A history of the Dowty marshalling yard wagon control system

D E Bick, BSc, CEng, MIMechE
Technical Consultant, Dowty Hydraulic Units Limited, Cheltenham, Gloucestershire

During the passage of wagons through marshalling yards accurate speed control is essential for high throughput and zero damage to rolling stock and freight. This paper deals with certain aspects of the history of the Dowty system, now installed in fourteen countries and five continents. It describes the novel concept, introduced in the 1960s, of power-operated oil-hydraulic units fitted at intervals to the rail track and operating upon the wheel flanges. Details are also given as to how it developed into the present form, which has the advantages of reduced capital, running and maintenance costs, being worked by the force of gravity alone. For his contribution to the project the author was awarded the Institution's Bramah Medal for 1980.

1 INTRODUCTION

The bulk of the world's railway traffic is still sorted in marshalling yards, which ideally must handle a high throughput and also enable wagons to buff together slowly to avoid damage. Since a relatively high velocity is essential in the switching area to provide sufficient separation between consecutive wagons, these requirements are not readily compatible.

The earliest yards managed as best they could with little or no automatic control, relying heavily on 'chasers' who ran alongside, pinning down the brakes as appropriate—a tiring and dangerous job.

In the UK the first mechanical clasp-type retarder yard introduced between the wars employed a single stage of retardation following the king switch (first division of the track below the 'hump') and was manually controlled. The system eventually developed to incorporate secondary retarders also, usually serving about six sidings each. Individual sidings control, though preferable, was generally ruled out on cost.

These latter yards often employed automatic control to take into account wagon weight, rolling resistance and wind forces, but even this sophistication could not compensate for a system inherently unsuited to the duty. The difficulties become clear when it is realized that from the hump to the end of the siding may amount to half a mile or more. In all weathers, to control accurately the motion of a wagon running under gravity over a long distance by the application of braking forces at two distinct and fixed points only, is clearly impossible. Indeed, tests conducted by British Rail at Temple Mills and Margam revealed that only 30 per cent of wagons buffered-up within the designed speed range of 0–2.13 m/s (0–7 ft/s); 20 per cent stopped short and 50 per cent collided at unacceptable velocities (**1**).

Apart from delays due to short-runners, much damage to rolling stock occurred from high-speed impacts, this in 1960 being computed at over £1 000 000 per annum in the UK, to say nothing of damage to freight. This figure may sound high but no worker subjected to the non-stop resounding crashes inseparable from such yards would doubt it.

Against this background, in the autumn of 1958 the author turned his attention to a radically new approach (**2**). The company by which he was employed was currently manufacturing its own design of hydraulic buffers for freight wagons and was thus well equipped to enter the new market. At this period the UK possessed no less than 1 250 000 wagons of all sorts and origins, a quantity exceeding the whole of Continental Europe.

2 GENERAL APPROACH

The concept consisted of controlling wagon speeds over virtually the whole journey through the yard by means of hydraulic devices dispersed along the rails. Such an aim promised the maximum possible performance, coupled with zero damage, although the potential took a number of years to realize fully for reasons explained later.

The history and development of the Dowty wagon control system falls naturally into two parts, the original concept which relied heavily on power-assistance, and the present simplified version which in virtually every instance is powered entirely by gravity, thus providing great reductions in capital and operating costs. Firstly however, it is necessary briefly to explain the gradient profiles for a Dowty yard and to note how they differ from the conventional approach with clasp-type retarders.

Figure 1 shows the optimum profile compared with a clasp retarder installation, using primary and secondary units, and the higher 'hump' in the latter will be noted. This is necessary because a much greater speed through the switching area is essential to prevent catch-ups where wagons of widely differing rolling resistance and wind resistance are running purely under gravity and without external control.

The constant gradient through the switching area in the Dowty system is sufficient to maintain virtually all wagons at the design velocity, the retarders limiting the speed to the required figure. Just inside the sidings a closely packed group of low-speed retarders, known

This paper was presented at an Ordinary Meeting held in London on 28 September 1983. The MS was received on 17 July 1983 and was accepted for publication on 25 July 1983.

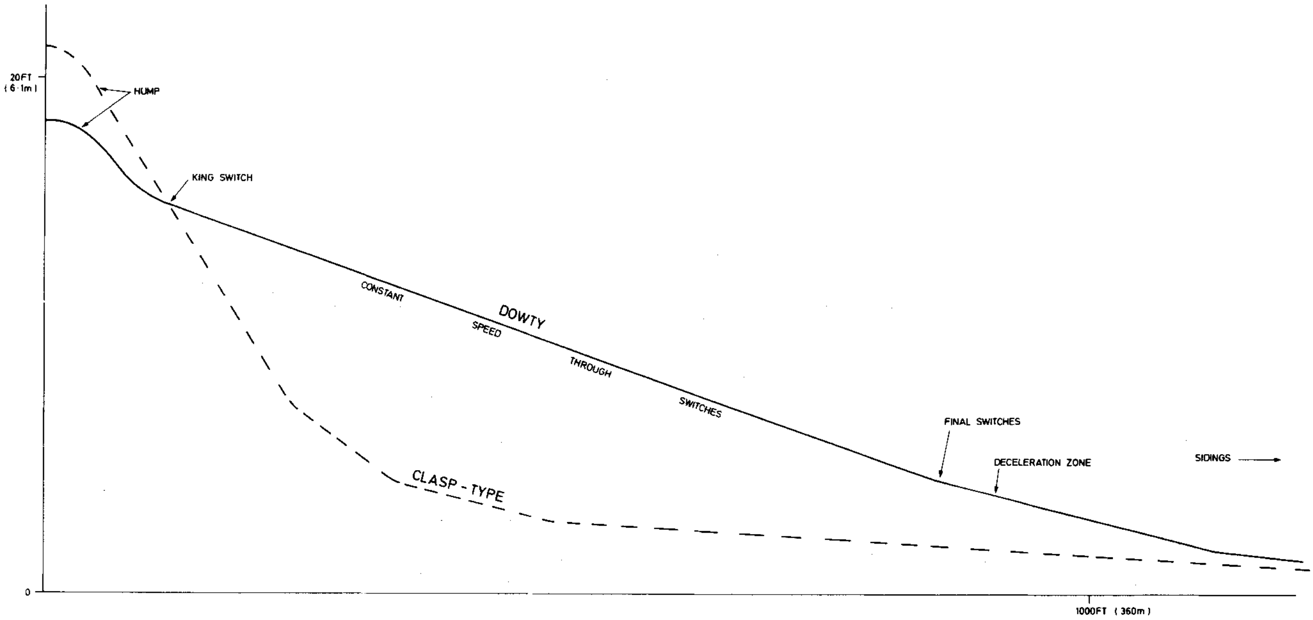

Fig. 1 Typical profiles of Dowty and clasp-type retarder yards

as deceleration units, are fitted in order to reduce rapidly the speed of incoming wagons to an acceptable value for buffing.

Taking the yard as a whole, the actual determination of gradients and disposition of units on the track is an involved and complicated procedure worthy of a paper in itself, that cannot be described here. Suffice it to say that the early methods of manual calculation combined with 'inspired guesswork' have given way to sophisticated computer techniques thus saving a great deal of labour in the process.

3 THE HYDRAULIC BOOSTER/RETARDER

In the 1950s most rolling stock in this country ran on grease-box axle bearings, the efficiency of which, when well maintained, unfortunately did not compensate for shortcomings when neglected. The resulting wide scatter of rollability (rolling resistance) ruled out a purely gravity operated yard because of the excessive requirement for retarding capacity to cater for heavily laden good-running wagons. A boosting feature was thus essential to permit the use of lesser gradients. Ideally the hydraulic device should perform either a boost or retard function, depending on the speed of the wagon. For such a requirement the unit should accelerate all wagons running below a certain critical speed, and decelerate all those running faster. Typically this was 3.66 m/s (12 ft/s) in the switching area and 0.90 m/s (3 ft/s) in the sidings. There was also a further requirement that sidings units must be direction-sensitive, so that wagons recoiling after impact would not be boosted back up the line. The energy for boosting was to derive from a hydraulic power source, 100 bar (1500 lbf/in^2) being the chosen pressure. The upthrust would be $1\frac{1}{2}$ tonnes limited by the axle-loading of the lightest wagons in service.

Even on paper, to meet such a specification was no easy matter, and for a time appeared impossible. On being impacted by the wheel flange, the unit had instantaneously to decide whether to offer a resistance on the downstroke and return under light pressure only (retarding), or to descend freely and return with full thrust on the up-stroke (boosting).

After some six months of trial and error which included proposals for working a number of track units in conjunction with a common grouping of valves, a promising solution was found, and became embodied in a provisional specification accepted by the Patent Office on 11 May 1959. This did not include the direction-sensitive feature, although such a device was incorporated in the complete specification.*

The key to the unit, and all subsequent developments, lay in the speed valve, a hydraulic device similar to an electrical circuit-breaker which closed an orifice whenever the flowrate (proportional to wagon velocity) exceeded a pre-determined value. This ensured a sequence of events which created retardation on the down-stroke, but if the critical flow was not reached another sequence took place, resulting in boosting on the up-stroke.

Six prototype booster/retarder units went on trial late in 1959, and it was a very encouraging moment when for the first time a wagon accelerated slowly forward by so unconventional a manner of locomotion. However, with all the implications of novelty, to say nothing of the associated power-pack and network of pipes and hoses, those who witnessed the trial may be excused an inner reservation as to whether so revolutionary a concept would ever gain acceptance in the practical world of railways. That it did so was in great measure due to the co-operation and encouragement of the British Railways Board, which had much at stake in the outcome. The system was first publicized by an article in the *Railway Gazette*, 13 May 1960.

These six prototypes are of some historical interest, and the mode of operation can be understood by reference to Fig. 2a.

---

* UK Patent 909181 published 24 October 1962.

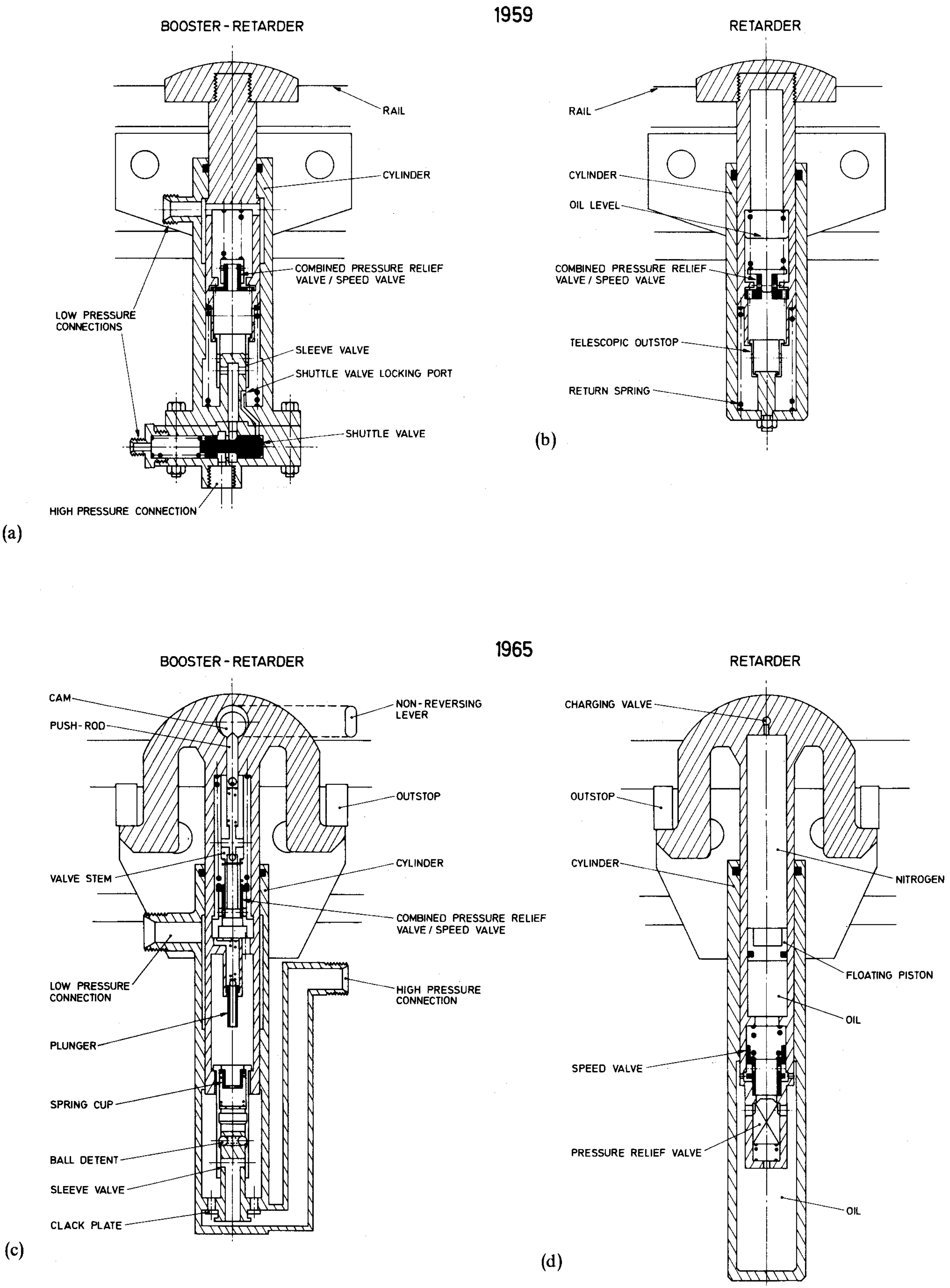

Fig. 2 Semi-diagrammatic illustrations of hydraulic retarder and booster/retarder units

3.1 Mode of operation

For boosting, a slow moving wagon in driving the piston down, did not create enough flow to close the speed valve, and the displaced oil passed into the return (low-pressure) line, maintained at 5.5 bar (80 lbf/in^2). At the bottom of the stroke the sleeve valve was pushed open, admitting high-pressure oil which closed the speed valve and provided thrust for boosting. Finally, a lost-motion device retrieved the sleeve valve to cut off the high-pressure supply.

For retarding, the higher wagon velocity closed the speed valve, the oil being displaced via the relief valve. At the bottom of the stroke the sleeve valve again opened but to no avail since the internal pressure had motivated a shuttle valve to isolate the high-pressure supply. On the up-stroke the speed valve opened, admitting low-pressure oil to push the piston upwards. The shuttle valve could not return because the sleeve valve had sealed the appropriate port. At the top of the stroke the sleeve valve once more blocked admission of high-pressure oil, although the shuttle valve had meanwhile returned to its original open position.

Although complex, this design performed well but suffered from the drawback that during a retard stroke the whole of the energy was dissipated through the relief valve. For a large installation this amounted to an intolerable waste of power, and later embodiments removed the objection by permitting regeneration by means of a non-return or clack valve into the high-pressure line. The final configuration is shown in Fig. 2c, and apart from a longer stroke differs considerably from its predecessor. An understanding of the improved mode of operation may be gathered from the drawing, or alternatively can be found elsewhere (3).

Among the design features requiring particular attention was provision of a sufficiently robust construction to withstand the piston assembly constantly hammering against its up-stop. This was solved by fitting lugs to the guides forged integral with the head of the unit and employed to prevent rotation about a vertical axis. In addition, the provision of adequate areas in the very confined space available for hydraulic oils flows, amounting to some 160 l/min (35 gal/min) at wagon speeds of 3.66 m/s (12 ft/s) called for considerable ingenuity of the ‘quart into a pint pot’ variety. Any increase in size to provide more space would have been self-defeating, since flow is proportional to piston area.

Since from calculation it was known that more retard strokes than boost strokes would be needed for optimum economy taking the yard as a whole, a self-contained retarder unit was also designed, as shown in Fig. 2b. This also employed a combined speed and relief valve, with a coil spring to return the unit. In certain production versions the spring was replaced by a pre-charge of nitrogen gas, separated from the oil by a floating piston, to provide a faster extension necessary to cater for higher critical speeds.

3.2 Testing and full trials

On test, the effect of continuous impacting created a ‘flat’ around the tip or periphery of the wheel flanges. This phenomenon gave rise to considerable concern, since the tip form had been standard since the 1840s and deviation was without precedent. Eventually however, it was realized that flange and tread re-profiling due to wheel wear would restore the original form long before any potential trouble arose.

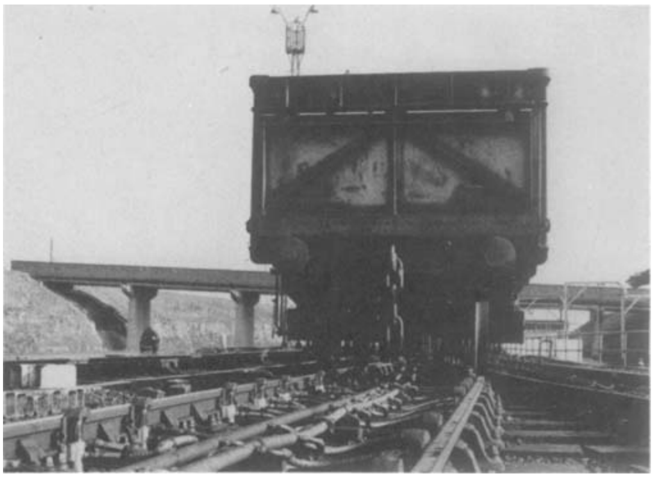

Fig. 3 Hydraulic booster/retarders at Tinsley yard

Many millions of cycles of endurance testing were carried out on a special length of track fitted with booster/retarder units with a steep incline at each end. A wagon was thus propelled to and fro, at the same time testing the units which supplied its means of propulsion. This proved very successful and represented as nearly as possible actual environmental conditions. Various attempts over the years to simulate service conditions without the use of a railway wagon to provide the exact geometry of wheel impact and load–stroke relationship never proved entirely satisfactory, except as a means of comparison. Another early doubt revolved around the question of weakening the rails by drilling holes to attach the units, but this again proved groundless.

The culmination of these efforts led to trial installations at Hull and Goodmayes yards, and in 1965 to the commissioning of British Rail’s Tinsley Marshalling Yard near Sheffield (Fig. 3) to handle 4500 wagons a day entirely on the Dowty system. This must surely rank as the biggest oil–hydraulic installation in the world, and some idea as the scale of operations is gained from these statistics:

Area of yard	59 hectares (145 acres)
Sidings	57 in main yard, 26 in secondary yard
Booster/retarders	14 600
Retarders	10 630
Circuit capacity	91 000 l (20 000 gal)
Flexible hoses	29 250 (29 km total length)
Steel feedpipes	42 km total length
Weight of equipment	7800 tonnes including power packs, pipework, boosters etc.

The energy ratings of the units are as follows:

Booster/retarder	
boosting	1020 J (0.31 ft ton)
retarding	1150 J (0.35 ft ton)
Retarder	1050 J (0.32 ft ton)

The hydraulic power supply is housed in a central power house and comprises 120 h.p. twin-Dowmatic pumps with off-loading facilities when working on reduced demand.

A further yard of twenty-one sidings was commissioned at Bescot near Wolverhampton in 1966, where a novel feature consisting of a negative or reverse gradient was introduced at the entry to the sidings. This reduced the energy head of wagons, thus lessening the number of retarders required to bring the vehicles quickly down to an acceptable buffing speed. It did, however, on rare occasions, display an alarming characteristic. The problem arose when for any reason, e.g. binding brakes, a wagon stalled at the top of the crest. In such an instance the following wagon would tend to recoil on impact, with unfortunate results since the booster units in the switching area were not fitted with an anti-reversing facility. The author once had the traumatic experience of witnessing such an event when a rake of empties slowly returned against the gradient towards the hump from whence they came, the demonstration incidentally vividly displaying the power of the booster units as a means of propulsion.

In spite of unavoidable complexity the standard production hydraulic booster/retarder units proved capable of service in an arduous environment including millions of hammer-blow impacts. In addition, from operating and wagon damage aspects, the concept fully realized expectations, and its worth was recognized by receipt of the Queen's Award for Industry, 1968. At the time of writing, Tinsley and Bescot yards are still at work, being the last new marshalling yards built in this country. Without such experience further important developments could not have taken place.

4 THE GAS–HYDRAULIC CAPSULE RETARDER

By 1969 a great deal of operating experience had accrued, and in addition far fewer of the old greasebox wagons remained in service. In short, the ideal solution consisting of a yard motivated entirely by gravity seemed within sight, if not within grasp. Devoid of power packs and pipework, and with simpler installation and reduced maintenance, the potential was very great. However, everything rested upon the availability of a low-cost and thoroughly reliable retarder.

Thoughts turned to a unit employing a gas–oil combination in which no attempt was made to separate the two fluids, thus avoiding the problems and expense of a separator piston. The principle was first applied on the Dowty gas–oil buffer for railway wagons, which had entered production some ten years previously, following an urgent need for a hydraulic buffer with high recoil force. To show what could be done, the idea for the buffer was drawn up and two prototypes were manufactured and brought back to the development site where they were put on test, the whole operation from start to finish occupying considerably less than three days.

Initial steps turned to converting the existing retarder to the new concept and Fig. 4a, shows the essential features. A coil spring provided the return force, the air space accommodating the thermal expansion of the oil and displacement of the piston rod. However, such a compromise could never do justice to the full potential, and was overtaken on the drawing board by a more imaginative approach.

The new embodiment consisted of a self-contained energy-absorbing capsule located in a cast-iron pot bolted to the rail and capable of being lifted clear for overhaul without disturbing the pot*. This was a great novelty and an advantage from the servicing aspect; fears that it invited pilfering of the capsule have proved virtually groundless.

Implicit in the approach was a domed head in place of the curved head and guide-ears of the original design. This avoided an expensive forged and welded assembly and also wear of the guides. If the descending retarder preferred to revolve under the action of the wheel flange, why not let it? This simple plan proved effective, and any theoretical increase in Hertzian stress at the point of contact was offset by a great reduction in inertia of the moving parts. The design (Fig. 4b) was also much better adapted for use with flat-bottomed rails which were now virtually standard throughout the world.

The mode of operation is as follows: on being impacted above the critical speed the speed valve closes virtually instantaneously and pressure rises to the relief valve setting. Further descent of the piston then subtracts energy from the wagon, depending on the pressure setting and stroke of the unit. After bottom dead centre is passed, the compressed nitrogen acting on the piston rod exerts an upward force, returning the capsule to its original position. The clack valve closes most of the area of the flow passages in the piston, thus limiting the upward velocity of the capsule to prevent possibility of the capsule jumping out of the pot.

Below the critical speed the speed valve remains open, so that the capsule descends with little resistance. Different pre-set critical speeds are obtained by varying the strength of the springs under the valve.

Before proceeding further, an inversion of the design was also considered, the alternatives being shown in Fig. 5. The relative merits may be briefly accounted as follows, leaving no doubt as to the choice of configuration A.

Energy capacity Since on the initial stroke, type B reacts as a solid column of oil, the energy capacity is potentially slightly greater, but there is nothing to choose between A or B when the oil is emulsified on subsequent strokes.

Accuracy of speed control In type B the delicate speed valve mechanism situated in the piston is subjected to a hammer-blow impact just at its moment of decision, an undesirable feature which type A avoids. Furthermore, the variation in response to initial and subsequent impacts mentioned under energy capacity will create additional errors.

Structural stress In type B the solid column of oil above the piston on the first impact creates very high Hertzian stresses, which type A avoids by the cushion of compressed nitrogen.

Overheating In type A the energy-absorbing capsule is directly exposed to the atmosphere and will therefore run cooler than type B.

---

* The invention is covered by UK Patent 1328186.

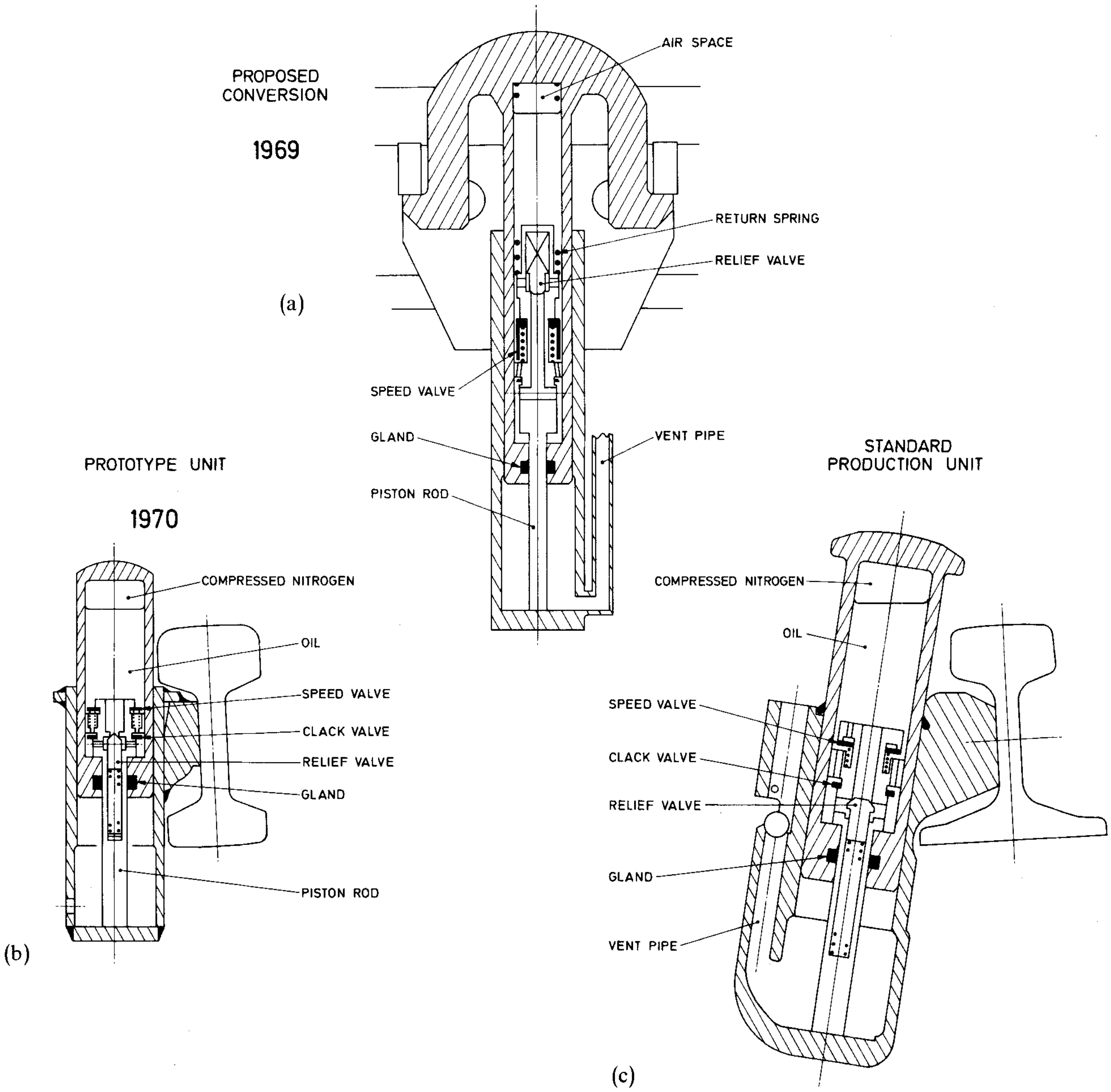

Fig. 4 Semi-diagrammatic illustrations of capsule retarder design

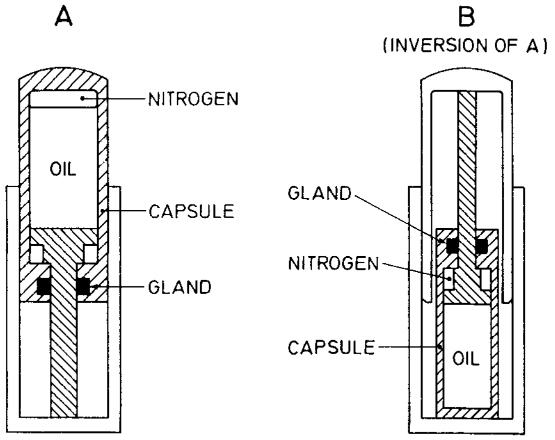

Fig. 5 Alternative embodiments of the capsule retarder principle

Seal life In both types the gland is well protected, but type A scores because it is always submerged in oil and therefore is less liable to leakage or 'welding' onto the rod after long periods of disuse. Also, the configuration of a rapid down-stroke and slower (damped) up-stroke is theoretically ideal for minimum leakage. This has been confirmed by extensive testing.

The efficiency of the dynamic seal was critical, since the saving in cost and space by replacing a coil spring with compressed gas, and indeed the whole concept of the design in great measure depended upon it. Utilizing experience gained elsewhere in the Dowty Group, the permissible leakage target was gained with virtually no development whatever, an example of how, not infrequently, fears of serious or even insurmountable obstacles in the path of technological progress prove groundless when put to the test.

A novel means of charging the capsule with nitrogen without the cost, complication and potential unreliability

Fig. 6 The prototype capsule retarder

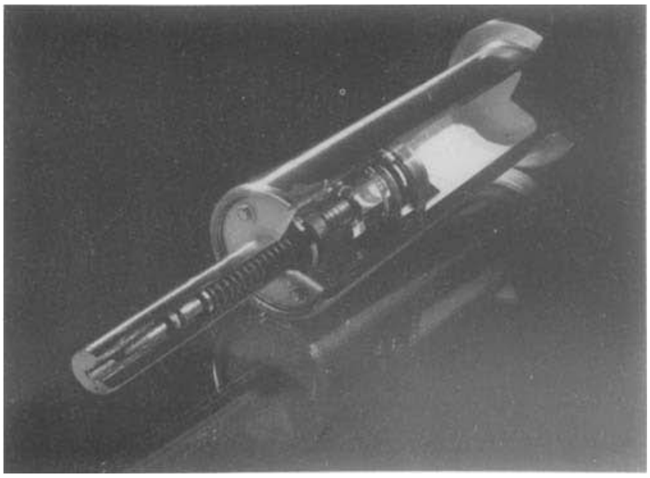

Fig. 8 Cut-away view of capsule, showing internal design

Fig. 7 Early capsule retarders in the switching area at Scunthorpe yard

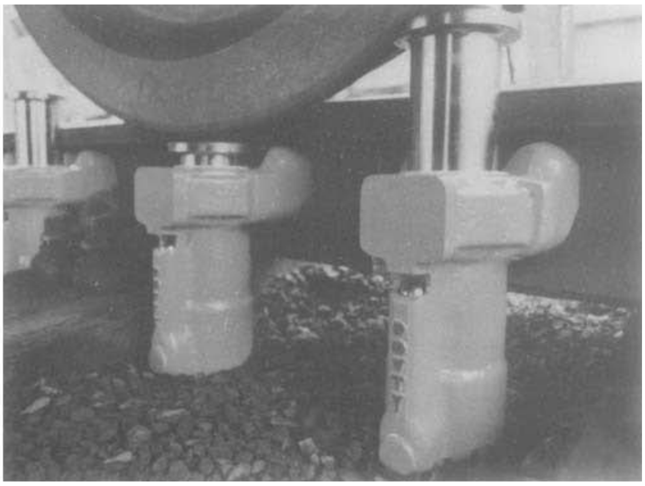

Fig. 9 Close-up of wheel flange acting on retarder

of a charging valve was also introduced. It comprised a small hole in the cylinder near the open end, around which a special collar could be attached. To this was fitted a flexible hose from a gas bottle and pressure applied with the gland nut screwed only partly in. On screwing home, the static 'O' ring on the gland nut engaged the bore, thus trapping the gas in the capsule cylinder. This method also had the advantage of automatically de-pressurizing the capsule on dismantling.

By good fortune, British Rail were at this time seeking to update a gravity yard of nineteen sidings at Scunthorpe to handle steel traffic, and the proposed new unit seemed very suitable for the purpose. A number of prototypes, as shown in Fig. 6, were fitted at Tinsley for evaluation and after minor modifications including cast-iron pots, became a standard production unit (Fig. 7).

To minimize costs the existing gradient of 1 in 157 was retained for much of the switching area, leading to a reduced gradient of 1 in 700 in the sidings. A final negative gradient of 1 in 100 prevented run-outs. A relatively low specified wagon throughput permitted switching area speeds of only 2.44 m/s (8 ft/s) with corresponding economies in deceleration units at entry to the sidings.

An order was received in February 1971, the yard being commissioned during the following year in two stages to prevent interruption of traffic. It was later up-rated to handle heavier wagons and is still in operation. Thus was provided a home market, an invaluable asset for launching the product into much larger markets abroad.

The simplicity and ease of maintenance of the all-retarder concept proved a great attraction, and led to many inquiries. The first overseas installation was for the Western Australian Government Railways at Forrestfield, consisting of thirty-one sidings and 7700 retarders, commissioned in 1973.

Subsequently a somewhat modified unit for higher speeds and greater axle-loadings became standard. It is illustrated in Fig. 4 (right), Figs. 8 and 9, which also shows the action of the wheel flange. The construction broadly follows the earlier unit except that the speed valve setting is adjusted by a screwed ring, and the relief valve by a grub-screw in the piston rod.

Having stated that the ideal solution aimed to replace the hydraulic booster/retarder concept with retarders only, it is more an illustration of exceptions proving the rule than an admission of defeat to concede that occasionally installations arise where boosting is still required. An instance may be cited where optimum gradients are rendered unacceptable due to civil engineering restrictions such as bridges, sewers etc. and to this end a compressed air unit was developed. With this fluid however, to incorporate the boosting

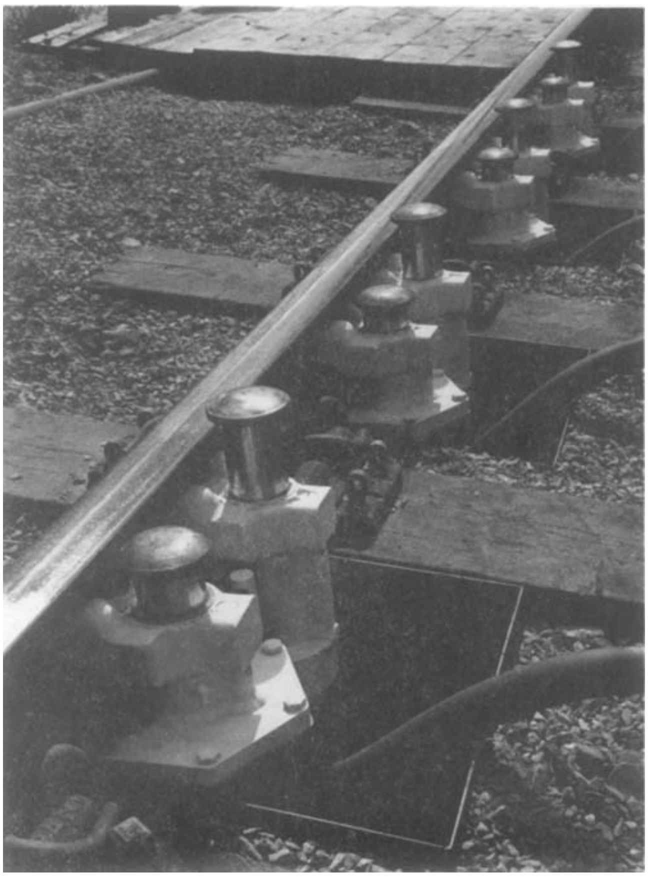

Fig. 10 Compressed air booster/retarder units in pairs; the booster is on the left

and retarding modes in a common unit has not proved possible. The adopted method applies the standard retarder capsule to trigger an air valve in series with the compressed air booster whenever the retarder fails to signal a retard stroke. Thus the two units operate in conjunction as a pair, as shown in Fig. 10, the direction of wagon motion being towards the camera.

These compressed air units also find application in loading bays and coach (car) washing plants, where they may also be used in reverse as retractable stops. Their largest application so far has been at Sentrarand, South Africa, where an installation comprising 18000 booster/retarders and 42000 retarders was commissioned in 1982.

The most recent development has been the introduction of a simple, remotely controlled, electro-hydraulic latch unit which can be bolted to the retarder pot, for the purpose of holding capsules in the 'down' position to aid rapid train withdrawal from the sidings.

5 CONCLUDING REMARKS

At a period when foreign competition is practically forcing British industry out of business, it is no longer reasonable to expect improvements in design or manufacturing methods applied to old and time-honoured technology to produce much benefit, for the ground has been far too heavily prospected for any real hope of worthwhile return (**4**).

The other approach, although uncertain in outcome and more costly in the short-term, is the pursuit of new solutions, where the full potential for development is there to be exploited. The Dowty system of wagon control falls into this category and it is pleasing to record that it has been justified by results.

ACKNOWLEDGEMENTS

The author would like to thank Dowty Hydraulic Units Limited for permission to present this paper and to acknowledge the role played by his colleagues in bringing this project to a successful conclusion.

REFERENCES

1 **Alexander, N. J. B.** Wagon retardation equipment in hump marshalling yards. *Proc. Instn Civ. Engrs*, 1966, 275–291.

2 **Konig, H.** Choosing hardware to automate marshalling yards. *Rly. Gaz. Int.*, Feb. 1980. (Gives details of current solutions of various kinds.)

3 **Checkley, P. E.** The Dowty wagon speed control system. *Proc. Instn Rly Signal Engrs*, 1964–65, 72–97.

4 **Bick, D. E.** Rotary engines—some design lessons from the past. *CME*, June 1978, 82–83.