allow the system to turn continuously, power supplies for the gyroscope and signal-processing amplifier circuits, and gyroscope space-rate output signals are taken via a ten-way slipring unit.

The motor control unit is a Swiss IRT1350 digital controller. When this was purchased, semiconductors available would not allow the application of the 415V three-phase supply, and so a step-down transformer was fitted, which limits the peak motor driving voltage to 300V. Since the motor is wound for 380V, the peak motor speed is 4737rpm, not 6000 rpm, so that the peak traverse load speed simulated by the rig is 39·5deg/s, not 50deg/s. Later versions of the controller would tolerate the full 415V supply voltage. Matlab/Simulink computer models of the system are clearly able to model the test rig servo performance with 300V applied to the motor (4737rpm peak motor speed), or with 380V applied (6000rpm peak motor speed).

All signal processing at present is analogue; conversion to digital adaptive could be carried out later

The controller was modified by the author so that additional parameters could be recorded. A Hall-effect sensor and analogue multipliers now allow dumped power and dumped current levels during dynamic braking to be recorded, and also motor power. The controller was also modified so that the control mode can be switched easily from speed loop to torque loop, and vice versa.

All signal processing at present is analogue and is contained in an electronic rack (Fig. 4). Conversion of the rig electronics to digital adaptive could be carried out later, as a separate research exercise.

The effect of the mechanical resilience is illustrated by Fig. 5. The Nichols plot shows a severe resonance of 53 dB at 8·7 Hz. To suppress this resonance, tuneable notch filters are used in the signal-processing circuits, the final closed-loop system responses also being plotted in Fig. 5, which gives Nichols plots with the resilience suppressed and with the flywheel both coupled and decoupled. The system gain has been adjusted to produce a 3dB first overshoot to a step input ($M = 1{\cdot}4$). For an analysis of mechanical systems containing a resilience, see Reference 4, Annex C, pp. 343-370, also Reference 6, chapter 2.

In order to operate the rig at load speeds as low as 0·1mrad/s, additional mechanical stiffening was required, particularly in the vicinity of the gyroscope assembly, to reduce vibrations in the rig framework. The gyroscope output voltage at 0·1mrad/s load speed is 573μV (0·1mrad/s = 0·344 arc-min/s). The rig design ensures that there is no net torque attempting to turn the rig frame. Although the peak motor power with 300V applied is 24·1kW, it is not necessary to fix the rig frame to the laboratory floor.

Performance of the laboratory servo test rig

Acceleration tests on the rig allowed the inertia figure for all shafts/gears/couplings and the 12:1 gearbox, referred to the motor, to be determined. With the flywheel inertia decoupled, the servo motor achieved its peak speed of 496rad/s in 32·5 ms, against a theoretical time of 18·06ms. The total parasitic inertia, referred to the motor, is therefore 0·00176kg m^2, penalising the intrinsic motor inertia figure of 0·0022kg m^2 by an additional 80%.

The gearhead has a stated inertia figure, referred to its input shaft, of 0·0008kg m^2, so that all other parasitic inertias equate to 0·00096kg m^2 at the motor. In an actual turret system, this additional inertia would not be present, being necessary on the rig to add resilience and backlash, but the motor would still be loaded by the referred inertia of the servo gearbox, still a 36% inertia penalty.

Checking on system losses, it was found that the 12:1 motor gearhead lost a considerable amount of power and that there was a large change in the power-loss/motor-speed curve as the gearbox heated from cold. Fig. 6 plots the losses for both a cold gearbox and a hot gearbox.

The gearbox ran very hot (75°C surface temperature) and a blown heat exchanger was clamped to the gearbox to reduce the problem, but during a period of extended high-power testing, the seal on the gearbox output shaft

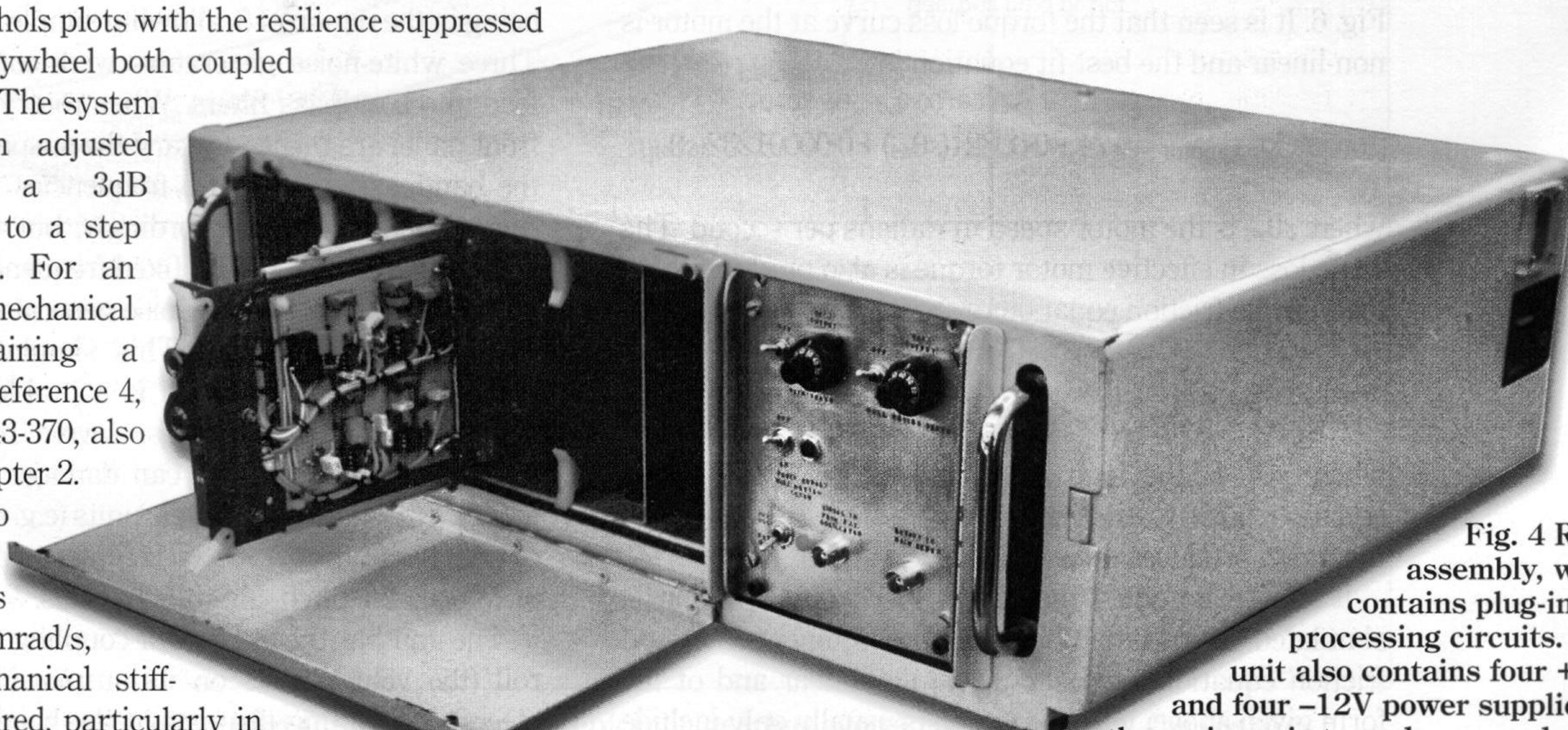

Fig. 4 Rack assembly, which contains plug-in signal processing circuits. The unit also contains four +12V and four −12V power supplies for the various rig transducers and signal-processing amplifiers