Martin-Baker

THE HISTORY AND DEVELOPMENTS OF MARTIN-BAKER ESCAPE SYSTEMS

The challenges and the success of Martin-Baker ejection seats

Introduction

'Martin's Aircraft Works' was founded by Sir James Martin as an aircraft manufacturer in 1934. The factory was established in 1929 and four aircraft prototypes were produced: MB1, MB2, MB3 and MB5. It was during the designing and testing of the MB1 where James Martin and Captain Valentine Baker started their friendship and 'Martin-Baker Aircraft Company Ltd' was established.

Sir James Martin, C.B.E., D.Sc., C.Eng., F.I.Mech.E., Hon. F.R.Ae.S.

On 12th September 1942, during a test flight of the Martin-Baker MB3 prototype, Captain Valentine Baker was tragically killed. The engine seized and he was forced to make an emergency landing, during which the aircraft struck a tree stump. Captain Valentine Baker's death greatly affected Sir James Martin, so much so that pilot safety became Martin's primary focus.

In 1944, Sir James Martin was invited by the then Ministry of Aircraft Production to investigate the practicability of providing fighter aircraft with a means of assisted escape for the pilot.

After investigating alternative schemes, it soon became apparent that the most attractive means would be by forced ejection of the seat with the occupant sitting in it, and that the most effective means of doing this would be by an explosive charge. The Martin-Baker ejection seat was then born.

EARLY EXPERIMENTAL WORK

Physiological Considerations

There was at that time, no information on what the human body could withstand in the form of upward compressive thrust. Some data was available concerning somewhat lower g forces applied horizontally in catapult launching of aircraft, but it was obviously inapplicable to the new problem. It therefore became necessary to carry out tests to determine the amount of upward g force the human frame would tolerate, and the idea was conceived of shooting a seat up a near-vertical path, loading the seat to represent the weight of the occupant, and measuring the accelerations and rates of rise of g involved.

A 16 foot test rig was built in the form of a tripod, one of the legs being in the form of guide rails. The seat was propelled up the guide rails by a gun, consisting of two telescopic tubes energised by an explosive cartridge. The guide rails were provided with ratchet stops every 3 inches, so that the seat was automatically arrested at the top of its travel.

Bernard Lynch prepared for the first live test shot – January 1945

The first dummy shot with the seat loaded to 200 lb was made on 20th January 1945, and four days later one of the Company's experimental fitters, Mr. Bernard Lynch, undertook the first "live" ride, being shot up the rig to a height of 4 feet 8 inches.

In three further tests, the power of the cartridge was progressively increased until a height of 10 feet was reached, at which stage Lynch reported the onset of considerable physical discomfort.

As the mean g being applied at this time was still less than 4, it was necessary to investigate the nature of the acceleration and the reason for the severe physiological effects produced.

In order to study the structure and physical limitations of the human spine, Sir James Martin arranged to see a number of spinal operations being performed, and later obtained a human spine for mechanical tests. From this study and from the records of further tests on the rig, he discovered that the damage was being caused by an excessively high rate of rise of g, being in the order of 600 to 800 g per second. Following further study, Sir James came to the conclusion that injury to the spine would not occur if the following conditions were fulfilled.

- That the peak acceleration should not exceed 21 g and that this peak should not be held for longer than about 1/10th of a second.

- That the onset or rate of rise of g should not be greater than 300 g per second.

- o That, in sustaining this acceleration, the body should be held in a position to ensure that adjacent spinal vertebrae are square to each other.

These factors are now generally accepted as design criteria for ejection seats.

Sir James Martin studying effects of the first test shot

Alterations were now made to the seat to meet the new conditions. To ensure that the g came on relatively slowly and did not exceed the first two conditions, a two-cartridge gun was designed, in which the first cartridge started the seat rising smoothly and the second cartridge was fired by the flame when uncovered by the moving piston, building up the pressure gradually to the maximum required.

To cater for the third condition, the sitting posture in the seat was altered by rearranging the footrests and by the adoption of the face screen method of firing the seat. In this method, the firing handle was positioned above the occupant's head and attached to the handle was a screen which, when the handle was pulled forward and downward, completely covered the occupant's face.

The advantage of the scheme was two-fold; in reaching for the handle, the occupant automatically assumed the correct attitude by straightening his back and squaring up his spinal vertebrae, and the screen afforded the necessary protection to the face from air blast as the seat left the aircraft.

The first dummy test with the new design was made on 20th January 1945, and the g curve obtained of the shot to the maximum height of the rig showed the desired characteristics. However, as the seat was now overshooting the available travel, it was not possible to check the physiological effect by means of a live shot, so it was decided to design and construct a 65 foot test rig.

Engineering Problems

Simultaneously with the physiological research work, the engineering problems of ejection from aircraft were being investigated. The loan of a Defiant aircraft had been obtained from the Ministry of Aircraft Production, and after the necessary structural alterations had been made, an experimental ejection seat was installed in the space previously occupied by the gun turret.

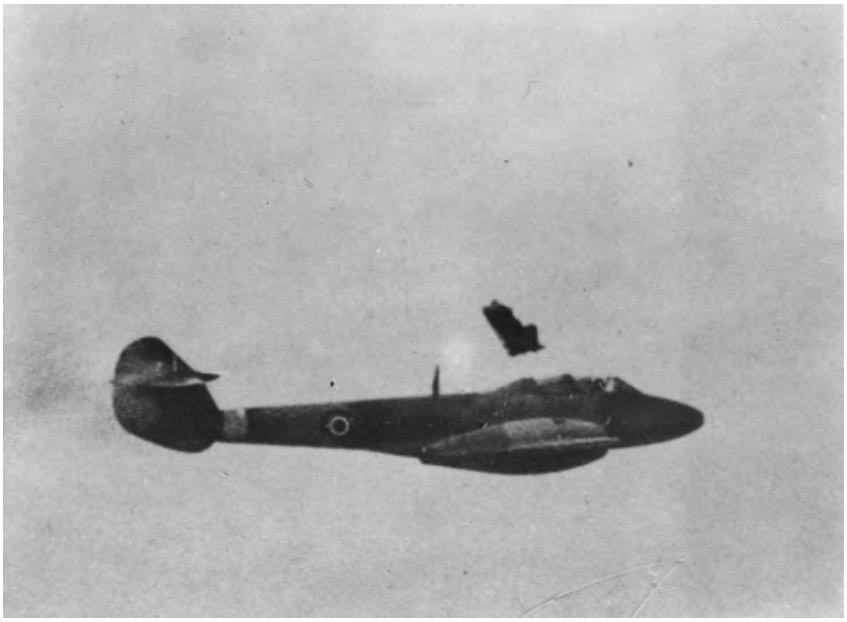
On the 10th May 1945, the seat, loaded with sand bags, was successfully ejected from the jacked up aircraft into a specially erected catch net and on the next day a successful dummy ejection in flight was made with Mr. Brian Greenstead piloting the aircraft.

This was the first ejection from an aircraft in flight in Great Britain. On 17th May 1945, six further dummy ejections from the Defiant were made at varying indicated air speeds up to 300 m.p.h. This was regarded by all concerned as an important step forward, the results obtained being encouraging. The technique employed consisted of ejection of the seat by an ejection gun consisting of two telescopic tubes, fired by an explosive cartridge. Once the seat was clear of the aircraft, a drogue was deployed to stabilise the seat, after which a 24 foot parachute was deployed by a delay action release. This arrangement permitted recovery of the seat for further use.

With the completion of the new 65 foot test rig, investigations into the physiological problems were resumed. The first dummy shot on this rig was made on 17th August 1945, and the first live shot on the rig with the new two-cartridge gun was made by Bernard Lynch on 22nd August. The height reached was 26 feet 3 inches and Lynch described the ride as now very “soft” with no adverse physiological effects whatever.

Considerable further development work was carried out on this rig covering all aspects of the eventual development programme.

Meteor Installation



It was now necessary to consider ejection tests at higher speeds and on the 12th September 1945 a contract was received from the Ministry of Aircraft Production for the design, development and manufacture of two pilot's ejection seats and their installation in a high speed aircraft. For this work a Meteor III was considerably modified to permit installation of the ejection apparatus in the ammunition bay behind the pilot's cockpit. On completion of the installation, a static dummy ejection from the jacked up aircraft was made on 8th June 1946, into a net suspended at the top of a 45 feet high tower.

Introduction of the Drogue Gun

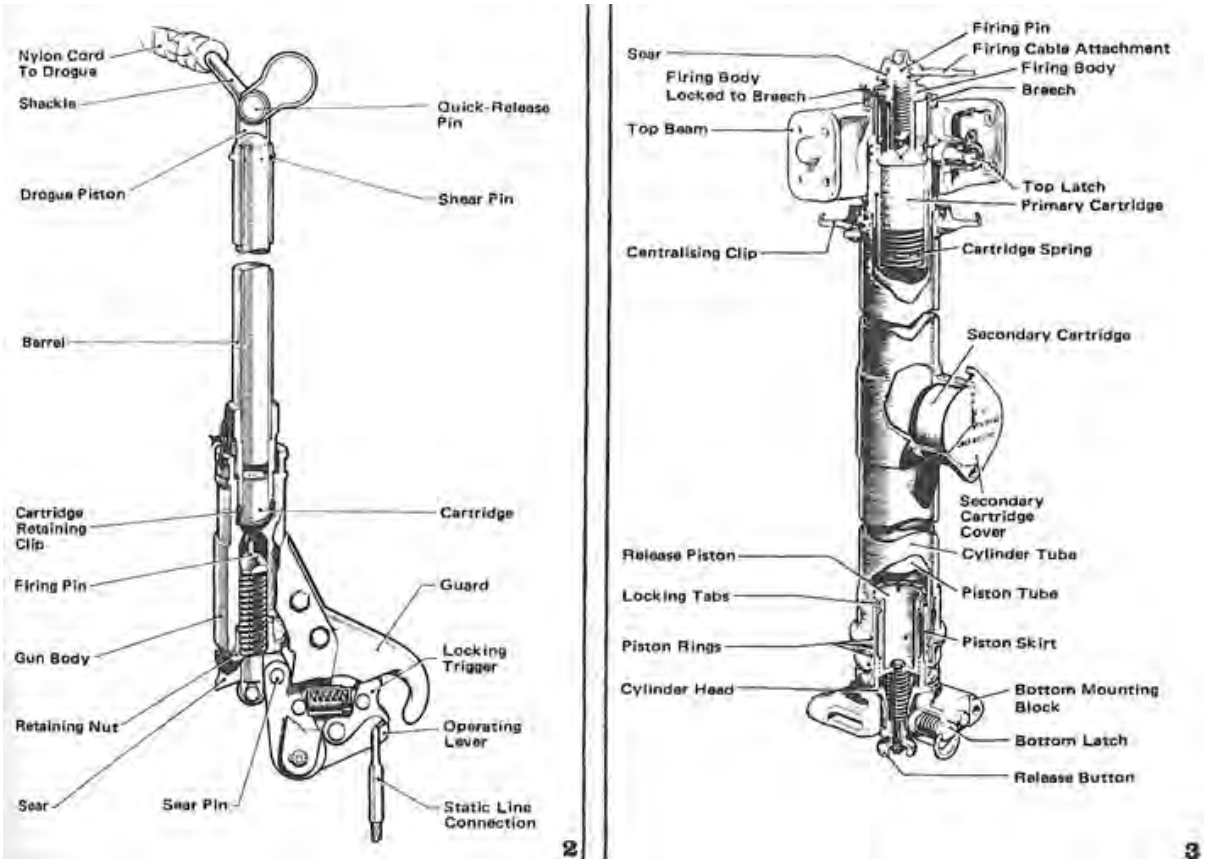
On 24th June 1946, a dummy ejection in flight was made at a speed of 415 m.p.h. IAS using the ejection technique as previously used on the Defiant. Due to the unsatisfactory action of a special type of delay action release used, the main parachute was opened too early and burst with the loss of the seat. A subsequent test with a modified release gave the same result. A hydraulic type delay action release was then developed, which consisted of a hydraulic dashpot interposed between the drogue and the seat. When subjected to the pull of the drogue, the dashpot extended, its speed of extension being controlled by the transfer of oil from one compartment to another through a calibrated orifice. On completion of the extending period, the pull of the drogue was transferred to the closure pins of the main parachute pack and thence to the canopy of the main parachute, which was then deployed.

When this release was first tested, the main parachute did not extract from its container and on examining a film of the test, it was seen that the drogue, which was spring-ejected, had been drawn into the wake of the seat and had become entangled with it. Further tests with springs of varying strengths for ejecting the drogue not being satisfactory, the idea was conceived of deploying the drogue by means of an explosive operated gun. A drogue gun (see illustration) was therefore designed which consisted of a barrel containing a piston secured to it by a split pin.

The bottom part of the barrel, which contained an explosive cartridge, was screwed into a body containing a spring-loaded firing unit, the sear of which was extracted by a 24 feet long static line. The top of the piston was connected by a nylon cord to a safety pin retaining four flaps over the top of the drogue container, and a further extension of the nylon cord connected to the drogue. As the seat ejected, the static line tautened and fired the drogue gun; the energy imparted to the piston sheared the split pin and propelled the piston with considerable force well clear of the seat vortex, taking with it the nylon cord and the drogue which could now develop properly and stabilise the seat immediately. The idea proved

successful and although subsequently modified in detail, the drogue gun has remained a basic feature of all Martin-Baker seats.

In the course of further dummy ejections from the Meteor, it was discovered that the loads produced at high speed by the drogue were considerably above those anticipated, resulting in the continual snapping of drogue cables at speeds in excess of 35 m.p.h. IAS. Considerable research work resulted in the design of a 2 foot drogue of special shape manufactured from aircraft linen with a 7½ inch vent and 12 nylon lines which functioned perfectly at speeds up to 500 m.p.h. and over.



2- Early design of drogue gun, fired by 24foot static line
3- 60 foot per second ejection gun

First Live Ejection

At this stage it was decided to make a live ejection and on 24th July 1946, Bernard Lynch ejected himself from the Meteor at 320 m.p.h. IAS at 8000 feet.

The main features of the seat used in this ejection were:-

A Face screen firing control to ensure correct ejection posture by squaring up the spinal vertebrae and also to provide protection to the face from air blast.

B Two-cartridge 60 feet per second ejection gun, ensuring an acceptable rate of rise of g forces.

C Drogue gun fired by static line after seat had risen 24 feet and drogue gun deployed clear of seat vortex.

D Seat stabilised in horizontal position and slowed down by the action of a single 2 foot diameter drogue.

E After a delay, controlled by the hydraulic release, the pull of the drogue was transferred from the seat to a 24 foot supply dropping parachute attached to the seat. This parachute then developed and supported the seat and occupant.

F The occupant then unfastened his seat harness, pushed himself away from the seat and when clear, pulled the ripcord of his personal parachute and made a parachute descent, the seat meantime came down on its own 24 foot recovery parachute.

Bernard Lynch seated in the rear cockpit of a Meteor 3 aircraft before carrying out the first live ejection.

The whole system worked successfully and Lynch made a perfect landing; this was the first live ejection from an aircraft made in England. Since then Bernard Lynch has made 30 live airborne test ejections, which courageous acts have earned him the respect of pilots all over the world.

Early Work for U.S. Navy

The United States Navy Authorities had displayed great interest in the early experimental work, and following a demonstration to them at Denham had placed an order for a 110 foot test rig to be erected in the Navy Yard, Philadelphia, and an ejection seat to be installed in the rear cockpit of a Douglas A-26 aircraft. Following experimental work on this rig and a series of dummy airborne ejections, a successful live ejection was made at Lake Hurst on 1st November 1946, by Lieutenant Furtek, U.S.N., using the Martin-Baker equipment.

U.S. Navy Yard, Philadelphia, August 1946.
Sir James Martin and U.S. Navy Officers examine a Martin-Baker ejection seat.

MANUALLY OPERATED SEATS Mark 1 (Mk.1)

Back in Britain the seat used by Lynch was completely re-designed, to allow for production on a quantity basis and the usual series of dummy ejections again repeated, perfecting the design of the drogue and its stowage and curing the various teething troubles which developed. Finally, on 19th August 1947, Lynch again ejected himself, this time at 12,000 feet at an indicated air speed of 420 m.p.h. He landed safely, and afterwards stated that no shocks had been felt, even at this high speed. This successfully demonstrated the smoothness of the ejection gun, the effective protection of the face screen and the efficiency of the stabilising drogue.

In June of the same year the authorities had decided to standardise the Martin-Baker Ejection Seat for installation in all new service jet aircraft, and the work of production and installation was put in hand for Meteor, Attacker, Wyvern, Canberra and later the Sea Hawk and Venom aircraft.

These were the original versions of the Mk. 1 seat and incorporated the same features as the experimental seat used by Lynch except that the 24 foot seat recovery parachute was dispensed with, the occupant had to unfasten his seat harness and fall away from the seat after the drogue had done its work of stabilising and slowing down the seat. In addition these seats were provided with a seat pan capable of being raised and lowered to accommodate pilots of varying stature without increasing the height of the seat, adjustable foot rests, and integral thigh guards to prevent the occupant's legs being forced apart by air blast.

The seat was guided during ejection by four rollers on the seat structure running in a guide rail assembly bolted to the aircraft structure, the ejection gun being located within the hollow guide rail assembly.

A considerable number of emergency escapes were made with these manually operated seats, which fully justified their introduction in Service aircraft. Their limitations, however, were already obvious and the idea of making the whole sequence of events automatic began to take shape.

AUTOMATIC SEATS Mark 2 (Mk.2)

Experience with the manually operated seats had shown that a number of fatalities had occurred, due to unconsciousness after ejection, inaction due to circumstantial stress, or lack of time to carry out the necessary manual operations when ejecting at low altitudes. Accordingly, effort was concentrated on producing a simple, yet effective, fully automatic ejection seat, capable of being produced in quantity, reliable in service, and designed to permit the retrospective conversion of most of the existing manually operated seats already installed in Service aircraft.

Scissors Shackle

Before and after release of scissor shackle.

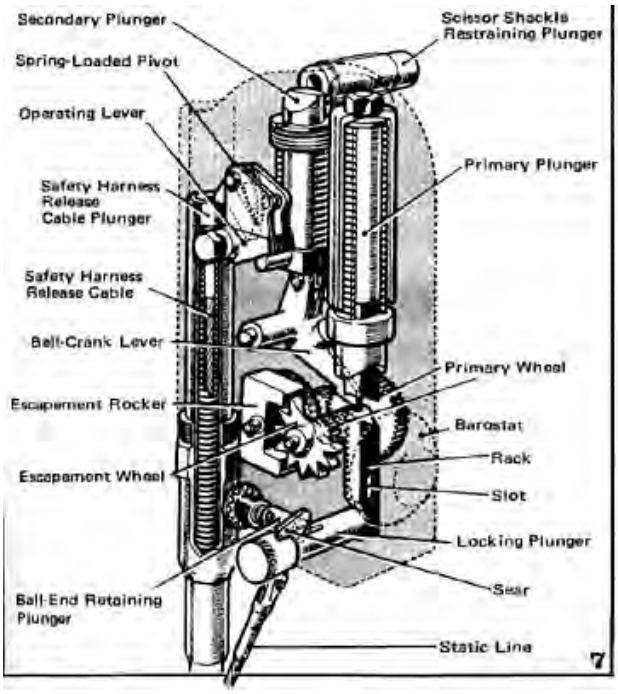
In the design of the first automatic seat, it was decided to house the personal parachute in a container in the back of the seat and the dinghy pack in the seat pan, to facilitate the use of the drogue to effect deployment of the parachute. It was also necessary to devise some means of disconnecting the drogue from the seat at the correct time and transferring its pull to the parachute, and simultaneously a means of releasing the occupant complete with his parachute and dinghy pack from the seat.

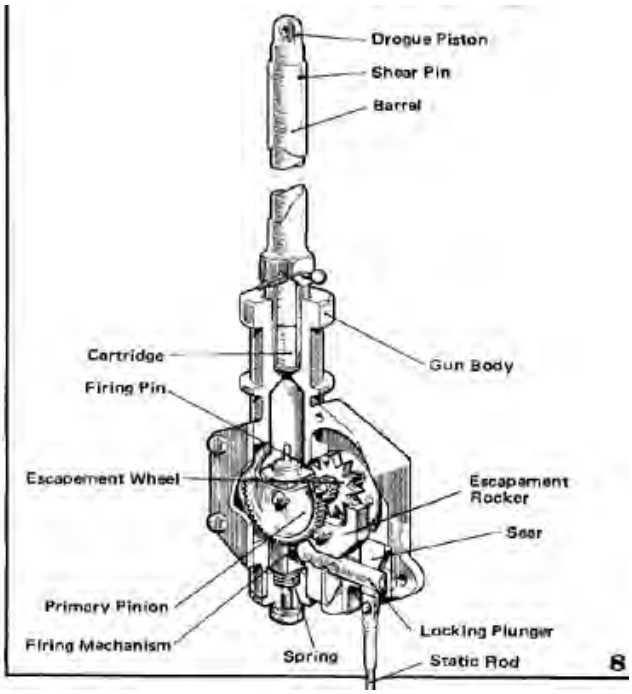
On the Mk. 1 seats, the drogue had been attached to the top of the seat by a solid shackle. This was now replaced by a “Scissor Shackle”, capable of being opened automatically at a pre-determined time.

Time Release Unit

A clock-work “Time Release Unit” (see illustration) was devised and bolted to the top of one of the side beams of the seat. Tripped by a static line as the seat rose on ejection, this mechanism ran for a period of 5 seconds, at the end of which time a plunger in the mechanism released the scissor shackle and the drogue pulled away from the seat. Simultaneously, the mechanism unlocked the seat harness by pulling on a cable which rotated the face plate of the modified harness release box. As the drogue pulled away from the seat its pull was transferred to a canvas apron, positioned between the back type parachute and its container, which then tautened and tipped the occupant forward and out of the seat. Attached to the apron was the parachute withdrawal line, which now released the parachute pack closure pins and pulled out the apex of the parachute. Concurrently with the drogue pulling free of the scissor shackle, the face blind was released so that the occupant was completely free of the seat, which then fell away, leaving the occupant to descend with his parachute deployed; the drogue and apron still being attached to its apex.

The Time-Release Unit consisted of spring-loaded plungers, which actuated the harness release and drogue scissor shackle, controlled and operated by a rack in engagement with gears, regulated by an escapement and starwheel.





7-Early Design of Time Release Unit
8-Improved design drogue gun

Barostat

To prevent the parachute from deploying at very high altitudes, where a slow descent could prove fatal due to lack of oxygen or the extreme cold, a barostat was fitted to the Time-Release Unit to prevent its running until the seat had descended to 10,000 feet. The barostat consisted of an aneroid capsule which engaged the starwheel at heights above 10,000 feet, thus delaying the operation of the mechanism, and permitted the occupant to ride the seat down through the cold and rarefied air, controlled by the drogue and breathing oxygen which was turned on automatically during ejection, until descended to a height where separation from the seat and deployment of the parachute could be effected safely and without injurious consequences.

Provision for Manual Separation

In order to guard against the possibility of failure of the Time Release Unit, provision was made for the seat occupant to make a manual separation from the seat. This necessitated some means of being able to disconnect the parachute withdrawal line now connected to the drogue via the apron, before the occupant manually unfastened his seat safety harness. The method employed consisted of a slide disconnect pin in the withdrawal line positioned inside the parachute pack, and operated by an additional D ring on the parachute harness similar to the ripcord D ring.
In the event of failure of the Time Release Unit after ejection, the following drill was carried out.

1 Pull the 1st D ring.
2 Unfasten the safety harness.
3 Push clear of the seat.
4 When clear of the seat, pull the 2nd D ring to deploy the parachute.

The two D rings were positioned adjacent to each other, but the second one was covered with a canvas flap, which was removed as the 1st ring was pulled, thereby exposing the second D ring for subsequent use.

Improved Drogue Gun

With these modifications it was considered worthwhile to change the drogue gun, which had until then been fired by a 24 foot static line. A greatly improved design was therefore adopted; this being operated by a 1-second clockwork time-delay and tripped by a short static line attached to the aircraft. Work commenced on the modification of the existing Mk. 1 seats in August 1953. Royal Air Force seats were modified at the Martin-Baker factory and Royal Navy seats were modified on site by Navy working parties trained for the task.

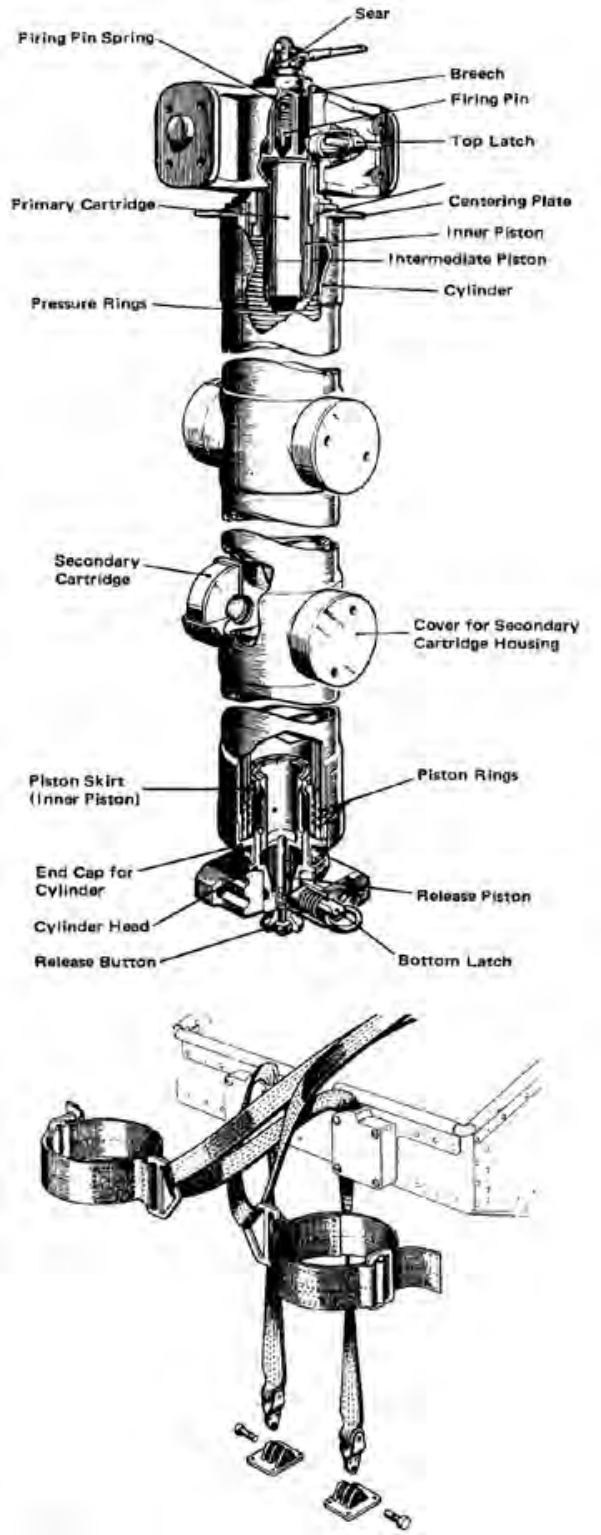
IMPROVING THE AUTOMATIC SEATS Mark 3 (Mk.3)

The Mk. 2 automatic seats were successful in providing safe escape from the aircraft in service at the period, but there was still room for improvement at very low altitudes and very high speeds. In addition, the advent of aircraft such as the Javelin and the V bombers with their high fin projections and higher operating speeds, made it necessary to increase the height of the ejection trajectory – any increase also improving the chance of a successful ejection at low altitudes.

80ft per Second Ejection Gun

The simplest way of increasing the trajectory height would have been to increase the explosive charge in the ejection gun, but enough has already been said to show that this would have increased the peak acceleration and onset of g to an unacceptably high limit, well beyond the limits of human toleration. To avoid this harmful effect while still achieving a higher ejection trajectory, an ejection gun with a stroke of 72 inches, giving a velocity of 80 feet per second, was designed to replace the existing 60 feet per second gun. While maintaining the characteristic low peak acceleration and rate of rise of g of the earlier gun, this provided the extra velocity necessary for increasing the trajectory height.

The gun consisted of three tubes, two of which telescoped inside the main outer tube, powered by one primary and four auxiliary charges, the latter being arranged in two pairs. When the primary charge was fired, an inner tube was unlocked by the generated pressure and began to rise, together with the intermediate tube, carrying the seat and occupant with it. After extending 16 inches, the lower two auxiliary cartridge ports were uncovered, allowing the flame to ignite the first pair of cartridges, and a further extension of 9½ inches uncovered and fired the second pair of auxiliary cartridges. The gun continued to extend until the intermediate tube was arrested by a flange on the outer tube, the shock being cushioned by fifteen hollow gas-filled rings. The inner tube continued extending until it broke away from the gun, carrying the seat and occupant clear of the aircraft.



Although this gun was designed primarily to give a trajectory adequate to clear the higher fins of the new aircraft, it was found, during tests, to possess the added advantage of gaining trajectory height at low speeds. Trajectory heights of the order of 90 feet above aircraft datum are obtained with this gun at moderate air speeds, and this enhances the chances of safe escape near the ground.

Leg Restraint

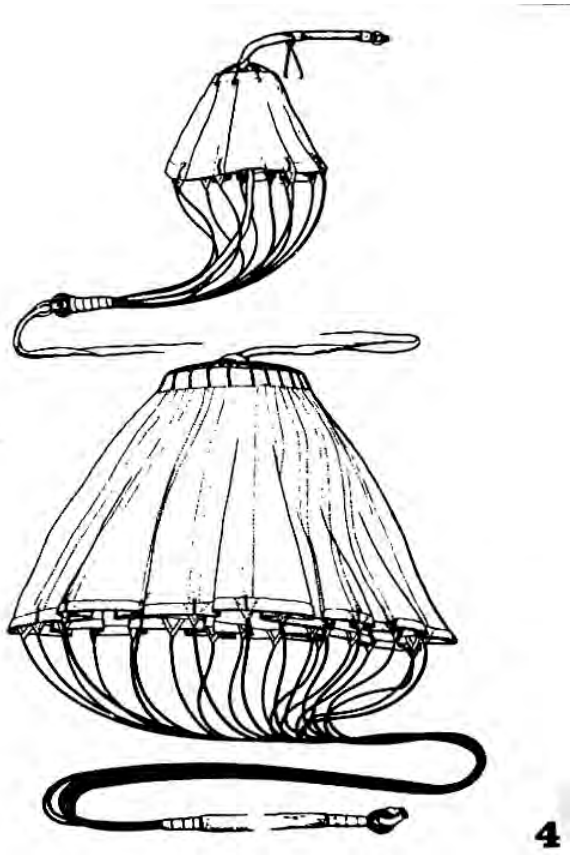
During ejection at very high speeds, it was found that the thigh guards of the Mk. 1 and 2 seats were not completely effective in the prevention of leg flailing. At these speeds the airstream could be sufficiently powerful to lift the feet from the footrests and carry the legs over the top of the thigh guards, where severe injury could possibly be caused to the knee and hip joints. It therefore became imperative that some form of mechanical leg restraint should be introduced on the seats used in the faster aircraft. A number of different methods were investigated, including guards which folded inboard over the thighs, but were discarded for a system securing the legs to the seat by nylon cords, subsequently
introduced on all Mk. 3 type seats.

80ft per second telescopic ejection gun & keg restraint system

The arrangement consisted of two reinforced nylon cords, each connected to the cockpit floor by a shear pin, designed to pull away at the load required to ensure that the legs were held back against the forward edge of the seat pan. The other end of each cord was passed through snubbing units fixed to the forward face of the seat pan, and then through metal rings on webbing garters strapped to the occupant's legs. The two free ends of the cords were then connected to the harness release box.

The cords were arranged to allow free movement of the legs whilst seated in the cockpit, but, on ejection, tightened up between the snubbing units and the harness release box before breaking away from the floor, thereby automatically securing the occupant's legs to the front face of the seat pan, where they were firmly held until the harness was released and the occupant separated from the seat.

Duplex Drogue System



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As already stated, the introduction of an 80 feet per second ejection gun resulted in a gain of trajectory height at low altitude.

In order to take full advantage of this, and further enhance the chances of safe escape near the ground, consideration was then given to the practicability of speeding up separation from the seat after ejection.

The drogue of 24 inches diameter, then in use, streamed the main parachute 5 seconds after ejection, but it was obvious that a drogue parachute of constant canopy size would only achieve efficiency at a certain combination of speed and altitude. The time interval, with this particular drogue, was selected to allow the speed to drop from the highest probable ejection speed to one safe for opening the main parachute, and in other conditions its performance was less efficient. Intensive development work and flight testing with various types of drogues led to the introduction of the Duplex Drogue system. This scheme employed two stabilising drogues in tandem, a small drogue of 22 inches diameter, known as the controller drogue, and a larger main drogue of 5 feet diameter. The controller drogue was automatically extracted by the drogue gun on ejecting, and, when deployed, brought the seat back into a horizontal attitude, then towed the main drogue out of its container. The main drogue streamed the parachute when separation occurred, and this, when developed, lifted the occupant clear of the seat. The action of the controller drogue was twofold: first, to get the seat into a horizontal attitude so that the subsequent deceleration on the seat and occupant was linear and consequently more tolerable; second, the most important, it prevented explosive opening of the main drogue. In tests, when a 5-foot diameter drogue was deployed without a controller at 600 m.p.h. and at a height of 150 feet, it was torn to shreds, the drogue producing such violent loads that the face screen was torn and the seat harness broken. With the controller drogue employed under similar conditions, none of the components showed any signs of distress. Similarly, the main drogue prevented the explosive opening of the parachute, thus opening shocks and decelerations were reduced to within the strength limitations of the parachute and the physical limitations of the body.

With the incorporation of the Duplex Drogue it was found to be practicable to reduce the time delay between ejection and the streaming of the main parachute from 5 seconds to 3 seconds. At the same time the delay in the firing of the drogue gun was reduced from 1 second to ½ second. These improvements were introduced, together with the 80 feet per second gun and leg restraint gear, in the Mk. 3 ejection seat, a great step forward from the older Mk. 1 and the first automatic seat, the Mk. 2.

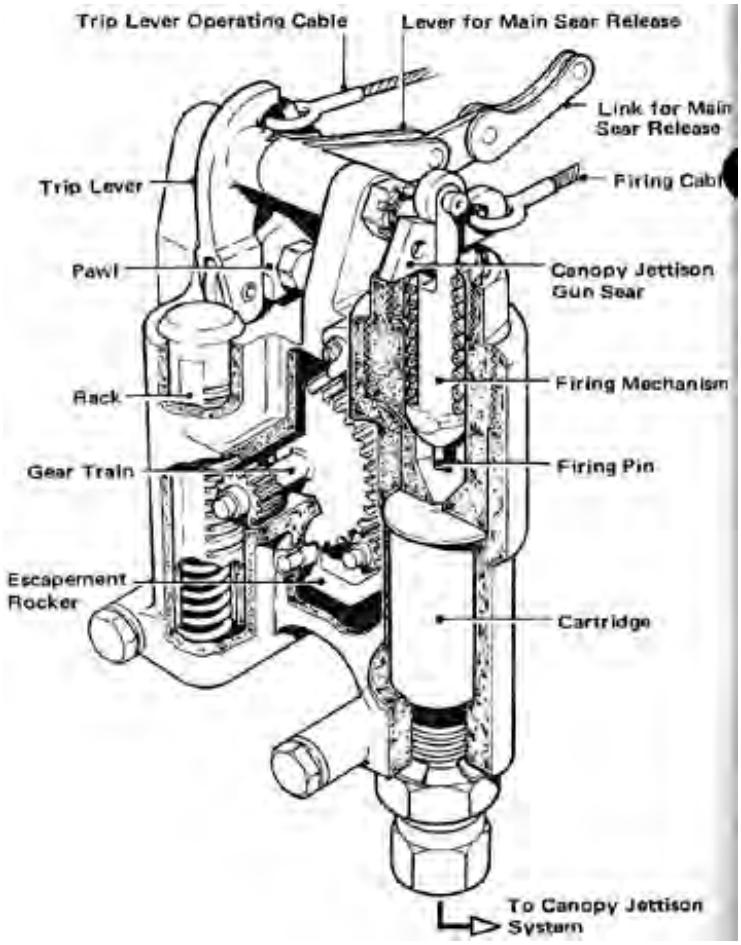
The Ground Level Seat

A series of fatal accidents involving aircraft of the Navy and Royal Air Force during take-off and the resultant ejections at too low an altitude, impressed the need for an ejection seat with ground level capabilities. The fact that the Mk. 3 seat was able to operate successfully from low altitudes was fundamentally due to the method and speed by which the Duplex Drogues deployed the main parachute, and the higher seat trajectory imparted by the 80 feet per second ejection gun. With ground level ejections, however, every second between the firing of the seat cartridge and the deployment of the main parachute is vital, and consideration was given to the reduction of the 3-second delay in the time-release mechanism. A delay of 1½ seconds was ultimately selected as being the most suitable to ensure deployment of the parachute at the top of the trajectory. With this 1½ second delay fitted to a standard Mk. 3 seat, Squadron Leader John Fifield, O.B.E., D.F.C., A.F.C., ejected from the Mk. 7 Meteor, taking off at Chalgrove on 3rd September 1955, the culmination of a long series of dummy runway ejections. Squadron Leader Fifield was safely on the ground six seconds after firing himself out of the Meteor, thus converting the sceptics who were previously convinced that a man would not survive such an ejection. The following month, again in a standard Mk. 3 seat, Squadron Leader Fifield made a test ejection from a height of 40,000 feet.

As previously described, the time-release mechanism of this seat was barostatically controlled to bring the seat down quickly from 40,000 feet, through the cold and rarefied upper atmosphere, to 10,000 feet where parachute deployment and separation from the seat took place. For the first 15 seconds of the fall the seat was fully stabilised, thereafter settling into a slow spin of from 15 to 20 r.p.m. about the longitudinal axis until it disappeared into a patch of stratus cloud. When seen again Fifield was suspended from his parachute. After his descent Squadron Leader Fifield said that he did not feel any unpleasant sensation from the spinning and that the seat was remarkably stable throughout. From this and other tests it was concluded that with this type of seat, safe ejections from 40,000 feet and higher are practicable, the occupant having the protection of the seat structure and face screen, the leg restraint preventing leg flailing, whilst the firing handle provides a positive hand-hold taking care of the arms, the face screen also holding the oxygen mask in position on the face, enabling the occupant to breathe the emergency oxygen supply turned on as the seat ejects.

Sqn. Ldr. Fifield making the first runway ejection at Chalgrove.

Canopy Jettison



Experience in service had shown that vital time was being used to operate canopy jettison gear and carrying out other pre-ejection drill. Under certain aerodynamic conditions, or if damage had occurred, it was possible that the canopy might not leave the aircraft cleanly, even though it had been unlocked. This could give rise to the ejected seat colliding with the canopy and becoming entangled with it. Under high-speed conditions, difficulty was also encountered in grasping the face blind firing handle, due to the slipstream entering the cockpit and causing severe buffeting once the protecting canopy had left the aircraft. By providing an explosive canopy jettison system powerful enough to force the canopy clear under all conditions, and by linking its operation to the ejection seat firing handle, it was possible to overcome these difficulties, the ejection position being adopted prior to the canopy leaving the aircraft.

The canopy jettison equipment consisted of a unit bolted to the rear of the ejection seat guide rail and containing a canopy jettison breech, together with a one second delay mechanism. On pulling the ejection seat firing handle, the sear of the canopy jettison gun was withdrawn, the cartridge detonated and the gases passed through piping to the two canopy jettison jacks. The expanding gases forced the pistons of the jacks upward, first operating the canopy locks and then raising the canopy for the airstream to carry it clear of the aircraft. At the same time as the firing of the canopy jettison cartridge the time-delay mechanism was tripped. This ran for one second, at the end of which the main ejection gun was fired, thus allowing the canopy to be well clear of the aircraft structure before the seat and occupant were ejected. The adoption of this system in Hunter, Javelin and other aircraft meant that one second after the pilot initiated the ejection procedure he would be carried clear of the aircraft, no time being wasted on any other pre-ejection action which may have prejudiced his chances of escape.

Mark 4 SEATS (Mk.4)

With the advent of a new type of aircraft known as the “light fighter” it became increasingly important to reduce the weight of the ejection seat. At the same time it was essential that the reduction in weight should not impair the operation and efficiency of the seat in any way. The construction of the Mk. 4 seat, although retaining the essential components of its predecessors, was therefore considerably modified.

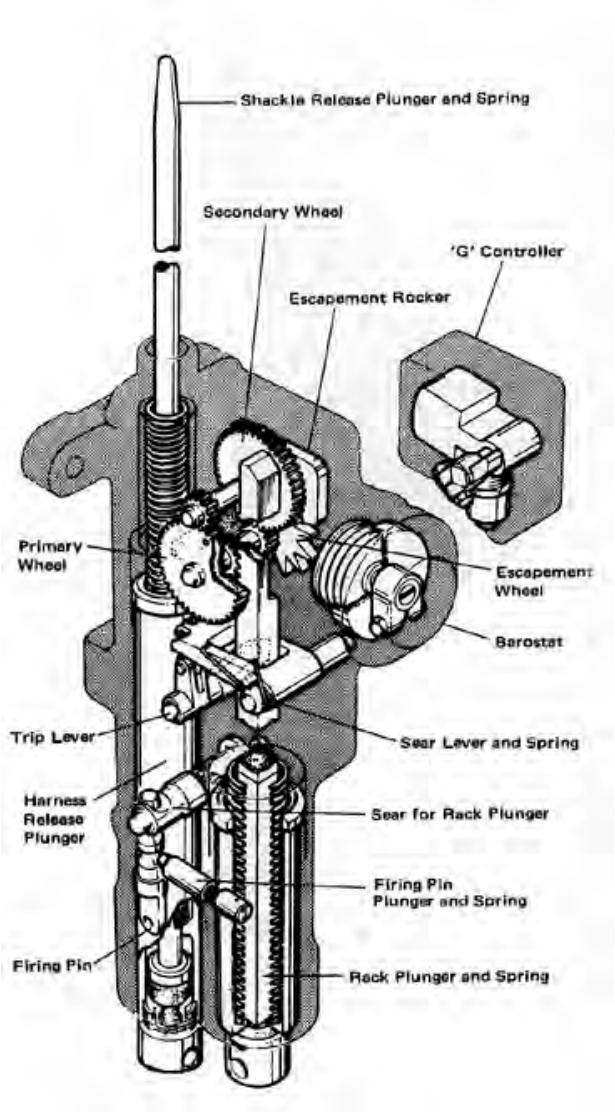
The basic 80 feet per second ejection gun was retained, having been proved to be sufficient for all current requirements, as was the Duplex Drogue system deployed by the half second time-delay drogue gun, together with a 1½ second time-release unit. The conventional type of guide rail was eliminated and superseded by channel members mounted on the sides of the ejection gun. Steel slipper pads mounted on the seat beams located the seat in position in the channels and guided it out of the aircraft on ejection. The seat structure consisted of a framework of two side beams bridged by three cross members, this framework supporting the seat pan and the drogue container; the drogue gun and the time-release unit being mounted on the side beams. The top cross beam took the full thrust of the ejection gun and contained the seat latch mechanism for locking the seat to the ejection gun. The centre cross member served as the attachment point for the shoulder harness whilst the lower member provided an anchorage for the seat height adjusting mechanism. Although fitted primarily with the face screen firing control, an alternative firing handle was fitted in the leading face of the seat pan. This enabled the occupant to eject when conditions of g precluded the use of the face screen control.

The comfort of the seat was considerably improved by the design of the parachute pack and dinghy pack alongside that of the seat, instead of trying to use the existing safety equipment. The parachute pack was a back-type, horseshoe in shape, and mounted high up on the back of the seat in the best position for automatic deployment, together with a high degree of comfort. The parachute harness was redesigned to combine with it the safety harness all in one, with only one quick-release fitting which was fastened by the occupant when strapping in the seat, and remained fastened throughout any subsequent ejection until released by the occupant at the conclusion of the parachute descent. This combined harness was attached to the seat by two locks in the rear of the seat pan and another lock in the back of the seat at shoulder height, the locks being released by a redesigned time-release unit at the correct instant after ejection, through a linkage system installed in the seat. The locks could also be

operated manually in the event of failure of the time-release unit by a manual separation lever on the seat. This arrangement of the parachute and harness was also fitted to some of the later Mk. 3 seats.

Later Mk. 4 seats were fitted with a snubbing unit in the top lock and a release lever which permitted the occupant to lean forward in the seat, but ensured that he was firmly held in the event of an ejection or crash landing. A number of variations of survival pack were designed by Martin-Baker according to the various requirements of the Air Force concerned, but all embodied the principle of seat cushion and container for dinghy and survival equipment. The seat cushion was designed to give maximum comfort and filled with a resilient padding slow to return to its original form after compression, thereby helping to absorb the acceleration forces imposed during ejection.

These Mk. 4 seats have been fitted to some 35 different types of aircraft, the first emergency ejection being from a Fiat G. 91 in March 1957.

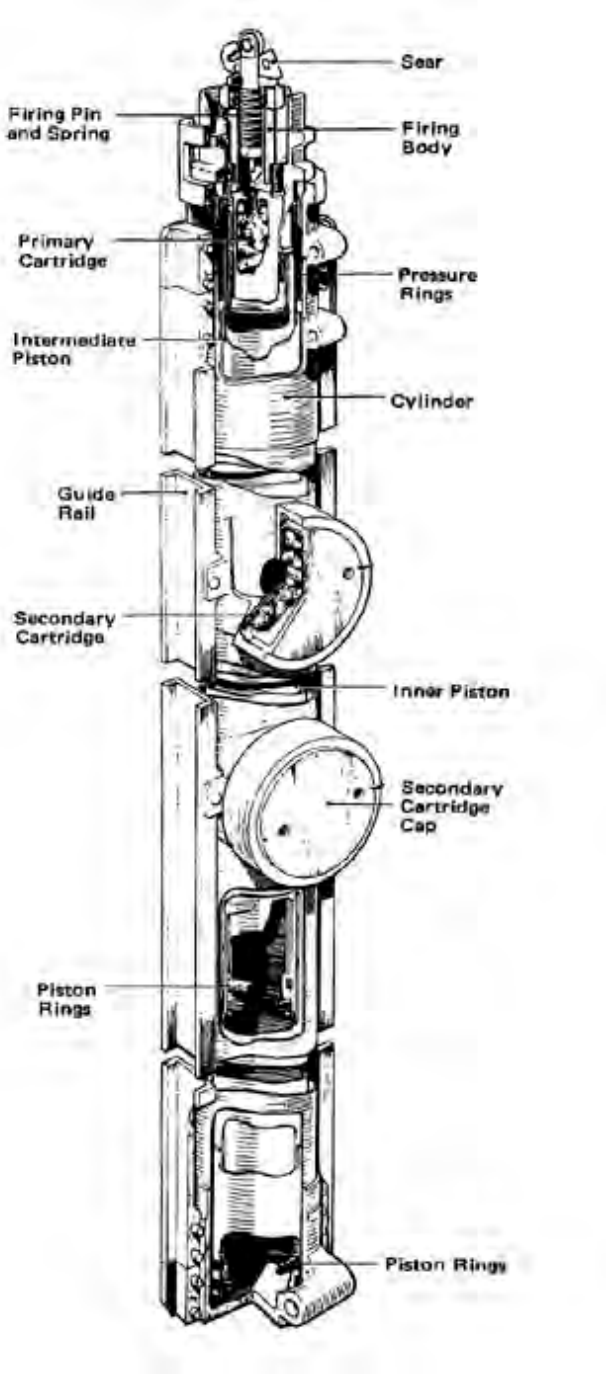


The 80 feet per second ejection gun and guide rail assembly fitted to Mk.4 seats onward.

G Switch

The time-delay required for safe ejection at ground level had been found to be 1½ seconds, but this was only the case if ejection took place at low speeds. At high speeds this period of delay was insufficient to permit the seat to decelerate to a speed at which it was safe to deploy the main parachute. Ideally, a unit was required which would incorporate a delay varying in accordance with the speed at the time of ejection, and some means was therefore sought of combining both the 3 second and 1½ second delays in the same unit. The result was an automatic selector, known as the g switch, which was adapted to fit the 1½-second time-delay unit.

The g switch consists of a small weight free to oscillate within the Time Release Unit. When the drogues develop, the seat assumes a horizontal attitude and the retarding force imparted by the drogues causes the weight to pivot forward, engage the starwheel of the escapement and prevent the unit from running out. As the seat is decelerated, the retarding force decreases and a light spring returns the weight to its original position, allowing the unit to run out.



Redesigned barostatic time-release unit introduced with the combined harness.
Below: Early Guillotine system fitted to Mk.4 seats.

When an ejection takes place at low speed, the time-delay unit runs unimpeded (providing the ejection is below 10,000 feet and not subject to barostatic control), allowing the drogues to be released 1½ seconds later, but, in the case of ejection at high speed, the g switch is engaged and the correct delay is automatically selected by the particular deceleration loads imposed.

With the introduction of the g switch it was therefore possible to provide for safe ejections at all speeds likely to be encountered by modern aircraft. At a later date the delay was further reduced by ¼ second and the 1¼ second time-delay became standard equipment on the majority of Martin-Baker seats.

Guillotine System

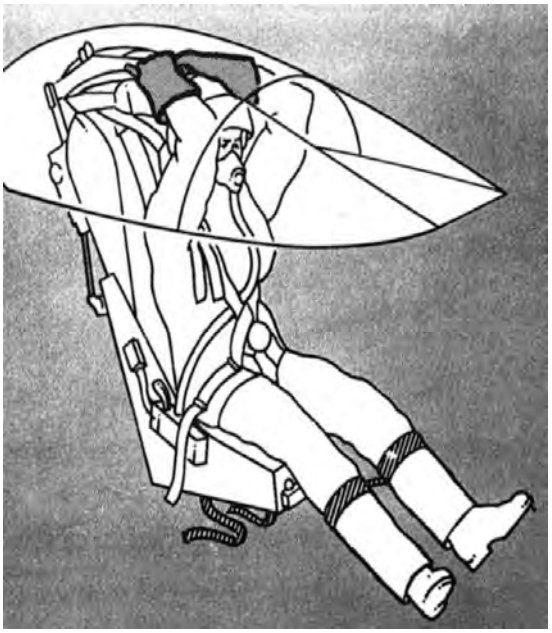
In order to reduce the number of operations necessary when making a manual separation after ejection, a guillotine system of disconnecting the parachute withdrawal line from the drogue was introduced. A small guillotine unit was mounted, usually on the side of the drogue container, with the parachute withdrawal line positioned in a spring-loaded guard immediately above the cutter of the guillotine. The cutter was operated by a cartridge, fired by a short static cable between the back of the parachute case and the sear of the guillotine firing unit. As the seat occupant moved forward on separation, taking his parachute pack with him, the cable removed the sear to fire the guillotine and cut the withdrawal line.

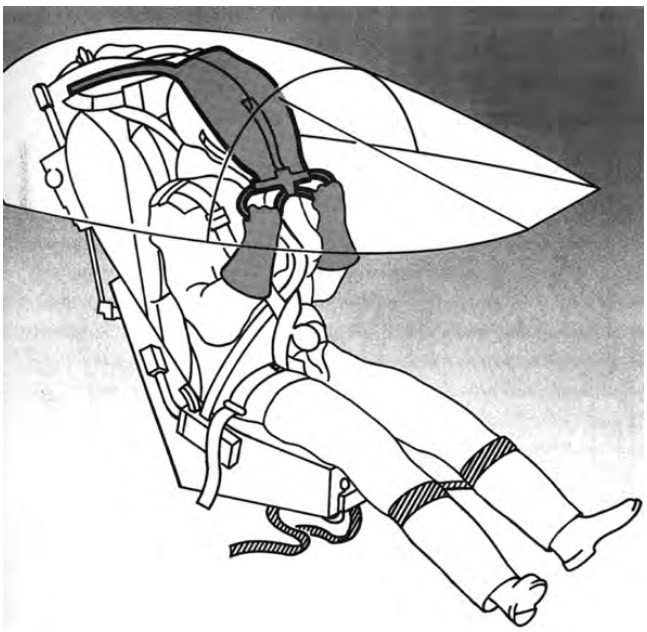
This arrangement rendered unnecessary the need for any operation of two D rings on the parachute harness. In the event of failure of the time-release unit, all that was now necessary was for the occupant to operate the harness release lever on the seat and pull his rip cord D ring to deploy the parachute.

An alternative method of firing the guillotine was later introduced which interconnected the firing of the guillotine with the operation of the manual separation handle, instead of using a static cable attached to the parachute pack.

Further Modifications

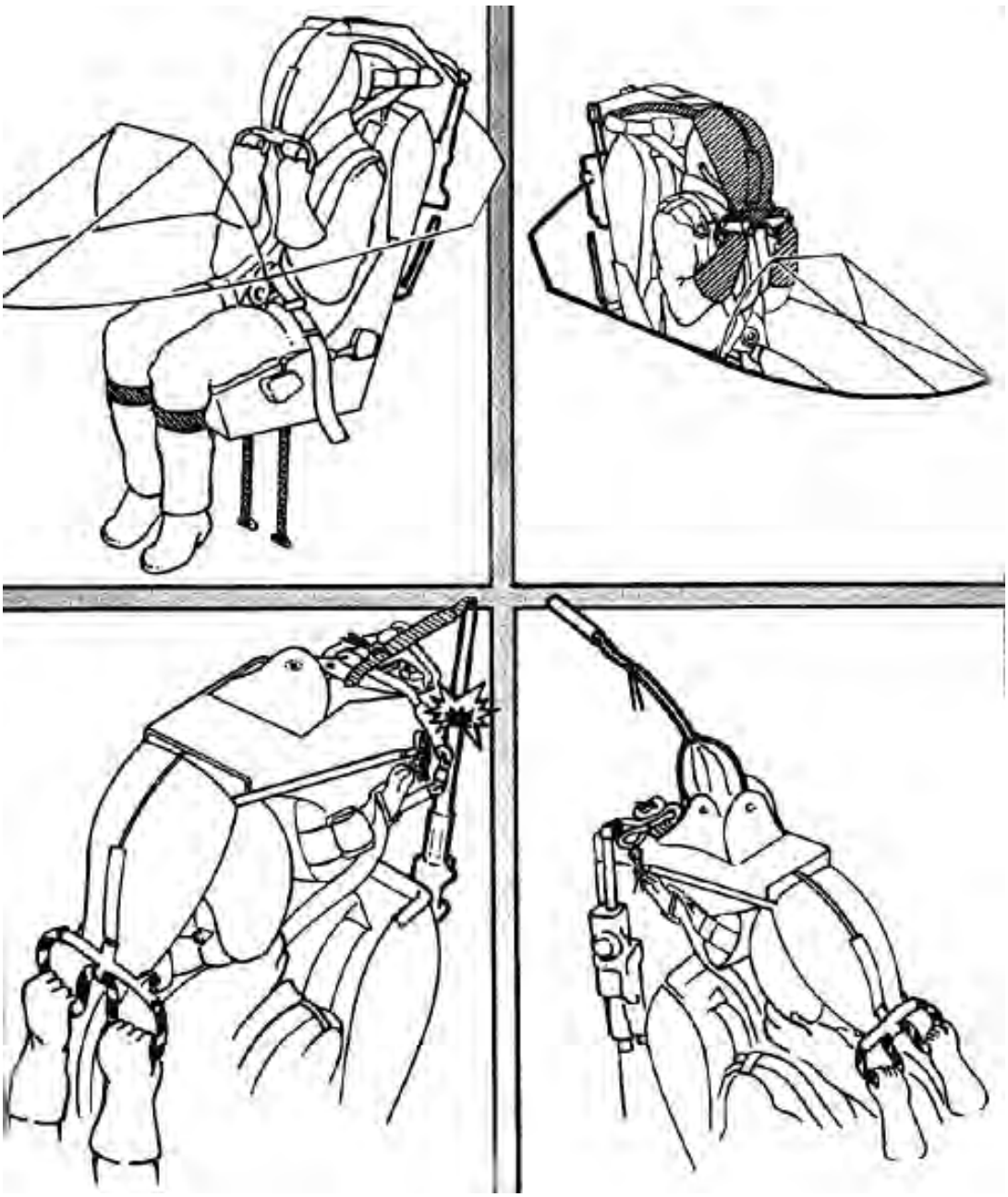
Further modifications have been made to a number of the Mk. 4 seats, including the adoption of leg restraint lines which plug into latch boxes on the front of the seat pan, instead of being secured to the harness release locks at the rear. The 1-second time-delay mechanism after the canopy jettison equipment has been initiated is now available contained in the breech of the main ejection gun, whilst the canopy locks can now be operated by the expanding gases of the canopy jettison charge via a by-pass valve instead of the initial movement of the jacks.



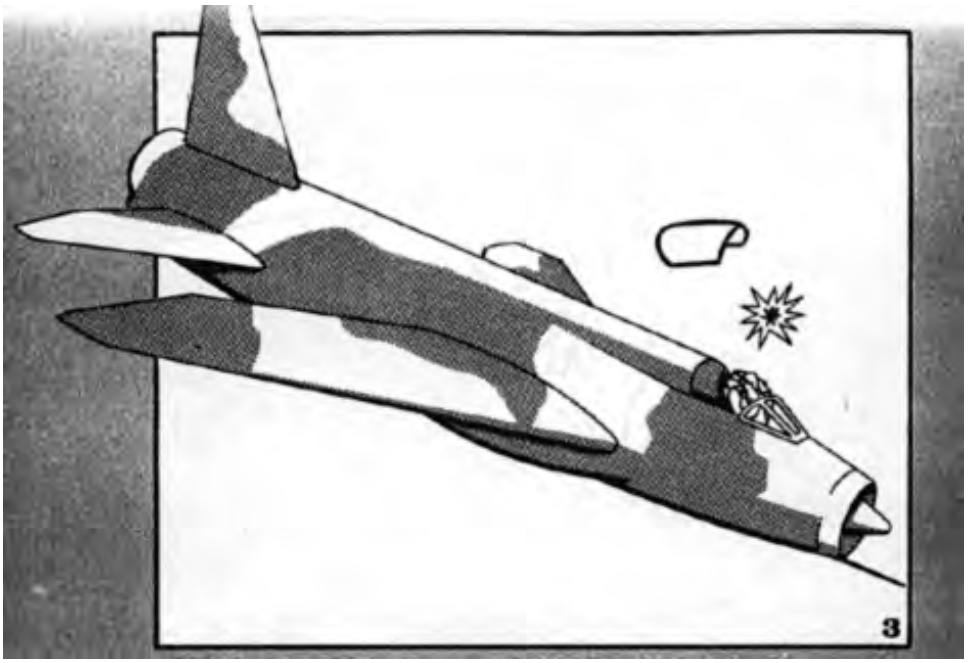


OPERATING SEQUENCE OF THE Mk.4 SEAT

***1**-Preparing to eject*
***2**-Face screen pulled to commence ejection sequence*



3- *Canopy jettisoned*



4- *Seat commences to eject, legs retracted and sear withdrawn from drogue gun.*

5- *Simultaneously the firing pin is withdrawn from time-release unit.*

6- *Half a second after ejection the drogue gun fires and the piston is ejected.*

7- *The line attached to the piston withdraws the drogues from the container.*

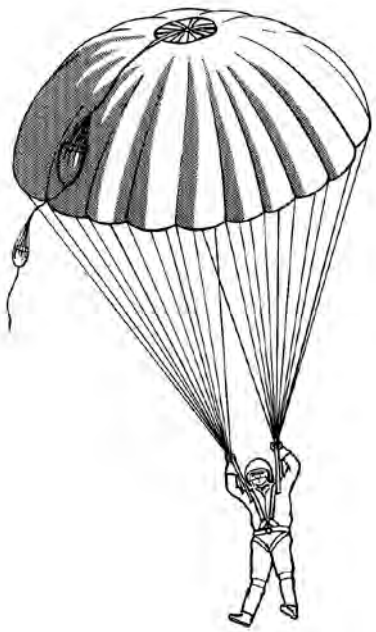
8- *Which stabilize the seat and reduce its forward speed*.

9- *When below 10,000 ft. and the speed reduced sufficiently, the time-release unit operates and the scissor shackle opens.*

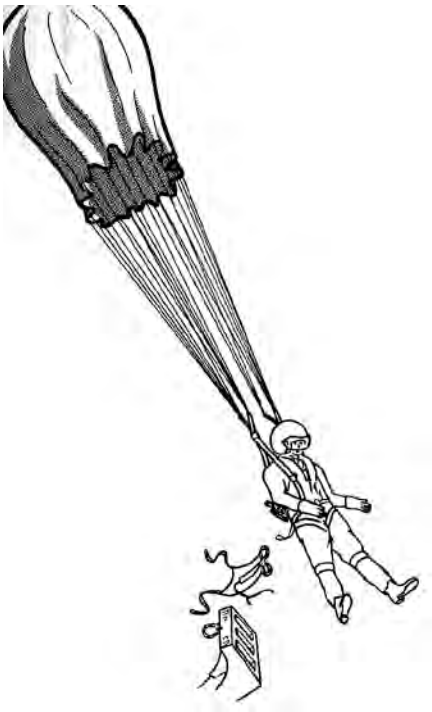
10- *The pull of the drogues is transferred to the lifting lines and the face screen and parachute are released from the seat.*

11- *The combined harness and leg cords are released from the seat.*

12- *The drogues deploy the parachute and the occupant is lifted out of the seat, allowing the seat to fall free.*



13- *The occupant makes a normal parachute descent.*



Mark 5 SEATS (Mk.5)

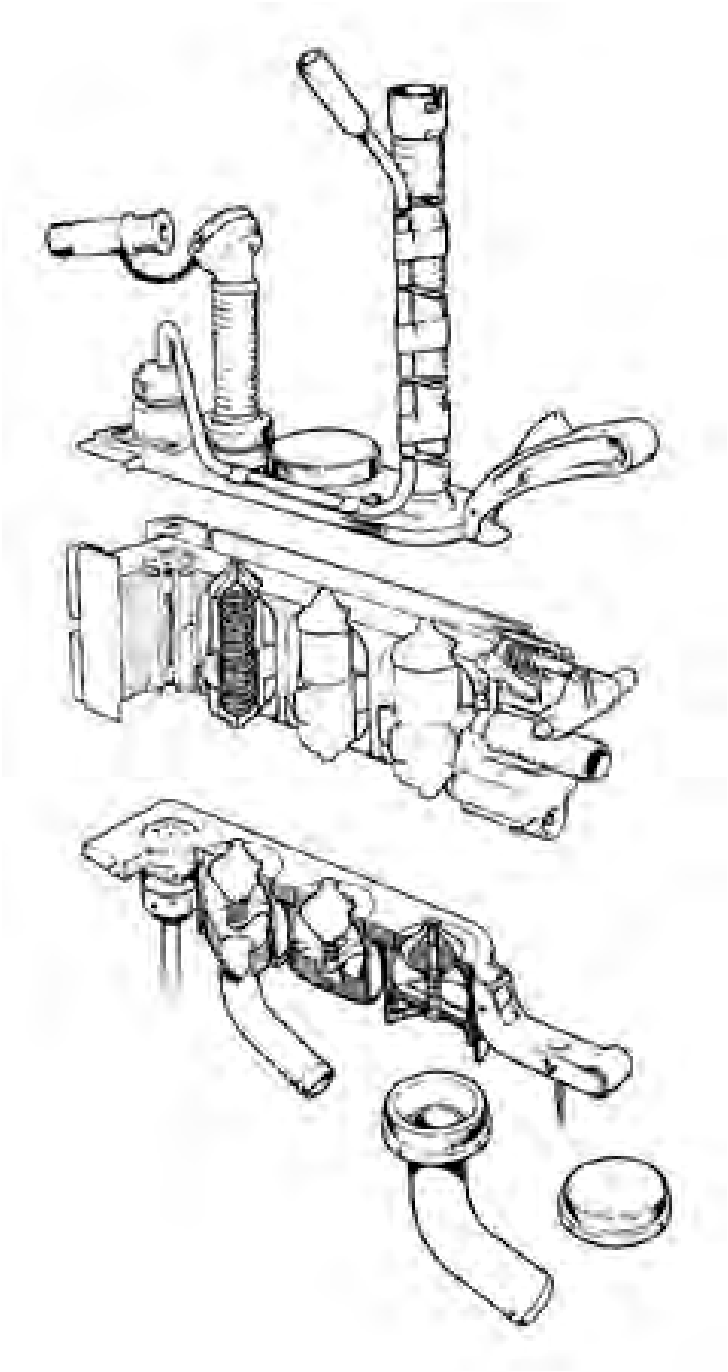
To suit the special requirements of the United States Navy, the Mk. 5 seat was introduced in 1957 and its production paralleled to that of the Mk. 4. In general the Mk. 5 seats conformed to the same basic pattern of the Mk. 4 and included the standard 80 feet per second gun, 1¼ second time delay with g switch and barostatic control, duplex drogue system plus all the other features necessary for their use at all speeds and heights. To meet specific American crash requirements however, the seat structure and harness were strengthened to withstand deceleration loads of 40 g, instead of the 25 g British specification, resulting in a slight increase in weight.

In addition, the seats were provided with special canopy breaker peaks on the headbox to provide for the eventuality of having to eject through the canopy, standard practice on the A.5 seat installed in the Grumman 9F-8T Cougar. On the majority of the other Mk. 5 seats the American system of jettisoning the canopy was linked up with the face blind firing handle.

The low level capabilities of the Mk. 5 seat were successfully demonstrated in August 1957, when Flying Officer Sidney Hughes ejected from a Grumman Cougar at the U.S. Naval Air Test Centre, Patuxent River, before a group of high ranking U.S. Navy Officers. Subsequently, the decision was made to standardise the Martin-Baker Mk. 5 seats for all United States Navy jet fighters and trainers, and many fuselages were sent to the Company's factory at Denham for trial installations.

North American Sabre and Republic Thunderflash aircraft of the Norwegian Air Force were the first of many N.A.T.O. aircraft to be flown into Chalgrove airfield where the installation of Martin-Baker Mk. 5 seats was made, replacing the original American ejection seats fitted in these aircraft, because the Norwegian Air Force preferred Martin-Baker seats. Altogether the Mk. 5 seat has been fitted to nearly twenty types of American aircraft, including such advanced aircraft as the McDonnell Phantom, L.T.V. Crusader, and Grumman Intruder.

Personal Equipment Connector



The connection of vital personal services between the aircraft and the seat occupant on later designs of Martin-Baker seats has been considerably simplified by the introduction of the Personal Equipment Connector (P.E.C.).

The connector saves much time in “strapping in”, as all the aircraft service lines combine at this point and are connected by one single action, instead of the several needed before its introduction. When the seat ejects, the supplies of anti-g, oxygen and air ventilation, as well as the tel/mic are automatically disconnected and sealed, whilst the emergency oxygen is turned on and admitted via the main oxygen supply line.

The P.E.C. consists of three portions, namely the seat portion, the man portion and the aircraft portion. The seat portion is permanently attached to the seat pan. The other two portions are detachable from the seat portion and connected respectively to the pilot’s equipment (man portion) and by a static line to the aircraft (aircraft portion). On ejection the static line pulls away the aircraft portion, and on separation from the seat the man portion is released, the air ventilating suit supply line being provided with a valve to prevent the ingress of water should the pilot alight in the sea.

An important feature of the P.E.C. is that coupling of all services is simultaneous and can easily be checked by use of the tel/mic, which, if speech is audible, shows that oxygen and the other supplies are correctly connected.

Rearward Facing Seat Research

During 1960, Martin-Baker carried out tests to demonstrate that safe ejection from aircraft fitted with rearward facing seats was practicable.

A specially designed seat was installed in a Valiant aircraft and after a series of static tests, a programme of three dummy ejections was carried out, one on the runway during the take-off run and two at a height of 200 feet at indicated air-speeds of 250 knots and 300 knots. The tests commenced on 27th June 1960, the dummy runway ejection occurring when the aircraft was travelling at 100 knots and was completely satisfactory, the parachute being fully developed 4.3 seconds after ejection initiation, allowing a fully controlled drop of 38 feet.

The series of tests was rounded off by a live ejection over Chalgrove airfield by Mr. W. T. Hay on 1st July 1960, at a height of 1,000 feet and a speed of 250 knots, witnessed by several Royal Air Force Officers from Ministry of Aviation Headquarters Bomber Command. The ejection was completely successful, Mr. Hay landing in the middle of the airfield after an uneventful ride and a completely controlled descent.

As far as is known, this was the first rearward facing live ejection in the world and it fully proved the feasibility of such ejections.

Rocket Assisted Seats

As a result of all the development work described in the foregoing pages, the Martin-Baker standard cartridge-fired ejection seat is now giving an aircrew recovery rate of around 93%. Of the small number of unsuccessful ejections, approximately 60% have occurred at low altitude with the aircraft descending at a high sink rate, and in most of these cases the ejection sequence was developing satisfactorily, but the pilot struck the ground with the parachute streaming but not developed.

Obviously if the trajectory height were increased sufficiently to ensure full development of the parachute canopy under such conditions, the pilot's chance of survival would be greatly enhanced.

The required increase in height could not be achieved by increasing the power of the ejection gun; the early physiological development lessons had been well learned, and it was considered that the ultimate had been achieved in ejection gun design. A means was therefore sought whereby the thrust imparted by the ejection gun could be prolonged without subjecting the seat occupant to any increase in acceleration forces, and this has been achieved by the addition of a rocket motor.

Sir James Martin with Mr. W.T. Hay after the first "live" rocket seat demonstration on the 1st April 1961.

Rocket Development

In some systems other than Martin-Baker, the ejection gun itself contains the rocket charge which initially acts as a conventional cartridge until gun separation occurs, when the rocket efflux is then directed 45° rearwards in order that the rocket thrust may act through the centre of gravity of the ejected mass, thereby preventing cartwheeling. However, because the jet efflux in these systems is thus directed rearwards, the resulting trajectory is low and flat. It therefore follows that in the low level, nose down ejection case, these guns will fire the seat in more horizontal trajectory, the all important upward component will be absent and the additional height required for parachute development in this low level, descending condition will not be reached. In a horizontal flight path such seats may prove satisfactory, but it is only in the descending case that the advantages of the Martin-Baker system become apparent.

Since the earliest Martin-Baker rocket seat designs, all efforts have been directed to providing a near vertical trajectory. Originally the rocket fuel was contained in two steel combustion tubes mounted on the rear of the seat pan and leading into an efflux chamber, which discharged downwards below the seat providing the desired thrust. Many tests were conducted using this twin tube system and a high degree of success was attained. These tests culminated in a live ejection under zero speed zero altitude conditions conducted by Mr. W. T. Hay at the Company's airfield on 1st April 1961. The ejection was a complete success and a descent of 200 feet on a fully developed parachute was achieved. Mr. Hay repeated this test at the Paris Show in 1961, which also met with success.

Although most successful, this arrangement was abandoned in favour of a multi-tube rocket pack which could be fitted underneath the seat pan, with the efflux thrust line almost vertical and passing through the centre of gravity of the ejected mass. The rocket pack is attached to the seat pan in a manner which facilitates quick and simple removal and replacement without the use of special tools, and greatly simplifies the retrospective fitting of the rocket to ejection seats already in service. The very minimum of modification action is required to install the rocket pack and no special considerations are required for its maintenance.

Multi-Tube Rocket Pack

The rocket pack consists of a number of combustion tubes, containing the solid propellant, which are screwed into a central gallery mounted transversely across the bottom of the seat pan. The gallery also accommodates the efflux nozzles screwed into its underside and pointing downwards. The number of efflux nozzles varies according to the design characteristics of the seat and rocket combination and is usually between 2 and 6.

One of the combustion tubes is fitted with a mechanical firing mechanism and cartridge. The design of this is based on other similar firing mechanisms of the sear and firing in type which are in use on all Martin-Baker seats and are consequently of tried and proven design. As the ejection seat nears the end of the ejection gun stroke, a static line attached to the cockpit floor withdraws the sear from the firing mechanism allowing the spring-loaded firing pin to descend and fire the cartridge. The cartridge produces an exceedingly hot flame, which flashes throughout the tube system causing simultaneous ignition. To ensure the correct light-up characteristics, the efflux nozzles are sealed by metal discs, which blow out when the correct pressure build up is attained.

Combustion Tube Sizes

The standard rocket pack now being fitted in various ejection seat installations is fitted with combustion tubes of approximately one inch in diameter and is designed to provide the additional thrust necessary to ensure a safe ejection under conditions of zero altitude and with a sink rate up to 30 fee per second.

V.T.O.L. aircraft, however, can encounter extremely high sink rates should an emergency arise whilst hovering, and it is for this purpose that a rocket pack employing approximately two inch diameter combustion tubes has been developed. This two-inch rocket motor is much larger and is designed to give the seat a trajectory high enough to ensure safe escape from an aircraft with a sink rate approaching 80 feet per second. It will also prove to be extremely beneficial should an emergency arise in a prototype aircraft whose "in flight" characteristics have yet to be ascertained.

Test Programme

Early tests were done on ground rigs to verify efficient performance and reliability, and when these tests were satisfactorily completed, dynamic and airborne tests were conducted. Test vehicles used during this extensive programme were a launching stand for the zero-zero ejections, a specially adapted motor vehicle for the low speed runs, a Meteor Mk. 7 aircraft for the medium speed test and finally, a Hunter Mk. 7 for the high speed runs. Tests were planned and executed to ensure simulated ejections at all critical areas, particularly zero speed, 40 knots, 90 knots, 250 knots, 450 knots, and 600 knots, the highest speed of which our airborne test vehicles are capable. The test also covered the wide range of body weights likely to be encountered between pilots of different weights and stature, resulting in changes of position of the c of g of the ejected mass.

These tests again culminated in a live ejection, this time by Wing Commander Peter Howard, a Royal Air Force Doctor at the Institute of Aviation-Medicine and a specialist in Aviation Physiology.

On 13th March 1962, Peter Howard ejected himself from a Meteor aircraft at a speed of 250 knots and an altitude of 250 feet. The test was completely successful and Peter Howard commented very favourably on the smooth ride. This was due to a significant reduction in acceleration, the peak g being about 15 and the rate of rise about 160 g per second.

Sir James Martin and W/Cdr Peter Howard after the first airborne rocket seat ejection.

Other live ejections followed and the successful results allowed Martin-Baker to offer the rocket pack for service use with the utmost confidence.

In order to evaluate the performance of a rocket seat when ejection occurs at speed near the ground, with the aircraft in a nose down attitude, Martin-Baker have constructed a rig to simulate this condition. The rig consists of a track 200 feet long, one end of which is supported on a tower 80 feet high with the other end at ground level, giving an inclination of approximately 20°.

The seat under test is installed on a rocket propelled sled, which is hauled to the top of the incline by mechanical winching gear and then propelled at speed down the incline and ejection initiated at a pre-determined point during its travel. This unique inclined sled track, the only one of its kind in the world, enables the seat to be tested in crucial diving conditions. In addition, a 6,000 feet long "supersonic" sled track is also used to test seats, particularly the high-speed tests.

In addition to the tests done by the Company and referred to above, a large programme of evaluation tests of the Martin-Baker rocket seat have been done in the United States with special reference to its installation in the Intruder, Crusader and Phantom aircraft. These tests have been done under the direction of the Bureau of Naval Weapons and carried out at their laboratories at Dahlgran, Philadelphia, and on the high speed sled-track at China Lake.

In September 1965, the U.S. Navy decided to fit Martin-Baker rocket seats in the three aircraft mentioned, both retrospectively as well as in future production models.

Engineering Arrangements

In addition to the test work to prove the system, installations have been carried out in a large number of operational aircraft with a view to its ultimate retrospective fit. The work already done in this area indicates that this rocket motor can be installed in most operational aircraft fitted with Martin-Baker seats, with very little modification to the seat or aircraft. Further, the operational disturbance of the aircraft involved will be kept at a minimum and the cost of retrospective fit will thus be proportionately low.

Emergency Ejections

On 14th September 1964, an emergency ejection took place from a VJ-101C aircraft fitted with a Martin-Baker rocket seat in the most exacting conditions. Mr. George Bright, an American Test Pilot employed by EWR Germany, took off in this aircraft at Manching, Germany. A conventional take-off was begun but when the aircraft unstuck, control was lost and the aircraft began a vicious left-hand roll. After rolling 320°, in other words with a 40° bank, the pilot ejected by using the seat pan handle. At the time, the aircraft's nose was elevated 18°, it was yawing 17° and the starboard wing tip was at a height of 10 feet above the runway when the pilot ejected. This ejection was entirely satisfactory. The unusual behaviour and attitude of the aircraft during this very short flight of approximately 8 seconds were recorded by means of a cine-camera, which was operating to film the take-off.

Regrettably, the actual ejection was not photographed because the camera operator understandably abandoned his camera as the aircraft came hurtling towards him. In service the rocket seat has been remarkably reliable and efficient.

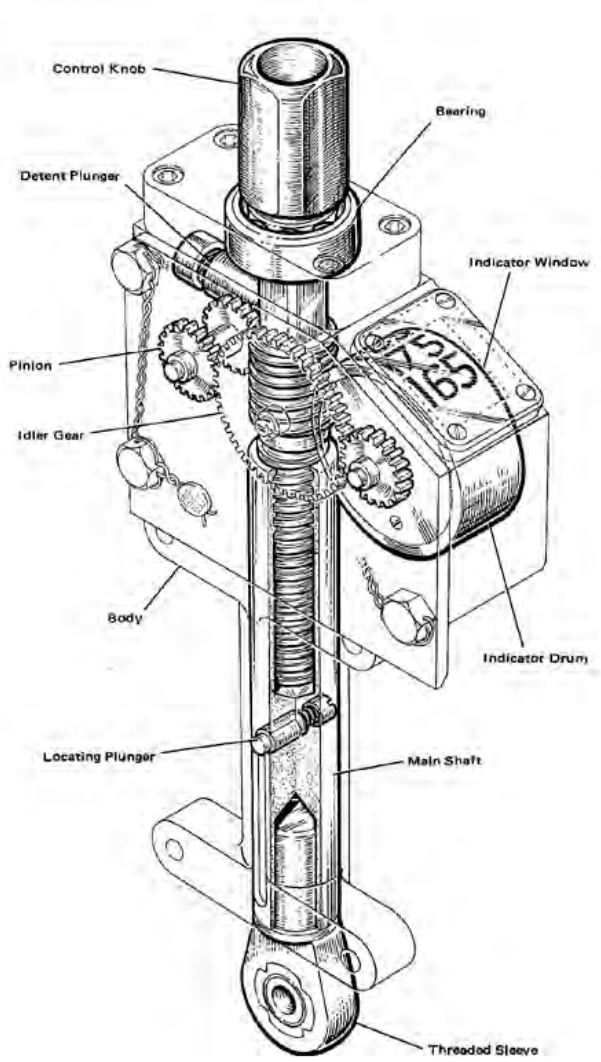
Service Use

Martin-Baker ejection seats fitted with a rocket pack are currently fitted in a wide range of aircraft, including the following:

> Fiat G91 and G91Y, Macchi MB326, Crusader, Intruder, Phantom, Buccaneer, Starfighter, Harrier, F14 Tomcat, Hawk, Jaguar and Tornado.

The rocket seat has a particular application to VTOL aircraft. With a conventional seat, safe escape would be virtually impossible in the very critical situation engendered by engine or control failure during take-off, landing or hovering flight.

Rocket Thrust Angle



A later refinement added to the rocket installation was the provision of a control for adjusting the angle of thrust of the rocket in relation to the seat, to compensate for variations in the weight of the occupant. The control, known as a “pitch control unit”, is mounted on the side of the seat pan and consists of a handwheel attached to a vertical screwjack, the lower end of which is attached to the forward part of the rocket pack. Rotation of the handwheel will cause the front of the rocket to rise or fall and thus vary the angle of the rocket’s thrust, to ensure that the thrust will pass through the centre of gravity of the ejected mass. A scale, calibrated in either pounds or kilogrammes, moves in a glazed aperture as the handwheel is rotated; the occupant sets his “dressed weight” on the scale when he enters the aircraft.

Marks 6, 7 and 8 SEATS (Mk.6, Mk.7 and Mk.8)

Introduction of the rocket pack to the range of Mk. 4 and Mk. 5 seats created the basic Mk. 6 and Mk. 7 ranges respectively. However, many of the Mk. 7 range of seats were subsequently embodied with additional improvements in design such as Power Retraction Systems, Remote Fired Rocket Systems and Sequencing Systems as later described. The Mk. 8 seat (developed for the T.S.R.2 aircraft), was a rocket assisted seat and was undoubtedly the most advanced aircrew escape system produced up to that time. Despite the unfortunate cancellation of the T.S.R.2, much valuable experience was gained, which was fully exploited in later designs.

Power Retraction

The ideal posture favourable for successful ejection is for the ejectee to sit upright in the seat, to ensure that his vertebrae are in line and square with each other before ejection. Under the stress of an emergency however, this may not be achieved without automatic mechanical assistance, and this is provided by a power retraction system.

A power retraction system consists of two straps attached to the shoulder straps of the harness, each strap being wound around a reel, the two reels being mounted on a horizontal shaft capable of being rotated under power, in order to pull back the shoulders of the seat occupant to the correct posture for ejection.

The power for rotation of the reels is provided by a cartridge, the gas produced operating on a piston, the reciprocating motion on which is converted to a rotary motion, either through a rack and pinion or a quick-start thread. The firing of the cartridge is linked to the seat firing handle; suitable delays being incorporated in the individual design to ensure that ejection is not commenced before retraction is complete.

Included in the design of all power retraction units is a device which allows the seat occupant complete freedom of movement in the cockpit, enabling him, during normal flight manoeuvres, to reach forward and twist around in his seat for maximum visibility, the straps pulling out of the unit as he moves forward and retracting on their spring-loaded reels as he moves back; each strap acting independently. Should however the occupant be subjected

to high g forces, the reels will automatically lock to prevent further forward movement, but will release immediately the g forces are relieved.

A control lever mounted on the seat operates a pawl and ratchet system, which, when engaged, will permit the occupant to move back in the seat but will prevent all forward movement, irrespective of whether or not g forces are applied.

Remote Rocket Firing System

As previously described, earlier designs of rocket were fired by a static line withdrawing a sear from a sear-operated firing unit on the rocket. The static line was originally clipped to the rocket tubes and in later designs was accommodated in a helical dispenser attached to the underside of the tubes. Neither method proved completely satisfactory; the static line was always vulnerable, easily damaged and consequently liable to fail.

This problem was solved by the introduction of a remote firing system, consisting of a firing unit mounted high up on the seat, usually either on the drogue container or the upper part of the main beams. The unit contains a sear-operated firing pin and cartridge, and the static line which is coiled inside the unit out of harms way, one end being attached to the sear, and the other end to a fitting attached to the aircraft, usually one of the tip rods for either the drogue gun or the time-release unit.

As the seat leaves the aircraft, the static line is withdrawn, pulls taut and removes the sear to fire the cartridge in the remote firing unit. Gas pressure produced is delivered by rigid pipe and then by flexible hose to a gas-operated firing unit in the rocket, which fires and ignites the rocket propellant.

Mark 9 SEATS (Mk.9)

After some 23 years of development, the design of the Martin-Baker Ejection Seats was becoming somewhat complex, and towards the end of the 1960 decade a new design was put in hand which eventually became the Mark 9 seats. The general design features of the ejection gun and guide rail, the barostatic time-release unit, the drogue gun and the personal equipment connector were retained, but considerable changes were made to the general seat structure, the drogue container, the parachute and the seat pan. These design changes resulted in a marked improvement in the appearance of the seat and in personal comfort for the occupant.

These seats were equipped with power retraction and a completely new gas-operated seat firing system, superseding firing cables and utilising one firing handle only, mounted on the seat pan, the face screen and its firing cable being dispensed with.

Seat Structure and Drogue Container

The seat structure of the Mk. 9 seats is made up of two main beams and three cross beams of similar design to previous seats, but the design of the drogue container and method of mounting the seat pan is changed. The drogue container is a more box-like construction with the drogue assembly enclosed by the usual four flaps on the top. The front surface is upholstered, contoured to fit the pilot's flying helmet to provide head restraint, and has a vertical channel in the centre of the upholstery to accommodate the parachute withdrawal line.

Two large tubes are attached to the front surfaces of the main beams on which are mounted two sliding members (one upper and one lower). The seat pan is attached to these sliding members by four nuts; this arrangement enables the seat pan to be quickly detachable to provide quick access to equipment in the cockpit. The seat actuator is positioned between the centre cross beam and the lower sliding member.

Parachute and Seat Pan

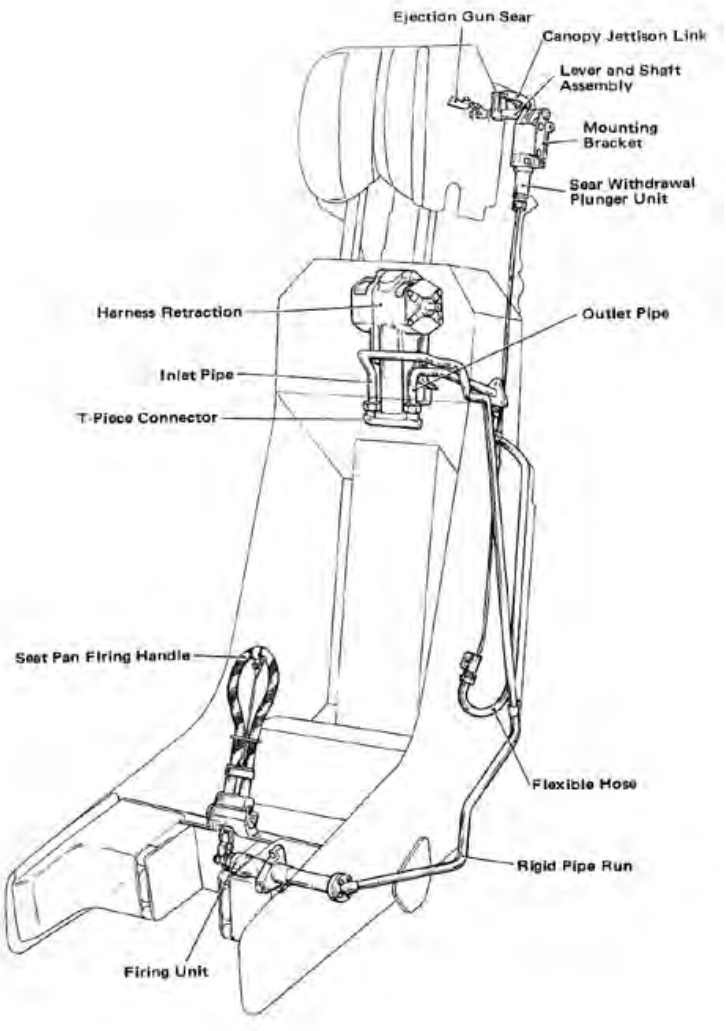
The design of the parachute is considerably changed on the Mk. 9 seats, being stowed in a near-rectangular container, contoured to provide a comfortable back rest and accommodated in a large recess in the back of the seat pan. The top of the container is closed by flaps secured by rip pins which are withdrawn normally by a withdrawal line connected to the drogue shackle, or on manual separation by a rip cord handle situated on the port lift web. A skeletal torso harness is used, being connected to the lift webs by Koch fittings. The harness power retraction unit is housed in the back of the seat pan, its retraction

straps being routed through small shackles on the parachute lift webs.

Gas Operated Seat Firing System

The seat firing system of the Mk. 9 seats differs completely from previous seats, the system is gas-operated, there being no firing cables, and only one firing handle which is positioned on the front face of the seat pan.

Experience has shown that a seat pan firing handle is quicker to operate than a face screen handle and, in addition, the modern flying helmet and its visor provides the face protection previously provided by the face screen.

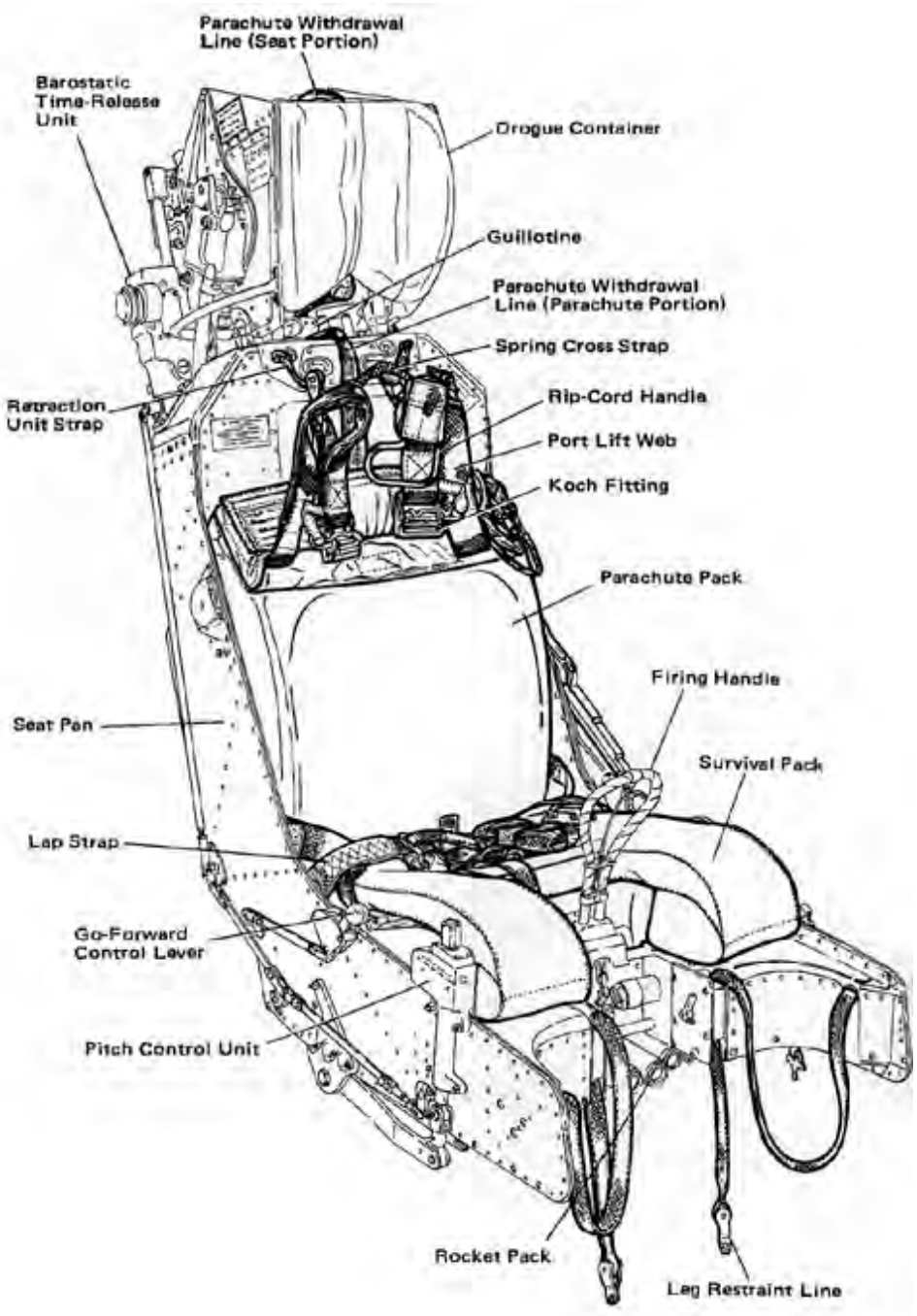


When the seat pan firing handle is pulled, a sear is withdrawn from a breech unit beneath the seat pan; gas generated is piped to the harness retraction unit and to a sear withdrawal plunger unit mounted on the top of the port main beam. The harness and the sear withdrawal unit rotates a cross shaft on the top of the seat structure to withdraw the sear from the ejection gun and fire the seat.

Utilisation of Mk. 9 Seats

Mk. 9 seats are installed in the Harrier and Jaguar aircraft. The seats showed a marked advance in ejection seat design and provided the basis for further development to the following Mark 10 series of seats.

The Mk. 9 seats provided the “break through” in ejection seat design with the gas-operated seat firing system, re-designed parachute pack and quickly detachable seat pan. Further improvements in design however, were soon to follow, involving an extension of the gas-operated system together with a number of new innovations, resulting in the introduction of a new series of Mk. 10 seats described in the following pages.



Mk.9B seat fitted to Jaguar aircraft

Mark 10 SEATS (Mk.10)

Considerable design changes are introduced on the Mk. 10 seats in an effort to reduce the time lapse between initiation of ejection and full parachute development. The main design changes are:-

1. Extension of the gas-operated firing system introduced on the Mk. 9 seats to include the release of the drogue and to operate the harness release system.

2. Re-design of the barostatic time-release unit and the drogue gun for inclusion in the gas-operated system.

3. The drogue and parachute have been combined as a complete assembly and stowed in one quickly detachable container at the top of the seat structure.

4. A simplified two-point combined harness.

5. Improved design of harness power retraction unit.

6. Introduction of arm restraint.

These, and other improved design features described in the following pages resulted in the introduction of the Mk. 10 series of seats, with a reduction of weight and an improved performance, the new seat being capable of providing safe escape at zero altitude and zero speed, and at speeds up to 630 knots IAS.

Mk. 10 seats are fitted in the Hawk, Tornado, Mig 19 (Pakistan), Macchi MB339, CASA 101, Sea Harrier and many other types of aircraft.

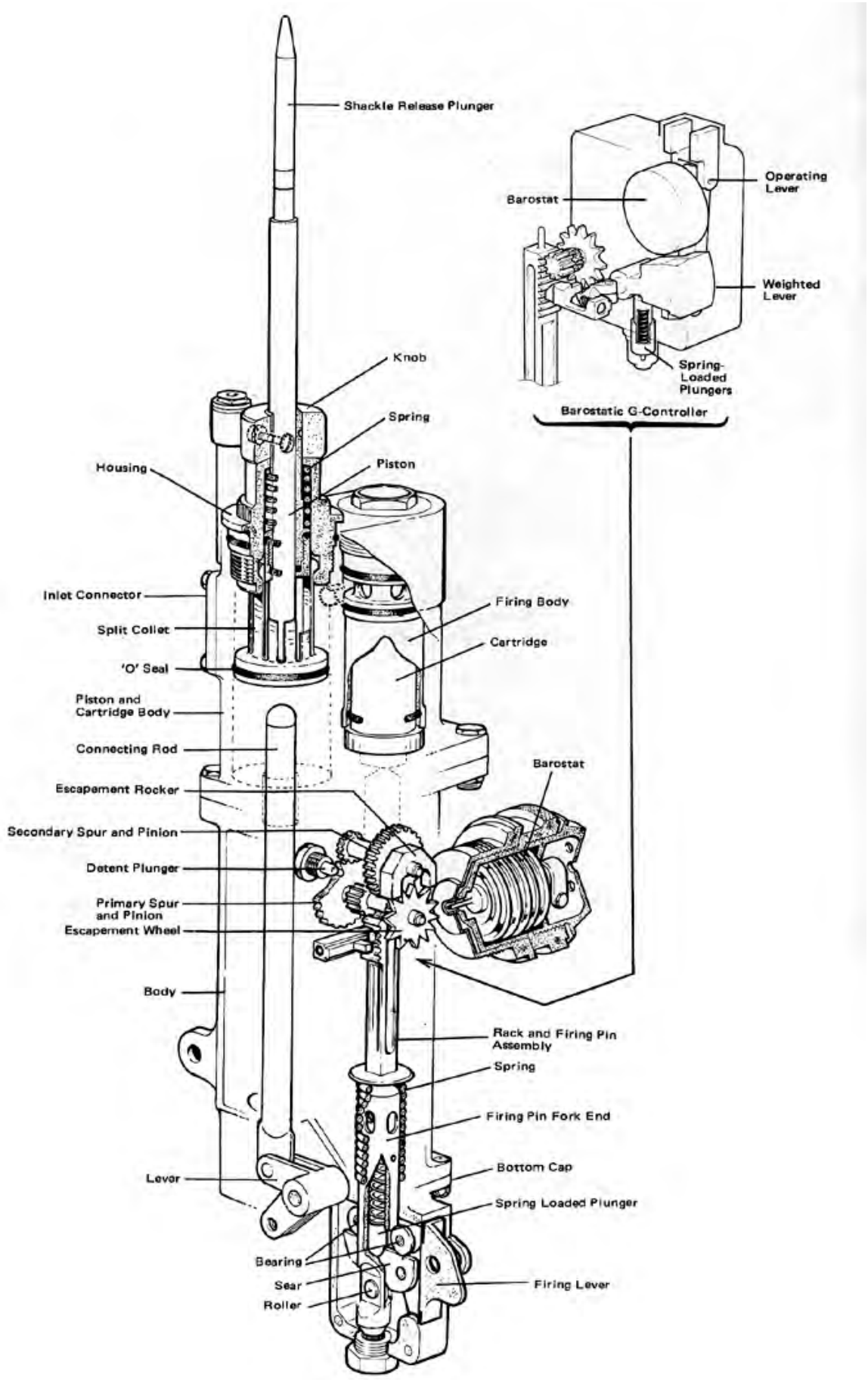
Barostatic time Release

The re-designed time-release unit for the Mk. 10 seats employs a time-delay mechanism operated by a trip rod as the seat leaves the aircraft, and controlled by a barostat at heights above the barostat setting, similar to previous designs. When the time-delay mechanism runs out a spring-loaded firing pin is released to fire a cartridge contained in the unit. Gas generated by the cartridge passes to a piston and rod assembly within the unit to withdraw the shackle release plunger to release the drogue, and mechanically operate the upper harness locks on the seat. Gas from the cartridge is also piped to a secondary cartridge in the drogue gun (to cater for any initial drogue gun failure) and to a piston unit in the lower rear portion of the seat pan, to operate the lower harness locks and release the P.E.C. man portion, leg and arm restraint, and the negative g strap lock.

The new unit also incorporates a barostatic g controller. The function of the g controller is to control the opening of the parachute at altitudes above 6000 feet. Rapid opening of the parachute is essential at low altitude to achieve the maximum recovery capability for the pilot, but as altitude increases, rapid parachute deployment becomes unnecessary. The g controller increases the parachute deployment time above 6000 feet, to limit the g forces experienced by the pilot on parachute opening.

The g controller consists of a barostat, an operating lever and a weight. Below 6000 feet the barostat is compressed by atmospheric pressure and moves the operating lever into engagement with the weight, preventing the weight from moving. Therefore, below 6000 feet the time-release unit will deploy the parachute in 1.5 seconds irrespective of speed. Above 6000 feet, the barostat expands, disengages the operating lever from the weight and allows the weight to operate.

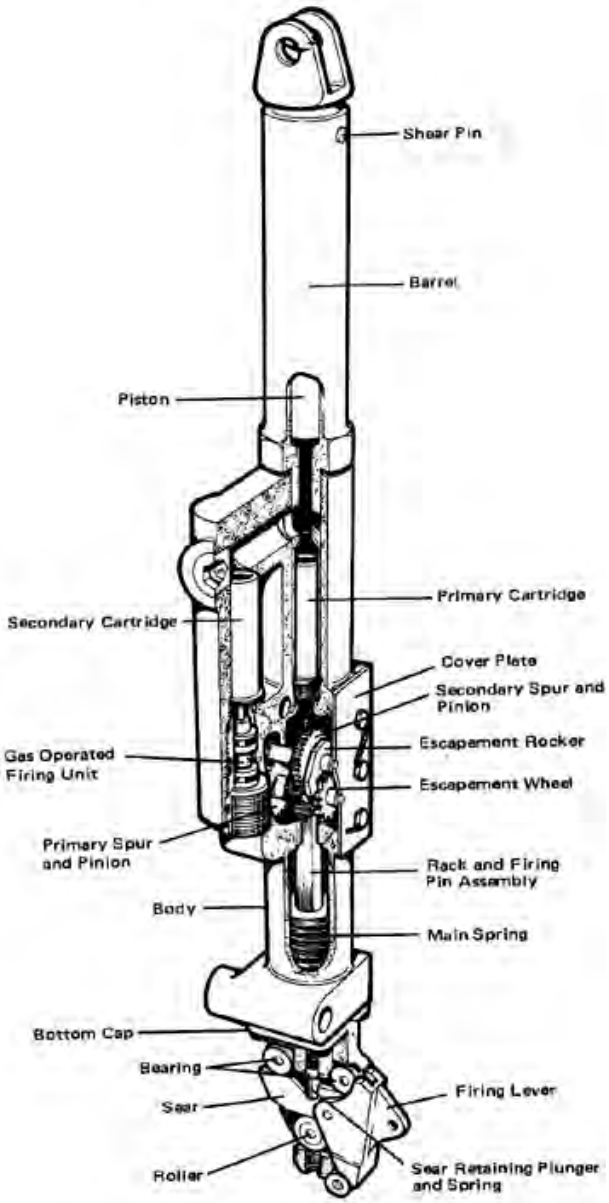
If deceleration forces of more than 3 g are exerted by the pull of the drogue, the weight will move down and engage a pawl with the starwheel in the time-release mechanism. As soon as these forces reduce below 3 g, the weight moves upwards, releasing the starwheel and permitting the time-release unit to operate.



Barostatic time-release unit fitted to Mk.10 seats

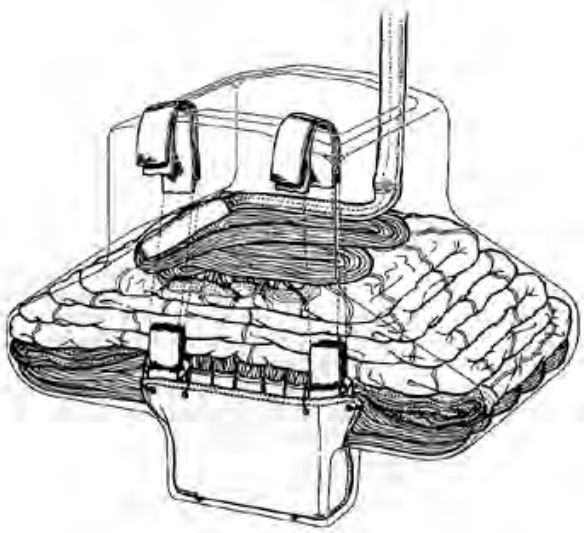
Drogue Gun

The re-designed drogue gun has a similar sear-operated firing pin controlled by a time-delayed mechanism, cartridge, barrel and piston arrangement as previous drogue guns, but is provided with a secondary cartridge contained in a breech parallel to the body of the gun. The lower end of the secondary breech is provided with a gas-operated firing unit and the upper end is joined by a horizontal gas passage to the body of the gun just below the barrel.



On normal operation the sear is withdrawn by its trip rod as the seat ejects; when the time-delay mechanism runs out, the firing pin fires the primary cartridge and the piston is expelled in the normal manner. Should however the gun fail in any way, gas pressure from the barostatic time-release unit will be supplied (when that unit functions), to the gas-operated firing unit of the secondary cartridge, firing the secondary cartridge to expel the piston. Should the time-release unit fail, gas pressure will be supplied by the manual separation breech in the seat pan, which is fired when the manual separation handle is operated.

Above: Drogue gun fitted to Mk.10 seats.



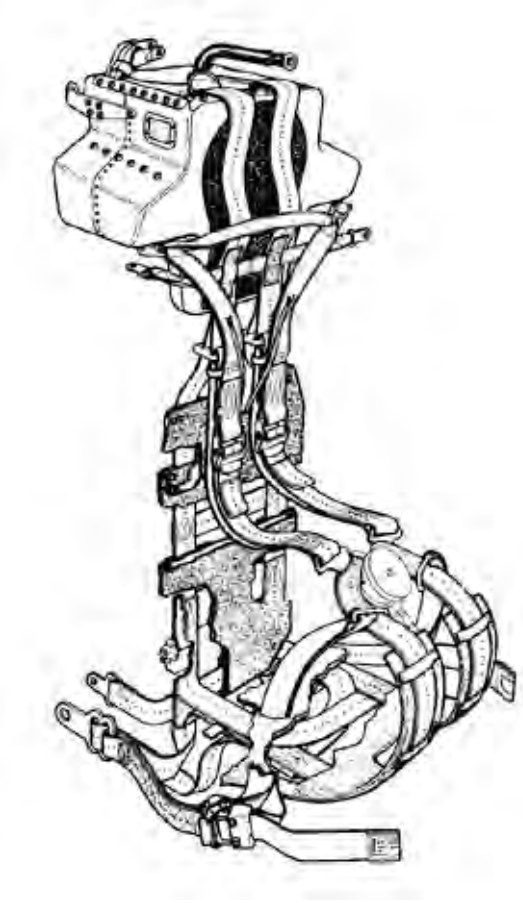
Parachute stowed in the headrest (Drogues removed)

Combined Drogue / Parachute

The drogue assembly and the parachute are packed in one container at the top of the seat main beams and forms the occupant's headrest. This design feature obviates the necessity for a separate parachute pack, simplifying the harness arrangement, and permits both drogue and parachute to stream quickly and clear of the seat structure. Servicing and packing of both drogue and parachute is simplified, as the container is quickly detachable for servicing in a parachute workshop.

A GQ Aeroconical parachute is used. This parachute opens rapidly without excessive deceleration loads, enabling the time delays to be significantly shortened.

Simplified Two-Point Combined Harness



The harness of the Mk. 10 seats is a combined parachute/seat safety harness as many of the previous seats, but has been simplified by mounting the quick-release fitting permanently on the negative-g strap, the lower end of which is held in a lock in the seat pan. The remainder of the harness consists of two lap straps, two leg loops, two shoulder straps and a back pad attached to the straps by beckets. Lugs fitted to the lower end of each shoulder strap are the only two connections made into the quick-release fitting when strapping in. Prior to plugging in the lugs of the shoulder straps, each leg loop is passed through a "D" ring on the extremity of the relevant lap strap and the appropriate shoulder strap passed through the leg loop before plugging into the quick-release fitting.

Harness assembly as fitted to Hawk aircraft

The upper end of each shoulder strap is provided with a roller shackle. Through these shackles are passed the straps of the harness power retraction unit, which are then plugged into the top harness locks. The lower straps of the harness are equipped with two metal lugs which plug into the lower harness locks.
This arrangement of harness considerably quickens and simplifies the strapping in procedure and provides a marked improvement in comfort and in the degree of restraint.

Single Action Manual Separation System

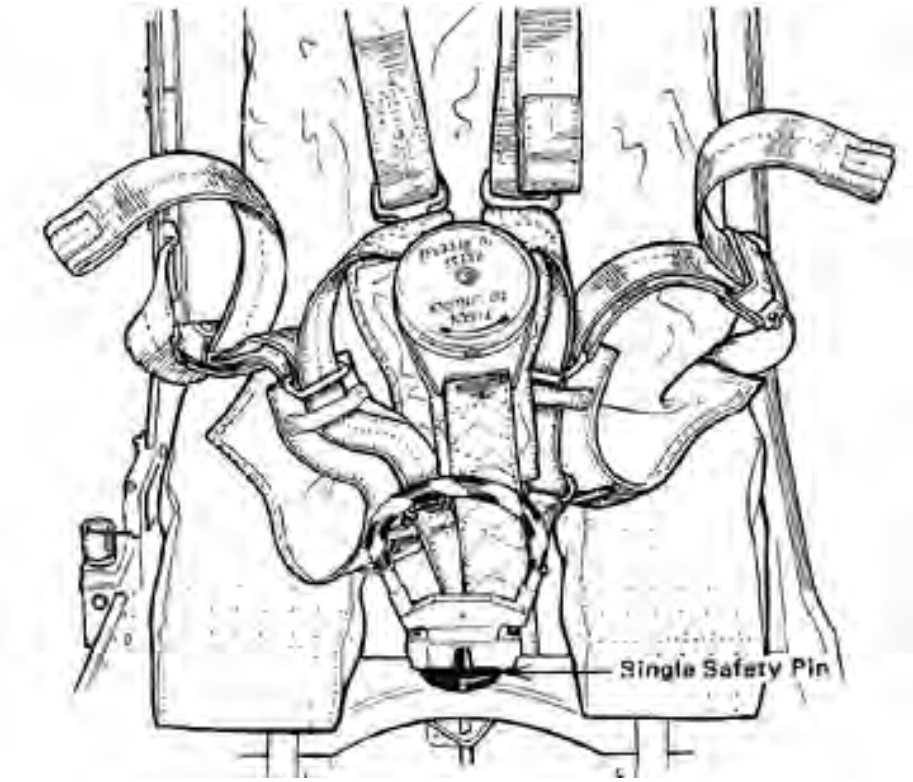
The newly designed manual separation system caters for failure of the barostatic time-release unit and failure of the drogue gun either above or below the height at which the barostat on the time-release unit is set. This is achieved by pulling up a manual separation handle on the seat pan which fires a cartridge to deliver gas pressure to operate the drogue

gun, time-release unit and harness release mechanism. This permits the drogue gun to deploy the drogue, which in turn pulls out the personnel parachute automatically, without the necessity for the occupant to manually deploy his parachute with a rip cord handle. No rip cord handle is fitted to the parachute harness.

A safety lock interconnected with the seat firing handle prevents the manual separation handle from being operated unless the seat firing handle is withdrawn first.

Single Safety Pin

A great improvement over earlier ejection seats is the reduction in the number of safety pins required to make the seat safe. Only one safety pin is required to make the seat safe for parking.

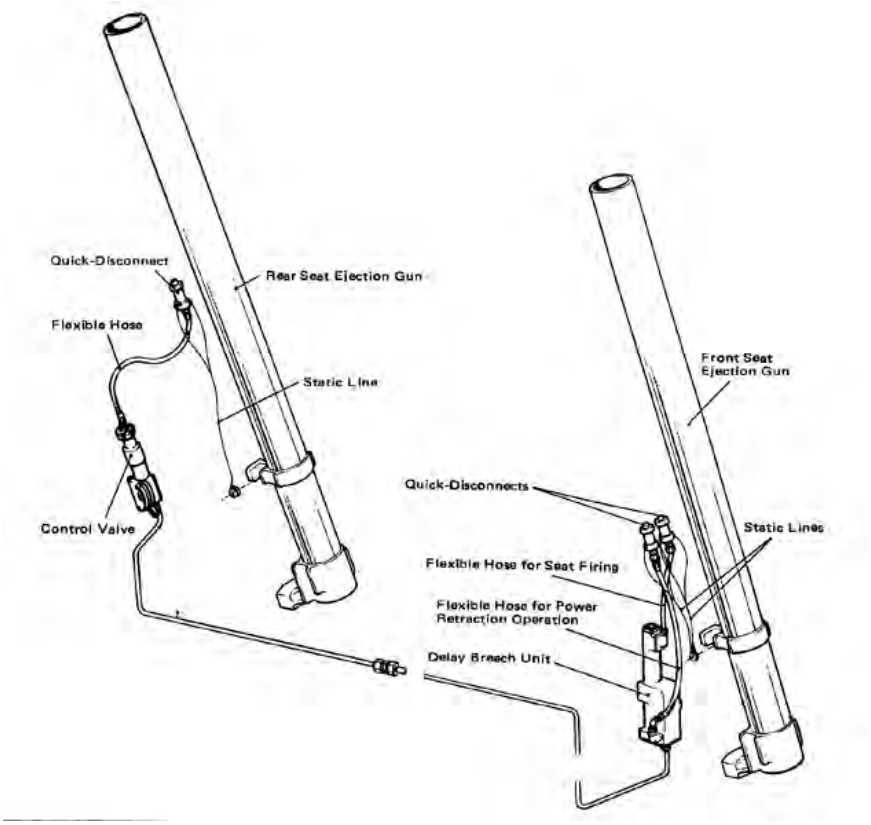


Location of Single Safety Pin

Arm Restraint

Arm restraint is a new innovation on the Mk. 10 seats; it restrains the arms during ejection to prevent injury during high speed ejections. The system consists of two restraint lines (one for each arm) and two snubbing units, each fitted with a guillotine. On ejection, the lines pull taut, pulling the arms inwards to the body where they are restrained by the snubbing units. When the time-release unit operates (or the manual separation handle is operated), gas pressure from the appropriate cartridge operates the guillotines to sever the lines and release the arms. The degree of restriction to the arms is limited to permit sufficient movement to operate the manual separation handle.

Command Ejection



Command ejection system as fitted to Hawk aircraft

Command ejection is the term applied to the facility embodied in two-seat aircraft to ensure automatic ejection of both seats in the correct sequence when ejection is initiated by one crew member. Before the development of this facility, it had been the practice when an emergency arose, for the pilot to order his crew member to eject, and then eject himself. At lower altitude, the time lag entailed in this procedure could well prove fatal to one or both. With a command ejection facility, the only action necessary when an emergency arises is for the pilot to pull his own firing handle. This action will result in all crew members being ejected in the pre-determined sequence; the whole sequence being automatic and, where a canopy jettison system is fitted, this is also phased into the sequence and the canopy jettisoned automatically before ejection commences.

The adoption of the gas-operated firing system has greatly enhanced the design of command ejection systems. The gas pressure produced by the initiator cartridge of each seat is piped to a disconnect block mounted on the seat; from this disconnect block, the gas, in addition to being delivered to the harness retraction unit and the sear withdrawal unit, is also piped to the other ejection seat via a control valve and a time-delay breech unit. The control valve has two positions, enabling the system to be selected OPERATIVE or NON-OPERATIVE. The time-delay breech unit ensures that the necessary time interval occurs between the seats ejecting before the unit fires its own cartridge to eject the other seat. The disconnect blocks are automatically disconnected by static cables as each seat ejects.

Improved Harness Power Retraction

A new design of harness power retraction unit is fitted horizontally to the front face of the seat structure. The trim roller brackets of the shoulder harness are attached to two webbing straps wound on spools within the retraction unit. The spools are spaced 8 inches (203 millimetres) apart to provide improved and more stable restraint. Selection to locked or unlocked condition is by means of a control lever on the seat pan. In the unlocked condition the unit permits freedom of movement under normal flight conditions, but will restrain the occupant in the event of excessive forward acceleration of the body.

When the seat firing handle is pulled to initiate ejection, gas pressure from the seat firing cartridge initiates ejection of the seat and also fires a cartridge in the power retraction unit.

Gas pressure from this cartridge acts upon a piston within the unit and the horizontal movement of the piston is transferred through a drive screw, to rotate a splined shaft on which are mounted the two webbing spools. At the same time the gas operates a locking panel to lock the unit in the retracted position.

Gas Operated System

The gas-operated system of the Mk. 10 seats includes not only the actual firing of the seat and operation of the harness power retraction unit, but also the release of the drogue and harness locks when the time-release unit operates. Provision is made for both drogue gun failure and time-release unit failure by the introduction of a gas-operated manual separation system. The rocket firing system is included in the complete gas-operated system.

Reference to the colour diagram opposite will assist in tracing the various gas flows of the system.

Ejection is initiated by pulling up the seat firing handle, which withdraws the sear from the seat firing unit under the seat pan and fires the initiator cartridge. Gas from this cartridge is piped to the harness power retraction unit breech, and to a sear withdrawal unit at the top of the main beams. The gas delivered to the harness power retraction unit breech, fires the cartridge in that breech to operate the retraction unit and pull the occupant to the ejection posture. The gas delivered to the sear withdrawal unit operates a piston to rotate the seat firing cross shaft and withdraw the sear from the ejection gun firing unit. The seat commences to eject and trip rods withdraw the sears of the drogue gun and time-release unit.

Towards the end of the ejection gun stroke, the remote rocket initiator cartridge is fired by its static cable; the gas produced is piped to the firing unit in the rocket pack, firing another cartridge, which in turn ignites the rocket fuel.

The drogue gun primary cartridge fires 0.5 seconds after ejection and deploys the drogue. The time-release unit fires 1.5 seconds after ejection and the gas produced operates mechanical linkages to release the drogue shackle and operate the upper harness locks. This gas is also piped to a cylinder and piston unit in the lower rear part of the seat pan, where it operates linkages to operate the lower harness locks, release the leg-restraint lines, man portion of the PEC (if fitted) and arm restraint (if fitted). If the ejection takes place above the height at which the barostat of the time-release unit is set (normally 10,000 feet), the operation of the time-release unit will be delayed until the seat and occupant have descended to that altitude.

Gas from the time-release unit cartridge is also piped to the gas-operated secondary firing unit of the drogue gun. If the drogue gun primary cartridge has failed to fire and deploy the drogues in the normal manner, the secondary cartridge is fired, the drogues are deployed and they in turn pull out the personnel parachute as the drogue shackle has already been released.

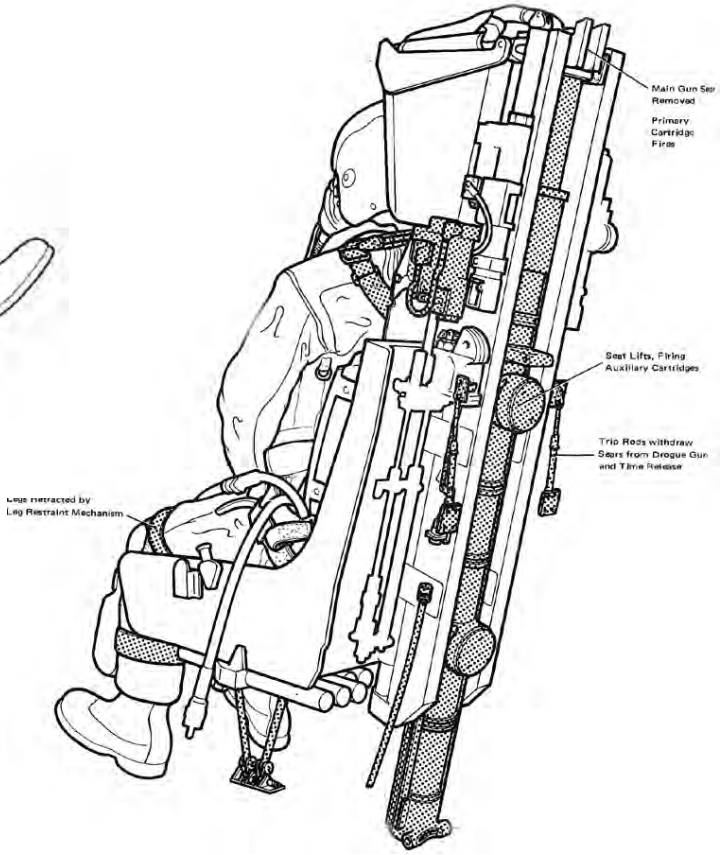
Should the drogue gun fail to fire during ejection, no action is required by the occupant. When the time-release unit operates at 1.5 seconds after ejection, gas passes to the drogue gun secondary cartridge, resulting in drogue and parachute deployment.

Should the time-release unit fail to fire following normal drogue deployment, the occupant

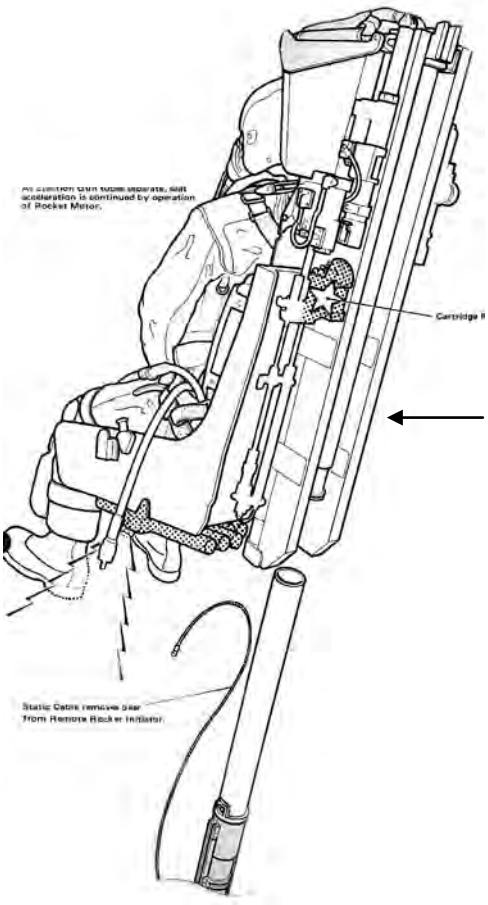
pulls up the manual separation handle. This results in the firing of a cartridge in the manual separation breech, the gas produced being piped to the time-release and the cylinder/piston unit in the seat pan to release the drogue and operate all the seat locks. The gas is also delivered to the drogue gun, so that in the event of a combined failure of drogue gun and time-release unit, the drogue is deployed to stream the parachute.

EJECTION SEQUENCE OF Mk.10 SEATS

1- Firing Handle pulled to initiate Escape Sequence, Pilot's body retracted to correct ejection posture.



2- Ejection Gun fires, unlocking seat from aircraft and ejecting seat. Seat movement operates Leg Restraint and Arm Restraint (if fitted), disconnects personal services, actuates Emergency Oxygen and trips Drogue Gun and Time-Release mechanism.
The Rocket Firing Cable starts to extend.



Depending on the aircraft type, the canopy is either:

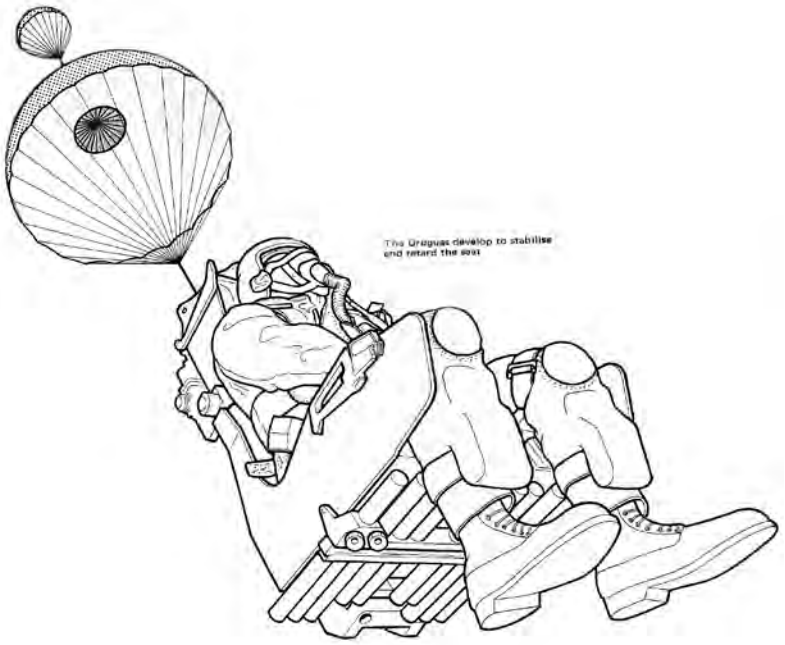
- Jettisoned by operation of Seat Firing Handle
- Fragmented by Miniature Detonating Cord
- Penetrated by ejection seat

Emergency Oxygen Tripped Aircraft Supplies Disconnect.

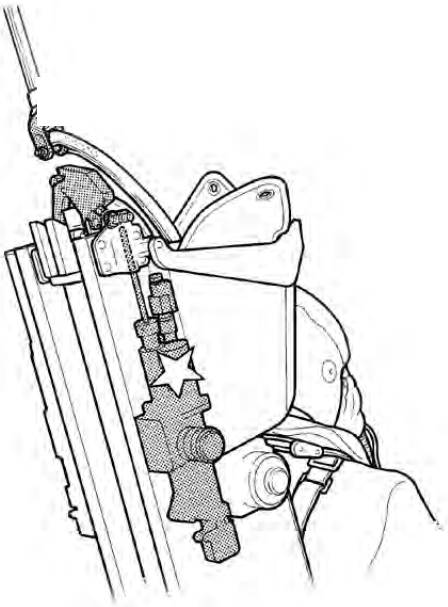
3- As Ejection Gun tubes separate, seat acceleration is continued by operation of Rocket Motor.

4- Half a second after initial seat movement, the Drogue Gun Fires and deploys the Drogues

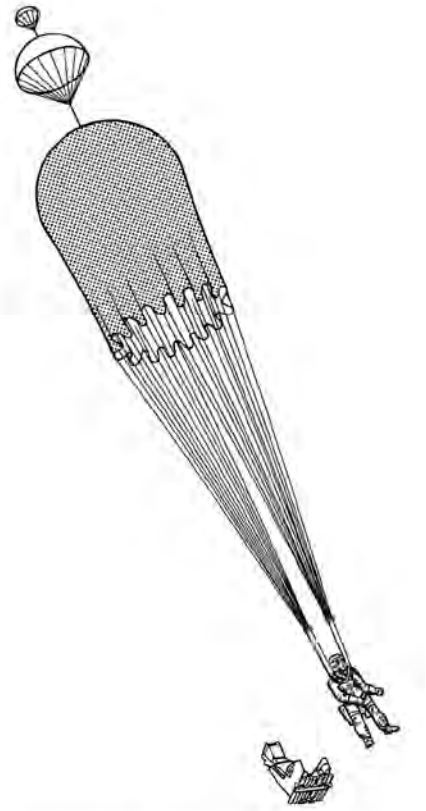
5- The Drogues develop to stabilise and retard the seat.

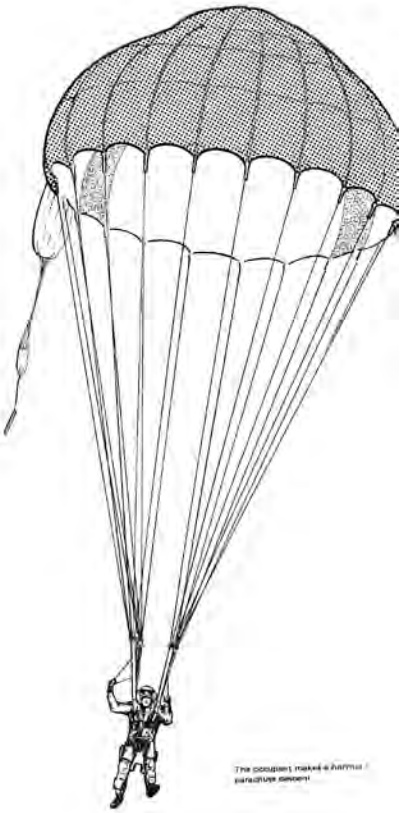


6- One and a half seconds after initial seat movement or at Barostatic Altitude, the Time-Release mechanism operates to release the Pilot's Harness, Leg Restraint System and Arm Restraint System (if fitted), and P.E.C. Man Portion from the seat. The Scissor Shackle releases the Drogues from the seat to stream the man-carrying Parachute.



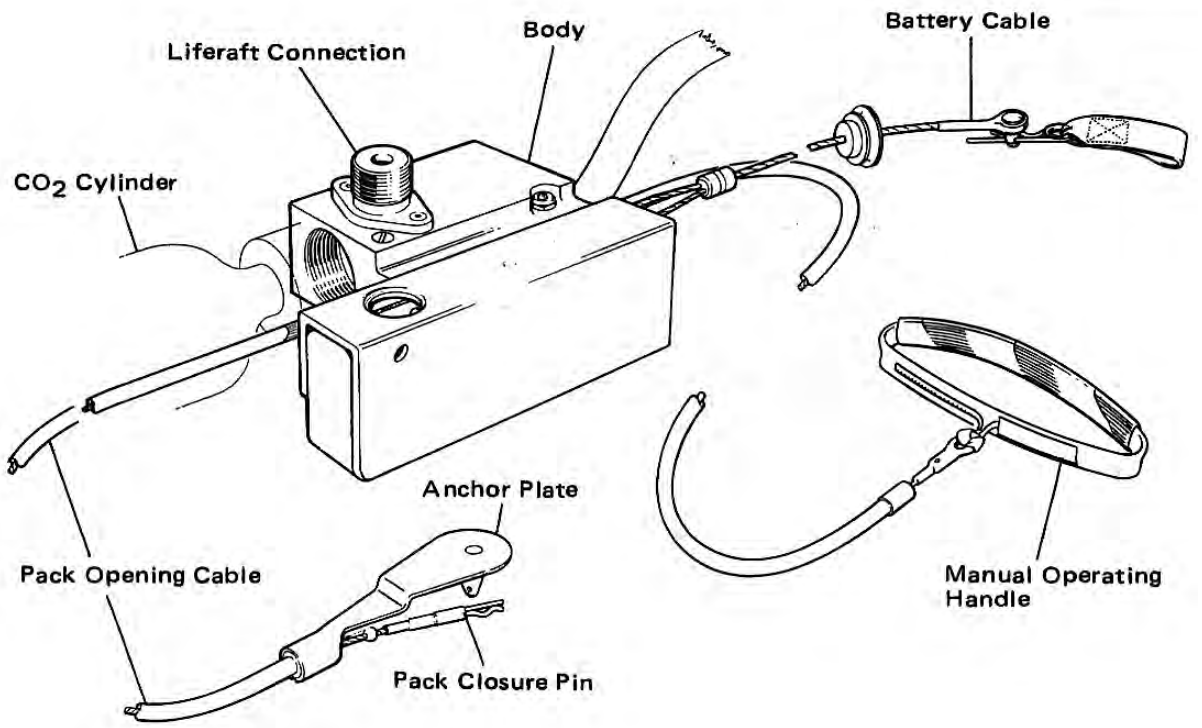
7- The Drogues deploy the Parachute and the occupant is lifted out of the seat, allowing the seat to fall free.





8- The occupant makes a normal parachute descent.

Martin-Baker Patent Automatic Liferaft Inflation Unit



Follo
wing the introduction of rocket assisted ejection seats, there has been a marked reduction in the number of fatal ejections due to lack of altitude. However, the number of cases in which the ejectee has drowned after an otherwise successful ejection has increased. In a number of these cases, it has been noted that the liferaft was not inflated; had it been, the chances of survival of the ejectee would have been greatly improved. From research of the problem of survival after water entry, a complementary device has been evolved, the Martin Patent Automatic Liferaft Inflation Unit. This will ensure that the ejectee, upon re-surfacing, will find his liferaft fully inflated and ready for boarding, even if he has not lowered his personal survival pack before entering the water.

The automatic inflation unit replaces the manual-operating head fitted to the CO2 cylinder of the liferaft and is initiated by a water-activated battery. To prevent inadvertent operation, the water inlet apertures of the battery are sealed with moulded-in nylon plugs, which require a predetermined load to remove them.

After ejection, as the seat falls away on separation of seat and occupant, the nylon plugs are removed by cables attached to the seat, exposing the battery apertures for activation. Where time permits, the ejectee will normally lower his personal survival pack to the length of its lowering line shortly before water entry, but this is not essential with this automatic inflation unit. On striking the water the battery will be immersed and an electrical impulse will fire a cartridge. Gas pressure generated by the cartridge will cause a piston to rotate an operating lever, which will withdraw the closure pins securing the survival pack flaps and allow the pack to open. Continued rotation of the operating lever will trip the spring-loaded cylinder operating head, thus puncturing the cylinder diaphragm and discharging the cylinder to inflate the liferaft.

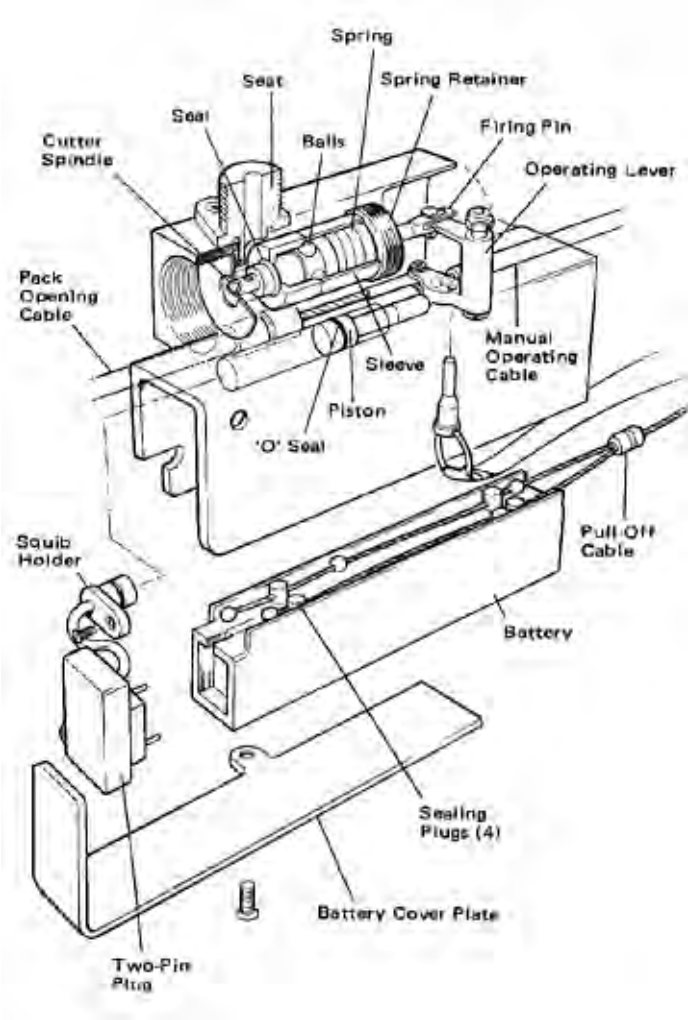
Less than two seconds will elapse from the moment of pack immersion to the start of liferaft inflation, so that the raft is ready for boarding by the time the ejectee has recovered from his water entry. To cater for the unlikely event of a malfunction in the automatic unit or if the

ejectee wishes to inflate his liferaft on land as a locating aid or accommodation, a manual handle is provided by which liferaft inflation can be accomplished in the normal manner. The manual inflation handle is located in the same position as on other personal survival packs, thus eliminating any retraining problem.

This automatic inflation unit can be fitted to any hardshell bottom-opening personal survival pack and can be easily adapted to fit any other personal survival pack.

The Martin Patent Automatic Liferaft Inflation Unit is a product of the continued research and development undertaken by Martin-Baker to further improve the outstanding lifesaving capabilities of their escape systems.

Single Handed Survival Pack Disconnect



This system provides for quick release of the survival pack during descent after ejection, by operation of one quick release connector instead of the customary two. This is particularly desirable if the seat occupant is incapacitated in one hand.

A single webbing strap passes through two buckles located one on either side of the survival pack. An arrowhead shaped fitting, fitted to each end of the single webbing strap, connects into two quick release connectors fitted to the harness (one on the left side and one on the right side).

Operation of either quick release connector will allow the pack to fall away, whereas previously it was necessary to operate both connectors.

Underwater Ejection

An underwater escape system has been designed by Martin-Baker to provide automatic escape from submerged aircraft, even though the occupants may be unconscious. An ejection seat fitted with this underwater system is capable of ejecting the occupant from the aircraft, separating him from the seat and bringing him to the surface by means of a fully inflated lifejacket, no action whatsoever being necessary by the seat occupant.

Incorporation of the underwater system provides the standard seat with this additional

facility, but in no way affects the normal ballistic operation of the seat during an airborne ejection.

Modifications to the seat consist of an air cylinder mounted either on the seat or on the aircraft bulkhead and charged to 3000 lb per square inch. Air from this cylinder is released at a pre-set depth as the aircraft sinks, and pressure is directed into the ejection gun cylinder. This results in the extension of the ejection gun tubes and subsequent seat ejection.

Air is also piped to a drogue gun trip rod release unit to disconnect the trip rod, to prevent the gun from firing and thus prevent the drogues from deploying.

The time-release unit operates as in a normal ejection to give seat/man separation. Bladders positioned behind the parachute pack and beneath the survival pack inflate during separation, to push the occupant clear of the seat. Parachute deployment is prevented by severance of the parachute withdrawal line by a guillotine as the occupant leaves the seat. After separation from the seat, the occupant rises to the surface aided by his inflated lifejacket, which is inflated by pressure from a CO2 cylinder mounted on his lifejacket, and actuated by air pressure from the air cylinder.

Conclusion

One cannot fail to be impressed by the progress made in ejection seat development since 1944 when ejection from aircraft was first being considered. This progress was made possible by the skill, guidance, and untiring effort of the late Sir James Martin C.B.E., D.Sc., C.Eng., F.I.Mech.E., Hon.F.R.Ae.S., producing an aircraft escape system second to none, which resulted in the saving of 5,000 lives by the end of 1982, a total which continues to increase at an average rate of more than 3 per week.

For his magnificent work in this field, Sir James received the following honours and awards:-

Appointed Officer of the Order of the British Empire in June 1950.

Appointed Commander of the Order of the British Empire in June 1957.

Appointed Knight Bachelor in 1965.

Doctor of Science conferred by Queen's University Belfast 1970 and by The College of Aeronautics Cranfield 1975.

Awarded the Wakefield Gold Medal of the Royal Aeronautical Society in 1951.

Awarded the Laura Taber Barbour Air Safety Award in 1958 (Sir James being the first non-American to receive this award).

Awarded the Cumberbatch Air Safety Trophy in 1959.

Awarded the Royal Aero Club Gold Medal in 1964.

Fellow of Institute of Science and Technology, University of Manchester.

Queen's Award

The Martin-Baker is proud and honoured to have received the Queen's Award for Export Achievement and the Queen's Award for Technological Achievement on a number of occasions.

Development continues in an untiring effort to keep pace with the development of modern aircraft. Today, the ejection seat still appears to be the ultimate means of escape from aircraft of the foreseeable future, and the name of Martin-Baker will remain in the forefront as representing the most reliable aircraft escape system in the world.