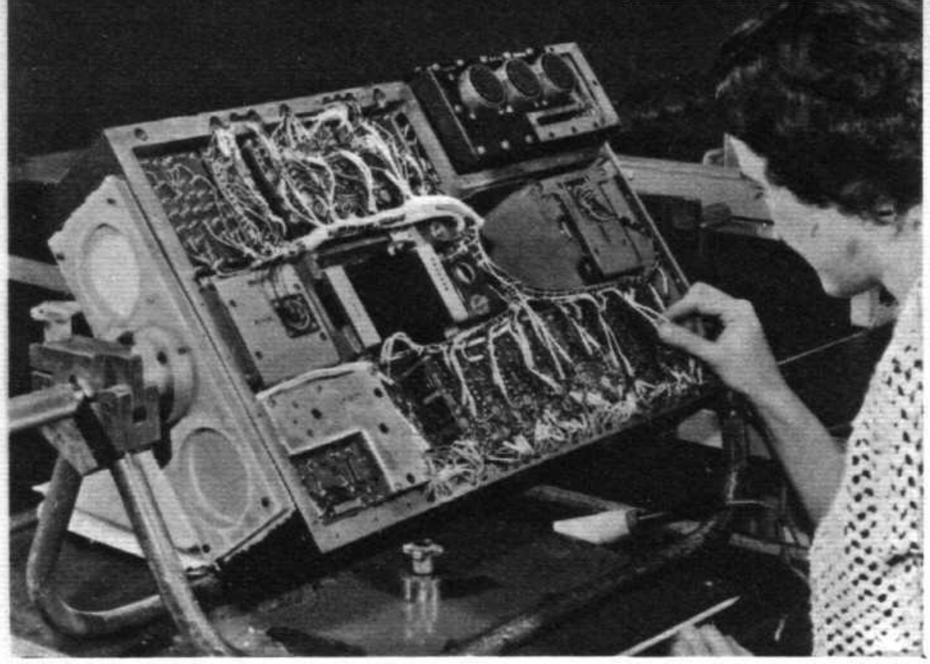

Part of the computer for the Achiever inertial-guidance system made for the Douglas Thor by A.C. Spark Plug division of General Motors

FLYING AIDS . . .

Inertial Navigation

The development of inertial-quality equipment has reached a point where the special gyros used for stable platforms (and in some cases as accelerometers) are small and cheap enough to be incorporated in master dynamic reference systems. While it is safe to say that genuine inertial navigation is not likely to find a place in airline use for some years to come, a number of master references are being planned to include inertial-quality gyros so that they are theoretically capable of being applied not only to flight control and instrumentation but also to short-term navigation.

Under the stimulus of military requirements during the development of the ballistic missile, tremendous progress was made in inertial design in a relatively short time. Many different approaches were tried and a great variety of gyros, accelerometers and computers is now available. But because the main application was in missiles with a flight time of about 30 minutes, the first few minutes of which would give anything an exceedingly rough ride, the main effort went into short-term systems capable of withstanding a distinctly hostile environment.

In its review of flying aids of May 16 last year, *Flight* recorded that inertial systems were not yet suitable for long-term navigation such as might be required during a trans-Atlantic flight. The subsequent voyages under the polar ice cap by the nuclear submarines *Nautilus* and *Skate* proved that a long-term inertial system, typified by the Autonetics Ships Inertial Navigation System (SINS), had now come of age. The application of a similar long-term pure-inertial system to aircraft use depends mainly upon reducing the weight of the equipment and increasing its tolerance to vibration and extreme temperatures.

Although work began on inertial systems in Britain at a relatively early date, rapid advances were mostly made in America where financial backing was virtually unlimited. The following record of achievement by the Autonetics Division of North American Aviation is, in view of this, not surprising, though nonetheless impressive. Autonetics flew the first "all-inertial autonavigator," the XN-1, in a C-47 in May 1950. Since then more than 800 flights with various systems have been made. During 1952 the XN-2 stellar-inertial autonavigator successfully tracked stars automatically during flights in daylight and picked up stars at night after the aircraft had taken off and climbed above cloud. By 1954 Autonetics had produced a completely manœuvrable inertial platform and was currently testing five inertial systems of three different types. The following year a stellar-inertial system guided a U.S.A.F. T-29 during a 13½ hr flight from Los Angeles to Patrick A.F.B., Florida. During 1956 a pure-inertial system guided the X-10 experimental vehicle through an out-and-return flight of several hundred miles at supersonic speeds. It also guided a test version of Navaho at Mach 3. By 1957 Autonetics had achieved in-flight alignment of an inertial navigation system from a cold start using an independent velocity reference. An idea of cost can be gained from the fact that development of the inertial guidance system for Titan by the American Bosch Arma Corporation cost slightly over $140 million.

A stable platform for the Sperry inertial system for the B-58 Hustler being tested in a transport aircraft

The first production application of an inertial system to a manned military aircraft is the AN/ASQ-42 primary navigation system made by Sperry for the Convair B-58 Hustler. Almost a hundred of these aircraft are being ordered. Late Republic F-105s and the North American A3J Vigilante will have inertial systems. The ASQ-42 is, in fact, a Doppler-inertial hybrid capable of providing accurate information over a period of hours. It is probable that the Doppler element would be used only intermittently to check the inertial element. In addition to providing navigational information, ASQ-42 supplies attitude and other information to nearly a dozen sub-systems such as those for reconnaissance and flight control. The navigation system can operate anywhere in the world and will automatically control the release of the Hustler's 50ft-long pod. The ASQ-42 is 20 per cent lighter and occupies 37 per cent less space than present systems such as that of the B-52, and it is claimed that it is more versatile and reliable.

In Britain, the Sperry Gyroscope Company flew an inertial navigator designed for manned fighters in November 1954. The company now holds the contract for development of the guidance system of the British ballistic missile. English Electric announced last year an agreement under which they will produce some of the range of Miniature Integrating Gyroscopes designed by Minneapolis-Honeywell in America. In addition to producing this equipment under licence, English Electric are designing complete stable platforms as well as the necessary gyroscopes for them. Elliott Brothers (London) Ltd. are designing the inertial navigation system for the Avro stand-off bomb.

During last year's S.B.A.C. Display, one of the six Miniature Stable Platforms which had then been produced by Minneapolis-Honeywell was publicly displayed for the first time. Although intended as a master dynamic reference, it is based on three GG49 Miniature Integrated Gyros which are of inertial quality. The two units comprising the platform weigh a total of about 40 lb, can be started up in three or four minutes and do not require a highly stable power supply. In one application, thirty different outputs have been supplied. Instead of being used as a master dynamic reference, M.S.P. can be used as a short-term or hybrid inertial system.

Five years ago S. G. Brown Ltd. produced the first two-gyro master reference unit (described in *Flight* for April 12, 1957). The Mk 1, which is fitted in all the latest British fighter and very high speed research aircraft, has now been succeeded by the Mk 2 which is 14in long, 7in wide and 8½in high, including the mounting frame and amplifiers. Because the vertical and azimuth gyros are set in line with the fore-and-aft axis of the platform their wheel diameters and therefore their efficiency have been increased. The rate of roll of the platform is 450 deg/sec. Only a 115 V, 400 c/s, three-phase power supply is required. The gyros have random wander rates of better than 0.25 deg/hr and platform vertical accuracy is 0.2 deg. A computer introducing appropriate signals to allow for the earth's rotation, sphericity and coriolis accelerations can be provided if the M.R.G. Mk 2 is to be used for navigational reference.

S. G. Brown last year concluded an agreement with American Bosch Arma (and not with Kearfott as stated in *Flight* for September 12, 1958) providing for an exchange of information. As a result of this, a Mk 3 M.R.G. is being planned to incorporate a pair of two-degree-of-freedom, Arma-Brown floated gyros. This equipment will be suitable for inertial navigation purposes.

The Sperry Rotorace vertical gyro, with the remarkably low drift (for a non-floated unit) of 0.25 deg/hr, has now been in service with Sperry C-11 compass system for more than a year. In this equipment gimbal-bearing imperfections are to a great extent cancelled out by rotating the concentric ball-bearing housings at about 20 r.p.m., the direction of rotation being