis with CONUS Prime BEEF augmentation. Two major training requirements are generated by this Prime BEEF augmentation concept. The first is that augmenting forces would be trained to the same team and individual skill levels of host BCE personnel. However, this is not always attainable since most CONUS deploying forces do not possess RRR assets at their home stations. The second requirement is that all personnel, in both the augmenting force and the host BCE squadron, understand how the Prime BEEF unit integrates to form a single, cohesive, and effective ground combat force capable of meeting RRR requirements. This means that training should be conducted at both ends of the "pipeline" concerning where each Prime BEEF person fits into the host BCE organization configured for wartime RRR operations, who is in charge, and how the system is to be employed.

A2.20.3. **RRR Training Concept.** To accomplish RRR in the envisioned intense postattack environment, the BCE at a high threat location should train his forces as they might be expected to perform during wartime. This approach requires that the unit’s RRR team be able to:

A2.20.3.1. Operate each item of RRR equipment at a consistent, high level of individual operator proficiency.

A2.20.3.2. Execute coordinated crater repair team efforts to ensure that individual units of equipment are optimally employed in and around each crater, and that fill hauling, debris removal, and other support tasks are accomplished when needed, without conflicting with other equipment operations.

A2.20.3.3. Conduct simultaneous repair of multiple craters at dispersed runway and taxiway locations.

A2.20.3.4. Protect the forces and equipment so they will survive the attack and be able to work in the high-threat postattack environment.

A2.20.3.5. Endure the demanding physical requirements of performing RRR tasks while wearing IPE, and compensate for the degraded performance in the gear.

A2.20.3.6. Integrate the deploying Prime BEEF forces into the host organization to achieve the optimum RRR organization.

A2.20.4. **RRR Training Requirements** (Officer and Enlisted Non-RRR Individual Skills). These are skills that permit each RRR team member to survive and operate in the postattack environment. These skills include physical conditioning, chemical agent awareness and contamination avoidance, IPE wear and care, small-arms proficiency, UXO identification, and self aid and buddy care. Each team member also must learn to recognize the marking signals used in explosive and chemical hazardous areas. These skills normally are provided through the unit's home station training program.

A2.20.5. **Rapid Runway Repair Individual Skills.** These are officer, NCO, and airman skills tailored to each individual’s responsibility in the RRR organization. The objective is to train to the level of proficiency needed to meet performance requirements. For example, excavator operators will be trained in upheaval removal, blade leveling, and aggregate compaction. Managers of multiple tasks at all levels should be trained both in task accomplishment and task sequence requirements. All managers also should be trained to perform the next higher level task, and individual operators will be trained in job sequencing (what to do next or who to ask once the task at hand is completed). Communications procedures; radio discipline, including "comm-out," attrition; and performance in IPE, coupled with both day and nighttime exercises also should be important instructional blocks of each training package.

A2.20.6. **Rapid Runway Repair Unit Skills.** These are building-block, task-integration skills geared to establish proficiency of the overall RRR effort. First-level training skills include individual team efforts, such as single-crater repair, spall-group repair, MOS marking, debris clearance, and other crater support operations. Second-level training consists of combining these units into simultaneous crater and spall repair operations. Third-level training consists of on-scene crater evaluation and rapid team reorganization or tasking to cope with a large number of small craters and spalls. This final level of unit skills is reached by employing multiple teams to train in an integrated BRAAT environment and should include all facets of BRAAT, from damage assessment through final sweeping and MAAS and airfield lighting installation.

A2.20.6.1. First-level training is provided as each unit's home station. To meet these demanding requirements, every effort must be made to incorporate base-wide engineer training scenarios into wing-level training plans and integrated BRAAT exercises to properly demonstrate the coordination and integration relationship between the engineer wartime response capabilities and the operational mission. CONUS Prime BEEF units tasked with lead and follow team mobility dockets should train at least annually using both the AM-2 minikit and FFM training kit. At high-threat overseas MOBs, extensive hands-on integrated exercises involving as many aspects of the RRR concept as plausible should be conducted quarterly. Second- and third-level RRR training is normally provided at MAJCOM operated Special Training Sites (STSs). Silver Flag Exercise Sites (SFESs) do not provide training--their primary function is to conduct task certification.

A2.20.6.2. Whenever possible, the subjects presented below should be included in the course of instruction conducted at a MAJCOM operated STS. Whenever feasible, training should be geared towards a combination of both hands-on and formal instruction.

- Short-notice responses.
- Site selection, and equipment and personnel dispersal.
- Damage assessment, day and night (including DAT training with the runway reference marker system).
- MOS selection.
- MOS layout.
- UXO safing in repair areas and UXO removal actions.
- Crushed stone large crater repair.
- Fiberglass mat positioning and anchoring.
- Utility damage repair (fuel line, electrical, etc.) in a crater.
- Personnel and equipment attrition (before and during repairs).
- "Comm out" procedures (before and during repair).
- Radio discipline.
- Reattack during repair and reconstitution of repair resources.
- Clearance and sweeping.
- RQC evaluations/calculations and crater profile measurements.
- Crater maintenance procedures.
- MAAS site selection and installation.
- EALS installation.
- Final clearance and sweeping.
- MOS marking system installation.
- MOS painting, and blackout procedures.
- Personnel protection trench selection procedures and construction techniques.

A2.20.7. **Realistic Training.** When Prime BEEF personnel are placed in the postattack scenario, they can expect that nothing will happen according to plan. Chaos most likely will prevail. This environment of real damage, debris, injured people, chemical warfare-impaired people, UXO, little or no communications, and confusion will be far different from the "pristine", single, dug-crater situation in which they train at home station. To be effective in the real postattack environment, personnel must train in full chemical warfare equipment and remain in the equipment through crew-change periods; practice in a blown, multi crater environment, integrated with all other base recovery activities; and train in attrition, communications out, and reattack during repair. They should train in and become accustomed to their wartime organization. Such realistic training can be provided only at dedicated training sites, such as those operated by the MAJCOMs. To train as they will fight is as necessary to the engineer repair teams and related BRAAT teams as it is to the front-line tactical fighter aircrew member. A less challenging training format will result in less than adequately prepared people and teams.

SEQUENTIAL RRR FUNCTIONS

A3.1. General. Functional areas in postattack repair operations remain similar for either the AM-2 mat or the folded fiberglass mat repair systems. However, functional procedures will differ, depending upon the system employed. The intent of this attachment is to present rapid runway repair (RRR) postattack activities in an abbreviated, sequential format. The topics covered are listed below:

- Airfield Damage Assessment.
- Minimum Operating Strip (MOS) Selection.
- Unexploded Ordnance (UXO) Safing.
- UXO Removal.
- Temporary MOS Markers (if needed).
- Crater and Spall Repair.
- Mobile Aircraft Arresting System (MAAS) Installation.
- MAOS Clearing and Sweeping.
- MOS Marking System Installation.
- Airfield Lighting Repair/Installation.

A3.2. Damage Assessment System. Damage assessment is normally the first function performed after an attack. It is extremely important to rapidly obtain a damage picture of the entire area of interest (runway, taxiways, shelter access, etc.). An armored vehicle may be used by the damage assessment teams (DATs) to survey assigned sections of the airfield in order to locate craters, spalls and utility breaks, and make an initial UXO reconnaissance. In the absence of a suitable vehicle, the assessment team must proceed on foot. The number of DATs required is dependent upon the size of the airfield; however, most bases will posture three of these teams.

A3.2.1. Quick initial reconnaissance to provide assessment of installation damage after an attack is a key part of recovery. All base personnel and organizations have a responsibility to report to the survival recovery center (SRC), through their respective control centers, any facility damage, casualties, suspected contamination, and unexploded ordnance within and around their specific areas. Each organization should identify and train specific damage reconnaissance personnel for this purpose. While base organizations report damage in and around their immediate areas, DATs assigned to the SRC perform damage assessment in specific areas, such as airfield surfaces.

A3.2.2. Damage assessment team manning normally involves one civil engineer technician (3E5X1), one explosive ordnance disposal (EOD) technician (3E8X1), and one augmentee (any AFS). These teams, under the SRC direction, should survey the runways and taxiways using preassigned routes. The civil engineer person will determine the location and size of craters and spalls while the EOD technicians will identify UXO by type, location, and, when possible, by fuse. Generally, the augmentee will be trained as a driver/observer and will serve as a data recorder. The team uses a grid-reference system and available visual references, such as prepositioned pavement reference markers, runway distance markers, centerline, runway edge, taxiway locations, runway lights, etc., to estimate the location of damage and UXO. The team also monitors vehicle-mounted detectors, M-8 paper, and M-9 tape affixed near vision ports for the presence of chemical agents. During this damage assessment period, speed is of the essence. All findings uncovered by the team are immediately passed onto the SRC. Damage assessment procedural details are presented in chapter 2 of this volume.

A3.3. MOS Selection. The SRC receives the damage information by radio, telephone, or runner; and plots the data on the MOS selection maps. Key MOS selection elements are plotting data, selecting the MOS, designating damage to be repaired, designating the area to be cleared of UXO, assigning repair quality criteria (RQC), and estimating recovery time. Repair quality criteria is normally accomplished after MOS candidates have been ascertained. Damage plotting and MOS selection are usually done simultaneously. The damage to be repaired then may be worked with charts containing aircraft loading information and RQC for the appropriate aircraft. This information will be used to determine the minimum acceptable repair qualities for each crater, depending on the crater's location, length, and spacing. The MOS is selected and recommended to the wing commander for approval. After MOS selection is approved, the SRC passes MOS location and repair instructions through the engineer damage control center (DCC) to the RRR officer in charge (OIC) who makes appropriate team assignments. The SRC also will direct UXO teams to begin safing and clearing the selected MOS. Details regarding MOS selection procedures are presented in chapter 3 of this volume.

A3.4. UXO Safing/Removal. Various render-safe procedures will be used to neutralize UXO on the MOS, access routes, and near the repair areas. Large UXO and some submunitions may be attacked with the standoff munition disrupter (SMUD) technique, if possible; otherwise, manual procedures will be used.

A3.4.1. Buried UXO, identified by an entrance hole with no accompanying upheaval, usually will remain undisturbed, depending on the situation and location. Holes of entry and camouflets normally will be filled or covered on the MOS or access routes, and the ordnance will be recorder and attended to later, when operations permit.

A3.4.2. Removing the safed UXO is accomplished by bomb-removal teams who haul or drag the UXO to a designated holding area(s).

A3.4.3. At best, UXO safing is dangerous and time-consuming, but it must be conducted before beginning repair operations. UXO removal can, and in many instances will, be conducted in conjunction with RRR operations. The UXO teams should concentrate their initial efforts on the access routes and areas immediately adjacent to the craters and spalls, so repair teams can begin work as soon as possible. During repair operations, at least one UXO safing crew will be available in the repair area to support RRR in case UXO are uncovered during crater excavation, or discovered in the crater or debris. In such situations, personnel and equipment will move away from the crater area, and the SRC will be notified. The SRC will dispatch the nearest UXO team to minimize repair delay.

A3.5. MOS Layout. When a usable MOS is immediately available without needing repairs, it must be outlined and marked with temporary MOS markers to designate the boundaries for the aircrews. However, if damage must be repaired, the MOS should also be outlined so repair personnel know where the repair boundaries are. The MOS marking team's first step is to locate the MOS centerline references. A MOS centerline then is marked with traffic cones or paint. The MOS edges are established by measuring from the centerline, and an outline is laid using portable edge markers. Details regarding MOS layout are included in chapter 5 and TO 35E2-6-1.

A3.6. Crater Repair. Folded fiberglass mats should be considered the primary FOD cover for use on all MOS repairs. AM-2 mats will be used only on taxiways unless FFMs are not available. If AM-2 matting is to be used on a MOS, extensive spacing between patches is required and transitional ramps are a must. Procedural details regarding both systems are included in TO 35E2-5-1 and chapter 5 of this volume.

A3.6.1. **Using a FFM Foreign Object Damage (FOD) Cover.** Regarding a MOS repair involving the FFM procedure, a FEL, excavator, or grader clears debris from the area around the crater, and the extent of upheaval is measured and marked using the line-of-sight technique. Upheaval is removed by first breaking the crater lip using the excavator with the moil point attachment to create a break line, then using either the excavator bucket attachment or FEL the fractured pavement is removed. An intermediate profile measurement is conducted to make sure the remaining surface is truly flush. The crater then is backfilled with debris if conditions are dry, or with ballast rock and a geotextile membrane for a wet crater, and topped with crushed stone. A vibratory roller compacts the fill, which is then graded level with the surrounding pavement. The team chief designates a mat delivery and assembly team, who concurrently assembles the mat near the crater and has it ready when needed at the crater. A final profile measurement of the filled crater is conducted to ensure that the crater repair does not exceed RQC limits. The last step is to tow the folded fiberglass mat over the repair and anchor it in place.

A3.6.2. **Using an AM-2 Foreign Object Damage Cover.** When using an AM-2 FOD cover on a MOS, the crater repair procedures are exactly the same as those outlined above for the FFM. However, keep in mind that rarely will AM-2 matting be used on a MOS because of the transitional bounce problem that is created when aircraft traffic it. More commonly, AM-2 matting will be used to cover taxiway crater damage. Here repair criteria is not nearly as stringent as that on a MOS. According to the RQC technical manual (35E2-4-1), a taxiway crater repair can have up to 6 inches of upheaval and a maximum 2-inch sag. These figures are predicated upon all aircraft operations within the repair area not exceeding 5 knots. Other procedural differences involved in a taxiway repair include:

- Bolting-down of AM-2 mat may not be necessary on taxiway repairs except in pivot and brake points.
- Often the actual patch will be reduced to a width of only 30 feet.
- Aircraft braking over the patch should be avoided as much as possible.
- A taxiway patch can be constructed with or without a keylock.
- AM-2 matting can be employed as a transitional taxiway when damage to the original taxiway is extensive.

NOTE: A new AM-2 ramp is being developed for the Navy that has been extensively elongated. The intent of this new ramp is to reduce the transitional bounce problem generated when aircraft pass over the patch. Also, development of a composite equivalent of the AM-2 mat are under consideration. The intent of this effort is to produce a much lighter and thinner mat that is comparable strength wise as the original AM-2 product. If the composite mat R&D effort is successful, the new system would prove effective for the construction of expedient landing strips, aircraft parking ramps, and other projects that require covering of a large surface. Procedural details regarding the construction of a standard AM-2 patch are included in attachment 4 of this pamphlet.

A3.7. Spall Repair. Compressed air is used to blow small debris and moisture from the spall. Silikal® is hand mixed, similar to concrete, in a plastic bag, poured into each spall, then leveled with a trowel. The Silikal® is rapid-setting and usable in wet environments. Pea gravel may be used as an extender. The noxious and irritating fumes produced during curing require personnel to wear masks and gloves. The mixture will support aircraft operations within minutes. If Silikal® is not available, alternative repair procedures involving various asphalt or quick setting magnesium phosphate cements may be used. Details regarding these substitute materials are presented in chapter 5 of this volume.

A3.8. MAAS Installation. The MAAS provides a capability for relatively quick mobile aircraft barrier installation that can be configured on either a soil or paved surface. Under ideal conditions, with a MAAS an aircraft arrestment can take place every 3 to 5 minutes. The MAAS installation team usually concurrently installs the arresting barrier while crater repair operations are proceeding. Procedural details regarding MAAS installation are contained in T.O. 35E8-210-1.

A3.9. Debris Clearance And Sweeping. While repairs are being completed, undamaged areas of the MOS and MOS access taxiways can be cleared and swept of fragments and debris. As soon as repairs are completed, remaining heavy debris on the MOS is cleared by FELs and graders. Dozers and FELs level the accumulated debris, so it is no closer than 25 feet from the edge of the MOS and no more than 3 feet high. Graders and towed sweepers or vacuum sweepers clear the remaining foreign object damage material.

A3.10. MOS Marking. The MOS must be marked sufficiently to identify at least the thresholds, centerline, edges, and remaining distances. A paint machine, edge markers, distance-to-go markers, and barrier markers are included as part of the MOS marking system. The MOS marking team must work at a speed which allows it to complete all marking shortly after the last MOS crater has been repaired. This effort must also include obliteration of any original runway markings that are no longer usable. Minimum operating strip marking procedures are outlined in chapter 6 of this volume and T.O. 35E2-6-1.

A3.11. Airfield Lighting. Lighting currently is provided by the emergency airfield lighting system (EALS). However, the RRR airfield lighting set may also be available at many main operating bases (MOBs) and can be employed if the damage to the original system is only slight. Basic components used in both the EALS and the RRR lighting sets are interchangeable. When possible, the system should be dispersed to a relatively safe area as part of preattack activities. Once the attack is over, the EALS trailers are moved with other RRR assets to the staging area. The actual start of system installation will be dictated by the circumstances at hand. Factors such as UXO clearance, night versus daytime operations, and MOS layout will directly impact EALS installation. However, ideally, the airfield lighting team should plan to have the EALS operational when the MOS can support aircraft generation. To do this, they may have to initially accomplish much of the assembly about 25 to 75 feet off the edge of the MOS and once the debris clearance is completed, relocate and anchor the assembled lights and wires into proper position 4-10 feet off the MOS edge. Procedural details regarding EALS installation are included in T.O. 35F5-3-17-1.

AM-2 MAT ASSEMBLY SEQUENCE
(Taxiway/Transitional Patch)

A4.1. General Policy. Taxiway repair team members must make sure that all tools and the matting are loaded on the lowboy to permit the most efficient off-loading and assembly of the AM-2 matting. The AM-2 patch can be either built directly over the repaired crater or as a standalone effort. The following comments refer to a standard AM-2 patch assembly (54 feet by 77 feet 6 inches--including ramps) that is conducted while the crater is being repaired. As discussed earlier in this pamphlet, a number of variations are available when conducting repairs on a taxiway. Some of the more consequential variations will be addressed as they become apparent.

A4.2. Select the Assembly Area.

A4.2.1. Early in the repair cycle, the crater crew chief should identify the patch assembly area. The area chosen should be undamaged, preferably on the taxiway, either to the side of the crater (figure A4.1, Method A) or to the top or bottom of the crater (figure A4.2, Method B). In addition, the selected assembly area should allow for a straight, single direction (either parallel or perpendicular to the taxiway centerline) short pull of the assembled matting.

Figure A4.1. Patch Assembly--Method A.

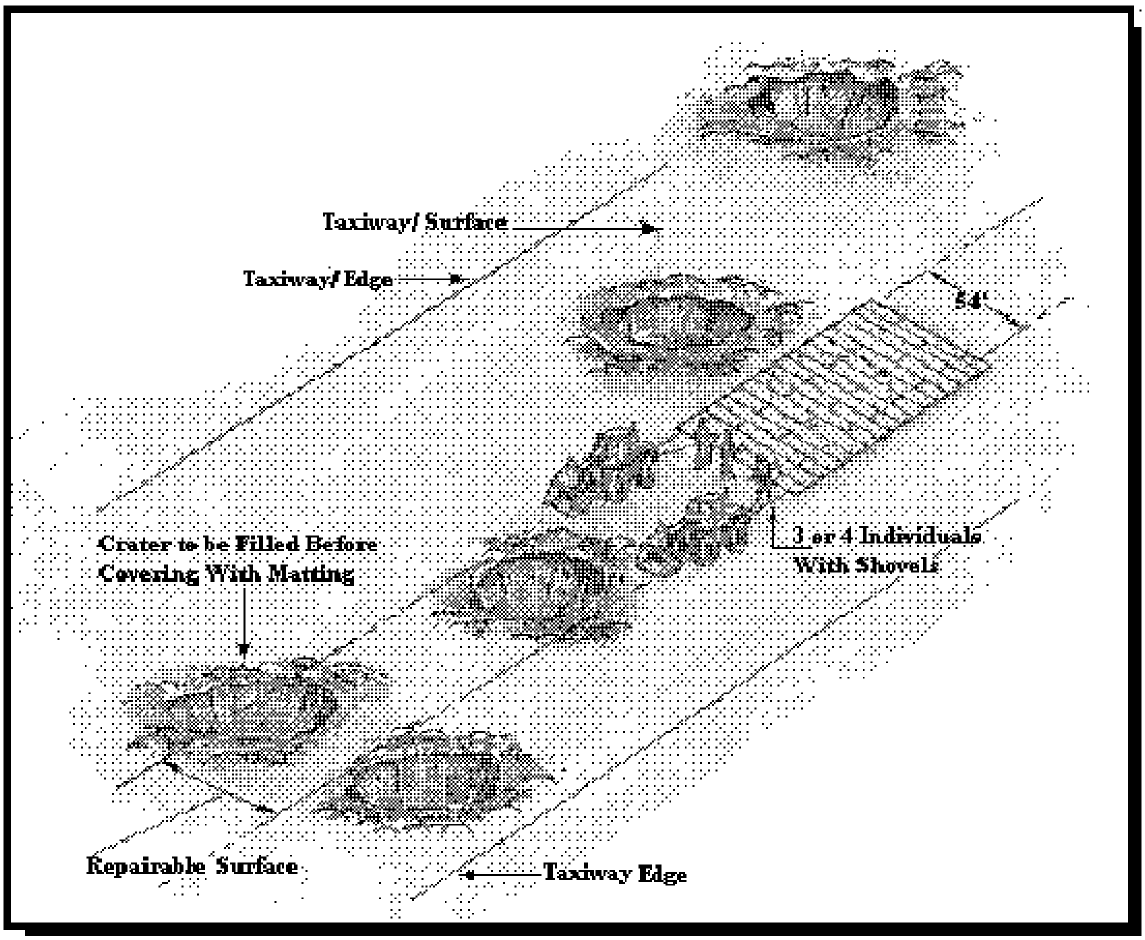
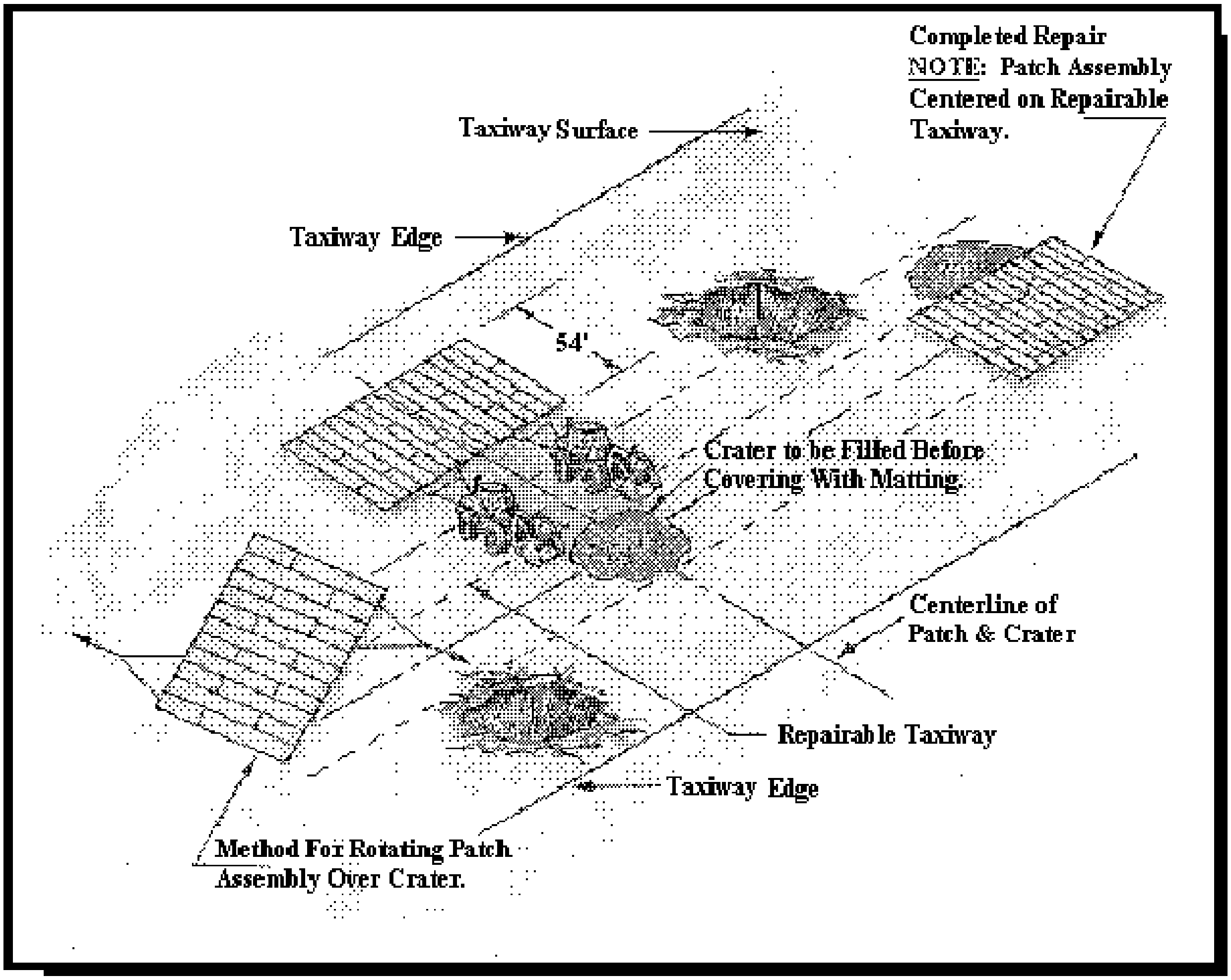


Figure A4.2. Patch Assembly--Method B.

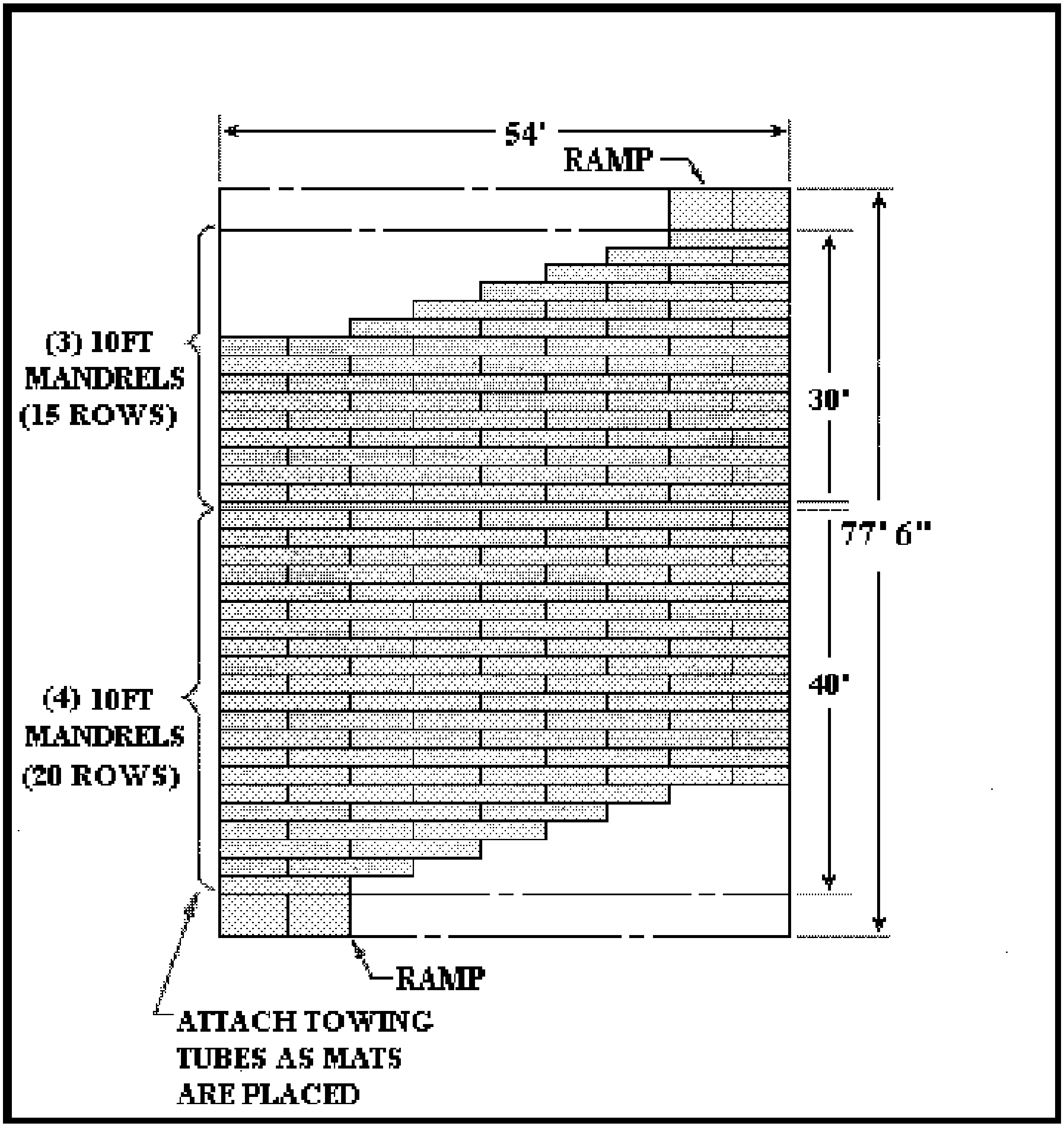


A4.2.2. Assembly areas must be cleared of all debris before the matting is fabricated. Also, the areas should be swept with the towed sweeper to remove small ejecta. Removal of small ejecta keeps debris from accumulating in the matting grooves.

A4.3. Assemble the Keylock. Assemble and place male-male keylock at the approximate extended centerline of the crater, either parallel or perpendicular to the MOS centerline. When assembled, a keylock is 54 feet long. ***NOTE:*** A taxiway patch can also be assembled without a keylock.

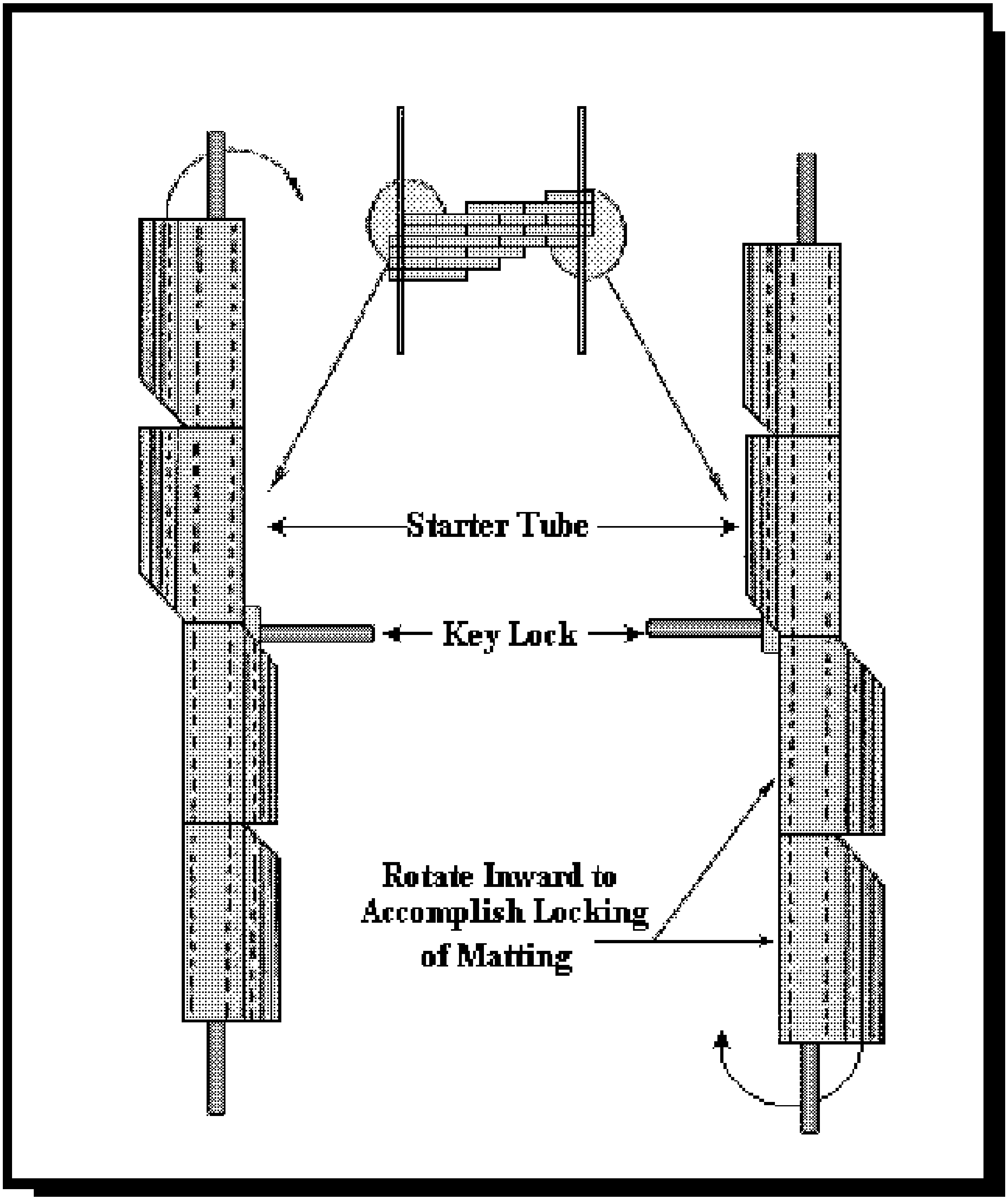
A4.4. Assemble the Towing Tubes. The towing tubes on the assembled patch serve two purposes. First, by attaching the proper towing harness, the assembled patch can be pulled sideways to properly align the patch. Second, by attaching the towing tubes on both sides of the patch, the assembled matting is totally locked together and will not separate or “stair step” during positioning or continued use. With a standard patch, fifteen rows of matting (30 feet) are placed on one side of keylock and 20 rows of matting (40 feet) are placed on remaining side (figure A4.3). There are various methods of attaching the towing tubes to the matting. Three examples follow:

Figure A4.3. Attachment of Towing Tubes.



A4.5. Method A--Attaching Towing Tubes. Concurrent with the keylock assembly, preassemble towing tubes, mandrel, connector fittings, stops, and end caps (do not tighten the end caps.) Towing tubes should be assembled perpendicular to the keylock assembly (figure A4.4) and are required on both sides of the assembled matting. The assembled keylock and towing tubes, prior to the placement of the matting, will resemble the shape of a capital "**H**".

Figure A4.4. Towing Tube and Keylock.

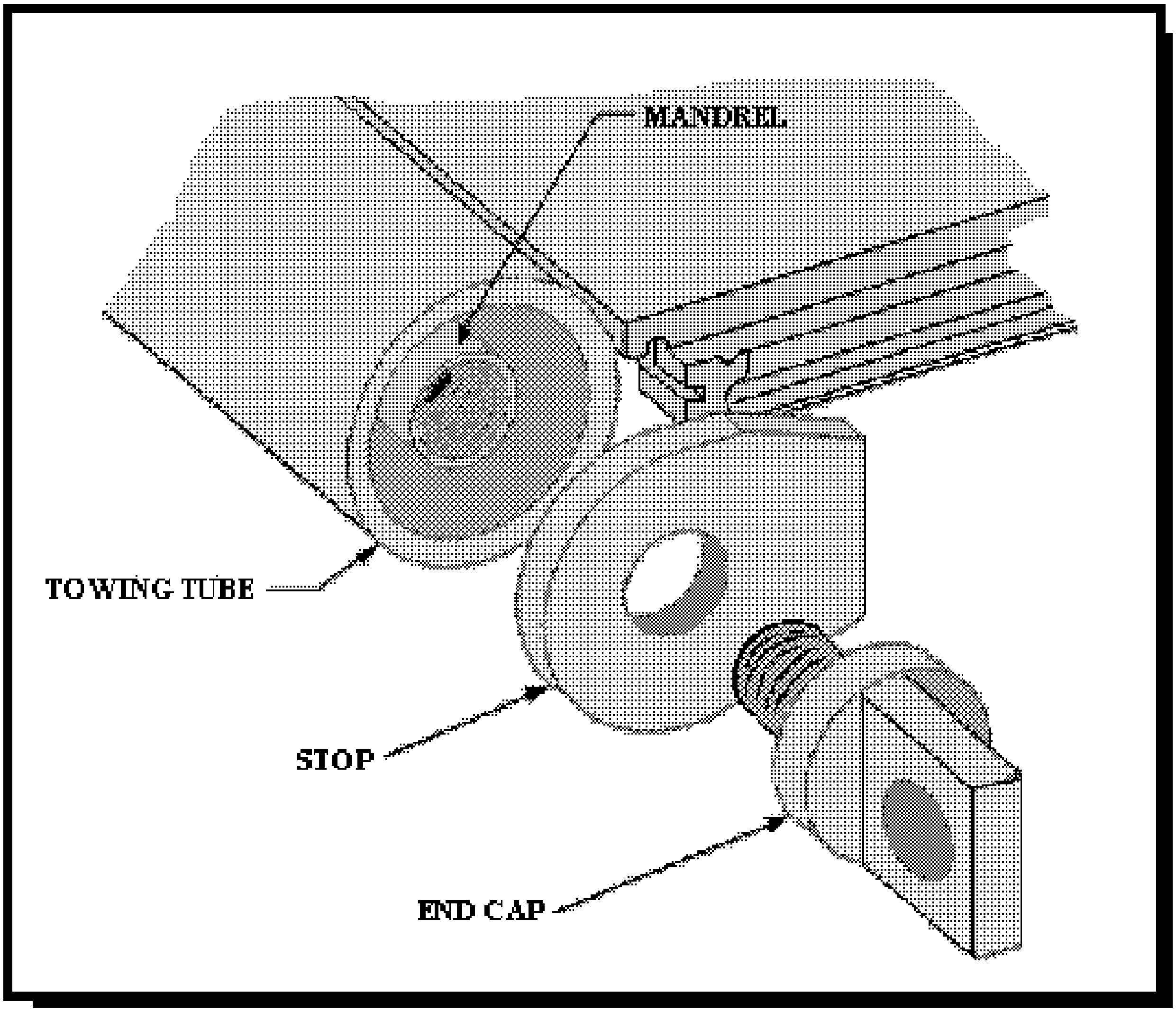


A4.5.1. Initially, two starter towing tubes are placed on a 20-foot piece of assembled mandrel, centered on the special connector fitting next to both ends of the keylock. **NOTE:** Starter towing tubes are 1-inch longer than the normal towing tubes and do not have a hole for connecting towing clamps. In order to avoid future confusion, we recommend these tubes, four each per patch kit, be identified and painted a distinctive color to readily differentiate them from normal towing tubes.
A4.5.2. The starter tube that receives the first piece of matting placed on the keylock must be placed on the mandrel with the prongs facing up. The starter tube that receives the last piece of matting from the first row must be placed on mandrel with prongs up also, but will be rotated to prongs down when attached to matting (figure A4.4).
A4.5.3. Place sufficient towing tubes (15 on one side and 20 on the other) and mandrels with connector fittings to

accommodate the total patch. If there are less than five mats remaining at the end of the patch, use a short mandrel for each one. Towing tubes should be placed with prongs located identical to the starter tubes.
A4.5.4. After all tubes are placed on the mandrels (a total of two starter tubes and 33 towing tubes on each side), place the stop and end cap on each end of mandrel. **NOTE:** Do not tighten end caps until the total matting patch has been assembled.

A4.6. Method B--Attaching Towing Tubes. As the first mat is placed starting a new row, connect the towing tubes to the left (looking toward the keylock) side of the matting. After each row of mat has been completed, connect the towing tube to the right side of the matting. Insert the locking bar between the mats and the tube as each connection is made. Place a starter tube on each side of the keylock, on each side of the patch (four starter tubes are required). After all tubes are placed (15 on one side and 20 on the other), insert a long mandrel with tapered bullet nose attached in the tube, from the end of the patch (figure A4.5).

Figure A4.5. Towing Mandrel and Mandrel Fittings.



A4.6.1. Using the connector fitting, connect another long mandrel to the first mandrel. Be sure that the connector is threaded all the way into the mandrel and that no threads are showing. Push this assembly into the towing tube and connect another long mandrel. Repeat this procedure until the bullet nose emerges at the opposite end of the towing tube. It will be necessary to install one extra mandrel so as to provide adequate spacing to remove the bullet nose and install towing bar stop and cap.
A4.6.2. After the towing bar stop and cap have been installed on one end, pull the mandrel so that the stop is flush against the towing tube. Next, remove the additional mandrel from the opposite end and insert a towing bar stop and cap at that end. Make sure that the long end of these stops is facing in toward the patch and that they clear the mat ends.
A4.6.3. Tighten the end caps equally, using the crescent wrench provided in the tool chest. If the panels expand so that the patch is longer than the assembled towing tube, add more stops (as a shim) from the spare stops provided in the kit. Tighten the caps at each end of the tube as tight as possible. Make sure that tubes are seated corrected.

A4.7. Method C--Attaching Towing Tubes (Preferred Method). This is a build-as-you-go method that is done concurrently with the mat assembly.

A4.7.1. Use one long connector to connect two long mandrels on each side of the end of the keylock.

A4.7.2. After mandrels are connected and laid out, slide on two starter tubes, centering them on each mandrel at the center connector fitting. Remember, starter tubes are 1-inch longer than the towing tube and do not have holes drilled for the towing harness.

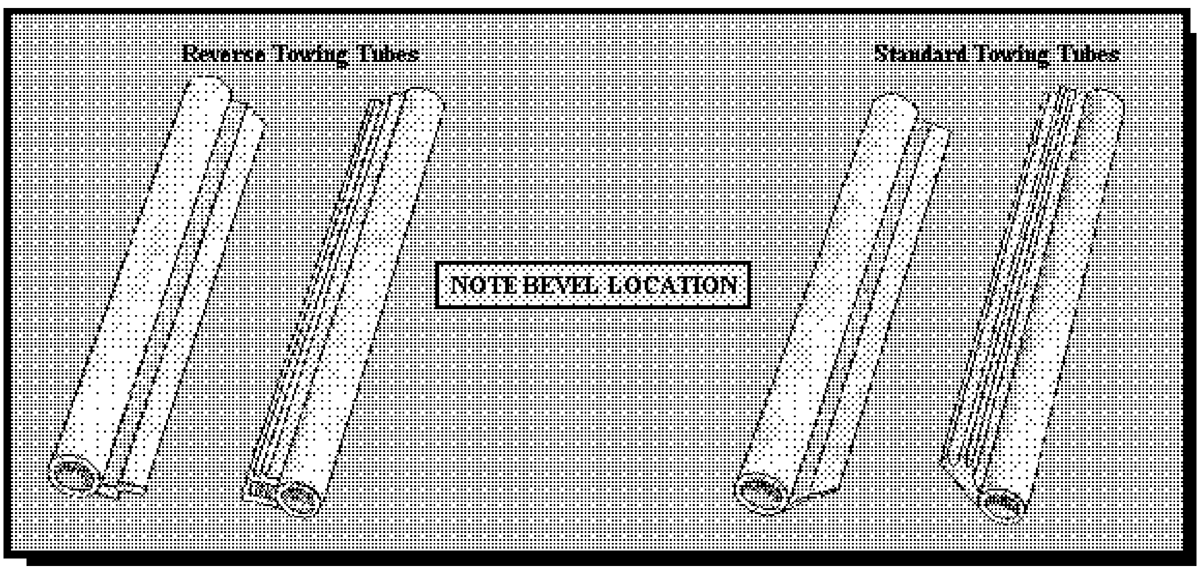
A4.7.3. Since the matting is always laid from left to right, the starter tube that receives the first piece of matting placed on the keylock must be placed on the mandrel with the prongs facing up. The starter tube that receives the last piece of matting from the first row must be placed on the mandrel with the prongs up and (when connected to the end of the matting) must be rotated 180 degrees on the mandrel to the prongs down position.

A4.7.4. Initial and final attachment of each tube on every row will be locked in place with a locking bar. Additional towing tubes should be placed on each mandrel as they are needed, staying ahead of the mat laying crew at least one mandrel length until the job is done.

A4.7.5. When all towing tubes have been installed on mandrels, place a stop and end cap into the end of each mandrel. Make sure that the long end of the stops are loose and are facing towards the patch.

A4.8. Assemble the Towing Tubes (Reverse Tubes). Inventories of select RRR kits indicate that some of the towing tubes supplies are reverse of the standard and cannot be assembled as recommended by Method A or Method B. These tubes are readily identifiable when compared to the standard towing tube (figure A4.6). The following is the recommended procedure for assembling the reverse towing tubes.

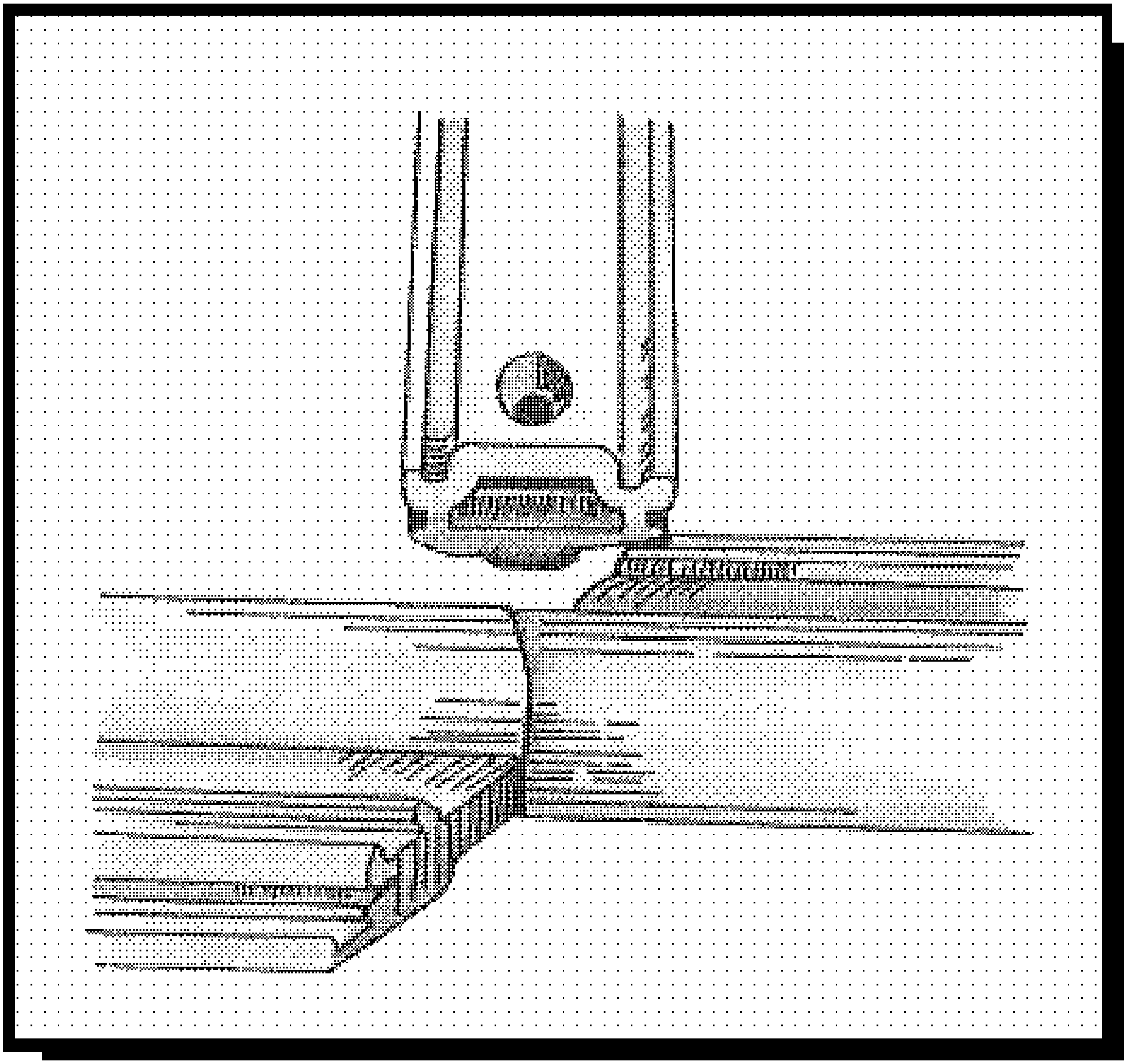
Figure A4.6. Comparison of Standard and Reverse Towing Tubes.



A4.8.1. Select sufficient reverse towing tubes, usually 35, to complete a towing tube assembly. ***NOTE:*** Reverse and standard towing tubes cannot be intermingled in a towing tube assembly. Also, the reverse starter towing tubes cannot be used in the assembly (Starter tubes are 2 inches longer and do not have a hole in the tube to attach the towing clamp.)

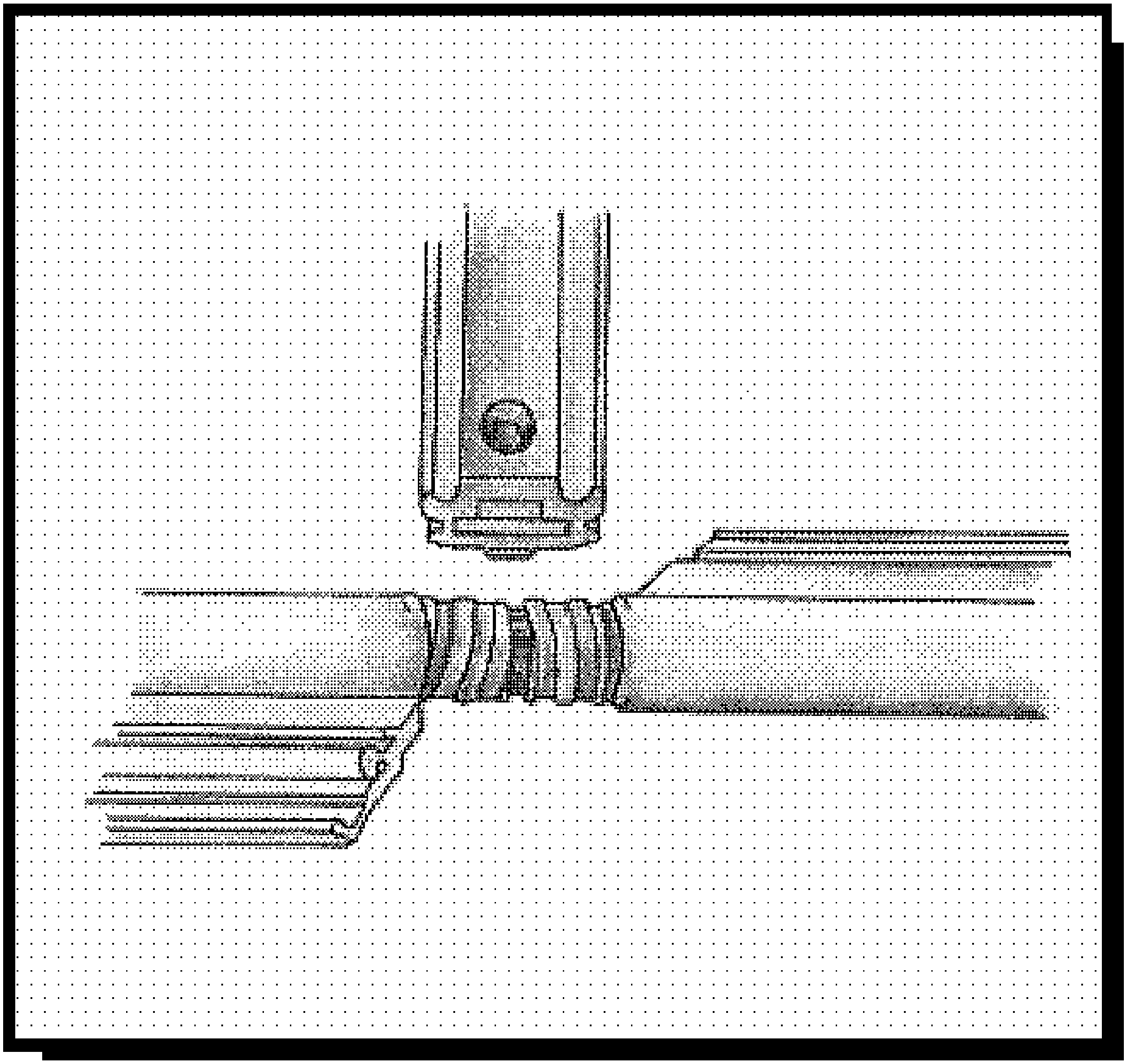
A4.8.2. Prior to placing AM-2 matting, the standard towing tube and keylock assembly will resemble the diagram as shown in figure A4.7.

Figure A4.7. Standard Towing Tube and Keylock Assembly.



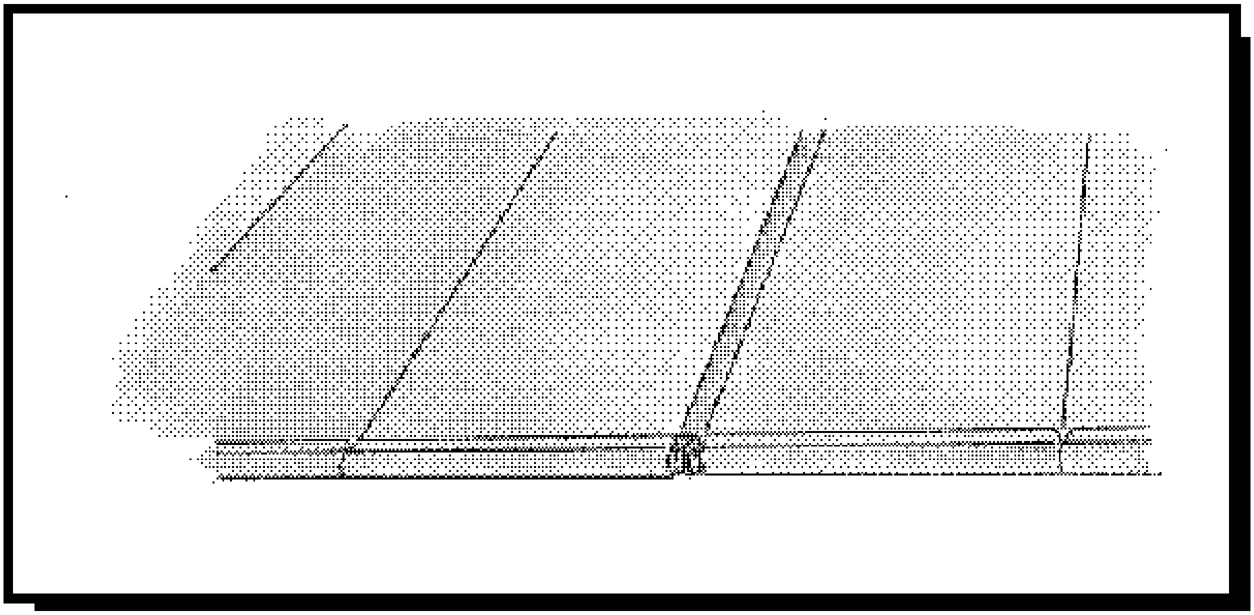
A4.8.3. To assemble the reverse towing tubes, place a piece of 1-1/4-inch pipe, 1-3/4-inch long (threaded or not threaded) on a 20-foot piece of assembled mandrel, centered on the connector fitting. Place the reverse towing tubes with flat end toward center (figure A4.8).

Figure A4.8. Reverse Towing Tube and Keylock Assembly.



A4.8.4. Proceed with assembly as detailed in Method A, except reverse the tube.
A4.8.5. Assembly can also be completed by Method B, except tubes are reversed and when the mandrel is installed, the pipe spacer must be used.
A4.8.6. Assembled patch will resemble diagram as shown in figure A4.9.

Figure A4.9. Assembled Patch Towing Tubes.



A4.8.7. Tighten towing tube assembly as previously described in a standard towing tube assembly.

A4.9. Assemble the Patch. Each patch assembly should be stored incrementally. This procedure will pay dividends in time savings during patch assembly. To keep confusion to a minimum, each patch assembly should be delivered in total to the selected assembly area. **NOTE:** If a fourth trailer is available or one of the three authorized RRR "lowboy" trailers is not required for moving the dozers, considerable time may be gained by preloading the tool chests and compartment chests. However, movement of the dozers normally has priority. Tool chest delivery may occur just after the repair areas have been selected. Assembly of the keylock and towing tubes can proceed while waiting for the remaining AM-2 matting.

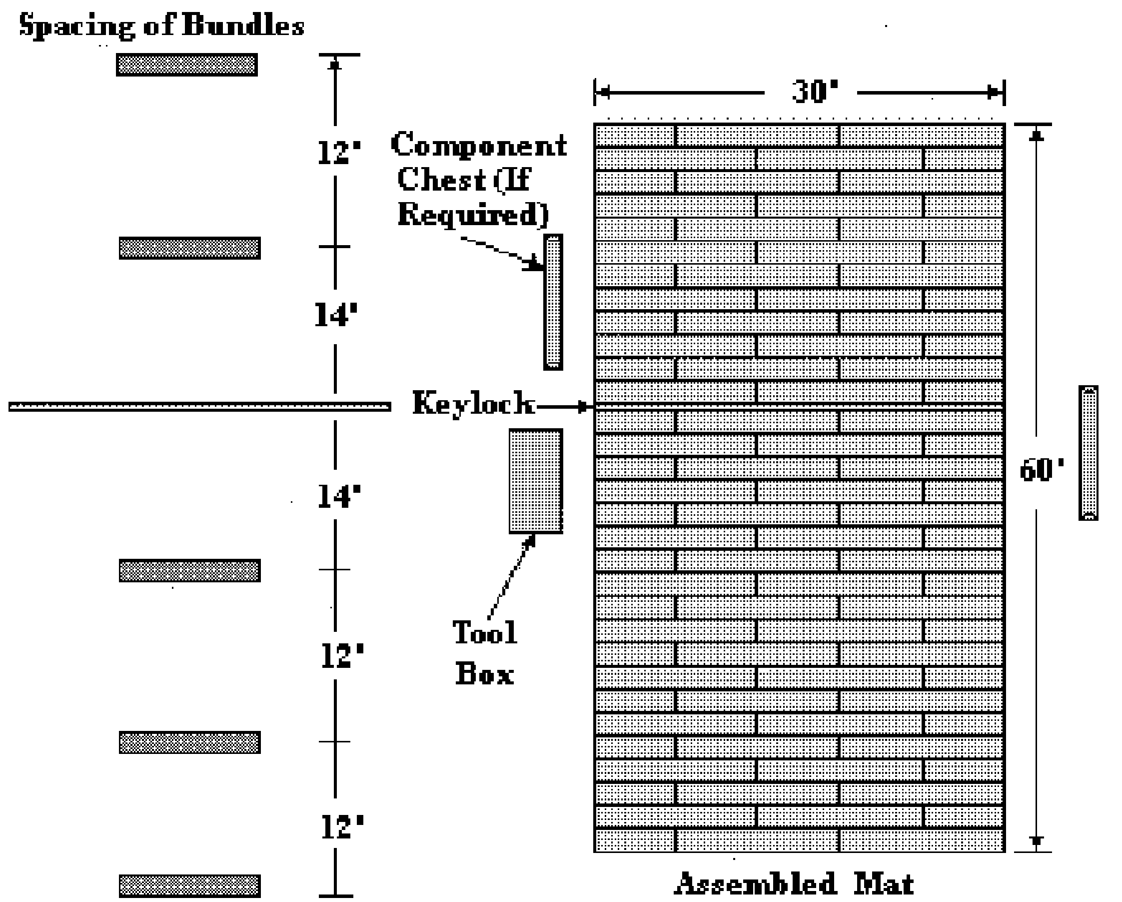
A4.9.1. Matting should be loaded on the lowboy in reverse order of use to allow efficient assembly.

A4.9.2. Truck the matting, components, and tools to the selected assembly area. Be careful in unpacking the materials and tools not to damage the containers, for they must be reused to store the matting tools and components when the patch is disassembled later.

A4.9.3. Proper off-loading and positioning the bundles of AM-2 matting enhance the assembly effort. Bundles are off-loaded by a FEL with the forklift attachment and should be positioned on wooden dunnage to prevent possible damage to the bottom mat during placement. Furthermore, bundles should be positioned so matting can be placed by matting teams using the shortest walking distance. When bundles are properly positioned, mats can be placed directly from bundles without rotating.

A4.9.4. Starting with the full size mats, connect a row of four 12-foot mats and one 6-foot mat to the keylock. Insert the locking bar at each end joint, as well as a locking bar at both of the towing tube connections (figure A4.10). Now lay a second row using the same procedures. The minimum required length of a standard patch is 77 feet 6 inches (including ramps) but may be longer, depending on the size of the crater. Attach the towing tube as previously described. ***NOTE:*** The 54-foot width can also be adjusted downward for taxiway repairs. Because taxiway widths are generally less than a MOS and repair criteria is much less stringent, often a taxiway patch will be built only 30 feet wide (figure A4.11). For a longer patch, use material from another repair kit.

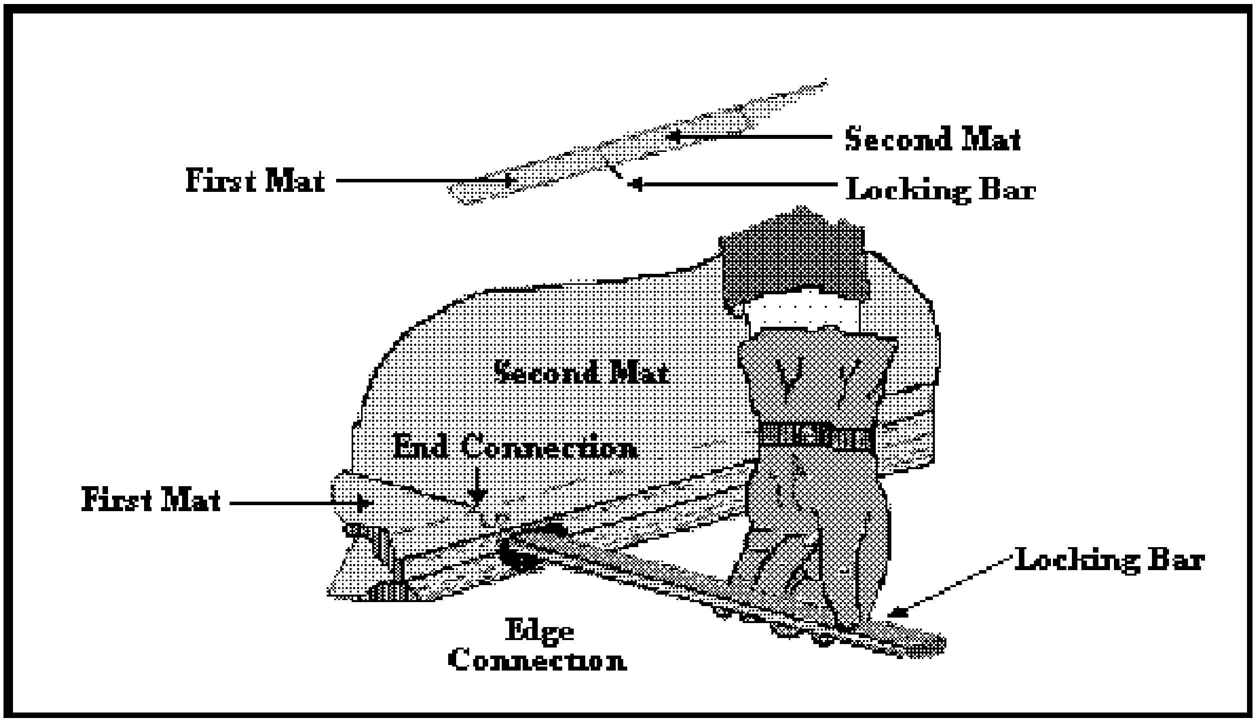
Figure A4.10. AM-2 Matting End Connectors.



REQUIRED MATERIALS:

5 Bundles of Matting
2 Each 12 Foot Keylocks
1 Each 6-Foot Keylock
2 Each Keylock Connectors With Screws
1 Each Toolbox Complete With Necessary Tools
150 Each Locking Bars
2 Each Component Chests With Accessories

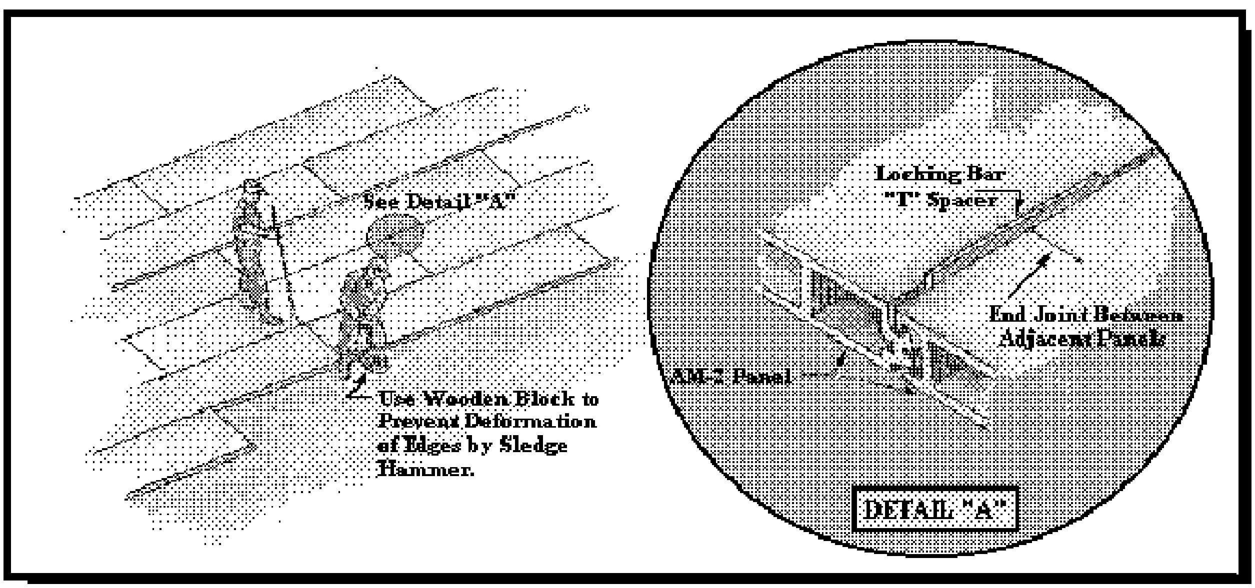
Figure A4.11. Reduced AM-2 Taxiway Patch With Keylock.



A4.9.5. Double check to make sure that the first two rows of mats and keylock are straight. Then, starting with a full size mat, lay one row of mats on the other side of the keylock to keep the keylock from shifting. After the matting has been placed on each side of the keylock, begin laying matting on both sides at the same time.

A4.9.6. Use a 3/15-inch locking bar as a spacer between mats in assembling the patch. (See figure A4.12 for a graphic illustration of how these bars are placed on edge.) This locking bar, also known as a "T" spacer, is left in place for at least three rows back from the row presently being installed.

Figure A4.12. Use of Locking Bar in Assembling Patch and Correction of Misalignment.
(***NOTE:*** Locking bar is used as a spacer between panels while the patch is being assembled.)



A4.9.7. After the patch has been completely assembled, the towing tube will have been assembled. Tighten the end caps as previously indicated. As an added convenience, an AM-2 Patch Fabrication Checklist has been provided in attachment 7.

CRATER-CREW CHECKLIST
(Dual Crater Fiberglass Mat Repair)

A5.1. Manpower:
- Crew chief.
- Three equipment operators--AFS 3E2X1 (minimum).
- One engineering specialist/technician--AFS 3E5X1 (conduct repair quality measurements).
- Four support personnel (mat assembly, anchoring, vehicle "spotting", etc.).

A5.2. Equipment And Materials:
- Two 4-cubic yard front-end loaders.
- One excavator.
- One vibrating roller.
- Fiberglass mats.
- Mat component kits/tools.
- Radio.
- Upheaval measurement devices.
- RRR concrete cutting saws kit and water truck (optional).

A5.3. Repair Procedures

Activity	Personnel/Equipment
• Travel to first crater. Equipment operators driving equipment. Front-end loaders lead convoy with buckets down clearing debris.	Crater repair crew and associated equipment.
• Clear debris around crater #1 to expose extent of upheaval. Most debris can be pushed back into the crater.	2 FELS.
• Clear area for crater #1 mat assembly.	FOD team's grader and sweeper.
• Determine and mark extent of upheaval of crater #1.	Engineer specialists and support personnel.
• Send one FEL to crater #2 to clear debris around crater and mat assembly area.	FEL and FOD team's grader and sweeper.
• Unload crater #1 mat.	Accomplished by haul team.
• Backfill crater #1 with debris to within 18" of surface. If water intrusion is a problem, use ballast rock and geotextile fabric.	FEL and excavator.
• Determine and mark crater #2 upheaval.	Engineer specialist and support personnel.
• Break up heaved pavement at crater #1.	Excavator.
• Backfill crater #2 with debris to within 18" of surface. See comments regarding water intrusion with crater #1 backfilling procedures above.	FEL.

• Unfold and splice crater #1 mat.	Engineer specialist and support personnel.
• Unload crater #2 mat.	Accomplished by haul team.
• Remove crater #1 upheaval.	2 FELs.
• Verify sufficient upheaval has been removed at crater #1 using line-of-sight procedures.	Engineer specialist and support personnel.
• Unfold and splice crater #2 mat.	Engineer specialist and support personnel.
• Break-up heaved pavement at crater #2.	Excavator.
• Fill crater #1 with a minimum of 18 inches of crushed stone.	FEL.
• Remove crater #2 upheaval.	FEL.
• Verify sufficient upheaval has been removed at crater #2 using line-of-sight procedures.	Engineer specialist and support personnel.
• Fill crater #2 with a minimum of 18 inches of crushed stone.	FEL.
• Rough level crater #1 fill approximately 3 inches above pavement level.	FOD team's grader.
• Compact crater #1.	Vibratory roller.
• Rough level crater #2 fill approximately 3 inches above pavement level.	FOD team's grader.
• Final grade crater #1 at pavement level.	FOD team's grader.
• Compact crater #2.	Vibratory Roller.
• Perform profile measurement on crater #1.	Engineer specialist and support personnel.
• Tow crater #1 mat into place.	FEL.
• Final grade crater #2 at pavement level.	FOD team's grader.
• Perform profile measurement on crater #2.	Engineer specialist and support personnel.
• Anchor crater #1 mat into position.	Support personnel.
• Tow crater #2 mat into place.	FEL.
• Anchor crater #2 mat into position.	Support personnel.
• Clear excess debris and sweep repair areas.	2 FELs and FOD team.

NOTES:
*Many of the activities listed should overlap during actual RRR operations--this checklist is meant to provide a general order for these activities. Detailed folded fiberglass mat installation procedures are outlined in TO 35E2-3-1, *Folded Fiberglass Mats for Rapid Runway Repair*.
** Though the RRR concrete cutting saws were primarily procured for the now obsolete concrete slab repair technique, they can be effectively employed in both the AM-2 and fiberglass crater repair procedure in certain circumstances. One example involving their use is when there is a shortage of available excavators, the RRR concrete saws can make heaved lip removal both much easier and faster for the substitute FELs by scoring the heaved material to be removed.

SPALL REPAIR TEAM CHECKLIST (SILIKAL®)

A6.1. Manpower.
- NCOIC.
- Two laborers.
- One driver.

A6.2. Equipment.
- One 5-ton dump truck.
- Two shovels.
- Two hand brooms.
- One pickax.
- Two bricklayer's trowels.
- Two bricklayer's floats.
- One bucket (for solvent to clean tools).
- Eight pairs of chemical resistant gloves.
- Six chemical cartridge respirators.
- Six pairs of safety goggles.
- Emergency eyewash or 5-gallon can of water.
- Fire extinguisher.
- One radio.
- Jackhammer/air compressor (joint use with crater repair teams).

A6.3. Materials.
- Dry pea gravel; equal in weight to Silikal® powder component.
- Silikal® kits.
- Solvent (to clean tools): use spare liquid component from Silikal® kits, or use acetone, methylene chloride, or trichlorethylene.

A6.4. Safety Precautions
- Wear chemical resistant gloves and respirators.
- If the liquid component comes in contact with the skin, immediately wash the involved area with water.
- Do not swallow the liquid component, or breathe in the vapors over an extended period.
- Keep sparks and flame away from the highly inflammable liquid component.

A6.5. Repair Procedure.
- Normally, start work on sections of the runway where initial debris clearance by the grader has been completed--it will be easier to find the spalls.
- Remove loose debris and unsound pavement from the spall hole.
- Sweep water from the spall; dry the spall with compressed air to remove residual moisture and, if the sides of the spall are very smooth, roughen them with the pickax or jackhammer.
- Mix Silikal®components in the mixing bag for 30 seconds.
- For spalls deeper than 2 inches, add dry pea gravel (equal in weight to the powder component) to the Silikal® in the mixing bag. Mix for an additional 30 seconds.
- Pour Silikal® into the spall and level the surface flush with the pavement, using the trowel or float. The material normally remains workable for 5 to 10 minutes, depending on the ambient temperature.
- Collect used Silikal® kit packaging, disposing of cans as toxic waste.
-

AM-2 PATCH FABRICATION CHECKLIST
(Build-As-You Go Method)

A7.1. Manpower.
- Crater crew chief or designated other.
- One equipment operator--AFS 3E2X1 (to load and unload matting).
- Four support personnel (mat assembly, anchoring, vehicle "spotting", etc.).

A7.2. Equipment And Materials.
- One front-end loader with forklift attachment.
- One tractor trailer or 22-ton RRR tilt trailer.
- One AM-2 mat kit (81 bundles).
- Mat component kit and tool chest.
- Radio.
- Area lighting set (for night operation).

A7.3. Construction Procedures.
- Load matting onto trailers. To save time, matting should be loaded in reverse order of use.
- Deliver matting to crater location. Matting is usually loaded on a RRR “lowboy” or the 22-ton RRR tilt trailer.
- Clear debris from the mat assembly area. This location must be swept of all loose debris. Furthermore, the assembly area should be located as near as possible to the crater that the patch is to be used on, but far enough out of the way as to not cause interference with crater repair activities.
- Select the keylock location and start unloading matting bundles. For ease of installation, bundles should be spaced to minimize walking. To do this, the bundles located closest to the keylock are positioned 10 feet from the keylock; all subsequent ones should be spaced at 8-foot intervals. **NOTE:** Always place the first two bundles on the long (20-row) side. Also, place bundles with female lip towards the keylock. To ease the removal of metal strapping and end-plates and preclude damaging the bottom mat during placement, set bundles on wooden dunnage.
- Assemble keylock at the approximate center of the mat assembly area and perpendicular to the centerline of the new taxiway/transition route/MOS.
- Connect two long mandrels on each side of the keylock. **NOTE:** When working with standard tubes, use one long and five short mandrel connectors on each side of the keylock. However, when working with reverse tubes, use two long and four short mandrel connectors on each side of the keylock.
- Slide two starter tubes into position, centering them on each mandrel at the center connector fitting. **NOTE:** Starter tubes are 1-inch shorter than standard tubes and do not have a hole for installation of a towing clamp. Tubes on the left side of the keylock will have the prongs facing outside the mat and are rotated 180 degrees to install locking bars. Whereas, tubes on the right side of the keylock will have prongs facing inward toward the mat and are rotated 180 degrees before installing a locking bar in the previous row.
- Start placing matting on the keylock (20-foot side) by installing a row of four full size mats (12-foot) and one short mat (6-foot). Matting is always laid from left to right. **NOTE:** It is important that the first row is straight on the keylock--double check to be sure.
- Install a locking bar at the end of each joint and both towing tube connections.
- Install a regular towing tube on each mandrel to receive the next row of matting.
- Install the second row of matting starting with a short mat followed by four long mats. This alternating procedure prevents the joining seams of one row from being aligned with those of an adjacent row. Once the second row is properly placed, install a locking bar in the same manner as was accomplished in the first row.
- Install a locking bars (T-Spacers) in each joint between rows of matting (four T-Spacers per row of matting). T-Spacers are used to maintain alignment of the patch. **NOTE:** Once a three row buffer has been established, alternate removing and adding T-Spacers between the oldest and newest rows of matting. This addition/deletion procedure is conducted on both the long and short sides of the keylock.
- Once two rows of matting have been positioned on the 20-foot side of the keylock, mat laying on the short side of the keylock can begin. To accomplish such, repeat the procedure used for the initial two rows on the long side of the keylock.
- At this point the mat laying procedure is repetitious for both sides of the patch until the desired length is reached--77 feet 6 inches for a standard patch.
- Install stops and end caps. Make sure that the long end of the stops are facing towards the patch.
- The patch is now fully assembled and the towing harness can be attached so the cover can be moved over the prepared crater repair--assuming it was not built in-place.
- Once the patch is positioned over the repaired crater, attach the ramps and anchor the patch, if required. Patches used on

taxiways often do not require anchoring, since the aircraft transiting them will normally be doing so at a slow rate of speed.

A7.4. Additional Information.

- AM-2 mats are packaged in pallets (bundles) for storage and shipping. Each AM-2 bundle contains 16 full sheets and 4 half sheets.
- The matting contained in one bundle of AM-2 matting will provide 4 rows (8 feet in length) on a standard AM-2 FOD cover. A standard patch is 54 feet wide and 77 feet 6 inches long.
- Keylock sections are fastened together using keylock connectors and associated bolts.
- Tow clamps that are provided with the kit are used for a side pull, whereas a locally fabricated pull assembly constructed from a piece of AM-2 matting must be used when an end pull is called for. Recently, one of the venders for AM-2 matting has developed a commercial version of the pull assembly. Information regarding this addition (Pull Fixture) is included in attachment 8.
- Depending upon the type of surface that the patch has to be secured upon, there are two types of anchors used with AM-2 matting. On a concrete surface, expansion shielded bolts are employed. While on both asphalt and asphalt overlays on concrete, plain machine bolts are secured by encasing them in lead sulfur.
- A standard AM-2 patch contains:
  - I. 35 rows of matting; 20 rows on one side of the keylock and 15 on the other keylock side.
  - II. 175 pieces of AM-2 matting (35 short and 140 long).
  - III. 14 mandrels (7 each lengths positioned on both sides of the patch), 4 on the long (20-foot) side and 3 on the short (15-foot) side.
  - IV. 70 tubes (33 towing and 2 starter sections, positioned on both sides of the keylock).
  - V. A complete keylock set consists of one 5-foot 6 3/4-inch section and four 12-foot sections. Each keylock section is 2 inches wide with a male lip on each edge to receive AM-2 matting.
  - VI. A standard patch requires 18 end ramps (nine per end).

A7.5 Tips.

- When using reverse tubes, a 2-inch spacer must be added to the keylock.
- For ease of construction, place a component chest on each side of the patch situated at about the midway point.
- To avoid unnecessary handling during subsequent use, restacking matting in the same manner that it was placed. In other words, working from the bottom up, stack the matting as follows: 4 long; 2 short; 8 long; 2 short; and lastly, 4 long.
- Lubricate mandrel connectors, end caps, and bullet nose with anti-seizing compound before use and when returned to storage.
- When selecting the mat assembly area, select a site that has as smooth a surface as possible. Surface irregularities can turn
- a mat laying operation into an almost impossible undertaking.
- If trailers are not available for transport of matting, dump trucks may be used instead. However, loading and unloading times will be considerably increased.
-

RAPID RUNWAY REPAIR (RRR) EQUIPMENT/COMPONENTS/KITS

Listed below are the equipment items necessary to conduct both actual (operational) RRR and associated training. Operational kit requirements are listed below in table A8.1. The levels shown for each kit are in direct proportion to the threat presented at a location. For example, at this time the maximum perceived threat would be the need for an organization to repair a total of 12 craters after an enemy attack. Such a threat analogy would dictate that the unit posture an R-3 capability in order to be adequately equipped to meet the possible repair requirements inflicted. Details regarding specific kit component item requirements are also outlined in this attachment. For ease of reference, operational and training requirements are listed separately. Operational requirements are presented in Section A and training requirements are outlined in Section B.

Table A8.1. Operational RRR Kit Requirements.

ITEM DESCRIPTION	NATIONAL STOCK NUMBER (NSN)	R-1 (3 CRATERS)	R-2 (6 CRATERS)	R-3 (12 CRATERS)
Basic RRR Equipment Support Kit	TBD	1-Kit	2 Kits	No Increase
Basic RRR Airfield Lighting Set	TBD	1-Kit	No Increase	No Increase
AM-2 RRR FOD Cover Kit	TBD	3-Kits	6-Kits	9-Kits
AM-2 Support Kit	TBD	1-Kit	2-Kit	No Increase
Folded Fiberglass Mat FOD Cover Kit (Kit-A)	TBD	1-Kit	No Increase	No Increase
Folded Fiberglass Mat FOD Cover Kit (Kit-B)	TBD	2-Kits	No Increase	No Increase
Spall Repair Kit	TBD	4-Kits	No Increase	No Increase
Minimum Operating STRIP Marking System (MOSMS)	N/A	1-Kit	No Increase	No Increase

NOTES:
1. Quantities shown in table A8.1 are not additive.
2. Power tools employed by both the AM-2 and folded fiberglass mat (FFM) foreign object damage (FOD) cover systems are activated by distinctly different methods. Many AM-2 tools are electrical, whereas FFM tools are pneumatic. This situation was brought about because both systems were designed and procured at separate points in time. It may prove prudent for a unit that employs both FOD cover methods to consider standardizing the system and tools used. If such were the case, we would suggest going all pneumatic. At this time, HQ AFCESA is looking into also standardizing the anchoring systems for both FOD cover systems. Initial indications are that a variation of the rock bolt systems used with the FFM could be effective with AM-2 mats as well. However, this still needs to be tested and validated before this procedure can be officially accepted.

Section A--Operational Requirements

Basic RRR Equipment Support Kit
5680 NCC614818
(A Maximum of 2 Kits Per Base)

The items shown in this kit are common to both the AM-2 and folded fiberglass mat repair techniques. Quantities shown are what are needed to meet an R-1 set requirement involving the employment of three crater repair teams. For R-2 and R-3 set requirements, simply double the amounts shown. Under R-2 and R-3 configurations, six crater repair teams are formed. Individual components can also be ordered separately, if desired.

ITEM	STOCK NUMBER	QUANTITY	NOTES
Compressor, Type MC-7	4310-00-595-3866	3	(1)
80-lb Breaker w/atch P/N MILB467	3820-00-292-0080	3	
Pneumatic Drill, 55-lb P/N 35357540	3820-00-275-2615	3	
Floodlight/Gen 6kW or Equal P/N TP5A4-DC	6230-01-096-3508	6	(2)
Geotextile Thermal Spunbonded Polypropylene Style 3601 Gray 151" Wide	REEMAY Inc.	3 rolls	(3)
Trailer, Platform (RRR) P/N GWT1684R	2330-01-308-8926	3	(4)
Pump Reciprocating P/N 82434	4320-00-287-4271	6	
Welding & Cutting Outfit P/N 92007	3433-01-295-9739	1	(5)
Technical Acetylene P/N ACETYLENE	6830-00-264-6751	1	
Technical Oxygen P/N BB-O-925	6830-01-049-5263	1	
Vibrating Tamper P/N S-28A	3895-00-231-1362	3	
Paint Striper, 2-Gal Cap. P/N 20	3825-00-192-5495	1	
Concrete Saw Kit P/N MSCRRR-01	3895-01-383-9008	1	(6)
Saw Blades 36" (Cage Code 9F999) P/N RRR0021-360A-187DX		4	
Saw Blades 18" (Cage Code 9F999) P/N RRR0021-180A-140DX		6	(7)

NOTES:

1. Compressors should be shared between crater repair and spall repair teams. However, since the excavator has a breaker attachment, compressors are usually assigned to the spall repair teams. An exception to this would be if a unit using AM-2 matting elected to replace the electric tools allocated under that system to pneumatic ones. As mentioned earlier, such a conversion would allow for better standardization between both folded fiberglass mat and AM-2 FOD cover systems.
2. Two floodlight units should be used to support each crater repair effort during nighttime operations. Functions such as spall repair, fill site operations, and MOS marking must depend upon vehicular lighting for illumination. Floodlight units can also serve as the power source for drilling operations when anchoring an AM-2 FOD cover.
3. Geotextile fabric is used to assist with crater fill material stabilization when wet conditions exist. The material indicated meets AASHTO M288-92 standards.
4. Each MOS and taxiway crater repair team should be supported with a dedicated RRR trailer in order to move the necessary numerous small equipment items and tools to the repair site. This applies to both the AM-2 or folded fiberglass mat repair methods.
5. The welding and cutting outfit will be used around crater repairs for the removal of exposed rebar.
6. Though the concrete saw system was used primarily with the now obsolete concrete slab repair system, it is still required as an alternate support method for heaved lip removal.
7. The small diameter saw blade is used for training purposes, its smaller size reduces costs. The larger size blade is intended for operational use. However, keep in mind that the durability of the blade depends upon the hardness of the material being cut. If these blades do not hold up well under use at your location, look into obtaining a local product that does.

Basic RRR Airfield Lighting Kit
5680 NCC614819
(1 KIT PER BASE)

This kit provides a very basic airfield lighting capability for a 50 x 10,000-foot minimum operating strip (MOS). If enhancement feature such as strobe lighting and a PAPI are required, the emergency airfield lighting set (EALS) is designed to meet those needs. The EALS is **not** part of this kit.

ITEM	STOCK NUMBER	QUANTITY
Generator Set, Diesel, 60kW P/N MEP 806A	6115-01-274-7390	2
200w Transformer P/N MS27288-1	5950-00-096-2552	110
Battery Alkaline C-Cell P/N VS1335	6135-00-985-7846	600
Connector Set P/N 320193-1	5935-00-646-6073	150
Control Panel P/N MS23007-1	6210-00-547-2693	1
Electrical Clamp P/N MS17815	6210-00-243-6882	150

Electrical Tape (rolls) P/N 1756654	5970-00-184-2002	200
Frangible Coupling P/N MS17814-1	6210-00-055-5659	150
Lamp, 204w P/N 6-6AT14P	6240-00-196-4471	200
Light-Marker Bean Bag P/N BEKON	6230-00-115-9996	150
Marker Mounting P/N MS27280	6210-00-937-7009	106
Power Cable (kft) P/N S158065	6145-00-617-1685	20
Power Cable, 7 conductor (kft) P/N MILC27212CLASS2	6145-00-752-2116	1
Regulator, 60 amp/208v P/N C901G311-01	6110-00-488-1866	2
Runway Filter-Marker, Green P/N MIL-L-5904	6210-00-500-4130	25
Runway Filter-Marker, Red P/N MIL-L-5904	6210-00-500-4141	25
Runway Light-Marker, Edge P/N 1568305A	6210-00-548-0129	106
Circuit Interrupter, Ground Fault P/N 3494	5925-01-135-2025	2

AM-2 RRR FOD Cover Kit
5680 NCC614821
(Between 3 and 9 kits, depending on the threat)

The AM-2 repair concept was originally adopted by the Air Force in the late 1970's as the primary RRR minimum operating strip (MOS) repair method. However, under today's RRR flush repair concept, AM-2 is usually not used on a MOS--primarily due to its thickness. The matting thickness (1.5") often makes it very difficult for a repair to meet RQC requirements. Also, when AM-2 patches are located within close proximity of each other, dangerous frame oscillations may develop that can result in damage to aircraft traveling over them. The quantities shown below are what are required to support a crater repair team for the installation of one AM-2 standard crater patch. Nine bundles of AM-2 matting are needed to build one standard patch. A bundle of matting contains 16 full sheets and four half sheets. The mats contained in one bundle of AM-2 matting will provide four rows (8 feet in length) on a standard patch. In short, the AM-2 RRR FOD cover kit contains nine bundles of matting, 18 ramps and associated hardware and tools configured within two component chests and one tool kit. At OCONUS (Overseas Continental U.S.) bases with an R-1 threat, three kits are required. In comparison, OCONUS locations with R-2 or R-3 threats that elect to use AM-2 matting should postured six and nine kits respectively. However, in order to have a complete AM-2 patch capability, the appropriate number of AM-2 equipment support kits must also be obtained.

ITEM	STOCK NUMBER	QUANTITY
AM-2 Matting P/N 613370-1	5680-00-450-8490	9 bundles
Ramp (9ea.) P/N 614355-1	5680-01-333-5875	2 bundles
Component Chest Assembly, P/N 614343-1	5680-00-132-1733	1 ea.
*Chest Component P/N 614184	TBD	2 ea.
*12-ft Keylock P/N DL13216E9212	5680-00-089-7653	4 ea.
* 6-ft Keylock P/N 413371-2	5680-00-132-1730	1 ea.
*Bullet Nose P/N 414864-1	5680-00-132-1732	2 ea.
*Connector Fitting, P/N 414865-1	5680-00-132-9989	20 ea.
*Connector Fitting, P/N 414865-2	5680-00-132-1728	4 ea.
*Mandrel, (Long) P/N 414867-1	5680-00-132-1727	14 ea.
*Mandrel, (Short) P/N 414867-2	5680-00-133-2319	8 ea.
*Straight Edge, P/N 414870-1	5210-00-133-1344	1 ea.
*Towing Bar Cap, P/N 414866-1	5680-00-132-1735	4 ea.
*Towing Bar Stop, P/N 414868-1	5680-00-132-9990	8 ea.
*Towing Bar Tube, P/N 509698-1	5680-00-132-9988	66 ea.
*Towing Bar Tube (Starter), P/N 509698-2	5680-00-132-1726	4 ea.
*Towing Clamp, P/N 415773-1	5680-00-132-1731	6 ea.
*Locking Bar (Approx. 170 additional req.) P/N 320660-1N	5680-00-072-8683	70 ea.

NOTES:
*****Items are sub-components of the component chest assembly.
Since AM-2 matting is currently intended primarily for taxiway repairs, anchoring is often not required, because aircraft trafficking them normally do so at a low speed. However, anchoring at pivoting and braking points is advisable and strongly recommended.

Though in reality a maximum of six of these kits should be required at a unit presented with an R-3 threat, since each taxiway crater repair crew is expected to repair two craters, a total of nine kits have been authorized. The three additional authorizations allowed are intended to provide some further capability in the event of a follow-on attack.

The NSNs for individual (one each) AM-2 mat components are as follows:

AM-2 Ramp	5680-00-132-9991
AM-2 Matting (12-foot)	5680-00-403-5349
AM-2 Matting (6-foot)	5680-00-403-5348

AM-2 Equipment Support Kit
5680 NCC614822
(1 Kit Per three Crater Repair Teams up to a Maximum of 2 Kits per Base)

Each AM-2 equipment support kit is designed to be used by three AM-2 mat laying teams. The authorization levels of this kit are tied directly to the "R" threat presented against a unit. Since a unit configured with an R-1 set has three crater repair teams, only one AM-2 Equipment Support Kit is authorized. See table A8.1 for details regarding authorization quantities. Once obtained, items should be divided among crater repair teams and stored in each team's respective RRR trailer. Storage arrangements for single quantity items should be determined locally. Replacement items can be ordered individually, if so required.

ITEM	**STOCK NUMBER**	**QUANTITY**
Tool Kit (F61) P/N 509700-1	TBD	1 ea.
*Tool Chest, P/N 614183-1	5680-00-135-1589	1 ea.
*Anti-Seizing Compound P/N MIL8907	8030-00-059-2761	1 lb.
*Crescent Wrench, 10" P/N D710	5120-00-449-8083	2 ea.
*Flat Screw, Socket Head P/N MS24667-51	5305-00-900-4614	110 ea.
*Hammer, 1 1/2-lb P/N BP24	5120-00-243-2963	4 ea.
*Pinch Bar, 7/8" x 36" P/N 11677049	5120-00-240-6040	6 ea.
*Pipe Wrench, (14-inch) P/N GGG-W-651 TY2CLA	5120-00-277-1486	2 ea.
*Pry Bar P/N 509702-1	5120-00-133-2329	4 ea.
*Pry Block, 4" x 4" x 8" P/N 509700-8	5680-00-229-1076	6 ea.
*Screw Wrench (5/16" Allen Wrench) P/N 58020	5120-00-198-5409	4 ea.
*Screwdriver, 3/8" x 8" P/N 66-1105120-00-293-3309		4 ea.
*Shackle, AN 116-12 P/N 1018491	4030-00-242-5575	6 ea.
*Shackle, AN 116-14 P/N 1018516	4030-00-162-9668	3 ea.
*Sledgehammer, 8-lb P/N 5886A13 also GGGH86TYPESACLASS2EIG	5120-00-251-4489	2 ea.
* Sling, P/N 414869-1	5680-00-132-1734	6 ea.
* Tool, Edge Straightener P/N 510827-1	5120-00-168-9943	1 ea.
* Pull Fixture P/N 622899-1	TBD	2 ea.
* Hook Assembly P/N 521208-1	TBD	2 ea.
Portable Electric Hammer P/N 00030467-TE24 or	5130-00-138-5552	6
****** Drill, 2" P/N 7AN4 (Cage Code 47805)	5130-01-344-0075	6
Strapping & Sealing Kit P/N 1035	3540-00-565-6244	1
Carbide Percussion Bit P/N 50169	5130-01-112-4051	12
Industrial Goggles P/N A-A-1110	4240-00-052-3776	20
Shovel, Square Point P/N GGG-S-326 TY5CBST1SZ2	5120-00-293-3330	6
Shovel, Round Point P/N GGG-S-326 TY4CBST1SZ2	5120-00-188-8450	6
Street Broom P/N 525 (Cage Code 84911)	7920-00-267-2967	6
Broom Handle P/N NN-H-104 TY2SZ3LG4.5	7920-00-141-5452	6
Garden Rake P/N 1291-1061	3750-00-171-7182	3
Flat Washer P/N 664288	5310-00-698-4460	500

Nuts P/N MS21042-6	5310-00-810-1786	500
Bolt Machine, P/N AN6-80	5306-00-151-2069	500
Hand Truck, Two Wheel P/N KKK-T-683	3920-01-113-0117	1
Electric Impact Wrench,(2") P/N WW650 or	5130-00-221-0607	3
****** Impact wrench, 2" drive P/N WP-411	5130-00-889-2134	3
3/8" Socket P/N A-A-1404	5120-00-227-6702	12
3/8" Drive Ratchet Handle (6") P/N 5226183	5120-00-240-5364	12
Electric Disk Sander, (7") P/N 6112-90 or	5130-00-596-9728	6
****** Grinder/Sander, Pneumatic P/N 7096D	5130-00-596-1176	6
Abrasive Disk P/N A-A-1016	5345-00-558-5928	3 boxes
Grinder Disk, Abrasive P/N MIL-W-43060 (Used with Pneumatic Grinder/Sander)	5130-00-049-7912	3 boxes
Capping Compound (100-lb bag) P/N CT59B	6635-00-497-8029	5 bags
Compound Warmer P/N L-115	5120-00-924-5213	6
Ladle P/N LT12	6635-00-124-0649	6

<u>NOTES</u>:
***** Items are sub-components of the tool kit assembly.
****** Indicates pneumatic equivalents for electrical tools originally provided with the AM-2 kit. These pneumatic substitutes are identical to that which is provided with the folded fiberglass mat kit.

<u>Folded Fiberglass Mat FOD Cover Kit</u>
<u>(KIT-A)</u>
5680 NCC614824
(1 KIT PER BASE)

Folded fiberglass mats are primarily used for MOS repairs. This kit will support a maximum of seven (7) crater repairs, which should be sufficient to meet most present-day threat probabilities--including R-3 requirements. However, in order to have a complete FFM repair capability, the anchoring system shown in Kit-B below must also be obtained. Under the current concept, this kit will support three crater FOD cover teams simultaneously. Each team should be provided with one-third of the kit's assets. With the exception of the air compressors, FFMs and the associated joining panels, all kit components should be stored in each respective crater team's RRR trailer. Items can be ordered separately, if desired.

ITEM	STOCK NUMBER	QUANTITY
Fiberglass Mat Assembly P/N 9139655	5680-01-368-9032	7
* Mat, Fiberglass, (30 'x 54') P/N 9139656	5680-01-354-8332	2
* Joining Panel, (24' x 2') P/N 9139638	5680-01-363-0089	2
* Joining Panel, (30' x 2') P/N 9139637	5680-01-363-0088	2
Bushing, Upper Sleeve P/N 9139654	3120-01-369-5950	756
Bushing, Anchor Sleeve P/N 9139653	3120-01-369-5952	525
Bag, Tool, Satchel P/N 225-20	5140-00-293-2379	2
Air Gun P/N 7184-1000	4940-00-027-8132	2
Tape Measure, 100-ft. P/N 7902214	5210-00-221-1882	2
Tape Measure, 12-ft. P/N 33-312	5210-00-182-9893	2
Socket, 7/8", 1/2" Drive P/N P280	5130-00-227-6694	5
Socket, 15/16", 1/2" Drive P/N P300-1-2	5130-00-227-6695	5
Socket, 3/4", 1/2" Drive P/N 785567	5130-00-221-8010	5
Ratchet, handle, 1/2" Drive P/N A702K	5120-00-230-6385	2
Extension, 2", 1/2" Drive P/N A-A-2170	5120-00-243-1697	2
Screwdriver, 3/16" x 5" P/N CB316-5	5120-00-042-6837	2
Screwdriver, 5/16" x 6" P/N 41S1104	5120-00-278-1283	2
Blade, Hole Saw, 1-1/4" (Cage Code 1DJ82) P/N HSV20	5130-01-368-4410	6
Blade, Hole Saw, 2-1/4" (Cage Code 1DJ82) P/N HSV36	5130-01-368-4442	6
Arbor, Type 2, 1-1/4" x 4-1/8" (Cage Code 1DJ82) P/N HSM45P	5130-01-369-5460	6
Adjustable Wrench, Size 12 P/N D712	5120-00-264-3796	2

Adjustable Wrench, Size 8 P/N D78	5120-00-240-5328	2
Hammer, Claw, 16-oz. P/N A-A-1306	5120-00-900-6113	2
Pliers, Slip Joint, 12" P/N G272	5120-00-781-0819	2
Die, 5/8-11 UNC, Rt Hand P/N 1266-5-8-11	5136-00-197-9556	2
Tap, 5/8-11 UNC, Rt Hand P/N 5303	5136-00-729-5683	2
Wood Chisel, 1" x 5-1/4" P/N 230	5110-00-640-5419	2
Chalk Line and Reel P/N GGG-C-291	5210-00-273-9793	4
Impact Wrench, 1/2" Drive P/N WP-411	5130-00-889-2134	4
Air Compressor P/N P250-W-D/4WHEEL	4310-01-149-6530	3
Hose, Compressor, 50-ft. P/N 9139646	4720-LP	4
Hose, Extension 50-ft. P/N 9139648	4720-LP	4
Hammer, Pneumatic, Portable P/N CP-9AK	5230-01-296-5527	5
Muffler Kit P/N F-815350	4330-01-302-3536	5
Drill Bit, Rock 3/4" P/N 3145 SPEC	3820-01-368-9671	36
Drill Bit, Rock 1-1/2" P/N HDC915012	3820-01-368-9672	12
Pneumatic Saw, 8-1/4" P/N S-80	5130-01-372-7994	2
Pneumatic Saw, Box P/N S12-4	5140-01-336-5026	2
Blade, Saw, 7-1/4", Fine P/N 6901A16	3230-01-239-7696	4
Drill, Pneumatic, 1/2" P/N 7AN4 (Cage 47805)	5130-01-344-0075	2
Grinder/Sander, Pneumatic P/N 7096D	5130-00-596-1176	3
Grinder Disk, Abrasive P/N MIL-W-43060	5130-00-049-7912	6
Grinder, Disk, Sanding, #24 P/N A-A-1016	5345-00-558-5928	1
Chain, 3/8", 20-ft. P/N RR-C-271	4010-00-171-4427	4
Nylon Strap P/N 9077T12	3940-01-291-7498	8
Chalk, Chalk Line, Bottle P/N 125B	7510-00-973-5637	1
Grease Pencil, Doz. P/N 173T	7510-00-240-1526	1
Sledgehammer, 8-lbs. P/N H8H	5120-00-251-4489	2
Shovel, Square Point P/N GGG-S-326 TY5CBST1SZ2	5120-00-293-3330	2
Shovel, Round Point P/N GGG-S-326 TY4CBST1SZ2	5120-00-188-8450	2
Broom, Push P/N 525	7920-00-267-2967	3
Handle, Wood P/N NN-H-104TY2SZ3LG405	7920-00-141-5452	3
Pry Block, 4"x 4"x 8" P/N 509700-8	5680-00-229-1076	3

NOTES:
The extra joining panels included in this kit allow expansion of a mat patch beyond the standard (54' by 60') measurements. Furthermore, the extra joining panels can be used along with packaging panels to conduct repairs to damaged mats. See chapter 8 of T.O. 35E2-3-1 for mat repair procedures.
* Items are components of the fiberglass mat assembly (NSN 5680-01-368-9032)

Folded Fiberglass Mat FOD Cover Kit
(KIT- B)
5680 NCC614825
(Anchoring System Components)
(2 KITS PER BASE)

Items can be ordered separately according to the anchoring requirement at the base where the matting is to be employed. However, for initial issue, all items should be provided, so that each possible anchoring variation is available to units that are tasked with a mobility commitment.

ITEM	STOCK NUMBER	QUANTITY	NOTES
Mat Support Kit B-1:			
Anchor bolt, (Type 1 Rock Bolts), 5-1/2" P/N 6954 (U/I Box of 20)	5340-01-371-2434 (Expansion Shield)	18	(1)
Mat Support Kit B-2:			

Anchor bolt, (Type II Rock Bolts), 9-1/2" P/N LAH34101H (U/I each)	5340-01-364-2009 (Expansion Plug)	360	(2)
Mat Support Kit B-3:			
Beaker, plastic, 1000 mil. P/N 02-543-36C (U/I = 24)	6640-01-369-0926 (Laboratory Beaker)	1	(3)
Kit Polymer P/N R-256 (U/I = Kit)	8030-01-376-7248 (Sealing Compound)	1	

NOTES:
1. Mat Support Kit B-1 is to be used when anchoring a mat over a concrete surface.
2. Mat Support Kit B-2 should be used when anchoring a mat over a concrete surface that has an asphalt overlay that is 6 inches or less thick.
3. Mat Support Kit B-3 is designed to be used when anchoring a mat over an asphalt overlay that is greater than 6 inches thick. Polymer plugs are used with the Type II Rock Bolts.
4. To anchor a standard FFM, 54 anchors are required (27 per joined end). With 7 mats, the maximum allowed under an R-3 configuration, a total of 378 anchors will be required. The extra bolts included in the second kit are to be used when maintenance actions are necessary.

Minimum Operating Strip Marking System
(MOSMS)
(1 KIT PER BASE)

The MOSMS was obtained as a one-time buy in the mid-1990s. It can no longer be obtained as a single entity--any additional requirements must be requisitioned individually. Table A8.2 is an alphanumeric listing by commercial and government entity (CAGE) code of the names and addresses of CAGE codes and venders listed in the Illustrated Parts Breakdown (IPB). Further CAGE code information can be found in T.O. 35E2-6-1 *Minimum Operating Strip Marking System (MOSMS*). Information regarding the MOSMS paint striping set can be found in TO 36C35-7-1.

ITEM	STOCK NUMBER	PART #	QUANTITY
Distance-To-Go Marker Set (Windmaster Syst or Equivalent)	9905-01-374-0882	30126	1
* Barrier Markers (2ea.)	9905-01-374-0884	X-02013	
* Sign Face, Number 1 (2ea.)	9905-01-372-6707	SA-05086	
* Sign Face, Number 2 (2ea.)	9905-01-373-6808	SA-05087	
* Sign Face, Number 3 (2ea.)	9905-01-372-7987	SA-05088	
* Sign Face, Number 4 (2ea.)	9905-01-374-5180	SA-05089	
* Sign Face, Number 5 (2ea.)	9905-01-372-6708	SA-05090	
* Sign Face, Number 6 (2ea.)	9905-01-372-6709	SA-05685	
* Sign Face, Number 7 (2ea.)	9905-01-372-6710	SA-05686	
* Sign Face, Number 8 (2ea.)	9905-01-373-6000	SA-05687	
* Sign Face, Number 9 (2ea.)	9905-01-372-6711	SA-05688	
* Sign Face, Barrier Marker (2ea.)	9905-01-372-8903	SA-05091	
* Sign Cross-Brace (22ea.)	9905-01-374-0883	SA-03631	
* Sign Face Bag, Number 1 (1ea.)	9905-01-371-5232	X-02004	
* Sign Face Bag, Number 2 (1ea.)	9905-01-371-7432	X-02005	
* Sign Face Bag, Number 3 (1ea.)	9905-01-371-4824	X-02006	
* Sign Face Bag, Number 4 (1ea.)	9905-01-371-7433	X-02007	
* Sign Face Bag, Number 5 (1ea.)	9905-01-371-7434	X-02008	
* Sign Face Bag, Number 6 (1ea.)	9905-01-371-7435	X-02009	
* Sign Face Bag, Number 7 (1ea.)	9905-01-371-7436	X-02010	
* Sign Face Bag, Number 8 (1ea.)	9905-01-371-7437	X-02011	
* Sign Face Bag, Number 9 (1ea.)	9905-01-371-7438	X-02012	
* Sign Holder (22ea.)	9905-01-372-0448	4814	
* Sign Holder Bag (22ea.)	9905-01-371-5493	SA-04504	

Edge Marker Set	5680-01-379-5818	EM001	1
****** Base, Edge Marker (140 ea.)	5680-01-378-8882	EM002	
****** Top, Edge Marker (152 ea.)	5680-01-378-8998	EM003	
****** Container, Edge Marker (2 ea.)	8145-01-385-6343	EM004	
Paint Striping Set (minimum operating strip (MOS) Paint Striper))	3825-01-408-9484	AF120	
MOSMS Accessories and consumables:			
Sand Bag U/I = 100)	MIL-B-12233		1
Tape, Measuring, 200 feet	5210-00-832-9368	C1288	2
Shovel, D-handle, Round Point	5120-00-293-3336	10501972	2
Traffic Cone, 18" (Reflective Orange)	5905-00-424-9829	MIL-M-17321	150
*** Beads, Reflective--Type III (U/I = pounds)	8010-00-082-2420	TT-B-1325	2000
*** Cover, Paint Roller	8020-00-682-6492		12
*** Paint, Roller Frame	8020-00-753-4915	H-R-550	6
*** Paint Roller Grid	Local Purchase		2
*** Paint, Roller Frame Handle	7920-00-682-6512	NO-H-104	6
*** Paint, Traffic Black (U/I = gallons)	8010-01-382-1915	TT-P-1952	200
*** Paint, Traffic White (U/I = gallons)	8010-01-382-1807	TT-P-1952	200
*** Paint, Traffic Yellow (U/I = gallons)	8010-01-382-1861	TT-P-1952	100
*** String line, 1,000’	4020-00-240-2146	M5040-5N	1
*** Template/Straight Edge	Local Manufacture		2
*** 5-Gal Bucket	Local Purchase		2
*** 1" Funnel	Local Purchase		2
*** 55-Gal Drum and Cover	Local Purchase		6
Paint Striper, 2-Gal	3825-00-192-5495	20	3
5-Gal Paint Shaker P/N 3467K5 or P/N 9584T12 (Cage Code 39428)	4940-01-320-5391		1
Solvent Transfer Pump P/N 272703-1-1 (Cage Code 70210)	4920-00-753-5442		2

NOTES:

* Items are sub-components of the distance-to-go marker kit (NSN 9905-01-374-0882).

.** Items are sub-components of the edge marker set (NSN 5680-01-379-5818).

***Items are not part of the original MOSMS.

Table A8.2. MOSMS CAGE Codes and Manufacturers.

CAGE CODE	NAME AND ADDRESS
0KES1	**Starflite Boats** Route 1 Box 96 Hwy 20 Freeport, FL 32439
37163	**Cooper Industries, Inc.** (Lufkin/Cooper Tools Division) P.O. Box 728 Apex, NC 27502
3X962	**MDI Traffic Control Products** 38271 W. Twelve Mile Rd. Farmington Hills, MI 48331-3041
54636	**The Sherwin-Williams Company** 101 Prospect Avenue, NW Cleveland, OH 44691-4764
79433	**The Wooster Brush Company**

	604 Madison Avenue Wooster, OH 44691-4764
81348	**Federal Specifications** Promulgated by GSA
81349	**Military Specifications** Promulgated by the Military

Spall Repair Kit
5680 NCC614826
(4 KITS PER BASE)

This kit contains the support equipment items needed for all types of present-day spall repair--Silikal, bituminous, and quick-set (magnesium phosphate) concretes. The actual spall repair material must be procured separately. The compressor that supports this kit is normally shared with the crater repair teams and is listed under the Basic RRR Equipment Support Kit. Spall repair kit items can be requisitioned individually, if so desired.

ITEM	STOCK NUMBER	QUANTITY
25-lb Breaker w/atch P/N 1A	3820-00-979-5595	2
80-lb Breaker w/atch P/N MILB467	3820-00-292-0080	2
Air Gun P/N 7184-1000	940-00-027-8132	2
Backpack Leaf Blower P/N GBI22	750-01-385-7554	2
Hand Broom P/N 378	920-00-165-7277	2
Pickax/Mattock Combination P/N 10501971	5120-00-243-2395	2
Handle, Pickax/Mattock P/N 10501973	5120-00-288-6574	2
Shovel, Round Point P/N GGG-S-326 TY4CBST15Z2	5120-00-188-8450	2
Shovel, Square Point P/N GGG-S-326 TY5CBST1SZ2	120-00-965-0609	2
Portable Floodlight Sets or equal P/N TP-5A4-DC	230-01-096-3508	2
Trailer, Platform P/N MIL-T-17479	3920-00-165-4135	1

Section B--Training Requirements.

Table A8.3. Training RRR Kit Requirements.

ITEM DESCRIPTION	NATIONAL STOCK NUMBER (NSN)	ALLOWANCE
Folded Fiberglass Mat System	5680-01-354-8331	1 Kit Per CONUS Base
AM-2 “Minikit”	NONE	1 Kit Per CONUS Base
Rapid Runway Repair (RRR) Minikit	NONE	1 Kit Per Authorized CONUS Base
NOTE: Allowances are shown in Allowance Standard 429.		

Folded Fiberglass Mat System
(Training Kit)
NSN 5680-01-354-8331
(1 KIT PER CONUS BASE)

With the exception of the matting, all components of the folded fiberglass mat system training kit are identical to that included in operational kits. However, in order to extend their usable life under heavy use, the training mats themselves are less flexible and slightly thicker than the operational versions. Training mats should not be procured or used for operational purposes.

ITEM	STOCK NUMBER	QUANTITY
Mat, Fiberglass, Training, (30 'x 54') P/N 9139636	5680-01-368-9038	2
Joining Panel, (24' x 2') P/N 9139638	5680-01-363-0089	2
Joining Panel (30' x 2') P/N 9139637	5680-01-363-0088	2
Bushing, Upper Sleeve P/N 9139654	3120-01-369-5950	108
Bushing, Anchor Sleeve P/N 9139653	3120-01-369-5952	75
Eye Bolt P/N MS51937-7	5306-00-017-6143	3

Note: Items can be ordered separately if need be.

AM-2 "MINIKIT"
(1 KIT PER CONUS BASE)

This kit was established in the early 1980s under a "one time" buy effort to support the home station Category II training program. At that time each active duty and Air Force Reserve units were provided a "one time" issue. Consequently, the kit will not be listed in Table of Allowance 429. However, if a unit wishes to either establish or replace worn-out components, items can be ordered separately.

ITEM	STOCK NUMBER	QUANTITY
Shackle, AN116-12 P/N 1018491	4030-00-242-5575	2
Tool Edge Straightener P/N 510827-1	5120-00-168-9943	1
Key Socket Head Screw 5/16", Long Series, Class 2 P/N 58020	5120-00-198-5409	1
Bar, Locking P/N-320660-1	5680-00-072-8683	40
Keylock 12-ft. P/N DL13216E9212	5680-00-089-7653	4
Tube, Towing Bar P/N 509698-2	5680-00-132-1726	4
Mandrel P/N 414867-1	5680-00-132-1727	4
Fitting, Connector P/N 414865-2	5680-00-132-1728	2
Keylock 6-ft. Long P/N 413371-2	5680-00-132-1730	1
Towing Clamp P/N-415773-1	5680-00-132-1731	2
Bullet Nose P/N 414864-1	5680-00-132-1732	1
Sling P/N 414869-1	5680-00-132-1734	2
Cap, Towing Bar P/N 414866-1	5680-00-132-1735	4
Towing Bar Tube P/N 509698	5680-00-132-9988	8
Connector Fitting P/N 414865-1	5680-00-132-9989	4
Stop, Towing Bar P/N 414868-1	5680-00-132-9990	4
Ramp P/N 622523	5680-00-132-9991	2
Mandrel P/N 414867-2	5680-00-133-2319	4
Airfield Matting, AM-2 (432 sq. ft. bundle) P/N 613370-1	5680-00-450-8490	2

Rapid Runway Repair (RRR)
Minikit
(1 KIT PER AUTHORIZED CONUS BASE)

The RRR Minikit program was developed by HQ AFESC (now HQ AFESA) in 1989, with the goal of providing CONUS Prime BEEF teams with the means (equipment and vehicles) to effect a realistic home station RRR training program. The concept included both individual and team proficiency training. Each unit involved in the program received a training syllabus, and the vehicle and equipment packages necessary to conduct the required training as part of a one-time acquisition.

All organizations that agreed to participate in the program were required to construct a dedicated training site. Specifications for the creation of the training site are outlined in the implementation guidance. Specifics regarding RRR Minikit authorizations are listed in allowance standards 019 and 429. A number of consequential program changes have taken place since this training concept was initially implemented in 1989, but the basic premise of providing a means for CONUS units to conduct viable RRR training at home station remains unchanged. The following represents what an RRR Minikit should include today.

*VEHICLES	QUANTITY
Excavator	1
Dozer (T-7)	1
4-Cubic Yard Front-End Loader	1
2.5-Cubic Yard Front-End Loader (other)	1
Water Truck	1
8-Cubic Yard Dump Truck	3
Roller	1
Grader (S-25)	1
Tractor Trailer	1

SUPPORT EQUIPMENT	QUANTITY
Concrete-Cutting Saw Kit	1
Folded Fiberglass Mat (A-Kit)	1
Folded Fiberglass Mat (B-Kit)	1
Spall Repair Kit	1
AM-2 Minikit	1

* Vehicle authorizations are not additives for existing assets at an organization. For example, if a unit already has a grader authorized and available, the RRR Minikit program will not be used to authorize an additional unit.

SUBJECT INDEX