INTRODUCTION

The importance of directional control characteristics having been emphasized recently in the case of the Curtiss P-40 airplane, it was deemed advisable to investigate the directional control characteristics of the North American XP-51 airplane, which at the time was undergoing flight tests for the determination of general flying qualities and which was recognized by the pilots as having good directional characteristics. Accordingly, the necessary data were obtained and this report is written for the purpose of presenting the directional control characteristics as indicated by rudder control variation with speed and power and in sideslips.
INSTRUMENTATION

Standard NACA recording instruments were used for measuring indicated airspeed, angle of bank, rudder pedal force, rudder angle, and yaw angle. All instruments were synchronized to take simultaneous records by means of a timer.

The airspeed static and total head tubes were mounted on a boom extending a chord-length ahead of the left wing tip. The static head was the free-swivelling type. Calibration of the static and total heads was accomplished by flying in formation with another airplane, the airspeed recorder of which had been calibrated with a trailing static bomb.

The rudder control force recorder was installed to measure the forces in the rudder cables at a point about midway from the cockpit to the tail.

The rudder control position recorder was attached to the right rudder cable at about the same point as was the force recorder. It was calibrated for stretch under load and found to be in error about one degree per 70 pounds of force. However, subsequent to the tests it was noted that the connection to the right cable would result in some error due to the slackness in the cable when left rudder forces exceeded the initial cable 63-lb tension. Only the accuracy of rudder positions obtained with left forces will be effected, and it is thought that with the application of the correction originally determined further error will be negligible.

A vane-type yaw angle recorder was mounted on a boom
about a chord-length ahead of the right wing tip. The vane was free to turn in a plane parallel to the plane of the wing and align itself with the relative wind. Yaw angle was measured as the angle between the thrust line and this vane. In some cases, a calibration is obtained correcting the yaw angle measured by a single vane to the mean angle obtained from two vanes, one mounted ahead of each wing tip, but in this case the calibration was not made. Previous tests on other airplanes have shown errors of from zero to three degrees varying with speed.
Directional stability characteristics were measured only for the cruise configuration of the airplane with power off and with rated power. Time histories of sideslips were made at 120, 155, and 205 mph, indicated airspeed, with power off and at 118, 155, 188, 256, and 313 mph with rated power.

From laterally level flight at the desired speed and with rudder force trimmed out, continuous records of airspeed, rudder angle and force, yaw angle, and angle of bank were made as the airplane was sideslipped in one direction until limited either by the control available or the force required. The pilot endeavored to apply the controls in such a way as to approach, as nearly as possible, a static condition at any instant. Use of the airspeed indicator connected to a free-swivelling static head greatly facilitated holding the airspeed constant.

Characteristic directional trim changes with speed and power were measured for the cruise configuration of the airplane. For two rudder trim tab settings (trim at 160 and 230 mph with rated power), runs were made from near the minimum speed to 380 mph, indicated airspeed, with power off and with rated power. Continuous records were taken of airspeed, rudder angle and force, yaw angle, and angle of bank. Control of the airplane was maintained by reference to the natural horizon for keeping laterally level and to the bank and turn indicator for direction.
RESULTS AND DISCUSSION

Directional stability characteristics are shown in figures 2 and 3 by the curves of rudder angle and force and angle of bank plotted as functions of sideslip angle. It will be noted that for all conditions tested the rudder force required is proportional to the angle of sideslip and is always such that the rudder will return to its trim position if the force is released. At low speed, power off and for small angles of sideslip (figure 2), the force gradient was small but was considered satisfactory by the pilot. At speeds up to 256 mph, power on and at high angles of sideslip to the right (figure 3), there appears a characteristic lightening of rudder force but never a reversal.

Directional trim change with speed is shown in figures 4 and 5 where rudder position and force, angle of sideslip, and angle of bank are plotted against indicated airspeed for two rudder trim tab settings.

Figure 4 shows trim changes for the power off condition. With the trim tab set at 1.8 degrees left, there is a left force change of 143 844 lbs in going from 110 to 370 mph. At the same time, the rudder moves about 1/2 degree from 1-1/4 degrees right to 3/4 degree right. With the tab set at 0.6 degree right, the left force required changes about 85 lbs while the rudder holds about steady at 0 degrees.

Figure 5 shows the trim changes when operating at rated power. With the 1.8 degrees left tab setting, there is a force
change from 10 lbs right to 145 lbs left, a total of 155 lbs, in going from 110 mph to 370 mph. Rudder position changes from 11.5 degrees right to 1.5 degrees right. With the tab set at 0.6 degree right, the force changes from 35 lbs right to 45 lbs left, a total of 80 lbs, and the rudder angle changes from 11 degrees right to 1 degree right.

The tab angle settings of 1.8 degrees left and 0.6 degree right correspond, respectively, to trim with rated power at 160 and 230 mph. Normally, this latter trim will be used for cruising and probably for maneuvering and combat. In such case, it is interesting to note that the maximum force required is only 100 lbs left at high speed, power off. With rated power, this force is reduced to about 50 lbs. 180 lbs is considered generally 80% of the average pilot's capacity and is the force accepted as the upper limit.

Force trim change in going from power on to power off amounts to 22 lbs left at 110 mph and 15 lbs left at 370 mph for the 1.8 degree left tab setting. For the 0.6 degree right tab angle, the change is 45 lbs at 110 mph and 50 lbs at 370 mph. These changes are considered small.

The degree of accuracy with which the airplane was controlled as shown by the curves of sideslip and angle of bank in Figures 4 and 5, would indicate that directional control is easy.
CONCLUSIONS

1. The XP-51 airplane is directionally stable in the cruise configuration with power on and power off. The rudder force required is always in the proper direction and is such that the control will always return to its trim position if released.

2. Rudder force change with speed is such that the maximum force required never reaches the 180-lb limit allowable limit for either of the trim tab settings employed. When trimmed for about normal cruising, the force change with speed is unusually small, amounting to only 80-85 lbs power on or off. For this same trim, the maximum force required in going through the speed range is less that 100 lbs for the power off condition.

3. Rudder force change with power is small. The maximum force change occurs at high speed and amounts to less than 50 lbs.