



Above left: stage wagons and an equaliser elevator, above right: a wagon drive unit, and right: a wagon seen from below

- 1: Drive trap closed
- 2: Drive pinion raised
- 3: Triple-swivel castor
- 4: Wagons on test – note lack of guide tracks or slots



Photos this page: Theatreplan

at all. After much investigation and analysis we finally settled on a rack and pinion drive.

We believed that it was practicable to have discrete slots in the floor as these would normally be covered by the working stage floor, which is the floor fitted on the wagons.

In operation the pinion rises and engages in a fully-machined rack mounted in the underside of the wagon. The pinion is mounted on the side of a gearbox, driven by an AC motor, and the whole gearbox and motor unit is raised and lowered by a linear actuator. The wagons are carried on triple-swivel castors, using double-castor units – these further reduce the resistance when the wagon is changing its direction of travel. These special allow for any direction of travel.

The machined rack is mounted within the heavy steel wagon from sections of rack are fitted, two stage, and two for up- and motion. These are mounted on removable central traps.

The wagons can each carry 16 tonnes and are 300 mm (12") high and each is carried on 16 triple-swivel castor units. Each wagon always remains engaged with at least two pinions, whether moving across stage or up-down stage. The next drive pinion required is signalled to rise and rotates at the same speed as those driving the wagon. When the wagon approaches the first laser detector, mounted in the drive unit in the floor, this provides a step-function signal which adjusts the phase of the motor drive so that the pinion is rotating in synchronisation with the moving rack. This process is called 'flying shear'.

The wagon continues to move by dead, but very accurate, reckoning between pinion



drives and this accuracy enables it to be positioned exactly when stopping at the end of its journey or adjacent to another wagon.

This is an extract from a paper on the stage engineering of the Copenhagen Opera House by consultant Richard Brett and is followed by Wolf-Guido Patten of Bosch Rexroth on their work in the Bolshoi Theatre and by consultant Tom Neville speaking about the technical installations in Kà in Las Vegas for Cirque du Soleil.

The wagons will, in fact, move over the full width of stage and side stages (which is 64 metres (210 ft)) and remain within the lateral tolerance of the gap between adjacent elevators which is ± 2 to 3 mm (0.12"). In addition, individual drives can be given a minute offset which can be used to accurately adjust the alignment of a moving wagon.

The parts which move horizontally, ie the stage wagons, and those that move vertically, the elevators, are clearly indicated in the side and rear stages by the colour of the floor. The wagons have pine flooring panels fitted to them, while the elevators are floored with birch plywood faced with a sacrificial layer of Masonite or oil-tempered hardboard.

One of the most worrying moves required was a single wagon moving up-down stage. For this direction of motion, two drives, one at each