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FORESTS DEPARTMENT OF WESTERN AUSTRALIA

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INTRODUCTION

Prescribed burning using aerial ignition was first developed as a joint project between the Commonwealth and Scientific Industrial Research Organization (CSIRO) and the Forests Department of Western Australia in 1965 (Baxter, Packham and Peet, 1966).

This publication describes the development of incendiary machines used for aerial burning in Western Australia (W. A.), from the original hand-operated machine to the most recent machine developed by the Forests Department (FD) of Western Australia and the Western Australian Institute of Technology (WAIT-Aid Ltd) in 1981.

HISTORICAL BACKGROUND

Since the earliest days of colonization in W. A., periodic summer wildfires have ravaged the forests. Early foresters were alarmed by the damage caused and after 1918 pursued a policy of almost complete fire exclusion. However, by 1953 heavy accumulation of forest fuels or debris in the protected areas had resulted in many wildfires which caused serious damage to the forest. It became apparent that complete protection of the forest could not be maintained with the limited manpower and equipment available, especially in the presence of heavy forest fuels.

As a result, a complete review of the fire policy took place in 1954. Prescribed burning over large areas to reduce fuel hazards was introduced (Peet, 1967).

Early programmes of "hand burning" were carried out by gangs of men on foot. This method was slow, expensive and risky in dense, inaccessible areas. Consequently, alternative methods of lighting up large areas of forest were sought, and ignition from aircraft was an obvious choice. However, there were many technical problems to overcome, the most important being the development of a suitable and safe incendiary machine to be used in the aircraft.

The first incendiary machine was developed in 1965 by the CSIRO. In December of that year, this machine was used on the first large-scale aerial burn, on the Pingerup Plains near Walpole in Western Australia.

Despite a number of initial problems, in the summer of 1965/66 over 20 000 ha of forest was prescribe burnt using the incendiary machine. The use of aircraft and the new incendiary equipment enabled large areas of forest to be covered in a short time. This was a major step forward in fire control, as greater areas could be lit for hazard reduction burning, under ideal weather conditions and at relatively low costs (Baxter *et al*, 1966).

The success of the first venture led to 180 000 ha of forest being prescribe burnt in the spring of 1967. By 1968 the aerial burning programme was operational in Western Australia and has since played an increasingly important role in fire protection of State forest.

The value of prescribed burning was amply demonstrated when, in the wake of Cyclone Alby on 4 April 1978, a large number of fires escaped from normal burning operations. It took fire fighting crews an entire week to completely suppress all the fires, which burnt a total of 48 700 ha. However, the area of State forest burnt was relatively low (less than 7000 ha of hardwood and 280 ha of pine plantation) and might have been considerably greater if not for the fuel-reduced areas.

EARLY INCENDIARY MACHINES

CSIRO MANUAL INJECTION MACHINE - 1965

The first incendiary machine, used in 1965, is shown in Plate 1. The unit was mounted on the aircraft seat rails. It consisted of a crashproof container holding 2 L of glycol, with a manually operated syringe and metal trays containing 700 incendiary capsules. These capsules consisted of polystyrene tubes preloaded with potassium permanganate which reacts with the glycol, causing it to ignite some 30 seconds after the two chemicals are mixed.

The operation of this incendiary machine was completely manual. The operator was responsible for injecting the capsules with glycol and, after a predetermined period, ejecting them through a hole in the floor of the aircraft.

One of the drawbacks with the machine was limited storage space, which allowed only 700 capsules to be carried. This restricted the maximum area that could be burnt to 1400 ha per flight. Other disadvantages involved the machine's hand injector system, such as:

(1) operator fatigue,

(2) operating speed being limited to 15 capsules per minute over extended periods.

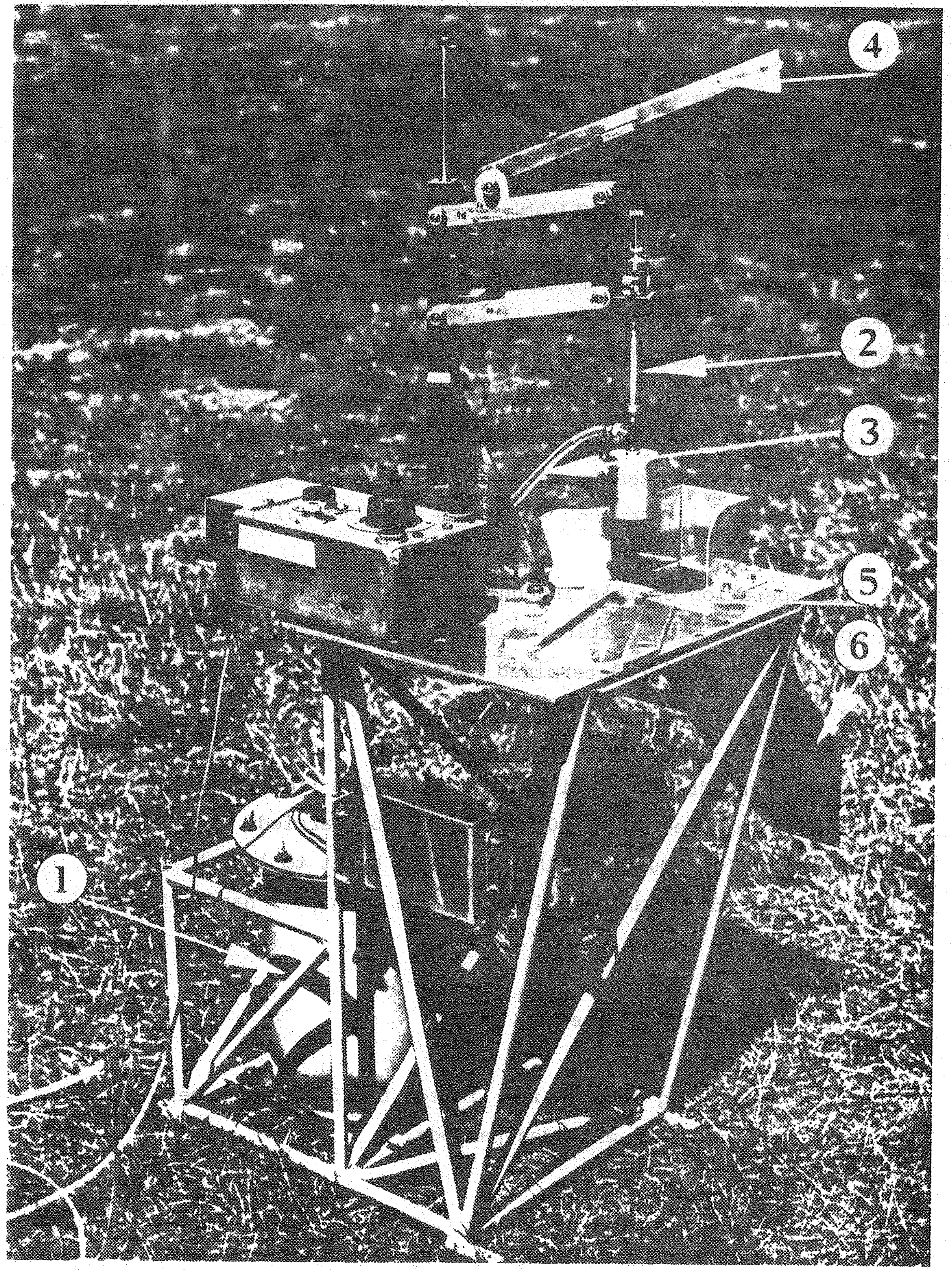

PLATE 1

THE CSIRO INCENDIARY MACHINE - 1965

1. Crashproof glycol container
2. Hypodermic syringe
3. Glycol feed tube
4. Hand lever to operate syringe
5. Loading position for incendiary
6. Ejection chute

CSIRO HAND LOADING INCENDIARY MACHINE - 1966

As a result of the successful trials with the original incendiary machine, considerable time and effort was spent on refining aerial ignition for prescribed burning by the CSIRO and the Forests Department of Western Australia (Packham and Peet,1967).

A new incendiary machine (Plate 2) was designed in April 1966 by Mr. C. A. Herring of the CSIRO and incorporated an electric motor to power an injector for priming capsules and an intermittent, rotating turntable. Capsules were manually loaded into the turntable and automatically injected with glycol. The primed capsules were then ejected from the aircraft at preset intervals. The machine's first operational flight was conducted on 8 November 1966 in the Mundaring area of Western Australia.

This semi-automatic priming machine allowed:

(1) capsules to be ejected more easily and at twice the rate than was possible with the hand priming machine,

(2) greater flexibility of the ignition pattern, to suit the weather and fuel conditions (Peet, 1967).

Other improvements included:

(1) the storage capacity for the capsules being increased to 4000 capsules, which were stored in metal trays to minimize fire risk,

(2) the capsules being reduced from 25 mm to 21 mm in diameter, to conserve space,

(3) designing a special diaphragm in the top of the capsule which melted when the capsule ignited. This allowed the release of any pressure build-up from the chemical reaction, thus preventing the capsule top from blowing off and scattering the capsule's contents.

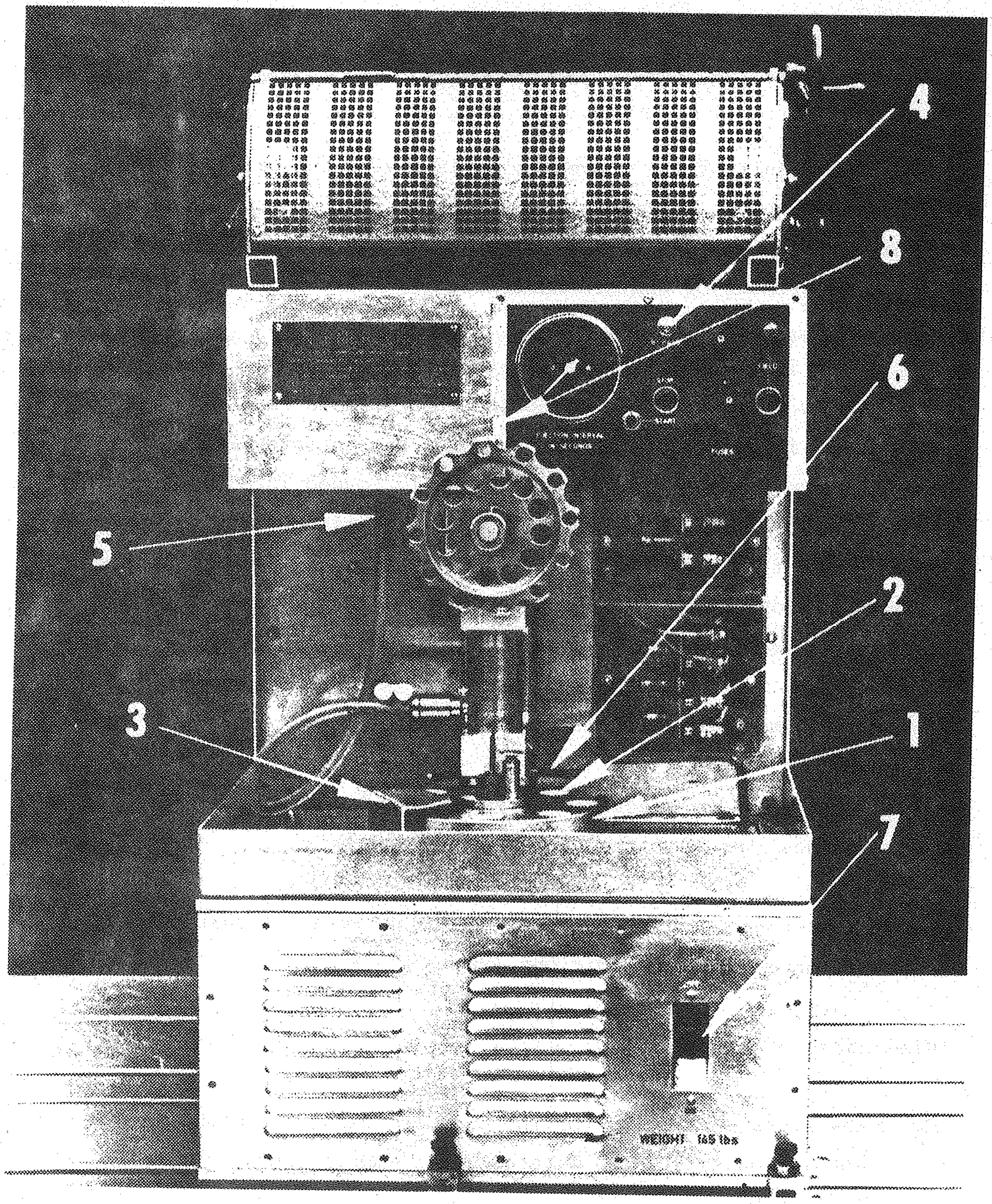

PLATE 2

THE CSIRO INCENDIARY MACHINE - 1966

1. Turntable for loading incendiaries
2. Ejection tube
3. Bridge to push down capsules
4. Bypass switch
5. Glycol on/off tap
6. Spray bar for fire extinguisher
7. Fire extinguisher switch
8. Emergency handwheel

PROBLEMS WITH THE CSIRO DESIGN

As the machine gradually deteriorated with time, more parts required replacement or rebuilding. When replacements were sought after ten years of operation, standard components were becoming more difficult, if not impossible to obtain.

The machine's design and reliance on hand loading of capsules limited the maximum speed of ejection to 37 capsules per minute. The method of power transmission also prevented the machine from operating at higher speeds.

Also, by 1979, the two existing CSIRO units had been in service for over ten years, and were considered to be nearing the end of their serviceable life. The alternative to continually replacing worn parts was to find or construct a new incendiary machine.

WESTERN AUSTRALIAN MACHINE (W.A.M.) 1980 - 1982

By 1980, the Forests Department's aerial burning programme was expanded to include small hazard reduction burns. Consequently a new incendiary machine that could eject capsules at a faster rate, thus reducing the distance between ignition points on the ground and increasing the intensity of the burn, was required.

One of the major advantages of using aerial ignition for smaller sized burns is that it eliminates the risk of sending ground crews into forests with dense undergrowth or logging debris, or on steep slopes, to set fire to the area by hand. Also, the cost per hectare of aerial ignition is approximately one-third that of hand burning, and the range and flexibility of the former allows a number of burns to be carried out in different localities in one day.

A number of prototype incendiary machines were tested, but none met the Forests Department's design and safety specifications (Appendix 1). Thus it was decided to construct a new incendiary machine that would comply with these specifications.

BUILDING THE PROTOTYPE

Construction Brief

The brief for constructing the new incendiary machine was to design and develop a machine which had lesser mass, better drive and a faster feed rate than the CSIRO machine.

WAIT-Aid investigated the alternatives and reached the conclusion that it was best to follow the design of the CSIRO incendiary machine because of its proven performance. They redesigned and produced equipment to meet the Forests Department's requirements, particularly for an increase in loading speed and a reduction of the machine's mass.

The construction of the prototype Western Australian Machine (W.A.M.) involved:

(1) modification to improve the existing drive system,

(2) replacing the horizontal chain drives with gears,

(3) eliminating the crown wheel and pinion to the injector cam,

(4) simplifying the injector by reducing the number of parts,

(5) redesigning the feed mechanism, the Geneva mechanism and the turntable, and adding a 240 capsule drum magazine,

(6) generally updating and miniaturizing the electronics.

MAJOR COMPONENTS OF THE W.A.M.

Motor and gearbox

Power for the W.A.M. is supplied by a .25 kw - 24 Volt Direct Current (VDC) shuntwound electric motor, which is connected to a 12.5:1 gearbox. (Diagram 1, parts 1 and 2).

The output shaft from the gearbox drives both the injector cam and the Geneva mechanism (Diagram 1, parts 3 to 5).

Geneva mechanism

The Geneva mechanism is an intermittent-motion device allowing power to be periodically transferred from the gearbox output shaft to the Geneva cam.

The gearbox output shaft rotates continuously to drive the injector cam which sets the injection cycle in motion. During each injection cycle the Geneva cam remains stationary, until the cycle is complete, and is then reactivated. The Geneva cam then drives the magazine which in turn moves the turntable (Diagram 1, parts 5 to 8). The intermittent motion of the magazine is synchronized to the movement of the turntable.

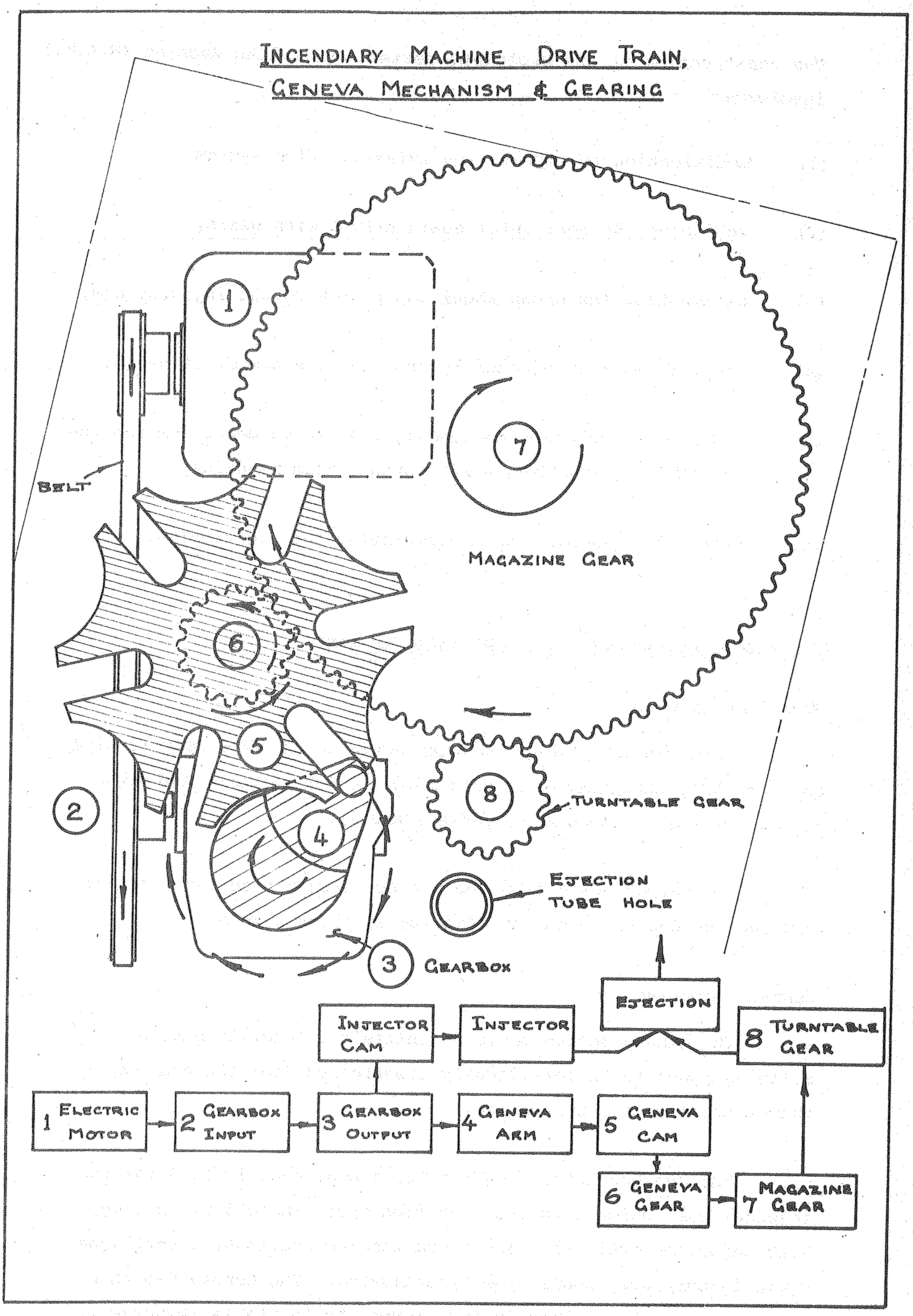

DIAGRAM 1

The six station Geneva mechanism supplies the intermittent motion to drive the magazine and the turntable which holds the capsules.

Injector cam and injector

The injector cam and injector perform five different functions during each injection cycle: pierce, inject, dwell, strip and dwell.

The injection cycle, which is in progress while the turntable (which holds the capsules) is stationary, consists of the injector cam activating the injector pump and syringe to "pierce" the capsule top, "inject" the glycol, "dwell" for 10^{o}, then "strip" or remove the needles from the capsule. During the final "dwell" stage the needles return to their original raised position and the turntable is again moved by the action of the Geneva mechanism (Diagram 2). As the turntable rotates, it positions the primed capsule over the ejection tube, from where it drops out of the aircraft.

Because of the system of interconnected gears, as one capsule is dropped from the aircraft, another capsule is simultaneously ready for priming, and a third falls from the magazine onto the turntable.

OPERATIONAL RESULTS

The prototype W.A.M. is shown in Plate 3, and Diagram 3 illustrates the assembly diagram specifications.

Testing first commenced in December 1980, and on 7 April 1981, after inspection by the Department of Aviation, the W.A.M. received official flight approval and was also approved for operational use.

Testing continued until May 1982, and in that period 38 000 capsules were ejected and prescribed burns were carried out under vastly differing conditions. These ranged from dense karri forest in the south-west of W. A. to grass fuels under very hot and humid conditions in the Northern Territory (N. T.).

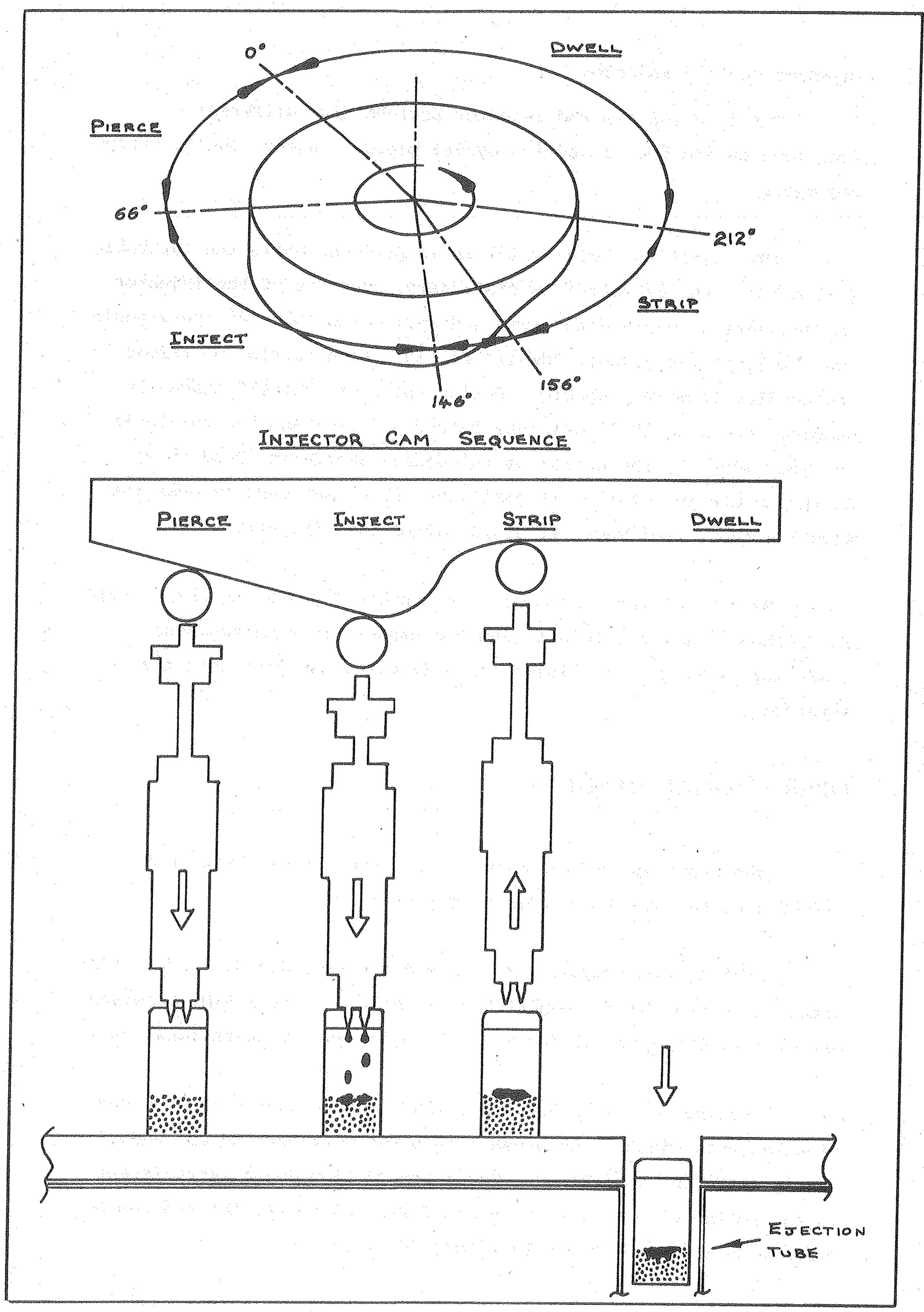

DIAGRAM 2

Diagrammatic sequence of capsule injection with rotating injector cam and single injector.

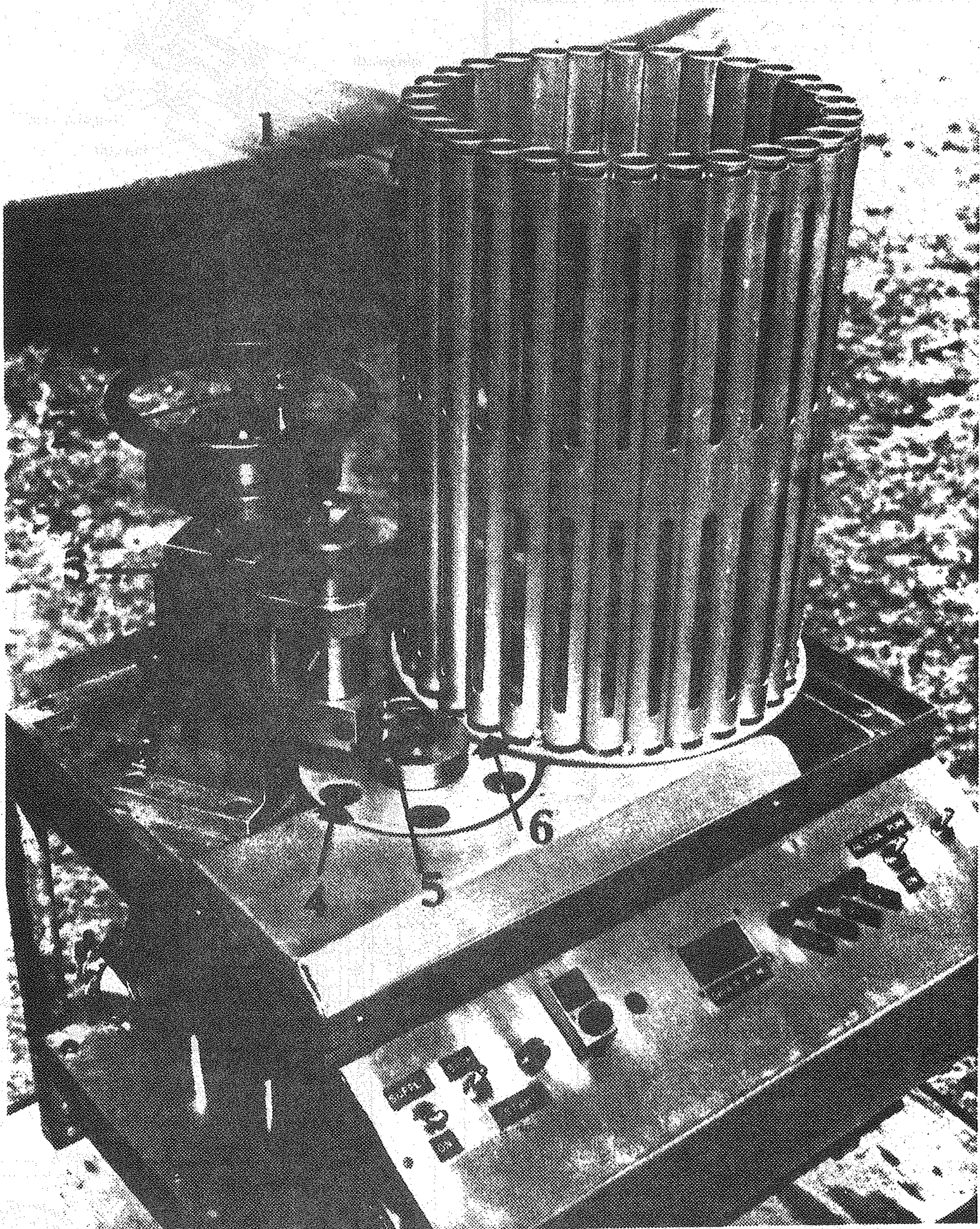

PLATE 3

THE PROTOTYPE W.A.M. - 1980

1. Gravity-feed drum magazine holds(240 capsules)
2. Injector cam release pin
3. Injector
4. Ejection tube
5. Turntable release pin
6. Loading position on magazine

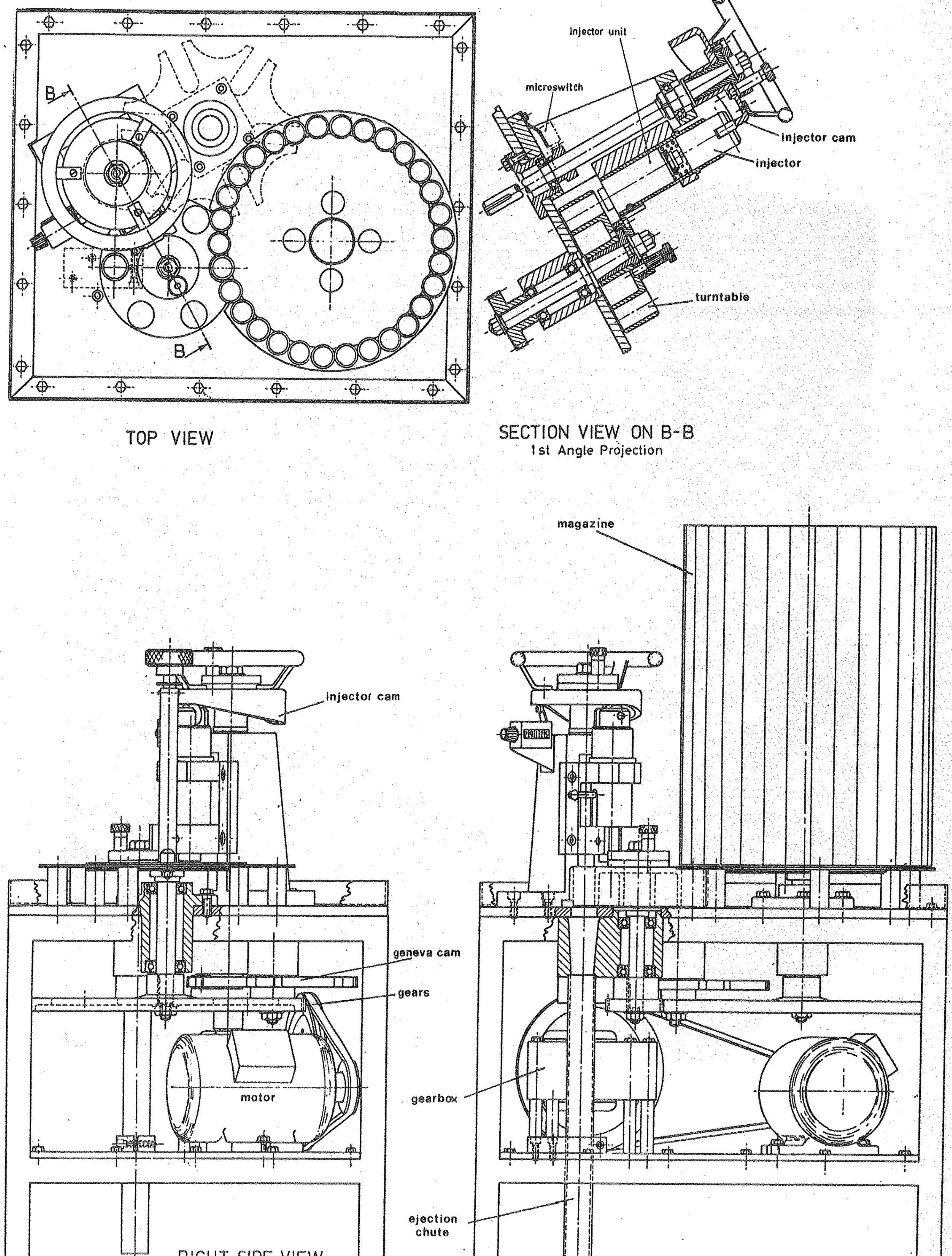

DIAGRAM 3

Assembly drawing of the prototype W.A.M.

Several modifications were carried out during the testing period, including moving the Geneva cam mechanism to provide better clearance for the dropping tube, and modifying the design of the gatling-type drum magazine to allow capsules to drop freely and avoid jamming. It was also necessary to replace some of the electronic components with special purpose, heavy-duty units to prevent burning out.

High temperatures in the N. T. (above 35°C) frequently distorted capsules. This made manual loading essential as the capsules would jam in the drum magazine. However, under the cooler conditions in Western Australia, the machine proved satisfactory for ejection rates of up to 60 capsules per minute. At faster rates, some capsules were sheared off and at present the machine is not recommended for speeds above 60 capsules per minute.

Problems with the automatic feed stage occur mainly at ejection rates of over 90 capsules per minute. At this speed, friction or obstruction in the magazine can occur, preventing the capsule from falling out of the magazine and into the turntable. Consequently the capsule is sheared and spills its contents as it comes out of the magazine. Spilled permanganate is considered an unacceptable safety hazard in this type of operation.

The design of the drum magazine for automatic loading is suitable at ejection rates below 60 capsules per minute. However, storage in the aircraft is not efficient, as each drum only holds 240 capsules for a volume of 0.042 m^3. More efficient ways of storing capsules safely in a smaller space are being investigated in conjunction with the shearing problem. Generally, drawbacks with the automatic feed system are caused by:

(1) the vertical loading position of the capsule,

(2) friction in the magazine tube,

(3) capsule shape or deformations which cause shearing when capsules do not drop freely.

FUTURE DEVELOPMENTS

Investigations are being carried out to:

(1) improve the automatic feed system by horizontally loading the capsules into the ejection position,

(2) reduce the space required for capsule storage.

As a result of the work for the Bush Fires Council of the N. T., a hand-feed adaption of the W.A.M. has been developed for burning pastoral leases. Two of these machines have been designed to fit into Britten-Norman Islander and Partenavia aircraft (Plate 4). However, modifications for other aircraft are readily achieved.

The W.A.M. will only be available to authorized fire control organizations. Further work is continuing to refine and improve the W.A.M. However, in order to maintain safety and operational performance, the Forests Department reserves the right to approve any modifications to this machine. Adequate testing will be arranged by the Forests Department before any modifications are introduced operationally.

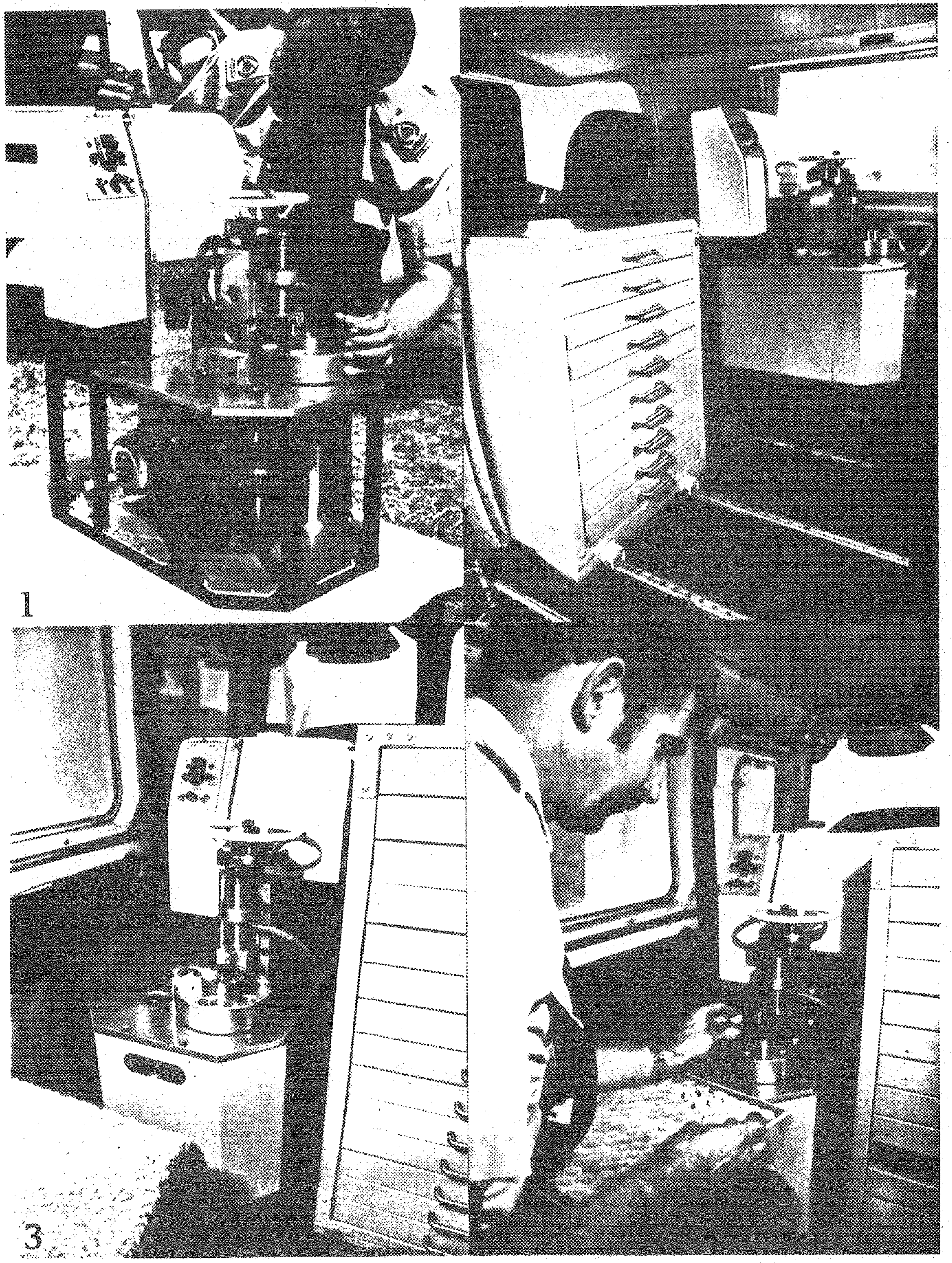

PLATE 4

THE WESTERN AUSTRALIAN MACHINE (W.A.M.) - 1982

1. Inspecting W.A.M. before installation.
2. Equipment installed in Partenavia P68B aircraft
3. Installation in Britten-Norman Islander aircraft
4. Loading turntable with capsules in Islander

ACKNOWLEDGEMENTS

I wish to thank Mr Harold Tooby, a lecturer in Mechanical Design Drawing at WAIT, for designing the prototype for the W.A.M. I would also like to thank Neil Rawlings of WAIT and Robert Gray of the Forests Department Communications Branch, for their work on the original electronic design of the W.A.M.

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APPENDIX I

Forests Department design and safety specifications for the construction of the W.A.M.

DESIGN SPECIFICATIONS

(1) The weight of the machine must not exceed 50 kg and be preferably under 30 kg.

(2) The materials used in construction must be light, strong, non-combustible, non-corrosive and non-magnetic.

(3) The machine must be suitable for installation in a fixed-wing aircraft operating directly from a 28 Volt Direct Current (VDC) power supply, with standard aircraft type circuit-breakers to protect the equipment.

(4) The machine must be designed for maximum continuous operation, six hours per day, six days per week, in temperatures of 15^{o} - 35^{o} C and humidity of five per cent to 60 per cent during operations.

(5) An automatic feed device capable of priming and ejecting capsules at rates between 20 and 120 capsules per minute must be designed.

(6) The feed chute and controls must be located in front of the operator.

(7) The glycol tank must have a 7 L capacity, be constructed of stainless steel and be fitted with a sight guage or meter.

(8) The construction of the incendiary machine must meet Department of Aviation Standards for acceleration loadings and must be approved and designed for aircraft installation and operation.

Also, incendiary capsules were redesigned to meet the performance specifications for those in the original CSIRO machine. The criteria used for the redesign were:

(1) The capsules must have an ignition delay after priming.

(2) The capsules must sustain a period of intense heat.

SAFETY SPECIFICATIONS

(1) Containment Zones

(a) Capsules must be stored in fireproof and crash-proof storage units.

(b) Ejection equipment must be designed to withstand fire. The primed capsule must be separated from other capsules by a solid metal barrier, preventing fire spreading to adjacent capsules and a fire path developing between the primed capsule and the storage container for unprimed capsules. A fire path can develop when there is a continuous supply of capsules leading from the priming source to the incendiary storage area.

(c) The automatic feed must be restricted to no more than eight capsules, which are separated from the other capsules by a metal barrier. Thus, in the event of a fire it would be easily extinguished.

(2) When the machine is switched off, the last capsule injected must complete the injection cycle and then be automatically ejected.

(3) The capsule transport and injection mechanism must have a manual override in the event of a power failure.

(4) The ejection hole and ejection tube must vertically line up at the completion of each injection cycle, without any bends or obstructions which could inhibit the free fall of a primed capsule.