Safety Assessment
of
Outdoor Live Fire Range

May 1989

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U. S. DEPARTMENT OF ENERGY
EG&G MOUND APPLIED TECHNOLOGIES
OUTDOOR LIVE FIRE RANGE

SAFETY ASSESSMENT REPORT

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U. S. DEPARTMENT OF ENERGY
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OUTDOOR LIVE FIRE RANGE

SAFETY ASSESSMENT REPORT

I. INTRODUCTION

A. General Description

The following Safety Assessment (SA) pertains to the outdoor live fire range facility (LFR). The purpose of this facility is to supplement the indoor LFR. In particular it provides capacity for exercises that would be inappropriate on the indoor range. This SA examines the risks that are attendant to the training on the outdoor LFR.

The outdoor LFR used by EG&G Mound is privately owned. It is identified as the Miami Valley Shooting Grounds. Mondays are leased for the exclusive use of EG&G Mound.

B. Location

The outdoor LFR is located at 7771 South Cassell Road in Vandalia, Ohio. Its post office address is Dayton, Ohio 45454. The attached area map shows the range location and the impact zone for the M-16 rifle.

C. Rationale

This SA is according to DOE Order AL 5481.1B, 27 January 1988. It thereby examines the risks to worker health and safety as well as risks to the public environment. The specific requirements for firearms training are pursuant to DOE 5480.16.

It addresses only the suitability of the site for EG&G Mound training as it is now being conducted. It specifically excludes any other activities that may be conducted at the facility with or without the knowledge of the lessor.

The terminology of Standard Operating Procedures and Range Operation Policy (ROP) dated October 1988 are followed in this report. The SOP and ROP are appended.

II. SUMMARY/CONCLUSION

A. General

The design of the LFR and the operating procedures are not according to contemporary standards for police and security training ranges.

B. Safety Considerations

The cited SOP and ROP for EG&G Mound are appended. These procedures are in place and minimize the risk from the operation of the outdoor LFR (1) [See references at end]. However, there remains the question

about the acceptability of the remaining risk. Risk reduction has been achieved by reductions in training efficiency. With increasing requirements for tactical training, further inefficiency may not be acceptable (2).

III. SITE DESCRIPTION AND ASSESSMENT

A. General

The attached area map and range layout show that the site is between South Cassell Road and the Baltimore and Ohio Railroad right-of-way. It is in the South East quadrant of the intersection of interstate highways I-70 and I-75. The facility consists of an indoor range, three outdoor ranges, a club house building, various small structures and a private residence which might be the owner's.

B. Security

Only minimal security is provided. There does not appear to be any practical way to guarantee peripheral security when shooting is in progress. Signage could be improved, however, that has been of only minor help on other outdoor ranges.

EG&G Mound uses the facility only one day a week. Therefore, its training equipment must be removed at all other times.

IV. DESCRIPTION OF FACILITY

One 50-yard range faces northwest. A second 50-yard range located behind the first one faces west. North of these ranges is a 100-yard rifle range which faces north. All three ranges are enclosed by earth berms. These are intended to terminate all properly directed shots. They can also be expected to capture some misdirected shots.

Two of the three outdoor ranges have sheltered firing lines but all lack both ground and overhead baffles. Overhead baffle systems are customary for suburban outdoor ranges for the containment of misdirected high shots. Ground baffle systems have been provided for some similar ranges in an attempt to contain the misdirected low shots.

Misdirected bullets from the north-facing 50-yard range may enter the West-facing 50-yard range. Misdirected bullets from the West-facing 50-yard range can impinge upon the railroad as well as the high tension electrical power lines, both of which are clearly in line of sight from the range. Furthermore, a manufacturing plant is in the free fall "fan" of the 100-yard rifle range.

V. DESCRIPTION OF OPERATIONS

There are two roles for the outdoor LFR activities. The first is to provide additional training capacity, because the indoor LFR is small for a program of this size. The second is to facilitate training that is not attainable at a sufficient level of efficiency with the indoor LFR.

In excess of 100,000 rounds a year are fired in the training program. Of these, a minimum of 40 rounds per person are high velocity rifle, which at present must be at the outdoor LFR. The balance of the firing is conducted on both the indoor LFR and the outdoor LFR according to the administrative needs.

Many activities required by DOE Order 5480.16 cannot be conducted on a conventional handgun LFR such as the one at the EG&G Mound plant. Among these are training for high velocity rifles, pyrotechnics and gas. Some other nontraditional training can be conducted but only on a limited basis. Most tactical courses are in that category. Therefore, all of the rifle training and most of the tactical training must rely on the outdoor LFR facility.

VI. ACCIDENT ASSESSMENT

A. General

Order AL 5481.1B, Chapter 1, paragraph 4 d, 6 extends the scope beyond accidents in order to address risks to the public, employees and the environment. Although the primary focus of this regulation is assumed to have been radiation, these provisions must be applied in this SA to all aspects of firearms training and range management. Therefore, we must consider risks that extend beyond those that would ordinarily be called accidents.

Table 6-2 from Failure Mode and Effect Analysis for IFR Operations (FMEA) is applicable in its entirety to the outdoor LFR as well as the indoor LFR.

A problem is presented, however, by FMEA Table 6.3. Categories I, II and III are difficult to distinguish for firearms related accidents. All are usually catastrophic in the allegations of the injured. Some events under Category IV may never become record, whereas some others will quickly escalate to a higher category. Table 1-1 of this SA Report is a proposed FMEA for categories of risk peculiar to the outdoor LFR.

B. Types of Risks

1. Ballistical Risks

The theoretical argument that bullets cannot escape these ranges because of the berms and covered firing lines is not defensible. Such arguments are based on the percentages of escaped bullets that can be tolerated. Some authorities have stated that for each million rounds fired, 10 to 20 will be misdirected, and of these 75% will be contained by the berms and firing line shelter. Others maintain that it is not the number of rounds fired that matters but the number of shooters served. Still others believe that the deciding factor is the instructor-trainee ratio. Even if there could be a one-to-one instructor-trainee ratio there still could not be any guarantees.

The matter is exacerbated by the fact that most studies have been based on the escape of high shots. This concern is understandable when one examines the condition of the firing line shelters of most active training ranges. This is alarming because it is conspicuous. Unseen except by a careful observer are the ground and berm ricochets. In actual police and security training these represent many, if not most, of the escaping bullets (2).

All of these theories about fugitive bullets have some validity. Unfortunately there are too many unsubstantiated variables to give full credence to any of them. Although there are no statistics to verify nor disclaim them, there is ample evidence that bullets do escape even the best planned outdoor ranges, and sometimes cause great harm. Physical accidents are rare, however, even one is too many. It must be remembered that the chief instructor for one of the nation's most prestigious police departments managed to shoot himself in the foot while on a range of this type a few years ago. The most common result of fugitive bullets is the abandonment of costly range facilities.

These remarks all related to traditional marksmanship type training in which all shooting is from a fixed firing line. Over 30 years ago the FBI popularized the PPC (Practical Pistol Course) training which added exertion, time constraint and multiple firing lines. A wide variety of such courses developed. Some of these for use on the outdoor LFR are contained in the SOP, Appendix 3. Thus, the probability for misdirected shots increased at the same time that the need to assume several firing lines defeated the use of ground baffles to contain the inevitable low shots.

There is now a great effort being made on the next higher level of training, the so called "tactical training" which attempts to simulate real firearms situations. Nearly all departments today either use or are considering some variation of this concept (3). This training would be difficult and inefficient (but not fully impossible) on the conventional indoor LFR. That is the reason it

it is desired on the outdoor LFR. These efforts and the problems they present are public knowledge having received much publicity. Therefore, a defendant in a case involving fugitive bullets and bullet particles has great difficulty showing the exercise of due diligence.

The justification heard most often when such matters are discussed is: "Well, we haven't had an accident yet." It is overlooked that there is only one accident. After it occurs, the range is closed, the training program compromised and the matter is in the hands of the attorneys. In this instance such a case would be difficult to defend. The plaintiff would attempt to show that money saved in travel time, student-instructor ratio and wear and tear on the equipment would have paid for an appropriate ballistically secure facility in a reasonable time.

The above remarks apply in general to all outdoor LFR's for police and security training. The risks are minimized by imperfect, but well established means such as baffle systems. Today, all progressive training officers agree that such training is inadequate and that situational training is needed. This is familiarly called "tactical training" or "advanced training."

This range facility can be expected to receive far more bullet terminations during its normal activities than during the one day a week it is used by EG&G Mound. Therefore, safeguarding ballistic security should be the responsibility of the lessor. However, EG&G Mound is a more attractive target for any real or capricious charges of injury. The minimum protection might be a waiver from the owner.

In order to assist with the necessary decisions, pages 51 and 52 from Notes About Shooting Ranges (SENEB 1987) are appended. These data should be extrapolated in respect to the one and two mile radii circles shown on the aforementioned map.

2. Environmental Risks

In addition to the ballistical risk considerations, examination of training ranges usually considers two other major categories of risks: noise and lead pollution.

There are two noise considerations. The protection of the hearing of the trainees and training staff is the most important. Both the SOP and ROP place sufficient emphasis on health and safety that the use of hearing and eye protection is implicit. Annual hearing tests are required by all members of the security force and none must show measurable impairment. These measures are specifically required by the SOP (4).

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In order to assist with the necessary decisions, pages 51 and 52 from Notes About Shooting Ranges (SENEB 1987) are appended. These data should be extrapolated in respect to the one and two mile radii circles shown on the aforementioned map.

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It appears that only one of the courses (5) of the SOP specifically calls for eye and ear protection. However, administratively at EG&G Mound, for all personnel involved with firearms training eye and hearing protection is mandatory. The success of sight and hearing protection programs depends upon their enforcement. Although that is an administrative matter and not a design function, it should be facilitated by adequate signage together with a carefully planned traffic pattern throughout the facility.

The second noise concern is the possible objection to the shooting by neighbors. That may not be germane. This is a leased facility that presumably has had a satisfactory experience history in its present location.

The concern about lead intoxication usually relates to aspiration of personnel in an indoor LFR. It rarely relates to outdoor ranges (6). However, lead checks should be included in the physical examinations of everyone involved in the handling of guns and ammunition. That includes the instructors, armorers, reloaders, house-keeping personnel and any others who have continual exposure. Some 16 persons in these categories are currently tested semiannually for their lead levels. All readings have been within acceptable limits.

At this outdoor LFR there is another lead pollution consideration. It is possible that lead in the berms may be leached into the ground water, thereby contaminating drinking water from wells as well as streams and agriculture in the area. This might not be a problem. However, it should be confirmed with the report of an appropriate specialist in that field.

C. Physical Injury

The SOP devotes considerable attention to the procedures for emergency medical assistance in case of training accidents (7). A preplanned route has been established to a hospital emergency room with firearm injury capability. It is kept current based on existing road conditions.

An entry on page 3 of the ROP requires that medical equipment be available at each LFR. In view of the fact that this is a leased facility, all training equipment must be transported to and from it on the training days. That includes minimum first aid supplies.

D. Vulnerability

No reason is known why the owner of the outdoor LFR should not be considered prudent and capable. He probably carries liability insurance to the maximum extent that the operation can support. However, he is not as tempting a target as is the lessee, EG&G Mound. The public would look to that organization as having the "deep pockets" in case of litigation. A matter that would ordinarily be fixed with a band-aid

might escalate into a suit for damages. There have been instances on other ranges in which no accident occurred, but charges were made on the threat of one.

This matter is exacerbated both by the distance that must be traveled to use the outdoor LFR and the circumstances for that use. The EG&G Mound plant and the range facility are many miles apart on opposite sides of Dayton. Training is conducted 16 to 20 Mondays a year with six round trips each time. Because, it is a leased facility and not controlled by the lessee, almost everything needed for the training must be transported to and from the facility. In addition to the trainees and instructors, this includes the firearms, ammunition and targets. (Medical needs are considered elsewhere.) This involves both firearms and vehicles. Fatigue from this travel and transport is an even greater consideration than the cost; but it is the cost that will be cited in case of litigation. An attempt will be made to show that the expense of conducting training in a potentially hazardous facility could have been applied to the acquisition of an inherently safer one.

Adequate signage is important. This is a weak defense in case of a serious problem. However, its presence might compensate for risks which otherwise might never be known; and it shows some degree of recognition of the problems and concern for them. There are two safety related roles for the signs. Signs within the range should reinforce the SOP and ROP. There should also be peripheral signs bordering the property that direct personnel away from the hazardous areas.

The signage is complicated in this case because the outdoor LFR is a leased facility. The normal uses of the range do not require the same signs as desirable in a police and security training range. Thus, the lessor may not consider it appropriate to provide the signs. If the signs must be erected and taken down exclusively for the EG&G Mound training, this would add to the nuisance, expense and unreliability of this facility.

On the days that EG&G Mound uses the range facility, the entrance road is chained and a sign is placed on the chain. It states that entrance is prohibited because the ranges are in use.

Because of these inherent problems in the use of the outdoor LFR, strong reliance must be placed on administrative controls. These are prescribed in the SOP and ROP attached (1).

VII. SAFETY RELATED DOCUMENTATION

A. EG&G Mound Documentation

Exceptional documentation that relates to this report is already in place. Among the items are the following:

1. Standard Operating Procedures, Protective Force Training, October 1988.
2. Range Operations Policy, October 1988.

B. Other Governmental Publications

1. DOE Order 5480.16, Firearms Safety; 1-12-88.
2. SAND82-1022, DOE/SNL Live-Fire Range SAR; March 1983.
3. WSI/SRP 5484.1, Standard Procedures Manual, 8-15-84.
4. DOE 1988, FSAR Pinellas Plant Indoor Firing Range, approved AL 30 Nov. 1988.

C. Non-Governmental Publications

1. Instruction manuals for all firearms, pyrotechnics and munitions involved in training.
2. The trade and professional publications for law enforcement and security.

VIII. REFERENCES

The following are the references for the parenthetical numerals in the SA. They are from the SOP except where otherwise noted.

- (1) I. Purpose; II. Scope, page 1.
- (2) V.D.1-8, pages 13-14.
- (3) V.D.1-8, pages 13-14.
- (4) V.A.8, page 8
VI.A.5.e, page 16.
- (5) Appendix 1, Task PFT1-9091.
- (6) IV.C.5, page 6.
VIII.A.3.i, page 32.
- (7) IV.B.3, page 5
IV.C.4, page 6
IV.F.3, page 7
V.A.9, page 8
VI.E.1-5, pages 25-28.

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T A B L E 1 - 1

FAILURE MODE AND EFFECTS ANALYSIS FOR OUTDOOR LFR SYSTEMS

SYSTEMS	FAILURE MODE	DETECTION	COMPENSATION	EFFECTS	E.Cat.
Berm backstops	Ricochets to firing line	Visual Inspection	"Mine" lead from berms	Risk of eye injury. Risk of skin wounds.	IIa
Berm backstops	Ricochet outside of range	Visual Inspection complaints	Same	Risk of injury Neighbor complaint	IIa IIh
Berm backstops	Contamination of ground water	Bore tests	No compensation	Stop of activity	IIg
Overhead firing/line shelters	Structural damage from high shots	Visual inspection	Repair or replace structure	Failure to limit high shots	IVg
Peripheral security	Defects in fences and accesses	Visual inspection	Repair or replace breaks and faulty locks	Danger to trespassers, service personnel	IId
Peripheral security	Omissions and errors in signage	Visual inspection	Correct selection and placement of signs	Danger to personnel and trespassers	IIIf
Articulation	Potentially hazardous walks, waiting areas	Visual inspection	Repair surfaces	Danger of falls while carrying firearms and ammunition	IIIg
Lighting	One or more lights do not illuminate	Visual inspection	Replace lamps or repair system	Range inoperative after dark	IIIg
Audio system	No amplification of voice commands	Manual inspection	Repair or replace faulty units	Megaphone to be used	IIIg
Containers	Missing, misplaced or mislabeled	Visual inspection	Replace	Temporary containers used	IVg
Emergency medical	First aid equipment depleted, missing or tampered with	Visual inspection	Replace missing items	Range may be operated	IIIg

TABLE 6-1
FAILURE MODE AND EFFECTS ANALYSIS FOR IFR SYSTEMS

SYSTEM	FAILURE MODE	DETECTION	COMPENSATION	EFFECTS	EFFECTS CATEGORY
Smoke and Heat Detectors	Detector fails mechanically	During weekly inspections	Multiple detectors cover a given area	Fire would be more advanced when detected	IIIf
Smoke and Heat Detectors	Power failure	Switch to emergency power triggers alarms	Detectors have battery backups	No interruption	IVh
Auxiliary Ventilation	Mechanical failure	Sufficient air flow not felt on firing line	No compensation	Range is inoperative until system is repaired	IVe
Auxiliary Ventilation	Electrical	Ventilation system does not engage when switched on	No compensation	Range is inoperative until system is repaired	IVe
Bullet trap	Steel plate becomes improperly aligned	During pre-use range inspection by RSO	No compensation	Range is inoperative until system is repaired	IVe

TABLE 6-2
FAILURE MODE AND EFFECTS ANALYSIS FOR IFR OPERATIONS

OPERATION	FAILURE MODE	COMPENSATION	EFFECTS	EFFECTS CATEGORY
Firing .38 Caliber Handgun	Loaded weapon is dropped while changing firing positions	GOP #07 presents specific Range safety rules; weapon holstered while moving firing positions	Weapon discharges and seriously injures nearby shooter	Ig
Firing .38 Caliber	While reloading weapon, bullet is dropped	Firing line is carpeted	Bullet landing on carpeted surface does not go off	IVg
Firing 9mm Rifle	Hangfire of 9mm round	GOP #07 requires all weapons to be pointed down range while on the firing line	Round does not immediately fire when trigger is pulled; after a few seconds' delay, round fires while weapon is still pointed down range; range and bullet trap contain the bullet	IVg
Firing 7.62mm Automatic Rifle	Cookoff of chambered round	GOP #07 requires all weapons to be pointed down range while on the firing line	While in automatic mode, a chambered round is discharged without trigger being pulled due to excessive heat from automatic firing; range and bullet trap contain the bullet	IVg
Firing .227 Caliber Automatic Rifle	Fired bullet lodges in barrel	Security Patrol's weapons manual and lesson plans for remedial weapons training instructs shooter to be aware of noticeable differences in firing sound and recoil for this weapon; shooter should stop firing and inspect barrel for lodged bullet	No effects	IVg

TABLE 6-2
FAILURE MODE AND EFFECTS ANALYSIS FOR IFR OPERATIONS
(CONTINUED)

OPERATION	FAILURE MODE	COMPENSATION	EFFECTS	EFFECTS CATEGORY
Firing 12 Gauge Shotgun	Round misfires	GOP #07 and weapon specific lesson plans instruct shoot- ers to wait 20 seconds to ensure that round does not fire before removing shell from chamber.	No effects	IVh

TABLE 6-3

QUALITATIVE ACCIDENT HAZARD SEVERITY

HAZARD CATEGORIES	CONSEQUENCES TO THE PUBLIC, WORKERS, OR ENVIRONMENT
Category I - Catastrophic	May cause deaths, or loss of the facility/operation, or severe impact on the environment.
Category II - Critical	May cause severe injury, or severe occupational illness, or major damage to a facility/operation, or major impact on the environment.
Category III - Marginal	May cause minor injury, or minor occupational illness, or minor impact on the environment.
Category IV - Negligible	Will not result in a significant injury, or occupational illness, or provide a significant impact on the environment.

TABLE 6-4

EFFECTS CATEGORIES

<u>CATEGORIES</u>	<u>CONSEQUENCES</u>
a	Hazardous Materials Released to the Environment
b	Hazardous Materials Released Within the Building
c	Loss of Plant Operational Capability
d	Loss of Plant Security Capability
e	Loss of IFR Operational Capability
f	Loss of System Capability
g	Personnel Exposed to Safety Hazards
h	No Hazard

USEFUL INFORMATION

Ballistics present problems for the range planner because the published data vary so widely. This is not the result of sloppiness on the part of the practitioners, but results from the many variables involved. Such matters as barometric pressure or barrel length might not be obvious but are understandable. However, other matters such as the ballistic coefficients which are unique for each and every round are pure arcana to outsiders.

The following are several axioms used by Seneb, Inc. for general work. They are compromises based on published data as well as private correspondence with various workers in the field. These data are, at the best, only points of departure. They in no way guarantee nor even imply safety.

Maximum Ranges

The maximum range is attained at angles between 30 and 37 degrees. It is influenced by barometric pressure. For example, most high velocity rifle rounds travel approximately 30 percent further at 12000 feet than they do at sea level. The following are representative distances for sea level ranges:

<u>Round</u>	<u>Meters</u>	<u>Feet</u>	<u>Miles</u>
Cal. 22 long rifle	1400	4600	.9
Cal. 30 carbine	2300	7550	1.3
9 mm Luger pistol, 124 grain	1950	6400	1.2
Cal. 38 revolver, ball	1600	5250	1.0
Cal. 357 revolver, 158 grain	2150	7050	1.3
Cal. 45 pistol, ball	1300	4270	0.8
12 gage shotgun, #9 shot size	204	670	0.13
12 " " 00 buckshot	600	1970	0.4
12 " " 1 ounce slug	750	2460	0.5
5.56 mm rifle, ball	3100	10200	1.9
7.62 mm " "	4100	13500	2.6
7.62 " " match	4800	15750	3.0
Cal. 308, 150 grain	4100	13450	2.5
Cal. 30-06, 200 grain	5700	18700	3.5
Cal. 50 machine gun	6500	21300	4.0

Terminal Ballistics for "Spent" Rounds

There is a widely held belief that bullets are harmless at the extreme limits of their range. In WW II tests established that 58 ft./lbs. of remaining energy would cause a casualty. In the following table it should be remembered that, for example, 27 ft./lbs. is equal to a weight of 27 pounds falling one foot on an area equal to the diameter of the bullet.

Conditions at End of Travel for "spent" Rounds:

<u>Round</u>	<u>Velocity</u>	<u>Energy</u>
Cal. 38, special, 158 grain	305 ft./sec.	33 ft./lbs.
9 mm Luger, 124 grain	289	23
5.56 mm, 55 grain	324	18
Cal. 308, 200 grain	421	79
Cal. 30-06, 220 grain	441	95

Bullets Fired Straight Up

A bullet fired straight up may retain its stability and return to earth tail first, or it may tumble. The following are typical handgun and rifle rounds fired at sea level:

<u>Condition</u>	<u>Max. Hgt.</u>	<u>Elapsed Tm.</u>	<u>Term. Vel.</u>
Stable Cal. 38, 158 gr.	4100 ft.	35 sec.	230 ft/sec.
same but unstable	4100	40	180
Stable Cal. 30-06, 180 gr.	10000	58	323
same but unstable	10000	81	180

Note that if fired at even a slight angle and the bullet remains stable the energy substantially increases. For the 30-06 it becomes 475 ft./sec. for a flight of 53 seconds.

Penetration Resistance for High Velocity Rifle Bullets

The following are the standards generally used by the U. S. military for positive protection from a single round fired at 90 degrees to the surface.

<u>Materials</u>	<u>Thicknesses Required</u>		
	<u>5.56 mm</u>	<u>7.62 mm</u>	<u>Cal. 50</u>
Concrete (5000 psi)	5 in.	7 in.	12 in.
Crushed rock	14	20	30
Dry sand	16	24	32
Oak logs	28	40	56
Earth, packed and tamped	32	48	60
" freshly turned	38	56	72
Clay, plastic	44	65	100

Penetration Resistance for Handgun Bullets

There has been much publicity about exotic materials and their ability to stop bullets. Which is the best? Except when light weight is a critical factor, steel is most cost-effective for nearly all requirements. Tests indicate the following:

16 ga. mild st.	Cal.22 LR	Penetrated, slight breakthrough if faced with 3/4 plywood.
14 ga.	" " Cal.38 Spec.	Penetrated, only dented if faced.
10 ga.	" " Cal.357 Mag.	Severely dented.
" "	" " Cal.44 Mag.	Penetrated even when faced.
3/16" AR 225	Cal.357 Mag.	Dented only.
" "	Cal.44 Mag.	Penetrated even when faced.
1/4" AR 400	Cal.44 Mag.	Dented only.