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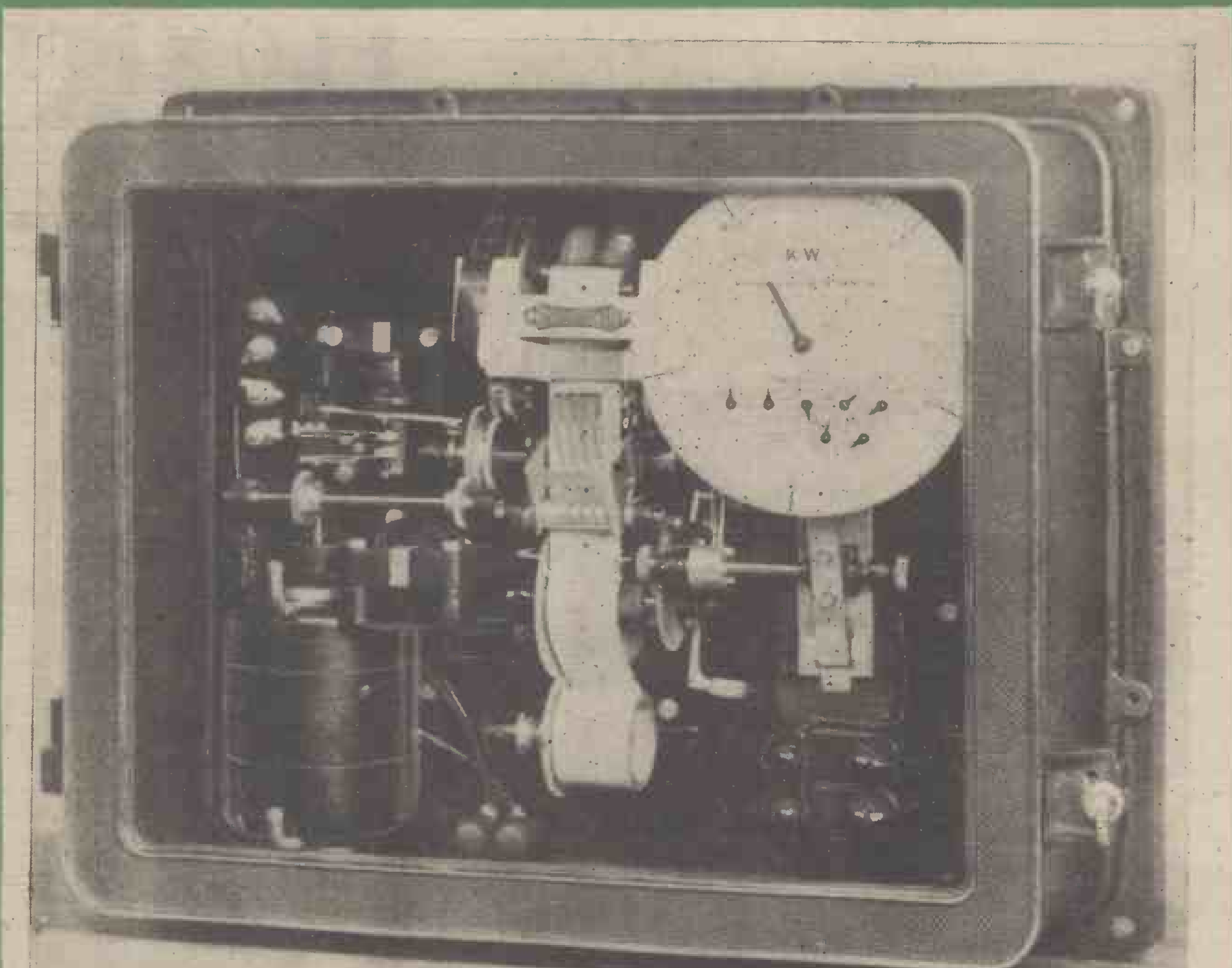

Rocket Propulsion

Pre-war Experimentation in Britain

By K. W. GATLAND

(*Continued from page 374, August issue*)

THE Manchester Interplanetary Society was the second organised British rocket group, having its inception in the summer of 1936, due to the efforts of Mr. E. Burgess (now president of the Combined British Astronautical Societies). Its function was entirely independent of the pioneer British Interplanetary Society, whose existence did not become widely known until some years later. Contact did not, in fact, materialise until after the original Manchester Society had been dissolved and another group, the Manchester Astronautical Association, inaugurated in its place.

Prior to its dissolution, the former Manchester Society carried out numerous experiments with powder charge rockets, and of these several are worthy of mention. It will be remembered that in the majority of similar experimentation previously mentioned, the propellant charges were obtained commercially, and while this was also true of the early months of the Manchester group's activity, their later research also concerned the manufacture of special charge cases as well as the charge filling.

Of the experiments conducted, the most promising lines of development were those resulting from the investigation of methods of combustive control in powder charge rockets and the flight stability of rocket projectiles.

The production of charge cases, too, formed an important part of the Manchester group's research during the 1936-7 period and many of these, fitted with special nozzles and heat-resistant liners, were proved during test greatly superior to similar charges of commercial origin. As an outcome of this research, there were also developed several original methods of loading and compressing the propellants, which resulted in increased steadiness of burning and a subsequent improved combustive efficiency. Later test firings were made with rockets which embodied various devices intended to control the rate of combustion.

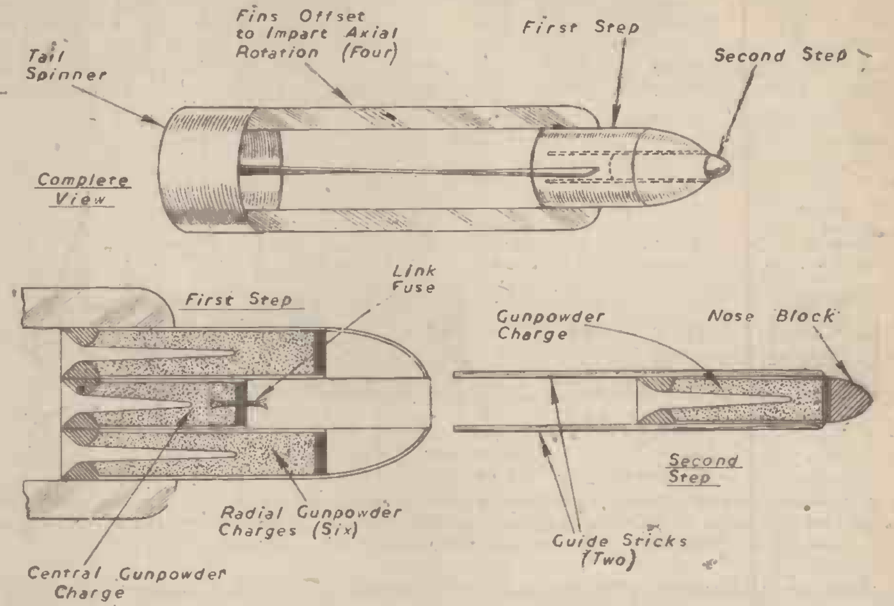

Fig. 33.—Diagram of two-step powder rocket, developed by the Manchester Interplanetary Society (1936).

Stability

The initial experiments concerned the flight trajectory of rocket projectiles, and a number of types were produced and flight tested with a view to determine the particular method of stability best suited to function under normal conditions of atmosphere.

There are several methods of achieving this stability, and the society found its most satisfactory results in axial rotation—created either by offset vanes fitted in the efflux, or airstream, or through the offsetting of grouped rocket tubes, or nozzles. Other models were fitted with the more conventional straight-set, stabilising fins and spinners. A selection of the types which featured in the testing is shown in Fig. 32.

Control of Combustion

The rockets constructed to test firing and combustion-control methods comprised several of the "step" type and, of these, a model having two propulsor components (Fig. 33) gave a highly creditable and stable performance.

The first "step" comprised seven individual black powder charges arranged in a cellular construction and fused so that the firing of the tubes took place in the order "four," "three." The second component, a single charge rocket, was fitted to form the rocket nosing, and designed to fire from the "carrier" rocket at the latter's greatest velocity. This was arranged through an intercommecting fuse ignited from the central charge.

Stability of the original component was achieved by the provision of offset airstream fins which causes rotation about the body axis. The second "step" embodied two balancing "sticks," but depended also upon the angular momentum which it derived from the parent rocket.

It will be appreciated that the main point of significance with this type of rocket is that the small component is released in combustion at a high velocity, and therefore its function is so much nearer the maximum propulsive efficiency.

A firing test carried out at Manchester in December, 1936, gave good illustration of this point. The complete rocket, propelled by the lower component, reached a height of between 150 to 200 feet before the release of the second "step," which

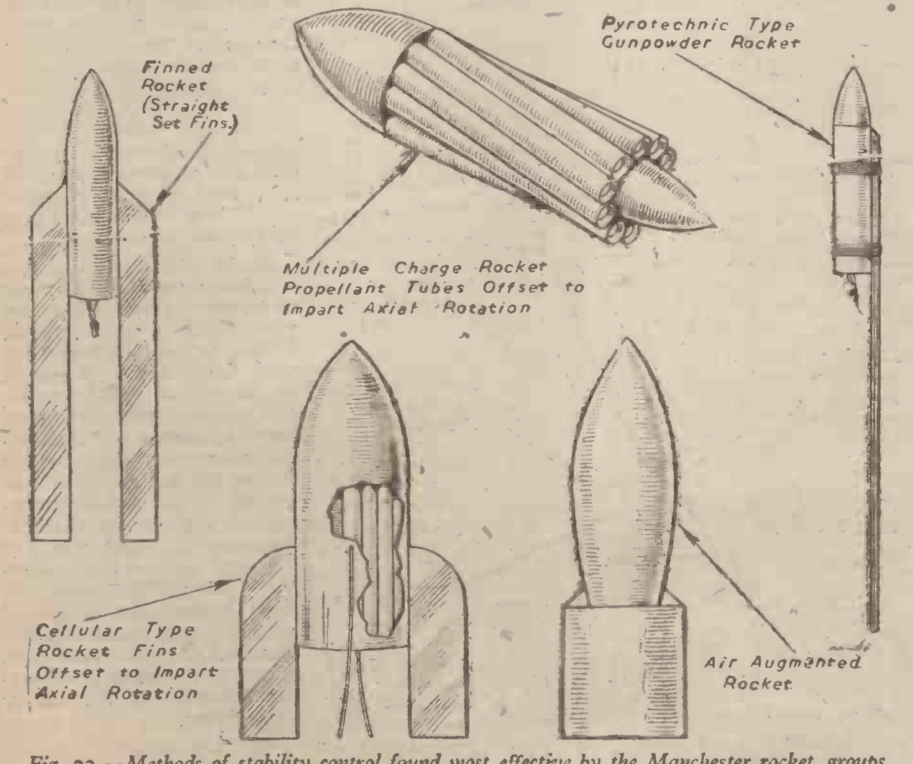

Fig. 32.—Methods of stability control found most effective by the Manchester rocket groups.

accelerated at such a rate as to render its trajectory invisible to the observers. The small rocket was not recovered after the experiments.

Fuel Developments

Working in conjunction with a pyrotechnical expert, the late Lt.-Col. W. T. Southam, the experimental committee of the Manchester Society developed several black powders of various constituencies, for use both with paper formed and metal charge cases. These experiments, which were commenced in December, 1936, involved the society for a year, and although their results can hardly be said to have contributed greatly towards propellant development, several of the powders proved highly effective for the type and were the means of testing several original propulsion systems.

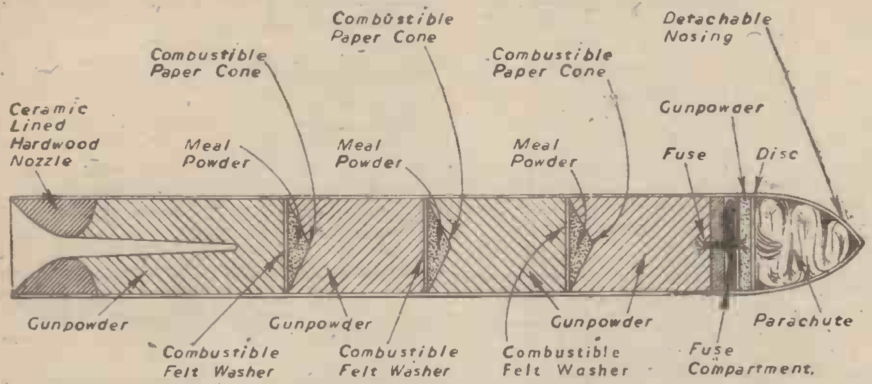

Fig. 34.—Diagram of a powder rocket having four charge compartments. This system is intended to prevent disruption of the entire propellant through isolation of the burning section. Developed by the Manchester Astronautical Association from a German idea (1938).

During the course of this research a number of public demonstrations involving the flight testing of rockets, both paper and metal, were undertaken by the society at Manchester. It was, in fact, while testing under these conditions before a large crowd who, despite repeated warnings, would not retire from the launching site, that an accident occurred in which several of the bystanders were slightly injured by fragments of an aluminium rocket which exploded on the launching rack.

This incident brought court proceedings against the society, and the findings showed that an infringement of the Explosives Act of 1875 had been caused by the admixture of potassium chlorate in a black powder composition which comprised the base chemicals, potassium nitrate, sulphur and charcoal. The union of potassium chlorate and sulphur was the offending act, any propellant of this constituency being decidedly unstable and liable to instantaneous detonation.

A few months later the Manchester Interplanetary Society was dissolved, to be followed almost immediately in December, 1937, by the inception of another group, the Manchester Astronautical Association. The founders were E. Burgess and the late T. Cusack, two prominent members of the former society.

The work of the new Manchester group was more or less a continuation of the earlier research, with the emphasis again towards the improvement of combustive control in powder rockets.

An interesting development aimed at improving the performance of single charge rockets is shown in Fig. 34. It will be observed that the propulsion charge is divided into a number of separate compartments, the powder in each being insulated by layers of combustible felt. The propellant sections are made as capsules, each of which has a conical-formed base of rapid burning powder, the idea being to produce the largest possible area of burning.

The main advantage of this arrangement is that any slight explosion which were to occur would limit the disruption of the fuel to one section, whereas a similar happening in a conventional "fuel store" rocket would invariably explode the entire filling.

The diagram shows a development of the original scheme which the experimental committee tested in August, 1938. The trial rocket had four fuel compartments and a conventional paper case, although an extended nozzle and fireclay choke were fitted. No parachute was incorporated in the test type.

Cellular Construction

Tests of cellular rockets followed, and in these the association found its most satisfying results.

In essence, the cellular method of rocket construction means simply a power unit composed of a number of "fuel store" charges arranged in lateral contact, each a complete propulsion element in itself and having individual means of ignition. The rocket illustrated (Fig. 32) had merely a single-bank cellular arrangement, but other types have been produced in which several banks of cellules are employed. In this latter instance the expended tubes are automatically jettisoned, succeeding tubes being fired upon their release until the entire propulsion system is expended. It will be readily appreciated that this removal of dead mass brings about a progressive improvement of the fuel/weight ratio, and a parallel increase of the propulsive efficiency.

The combustive control is another factor that is much improved by cellular construction. It is obvious that the thrust of the unit can be increased or decreased at will by the firing of varying numbers, or different sizes, of cellules.

Apart from light "retaining" members, the cellules themselves compose the structure, and the strength of the rocket is very largely dependent upon the density of the propellant and the cellular formation. The need for any involved and weighty arrangement of forming members is thereby eliminated.

The model tested in the Manchester experiments was a single-bank cellule rocket, and this proved to be one of the best stabilised of any type produced during the entire period of active research. Stability in this instance was achieved by the offsetting of four small fins to the air-stream, which caused rotation about the body axis. In order to ensure stability during the initial moments of ascent, the launching device had means for pre-rotating the rocket, thus enabling correct function from the instant of release. This was simply a turntable with a length of metal rod projecting from its centre, mounted to a base platform, and the rocket, which had a metal sleeve built in along its axis, fitted over the guide rod and rested on the turntable (Fig. 35). The turntable was rapidly rotated just prior to launching, thereby imparting an initial spin to the rocket, which was maintained in flight by air reaction on the fins.

Only one problem of significance arose from the cellular tests. This involved burn-out of the power element, in that should one of the cellules burn through, it was capable of destroying the entire make-up of the cellular unit. A later series of firings, however, proved the remedy to be dependent entirely upon the efficiency of tube construction and, using carefully prepared tubes, these further trials gave no evidence of burn-out.

In the autumn of 1938 the association constructed a light air-augmented rocket (Fig. 36) powered by a single charge. In this model four small fins were fitted at the aft end of the body shell, and attached over these, and extending from the rear, was a cylindrical augmenter tube, which also served as a stabiliser. On test the rocket showed a particularly high rate of acceleration, and the flight was well stabilised with a high trajectory. As in the majority of flight experiments conducted by the group, the rocket was launched from a metal tube. A two-rail launching apparatus featured in the earlier experiments.

The foregoing is a review of the pre-war experimentation

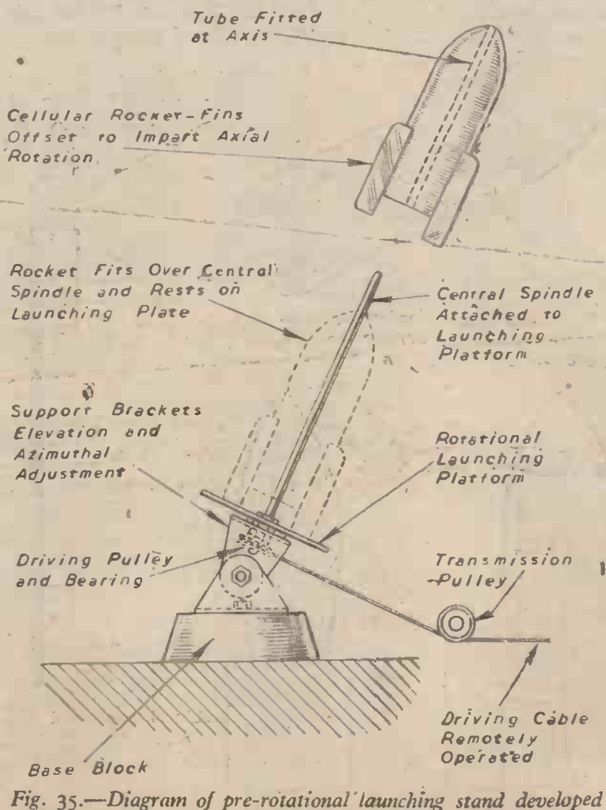

Fig. 35.—Diagram of pre-rotational launching stand developed by the Manchester Astronautical Association (1938).

conducted by the Manchester rocket groups. A great deal remains to be said of their work during the war period; but first, a word about the investigations of contemporary organisations which functioned in Britain in the years leading to the outbreak of hostilities.

The Paisley Research Group

Among the early rocket groups whose activities largely concerned the practical was the Scottish, Paisley Rocketeers' Society, a student body of some twenty members, subsequently affiliated to the Manchester Astronautical Association. Its inception took place in February, 1936, and working under the direction of its founder-president, Mr. J. D. Stewart, the group carried out a programme of technical development which involved the design, manufacture and testing of various powder charge rockets.

Of these perhaps the most significant were the rockets produced for aerial survey. The first model of this type was fired in August, 1938, and its initial weight, complete with a miniature camera and parachute was only 9oz. The operation of the camera was achieved through the pull on a wire cable, which connected the parachute shrouds and the shutter, and thereby ensured the function of the shutter at the same time as the ejection of the parachute, when the rocket was at its peak trajectory. In this first flight trial the rocket rose to a height of approximately 300ft. before ejecting its parachute, and landed at a point 600ft. from the launching rack. Although in this test the camera operated as arranged, the photograph secured showed only sky.

A second rocket was constructed, and as in the previous model, the camera was fitted at the nose, with the lens aperture at the side, the sole difference being the provision of a small mirror fixed above the lens at an angle of 45 degrees. This arrangement ensured that the resultant picture was of what lay below the rocket at the instant of the parachute's opening.

Further trials were made with a rocket having a parachute and camera which operated on the ejection of the expended propulsion charge—this latter arrangement was adopted in order to lessen the rate of descent by reducing the weight and so ensuring that the camera, and any other delicate equipment carried, reached the ground with the least chance of damage. Other models, of light construction and not fitted for delicate apparatus, simply incorporated an ejecting device to free the propellant case, and no parachute, thus making the rockets so light that they dropped without harm. The loss of momentum which occurred with the release of the case, however, caused an appreciable reduction of the range. A solution would appear to be the provision of a simple time fuse, set to discharge the case at the peak trajectory.

Stabilised

The society carried out still further tests of rockets stabilised by rotation, and though of simple construction and small size, several of these proved highly effective, both as regards range and accuracy of trajectory.

The first model of this type comprised simply three small powder charges grouped around a short length of dowel, each unit set at a slight angle to the longitudinal axis. This rocket, whose initial weight was $\frac{3}{8}$oz., travelled a distance of 250ft. in well-established flight before assuming a spiralling trajectory, due presumably to the reduction of the rotational velocity as the fuel became exhausted. Its final range was a little under 500ft.

A second rocket, having four inclined tubes and no central stick, travelled a distance of 150ft. Its path of flight was at first irregular, but became more stable as the angular rotation increased, the poor range being accounted to excessive drag created at the commencement of flight.

To overcome the initial instability the society built a special launching apparatus for pre-rotating the rockets, similar, in fact, to the one developed earlier by the Manchester group. When pre-rotated, the models rose smoothly and were quite effective until the latter stages of flight, when "spiralling" would invariably occur. In some instances the oscillatory motion was apparent under power as well as during momentum, and it is likely that this was caused by unequal thrust in the tubes and through the rocket shell not being truly symmetrical.

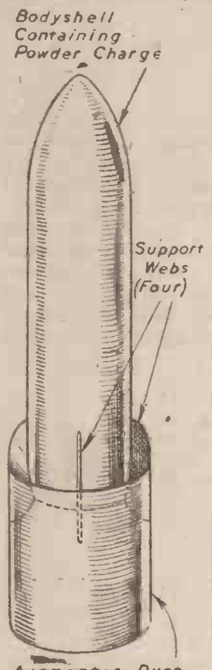

Fig. 36.—Air-augmented powder rocket by the Manchester Astronautical Association (1938).

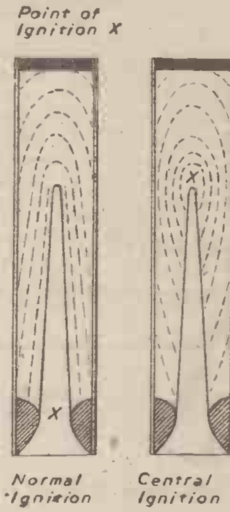

Fig. 37.—Diagram showing burning lines in conventional powder charge, and one centrally ignited. Paisley Rocketeers Society (1939).

Later experiments concerned the thrust augmenter and, using standard $\frac{3}{8}$oz. charges, flight trials showed a generally improved performance in the use of "augmented" tubes, despite their greater weight, also that rockets thus fitted were capable of sustaining a more accurate trajectory. The latter factor may be accounted jointly to an increased mass effluent and the stabilising effect of the augmenter "spinner."

Commercial Charges—Unmodified and Developed

The charges used during the entire period of the Paisley group's active research were obtained commercially, and while in the majority of tests these were unmodified, in certain cases the tubes were fitted for "central ignition" of the propellant.

In the accompanying diagram (Fig. 37) are shown the progressive burning phases in powder charge rockets, and indicates both the firing faces as formed in the conventional tube and those of a tube centrally ignited.

Proving stand tests have shown that the latter method of ignition provides a marked increase in thrust, and this is attributed to the greater burning area and a more uniform rate of combustion.

The thrust figures as derived from four proving tests of standard $\frac{3}{8}$oz. rocket charges are as follows: using unmodified tubes, $1\frac{7}{8}$lb.; 2lb.-tubes "centrally ignited," $2\frac{1}{4}$lb.; $2\frac{3}{8}$lb.

Improved performance also resulted from the use of an extended fire-clay nozzle ($\frac{1}{2}$in. long, 14° flare angle), fitted to unmodified standard charges, but unfortunately, in the absence of proving stand data, it is impossible in this instance to give any comparative figures.

(*To be continued*).

In the Far Eastern theatre of war a famous Artillery Regiment carried out repairs to their medium guns on the field. The illustration shows a gun crew hauling a gun barrel into position.