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By Thomas Carroll and Smith J. DeFrance
Langley Memorial Aeronautical Laboratory

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THE USE OF WHEEL BRAKES ON AIRPLANES.

By Thomas Carroll and Smith J. DeFrance.

S u m m a r y

This report discusses the use of wheel brakes upon airplanes. The results of tests to determine the effect of wheel brakes on the landing run of an airplane under various conditions of load and at various wind velocities are presented. The advantages of the use of brakes in reducing the landing run and in increasing the facility of ground maneuvering are discussed, together with methods of operation and application.

Introduction

With the development of aviation, the problem of reducing the landing or ground run of airplanes has increased in importance, particularly because of the restricted and congested areas of many commercial airdromes. Several methods have been considered and used for this purpose. These have been largely methods for increasing the drag, either aerodynamically or by friction of the tail skid on the ground. The method which has become very widely used recently, although not yet of the proportions of universal use, and which provides the least detrimental effect aerodynamically, is the use of wheel brakes.

The use of wheel brakes was consistently avoided for many years on account of the belief that their use would produce an overturning moment which would be hazardous. However, within the last few years wheel brakes have been adapted to airplanes with considerable satisfaction. With this in mind, the National Advisory Committee for Aeronautics determined upon a program of investigation into the effects of their use.

Methods and Apparatus

A Douglas M 3 airplane was equipped with an internal expanding type of wheel brake with a specially devised mechanism for operation differentially by foot pedals. A tail wheel replaced the usual tail skid (Figs. 1 and 2).

This airplane was selected as it had a large range of disposable load and it was desired to investigate the conditions of landing under various loading conditions, as well as under various wind velocities. It was found that in the lightest condition, that is, with a minimum amount of fuel and pilot alone, the gross weight was 3785 pounds. The intermediate load consisted of a full fuel load, pilot, and one passenger, making a gross load of 4685 pounds, and the heavy load, with the addition of 700 pounds of lead shot in bags, made a gross load of 5385 pounds. Landing with each of these three conditions of loading was studied in each of three different wind velocities of approximately 0, 10, and 17 M.P.H. The actual wind veloci-

ties at the moment of landing, measured at a point as close to the point of landing as possible, were used in the preparation of the data.

All landings were made on a selected portion of the landing field which was as smooth and dry as possible, and on which the grass was not more than 6 inches in height. In addition to the variation of loading and wind velocities, the brakes were used in two ways: (1) the brake pedal force was applied smoothly throughout the landing; and (2) the brakes were locked in the air before the landing was made and held in this condition as far as possible throughout the ground run.

Instruments and Measurements

The following instruments and measuring methods were used: (1) an N.A.C.A. recording air-speed meter to obtain the air speed at the moment of landing; (2) an N.A.C.A. single component accelerometer to indicate the point of landing; (3) an N.A.C.A. timer to synchronize the air speed and accelerometer records; (4) a hand-type of anemometer, installed upon a mounting 6 feet above the ground in the vicinity, and observed at the moment of landing, to determine the wind velocities; (5) The distance covered in the ground run of the airplane was measured by a tape, it being found that the point at which the airplane touched the ground was easily determined by using a number of ground observers before whom the landing was made at close range.

As these observers approached the point of contact according to their visual observation they invariably found, readily distinguishable, marks upon the turf where the wheels had first made contact. The other end of the run was positively determined by holding the airplane at the position at which it stopped until the measurement was completed.

R e s u l t s

From the numerous landings thus observed, the curves of ground landing speed against ground run were plotted (Figs. 3, 4, and 5). The ground speed was determined by subtracting the wind velocity from the air speed of the airplane at the moment of landing, as determined by the methods described above.

For all three conditions of loading the application of the brakes after landing was considered the normal method of operation. This method gave a consistent reduction in length of landing run as compared to the length of run without brakes. A further reduction in length of run may be obtained by applying the brakes before the landing and holding them in the locked position throughout as much of the landing run as is possible. This, however, is an unusual and somewhat rough method of handling. Under some conditions and with some airplanes it may be expected that a tendency to nose over or to ground-loop badly will occur with this method of handling. In Figure 4 and to some extent in Figure 5, it will be noticed that at the higher

speeds of landing the curves of ground run with the brakes applied before landing, have a tendency to converge toward the curves of ground run with brakes applied after landing. This is explained by the fact that in these tests the tendency to nose over or to ground-loop became sufficiently great to force the pilot to relieve the braking pressure.

It also will be noted that the landing run in the light load condition without brakes is longer than in the intermediate condition of loading. This is due to the fact that in landing in the light load condition it was very difficult to get the tail down so as to effect a good three-point landing. This condition is inherent in this type of airplane when so loaded. The landing was therefore made at a low angle of attack, with correspondingly low drag, and hence the air speed at the point of landing was from three to five miles faster than it would have been with a normal three-point landing. Tests and measurements were conducted in the same manner on a Douglas O2 H airplane, the results of which are illustrated in Figure 6. The results from these two quite different types are in agreement, which confirms the opinion that the results on the Douglas M 3 are applicable to most other types.

Discussion of Results

In the preparations for these experiments, brakes have been used and studied upon a number of military and commercial airplanes. Efficient wheel brakes of both the internal expanding

and external contracting types have been used. The methods of operation are, however, of greater diversity. They may be hand-operated or foot-operated, individually operated or equalized and used simultaneously.

While the value of wheel brakes is clearly evidenced by the material reduction in ground run which they afford, it should be noted that they provide other advantages of very great value. It has been found that they provide easy maneuverability, aid in the effecting of very short turns while taxiing; and enable the pilot to offset tendencies to ground-loop. The airplane may also be held without chocks while warming up the engine, by locking the brakes. With these secondary ends in view, it can be seen that the equalized, simultaneously operated brake is of reduced value on single-engined airplanes. Multi-engined airplanes, of course, may be maneuvered by use of the outboard engines individually.

The hand-operated control of brakes can hardly be recommended where it is necessary for the pilot to use them, but prove quite satisfactory where an assistant pilot or mechanic is available to work the brake control, as on large commercial types. Individually foot-operated brakes offer by far the greatest advantages. These usually have taken the form of additional small pedals attached to the rudder bar or rudder pedals or, as has at times been done, by separate brake pedals in no way connected with the usual rudder controls.

The brake controls connected to the rudder control have been so installed as to be operated by the toe or by the heel and in other cases a treadle, which is operated by rocking the whole foot. Many of these are quite satisfactory. Some introduce a difficulty since it might be possible to use the brakes unintentionally at improper times, such as in taking off. It might be possible to alleviate these difficulties, whether the operation was by toe or heel, by fitting a lever control which, in a first position, would lock the wheel brakes without pressure on the pedal control, in a second position would permit the individual use of the wheel brakes and, in a third position, would entirely cut out the braking system from operation by the pedal controls. This arrangement would permit the wheels to be locked similar to an automobile parking brake in the first position, in the second position would permit the usual brake operation, and in the third position, would prevent unintentional use of the brakes.

The successful operation of brakes is largely dependent upon the position of the landing gear and wheels with relation to the center of gravity. The wheel position should be well forward, as is now becoming the common practice, in order to counteract the tendency to nose over. This will not present any unusual difficulty due to tail heaviness on the ground, because with the use of the tail wheel the necessity for lifting the tail in ground handling will be eliminated.

It should also be borne in mind that tail skids are very destructive to the surfaces of landing fields. It will only be a matter of time when the use of the tail skid will be prohibited or penalized on all regulated airports. The replacement of the tail skid with a tail wheel will, of course, necessitate the use of wheel brakes.

The use of wheel brakes imposes a load upon the tires which the usual airplane type of untreaded tire is not capable of standing. Aircraft tires for use with brakes should have an additional heavier tread. Whether the additional tread should be smooth or of the non-skid type, is a matter of selection. The non-skid type will undoubtedly give more effective braking, although its tendency to tear may be as great as in the smooth tread aircraft type of tire.

C o n c l u s i o n s

Airplanes upon which it is intended that wheel brakes are to be used, should be so designed as to eliminate the tendency to nose over by placing the landing gear far enough ahead of the center of gravity.

There can be no doubt that wheel brakes are of very great advantage on any airplane, particularly when the airplane is equipped with a tail wheel in place of a tail skid. Their use

is not limited to the reduction of ground run, but is of very practical additional advantage in ground maneuvers.

From these experiments and experiences it is evident that wheel brakes are necessary equipment on an airplane. The only tenable reason for omitting them from a new design must be the desire to reduce the cost to the lowest possible figure.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., April 5, 1929.

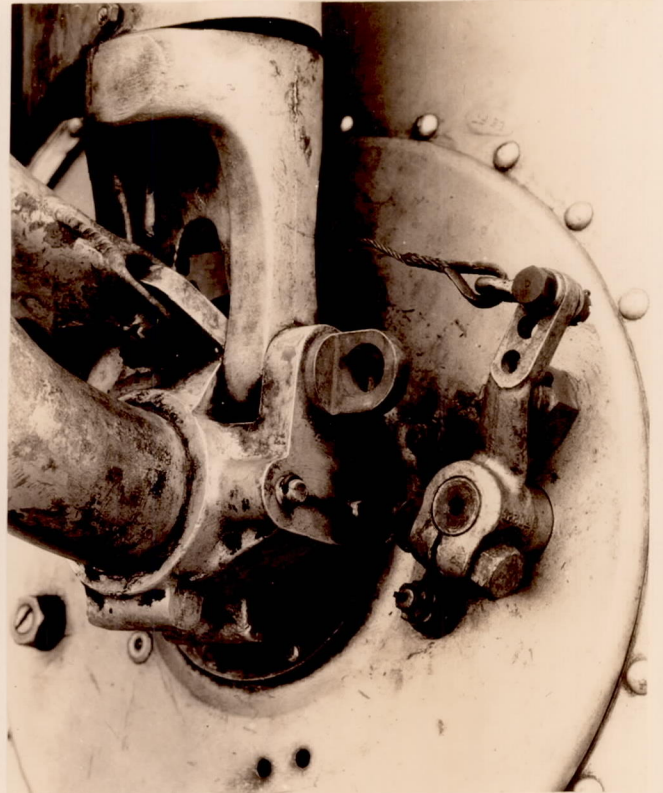


Fig.1 The wheel brake as applied to the Douglas M3 for the landing run tests.



Fig.2 The tail wheel of the Douglas M3.

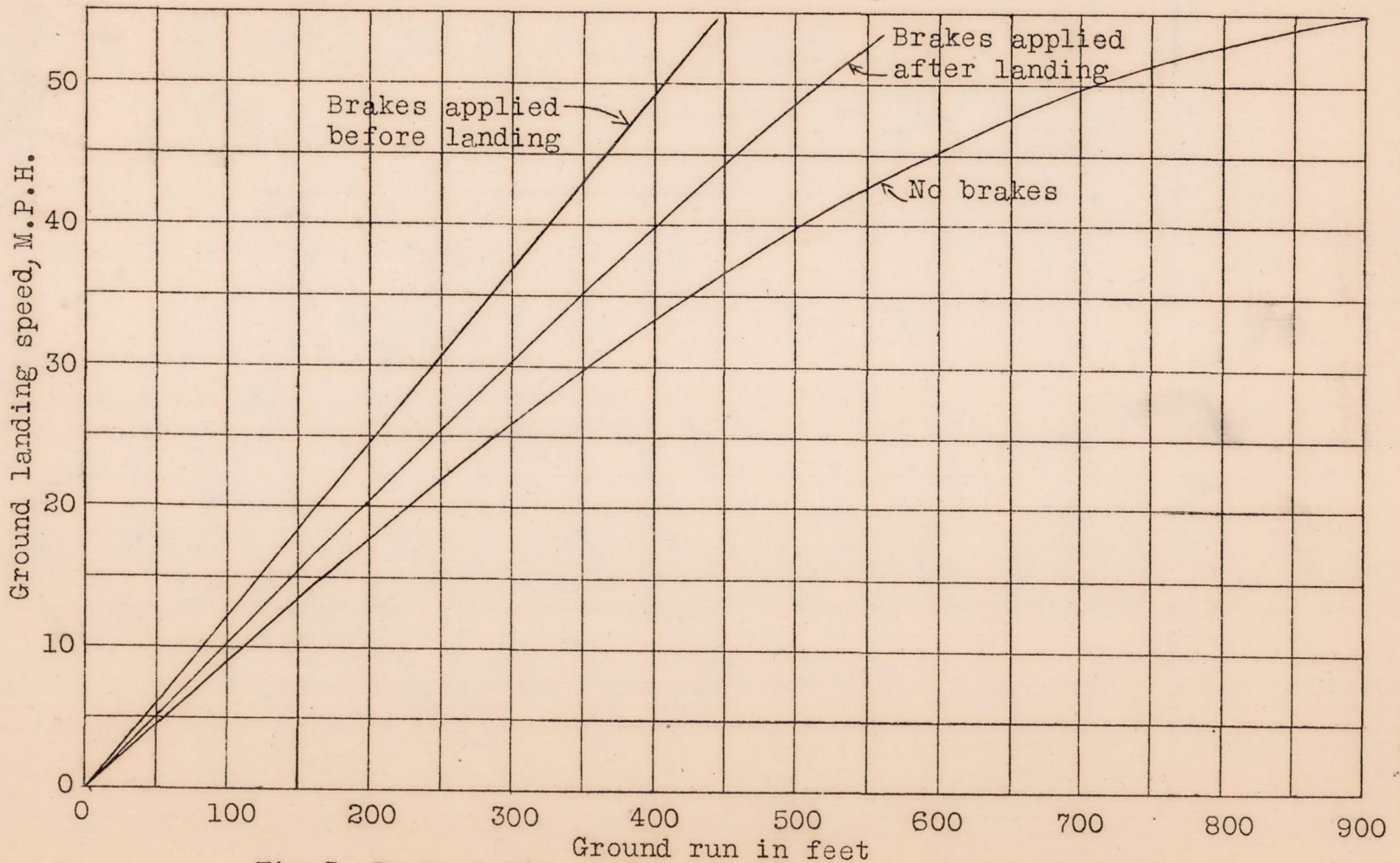


Fig.3 Brake tests on Douglas M3. Gross weight 3785 lb.

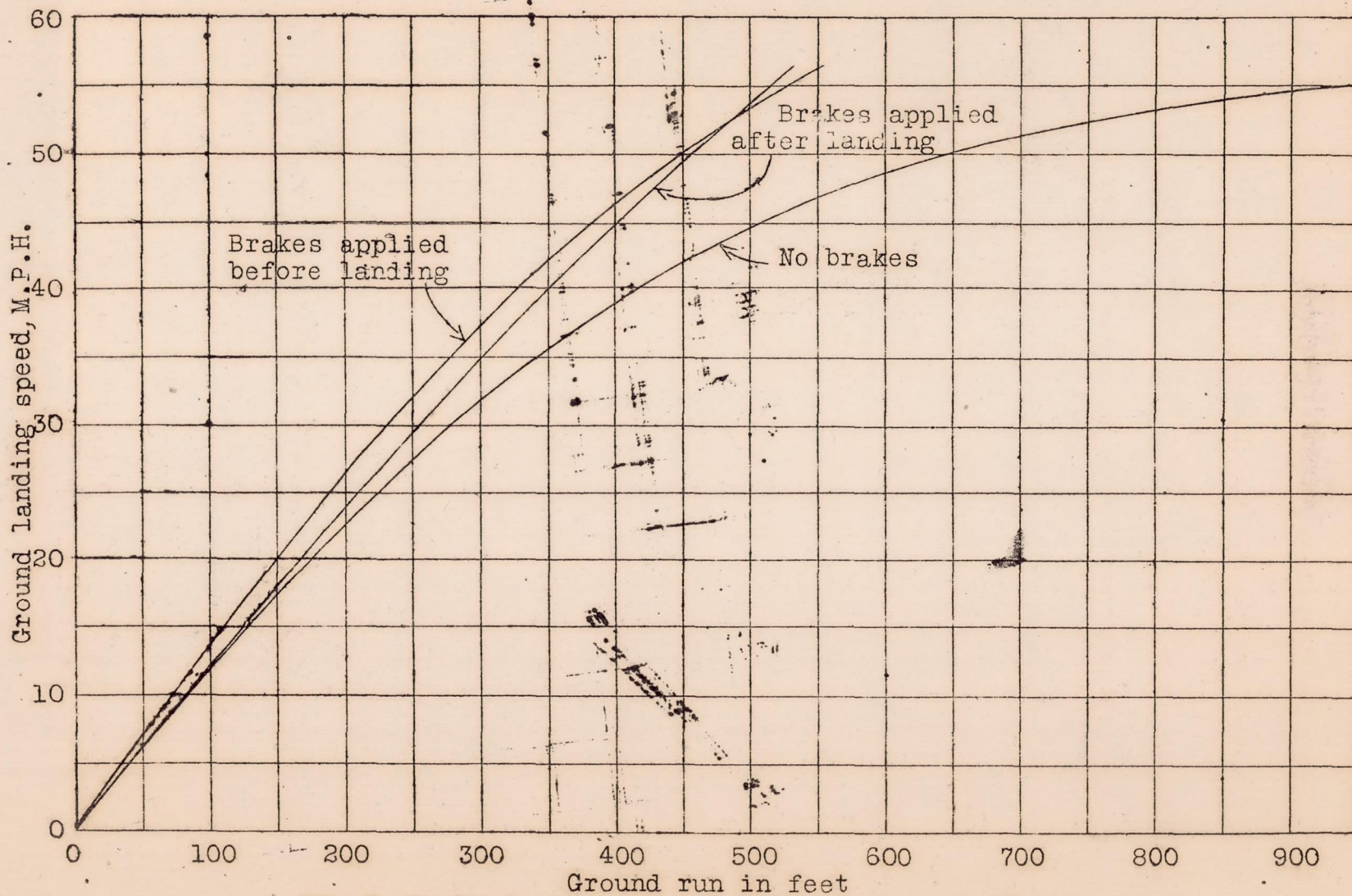


Fig. 4 Brake tests on Douglas M3. Gross weight 4685 lb.

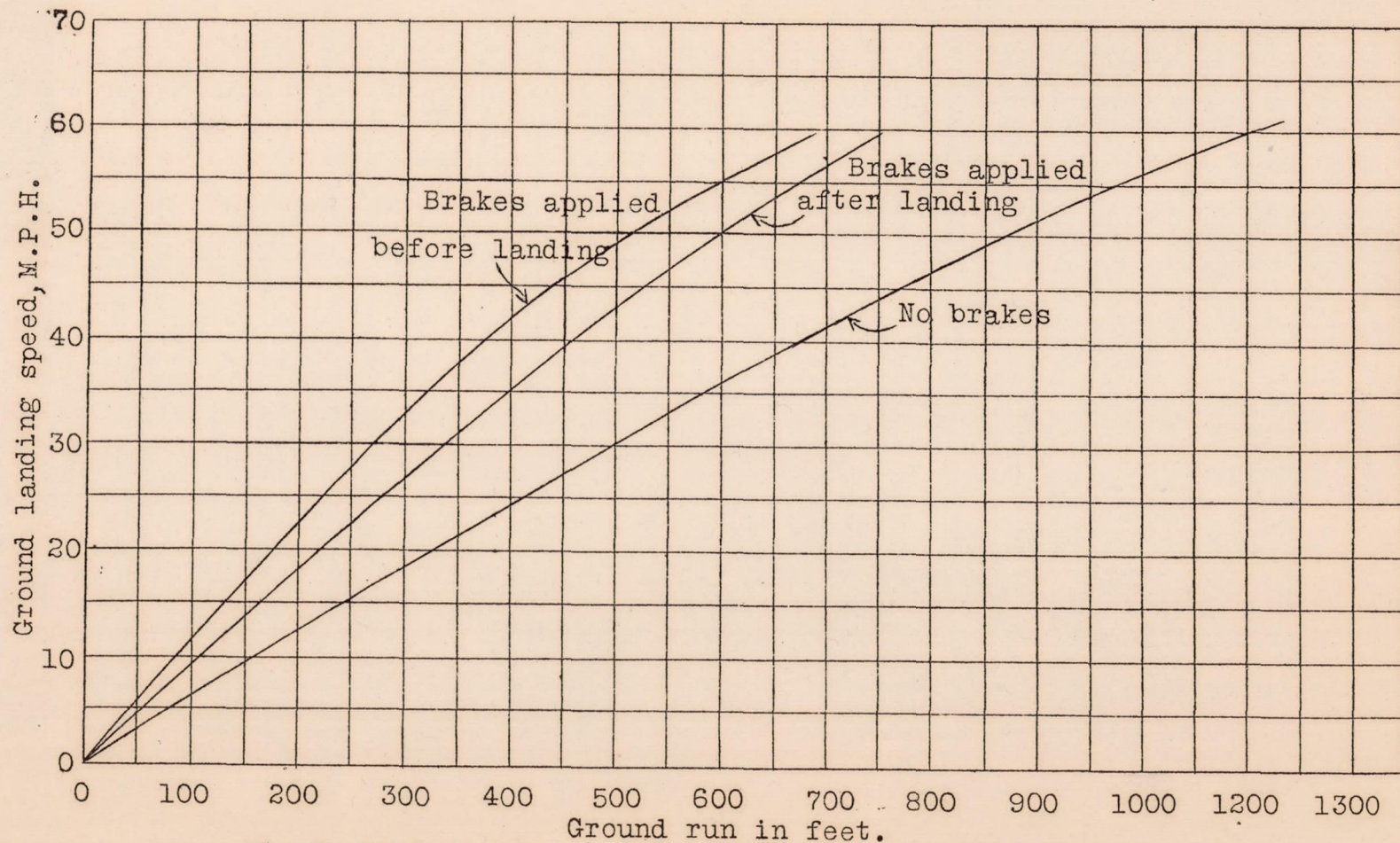


Fig. 5

Fig.5 Brake tests on Douglas M3. Gross weight 5385 lb.

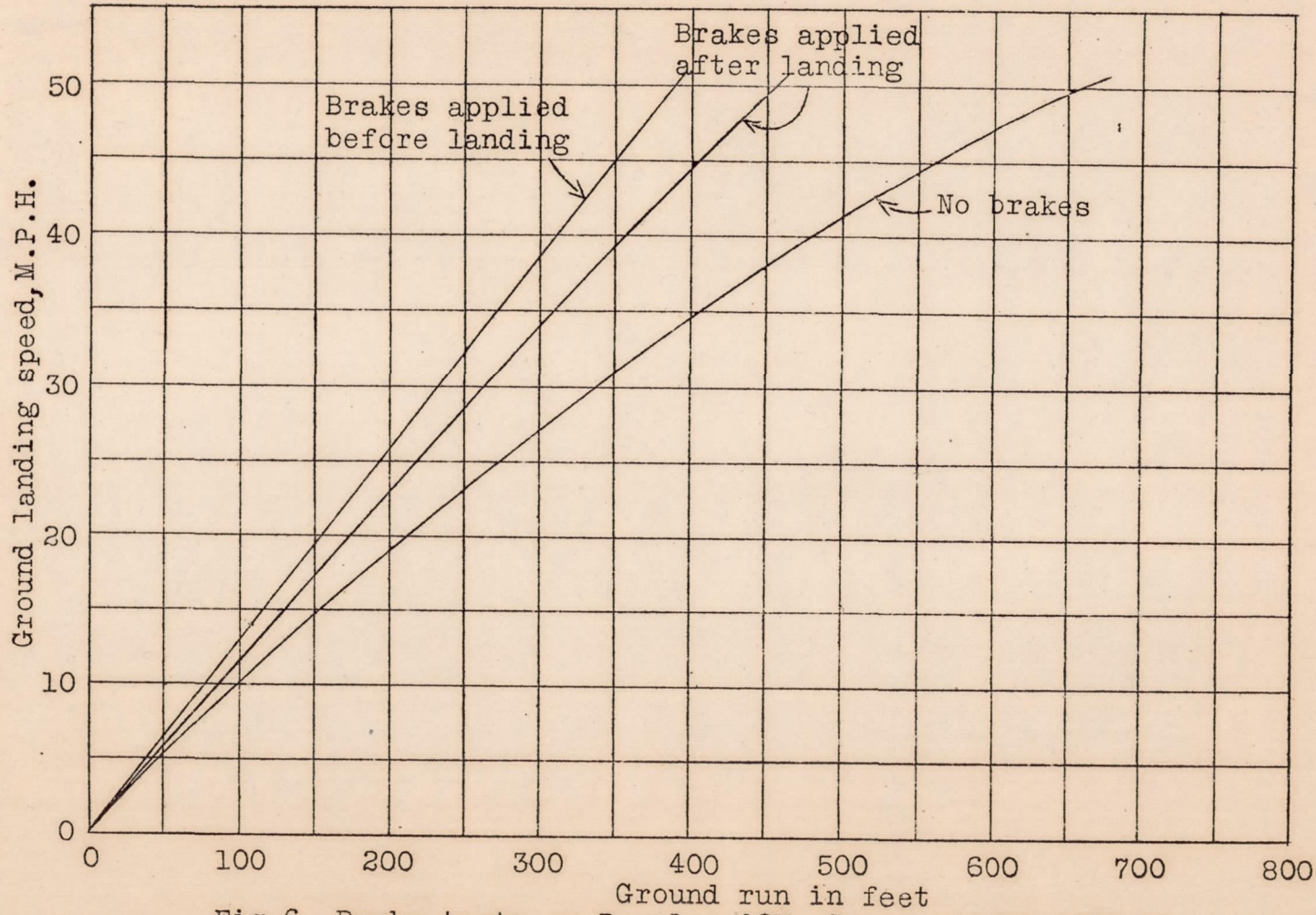


Fig.6 Brake tests on Douglas O2H. Gross weight 4465 lb.