

APPENDIX C
CHARACTERISTICS AND ANALYSIS OF FLARES

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1.0 INTRODUCTION

The F-22A employs MJU-10/B self-protection flares. Self-protection flares are magnesium pellets that, when ignited, burn for 3.5 to 5 seconds at 2,000 degrees Fahrenheit. The burn temperature is hotter than the exhaust of an aircraft, and therefore attracts and decoys heat-seeking weapons targeted on the aircraft. Flares are used in pilot training to develop the near instinctive reactions to a threat that are critical to combat survival. This appendix describes flare composition, ejection, risks, and associated regulations.

2.0 FLARE COMPOSITION

Self-protection flares are primarily mixtures of magnesium and Teflon (polytetrafluoroethylene) molded into rectangular shapes (United States Air Force [Air Force] 1997). Longitudinal grooves provide space for small amounts of materials that aid in ignition such as:

- First fire materials: potassium perchlorate, boron powder, magnesium powder, barium chromate, Viton A, or Fluorel binder.
- Immediate fire materials: magnesium powder, Teflon, Viton A, or Fluorel
- Dip coat: magnesium powder, Teflon, Viton A or Fluorel

Typically, flares are wrapped with an aluminum-coated mylar or filament-reinforced tape (wrapping) and inserted into an aluminum (0.03 inches thick) case that is closed with a felt spacer and a plastic end cap (Air Force 1997). The top of the case has a pyrotechnic impulse cartridge that is activated electrically to produce hot gases that push a piston, a safe and initiation (S&I) device, the flare material, and the end cap out of the aircraft into the airstream. Table 1 provides a description of MJU-10/B and, for comparison, MJU-7 A/B flare components. Typical flare composition and debris are summarized in Table 2. Figure 1 is an illustration of an MJU-10/B flare.

Table 1. Description of MJU-10/B and MJU-7 A/B Flares

<i>Attribute</i>	<i>MJU-10/B</i>	<i>MJU-7 A/B</i>
Aircraft	F-15, F-22	F-15
Mode	Semi-Parasitic	Semi-Parasitic
Configuration	Rectangle	Rectangle
Size	2 x 2 x 8 inches (32 cubic inches)	1 x 2 x 8 inches (16 cubic inches)
Impulse Cartridge	BBU-36/B	BBU-36/B
Safe and Initiation Device (S&I)	Slider Assembly	Slider Assembly
Weight (nominal)	40 ounces	13 ounces

Table 2. Typical Composition of MJU-10/B and MJU-7 A/B Self-Protection Flares

<i>Part</i>	<i>Components</i>
Combustible	
Flare Pellet	Polytetrafluoroethylene (Teflon) ($-[C_2F_4]_n - n=20,000$ units) Magnesium (Mg) Fluoroelastomer (Viton, Fluorel, Hytemp)
First Fire Mixture	Boron (B) Magnesium (Mg) Potassium perchlorate (KClO ₄) Barium chromate (BaCrO ₄) Fluoroelastomer
Immediate Fire/ Dip Coat	Polytetrafluoroethylene (Teflon) ($-[C_2F_4]_n - n=20,000$ units) Magnesium (Mg) Fluoroelastomer
Assemblage (Residual Components)	
Aluminum Wrap	Mylar or filament tape bonded to aluminum tape
End Cap	Plastic (nylon)
Felt Spacers	Felt pads (0.25 inches by cross section of flare)
Safe & Initiation (S&I) Device	Plastic (nylon, tefzel, zytel)
Piston	Plastic (nylon, tefzel, zytel)

Source: Air Force 1997

MJU-10/B Flare

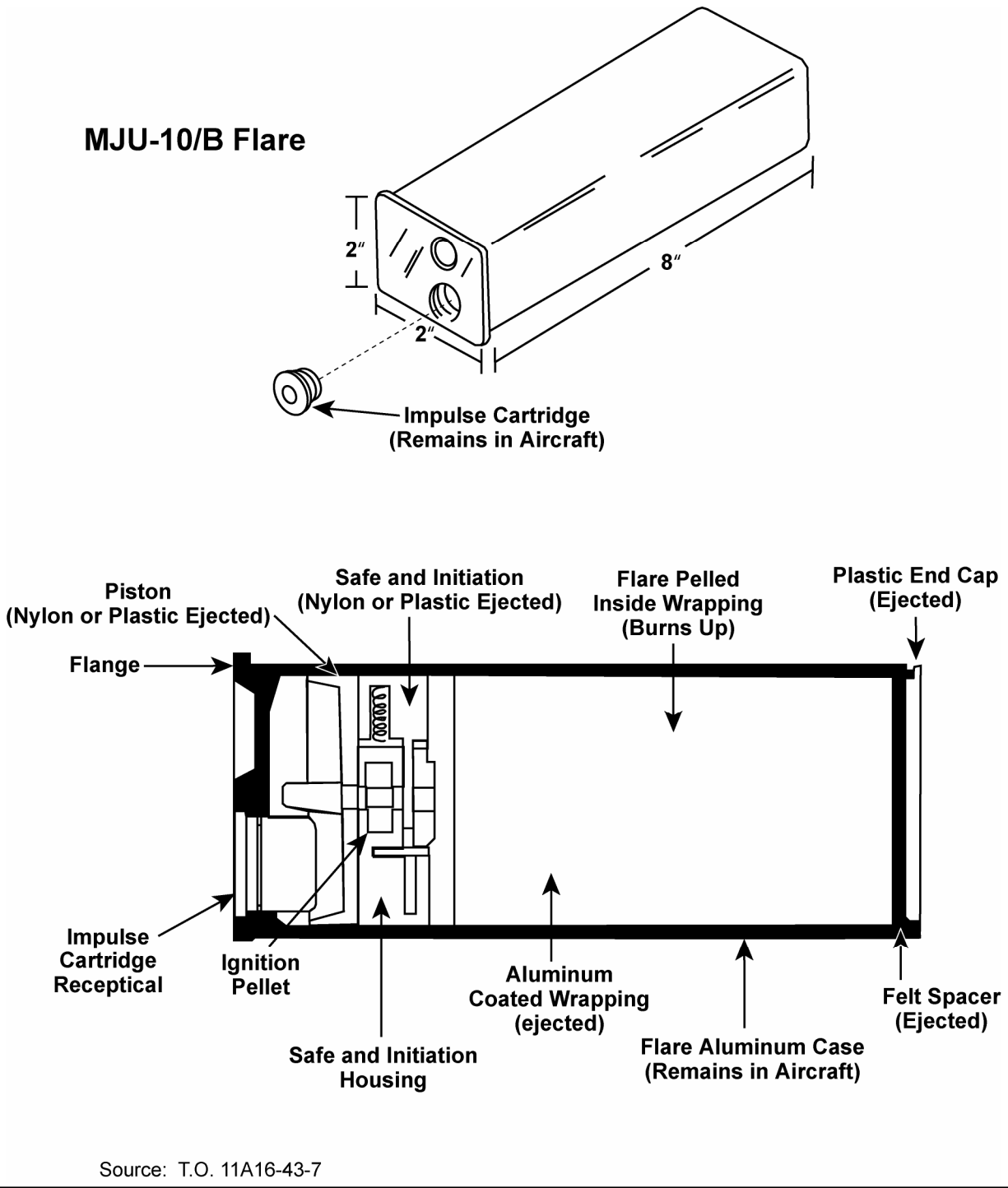


FIGURE 1. MJU-10/B FLARE

3.0 FLARE EJECTION

The MJU-10/B is a semi-parasitic type flare that uses a BBU-36/B impulse cartridge. In these flares, a slider assembly incorporates an initiation pellet (640 milligrams of magnesium, Teflon, and Viton A or Fluorel binder). This pellet is ignited by the impulse cartridge, and hot gases reach the flare as the slider exits the case, exposing a fire passage from the initiation pellet to the first fire mixture on top of the flare pellet. Table 3 describes the components of BBU-36/B impulse charges.

Flares are tested to ensure they meet performance requirements in terms of ejection, ignition, and effective radiant intensity. If the number of failures exceeds the upper control quality assurance acceptance level, the flares are returned to the manufacturer. A statistical sample is taken to ensure that approximately 99 percent must be judged reliable for ejection, ignition, and intensity. Flare failure would occur if the flare failed to eject, did not burn properly, or failed to ignite upon ejection. For training use within the airspace, a dud flare would be one that successfully ejected but failed to ignite. That probability of a dud flare on the ground is estimated to be 0.01 percent based upon dud flares located during military range cleanup.

4.0 RISKS ASSOCIATED WITH FLARE USE

Environmental risks associated with the use of defensive flares fall within two main categories: the risk of fire from a flare and the risk of being struck by a residual flare component.

4.1 FIRE RISK

Fire risk associated with flares stems from an unlikely, but possible scenario which results in the flare reaching the ground or vegetation while still burning. The altitude from which flares are dropped is strictly regulated by the airspace manager, and is based on a number of factors including flare burn-out rate. The flare burn-out rate is shown in Table 4. Defensive flares typically burn out in 3.5 to 5 seconds, during which time the flare will have fallen between 200 and 400 feet. Specific defensive flare burn-out rates are classified. Table 4 is based on conditions that assume zero aerodynamic drag and a constant acceleration rate of 32.2 feet per second per second.

$$D = (V_o * T) + (0.5 * (A * T^2))$$

Where:

D = Distance

Vo = Initial Velocity = 0

T = Time (in Seconds)

A = Acceleration

Flares used in training missions are designed to be fully consumed before reaching the ground. Under the Proposed Action, flare use would occur in the new and expanded airspace. The risk of fire as a result of flare use is minimal due to the low failure rate and procedures that require flare use only above 2,000 feet AGL. Concerns with fire of any cause, however, are real. Flare use would be suspended under periods of very high or extreme fire danger to reduce those concerns expressed by scoping meeting participants. The Air Force follows established procedures for claims in the unlikely event that an Air Force-caused fire should occur and subsequently damage livestock or infrastructure.

Table 3. Components of BBU-36/B Impulse Charges

<i>Component</i>	<i>BBU-36/B</i>
Overall Size	0.740 x 0.550 inches
Overall Volume	0.236 cubic inches
Total Explosive Volume	0.081 cubic inches
Bridgewire	Trophet A
Closure Disk	Scribed disc, washer
Initiation Charge	
Volume	0.01 cubic inches
Weight	100 mg
Compaction	6,200 psi
Composition	42.5% boron 52.5 % potassium perchlorate 5.0% Viton A
Booster Charge	
Volume	0.01 cubic inches
Weight	150 mg
Compaction	5,100 psi
Composition	20% boron 80% potassium nitrate
Main Charge	
Volume	0.061 cubic inches
Weight	655 mg
Compaction	Loose fill
Composition	Hercules #2400 smokeless powder (50-77% nitrocellulose, 15-43% nitroglycerine)

Source: Air Force 1997

Table 4. Flare Burn-out Rates

<i>Time (in Sec)</i>	<i>Acceleration</i>	<i>Distance (in feet)</i>
0.5	32.2	4.025
1.0	32.2	16.100
1.5	32.2	36.225
2.0	32.2	64.400
2.5	32.2	100.625
3.0	32.2	144.900
3.5	32.2	197.225
4.0	32.2	257.600
4.5	32.2	326.025
5.0	32.2	402.500
5.5	32.2	487.025
6.0	32.2	579.600
6.5	32.2	680.225
7.0	32.2	788.900
7.5	32.2	905.625
8.0	32.2	1030.400
8.5	32.2	1163.225
9.0	32.2	1304.100
9.5	32.2	1453.025
10.0	32.2	1610.000

Note: Initial velocity is assumed to be zero.

A slightly greater possibility exists for an individual locating a dud magnesium flare on the ground under the airspace. Although the risk of combustion of such a dud is low, it could be ignited by an extremely hot (2,000 degree) fire or by friction from a strike with something like a saw or a bullet. The basic rule for a dud flare is to identify its location, do not touch it or experiment with it, and notify a safety authority of its location.

4.2 FLARE STRIKE RISK

Residual flare materials are those that are not completely consumed during ignition and fall to the ground, creating the risk of striking a person or property. Residual material from the MJU-10/B consists of an end cap, an initiation assembly (safe and initiation device [S&I]), a piston, one or two felt spacers, and an aluminum-coated mylar wrapper (Table 5). The wrapper may be partially consumed during ignition, so the wrapping residual material could range in size from the smallest size, 2 inches by 2 inches, to the largest size, 4 inches by 13 inches. The size of the residual wrapping material would depend upon the amount of combustion that occurred as the flare was deployed.

Table 5. Residual Material from MJU-10/B Flares

<i>Component</i>	<i>Weight</i>
MJU-10/B	
End cap	0.0144 pounds
Safe & Initiation (S&I) device	0.0453 pounds
Piston	0.0144 pounds
Felt spacer	0.0025 pounds
Wrapper (4 inches x 13 inches)	0.0430 pounds

After ignition, as described in section 3.0, most residual components of the MJU-10/B flare have high surface to mass ratios and are not judged capable of damage or injury when they impact the surface. One component of the MJU-10/B flare, the S&I device, has a weight of approximately 0.725 ounces (0.0453 pounds). It is sized and shaped such that it is capable of achieving a terminal velocity that could cause injury if it struck a person.

The following discussion addresses the likelihood of an S&I device striking a person and the effect if such a strike were to occur.

4.2.1 TECHNICAL APPROACH

Aircraft training flights are distributed randomly and uniformly within the Restricted Areas, Air Traffic Control Assigned Airspace (ATCAAs), or Military Operations Areas (MOAs). Avoidance areas that are designated for low altitude flight need not be avoided for higher altitude flight. Flare component release altitudes and angles of release are sufficiently random that ground impact locations of flare materials are also assumed to be uniformly distributed under the airspace.

For any particular residual component of a released flare, the conditional probability that it strikes a particular object is equal to the ratio of the object area to the total area under the airspace. For multiple objects (i.e., people, structures, vehicles), the probability of striking any one object is the ratio of the sum of object areas to the airspace. The frequency of a residual component striking one of many objects is the frequency of releasing residual components times the conditional probability of striking one of the many objects per given release.

In equation form, this relationship is:

$$\text{Strike frequency} = \text{drop frequency in airspace} \times \frac{\text{area of object} \times \text{number of objects in airspace}}{\text{airspace (area)}}$$

The potential consequences of a residual component with high velocity and momentum striking particular objects are postulated as follows:

- Striking the head of an unprotected individual: possible concussion
- Striking the body of an unprotected individual: possible injury
- Striking a private structure: possible damage
- Striking a private vehicle: possible damage (potential injury if vehicle moving)

The effect of the impact of a residual MJU-7 A/B or MJU-10/B component from Table 6 is judged by computing the component’s terminal velocity and momentum.

Terminal velocity (V_T) is calculated by the equation:

$$V_T = \left[\frac{2}{\rho} \left(\frac{W}{A \times C_d} \right) \right]^{0.5} = 29 \times \left(\frac{W}{A} \right)^{0.5}$$

Where: V_T = Terminal Velocity (in Feet/Second)

ρ = Nominal Air Density (2.378×10^{-3} lbs-sec²/feet⁴)

W = Weight (in Pounds)

A = Surface Area Facing the Air stream (in feet²)

C_d = Drag Coefficient = 1.0

Drag coefficients are approximately 1.0 over a wide range of velocities and Reynolds numbers (Re) for irregular objects (e.g., non-spherical). Using this drag coefficient, the computed terminal velocities (Table 7) produce Re values within this range ($Re < 2 \times 10^5$), which justifies the use of the drag coefficient.

The weights and geometries of major flare components are approximately as listed in Table 6.

Table 6. MJU-10/B Flare Major Component Properties

<i>Component</i>	<i>Geometry</i>	<i>Dimensions (inches)</i>	<i>Weight (Pounds)</i>
MJU-10/B			
S&I device	Rectangular solid	2 x 0.825 x 0.5	0.0453
Piston	Rectangular open	2 x 2 x 0.25	0.0144
End Caps	Rectangular plate	2 x 2 x 0.125	0.0144

Terminal velocity momentums of these components are computed based on maximum (two square inches) and minimum (one square inch) areas and are listed in Table 7. Actual values would be between these extremes. The momentum values are the product of mass (in slugs) and velocity. A slug is defined as the mass that, when acted upon by a 1-pound force, is given an acceleration of 1.0 feet/sec².

Table 7. MJU-10/B Flare Component Hazard Assessment

<i>Component</i>	MAXIMUM SURFACE AREA			MINIMUM SURFACE AREA		
	<i>Area (in²)</i>	<i>Terminal Velocity (ft/sec)</i>	<i>Momentum (lb-sec)</i>	<i>Area (in²)</i>	<i>Terminal Velocity (ft/sec)</i>	<i>Momentum (lb-sec)</i>
MJU-10/B						
S&I device	1.65	58	0.08	0.41	115	0.16
Piston	4.0	21	0.009	0.50	59	0.03
End Cap	4.0	21	0.009	0.25	84	0.04

The focus of this analysis will be the S&I device. Other flare components are not calculated to achieve a momentum that could cause damage.

The maximum momentum of the S&I device would vary between 0.08 and 0.16 pound-seconds depending upon orientation. In this momentum range, an injury is postulated that could be equivalent to a bruise from a large hailstone. Approximately 20 percent of any strikes could be to the head. A potentially more serious injury could be expected if the head were struck.

What would be the likelihood of a hailstone sized S&I device striking an individual? People at risk of being struck by a dropped S&I device are assumed to be standing outdoors under a training airspace (people in structures or vehicles are assumed protected). The dimensions of an average person are approximately 5 feet 6 inches high by 2 feet wide by 1 foot deep (men 5 feet 10 inches; women 5 feet 4 inches; children varied). The S&I device is expected to strike ground objects at an angle of 80 degrees or greater to the ground to allow for possible wind or other drift effects. With the flare component falling at 80 degrees to the ground, a person's body (5.5 × 2 × 1 feet) projects an area of 3.9 feet² normal to the path of the dropped component. In a normal case, a person would be outdoors and unprotected 10 percent of the time based on Department of Energy and Environmental Protection Agency national studies (Tennessee Valley Authority 2003; Klepeis et al. 2001). In the case of hunting or fishing, a person is assumed to be out of doors and unprotected 2/3 of the day (although a person would probably be wearing a hat or other head covering during such activity).

The frequencies of a strike to an unprotected person can be computed based on the data and assumptions presented above. Flight maneuvers to deploy flares are assumed to be randomly distributed throughout the training airspace.

A personnel injury could occur if an S&I device struck an unprotected person. The frequency of striking a person is:

$$\text{Injury frequency} = \text{comp drop freq} \times \frac{\text{body area} \times \text{pop. density} \times \text{Fract unprot} \times \text{area}}{\text{area}}$$

Under an area the size of the Cowboy ATCAA, this calculates to approximately:

$$\begin{aligned} \text{Injury frequency} &= 2,000 / \text{year} \times 3.9 \text{ ft}^2 / \text{pers} \times 10.0 \text{ pers} / \text{mi}^2 \times 0.67 \times 3.59 \times 10^{-8} \text{ mi}^2 / \text{ft}^2 \\ &= 0.0019 \text{ injuries/year} \end{aligned}$$

This means that in a representative New Mexico area beneath the Cowboy ATCAA used for F-22A pilot training (see Table 2.2-4), the annual expected person strike frequency would be approximately one person in every 500 years.

The maximum momentum of the S&I device, either from an MJU-10/B flare, would vary between 0.08 and 0.16 pound-seconds depending upon orientation of the falling S&I device. In this momentum range, an injury is postulated that could be equivalent to a bruise from a large hailstone. Approximately 20 percent of any strikes could be to the head.

As a basis of comparison, laboratory experimentation in accident pathology indicates that there is a less than a 1 percent probability of a brain concussion from an impulse of less than 0.10 pound-seconds to the head, and a 90 percent probability that brain concussions would result from an impulse of 0.70 pound-seconds to the head (Air Force 1997). The only MJU-10/B component with momentum values near 0.10 pound-seconds is the S&I device with a momentum between 0.08 and 0.16 pound-seconds. A strike of an S&I device to the head has approximately a 1 percent probability of causing a concussion.

This means that there would be an approximately 1 in 100 chance of a concussion in 1,000 years of flare use in the Cowboy ATCAA. This level of risk is negligible.

The S&I device maximum momentum would vary between 0.08 and 0.16 pound-seconds depending upon orientation. A strike to a vehicle could cause a cosmetic dent similar to a

hailstone impact. Although not numerically estimated, a strike to a moving vehicle could result in a vehicle accident.

5.0 POLICIES AND REGULATIONS ADDRESSING FLARE USE

Air Force policy on flare use was established by the Airspace Subgroup of Headquarters Air Force Flight Standards Agency in 1993 (Memorandum from John R. Williams, 28 June 1993) (Air Force 1997). This policy permits flare drops over military-owned or controlled land and in Warning Areas. Flare drops are permitted in MOAs and ATCAAs only when an environmental analysis has been completed. Minimum altitudes must be adhered to. Flare drops must also comply with established written range regulations and procedures.

Air Force Instruction (AFI) 11-214 prohibits using flare systems except in approved areas with intent to dispense, and sets certain conditions for employment of flares. Flares are authorized over government-owned and controlled property and over-water Warning Areas with no minimum altitude restrictions when there is no fire hazard. If a fire hazard exists, minimum altitudes will be maintained in accordance with the applicable directive or range order. An Air Combat Command supplement to AFI 11-214 (15 October 2003) prescribes a minimum flare employment altitude of 2,000 feet above ground level (AGL) over non-government owned or controlled property (Air Force 1997).

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