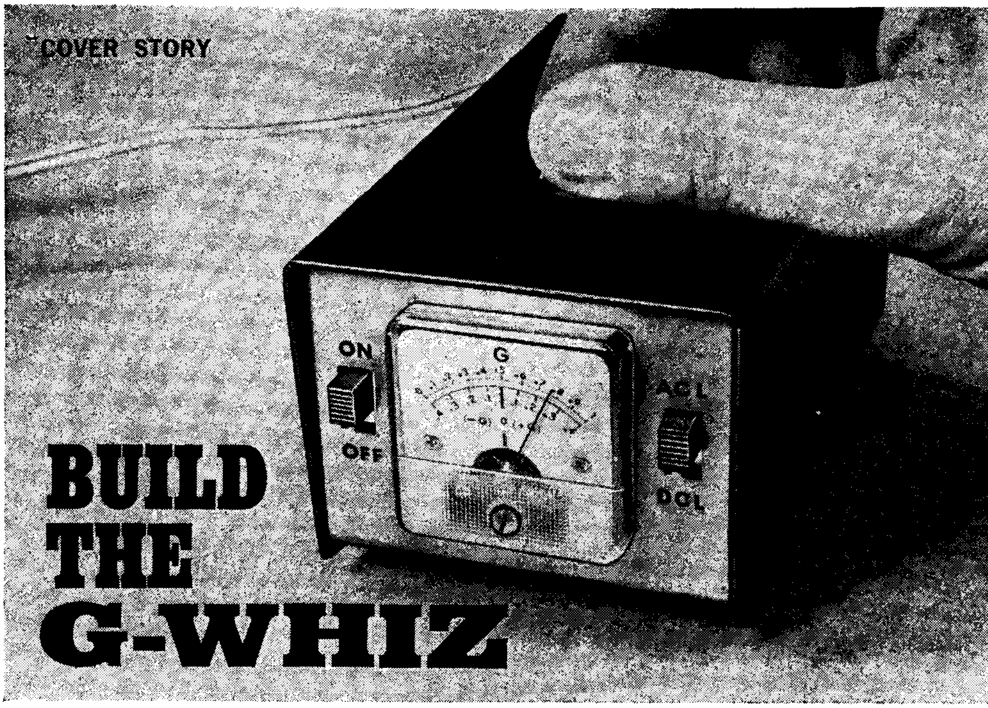


BUILD THE G-WHIZ

SIMPLE ACCELEROMETER MEASURES POSITIVE OR NEGATIVE G FORCE

BY GEORGE J. WHALEN

EVER WISH THAT YOU had some way to check your car's acceleration performance under actual road conditions? Or, would you like to check the effect that a tune up, carburetor adjustment, change of fuel grade, timing correction, valve setting, or change in tire pressure has had on your car's performance? Or, if you have stick shift, would you like to determine the optimum shift speeds for each gear to get best performance and fuel economy?

You can do all of this with the "G-Whiz," an indicating accelerometer similar to instruments used widely in aerospace applications, military aircraft, and missile systems. The G-Whiz is specially designed for automotive use and measures both acceleration and deceleration. Except for a 12-volt power supply, it requires no electrical connection to the vehicle. It provides the driver with an accurate means of checking the car's overall road performance and may even help in correcting poor driving habits.

In coming years, accelerometers like this one may become standard equipment on all new high-performance cars, so here is your chance to get ahead of the times.

Construction. The circuit of Fig. 1 is assembled in the U-shaped portion of a 5" x 3" x 2%" metal case, drilled as shown in Fig. 2. A cover fabricated by following the layout of Fig. 3 can be covered with a contact-adhesive leatherette finish. Construct the mounting brackets for R5 and ***R4*** as shown in Fig. 4. Build, or purchase (see Parts List) the pendulum following the information given in Fig. 5.

Mount zero-adjust potentiometer R5 on its bracket (see Fig. 4), and mount the bracket as shown in the photos. Mount all the other parts, except for po-

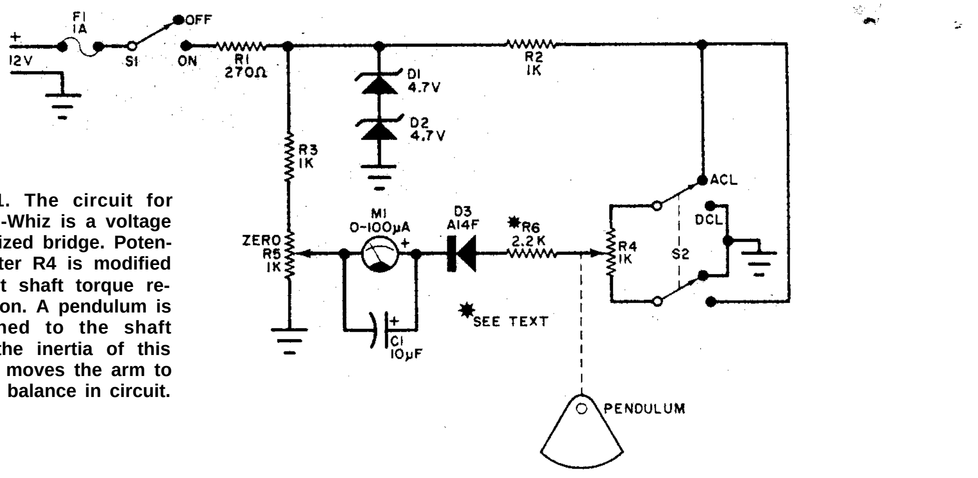


Fig. 1. The circuit for the G-Whiz is a voltage stabilized bridge. Potentiometer R4 is modified to cut shaft torque restriction. A pendulum is attached to the shaft and the inertia of this mass moves the arm to upset balance in circuit.

PARTS LIST

C1—10-μF, I5-WVDC electrolytic capacitor
Dl, D2--4.7-volt zener diode
D3-A14F silicon diode (General Electric)
Fl-l-ampere fuse
Ml-IOO-μA meter
RI--270~ohm, ½-watt resistor
R2, R3-lOOO-ohm, ½-watt resistor
R4-lOOO-ohm subminiature linear potentiometer (Mallory MLC-I3L or similar)
R5-lOOO-ohm linear Potentiomcter
R6---2200-ohm. 5%, ½-watt resistor (see tcxt)
Sl--S.p.d.t. switch
SZ--D.p.d.t. switch
Misc.--Pendulum lead weight (see text), 5-point terminal strips (2), case, fuseholder, right-angle brackets, knob, wire, solder, etc.
A complete kit of parts including punched case, mounting material, etc., is available from *Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, Texas 78216, $12.75 postpaid.*

tentiometer **R4** and the pendulum as shown in the photos, and wire point-to-point in accordance with the schematic. The author elected to solder S1 and S2 to the front wall of the chassis. Mount a 5-pin terminal strip at R5 bracket mounting screw (point B in Fig. 2) and a 5-pin terminal strip at **R4** mounting bracket (point A in Fig. 1).

Potentiometer **R4** will have to be opened and its wiper contacts adjusted to reduce its shaft torque requirement to the minimum. Remove the nut and lock-washer from the shaft bearing and hold the potentiometer so that the shaft faces you. Using a small, thin-blade screw-driver, gently pry up the tabs securing the metal cover to the shaftplate. Slip the cover off to expose the resistance element and wiper assembly. Hold the potentiometer by the shaft and look through the side into the space between the wiper assembly and the resistance element. The larger wipers contact the resistance element and are arranged in opposition. To reduce contact friction, slip a tiny jeweler's screwdriver (or sewing needle) under the back of each contact and gently pry upward a fraction of an inch. After doing this to both wipers, check shaft rotation and note that less

HOW IT WORKS

The circuit, shown in Fig. 1, is basically a bridge that can be balanced at zero G by means of potentiometer *R5.* The pendulum is physically attached to the shaft of potentiometer R4; and if the pendulum tries to rotate about its pivot axis, the bridge becomes unbalanced and meter *Ml* indicates the amount of unbalance (meter) scale is calibrated in G values). The position of S2 determines the direction of current flow through R4 so that an increasing positive-going voltage may be obtained from the movement of the R4 wiper arm in response to either a backward swing (acceleration) or forward swing (deceleration) of the pendulum. Resistor R6 is selected to set the full-scale current through Ml to correspond to +45° or -45° of potentiometer shaft rotation from its normal (zero G) position.

Diode D3, in series with the meter, permits current to flow in only one direction,, preventing the needle of *Ml* from slamming against its limit stop during a sudden stop when S2 is set for acceleration. or vice versa. Capacitor Cl provides electrical 'damping of the meter to smooth out peak transients due to the inertial effects of the eccentric weight.

Power is obtained from the car's 12-volt d.c. system via fuse *Fl,* current-limiting resistor *Rl,* and a 9 4-volt regulator consisting of zencr diodes D1 and D2.

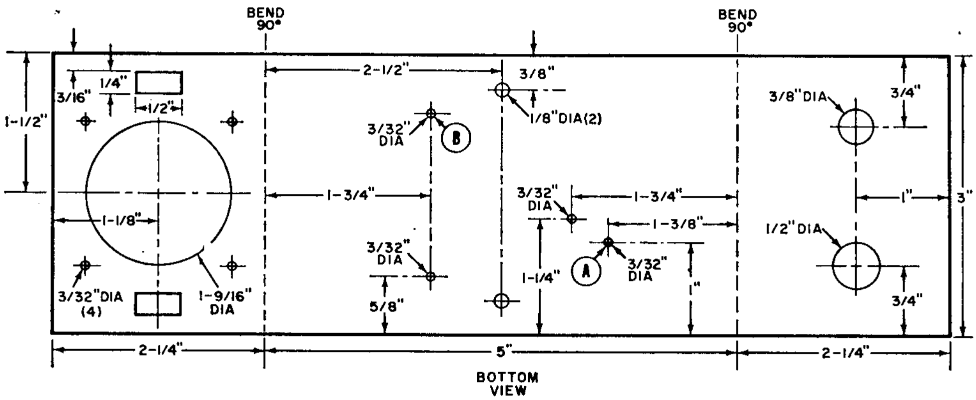


Fig. 2. The author bent a chassis and cover out of sheet metal. The bending, drilling, and cutout information is shown above. The two slide switches are soldered to the rear of the front panel.

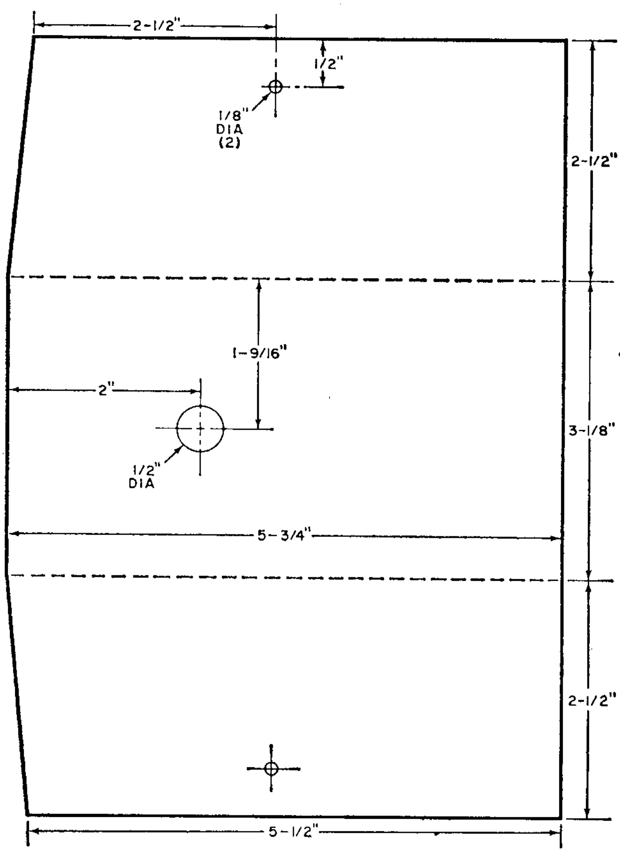


Fig. 3. The cover forms a cowl over the front panel. If desired, the front can be cut in a straight line.

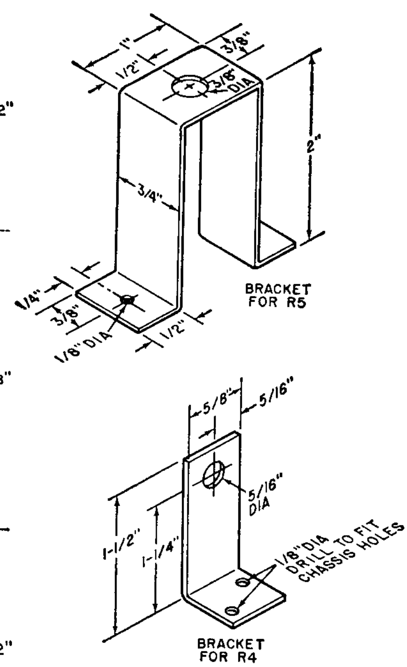
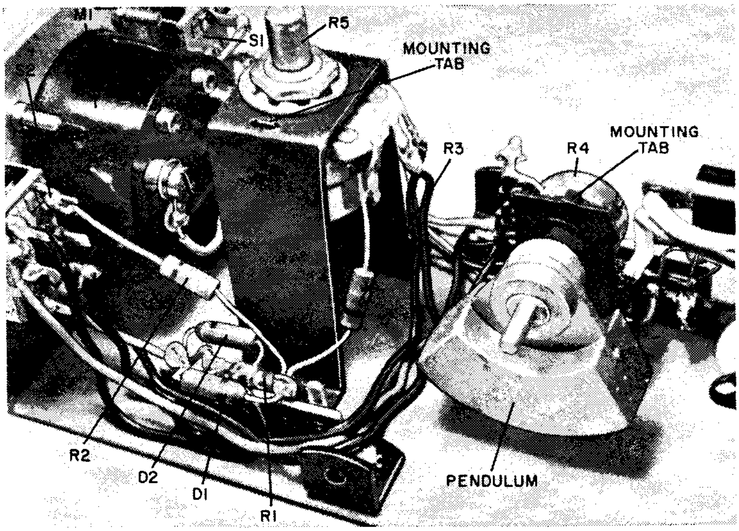


Fig. 4. The mounting brackets for the two potentiometers can be made from sheet metal or aluminum strips.



Wiring and assembly is open but very rigid. The pendulum must have room to swing freely. The shaft of zero-G setting potentiometer R5 is accessible through a hole in cover of the metal box.

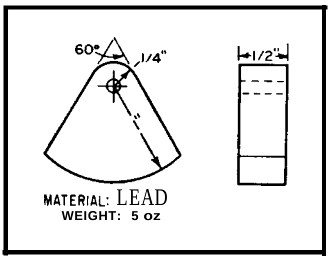
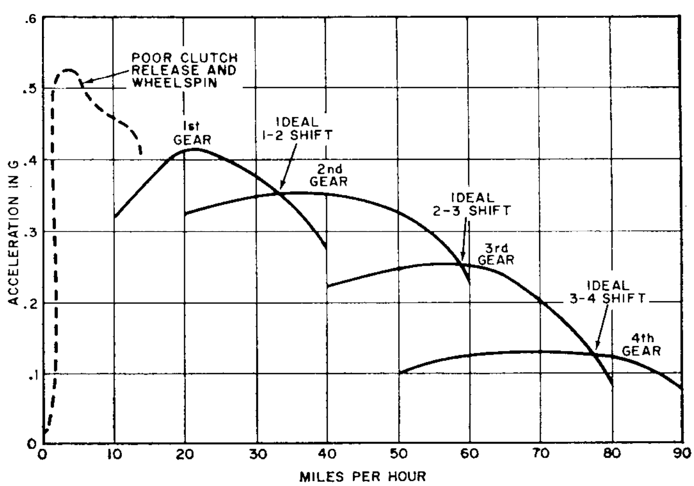


Fig. 5. You can fashion a pendulum from a piece cut from an old tuning flywheel.

torque is required to rotate the shaft. Next, loosen the tiny pair of wipers directly opposite the first pair (riding on the center slip ring). Use a tiny sewing needle to lift each finger gently to reduce contact pressure. Again check shaft torque to see that it has again been reduced. Inject a drop of contact cleaner and lubricant on the contacts. Calibrate the meter using the table as a guide.

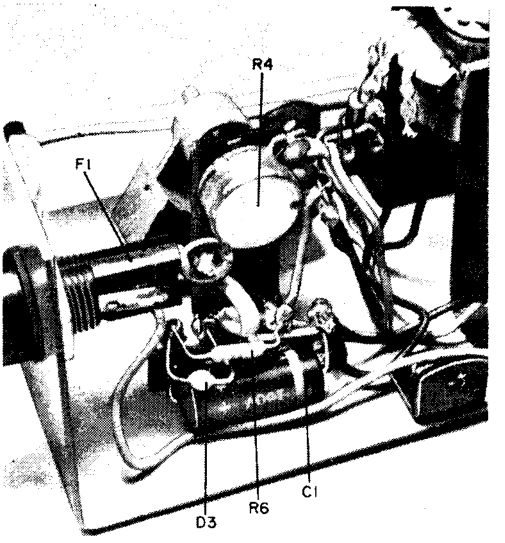
Before replacing the cover, check the resistance between either end terminal and the rotor to make sure that contact is still established. If necessary, you may have to tighten up on the contact fingers very slightly. Slip the metal cover back on the pot, making sure that the cutout is opposite the three terminals and does not contact either of the terminals. Use

Fig. 6. A typical stick-shift sports car should produce G forces roughly equivalent to those in this graph. If you plot a similar graph you will be able to determine the optimum speeds for shifting of gears.



the flat blade of a screwdriver to bend the securing tabs flat against the shaft-plate. Mount ***R4*** in its right-angle bracket (see Fig. 4) so that its mounting tab rests atop the bracket. Secure the bracket in place.

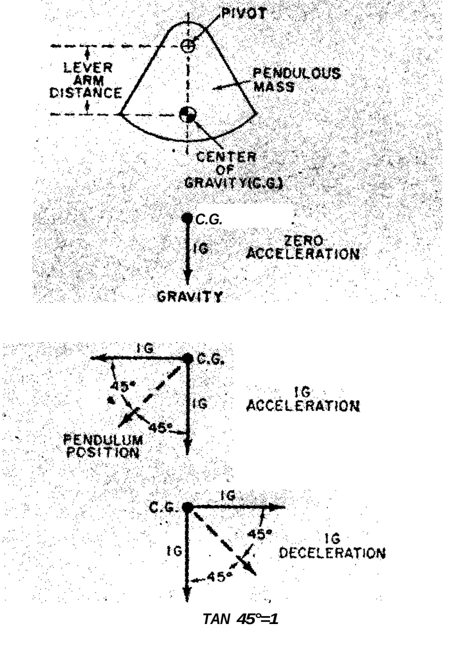
Being very careful, coat the potentiometer shaft with solder from its end to a point about ½ inch from the shaft bearing. Do not get any solder between the shaft and bearing. After the shaft has been tinned, install it in position on its mounting bracket as shown in the photos. Temporarily jumper the two end terminals and connect an ohmmeter between the end terminals and the wiper. Rotate the shaft of the pot for maximum indication on the ohmmeter and leave the shaft there. Slide the pendulum on the pot shaft, trying to keep the pot shaft from rotating. When the pendulum is positioned close to the shaft bearing, recheck that ***R4*** is at true midscale with the pendulum hanging straight down, then solder the pendulum to the shaft. After the metal cools, swing the pendulum back and forth and note that the ohmmeter shows a resistance variation, and that the weight swings freely across a 90° arc. Connect ***R4*** into the circuit.



Drilled and tapped right-angle brackets (top center and bottom right) are used to hold cover in place.

Install a pair of small right-angle brackets on the chassis base (see photos) so that the cover can be easily attached. Make sure that all wiring is dressed away from the area of pendulum swing so as not to hinder operation.

HOW A PENDULUM RESPONDS TO ACCELERATION



TAN 45°=1

All forces acting on the pendulum mass act on its center of gravity, which is eccentric with respect to its pivot point The lever arm is the distance from the pivot point to the center of gravity and transmits the farce acting on the center of gravity to the pivot in a rotatational manner.

The pendulous mass responds to the "pull of gravity" and tends to hang down (toward the center of 'gravity of the earth) unless acted upon by the horizontal push of acceleration or deceleration forces. Thus, gravity provides the reference against which the horizontal forces are compared.

The physical response of the pendulum to gravity and acceleration is a vectorial quantity, since the two forces act at right angles to the center of gravity. The pendulum acts to maintain an equilibrium position, balancing the two forces by rotating in a vertical arc about the pivot. If the two forces are equal, the pendulum assumes a 45° angle from its zero acceleration position. For lesser acceleration or deceleration forces, the pendulum pivots to a smaller 'angular position. The tangent of the angle described by the pendulum's position under acceleration or deceleration is equal to the horizontal G force.

Testing.. Insert the fuse (F1) and connect the power cord to source of 12 volts d.c. observing lead polarity. With S1 turned ON, the voltage across zener diodes D1 and D2 should be 9.4 volts, indicating that the regulator is working properly. Place the G-Whiz on a flat horizontal table and with the power still turned on, set S2 at ACL and adjust R5 (zero control) until the meter just indicates zero G (left-hand scale limit).

Since it is difficult to simulate one-G forces, the best thing to do is displace the pendulum to simulate this force. For this, you will need a 45” triangle. Stand the triangle up on one of its sides (not the hypotenuse), and place the case on the hypotenuse with the meter facing down. Note that the pendulum swings so as to “point” straight down due to the pull of gravity. The meter should indicate one G (at right-hand scale limit). If the meter does not read exactly full scale (one G), the value of R6 will have to be adjusted.

Now place the device on a flat horizontal surface, set S2 to DCL and adjust R5 for a zero indication on M1. Place the case on the hypotenuse of the triangle, meter face up, and note that the pendulum swings to hang down and the meter indicates full scale (right-hand limit).

Once tested, install the cover on the device, feeding the shaft of R5 through its hole and place a small knob on the shaft of R5.

Installation. The G-Whiz can be installed almost anywhere in the car as long as it is mounted as horizontal as possible. Make sure that the long side of the chassis is always parallel to the direction of travel of the vehicle. (The swing arc of the pendulum must be in the direction of vehicle travel.) The device can be bolted, strapped, or secured with two-sided adhesive tape to the top of the dashboard or other convenient horizontal surface. If the case is slanted to one side or the other, the pendulum will not respond to true acceleration but to an angular component of this force, thus producing erroneous indications. However, if the long side of the chassis is slightly tilted, this can be corrected by adjusting R5 for a true zero.

Road Testing. Before testing the G-Whiz, make sure that you can observe all traffic safety laws before performing the following tests. It is advisable to have a passenger use a clipboard, pad, pencil, and stopwatch to record the meter readings.

Before making the road tests, remember that the G-Whiz is sensitive to horizontal attitude, so try to use a level road for best accuracy.

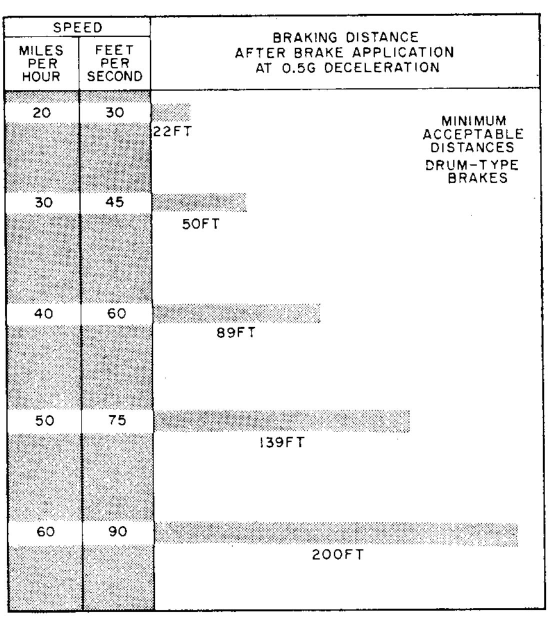


Fig. 7. The G-Whiz is an excellent device to check performance of drum or disc-type brakes. A good test is to decelerate at 0.5 G and measure the braking distance vs. miles per hour. Acceptable distances are shown in this graph. Brake fading can be observed on the G-Whiz as described in the text on page 40.

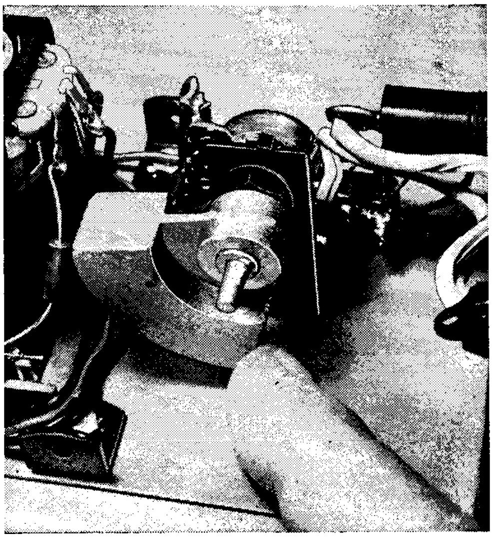
With the car stopped, turn on the power (S1), set S2 to ACL, and rotate ***R5 to*** set the meter needle just to the left-hand zero mark (0 G). The driver watches the road and keeps an eye on the speedometer, while the passenger watches the G-Whiz dial. Start the car, put it in low gear, and make as fast a start as possible. At each 10-mph interval, the driver calls out "check," and the passenger records both speed and G readings. Carry out this procedure to at least 10 mph faster than your normal shift speed for this gear. This speed depends on your type of car. Therefore, before you begin, check your manual to determine just how fast you can go in this gear without damaging the vehicle.

Next, perform the same test in second gear. Start in first, then shift to second about 10 mph slower than the normal shift speed. Accelerate full throttle to at least 10 mph faster than normal second-to-third shift speed, calling out each 10 mph so that the passenger can record both speed and G value. Do the same for any other gears you have in your vehicle, starting at about 10 mph slower than normal and running to about 10 mph faster.

Once all the data has been recorded, a graph similar to that shown in Fig. 6 can be plotted. On a sheet of conventional linear graph paper, draw a horizontal axis marked in miles per hour from zero to 100 mph, letting each small box represent 2.5 mph. Draw a vertical line from the O-mph point and mark this off from zero to one G with each small box representing .025 G.

Once the acceleration curves have been drawn on the graph, they can be interpreted. Obviously, first gear is the big performer, as indicated by the sharp rise in G readings in comparison with the other gears in Fig. 6. This is also the gear in which most errors can be made. For example, popping the clutch or excessive wheel spin may decrease efficiency in this gear as shown by the sudden high-G peak of the dashed-line curve of Fig. 6. If your actual curve shows this characteristic, you need to improve your clutching and braking techniques.

Note that the curves for each gear overlap. The crossover point in each case represents the ideal shift point between the two gears. If you shift out of a lower gear as the acceleration is tapering off into a higher gear where more acceleration can be picked up, you can maintain a higher overall acceleration. If your car is equipped with an engine tachometer (RPM), ***you*** may be surprised at the relatively low RPM readings corresponding to each ideal shift point. Contrary to popular belief, winding out in each gear and running near the engine red line actually wastes time, results in decelera-



Before sealing up the G-Whiz makes a bench test to be absolutely positive that the pendulum is free.

WHAT IS G?

To understand what "G" is, you must first understand the difference between speed and acceleration. Speed is a measure of distance traveled per unit of time, usually expressed in feet per second or miles per hour. Acceleration is a measure of change in speed per unit of time, expressed in feet per second per second or miles per hour per second. Remember that you can have speed without acceleration, but you can't have acceleration without speed.

Since the units for acceleration are somewhat cumbersome, it is usually expressed simply in terms of the letter G. Taken from the word gravity, the G is an international standard unit defined as the acceleration produced on a dropped object by the earth's gravitational field. In actual figures, an acceleration of one G is equal to 32.2 ft/sec/sec/or 22 mph/sec

Precise measurements of low values of G can tell us quite a bit about the performance of our cars, as explained in the article.

tion due to frictional losses, and poses the threat of valve float. The reasons can be found in your engine manual. Most engines deliver maximum torque at fairly low RPM, while maximum horsepower occurs at a somewhat higher RPM. Always remember, it is the torque that counts!

Checking Brakes. To check the brakes, place S2 in the DCL position and rotate R5 until the meter needle just rests on the left-hand zero-G mark. Accelerate the car to 40 mph and firmly apply the brakes as you would for a hard stop. The meter should indicate about 0.5 G if your car is an American make, equipped with conventional drum brakes. If your car is equipped with disc brakes, you may pull as high as 0.7 to 0.9 G. Minimum acceptable braking distances for cars equipped with drum brakes are shown in Fig. 7. You should obtain a 0.5-G reading within these distances.

To check the fade characteristics of the brakes, make a series of hard stops from 40 mph, noting the G readings. Fade will be evidenced by a lowering of the G value each time.

Economy Driving. Except for major repair costs, the biggest expenses incurred in operating a car are for gasoline and tires. Exact figures vary, but they may total 12% of the original cost of the car each year. It is assumed that the driver uses the proper driving techniques-no jack-rabbit starts or hard stops-and that the car is kept tuned up.

While the car is in motion, place S2 in the ACL position, and adjust R5 until the meter indicates the zero-G center of the lower scale. In this way you can check both drag and accelerator "diddle" at highway cruising speeds. Drag results from the aerodynamic resistance of the car, excessive tire friction, and the viscosity of the lubricant in the crankcase. Accelerator "diddle" is a driver problem. Some people unconsciously tap the accelerator; and with each tap, the carburetor pump squirts a stream of gas into the throat. The amount of gas is not enough to alter the vehicle speed much, but the wasted gas can add up. Once you have attained the desired highway speed, drive to keep the needle at the zero-G center mark.

METER CALIBRATION

METER CURRENT (μA)	G	PENDULUM ANGLE (deg)
O-to-I G scale*		
0	0	0
13	.1	6
26	.2	11
39	.3	17
51	.4	22
62	.5	26.5
71	.6	31
79	.7	35
87	.8	38.5
94	.9	42
100	1.0	45
.4-0-.4 scale		
100	+.4	22 (aft)
89	+.3	17 (aft)
76	+.2	11 (aft)
63	+.1	6 (aft)
50	0	0 (null)
37	-.1	6 (fwd)
24	-.2	11 (fwd)
11	-.3	17 (fwd)
0	-.4	22 (fwd)

**Pendulum angle is measured from the normal null when the chassis is horizontal and the pendulum hangs straight down. The 0-to-1 G scale applies for either ACL or DCL conditions. In the second, zero-center scale, aft (+) is for acceleration with the pendulum swing to the rear of the chassis, while fwd (forward) is for deceleration with the pendulum swing to the front of the chassis. A low-voltage power source and a series potentiometer can be used to produce the desired meter current deflections.*

You can detect drag by removing your foot from the accelerator after reaching a constant speed and observing the reading in G's as the needle deflects to the left of the center-scale zero. Drag increases with speed, so make this test at an initial speed of 60 mph. The deeper the needle dips, the greater the fuel-robbing drag. Drag can be reduced by keeping tire pressure up to recommended value and compensating for excessive weight (passengers, etc.) by increasing the tire pressure slightly.

Heavyweight lubricants are also a source of drag. These thick lubricants may be all right for hot weather driving, but they can become a sticky medium that contributes to drag at moderate and cold temperatures. Change your lubricant to fit the season.