GREAT BALLS OF FIRE!

Heat-seeking missiles were responsible for around 80% of US aircraft losses in Operation Desert Storm. Decoy flares, aka aerial infra-red countermeasures, burn at more than 3,600°F and are designed to 'seduce' the missiles away from their intended target. **John Sootheran** explores the super-hot world of burning metals

EVER SINCE THE heat-seeking Sidewinder missile was conceived in the 1940s by the pioneering Dr William Burdette McLean, military forces and manufacturers have sought ways to outwit the deadly weapon.

Dr McLean's work took place at the Naval Ordnance Test Station (NOTS) at China Lake in California, where he recruited teams of brilliant scientists and engineers himself. McLean often pitched team against team to be first to solve a problem, using their natural competitiveness and 'workaholic' mindsets to speed up the process.

Of course, for every action there's an equal and opposite reaction, so, as McLean's Sidewinder missile was being developed, so the decoy flare soon came into being.

Infra-red (IR), heat-seeking missiles, like those developed by McLean, do not emit a signal in the same way that radar-guided ones do, which means than an aircraft's defensive systems will struggle to detect them after they have launched. At best, a pilot would rely on his co-pilot or wingmen to spot the smoke trail emitted by any missile. This is made more unlikely, as heat-seeking missiles focus on the hottest part of their target, which on any jet is the exhaust at the back of the plane, so, most often they'll approach the aircraft from behind. Clearly, some way of diverting these weapons away from an aircraft was going to be essential.

Previous pages: Three US Air Force F-15C Eagles from the 18th Wing/67th Fighter Squadron launch flares during a dramatic formation break **Jim 'Hazy' Haseltine**

Below left/centre: A Qatar Emiri Air Force C-17A Globemaster shoots flares during the Lahoub exercise **USAF**

An AC-130H Gunship (16th Special Ops Squadron) fires flares as an infrared countermeasure during multi-gunship formation egress training **USAF**

In fact, the countermeasure flare started life as the T-131 IR tracking flare, a target for heat-seeking missiles in development.

In early tests, a Grumman F6F-5K Hellcat drone aircraft would be painted hi-vis red and loaded with between six and 16 T-131 IR tracking flares to create a suitable heat signature for the test missile to track. The drone was then flown remotely out over the Pacific, and heat-seeking missiles were fired at it. As well as providing a super-hot target, the flares offered the added bonus of being highly visible to test teams on the ground, and they made it easier for technicians filming the tests. In 1954, work began on two major decoy flare projects: RITA Flare development for B-52 bomber protection and the Balls of Fire (BoF) program.

This image: A Kamov Ka-52 puts on a dramatic 'fireworks display' **Piotr Butowski**

Below: A C-17 Globemaster III from the 14th Airlift Squadron, Charleston Air Force Base, South Carolina, flies off after releasing flares over the Atlantic Ocean near Charleston, SC, during a training mission. The 'smoke angel' is created by the vortex from the engines **USAF/Tech. Sgt. Russell E. Cooley IV**

On October 25 that year, Mr J.L. Hult of the RAND Corporation in Santa Monica, California reported back to the Air Force on the results of the company's IR countermeasure program. It was a comprehensive study, including deep insights into radiation characteristics, thermodynamics and chemistry and it resulted in the BoF concept.

The Air Force contracted the Armour Research Foundation to develop the project, with the goal of protecting the country's B-47, B-52 and B-58 bombers from any Soviet missile threat.

That same month, the RITA research began at the Picatinny Arsenal company and culminated in the ALA-17 MTV flare. It burned for 4.5 seconds (statically) or 2.5 seconds when dispensed at 50 to 100 feet per second. The developers had initial issues with the expelling charge, but 1,000 flares were delivered to the Air Force by May 1955.

Over the decades the decoy flare continued to evolve, and IR countermeasures became more and more essential as up to half a million relatively cheap, shoulder-launched SAM missiles were manufactured, many finding their way into the hands of terrorist groups and insurgents around the globe.

Left: The A-10 is a prime candidate for flare protection as it's often found flying slowly at low level, supporting ground forces
Jim 'Hazy' Haseltine

Below: Staff Sgt Matthew Calvo, a communication, countermeasure and navigation system craftsman, uploads a flare magazine onto a C-17A Globemaster III at Dover Air Force Base, Delaware
USAF/All pics Senior Airman William Johnson

A 436th Maintenance Squadron munitions inspector, spray paints identifying marks on flares for accountability purposes

Airman 1st Class Clay Sherrill, loads a flare stick into a magazine box at Dover Air Force Base, Delaware

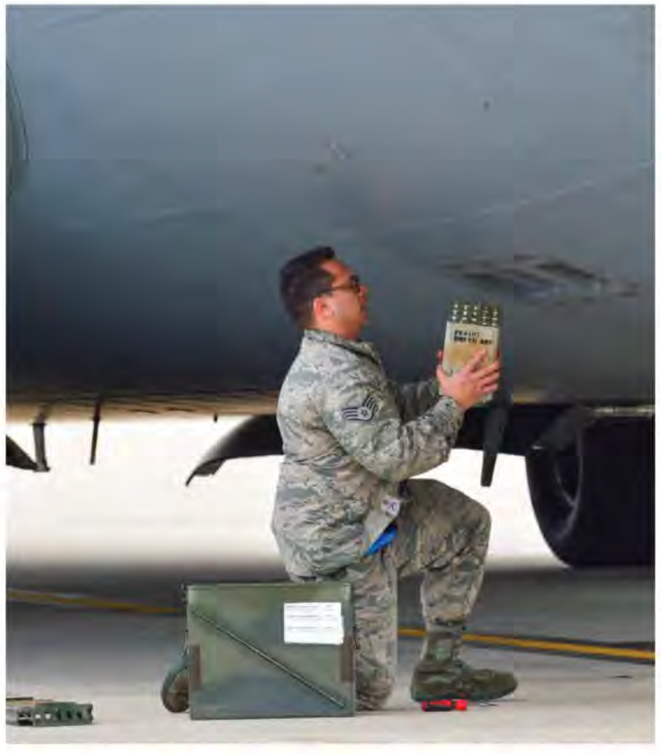
What is a decoy flare?

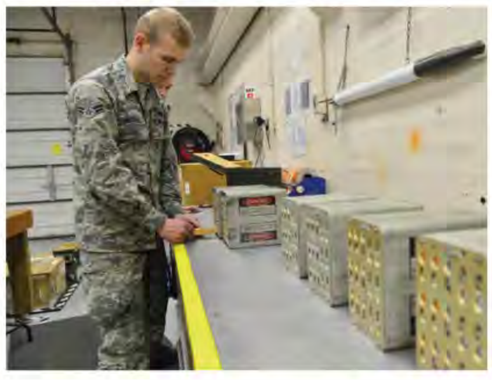
In simple terms decoy flares are 'fireworks', containing a compound of magnesium, or some other hot-burning metal. The aim used to be simple: the temperature of the decoy 'burn' should be hotter than that of the target aircraft's exhaust. In this way, any heat-seeking missile would perceive the heat signature of the flare as a more obvious target than the aircraft's jet-engine nozzle. Once a heat-seeking missile had lost its 'lock' on its target it was unlikely to reacquire it, given that its field of view is limited to one or two degrees.

These days, a large number of individual flares are packed into a 'bucket' dispenser, which, in turn, slots into an aperture, usually underneath the aircraft. When needed, they automatically, or at the push of a button in the cockpit, fire outwards in sequence and stream away from the aircraft. They can be programmed to fire individually, in a timed sequence or in clusters to create a sufficient diversion to 'distract' an IR-guided missile. At the point the flares are dispensed, the aircraft normally makes a sudden turn away from its previous flight path and the missile.

IR-guided missiles quickly became more sophisticated. As early as 1961 smart technology designed to distinguish decoy flares from exhaust signatures was being developed. This meant the effectiveness of countermeasures was reduced. In response to these missile advances, decoy designers created flares that burned in a way that closely resembled the heat signature of a particular jet engine.

"A basic flare, containing magnesium, Teflon and Viton (MTV), will deal with a simple heatseeking missile which is looking for a jet engine," says Andy Hogben, Managing Director of leading decoy manufacturer Chemring Countermeasures UK. "But as the missile manufacturers got clever, they put in countermeasures to defeat the countermeasures. "They realized all temperatures aren't the same on an aircraft; the jet engine may be 3,000°F, but the wing tips are somewhat cooler and the cockpit will be cooler, too. They developed seekers that look for a spectrum of heat sources. So, we went away and developed a Spectral flare, where we use a chemical composition to generate a range of heat signatures."





> "The pressure is back on the countermeasure manufacturers in this high-stakes 'poker game', where ever-improving technologies are your Royal Flush and survival is the prize.

CHEMRING COUNTERMEASURES UK

"We have a manufacturing facility right here at High Post [near Salisbury]," says Chemring MD, Andy Hogben. "It's a 100-acre, licensed site where we make a full range of air and naval countermeasures. On site there are about 350 staff.

"We have an automated facility here, where raw chemicals are processed, mixed and dried before being pressed into a range of flare formats. It's a high-hazard technical process in which we minimize exposure of our workforce to hazardous compositions at every stage, with controls in place to contain the potential explosive risk inherent to this type of product.

"Here in the UK, we have a very close relationship with the UK MoD and other NATO allies. When a threat or a problem set emerges, they'll tell us a requirement of what they need to counter it, and we'll then develop a flare to allow them to do that.

"There are several manufacturers who make the flare dispenser units: Boeing, BAE, Thales and MBDA all make dispensers, which our flares are compatible with. It's a bit like a printer. You have your branded cartridges, and then you have other-brand, compatible cartridges.

"We operate under the strict rules of the UK Export Control Office, ensuring our products and technology are only exported to those allowed to use them."

A US Marine Corps EA-6B Prowler from VMAQ-3 banks away after launching flares during a training flight off the North Carolina coast. The type has since been retired from service
Scott Youmans

To neutralize this change, leading counter-countermeasure (CCM) technologies looked for other characteristics they could focus on to reject a decoy. The basic MTV flare was supplemented by more advanced spectral flares to counter the missile seeker rejecting a single point of IR heat signature. This advance was followed by aerodynamic flares to give movement to decoys and then thrusted flares to get closer still to realistic aircraft IR signatures.

"In this way," says Hogben, "it's a constant battle between the missile manufacturers and the flare makers. It's a defensive arms race in itself."

The next missile evolution, including weapons like the FIM-92 Stinger, featured both IR and UV sensors. The decoy makers can closely match an aircraft's IR signature, but exhaust emissions from burning kerosene have a very different UV signature to flaming magnesium.

So, the pressure is back on the countermeasure manufacturers in this high-stakes 'poker game', where ever-improving technologies are your Royal Flush and survival is the prize.

How they work

There are two basic types of flare.

By far the most common, according to Andy Hogben, are pyrotechnic flares, which, like an everyday firework, require some form of ignition to make them burn. In the case of flares, the ejection is achieved through an impulse cartridge, where an electric charge is passed through a bridge wire that ignites a propellant and ejects the flare from the dispenser. In doing so, the propellant also ignites the flare, which then burns in the aircraft's airstream to give the decoy its effect.

The second type are called pyrophoric flares. These contain compounds that ignite on contact with air, so don't require an ignition system to be built in. They are held in an air-tight canister and start to burn when released.

There are pros and cons to both systems. A pyrophoric flare would ignite on board, if there were an air leak. Likewise, a pyrotechnic might accidentally ignite.

These days, almost all aircraft will fly with pyrotechnic flares. Only a small percentage fly with a pyrophoric solution. One of the most common chemical compositions that makes up a pyrotechnic decoy flare is MTV. The compounds can be tweaked to resemble the heat spectrum of a specific engine or to create cleaner burns that don't leave a smoke trail.

Compounds that are high in carbon and hydrogen, such as alkyl aluminum, burn most brightly and best resemble burning jet fuel, while the pyrophoric fuels can create flames up to several meters in size, compared to less than one meter for pyrotechnics.

"On the whole flares tend to be quite generic," reveals Hogben, "though we can make solutions tailored to the threat. So, if you know the certain parameters of a missile's seeker, you can tailor your flare to that seeker, as opposed to designing it for the aircraft.

"By changing the shape of the pellet, milling grooves into it, pressing it as a crucifix shape or extruding it in a different way, you can increase or decrease the surface area, which increases or decreases the burn rate. Also, you can use prime on it to alter or delay the burn rate. There are lots of things you can do to tailor it to the threat it has to meet."

"It's a pyrotechnic material that we burn, so one of our basic compositions is MTV – which goes from nought to 2,000°C [3,632°F] in a couple of milliseconds" says Hogben. "We have that in different formats. That might be one inch by one inch by eight inches, a 118 – which you'd typically use on a helicopter; or on a fast jet it'll be a two inch by one inch by eight inch – a 218. You also have round formats as well, like the ones used on the Typhoon, that's a 55mm [2in] round flare.

"To get the decoy off the aircraft you have what's called an impulse cartridge, a charge inside a copper casing. There's a wire that, when you put a voltage through it, burns and ignites the gunpowder; this ejects the flare. As the flare leaves the dispenser, there's something called a takeover cup which also ignites, so the ejection charge lights the flare itself. The airflow outside the aircraft helps the flare to burn."

Testing times

"The thing with flares is they have to work right, first time, every time," Hogben adds. "Typically, in an air engagement a pilot has less than two seconds to deploy a decoy. You can't afford for a flare not to work. So, we have very rigorous proof testing. We do that here at High Post. We'll fire flares and measure their IR performance and their ejection velocity, but in terms of testing against a missile, we work with our NATO partners to test against those threats.

"We test all our flares and give them an operational life, say 100 hours. We heat them up, cool them down and subject them to the full range of forces that would be exerted on them when flown in an aircraft. That gives us the confidence to offer a guaranteed operational life. We have safety-arming mechanisms in our flares, too, so there's a physical barrier between the pyrotechnic pellet and the initiator, which can only open as it leaves the aircraft. Part of our testing is to see if there's the danger of a 'sympathetic detonation' with the flare next to it, if it did ignite in the dispenser. Our flares are designed to prevent that happening.

Cost

The math is simple. A jet fighter or combat helicopter can cost anything from $20m

This image: A Saab 2000 Erieye AEW (Airborne Early Warning) aircraft makes like an angel
Peter Liander/Saab

Right top: A US Marine Corps/ VMGR-252 KC-130J Harvest Hawk dispenses covert flares. These don't burn brightly, so as not to give away the position of the aircraft at night
James Deboer

Right: A Missouri Air National Guard, 139th Airlift Wing C-130H Hercules dispen… dusk

A C-130H Hercules from the 153rd Airlift Wing, Wyoming Air National Guard, fires off flares over Camp Guernsey Joint Training Center, Wyoming, during a training mission. **US ANG/ Staff Sgt Jon Alderman**

to $100m. An AIM-9 Sidewinder costs $427,000 (US defense budget FY2019), while a decoy flare costs from $35. So, you're spending a few hundred dollars to protect a multi-million-dollar aircraft, and all the priceless lives on board.

A simple flare, like the M206 (used by the A-10, C-17, C-130, F-16 and other aircraft), is dispensed from the AN/ALE-47 system. In 2018 a single M206 cost $35, so a full load of 30 flares cost $1,050.

This cost increases for more advanced flares types and those designed for specific uses. For example, according to Pentagon budgets, the IR countermeasures designed for the F-35 cost an eye-watering $3,000 each!

There's a whole range of decoy flares between these two extremes.

Flaming futures

"The countermeasure market will evolve in the future, but the affordability of our flares and the capability they offer in relation to the cost of a missile, is hugely in our favor," summarizes Hogben. "In the future, there will be a combination of countermeasures, including things like DIRCM – directed energy, infrared countermeasures – which essentially attempts to 'blind' a heat-seeking missile, but this will still most likely be used in conjunction with a flare for optimized effect. I think what we'll find going forward is that the flare will become part of a system of systems of defense for an aircraft. Plus, there's a huge legacy fleet that will continue to use flares. "I think the flare countermeasure's future is secure, especially as it's an expendable and affordable countermeasure that protects valuable aircraft and priceless lives."