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AK-47 Risk Assessment and ALARP Justification for the Ejection of
Hot Cartridges

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Abstract

This report covers the AK-47 Hazard Assessment and ALARP justification for the given hazard: Ejection of hot cartridges (H1). It builds upon an initial group hazard identification activity and evaluates control measures for 5 identified hazards. It later provides a more in-depth analysis on H1 and justifies its ALARP position. The report finds that the activity was not in depth and needs to be reperformed to a greater depth to satisfy regulatory requirements.

Keywords: ALARP, Safety case, Risk assessment, AK Pattern, Hazard, Control Measure

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List of Abbreviations

ALARP	As Low As Reasonably Practicable
HSE	Health and Safety Executive
MTDS	Manufacture To Disposal Sequence
PFD	Probability of Failure on Demand
SSO	Safety Serviced Organisation
UK	United Kingdom
HAZ-ID	Hazard identification
ASEMS	Acquisition Safety and Environmental Management System
STANAG	Standardization Agreement (NATO)

1 Introduction

1.1 Purpose

This safety assessment identifies and evaluates the risks present during the operation of an AK pattern rifle and records the controls reducing those risks to a tolerable, As Low As Reasonably Practicable (ALARP) position. It develops from a previous hazard identification meeting, with each estimate being rederived for the purposes of this report.

1.2 Scope

The report only considers the weapon from the point ammunition is introduced, until it is cleared and unloaded, in an operational environment, while authorised for use. Ammunition is only considered as far as its behaviour arises from the use of the weapon for its intended purpose, and design, manufacture, transport, storage, issue, maintenance, and disposal of the weapon system are excluded.

This scope covers generic armed forces operators outside of UK jurisdiction but uses UK health and safety legislation and HSE guidance as a benchmark minimum for constructing its operational safety assessment.

A shortcoming within this assessment and scope is that several administrative controls during training will have some form of supervision. Such assumptions cannot be guaranteed during active operations and therefore the report applies a pessimistic approach to reducing risks. For training purposes, alternative hazard assessments and further control measures should be documented by the subsequent duty holders to allow for mitigating circumstances.

1.3 Definitions

For the purposes of this report, the following definitions were based on those found within the Acquisition Safety and Environmental Management System (ASEMS) and Def Stan 00-56 Part 1, [1], [2].

- **Hazard** – An item or situation with the potential to cause harm.
- **Harm** – a form of damage.
- **Likelihood** – The chance of something occurring.
- **Risk** – The product of likelihood and severity of a hazard.
- **Accident** – The result of a hazard that causes harm.
- **Controls** – Methods that reduce risk.
- **Mitigation** – Methods that reduce the severity relating to accidents.

2 Initial risk assessment

Risk is defined as the product of likelihood and severity. The scale for likelihood within this report covers 1 to 5 with exponential weightings for severity (1-15), biasing hazards with highly consequential accidents towards higher risk ratings. The risk matrix used is seen in Figure 1 which contains the numerical values for (likelihood)*(severity), and a colour chart which can be compared to Table 1 to indicate the Risk Class.

Table 1: Risk Classification and description, with associated colour indicator.

Risk Class	Meaning
A	High - "The risk is considered Intolerable/ Unacceptable. The activity shall not proceed, or the system shall not be used."
B	Medium/High - "The risk can only be considered Tolerable and ALARP if demonstrated that further risk reduction is impracticable."
C	Medium/Low - "The risk is considered Tolerable and ALARP."
D	Low - "The risk is considered to be Broadly Acceptable. Additional risk reductions may be introduced only if the benefits justify the cost (time, money, inconvenience)."

135	60	45	30	15
81	36	27	18	9
45	20	15	10	5
18	8	6	4	2
9	4	3	2	1

Figure 1: Risk matrix with calculates risk values.

2.1 Likelihood and Severity

Likelihood is the probability of the hazard happening. Ejection of a hot case (H-1) occurs every round and therefore has a high likelihood rating. The probability of the accident occurring itself does not define the likelihood rating. The values assigned to each likelihood level were determined at the initial group hazard meeting, as seen in Table 2.

Severity is assessed on the damage that the hazard will cause. This considers the worst possible accident that could happen as a result of the hazard, without any other constraints. Severity levels and descriptions are published in Table 3.

This report considers two hazard exposure groups, one for trained personnel and one for civilians. The civilian scale uplifts the severity of an incident to consider the decreased risk acceptance levels for the public and any resulting reputational damage to the business that would follow. Civilian estimates are conditional on presence within the hazard footprint. The Risk Class is increased by one level above the calculated value for civilians. Weighting values for likelihood and severity can be seen in Table 4.

Table 2: Likelihood levels, description, and indicative probabilities.

Likelihood Level	Description	Indicative Probability
1 (Impossible)	Extremely unlikely	$0 \leq 10E-6$
2 (Unlikely)	Not expected, but credible	$10E-6 < 0 \leq 10E-5$
3 (Occasional)	May occur sometimes.	$10E-5 < 0 \leq 10E-4$
4 (Likely)	Will occur several times.	$10E-4 < 0 \leq 10E-3$
5 (Frequent)	Expected to occur repeatedly	$10E-3 < 0 \leq 10E-2$

Table 3: Severity levels and their descriptions.

Severity Level	Description
5 (Catastrophic)	Fatality or multiple fatalities/Public Life-altering
4 (Critical)	Life-altering injury/Public High Triage
3 (Severe)	High Triage Recoverable/Public Low Triage
2 (Minor)	Low Triage Recoverable/Public Negligible Harm
1 (Marginal)	Negligible harm

Table 4: Weighted values used for likelihood and severity for risk class calculations. Civilian severity weightings included.

Level	1	2	3	4	5
Likelihood	1	2	3	4	5
Severity	1	2	5	9	15
Severity (Public)	2 (Eq. Risk Level 2)	5 (Eq. Risk Level 3)	15 (Eq. Risk Level 4)	15 (Eq. Risk Level 5)	15 (Eq. Risk Level 5)

3 Hazard Register

Table 5 presents the hazards from the initial group hazard assessment. This does not cover all hazards, only the ones current identified for the purposes of this report. The hazards are referred to by their associated HAZ-ID, for ease of communication. The description of the hazard captures the bounding scope for each case. Table 6 indicated the accidents that can arise because of each hazard, as well as the causes for each accident. The accidents themselves are not hazards but instead are possible to occur when the hazards are present. To mitigate the accidents from occurring, the causes must be prevented, or mitigations should be put in place to lower the likelihood of each cause causing an accident.

Severity will lower if the mitigations put in place drop the likelihood of serious accidents from occurring to zero. Minimisation of an accident because of a control measure (e.g. instead of a bullet going through a person completely, it gets lodged inside due to body armour absorbing the initial energetic impact) are themselves separate accidents and therefore should be added to the hazard register and attempted to be minimised.

Table 5: Hazard (1-5) descriptions.

ID	Hazard	Description
H1	Ejected hot cartridge case	Spent case ejected at velocity and elevated temperature through port. Occurs every fired round and is inherent to the operation of the weapon system.
H2	Misfire, hang fire, or squib	Ammunition fails to function correctly following a firing pin strike.
H3	Noise exposure	Muzzle blast and bullet shock wave produces an impulse above legal exposure limit.
H4	Unintended fire	Discharge of weapon without operator intention.
H5	Breech explosion	Uncontrolled explosion within the weapon system.

In preference, the hazard register is ever growing and should be updated with every control measure or new finding. The HSE states that risk assessments must be reviewed by the employer if “For any reason the assessment is considered to be not valid, or the work has changed, or some other information has been available and indicates that the assessment is no longer valid” [3], which also states another requirement to record both: “the risk assessment, and the preventative control steps to be put in place, including administrative measures, to comply with the regulations”.

Table 6: Hazard (1-5) accidents and causes.

ID	Accidents	Causes
H1	• Contact burn • Facial injury to firer or adjacent person • Escalation to H4 • Ignition of combustible material	• Normal usage • Energetic ejection • Fixed ejection site • No deflector • Ejection path in line with gun firing position • Rebound
H2	• Out of battery firing • Obstructed bore • Escalation to H5	• Worn firing pin. • Inconsistent primer • Particulate ingress
H3	• Permanent hearing loss • Tinnitus • Trauma	• Muzzle blast • Confined space • Body firing position • Cumulative exposure
H4	• Gunshot wound to user, adjacent, or bystander	• Incorrect handling of weapon • Startle induced

	Uncontrolled round beyond intended area	- Involuntary contraction - Thermal cook off - Misunderstood commands
H5	- Fragmentation damage - Blast and burn injury. - Weapon destruction	- Bore obstruction. - Muzzle ingress - Overpressure - Incorrect ammunition - Thermal cook off

3.1.1 Hazard interactions

Hazards are linked and preventing one from occurring can result in the increase of likelihood for another. E.g. Preventing the ejection of cartridges will increase the likelihood for a breech explosion. In addition, H1 may result in H4 due to a startle reaction [4].

Therefore, the hazards cannot be eliminated but instead decreased to an ALARP position while carefully factoring in likelihood of occurrence because of modification.

3.2 Pre control risks

All five hazards are shown in Table 7 to be within risk class A – intolerable,

Table 7: Pre control risk classes and risk score for each hazard

ID	Likelihood Level	Severity Level	Score (Likelihood x Severity weighting)	Class
H1	5	4	81	A
H2	3	5	45	A
H3	5	4	81	A
H4	3	5	45	A
H5	2	5	30	A

3.3 Control measures and Post Control Risk

As seen in Table 8 - only severity changed for H1, as the hazard itself is a function of the weapon which cannot be altered, but the mitigations can make the accidents impossible to occur. For H2, H4, and H5, only likelihood changed with the accidents less likely to occur with checks in place to ensure the weapon functions correctly before use. Severity will be stuck at Level 5 for such hazards unless death can be mitigated. The control measures which were not used can be seen in Table 9.

Table 8: Control measures used for each hazard and the updated severity, likelihood, and risk levels.

ID	Control Measures	L'	S'	Score'	Class'	Public Class'
H1	- Personal Protective Equipment (skin covered, eyewear, headwear, boots) - Clamp on deflector - Firing position change - Drills to address hot components. - Environment observation checks	5	2	10	B	10 (C)
H2	- Unconditional wait period before muzzle safe command - Bore inspection after suspected squib (Learning from experience (LFE)) - Firing pin and channel cleaning - Ammunition control - Training to recognise weapon system changes	1	5	15	B	15 (A)
H3	- Personal Protective Equipment (Ear plugs) - Level dependent electronic defenders - Exclusion distances for non users - Open area preference for ranges - Fired round limits - Audiometric data analysis - Regular ear tests	2	1	2	D	4 (C)
H4	- Correct holding and handling procedures while loaded - Chamber flags when not in use - Safety switches - Set fire rate limits	1	5	15	B	15 (A)
H5	- Bore inspections - Muzzle covers - Rate of fire limits	1	5	15	B	15 (A)

3.4 Proposed and rejected control measures

Control measures are accepted when they produce an ALARP hazard. This means that they must be proportionate to the hazard in all forms of investment.

Table 9: Rejected control measures and grounds for dismissal.

ID	Measure	Rejection grounds
H1	1. Reduced ejection gas energy 2. Universal catchers	1. Adverse risk transfer towards H2 and H5. 2. Grossly disproportionate and introduces new hazards
H2	1. Sole source ammunition only 2. Extend permission to fire times similar to explosives	1. Grossly disproportionate. 2. Decreases operational availability by increasing superficial wait period disproportionately past universally accepted times.
H3	1. Subsonic ammunition 2. Universal suppression	1. Grossly disproportionate and negative capability progression. 2. Marginal benefit without decreasing severity or likelihood and decreases operational effectiveness
H4	1. Auto authorised user lock 2. Two person system	1. Grossly disproportionate and potentially capability preventing failure mode. 2. Requires mission alteration and increases operational burdens.
H5	1. Non-destructive ammunition inspections	1. Grossly disproportionate and decreases capability operational life span.

3.5 Risk tolerance

The risk class proposed for the trained operators in Table 8 are lower than those for the public. By law, the Health and Safety at Work Etc. Act 1974 [5] is still bound, but by considering the operator as a trained and informed individual, who is more knowledge, competent, and has more benefits and provisions for protection than the public, it allows for a greater risk appetite. The risk tolerance profile for trained operators allows for minor burns, such as those because of H1, to be tolerable and therefore acceptable as ALARP.

4 ALARP justification for H1: Ejected hot cartridge case

4.1 ALARP introduction

ALARP is a measure of proportionality, driving the reduction of risk until any further sacrifice becomes grossly disproportionate to its benefit. This is always in favour of safety, and therefore decisions on ALARP are done at large with multiple input sources.

The term “reasonably practicable” was defined by Lord Justice Asquith' on Edwards v National Coal Board [1949] where he stated that the quantum of a risk must be weighed against the money, time, and the trouble of averting it [6]. Only when the risk is completely insignificant to the sacrifice needed to fix it can a duty holder prove that compliance is not reasonably practicable.

The HSE later defined ALARP as a scale with three regions: unacceptable, broadly acceptable, and tolerable [7], [8].

Misjudgement of ALARP results in costly accidents. Typically, this falls upon the duty holder for reprimand. In court, defendants must prove that the cost of further risk reductions were grossly disproportionate to its safety benefit. This is incomparably harder than the opposite, defending why you should implement something extra, as it revolves around the amount of effort and investment that saving a human life would cost.

The Haddon-Cave review found Nimrod historically failed to adhere to ALARP principles and is the primary reason as to its demise. E.g. Hazard-73 was incorrectly signed off as 'Tolerable' despite presenting a catastrophic risk [9]. ALARP principles are bound by UK law and hazard reviews exist specifically to avoid such mistakes from progressing.

ALARP can broadly be broken down into the following logic: Reject (if) $\text{Cost} > \text{DF} \times \text{Benefit}$. With DF representing a disproportion factor, a ratio decided upon uniquely in each circumstance to reflect how much extra cost you are willing to spend on a given hazard.

4.2 H1 overview

When the weapon is fired, cases are ejected at elevated velocity and temperature through the right side port of the AK-47.

The severity occurs from four accidents, namely: case striking the eye or face and causing life altering injury or death (the firing position of the gun being in line with the face makes this easier for the cartridge to take this path), the case makes contact with the skin or body (by getting past loose clothing items, or through direct contact), the case ignites flammable material nearby (transfer of heat to combustible material), and escalation to other hazards (such as the shock from a burn causing one to accidentally discharge the weapon).

The likelihood for this hazard will stay constant, as the ejection of the casing is fundamental to the weapons operation.

H1 sits as a Class 'A' risk (pre mitigation), defined as intolerable and relates to the HSE region of 'unacceptable'. After mitigation it becomes a Class 'B' risk.

4.3 Control Selection

Control measures were selected using the hierarchy of hazard control method ERICPD: Eliminate, Reduce/Substitute, Isolate, Control, PPE. Discipline, satisfying ASEMS Policy requiring a hierarchal approach to risk reduction [10]. However, relevant good practice was first applied, using HSE's advice that where established practice meets ALARP principles, cost and feasibility need not to be separately computed. This was the case for general solutions such as eyewear; this is a universal mitigation for unpredictable moving objects. The minimum requirements are defined within BS EN 166 and STANAG 2920 for ballistic related eye protection [11], [12].

Risk reduction was constrained by the design of the system itself, so control measures concentrated on isolation, protection, and discipline, such as:

- Unique firing position for this weapon system
- Proper training on the handling of hot cartridges
- Physical deflector plates

New emerging technology was considered at selection, such as:

- Polymer and composite cased ammunition (case material that would reduce the store of thermal energy),
- Caseless ammunition (reducing the risk entirely, but equally presenting new hazards),
- Self regulating ejection systems (matching the exact energy needed to eject)

Only after, were measures that could eliminate or reduce considered, such as:

- Swapping the weapon system for an alternative model
- Modification of the weapon system to move the ejection port elsewhere
- Modification of the weapon system to store the ejected casings within the system itself.

4.4 Control assessments

Each control measure was evaluated using the following criteria:

- Controls that eliminate an accident pathway were preferred over those that reduce.
- Controls that did not rely on compliance were preferred over those that depended on human behaviour.
- Controls that resulted in other hazards elevating were ranked lower than those that did not.
- Controls that moved the risk to others, instead of the user, were disregarded.
- Controls that followed good practice were accepted with no cost analysis.
- The easiest to implement controls that moved the hazard from risk class 'A' to 'B' were implemented.

A larger DF factor has not been used despite the initial Class 'A' risk posed as the generic good practices already lower the risk value to the lower end (more ALARP) of tolerable in class 'B'

4.5 Controls rejected

Grossly disproportionate is not the only factor for failing to be ALARP, technical constraints, risk transfers, and arising hazards associated with controls are also valid reasons. In addition, duty holders may implement effective controls that provide mitigation but fail to prove that it is ALARP. The HSE guidance states that proof of (or lack of) ALARP status must be documented for controls both accepted and rejected. Rejected controls that are later found to be ALARP are a breach of care in responsibility for a duty holder.

For safety cases, all suggestions should be explored without any existing prejudice. Examples of those which have been rejected are seen in Table 10.

Table 10: Rejected control measures and the reasoning for dismissal.

Control Measure	Rejection grounds
Forward ejection (redesign of system)	Technically infeasible on the AK47 unless using grossly disproportionate cost.

Reversible bolt	Technically infeasible on the AK47 unless using grossly disproportionate cost.
Replacement with deflector equipped rifle	Grossly disproportionate as would require disposal of current weapon system and purchasing of new (pricier) system
Suppressor	Increases the pressure and increased ejection energy of casing
Universal casing catcher	Limits weapon systems capability for sustained fire when catcher is full
Full face covering	Degrades peripheral vision and will prevent issues in heated environments.
Left shoulder firing	Inhibits operator and requires full retraining
Prohibition of firing in a confined space	Reduces capability greatly
Prohibition of firing within green spaces or near flammable material	Reduces capability greatly
Caseless ammunition	No current design compatible with the weapon system
Composite casing	No current design compatible with the weapon system
Substitution of ammunition for simulation	Reduces capability greatly
Reduce round amount	Does not reduce likelihood or severity

5 Review

5.1 Scope definition

The scope is defined but excludes phases which are covered as mitigations within this assessment. For example: ammunition quality, a factor affecting the likelihood of hazard H2, is out of bounds of the scope and instead sits within the procurement and manufacturing stage. The assessment can state assumptions but has no jurisdiction to evidence them. A full reworking of the scope to include the entire Manufacture to Target Disposal Sequence (MTDS) may suit this hazard study better.

5.2 Hazard ID

Only five hazards are present within this study, derived by group exercise rather than a systematic technique. An example of a major missing hazard would be propellant gas inhalation, something legally required to be mitigated by COSHH 2002 [13]. A full Hazard identification study which uses existing frameworks would benefit this study by broadening the number of hazards captured and mitigated, making the weapon system safer and more ALARP.

5.3 Controls

The control measures identified are evaluated all together than individually. For a greater defence-in-depth each control measure should have a reduction factor, and each accident should have its own severity and likelihood rating. This would allow users to identify the critical safety functions for the system are and allow for a Probability of Failure on Demand (pfd) to be calculated. Such would provide a future safety case based in sound reasoning.

No human factor calculations were performed, which some claim attribute to the cause behind most accidents [14], [15].

5.4 Future technology

Alternative casing material and ammunition designs would open the Reduce/Substitution tier of ERICPD and trigger reassessment of the control measures.

5.5 Recommended continuations

The report should be subject to independent scrutiny before accepted, with a systematic hazard identification used instead of the inherited list. Ak specific information and data should be gathered and used to inform the hazards, accidents, causes, and will influence the good practice control measures used. This would present an evidence based approach to safety rather than the subjective and judgement based approach taken within this report.

5.6 Future assessments

Along with the other recommendations, the risk bands should be reworked to fit the AK-47 better, considering how many bullets are fired on average and the existing frequency of hazards. The likelihood probabilities should be changed to fit a better exposure basis,

as the current per person per year units do not fit with the normal usage of the weapon system or the probability ranges defined. In addition, ALARP should be separated from tolerable and declared as separate things. Tolerable is a measure of what users are willing to accept, but ALARP is a legally bound requirement.

5.7 Conclusions

The Ak-47 is a weapon system designed to effectively incapacitate an enemy and is inherently safe by design when used by a trained operator. Training and PPE will mitigate most hazards that arise with the AK-47 with further mitigations such as modifications or attachments erring on the side of grossly disproportionate when factoring in demand.

For H1, the risk profile of the user will capture minor burns but should not cover anything more serious. It is recommended that for accidents greater in severity, training and PPE are utilised, and installation of a deflector plate is trialled. Otherwise, a costly modification to the weapon is needed and would render the usage of the AK grossly disproportionate.

The currently proposed justification for H1 lacks proper argument to defend its ALARP position. To provide greater detail, it must define proper bounds for being grossly disproportionate, as well as assigning proper values to each accident and control measure to propagate through mitigation selection. Real data from past incidents concerning the AK-47 should be utilised along with other data obtained from similar weapon systems.

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