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THE RESEARCH, DESIGN AND DEVELOPMENT OF AN ORIGINAL AUTOMATIC DOOR CLOSER FROM CONCEPT TO PROTOTYPE PRODUCTION



ABSTRACT

Many engineering companies in Britain have been forced to innovate in order to maintain, or develop, a strong hold and high profile in varying competitive markets, researching, designing, redesigning and developing new products. With the imminent introduction of the European Economic Community such companies face even greater competition with their European rivals all seeking to develop into larger markets. The time is ripe for innovative new products.

The work presented in this thesis concerns just such a product, a single arm automatic door closer/control designed for Newman Tonks Engineering Ltd, the project sponsors.

The body of work may be divided into three main parts :-

- A conspectus of door closers in general familiarising and educating the reader with the types and features available, including the general performance and ergonomic requirements of the product to be designed.
- 2 Complete research with the analysis and assessment of selected products resulting in the compilation of a data base instructive in the project development and a general reference for Newman Tonks Engineering Ltd.
- 3- The design of an original door closer from concept, in terms of engineering and aesthetics, through to the production of a working prototype with full evaluation

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- 4 To Syd Pace, Department of Design and Technology, LUT, Alan Underhill, Department of Mechanical Engineering, LUT and David Yates, Director of Research and Development, NTEL for initiating the project and for their continual support and advice throughout its duration.
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NOMENCLATURE

A	=	Area (m²)
a	=	Die spring displacement(core/detente displacement) (m)
a 1	=	Cam radius at angle (m)
С	=	Basic dynamic load rating for a bearing (N)
с	=	Damping coefficient
с ₁	-	Minimum distance between drums of a constant force spring
		mechanism (m)
Da	-	Outside diameter (m)
Dı	-	Inside dlameter (m)
d	50	Distance from hinge to door closer arm contact point (m)
d 1	=	Constant force spring storage drum diameter (m)
d_2	-	Constant force spring torque drum diameter (m)
e	=	Eccentricity of load (m)
F	=	Force (N)
f ₁	=	Free length of helical compression spring or die spring(m)
f ₂	=	Formed length of helical compression spring or die spring
		(m)
h	=	Formed height of unloaded disc spring (m)
L ₁	-	Helical compression spring load (N)
L ₂	=	Die spring load (N)
1	=	Door closer arm length (m)
¹ 2	2	Piston length (m)
10		Total height of unloaded disc spring (m)
м		Moment of inertia (Kgm ²)
Mt	=	Bending moment (Nm)
N	=	Factor of safety
P	=	Pressure (N/m ²)
P2	-	Maximum Load (N)
P r	=	Preload of helical compression or die spring (N)
P	-	Life exponent for a bearing
R		Spring rate (N/m)
R ₁	=	Reaction Force (N)
R ₂	=	Reaction Force (N)

r	=	Pinion radius (m)
r ₁	=	Piston/bore radius (m)
S	=	Disc spring or constant force spring thickness (m)
т	=	Door Torque total (Nm)
T ₁	=	Door toque due to helical compression spring (Nm)
т ₂	=	Door torque due to die spring (Nm)
т _з	=	Door torque due to die spring through the blend cam (Nm)
τ	-	Time (s)
V	=	Volume (m ³)
W	=	Constant force spring width (m)
x	2	Mechanical advantage (or used locally as a distance
		measurement) (m)
У	=	Perpendicular distance between the line of action of the
		spring load and pinion centre (m)
уl	=	Distance from the neutral axis to the extreme point (worst
		stress point) (m)
	∝ =	Angle at which a force acts on the door (degrees)
	β=	Angle between the line of action of the die spring load
		and pinion centre (degrees)
	9 =	Angular position of the door (degrees)
	σ =	Stress (N/m ²)
	μ =	Coefficient of friction
	ク =	Efficiency (%)

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INTRODUCTION

1.0 INTRODUCTION TO DOOR CLOSERS

A door closer of the type to be designed, when fitted, automatically closes a door which has been opened manually and then released. There are many types incorporating varying refinements and functions described in the next section.

On top of the basic function of door closing they have additional purposes :-

- (a) In preventing the spread of fire and smoke in buildings which can only be guaranteed if doors are held in a closed position, preferably latched. Often an intumescent seal is built into the door set but can only operate correctly in the event of a fire when the door is closed.
- (b) In the conservation of energy by keeping doors closed thus preventing unnecessary heat loss to both the outside of a building and between sections within a building.
- (c) In security when used in conjunction with doors which are selflocking when closed.
- (d) In lessening the damage caused to both the door and door furniture, frame and walls by arresting the movement of a door in closing and opening; such as under abuse when kicked, thrown and blown open or closed.

1.1 TYPES OF DOOR CLOSERS

It is possible to divide door closers into the following main categories by function \cdot -

1.1.1 Overhead Door Closers

These are usually mounted at the top of the door or frame and are used to provide full control of single action doors. They are usually surface mounted so simple to install. Used in combination with door latches, by design, they must produce a high torque near the door closed position so overcoming the latch bolt friction and resistance. 1e, the door closer must have a 'snap' action. This type of door closer is perhaps best described as a door control, because closing and latching speeds are controlled as well as closing torques, and the door closer resists efforts to be pushed closed at a faster rate than it would normally, such as due to wind pressure on an outside door. They often have an adjustable back check incorporated into the mechanism which arrests the door when it is 'flung' open preventing damage to the door furniture, the frame or the door itself

The mechanism is usually a rack and pinion hydraulic damped system, such as the NTEL 2000 series. See Appendix 4, page 229.

1.1.2 Concealed Overhead Check Action Door Closers

These are as above except that they are not surface mounted but are set into the door.

1.1.3 Concealed Transom Mounted Check Action Door Closers

These are as above except they are set into the door frame above the door.

1.1.4 Floor Springs

These are positioned in the floor below a door supporting and controlling the door. A hole must be dug below the door to accommodate the closer which is often set in concrete. They are most commonly used in double action doors where the door closer itself holds the door in a closed position rather than forcing it against a jamb and over a latch.

The mechanism usually used is a cammed drive shaft with a spring loaded roller follower, again hydraulically damped to give control.

1.1.5 Concealed Non Check Door Closers

These are set into the door and frame on the hinge side of the door See Appendix 7 on page 229.

They do not offer any additional force to overcome the latch bolt resistance of the door relying instead on the momentum of the door slamming it shut. ie, no 'snap action' is incorporated in the door closing mechanism. They have limited strength and no control over closing speed.

The mechanism is based on the compression of a helical compression spring when in opening a door a chain connecting the door to the frame is pulled Obviously this means in some situations the door may be forced closed faster than it would close normally due to the chain which has no compressive strength. Consequently this type of door closer cannot control the door.

1.1.6 Concealed Jamb Fixing Check Action Door Closers

These are the same as above but incorporate an adjustable back check. They may also be hydraulically damped to control closing,

but the dependence of this design on the chain connecting the door to the door frame limits its control as above.

1.1.7 Jamb Fixed Non-check Door Closers

These fix to the door jamb and usually have an arm projecting from the door closer to the door, which closes the door. Again see Appendix 7 for a typical example. Its limitations are the same as the above, but the spring tension and so closing torque are easily adjusted.

The mechanism is based on the arm twisting a tension spring

1.1.8 Single and Double Acting Spring Hinges

These are incorporated into the door hinges so also carry the door Accurate fitting is therefore necessary. They may be further divided by the mechanism used. Appendix 8, page 229 shows both types. The 'Hawgood' type uses a compression spring where the opening of the door causes the spring to be compressed via a tension member. The 'Fridavo' type uses either one or two torsion springs in the hinge axis for single or double acting doors respectively. The second type has only limited adjustability, but neither is controlled or has a 'snap' action.

All of the door closers described are mechanical relying on the opening of the door to generate enough energy to then close it. Electronic door closers were not considered in the project because they are not 'free standing' requiring instead, some form of electrical supply.

The Guild of Architectural Ironmongers (GAI) only recommend using types 1 and 4 above for use on fire resisting doors in public buildings. ('Fire Resisting Doors', Part 1, section 5, Door Closing Devices). This will soon be published as Pt 4 of BS 6459. If the door closer does not satisfy what are now GAI recommendations then they will not qualify for classification as BS door closers in future.

1 and 4 are recommended because they both latch or close the door and control the door in shutting. The others either do not do this or so much material is removed from the door or frame for fixing that the door's effectiveness in preventing the spread of fire is reduced.

1 2 SURFACE MOUNTED OVERHEAD DOOR CLOSERS

The type of door closer which NTEL wished to have designed was a surface mounted overhead door closer because it may be used with fire resisting doors without affecting the integrity of the door and so compliance with the GAI recommendations That is they :-

- (a) should not be capable of being disconnected easily
- (b) should not be fitted with a mechanical stand open facility
- (c) should override any latches fitted to the doors on which it is used
- (d) should be of a type that has been shown, by test in accordance with BS 476 Pt 8, to be capable of holding a door into a frame until an intumescent seal has been activated
- (e) should effectively close the door from any angle of swing. (Fire Resisting Doors, Pt 1, Door Closing Devices).

Such overhead door closers design is comprehensively specified in British Standard, Door Closer, Pt l 'Specification for mechanical performance of crank and rack and pinion overhead door closers', 9 October, 1986 and fully supported by the GAI.

This most common type of surface mounted overhead door closer usually uses a crank or rack and pinion mechanism (although other mechanisms exist). When the user opens the door the spring inside the door closer is compressed storing the user's energy input. Once released the compressed spring returns this stored energy and so the door to its original closed state. Often the speed of the door's motion is controlled by regulating the flow of a fluid (usually oil) through a system of valves. The fluid's movement is induced by a piston moving laterally with the motion in the spring chamber.

1.3 TORQUE

The opening and closing torque of a door may be defined by the following equation :-

 $T = \frac{M.d^2\theta}{dt^2} + \frac{c.d\theta}{dt} + R.\theta x$

Where :-

- T = Torque (Nm)
- M = Moment of inertia about the hinge (kgm²)

 θ = Angular position of the door (degrees)

t = Time (seconds)

c = Damping coefficient

R = Spring rate (N/°)

x = Moment arm for a particular door closer/door configuration (m)

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The acceleration of the door and its velocity functions, ie, the $\frac{M.d^2\theta}{dt}$ and $\frac{c.d\theta}{dt}$ terms of this expression are commonly ignored when $\frac{dt^2}{dt}$ dt deriving a characteristic for a door closer Static opening forces (the force required to push the door open) and closing forces (the force returned by the door closer in closing the door) at various angles of door position, measured at known distances from the door hinge, give the torque. This Torque versus Door Angle characteristic is known as the 'Powercurve'.

1.4 THE POWERCURVE

The closing torque on a door should be large at zero degrees to overcome the latching resistance of the door and any draught it may experience which are most noticeable at this point. Following this peak torque it is preferable that the torque then drop to a lower level which is only necessary in overcoming the momentum of the door, resistance of hinges and draughts.

The opening torque on a door should be small so that the user finds the door easy to open, although large enough to give the user some resistance and to overcome the doors residual momentum once the user releases it. This dictates an approximate ideal powercurve shown in diagram 1, page 8.

In practice such a powercurve characteristic is unachievable for a self contained door closer relying on energy storage and not on some form of energy input such as electric or pneumatic power. This is because the energy input to the door closer must equal the energy returned (assuming 100% efficiency) or, in fact, be greater to compensate for any inefficiency. So where the user, as a matter of ergonomic preference, would like the opening torque to be low and remain low the energy input to the system, the area under the graph, is not enough for the energy returned to give the desired peak closing torque at the latch.



Diagram 1



Diagram 2



Diagram 2 shows the next best alternative. The overall energy input of the opening torque characteristic would be equal to the energy of the overall closing torque characteristic Here a compromise is struck by reducing the ergonomically undesirable high latching torque so that opening the door is less difficult. However, the rest of the opening torque is required to be higher thus making up the additional energy necessary. Sadly this requires the door to be opened fully for the energy in the door closer to equal the energy returned by it and so close and relatch the door. ie, if it were only opened to 2°, just off the latch, then there would not be sufficient energy in the door closer for it to close the door.

This discussion outlines some of the limitations of energy storage devices and so, in turn, the limitations placed on the powercurve characteristics. It can, therefore, be seen that the opening torque characteristic must replicate the closing torque characteristic but at a higher level to compensate for energy losses due to inefficiency. This means the energy stored in the door closer at any one point, whether the door is opened to two degrees or one hundred degrees, is always enough to close and relatch the door. See diagram 3, page 8. The powercurve shape is discussed in more detail in the Discussion of Powercurve and Efficiency Characteristics section 3.6C page 37

Due to the considerable variance of doors in both mass and width there are variable 'power sizes' of door closer. Where the door closer is wider or heavier the 'power size' rating must be larger so the closing torque is large enough to overcome the greater latch resistance, inertia of the door etc. Likewise, if the door is narrow or light a smaller 'power size' is necessary

So the opening torque of the door closer is always going to be greater than its closing torque to compensate for losses due to inefficiency from the door closer mechanism, armset, hinges of the door, etc. This level of efficiency may be defined in the following equation :-

Efficiency
$$(\eta) = \frac{\text{closing torque (Nm)}}{\text{opening torque}} \times 100\%$$

The efficiency requirements of a door closer also vary according to the power size ratings. Where the efficiency is high then for any given closing torque, the corresponding opening torque need only be marginally more equating to an easier door to open The efficiency requirements are less for smaller power size ratings and larger for higher power size ratings. This works out ergonomically favourable, in absolute terms this means the increase of what is a smaller torque anyway which causes little problem. If it were an inefficient, larger rated door closer the user would find it very difficult to open the door.

This is as much to do with the manufacturers ability to make larger door closers to proportionally higher tolerances as it has with achieiving desirable user friendly ergonomics

BS 6459 Pt 1 'Door closers specification for mechanical performance of crank and rack and punion overhead door closers' specifies the power sizes with corresponding maximum door leaf width, maximum door leaf mass, minimum closing moment (torque) 2°, minimum closing moment (torque) 90° and minimum efficiency. Refer to table 1, page 11.

Door clo	oser power size number		1	2	3	4	5	6
Maxımum	door leaf width	(mm)	750	830	930	1030	1130	1330
Maximum	door leaf mass	(kg)	30	45	60	80	110	150
Minimum	closing moment (T)2°	(Nm)	5	10	17	27	37	48
Minimum	closing moment (T)90°	(Nm)	1	2.5	5	9	13	17
Minımum	efficiency	(%)	40	40	50	60	60	60

TABLE 1

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The additional data for size 1 door closer is based on the ARGE 1973 : 'Specification of overhead door closers'. They are for weak user groups such as the handicapped, elderly, infirm or young. They should only be used in draught free situations. The latches with which door closers are used and around which the BS 6459 specification is based are according to the MOB Statement of Requirements, 1986, which states that the latch should have a closing torque of not more than 15 Nm. This is because the performance of a latch can be significantly reduced if it is incorrectly fitted or incorrectly adjusted while in position, likewise the strike shape is also important often being shaped for the best factory operation, not efficiency.

The BS data is a guide and not absolute, where a heavy door is mounted on needle bearings a smaller power size door closer would be necessary. When closing against a draught it is often best to specify a larger power size, for example on external doors, similarly if a door is large dimensionally and so on. Manufacturers will usually advise.

It is not unusual for a door closer to have an adjustable power size rating achieved by increasing or decreasing the preload compression on the spring inside the door closer. This makes it possible to reduce the power size to the minimum necessary to latch the door and as a consequence make it easier to open. The adjustable power feature is also used when the door closer has a universal fitting application. ie, where both single arm applications and projecting arm applications are possible with the same door closer, so compensating for any variance in mechanical advantage between fixing methods.

1.5 FUNCTIONAL FEATURES AVAILABLE ON OVERHEAD DOOR CLOSERS

Controlled door closing is of prime importance in door closers, typically taking between 5 and 7 seconds to close a door from 90°. This timing is the result of the hydraulic damping mentioned earlier. The door should not be slammed shut by the device but should latch. If the door is only opened to just off the latch it should relatch is, relatch from this 'worst' position without relying on any build up of momentum.

Overload facilities are often built into overhead door closers so that damage does not occur to the fixing, or the door closer itself, if the door closer is forced closed quicker than in normal closing.

1.5.1 Back check

A back check is a form of 'buffer' within a door closer which prevents the door passing a certain angle, in the same way as a floor mounted stop, but is used in situations when a floor mounted stop would be impractical or hazardous. The back check is usually adjustable to differing door positions.

1.5.2 Delayed Closing

The delayed closing feature will hold a door open for a variable and often adjustable length of time before closing. It usually operates between 180° and 70°, typically delaying for twenty seconds. It is a useful feature to incorporate on doors regularly used by, say, the elderly or handicapped. Because it only delays temporarily the door closer may still be used on fire resisting doors without infringing standards.

Where the resistance that a door closer causes to a door results in opening difficulty, such as when a wheelchair user passes through regularly or on a door opening into a hospital ward or one where luggage is often carried through, trays, etc, the circumstances dictate the need for some form of hold open or 'stand open' facility.

(a) Mechanical:

A mechanical 'stand open' device will act like a 'wedge', keeping the door propped open at a predetermined angle. Often this is achieved by incorporating a locking mechanism on the arm set which can only be released manually. Such a mechanism is perfectly acceptable unless used on fire resisting doors where the door needs to be released automatically, essential for the barrier/seal which prevents the spread of fire to work. Here there is the need for another sort of stand open facility :-

(b) Electromagnetic:

The electromagnetic stand open device has the same effect as the mechanical stand open device except that here the door may be released manually, as before, and automatically after receiving a signal from a fire alarm or from smoke detectors on both sides of the door. (Fire precaution Act 1971). These break the electromagnetic circuit. Consequently this facility may be used on fire doors It is also important to note that, should there be a power failure, the door will simply close, a vital 'fail safe'. Often a test switch is placed near the door so the device may be periodically checked.

1.5.3 Electromagnetic Swing Free

After first opening the door manually the energy stored in the door closer, ie the compression of the spring, is held electromagnetically allowing the door to swing free as if there were no door closer attached. But if the alarm goes off, or there is a break in the power supply, the door closer comes back into operation closing the door as normal. These are most commonly used in old people's and disabled people's homes and should also be tested regularly as above

1.6 FIXING POSITION

Handing

BS 1192 Pt.3 defines a single action door as clockwise closing or anticlockwise closing depending on whether the hinges are set on the right or left hand side of the door (ie the handing).

Doorface

The opening face of the door 1s defined as the face which opens towards the user, the hidden face being furthest away. See diagram 4 page 16.

These definitions help in understanding the various armset applications of the door closer.

- 1.6.1 The projecting arm application, or 'normal' application, is when the door closer is fixed to the opening face of the door with the armset attached to the door frame. The door may close clockwise or anticlockwise.
- 1.6.2 The parallel arm application is when the door closer is fixed to the closing face of the door. The armset is attached to the underneath of the frame. The door may then close either clockwise or anticlockwise. This has the advantage of hiding the door closer leaving the opening face clear.
- 1.6.3 The transom application is where the door closer is fixed to the frame above the closing face of the door with the armset fixed to the face of the door. They are used on outward opening external doors so that the door closer remains inside. They are also used on doors with narrow top rails where the door closer itself would not fit.



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Diagram4

- 1.6.4 The universal application refers to a door closer supplied with all the fitments necessary to be attached in any of the above applications. The parallel arm application is a geometrically weaker arrangement so adjustable power sizes are often used in this type.
- 1.6.5 The single arm application is where the door closer is mounted on the opening face of the door. The single arm is, in the resting position, parallel to the door face. The end of the arm incorporates a roller or slider which runs along a channel fixed to the door frame. It cannot be mounted on the closing side of the door because it restricts the door opening. This application not only looks sleeker in position but it reduces the risk of vandalism to the arm set.

It is also possible to have a single arm door closer fixed in a transom position as described in 1.6.3 above.

1.7 DOOR CLOSER CLASS

A door closers class is determined by two factors :-

1.7.1 The angle through which the door closer will allow the door to move 1.7.2 The angle over which the door is controlled on closing.

- Class A The door can open to greater than 90° and will close and control the door from a minimum of 45° down to the closed position.
- Class B The door can open to greater than 90° and will close and control the door from a minimum of 70° down to the closed position.
- Class C The door can open to greater than 175° and will close and control the door from a minimum of 115° down to the closed position.

2 THE PROJECT AND ITS OBJECTIVES

2.0 INTRODUCTION TO NTEL

On 20 July 1988, some months prior to the start of the project, the author visited NTEL The reason for this visit was :-

(a) To be introduced to various members of the technical staff at NTEL whose specialised skills would be of essential assistance throughout the development of the project. They were :-

Mr Dave Yates - Director of Research and Development Mr Dave Evans - Development Manager Mr Arthur Bishop - Chief Designer Mr Roger Dutton - Testing Manager

- (b) To be given a preliminary guide around the testing, manufacturing and assembly plants at NTEL and so gain an understanding of the nature, scale and range of the company and its manufacturing capabilities which influence, to some degree, the developmental direction of the project.
- (c) To be advised on the performance requirements NTEL wish to incorporate in the proposed new range of overhead door closers with a single arm/slide arm application. These were factors NTEL considered essential to remaining competitive in the surface mounted single arm overhead door closer market.
- (d) To collect British Standards for door closers (already referred to), NTEL trade literature, competitors trade literature and relevant NTEL literature concerning door closer powers, the effects of air pressure on closing doors, sizings, powercurve characteristics, efficiencies and guides to special applications.

This initial phase resulted in the drafting of a Product Design Specification.

The layout of the PDS was based on the SEED publication 'Package of Preparation Material for Design Teaching. Specification Phase' Prof. S Pugh, University of Strathclyde. 1986, which is, in turn, based on BS PD6112 'Guide to the Preparation of Specifications' May 1967.

2.1 THE NATURE OF THE PROJECT

-

The project was formerly initiated at a meeting convened on 26 October 1988 where a programme of work and the proposed Product Design Specification were discussed. Those present and their relation to the project were :-

Mr	David Yates	-	Director of Research and Development, NTEL
Mr	Syd Pace	-	Project Supervisor and lecturer in the
			Department of Design and Technology, LUT
Mr	Alan Underhill	-	Project Supervisor and lecturer in the
			Department of Mechanical Engineering, LUT

The author

The proposed work was agreed at this meeting and outlined in a letter sent to NTEL dated 7 November 1988. This has been adhered to throughout the project and any changes of plan have been agreed by all parties.

The proposed Product Design Specification was amended resulting in draft 2:27/10/88, Appendix 1 page 229. The amendments made lessened the constraints imposed on the conceptual design with a view to increasing the scope for originality and lessened the factors by which the project would be evaluated to those where the author's contribution was additional to NTEL's own capabilities. For example, the specification excludes any direct consideration of cost although it is recognised by all involved that the solutions finally proposed by the author should be viable. Detailed development to full production relating to manufacture, finish, production techniques etc. are, instead, left to the staff at NTEL whose knowledge and experience in these techniques enable them to tackle such tasks more effectively. It is simply a question of priorities and quite wisely NTEL wished the author's time, and that of NTEL, to be spent appropriately.

It was understood that the door closer be capable of being fitted to the opening or closing face of the door, or transom mounted whether left or right handed a factor not specified in the PDS, ie. be a realistic replacement to the present NTEL 2000 series door closer.

3 PRODUCT RESEARCH

3.0 INTRODUCTION TO RESEARCH

A methodical and ruthless programme of researching was necessary for the author to collect the greatest amount of relevant information about the field of door closers in the short time available. The approach used was based on the advice of Mr R G Rhodes, Information Retrieval expert at LUT. This research programme may be split into the following areas .-

- 3.1 Standards and Legislation
- 3.2 NTEL Literature
- 3.3 Factors Influencing Architects' Choice of Door Closers
- 3.4 Currently Marketed Product Review Trade Literature
- 3.5 Currently Marketed Product Review Current Product Testing
- 3.6 Door Closers Tested
- 3.7 Use of patents

3.1 STANDARDS AND LEGISLATION

Most of the necessary standards and legislation were supplied by NTEL as described in the 'Introduction to NTEL' section, page 139. These included :-

- (a) BS 6459 Pt 1, 9 October 1986 'Specification for mechanical performance of crank and rack and pinion overhead door closers'
- (b) BS 6459 Pt 3a, 1987 'Specification for the performance of floor springs'
- (c) Fire resisting doors. Pt 1, section 5 'Door Closing Devices'. GAI recommendations

BSI is proposing an adjunct to BS 6459 specifying performance of door closers on fire resisting doors. This would appear as part 4 of the standard. It will be similar in content to (c) above.

These standards formed the basis of the performance section of the Product Design Specification. As had already been stated such standards are the result of a consensus of opinion by a number of manufacturers on well established concepts such as the rack and pinion type door closer. A certain amount of objectivity must, therefore, be kept when using such standards to design a <u>new</u> concept, bearing in mind that, at this stage, the concept could have been quite different to those defined in BS 6459. This does have an influence on the design phase because new products not covered by standards, although-perhaps equally as 'good', are of a greater risk to the manufacturer, in terms of liability, who cannot then claim compliance with a standards protection. With recent changes to liability laws manufacturers are increasingly less prepared to take this risk so innovation can suffer.

3.2 NTEL LITERATURE

The following NTEL trade lterature was researched .-

(a) Briton 2030 'Non projecting sliding arm series'. Oct 1988 Ref A-12-3 'Briton door controls': July 1987 Ref 87 (b) 'Briton floor springs and accessories': Jan 1989 Ref C-01-13 (c) 'Briton fire and smoke door controls': Mar 1989 Ref F-01-13 (d) (e) 'Briton 1000 series overhead door closers': Apr 1989 Ref A-09-7 (f) 'Briton 2000 series overhead door closers': Aug 1989 Ref A-01-11 'Briton 5000 series overhead door closers': Mar 1988 Ref A-08-10 (g) (h) 'Briton 8800 series door closer for concealed transom mounting': Sep 1988 Ref A-11-5 (i) 'Briton 'T' shape overhead door closers': May 1988 Ref A-02-6 (j) 'Briton emergency exit hardware': May 1988 Ref B-01-6

The reason for such research was so that an idea of the range of products, their application, the available features, corporate aesthetics, the materials and manufacturing techniques used (such as steel or plastic cases, cast or extruded bodies) were understood.

Additional NTEL inhouse literature was used so that the author could understand common terminology relating to the door closer and common service problems associated with door closers such as wind and air pressures, the selection of closer size relative to door width and/or weight, etc. :-

- 'Door Closers: Effects of moving nearer to the hinge for greater angle of opening.' R and D Department, Eng Division 31 Oct 1985.
- (b) 'Door Closer Powers' R and D Department, Eng Division 18 Apr. 1985
- (c) 'Determination of approximate opening and closing forces where variations in both efficiency and spring load are expected from a measured door closer unit' A E Bishop.

3.3 FACTORS INFLUENCING ARCHITECTS' CHOICE OF DOOR CLOSERS

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On 4 Apr 89 the author visited professor Hallam a practising architect and Head of Department for Industrial Design at Leicester Polytechnic. The aim of the visit was to establish why an architect, or customer, chooses one door closer in favour of another.

The majority of NTEL's door closer sales are, in fact, the result of specification by architects. Speaking objectively, and thus attempting to voice the opinions of architects as a whole, the factors which influenced him are listed below :-

- (a) The architect would naturally assume that the product satisfied all BS requirements and fire resisting door standards before the door closer was specified. It was agreed that the proposed new door closer powercurve characteristic would be of benefit to the user and would probably influence his choice, provided that the price of such a product was not significantly different to other door closers fulfilling BS performance requirements but which may not have the improved 'ergonomic' powercurve
- (b) There is a preference for a simple product which is less complex to fit and adjust and with less bits to go wrong.
- (c) Installation, removal and replacement by one person using 'normal' tools to a variety of different door types with minimal damage to the door (necessary for compliance with GAI recommendations). Fitting instructions should be included which should be explicit and unambiguous and preferably include templates. (This is much appreciated by contractors).
- (d) Past reputation and reliability are important. This avoids the need for replacement in a failure situation and the detrimental effect it may have on the user's perception of the manufacturer and that of the building itself in the case of the architect.

- (e) The architect likes to see consistency in design, a corporate image, across door closers of different sizings when fitted to different door types in different applications which would occur in any building. (eg, some will be on outside doors, inside doors, double doors, etc). An adjustable power size rating is considered a useful feature in attaining simplicity of aesthetic because the same product is used for all power sizes. It does, however, compromise simplicity and has cost implications
- (f) Architects prefer a door closer to be unobtrusive in design. This is as much to do with size as shape and colour. Unobtrusive should not be interpreted as ignorable.
- (g) A door closer which usually links or blends its constituent parts together rather than looking like a collection of parts performing a function, as is often the case, would be desirable Obviously an important consideration for the aesthetic design phase of the project.
- (h) A range of colours should be available so the door closer matches a range of interior colour variations, particularly those of office furniture, warm greys and creams.

Professor Hallam also advises that careful consideration of matt and gloss finishes should be made, ie. matt on upward facing surfaces likely to collect dust. Such consideration often enhances the visual quality of the product.

An architect 1s perhaps more in tune with the visual look of a door closer than the average member of the public. He is also often the specifier of the door closer so, after performance which is to some extent assumed, aesthetics are important. There is a limit to how unobtrusive an overhead door closer can be positioned where it is. A strong argument for careful aesthetic consideration.

3.4 CURRENTLY MARKETED PRODUCT REVIEW - TRADE LITERATURE

- 3.4.1 'ABC European production' 1988
- 3.4.2 'Barbour Compendium 1988' Building Products
- 3.4.3 'Kelly's Business Directory' 1988
- 3.4.4 'Kompass, UK Products and Services' 1988

These were used as the basis of the trade literature search. The search was initially limited to Europe for the following reasons :-

- (a) To keep the size of the search to manageable proportions and so reduce the time taken for the search.
- (b) NTEL indicated that their main competitors were, in fact, based in Germany and not elsewhere in the world.
- (c) This was considered a large enough cross section for all the common door closers available to be identified.

Some additional companies based in Japan, Taiwan and the USA were also included in the search having been highlighted as products/concepts of particular interest during the patent search, discussed later

The list of companies written to is included in Appendix 2, page 229

A standard letter was sent to each company requesting the following information (see Appendix 3, page 229):-

(a) The torque characteristic, or powercurve, of the door closers that the companies manufacture, which is the prime performance criteria. Any overhead door closer which had an ideal powercurve was of interest and tested. Door closers without this ideal powercurve were also of interest and assessed to see if subsequent development work may result in viable concepts.
- (b) The mechanical operation of the door closer combined with the energy storage device used was to enable basic product concepts to be related to particular powercurve characteristics
- (c) The measures taken to meet the efficiency requirements of BS 6459 which was recognised as the aspect of BS most difficult to achieve by a considerable number of products.

The reference made to door closers attaching to the door rather _ than being an integral part of the door was to minimise the amount of irrelevant information received. Although, at this stage, it was difficult to say when requesting information just what exactly was going to be relevant or not. For example, a principle applied to electrically powered door closers may initiate original thoughts or be directly applicable to mechanical overhead door closers. The author also hoped that being more specific would encourage a more favourable response.

Finally, trade literature was requested so companies not willing to divulge the above information would respond in a way that indicated, at the very least, their product range.

The literature search enabled the author to understand and appreciate an essential cross section of door closer concepts, their different price ranges and different aesthetic considerations from country to country and company to company.

There are two companies producing door closers of the variety this project is concerned with, they are Geze with the TS5000 (2-4) and Dorma with the TS93 (2-6). Both companies are German and both products are tested in the following section.

Although the Geze and Dorma products exhibit the 'ideal', or at least preferred, powercurve they are not yet competitive with the

NTEL existing product range on price, reducing any immediate threat in the UK. NTEL is keen to be the first UK manufacturer to develop a door closer of this type and so guarantee a large share of the UK market at least The trade literature did show that other UK companies, which as yet produce door closers aimed at the cheaper end of the market, have the resource and technology to developinto this area.

3.5 CURRENTLY MARKETED PRODUCT REVIEW - CURRENT PRODUCT TESTING

In November 1988 a rig was built to test a number of door closers. This is shown in Figure 1 pages 29 and 30.

Fitted to it is the Briton 2033, NTEL's present slide arm/single arm overhead door closer. See Appendix 4 page 229. Its characteristic is shown later in this section. The test rig enabled -

- (a) Powercurves for a selection of door closers to be generated
- (b) An assessment of their general performance to be made as defined in the Product Design Specification Appendix 1 page 229.
- (c) An idea of how easy or otherwise the product was to fit and the instructions to follow.
- (d) An easier assessment of product aesthetics and quality to be made.

The powercurve was generated by measuring :-





Fig.1 Test Rig





Fig.1 (continued)

- (a) The mass needed to begin pulling the door closer open at each of the angles measured. Thus enabling the opening torque to be calculated.
- (b) The mass needed for the door closer to begin shutting the door at each of the angles measured. Thus enabling the closing torque to be calculated.

The rig design is such that the point of application of the load on the door closer rig is central between its two hinges, tangential to the arc described by the door and perpendicular to the face of the door at each angle described acting 750 mm from the hinges of the rig.

The angles at which the torque is measured are BS specified although some additional angles are included to generate a more accurate characteristic.

It was not necessary to test examples of every door closer type described in the 'Types of Door Closers' section page 2. Those tested were the two German products, NTEL's own product and those types of door closers whose 'powercurve' characteristics were not predictable or those which were of interest or where information concerning fitting, ergonomics and quality of instructions were of interest. These latter products were not necessarily designed as door controls and so British Standards 6459 is not relevant.

An aesthetic appraisal and discussion of the powercurve and efficiency characteristic was only carried out on NTEL's own single arm overhead door, closer the Dorma TS 93 (2-6) and the Geze TS 5000 (2-4), to enable a comparison to be made directly between NTEL's product and the two door closers which already offer a solution to the desired powercurve characteristic described in the PDS.

3 6 DOOR CLOSERS TESTED CONTENTS

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3.6D	Discussion of Door Closer Sizing	38

NAME OF PRODUCT

Dorma TS 93 (2-6)	39
Geze TS 5000 (2-4)	47
Briton 2033 Non Projecting Slide Arm Series	59
Gibcloser 'Original' Door Closer	65
Crompton Door Closer	68
Hawgood 4000 Sprung Hinge	72
B and Q Lay on Sprung Concealed Hinge (Corner Joints Ltd)	78

3.6A GENERAL ASSESSMENT

As well as the physical testing of each door closer to produce powercurves and efficiency characteristics each door closer underwent a more general assessment in the following areas :-

(a) Price Range

This allows the reader to make some judgement of what to expect from a particular door closer. For example, it would be expected that as the price of a door closer increases then it would begin to <u>control</u> and not just close the door.

(b) Description

What type of door closer it is.

(c) <u>Fitting</u>

This is concerned with the versatility of the door closer's fitting positions. For example, whether it may be fitted to the opening or closing face of the door, normal or transom mounted on either the left or right hand of the door etc

(d) Application Tested

This is the fitting position in which the particular door closer was tested. Normal positions were tested mostly but it must be remembered that different fitting positions affect the geometry and so torque of the door closer characteristic

(e) <u>Mechanism</u>

This is the mechanism or concept used as the basis of the door closer's operation. The resulting powercurve and efficiency characteristics may, therefore, be associated with the mechanism used rather than the product itself, a useful association for design purposes.

(f) Fixing

This was concerned with the method by which the door closer was fixed to the door and how easy it was to do so using the instructions and/or templates provided.

(g) Performance Specification

This is an indication as to whether the door closer satisfied BS 6459 requirements or not.

(h) Adjustment

The door closer may have integral adjustment facilities incorporated. This section lists and explains them.

(i) <u>Colour/Finish Available</u>

The range of colours and finishes available.

(j) Footprint

"The dimensions of the space it takes up on the door or frame.

(k) Aesthetic Appraisal

The door closer is aesthetically assessed on the following points :-

- (i) Simplicity of form
- (ii) Use of sharp or round edges
- (iii) Use of details (such as logos, textures, etc)
- (iv) General design consistency throughout the product
- (v) Aesthetic in situ

(1) Powercurve and efficiency characteristics and power size ratings

(m) <u>Conclusion</u>

3.6B DISCUSSION OF DOOR CLOSER AESTHETICS

The aesthetics of any door closer, particularly surface mounted overhead door closers, are highly influenced by practical requirements. They may be fixed on a left or right handed door, on its opening or closing face or transom mounted. It should look 'in place' or suitable in any one of these fixing positions not as if designed for a particular fixing position but used 'wrongly' in another. This requirement dictates some symmetry about the central, vertical axis, as viewed from the front in both the channel and body of any such door closer.

Fixing, number of constituent body and/or casing parts and manufacture quite obviously influence the aesthetics but are constraints imposed by choice of, or type of, door closer rather than those associated with prime function. Being less constrained than the practical requirements described above they become aesthetically more important because they are what makes one door closer look visually different to another So assuming that comparable door closers do, in fact, function in the same way, or reasonably similarly, it must be concluded that the buyer/specifier's decision to buy one door closer and not another is heavily influenced by their relative aesthetic merits. It is in this context that the importance of aesthetics may be understood.

The aesthetic factors discussed with Professor Hallam, section 3.3 page 24 were consistency throughout the constituent parts; whether some effort had been made to blend the parts together so the door closer could be seen as a single 'product'; unobtrusiveness and finally the range of colours available.

Assessing the door closers point by point like this enables, as far as possible, an objective aesthetic appraisal to be made.

The aesthetic part of the analysis has only been carried out on the Geze, Dorma and NTEL product. The others were analysed for their mechanism type, their aesthetics often being in no way comparable to the door closer to be designed and often much more the result of the mechanism used.

3.6C DISCUSSION OF POWERCURVE AND EFFICIENCY CHARACTERISTICS

As discussed in section 1.4 the closing torque characteristic follows the opening torque characteristic but at a lower level, the result of mechanical inefficiency in the door closer. The ideal shape of these characteristics is determined because in closing the latch torque is required to be high and at any point other than this the torque should be low to make the door easy to open. BS 6459 only defines torque in closing and only at 2° and 90°, it is the PDS that requires the shape. Similarly BS 6459 only specifies the efficiency requirements at 2°, not over the full movement. Again, ergonomically, efficiency should be high since an inefficient door closer is harder to open. (The type of mechanism used in the design is significant here, not just the accuracy of manufacture).

3.6D DISCUSSION OF DOOR CLOSER SIZING

Each of the BS power size ratings is specified by a minimum torque value at both 2° and 90°. So a size 1 door closer, for example, would have torque values between the minimum size 1 rating and the minimum size 2 rating. Size 2 would be between the minimum size 2 rating and the minimum size 3 rating, up to 6, which has no upper limit.

A non adjustable door closer can, therefore, be categorised into one of these bands. Where a manufacturer claims a range then the door closer must be adjustable across the ranges claimed. A range of 2-4 would then completely encompass the range of torques between the minimum size 2 requirement and the minimum size 5 requirements.

BS does not, however, apply to anything that is not a UK manufactured product. So the range take claims of Geze and Dorma specified as 2-6 or 2-4, are to German standards not BS. Similarly different countries have preferences for different nominal torque values, ie, in the UK the size 3 constitutes some 65% of the market In Germany a higher torgue in any application is preferred, equivalent to the BS size 4. This must be borne in mind in the following section for a fair comparison to be made.

DORMA TS 93 (REF APPENDIX 5 PAGE 229)

- a <u>Price Range</u> £40+
- b <u>Description</u> Single arm surface mounted overhead door closer.

c <u>Fitting</u>

It may fit to the opening or closing face of the door or be transom mounted whether the door is left or right handed.

d Application Tested

To the opening face of a left handed door.

e <u>Mechanism</u>

f

Cammed rack and pinion.

Fixing

Simple screw fixing on all parts marked out using a paper template

- g <u>Performance Specification</u> To BS 6459. Class C door control.
- h <u>Adjustment</u> The Dorma TS 93 is available with the following adjustments :-

(1) Closing torque (power size 1-4 or 2-6 ie, two door closers in the range)

- (11) Backcheck on or off
- (111) Latch action/speed
- (iv) Sweep action/speed

Additionally the TS 93 'special model' is available for delayed action closing; and with different guide rails the following variations are possible :-

- (i) TS 93 HO with mechanical hold open facility
- (11) TS 93 EMF with electro-magnetic hold open facility
- (iii) TS 93 EMR with electro-magnetic hold open and optical smoke detector facility

The above variations are available with a 'door selector (Coordinator)' (SR) incorporated in the slide channel so that double doors close in the correct sequence if they are single action.

(i) TS 93 SR

(ii) TS 93 SR EMF with electro-magnetic hold open facility and door selector/sequence controls.

All the control adjustments are on the front of the door closer which means adjustments are easily made although the door closer appears somewhat complex.

i Colour/Finish_available

Dark bronze anodised, silver anodised, red, green, yellow, gold and white which is a basic but comprehensive range. The annodised finishes are a good contrast with most environments.

j Footprint

The Dorma TS 93 body footprint is a compact 299 x 68 mm and the normal channel footprint is 467.5 x 20 mm. \sim

k Aesthetic Appraisal

The TS93 has a simple basic form. The body and channel are both cuboid with a square/rectangular cross section. The front edges of the body, channel and arm are of a small/tight radius giving crisp, easily read lines. The ends of both the channel and body are of a much larger radius so the ends and front visually run into one another. These radiused ends are formed using 'end caps' to the channel and by 'sides' mounting a casing to the body, but in both the channel and body consistency is maintained. The radius of the ends is visually arrested at join lines so the end caps and body shapes are read easily. The join line, if viewed from the front, lies within the footprint of the door closer in the vertical plane, the effect being to shorten the apparent visual length of the door closer and so increase the apparent visual height of both the channel and the arm.

The radii, end caps and join lines maintain a consistency throughout the product blending the constituent parts together, a factor further emphasised in the use of colour and finish on the body, channel and arm.

This combination of radii used visually softens the shape making it a little less hard and masculine looking and contributes to it being successfully unobtrusive without losing visual strength.

The relieved Dorma logo in the bottom right hand corner of the body and the fixing screws at either end of the channel are the same colour and finish as the rest of the door closer so do not distract from the basic shape. The logo provides a means of breaking the symmetry of the door closer body and gives the viewer some essential detail, however subtle, preventing the body of the door closer looking like a solid machined block but in fact appear much lighter.

In the author's opinion there are perhaps two specific areas where the aesthetics may be improved. The first would be to extend the channel length so that it starts level with the body end. This common edge would encourage the viewer see the channel and body as one. Secondly the fixing screws on the channel should be covered or disguised, perhaps by incorporation into the end caps of the channel. They offer an unnecessary distraction inconsistent with the body. Were they not there then the door closer would look simpler, with the viewer's eye being drawn to only one detail on the door closer, the Dorma logo. This may give the door closer even more visual impact further emphasising its visual quality and simplicity

The design does not blend the channel and body together so they are seen as a separate units rather than as one, which would be more desirable.

Finally consideration has been given to the TS 93 in situ. Throughout a building, no matter what the required power size, if the TS 93 is used, even of different power sizes, its body would be identical just simply adjusted to suit the application whether size 2 or size 6. Consistency, and so an inherent aesthetic, is therefore generated throughout a building which certainly appeals to the architect.

When features like electro-magnetic hold open or smoke detectors are included they are incorporated in the channel section which varies in size accordingly but maintains the same aesthetic This size variation or inconsistency is less noticeable to the viewer because in most applications the channel is mounted on the door jamb not the door (the door being the more prominent position). In the case of double doors a channel is available which runs the length of the top of the door frame. This looks like an integral part of the door jamb and so is all but ignored by the viewer, it is again consistent with the well considered overall aesthetics of the TS 93.

1 Powercurve and Efficiency Characteristics and Power size Ratings

See graph la, 1b, 2a and 2b pages 44 and 45.

The TS93 is available in one standard body size. It is, however, available with two different adjustable spring strengths corresponding to BS 6459 power sizes of 1-4 and 2-6 see Appendix 5 page 229. This allows the door closer to be adjusted on sight for any door closer application, one being adjustable upwards from the German size 4 average setting for heavier/larger doors and one downwards for lighter/smaller doors. The type tested was adjustable from 2-6. The two powercurves and efficiency characteristics refer to the minimum, size 2, and the maximum size 6 settings.

In both cases the powercurve characteristic is the ideal shape There is a high torque at the latching point tailing off to a lower torque which is maintained from 30° onwards. It is quite interesting to note that at the size 2 setting the specified BS 6459 torque of 10 Nm at 2° and 2.5 Nm at 90° is cleared in closing but at the size 6 setting falls short of the requirement for 48 Nm at 2° by 6.6 Nm. The 17 Nm requirement at 90° is cleared.

German sizings are therefore not directly applicable to the English.





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The efficiency for a size 2 door closer should be 40% at 2°. For the size 2 setting the TS 93 has a lowest level of 42%, but at the critical 2° position it is 67% efficient. For the size 6 setting the door closer should be 60% at 2°. The TS 93 does fall to 45% but at the critical position is a safe 69% efficient. Although this satisfies BS it does mean that the user is required to put a lot of excess energy into the system which is not desirable (see Discussion of Powercurve and Efficiency Characteristics on page 37). Certain user groups may find this a problem, particularly for the higher size ratings where the torque input, in absolute terms, becomes quite high.

It is interesting to note at this point that the arm of this door closer actually slides in the channel rather than having a roller like the Geze and the NTEL 2000 discussed later. One would assume that this would create additional friction causing a fall in efficiency but, in fact, is not the case. In a lot of door positions a roller was found to slide anyway. The benefit a slider has over a roller is that it can be to closer tolerances inside the channel making the door closers hold on the door firmer. The low efficiency of this door closer is due to the rack and pinion mechanism used although BS requirements are fully satisfied

m Conclusion

The Dorma TS 93 achieves the desired powercurve characteristics while satisfying the BS efficiency requirements. It is adjustable to every power size rating so may be used in any application. It is a well thought out product in both engineering and aesthatics and undoubtedly the best single arm overhead door closer on the market at the present time, although rather expensive.

<u>GEZE TS 5000 (REF APPENDIX 6 PAGE 229</u>)(Also available with case as the TS 5500) See figure 2, page 48.

- a <u>Price Range</u> £30 - £40
- b <u>Description</u>
 Single arm surface mounted overhead door closer.

c <u>Fitting</u>

To the opening or closing face of the door whether left or right handed.

- d <u>Application Tested</u> To the opening face of a left handed door.
- e <u>Mechanism</u>

Cammed drive shaft with piston action spring loaded roller follower. A mechanism more commonly found in floor springs, see section 1.1.4.

- f <u>Fixing</u> Simple screw fixings marked out from instructions in the packaging.
- g <u>Performance Specification</u> To BS 6459, class C.

h <u>Adjustment</u>

The Geze TS 5000 series is available with the following adjustments :-(i) Closing torque (power size 2-4)

- (ii) Back check on or off
- (1ii) Latch action/speed
- (iv) Sweep action/speed (thermo stabilised)

Additional features include :-

- (i) TS 5000 S/TS 5500 S delayed action closing
- (ii) TS 5000 IS/TS 5500 IS integrated closing sequence control





Fig 2 Geze TS 5000 (without cover)

And with different guide rails, the following adjustments are possible :-

- (1) TS 5000/TS 5500 with mechanical hold open facility
- (11) TS 5000 E/TS 5500 E with electro mechanical hold open facility
- (111) TS 5000 R/TS 5500 R with electro mechanical hold open facility and built in smoke detector.

These same facilities are available on the integrated closing sequence control type (IS) so double doors close in the correct sequence. ie,

- (i) TS 5000 E IS/TS 5500 E IS has electro mechanical hold open facility and integrated closing sequence control.
- (i1) TS 5000 R IS/TS 5500 R IS has electro mechanical hold open facility with smoke detector and integrated closing sequence control.

All the adjustment controls are on the front of the door closer, easy to use and clearly labelled, although apparently complex.

i Colours/Finish Available

Silver, white, brass (matt), brass (polished), stainless steel (matt), stainless steel (polished), to RAL red, to RAL blue, to RAL yellow, to RAL black, a comprehensive range.

j <u>Footprint</u>

The footprint of the Geze TS 5000/5500 body is 287 x 60 without case and 301 x 70 mm with case. The normal channel is 449.5 x 20.5 mm. The dimensions of the TS 5500 with the case compare with those of the Dorma although the channel is some 19 mm shorter. Without the case the body height is reduced by some 10 mm so looks noticably longer and thinner.

k <u>Aesthetic Appraisal</u>

The Geze 5000 series door closer is available with and without a case/cover, the TS 5500 and TS 5000 respectively. Their performance is identical. Although the case is available for practical reasons, better dust proofing, tamper/vandal proofing, etc, the net result is to leave the user/specifier a choice aesthetically.

First the aesthetics of the unit without the case will be considered.

The TS 5000 has a simple basic form. The body and channel are both extruded cuboid shapes with a square/rectangular cross section. They both start at the same distance from the door hinge so have a common edge which helps blend the channel and body together. All the edges of the body, arm and the front horizontal edges of the channel are of a small/tight radius giving crisp easily read lines. The 'end caps' on the channel are of a larger radius on the front vertical edge similar to the Dorma TS 93 end caps described earlier. Again the radii on these end caps are visually arrested by a join line which makes the channel shape easy to read visually. They are, in this case, inconsistent with the rest of the product The crisp edges give a hard, functional, masculine look to the product, more aggressive than the Dorma

A front cover protects and hides all the adjustment controls sliding into a horizontal lip at the top and bottom of the body. See fig 2 page 48 and diagram 5 page 51. This creates horizontal lines within the external perimeter or 'foot print' of the body at the top and bottom. The channel, on the other hand, has vertical join lines between the end caps and channel section within its perimeter or 'foot print'. The inclination is for the body to look narrower and longer and the channel is the opposite. This demonstrates an inconsistency in the design's aesthetic.



Diagram 5



Diagram6

The colour and finish on the body, arm and channel is the same. Details such as screws on the channel and the logo are the same colour, the logo being in relief. The logo breaks the symmetry of the body, gives some essential detail, and makes the body look smaller and lighter than it would otherwise. The body has round end plugs screwing into the piston bore which emphasises the functional engineering element of the product, it is a solid machined block. This promotes a stronger more masculine aesthetic consistent with the sharp edges used throughout the product.

In the author's opinion the aesthetic of the TS 5000 would be greatly improved were the end caps on the channel to be made flush with the channel's end. See diagram 6 page 51. This would maintain a consistency of radii throughout the product as well as removing the vertical join lines on the channel which were at odds with the horizontal lines on the body. Finally, disguising the fixing screws would improve the aesthetic.

The overall aesthetic of the TS 5000 is again functional and largely unobtrusive, although visually harder and more masculine than the Dorma TS 93.

Next the aesthetic of the unit with a case will be considered (the TS 5500).

The case has large radii on all its edges making it difficult to read visually as well as introducing inconsistency with all other radii in the product except those of the front vertical 'rounded' edges on the end caps. The case makes the body foot print longer by 4 mm and taller by 10 mm which is significant in terms of visual size. The increased height is further emphasised by no longer having horizontal visual lines within the foot print. So with the cover the body and channel designs are actually more inconsistent.

The logo on the case, is set in a recess in the bottom left hand corner of the face. Its contrasting colour and bold letters create a definite focal point for the product which draws the eye. This bold logo also serves to break the symmetry of the body and adds a point of interest to what is essentially a soft, ill defined shape.

The aesthetic of the design is less masculine than that of the TS 5000 having none of the raw functional components showing such as end plugs, the slide on face, etc. It is less obtrusive than the 5000 but acheives this by being visually weak, this also reduces the visual quality of the product.

Finally, like the Dorma TS 93, consideration has been given to the Geze TS 5000/5500 in situ. Throughout a building, no matter what the required power size, if the TS 5000 or 5500 is used its body is identical, simply adjusted for the particular application although its range is less than that of the Dorma Consistency, and so an inherent aesthetic, is kept throughout a building which appeals to the architect/specifiers. When features like electromagnetic hold open or smoke detectors are included they are incorporated in the channel section which varies in size to accommodate them. The aesthetic remains the same, This size variation is less noticeable to the viewer because the channel, in most applications, is mounted on the door jamb not the door. In the case of double doors a channel is available which runs the length of the top of the door frame. This looks like an integral part of the door jamb and so is all but ignored by the viewer. The overall aesthetic of the TS 5000/5500 is less well considered than the Dorma, more design inconsistencies occur within ıt.

Powercurve and Efficiency Characteristics and Power Size Ratings See graphs 3a, 3b, 4a and 4b on pages 54 and 55 The TS 5000/5500 is available in the standard body types described being adjustable from power size 2-4. This means adjustment on





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sight is possible to suit any application, except heavier or wider doors where a size 5 or 6 would be needed The two powercurves and the two efficiency characteristics refer to the minimum size 2 and the maximum size 4 settings.

Both powercurve characteristics for the maximum and minimum sizes are quite different.

For the maximum size 4 setting, when closing, the powercurve characteristic peaks at the latch/2° door angle position with a torque of 44.15 Nm thus clearing the BS 2° requirement of 27 Nm significantly. By 90° the torque has tailed off to 20.6 Nm in closing, again clearing the BS minimum requirement of 9 Nm significantly. This clearance is large enough for the door closer to be classified as a BS size 5 which is an additional power size to that claimed. In fact it only falls short of the size 6 minimum requirement by 3.85 Nm at the latching position. The characteristic follows the correct shape shown in the PDS except that ideally the torque would fall faster from the latching position.

For the minimum size 2 setting, in closing, the powercurve characteristic does peak at around 2° with a torque of 16 19 Nm clearing the BS minimum requirement of 10 Nm significantly At 90° the torque is 10.48 Nm, again clearing the BS requirement of 2 5 Nm significantly. This minimum setting is nearer the BS size 3 requirement. The shape of the powercurve itself is, however, not so good. In the ideal curve, at 40°, the torque should be plateauing to a level comparable to the BS requirement for 90° but instead it has hardly dropped. This is worse in opening ie, that actually 'felt' by the user and whose shape is the more critical of the two. The characteristic actually rises after latching and remains high until 40° after which the torque begins to tail off. In this power size setting the power curve characteristic is no better than the rack and pinion mechanism it replaces.

The efficiency of the TS 5000/5500 is high for both the minimum and maximum power size applications. In the minimum setting the efficiency characteristic rises to, and peaks at, 76 8% at the 2° position. BS requires it to be a minimum of 40%. At the maximum setting the efficiency peaks at 85.7% in the 2° position where it is required to be 60%. The efficiency is then high for the rest of the door's motion which, from the user's point of view, is excellent. Very little excess energy is required to open the door so one's passage through is easy, although the effect is counteracted by a less desirable powercurve shape.

Such a high efficiency is the function of the mechanism. It is better for the maximum setting because the integral friction/ inefficiency of the mechanism becomes proportionally less due to the higher forces involved. The only criticism is that this efficiency costs and savings must be possible in manufacture while still retaining more than adequate levels of efficiency, ie this may leave room to reduce the product cost.

Should this mechanism type be developed by NTEL in their own product then the power size adjustability function should be carefully considered. A compromise occurs, so much so that in the lower power size settings, where the spring preload values are less the powercurve characteristic is barely any better than the conventional rack and pinion door closer it is replacing, although much improved in the higher sizings. The evidence also suggests that in the higher power size settings adjustability may be limited because such large/strong components are required that the product would become too big.

m <u>Conclusion</u>

The door closer achieves a reasonably desirable powercurve for the more popular power size settings in its range, its adjustability is limited and its characteristic, in lower size settings, is little improved. The overall aesthetic of the door closer without the case is of a strong, functional, engineering solution, whereas with the case some visual strength is lost. It does, however, lack some of the Dorma's aesthetic refinement and consistency and, as a consequence, looks a cheaper product than the Dorma, which it is.

BRITON 2033 (REF APPENDIX 4 PAGE 229)

- a <u>Price Range</u> £20 - £30
- b <u>Description</u> Single arm surface mounted overhead door closer.
- c <u>Fitting</u> To the opening or closing face of the door or transom mounted whether left or right handed
- d <u>Application Tested</u> To the opening face of a left handed door

e <u>Mechanism</u> Rack and Pinion.

- f <u>Fixing</u> Simple screw fixing marked out from instructions in the packaging, not a template
- g <u>Performance Specification</u> To BS 6459. Class B.
- h Adjustment

The Briton 2030 series which, includes the 2033, are available with the following adjustments :-

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- (i) Backcheck
- (11) Latch action/speed
- (111) Closing action/speed

The power size is not adjustable so the correct power size must be specified for each application. They are available as follows :-

2032/2532 = size 2 2033/2533 = size 3

- ----
- 2034/2534 = size 4

The simplicity and product cost savings this gives compromises the versatility that adjustment gives.

All other adjustment controls, such as door speed, latch action and back check are on the ends of the door closer They are easy to use with the adjustment tools supplied with the door closer. These adjustments would be better though if they were front mounted, for ergonomics, using standard rather than supplied tools.

i <u>Colour/Finish Available</u>

Sprayed silver, gold or brown bronze on steel, polished brass, imitation bronze, satin nickel and stainless steel and also available in colours to match NT Hardware's Normbau Range. The arm and channel are always sprayed black. A very comprehensive range.

J Footprint

The foot print of the 2000 series body is 268 x 55 mm for sizes 2 and 3 closers, and 299 x 55 mm for size 4 closer. The channel foot_print is 490 x 20 mm The larger size 4 body is about the same length but considerably narrower than both the Dorma and Geze body so is noticeably thinner visually. The size 2 and 3 door closers are shorter as well so they, too, are visually smaller than the Dorma and Geze products.

k <u>Aesthetic Appraisal</u>

The NTEL 2000 series door closer has a simple basic form. The channel and body are both cuboid with a square/rectangular cross section. The front edges of both the channel and body are of a small/tight radii giving crisp easily read lines. The arm edge radii are more rounded, but in this case the less precise edge that this creates serves a purpose. When in position on a door, with the door closed, the arm front is not always parallel to the body and channel front. This would be more obvious if there were sharp edges on the arm.

The arm is black, not the body colour, so is not so immediately noticeable against the body. The product, therefore, looks even smaller and by definition less obtrusive.

The end caps on the channel have crisp edges and are flush with the channel's end. The join line created between the channel and the end cap is scarcely noticed. ie, the channel is seen as a simple rectangular block consistent with the body. With no lines on the body, whether applied or join lines, no illusion of a longer or shorter body or channel is made. It is as simple as possible.

The projection of the main central pinion shaft, top and bottom of the body casing, adds a functional, masculine feel to the design. It also means that the dark channel and arm, which would give the design a one sided appearance, are, to some extent, balanced. Some of the body casting protrudes from the case at this point giving the viewer an idea of what is beneath the case. This helps to promote a functional and practical aesthetic.

The Briton logo/badge on the case in the bottom right hand corner It is a simple lettered badge reflecting the simplicity of the door closer form.

The screws on the channel, although the same colour and finish as the channel, would be better disguised to create less of a distraction. It is interesting to note that the simpler, 'normal' screw head has been used rather than the Posidriv or Phillips head which are visually more complex. The screws on the ends of the case fixing the case to the body are not disguised but are bright steel. Some localised pressing in the case here would stop them looking like an afterthought, or indeed they could be disguised in some way, even having them black would be an improvement. Unfortunately these screws cause a slight buckle or bend in the body sides local to the screw. This is visually messy and has a tendency to make the case look thin and weak. The perceived quality of the case would also be improved if the NTEL logo fitted into a pressed recess rather than directly on to the case surface.

Finally, some consideration has been given to the Briton 2000 series in situ. Although there is some variation in body length between the size 4 and sizes 2 and 3 door closers, unless they were used in a situation where a direct comparison was possible, the difference would not be immediately noticeable, in every other respect they are identical. On site adjustment of a door closer to suit a particular application is, of course, not possible relying instead on the accurate specification of the door closer before fitting.

The overall aesthetic of this door closer is one of utilitarianism. It is basic, functional and unobtrusive. A very safe design and consistent throughout.

Powercurve and Efficiency Characteristics and Power Size Ratings (See graphs and 5a and 5b, page 63)

The size 3 Briton 2033 was tested. Because there is no adjustability there is only one powercurve and efficiency characteristic.

NTEL are very conscious that the powercurve for this door closer (and the 2032 and 2034) is far from perfect hence initialising this project.

The 2033 satisfies BS minimum requirements for a closing torque of 17 Nm at 2° and 5 Nm at 90° with no trouble, the actual values measured were 18.1 Nm and 11.6 Nm respectively. The problem is that the characteristic peaks at around 40 - 45° which is undesirable ergonomically as previously discussed.

The efficiency of this door closer again satisfies the BS minimum requirement of 50% at 2° for a size 3 door closer, the measured value being just 50.2%. However at 122.5°, the maximum opening angle of this door closer in this application, the efficiency level is only 32.5% which is undesirable for the user.


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This low efficiency is due to the mechanism used but it could be improved if frictional elements such as bearings, rack and pinion teeth surface finish and bore/piston tolerances were improved Cost would increase but then the user would benefit.

It is hard to decide whether to admire the manufacturer for satisfying BS by such a small margin, in that over specified parts are removed or replaced with appropriate minimally specified components or to criticise the manufacturer for giving the user's preferences/ergonomics an obviously lower priority than its own profit margins. The reader must appreciate, though, that the present 2000 series door closer, in the single arm application, is only a temporary measure while a new product is developed with improved characteristics. It must also be remembered that the Briton is perhaps 60% of the price of the two German competitors so minimal specification becomes important in keeping that price low.

m <u>Conclusions</u>

Despite satisfying BS 6459 the 2000 series door closer has a far from desirable powercurve. There is no adjustability which means once one is chosen it is not possible to adjust it to suit individual applications. Adjustability makes the task of specifying the correct door closer easier but then relies on the correct adjustment on site. A second problem is that because the torque values for each size are constant it is always possible that the ideal size for a particular application falls between those constant sizes. 1e, it could force a performance compromise in situ. Adjustability, although leading to a more complex product is desirable, except in cost.

The overall aesthetic of the door closer is one of a strong, simple, purely functional engineering solution. It is very well thought out but sadly does not compete with either the Dorma or Geze products in terms of powercurve. It is, however, substantially cheaper.

GIBCLOSER 'ORIGINAL' (REF APPENDIX 7 PAGE 229)

- a <u>Price Range</u> f4 - f6
- <u>Description</u>
 Surface mounted jamb fixed non check door closer.

c <u>Fitting</u> It fits so the arm contacts the opening face of the door. The door may be left or right handed.

- <u>Application Tested</u>
 To the jamb on the opening face of a left handed door.
- e <u>Mechanism</u> Torsion spring
- f <u>Fixing</u>

Simple screw fixing marked out from the instructions on the packaging.

g <u>Performance Specification</u> N/A

h <u>Adjustment</u>

It is possible to adjust the torque supplied by the door closer by altering the initial spring torsion. The manufacturers claim it can close a '150 lb' fire door, but this relies on a build up of momentum of the door to overcome the latch action of the door.

i <u>Colour/Finish Available</u>

It is sold in white, normally, but other colours may be supplied on request from the manufacturer - subject to minimum order quantities.

Footprint

116 x 32 mm body with an arm which projects a further 117 mm

k <u>Aesthetic Appraisal</u> N/A

i

Powercurve, Efficiency Characteristic and Power Size Ratings (See graphs 6a and 6b page 67)

This is not a BS door closer. There is no control of the door and the powercurve and efficiency characteristics are not of the preferred shape. The powercurve steadily rises from its preload, which is adjustable, consistent with increasing the torque on a torsion spring. This is approximately the opposite to the preferred powercurve defined in the PDS.

At 2° the efficiency is lower than that specified for any door closer sizing. Power size rating is therefore not possible.

m <u>Conclusion</u>

For the price this is a perfectly reasonable door closer but is not really comparable to the door controls defined in BS. Its aesthetics are dictated by function. This demonstrates the level of efficiency and the shape of powercurve to be expected from a torsion spring type mechanism.



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CROMPTON 'DOOR CLOSER' (REF FIGURE 3 PAGE 69)

- a <u>Price Range</u> £4 - £5
- b <u>Description</u> Surface mounted jamb fixed non-check door closer.

c <u>Fitting</u> It may only fit so the arm contacts the opening face of the door. The door may be left or right handed.

d <u>Application Tested</u> To the jamb on the opening face of a left handed door.

e <u>Mechanism</u>

Torsion spring

f <u>Fixing</u>

Simple screw fixing marked out from the instructions on the package. The screw fixing projection fits between the door spine and frame gap requiring two persons to fix the closer to the door, one to hold it on one side of the door and the other to screw it in place from the other side of the door. This the author believes shows a lack of thought in the design, or rather, compromises basic ergonomics for the visual look of the product. Considering it has a Design Council Award one would have expected fitting to be easier.

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g <u>Performance Specification</u> N/A

h Adjustment

It is possible to adjust the torque supplied by the door closer by altering the initial spring tension.





Fig. 3 Crompton DC

- i <u>Colour/finish Available</u> White.
- j <u>Footprint</u> N/A, it appears like a hinge on the door
- k <u>Aesthetic Appraisal</u> N/A.
- Powercurve and Efficiency Characteristics and Power Size Ratings See graphs 7a and 7b page 71. As in the Gibcloser 'Original' except that the efficiency at 2° is far greater at approximately 62.5% A power size rating is not applicable.
- m <u>Conclusion</u>

For the price this is a perfectly reasonable door closer but again is not really comparable to the door controls defined in BS. There has been far greater consideration given to the aesthetics of this door closer than its nearest 'rival', the Gibcloser, but it is more difficult to fit.



HAWGOOD 4000 SPRUNG HINGE (REF APPENDIX 8 PAGE 229)

The type tested was a twin spring type. (See figure 4 page 75)

- a <u>Price Range</u> £10 - £20
- b <u>Description</u> Semi concealed double acting sprung hinge.

c <u>Fitting</u>

The piston shaft fits to the jamb requiring two holes and the hinge straddles the door and sits in a groove. (See diagram 7 page 74) It may fit to a left or right handed door.

- d <u>Application Tested</u> Two were tested in unison on a left handed door.
- e <u>Mechanism</u> Cam displaced compression spring piston.
- f <u>Fixing</u>

Screw fixing. Instructions are not included and drill hole diameters not suggested. Because it is also the hinge of the door accurate fitting is necessary to prevent any contact of the door with the frame or the floor Instructions should be given because this is difficult to fit

g Performance Specification N/A.

h <u>Adjustment</u>

No adjustment is possible, the correct size must be ordered to begin with which is dependent on different door weights and thicknesses.



Fig.4



Type 4000D and 4500D, twin spring for door thickness 20-25 mm and maximum weight 33 kg. Type 4000E and 4500E, single spring for door thickness 20-25 mm and maximum weight 22 kg Type 4142, single spring for door thickness up to 39 mm and maximum weight 60 kg.

- i <u>Colour/Finish Available</u> Polished brass or nickel plated, although little of it shows in situ.
- j <u>Footprint</u> Showing 45 x 47 mm both sides of door in each door position.
- k <u>Aesthetic Appraisal</u> N/A.

reflected about the 0° line.

Powercurve and Efficiency Characteristics and Power Size Ratings See graph 8 page 76. The closing torque powercurve for this door closer falls below zero after 80° because beyond this angle the door closer will hold the door open. If the door is not opened this far it will close the

The characteristic is far from desirable rising after the 2° position. The hold open mechanism also defies 'fire resisting door' recommendations.

door. The door closer is double acting so its characteristic is

It is only possible to calculate the efficiency at the 2° position before the characteristic starts to become negative. ie, before the opening effect of the mechanism takes effect.

Power Size N/A



m <u>Conclusion</u>

This door closer was tested because the author was interested in generating its powercurve thus deciding whether such a mechanism or combination of mechanisms could be utilised in this project. The powercurve is in fact favourable but no control of the door is afforded even though its price is high. B AND Q LAYON SPRUNG CONCEALED HINGE (CORNER JOINTS LTD) REF FIGURE 5 PAGE 79 AND DIAGRAM 8 PAGE 80

- a <u>Price Range</u> £1-2.
- Description
 Concealed single acting sprung hinge.

c <u>Fitting</u> To the inside of a door and jamb on either a left or right handed door. (eg, fitted kitchen cupboard hinge type)

- d <u>Application Tested</u> To the closing face of a left handed door.
- e <u>Mechanism</u> Over centre snap action.
- f <u>Fixing</u>

Screw fixing. The fixing method is explained in the packaging. Because it is also the hinge, accurate positioning is important for correct functioning of the door.

- g <u>Performance Specification</u> N/A.
- h <u>Adjustment</u> None
- i <u>Colour/Finish Available</u> Polished brass or white.



Fig. 5



Diagram8

k <u>Aesthetics Appraisal</u> N/A.

Powercurve and Efficiency Characteristics and Power Size Ratings See graph 9 page 82. As in the previous example the door closer either snaps open to 90° or snaps closed so the powercurve characteristic has negative torque values after, in this case, 30°. For this same reason an efficiency characteristic is not possible, just the efficiency of the critical 2° position which is high.

Power Size

N/A

m <u>Conclusion</u>

This seemed an interesting and ingenious mechanism which, with some variation, could have been applied to this project so generating its characteristic was important.



3.7 USE OF PATENTS

A lot of the following section 1s based on information supplied by The Patent Office acknowledged in the bibliography.

A patent discloses an invention in quite some detail. So much so that people with appropriate skills would be able to repeat the invention. The 'prior art' sections within each patent give an account of the reasoning which led to the invention as well as information on any previous related technology. Consequently they are an excellent source of technical information.

3.7 1 Method of finding relevant patents

The 'Catchword Index'¹ identifies subject areas into which patents are grouped giving a 'Heading'¹ in the 'Classification Key'¹. For example, the catchword 'door closer' gives the code E2M in the classification key.

There are a number of entries under the 'heading' which are sub divisions or terms within this catchword area and each has an additional code. For example M16 "crank, cam, lever and link mechanism (414)". After each term there is a number in brackets, the 'term frequency,¹ which indicates the number of specifications assigned to this term after the patent serial number 1,000,000.

The list of all specification serial numbers assigned to each term, the 'file list'¹, may be ordered from the Patent Office by stating each term's code and heading as one code, so the term given as an example above would be ordered under E2M(M)16. The file list includes specification serial numbers for World, European and Great Britain patents. The specifications are numbered in a similar way to drawings in a drawing office, the larger the number the newer the patent. They are located by this serial number not by subject. Eleven file lists were ordered under the E2M heading, 'door closers' defined as :-

"door and gate operating - appliances, and controlling devices, therefore, (ie means for opening, closing, balancing and controlling the operation of doors, gates and barriers of buildings, ships, vehicles, roads and railways; operating lift- cage doors independently of movement of the cage; operating appliances for doors, lids and covers for resisting fluid pressure (other than tightening on seats) and for soaking pits; door checks for cabinets and showcases; and operating and control appliances of general and unspecified application for other doors and barriers) - " then the category is subdivided.

E2M(M)11F2 - "applied to doors and gates having special movements" - "hinging and pivoting (other than sliding- folding and so on)" -"about a vertical axis".

E2M(M)13 - "chain and cord arrangements"

E2M(M)16 - "crank, cam, lever and link mechanism".

E2M(M)12A - "electric and magnetic".

E2M(M)12G - "float (including by incoming leakage)".

E2M(M)26 - "interconnected with or operated in conjunction with, latching means (including appliances adapted to open or close door on release of latching means)".

E2M(M)AX2 - "miscellaneous" - "interlocking doors and door-operating mechanism"

E2M(M)AX3 - miscellaneous" - "selective operation of doors through disengaging-gear".

E2M(M)14 - "screw-and-nut mechanism acting directly and through links"

E2M(M)12E1A - "spring" - "door closers of the type which incorporate check devices (including door closers of this type not provided with checks)" - "adapted to be" - "attached to surface of door or door frame".

E2M(M)12E1C - "spring" - "door closers of the type which incorporate check devices (including door closers of this type not provided with checks") - "adapted to be" - "mounted inside door or door frame"

E2M(M)12EX - "spring" - "unclassified".

E2M(M)1E - "kinds or types" - "operated hydraulically, pneumatically, electrically and automatically".

One additional file list was ordered under the 'E2F' heading "Hinges and so on" and was .-

E2F(F)110 - "assisting or resisting movement by energy storing devices, eg, springs, integral with the hinge or pivot" - "positive engagement devices including cam-like devices" - "effective at more than one position of the hinge or pivot".

Quite obviously many more categories exist but the author could only realistically search this number of patents. The ones chosen were those considered most likely to demonstrate concepts with which the author was not already familiar.

When using the Patent Office the procedure from this point onwards is usually to try and zoom in on, and locate, a single patent. For example a patent with a serial number falling into more than one of the terms thus narrowing the file lists down to manageable proportions. For example, if the door closer required should fall into the following E2M(M)13, "chain and cord arrangement", and also E2M(M)12A "electric and magnetic" then the patent number wanted would be one of a smaller number of patents which are in both sets of lists.

The objective of the patent search in this particular circumstance was to summarise the different basic concepts within these twelve areas. Consequently there are no short cuts, as many patents as possible needed examining under each term. With each patent being significantly different from the next (otherwise the patent would not exist) it is arguably worthwhile looking at every patent on all 12 lists, although not practical. The method used was to look at the front page of the patent of interest, which in most cases fully describes the invention in a concise manner. One can see what will be relevant from this. If it is of interest then the patent specification can be read in greater detail.

Due to the overall time span of the project it was not possible to look at all the patents on the lists, a task which would take weeks, if not months. Instead the author visited the Science Reference and Information Service, London (formerly the Science Reference Library) on two occasions, the 17th November 1988 and 15th December 1988, one of eight public libraries in the country housing a complete set of patents (World, European and Great Britain). Only Great Britain patents were consulted and in the time designated it was only possible to go back to approximately 1980 for all 12 file lists, some 400 patents altogether.

This patent search fulfilled the chief objective of summarising the main concepts within these twelve terms.

Searching patents in this way was an invaluable source of information and, to some extent, inspiration. How much they positively influenced the author's thought process is impossible to It must be remembered that the trade literature search guess. concerns itself with concepts in production, only, whereas patents are equally likely to cover the concepts not in production that may now be viable, perhaps in some new context, such as material development or by combination with another concept. The patent search, again unlike the literature search, was confined to overhead surface mounted door closers covering car doors, automatic swing doors and many more. If these had all been literature searched thousands of companies would need to be consulted, a massively time consuming and largely unnecessary process. The patent search saved this time and, of course, companies of particular interest could be singled out for inclusion in the literature search. Some Taiwanese, Japanese and American companies were included in this way. It was pointless wasting time developing 'new ideas' and finding they were conceived 50 years before, reinventing the wheel as it were.

Definitions used from <u>Patents</u>, <u>a source of technical information</u> (1986) Patent Office, Department of Trade.

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3.8 PRESENT COMPETITIVE PRODUCTS SUMMARY

This section is concerned with assessing the relative merits of the systems used by Dorma and Geze to achieve an improved powercurve characteristic, their implications on manufacture, and how available such systems would be should NTEL wish to develop products along similar lines.

The Dorma TS 93 uses a cammed rack and pinion system which may be shaped to achieve the ideal powercurve characteristic or, indeed, any powercurve characteristic the manufacturer wished; it is versatile in the extreme. Its only significant disadvantage 1s the high friction between the teeth which causes the efficiency of the system to be low, like a 'normal' rack and pinion system. The cammed rack and pinion teeth profiles are actually produced by extrusion, not machining like the usual rack and pinion systems. Although it is not actually necessary the efficiency could be improved if the teeth profiles were smoother, such as if they were ground. Most importantly, though, is that it functions in the same way. It uses oil damping to control the door and the parts in the product use the same plant and so expertise and technology of a manufacturer who produces rack and pinion door closers already Investment by NTEL into this type of system would be limited primarily to engineering design, so as a concept it would be extremely attractive.

Unfortunately the system is completely patented by Dorma preventing other companies using it.

The Geze TS5000 mechanism uses a plain cam on the axis of the pivot arm with a sprung loaded roller follower. It is mechanically efficient but does not produce such an ideal powercurve characteristic, nor is it so adjustable in terms of powersize. Again the manufacturing facility required to produce it is common to existing door-closer technology being based, in concept, on floor springs. There are two further problems with the system.

The first is that the cam profile must reverse a positive spring rate as well as be angled to maintain a torque on the pivot arm which must be particularly high at the latch position. Diagram 9 page 90 demonstrates the problem. The result is that a very high preload is required of the spring. The problem is then further emphasised because in order that the resulting door closer is of practical dimensions, ie comparatively small (where a floor spring need not be) the cam dimensions and so piston stroke are also small. The spring rate is then required to be high to compensate so the forces within the unit become high and it becomes very substantial, corresponding wear, therefore is also a problem.

The second problem is that the stroke of the roller follower piston is not far enough to move a large enough volume of oil to dampen the system sufficiently, this controls the door in closing A second cam is needed for this which means more parts. The test work carried out on the product previously suggests that to have adjustment for different power sizes in this product compromises the powercurve characteristic, ie, it may lend itself more to a product per power size, as NTEL already do. This would allow the powercurve to be optimised. The powercurve would be a large improvement on NTEL's existing product and the concept, which is an old one, is no longer protected by comprehensive patents so is free for use. Without doubt it would be a reliable concept on which to develop a viable product.



Diagram 9

4 PROPOSED CONCEPTS

4.0 THE CONCEPTS

The author considered a number of possible solutions to the door closing problem. These may be divided into two main categories.

4.0.1 Energy Storage Concepts

This was concerned with using energy storage devices other than the helical compression spring usually used and how they may affect the torque/powercurve characteristic when applied to existing mechanisms. Examples of these include accumulators, disc springs and constant force springs.

4.0.2 Mechanism Concepts

These were proposed original mechanism concepts for door closers which were likely to fulfil the proposed PDS when, and if, developed. They include the 'Bowden' mechanism and Briton 'Snake' idea.

These solutions were developed during the Design Development phase of the project and run in parallel to, and influenced by, the research phase. Please see the sketches on the following pages.




































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The following section takes the concepts outlined in the development sketches and examines them in more detail.

4.1 ENERGY STORAGE CONCEPTS - REPLACING THE HELICAL COMPRESSION SPRING WITH AN ACCUMULATOR

Using an accumulator instead of a helical compression spring was an idea proposed by Mr Alan Underhill, the author's supervisor in Mechanical Engineering, LUT. The reasoning behind this being to combine the oil damping and energy storage in one thus reducing parts and the problems associated with wear. The following is a simple investigation into this system based largely on information supplied by Fawcett Christie Hydraulics Ltd, Deeside, Clywd.

4.1.1 How an Accumulator Works

See diagram 10, page 111. The design of an accumulator is based on Boyles law making use of the difference in compressibility between a gas and a fluid. The shell of the accumulator contains a bladder precharged with nitrogen gas (usually) to a pressure determined by the work to be done. After precharging the bladder occupies the whole of the volume of the shell (10a) from here the working can be split into three stages.

- (a) When the hydraulic pump in the system causes the fluid to enter the accumulator the nitrogen contained in the bladder compresses and its pressure is increased (10b)
- (b) The process of distortion of the bladder ceases when the fluid and nitrogen pressure balance. The bladder, at this stage, is not subject to any abnormal mechanical stress. (10c).
- (c) If the system pressure then falls the stored fluid is returned to the system under the pressure exerted by the compressed nitrogen. This returns the accumulator to the state described in (10b).



Diagram 10



Diagram11

Accumulators have many applications being commonly used in the following ways :-

- (a) Dampening the pulsation of pressure in a system for example pressure changes caused by the pulsation of a pump (this will often also reduce sound levels). This may also be instant pulsation such as in shock absorbers.
- (b) Monitoring pressure by using an accumulator charged in advance.
- (c) Absorbing pressure differences caused by thermal variation in a closed hydraulic circuit.
- (d) As a 'transfer' barrier system where pressure may be transmitted from one hydraulic or pneumatic system to another hydraulic or pneumatic system containing a different fluid without danger of mixing.
- (e) As an energy storage device.
- 4.1.2 The Use of an Accumulator as a Helical Compression Spring Replacement

In this particular concept the accumulator is used as an energy storage device. See diagram 11 page 111.

To demonstrate this concept a Fawcett Christie Hydrocushion was used. It is a welded, non repairable accumulator for high volume, low cost applications (approximately £50). The size chosen for the example was .13 litres with a working pressure of up to 50 bar.

```
The sizing of an accumulator is based on Boyles law for the
expansion and compression of gases
PV^n = C
where
      P = pressure (N/m^2)
      V = volume (m<sup>3</sup>)
and n = 1.4 (the adiabatic constant dependent on the type of gas
                   used and its temperature and pressure)
      C = constant
P_1V_1, P_2V_2 and P_3V_3 may be related as follows. Where there is an
isothermal compression of the gas it is assumed that P_1 V_1 = P_3 V_3
and where there is an adiabatic comparison of a gas it is assumed
that P_1 \cdot V_1^{h} = P_2 \cdot V_2^{h} = P_3 \cdot V_3^{h}
Assume the minimum allowable pressure P_{2} = 5 217 bar, the
precharge P<sub>1</sub> is 90%P<sub>2</sub> so P<sub>1</sub> = 4.695 bar.
Using the equation :
P = \underline{F} or Pressure = <u>Force</u> (N)
A Area (m<sup>2</sup>)
A_1 = \underline{F_2} = \underline{531} where Force 'F' is an arbitrary force of
P<sub>2</sub> 5 217 similar size to that of a preloaded spring
                         in a comparative rack and pinion application
A_1 = 1.0178 \times 10^{-3} m^2 = \mathcal{M} \times \frac{2}{10} - 10^{-3}
x = \sqrt{\frac{4 \cdot A_i}{\alpha}} = 36.00 mm where x = accumulator piston diameter
The maximum allowable pressure P3 is defined as
P_{3} = \frac{F_{2}}{A_{1}} = \frac{976N}{1.0178 \times 10^{-3} \text{ m}^{2}} where Force 'F<sub>2</sub>' would equate
to the final compressive force of
                                              the same spring described for F
```

Assuming the nitrogen is compressed isothermally from the precharge to the maximum allowable pressure, then

$$P_{3}V_{3} = P_{1}V_{1}$$
 $V_{3} = (4.695bar \times V_{1})$
9.589bar
so $V_{3} = .4897 V_{1}$

Assuming the accumulator exhausts adiabatically to the minimum allowable pressure then :-

 $P_{3}V_{3}^{1.4} = P_{2}V_{2}^{1.4} \quad V_{2} = \left(\frac{9.589\text{bar}}{5.217\text{bar}}\right)^{1/7}V_{3}$ $V_{2} = 1.5446 \times .4897V_{1}$ $V_{2} = .7563V_{1}$

Where $\nabla_2 - \nabla_3$ = volume of oil displaced by the piston shown in diagram 11.

 $V_2 - V_3 = .2666V_1$ and $V_1 = .13$ litres for this hydrocushion So the volume of fluid displaced = .0346 litres = 3.46 x $10^{-5}m^3$

Since $A_1 = 1.0178 \times 10^{-3} \text{ m}^2$ then the length swept out by the cylinder $y = \frac{3.46 \times 10^{-5} \text{m}^3}{1.0178 \times 10^{-3} \text{m}^2} = 34 \text{ mm}$ stroke

So, referring to diagram 11, the internal piston diameter 'x' and stroke length 'y' are 36 mm and 34 mm respectively. These values define a volume of oil displaced which is what creates the pressure in the system. Providing the volume remains constant then the stroke length may be decreased and the piston diameter increased, or vice versa. For the example the values of force for the piston at the instroke (preload) and outstroke, and the stroke length itself were chosen so that they roughly compared to a NTEL size 3 rack and pinion system.

The force/displacement characteristic for this concept is linear see graph 10 page 116 - comparing directly to the spring rate of a helical compression spring. So as an energy storage device alone an accumulator offers no benefits over a helical compression spring. It would still have to be used in conjunction with some mechanism which would 'convert' the characteristic to the desired torque characteristic. Nevertheless the pros and cons of the system warrant some thought

The main advantages of this concept are :-

- (a) There is no need for a spring which means a reduction in wear and its associated problems.
- (b) Any oil damping could be an integral part of the device utilising the oil flow already taking place. Because of the reduction in wear, as described above, and because high wear areas such as a rack and pinion mechanism or roller follower/cam mechanisms contaminate the damping oil orifice sizes may be safely reduced without risk of blocking. The accumulator size may, therefore, also be reduced and so the door closer itself.
 - (i) reducing the orifice size without risk of blocking means a correspondingly smaller amount of oil needs to be displaced for damping which means the accumulator may be small, a factor further assisted if,

The accumulator could be reduced in size if it were designed specifically for the task, possibly using a piston system rather than a nitrile bladder (see diagram



-

116



12 page 117). The resulting door closer could be smaller and perhaps cheaper so maybe more viable.

- (c) Sizing adjustability could be easily incorporated over a large range by altering the volume of oil available in the piston, ie, pressurising it which would increase the preload on the system. This may be achieved using a screwed end plug on the piston for example.
- (d) Fawcett Christie (the accumulator manufacturers) verify that the nitrile material used for the bladder would stand 500,000 cycles corresponding to the cyclic performance requirement of BS 6459.

The main disadvantages of this concept are :-

- (a) Sealing the piston mechanism. Due to the large pressures involved and because any seals would need to allow for movement axially, leakage would occur if seals were not of a precision tolerance which would be expensive. Leakage would cause the loss of essential pressure and so prevent the mechanism working. Regular readjustment to counteract this would not be acceptable.
- (b) The rack and pinion or piston roller follower/cam mechanism and needle bearing for the drive shaft and moving channels could not easily be in the same oil as that used in the accumulator itself without risk of blockage so a second chamber would be needed requiring containment and seals.
- (c) Fawcett Christie were not prepared to guarantee a life of ten years for the nitrile bladder as per BS suggesting instead a repairable system, which would be impractical, or a piston accumulator arrangement as described in diagram ll page 111.

(d) The hydrocushion specified in the example would cost some 150%¹ that of a complete NTEL 2000 door closer (a price based on a large order). With the addition of the 'door closer' parts, including the precision toleranced seals, some form of body, arm, channel and so on, the concept becomes prohibitively expensive.

The pros and cons were discussed with Dave Yates (9 Dec 88) and the sealing problems and their associated cost were concluded to outweigh the pros.

The concept is more viable in a floor spring application involving higher forces. Here the mechanism may be submerged in oil for friction reduction and, because the floor spring is always mounted in the same position relative to the door, ie, it is never upside down or back to front like an overhead door closer may be, the submerged oil chamber only needs one seal around the support hinge shaft at the foot of the door. The oil level need not touch the seal and the seal would act more in preventing dust and water entering the system rather than preventing the oil within it escaping

The cost would be reduced if NTEL designed and manufactured their own accumulator. The manufacturing processes needed are similar to those NTEL use for the piston/bore manufacture in most of their present door closers especially if the piston rather than bladder accumulator were used

This concept is not yet viable for overhead door closers. Should low cost sealing techniques be developed then it is a concept worth consideration.

NOTES :

1 Based on relative prices for large orders, Fawcett Christie Hydraulics Ltd, Deeside, Clwyd 1988 price list. NTEL 1988 prices for single arm rack and pinion door closers.

4.2 ENERGY STORAGE CONCEPTS - THE USE OF DISC SPRINGS

Based on information from the Schnorr Disc Spring Handbook. (A Schnorr KG, Machingen bei Stuttgart, Germany, 6th Ed.)

4.2.1 Introduction

Disc springs are usually radially straight conical discs with a rectangular cross section. See diagram 13 page [2] An elastic deflection occurs when a load is applied around the inner and outer circumference. Like any spring the respective values of load and deflection generate its characteristic.

A disc spring's characteristic is not straight but regressive. This is because when a disc spring is compressed the relationship between logitudinal displacement, change in 'h', and the radial displacement, the change in 'Da', is sinusoidal. The stress changes in the spring are also proportional to the radial displacement change in Da. The extent of this is dependent on the ratio of h/s When this tends towards zero, corresponding to a thick disc spring, the characteristic is straight. As the h/s ratio rises it becomes increasingly regressive until $h/s = \sqrt{2}$ where, as the spring is compressed the characteristic has an almost horizontal portion, ie, the disc spring pressure remains constant with increasing stroke, see diagram 14 page 21 As the h/s ratio increases still further and the spring gets still thinner the characteristic will peak and then drop, corresponding to turning inside out. It is usual to only use the first part of the characteristic, often deflecting not much further than 75% of its original height. This also avoids fatigue fractures due to dynamic overload, a problem aggravated with the constant cycling a door closer would experience the net result being to shorten the door closer life

Disc spring characteristics may be altered by the way they are stacked, as in diagram 15 page 122



Diagram 13





Diagram 15



Diagram 16

To generate a progressive characteristic a disc spring stack may be assembled in single, double and triple layers as in diagram 16a page 122 or, if disc springs of various material thicknesses are stacked, 16b. Obviously the layers, or individual discs, of lighter section will be displaced further than the disc spings of heavier sections. Excess stress may be eliminated by decreasing the formed height of a disc or by using spacer washers or rings to restrict the deflection.

4.2.2 Replacing a Helical Compression Spring by Disc Springs in a Single Arm Rack and Pinion Door Closer Application

Graph 11 page 124 shows how the regressive straight and progressive disc spring characteristics affect the powercurve of a conventional single arm rack and pinion door closer, (ie, if the geometry remains the same). The initial pre load on the disc spring determines the latching torque on the door closer and the rate determines the shape of the powercurve characteristics as shown.

A progressive spring rate is the best energy storage device for the mechanism described because the present powercurve, equating to a 'straight line' spring rate, peaks too late at 45°. Combinations of different disc springs in a stack can be used to alter the spring rate, for example, if the disc spring stack rate remains low for as long as possible more and more of this late powercurve peak is lost which is preferable.

The advantages of a disc spring system are :-

(a) The ability to produce a progressive characteristic with them.



Graph11 Characteristic Relationships

- (b) The small space they use, even when stacked. In order to achieve a reasonable overall deflection for a rack and pinion mechanism, some 20 disc springs may be stacked. Even these would take up perhaps one third to half the space of a helical compression spring for a similar application thus reducing door closer body size.
- (c) According to Belleville Springs² a half million cycles may be achieved by a disc spring. This is only possible if the disc spring is not deflected beyond 75% of its height 'h' avoiding fatigue with its associated problems.

The main disadvantage of a disc spring system is the friction that occurs when the stack deflects. This occurs between :-

- (i) the discs and the guide or bore that they are mounted in.
- (i1) the contact surfaces of the discs which move radially. The worst case being springs in parallel where the touching surfaces are large ie, the upper and lower faces of the spring and secondly in series, ie, end to end, although the friction can be lessened if the springs in contact are deflecting at the same rate and the same size. Obviously if the springs in contact are of different rates and sizes then more friction will occur because they will not move relative to one another.
- (111) the contact surface of the discs at the top and bottom of the stack again move radially on non moving surfaces.

This high friction causes wear and even the complete submersion of the stack in oil, which would occur in the door closer would not alleviate the problem enough. It may be necessary to somehow separate the stack oil and damping oil because particles in the oil, caused by wear, may block damping holes or damage bore/piston surfaces. The lubrication coupled with careful manufacture of guide components, radiused spring edges and flats on the top and bottom of the springs would all help to reduce friction and make the system more viable, but nevertheless achieving the BS 6459 requirements for minimum efficiencies may be difficult using disc springs

(c) A typical disc spring stack of say 20 costs approximately 1607 ⁻³ that of a typical helical spring, based on large orders. The cost of the stack would be reduced if less springs could be used which may be possible but would be dependent on the mechanism design itself, ie, smaller pinion p.c.d. or smaller cam. The factors necessary for reducing friction, radii, flats and so on, increase cost still further but would probably be necessary to satisfy BS 6459 minimum efficiency requirements. The introduction of flat washers and inserts essential in generating the desired progressive characteristic again increase cost, not only in extra parts, but in assembly which would become complex.

(d) The desired progressive characteristic is not actually as easy to achieve as first indicated. All the 'weaker' disc springs could be fully compressed before the preload force is reached meaning the effect is to some extent lost. In practice, from the preload onwards, the disc spring characteristic would probably be steeper than a 'normal' helical compression spring. (See graph 13 page 127). The effect on the powercurve is that it will, probably rise.

NOTES

1 K -H Hertzer "Fatique Strength and the Setting of Disc Springs", paper read at the Brunswick Technical University (1959).

G Schremmer "The Dynamic Strength of Disc Springs", paper read at the Brunswick Technical University (1965).



Graph12 Progressive D.S. Characteristic and Preload.



- 2 Belleville Springs Ltd, Redditch, Worcs, B98 8JY. Letter received by author from Mr N M Creary (9 Jan 89).
- 3 Relative prices based on Stock Precision Engineered Components (SPEC) catalogue, Associated Spring, October 1988.

4.3 ENERGY STORAGE CONCEPTS - CONSTANT FORCE SPRINGS

4.3.1 The information so far indicates that the best 'rate' for a spring must be as low as possible after the initial preload. The latching torque is then achieved and then the rest of the powercurve would be low. Trying to do this with a helical compression spring is very difficult. If the rate were low the spring would have to be compressed a large distance to the preload, that is, a long spring is needed. A long spring makes assembly of the door closer difficult due to the compression of the spring into the bore and when compressed it would take up a lot of space so a larger body would be needed. Costs therefore rise.

It was looking at the problem in this context that led to the consideration of Constant force springs, analysed here.

This section is based largely on information supplied by Tensator Ltd, Tickford Street, Newport Pagnell, MK16 9BE "Constant Force Springs, A Standard Range" 1989.

Constant force springs are a special variety of extension spring. They consist of a spiralled strip material with integral curvature so that each turn of the strip wraps tightly against the next. As the strip is deflected the inherent stress resists the deflection at a nearly constant rate, see diagram 17 page 129.



Diagram 17 Constant Force Spring and Characteristic

The spring is usually mounted with the internal diameter tightly wrapped around a drum and the free end to the load, in this case a second drive attached to the door closer 'pinion'.

The capacity of constant force springs may be increased by mounting more than one together.

The concept, shown in diagram 18 page 131, uses a constant force spring in what 1s termed the 'spring motor' application. Drum d_1 1s free running and drum d_2 1s the drive shaft of the arm of the door closer. It is drawn so that the arm turns in an anticlockwise direction as the door opens. An oil damping system may be incorporated by attaching a simple mechanism to the central drive shaft, such as a rack and pinion or cam to create a lateral piston movement.

4.3.2 Generating the Predicted Powercurve for the Constant Force Spring Mechanism

It is assumed, for the sake of the calculation, that the door closer would be mounted in the 'Normal' position relative to the door. The arm length is considered to be 350mm with the pinion/ drive shaft axis 190 mm from the hinge axis and 26 mm from the face of the door, all typical dimensions. The geometrical relationship of the arm and door in the 0°. 45°, 90°, 135° and 175° positions may be used to generate the characteristic, see' diagram 19 page 144.

As a basis for the calculation it is assumed that the original torque at the door latching/ 2° door position is 22 Nm, 5Nm more than the BS 6459 minimum requirement for a size 3 door closer, although it is the powercurve shape which is of interest not the absolute values.



Diagram 18 Constant Force Spring Doorcloser Concept

Using the equation · -

Force due to constant force spring on door x Distance from hinge x Angle at which force acts = Torque on door.

F.d. $\cos \alpha = T$ where F = force due to constant force spring (N) d = distance from hinge (m) $\alpha =$ Angle at which the force acts on the door T = Door torque

The first requirement is to establish the force that the constant force spring produces. At 2° the BS minimum torque requirement is 22.0Nm as discussed so :-

 $F = \underline{T} \quad \text{refer to diagram 19 for geometry}$ d. $\omega s \propto$ $= \underline{22.0 \text{ Nm}}$.54m.cos4° F = 41 N

At 45° $41N \times .438m.\cos 23^{\circ} = 16.5 Nm$ At 90° $41N \times .276m.\cos 30^{\circ} = 9.8 Nm$ At 135° $41N \times .180m.\cos 17^{\circ} = 7.1 Nm$ At 175° $41N \times .158m.cas 4^{\circ} = 6.5 Nm$

This generates the powercurve shown in Graph 14 page 133

So the main advantages of this concept are :-

(a) The powercurve is ideal dropping from a peak latching torque quickly and then leveling out at a low level.



- (b) An oil damping system may be included, as described, but would reduce efficiency and fully housing it would be difficult requiring a large body. However the rack and pinion damping system may be isolated from the spring putting bearings and seals either side of the pinion with the spring mechanism outside.
- (c) The efficiency of a system using a constant force spring alone would probably be higher than that of NTELs present 2000 series of door closers, although the damping mechanism would reduce this if included.

The main disadvantages of using the constant force spring mechanism are :-

- (a) One with a large enough torque, could be ten times more expensive⁻² than the helical springs necessary in the standard rack and pinion overhead door closer. It must, however, be pointed out that this price is based on a spring which will extend to nearly 1.5 meters and has 27 working coils. A spring designed specifically for this application would cost considerably less needing only one working coil and perhaps extending one twentieth of the distance.
- (b) The constant force spring necessary is quite large, one supplying a torque of 10 Nm has an outside diameter of 138mm with a width of 50.8 mm. Again size would be considerably reduced were a spring designed specifically for the task or if a number of smaller springs were used in parallel.
- (c) Fatigue is the greatest problem. It is greatly influenced by the ratio of width 'w' to thickness 't' of the material used, the diameter of the torque output drum and the distance of the two centres apart. This defines the extent to which
the material is bent back on itself. Obviously the less the bend the greater the fatigue life. Even so fatigue would set in after some 20,000 cycles at the best, a far cry from the half million cycles required by BS 6459. This assumes the use of normal materials such as spring steel or stainless steel A higher fatigue life may be obtainable using more advanced materials such as carbon fibre, however the increase necessary is exceedingly large and such materials incur a cost penalty both materially and in terms of development for the application.

(d) Lastly there would be no facility for adjustment across a range so a different spring would be necessary for each power size rating.

Were it not for the limitation of fatigue a viable product could prbably be developed using a single or combination of constant force springs in conjunction with a rack and pinion mechanism. A constant force energy storage device or spring with a horizontal spring rate would actually generate a powercurve shape close to the ideal through the geometry of the parallel arm system.

NOTES ·

 Based on terms used in Tensators' "Constant Force Springs A Standard Range". Catalogue 1989
Based on Tensator prices, September 1989.

4.4 MECHANISM CONCEPT - "THE BRITON SNAKE".

This concept was based on the Hawgood 4000, see Appendix 8 page 229 and the testing section page 72. Rather than having only one 'joint' or pivot point like the Hawgood 4000 hinge the snake concept has more than one. The principle of its operation is that by choosing different spring rates for each joint the flexing of the snake may be varied altering the rollers position in the channel and so its point of contact on the door or frame relative to the hinge. Although each joint would be sprung loaded using a helical compression spring of positive spring rate the controlled flexing of the snake, and so the position of the roller would counteract the effect.

By generating the Hawgood 4000's powercurve characteristic it was possible to predict a characteristic for this type of door closer and more accurately assess its viability. Sadly it is probable that this effect would not be enough to counteract the rising spring rate problem nor to generate the necessary torque to latch the door. So it was left at the undeveloped stage.

4.5 MECHANISM CONCEPT - THE BOWDEN MECHANISM

Because this was the solution finally developed the layout drawing on page 194 can be used to explain the system

Two spring mechanisms effectively work in parallel. The rack and pinion/helical compression spring mechanism creates a base torque on the arm throughout the door movement/door closer arm movement which is at a low level. The additional peak torque necessary for latching is provided by a detente cam/die spring mechanism. After the roller follower has left the detente a blend cam smooths the two characteristics together. Finally the blend cam runs into the dwell where the centre line of the roller follower detente cam/blend cam centre and the point of contact of the roller follower on the cam face are common so no torque is generated. This enables the die spring energy to be stored so the door closer's arm torque falls to the base level generated by the rack and pinion/helical compression spring alone.

The advantages of this system are :-

(a) It is possible to achieve a Torque Characteristic of the correct shape.

- (b) A smaller rack and pinion spring can be used. ie, only that necessary for the sweep of the door and not the latching action, which could mean a smaller bore hole for the rack and pinion mechanism.
- (c) Damping can be included in exactly the same way as existing rack and pinion systems.
- (d) It would be capable of being manufactured, for the most part, by NTEL's existing manufacturing facilities so investment in the new machinery, and associated training, is not necessary.
- (e) The system is very versatile The torque may be changed by varying the cam profile or rack and pinion system and their associated spring rates.

The main disadvantages are ·-

- (a) More parts are necessary because there are two systems incorporated in one. Careful design and development would be necessary to reduce and simplify these parts as far as possible and to use standard parts or parts common to other NTEL door closers.
- (b) There was also some concern that the added forces from the detente mechanism may cause detrimental wear, in particular the lip radii of the detente itself but also in fatigue on the pinion shaft. Care would have to be taken to bolster these areas for the additional strength required. In discussions with T Davies¹ on the cam design he suggested the careful choice of bearings and to maximise the size of roller follower. ie, These he identified as potential weak links in the system.

Probably the only serious disadvantage of the system is the number of parts. By careful design the wear and fatigue problems can be overcome. The original 'Bowden' Mechanism used a disc spring system for the energy storage in the detente but throughout the product's development it was realised that a larger deflection was necessary giving a deeper detente profile than that initially considered hence the use of a die spring. A die spring still delivers high levels of force though. The larger deflection increases the angular distance over which the detente torque acts. This means the peak torque is spread which reduces the necessity of accurate arm to pinion tolerances and fixing tolerances. This avoids the situation where the peak torque may not correspond to the latching position of the door The die spring still only use a small space compared to that of an equivalent helical compression spring.

NOTE ·

1 T Davies, mechanism expert and Reader in the department of Mechanical Engineering, LUT.

4.6 <u>CONCLUSION</u>

Many more concepts than the ones described were considered during the development phase as shown in the sketches. Those outlined here are either the ones with more potential, the ones which had some influence on the final project development, or the one eventually developed.

5 THE DEVELOPMENT OF THE BOWDEN MECHANISM

5.0 INTRODUCTION

A meeting was convened on the 19th January 1989 and those attending were :-

Graham Chapman	-	Director o	f	Research				
David Yates	-	Director o	f	Research	and	Development	for	NTEL
Alan Underhill		Supervisor						
Syd Pace	-	Supervisor	•					
Nick Bowden	-	Author						

The main purpose of this meeting was to decide which of the previously discussed concepts should be chosen for development to working prototype. The pros and cons of each system were discussed and all those present agreed that this system should be the 'Bowden' Mechanism.

5.1 PROTOTYPE DEVELOPMENT

The purpose of prototyping the 'Bowden' Mechanism was to prove that the concept worked. There is, however, an inherent conflict of interests between a prototype proving a concept and a product which fully satisfies the Product Design Specification. The production item is the best compromise between function/performance, strength, cost, size and manufacturability, optimising the product. Conversely a concept prototype should reliably prove the concept but should, as a one off, utilise as many parts as possible that are standard. ie, cannibalised from other NTEL existing products or off-the-shelf items. Only as many 'custom' parts as is absolutely necessary should be specified due to their high cost in design and manufacture time. So in a prototype the function/performance and necessary strength take precedence and the cost, size and manufacturability temporarily take second place.

5.2 GENERATION OF A 'DESIGN' POWERCURVE

It was decided that the door closer to be designed should have a BS 6459 power size rating of 3, the size which makes up some 65% of NTEL's door closer sales (although not all of the single arm variety) The minimum torque requirement for a size 3 is 17Nm at 2° door angle and 5Nm at 90°, with a minimum efficiency at 2° of 50%.

In order that a design powercurve characteristic for the door closer could be generated an estimate of its eventual efficiency was required as well as some estimate of calculation tolerance. Because the mechanism used was a rack and pinion based system, known from the test section to be typically 50% efficient (in this sizing) then 50% seemed a realistic level to choose. A further 10% was included for component tolerance and calculation error. The design powercurve was therefore, at a level of 60% above the 'ideal' powercurve. Any subsequent calculations could then ignore frictional elements, component tolerance and calculation errors. If the concept prototype characteristic were to fall below the BS values it would be known immediately that the inefficiency was too high.

The Design Powercurve generated has a 2° door angle torque requirement of 37.4 Nm and a 90° door angle torque of 11 Nm and, most importantly, its shape is that of the ideal powercurve, see graph on page 142.

5.3 GENERAL INTRODUCTION TO THE DEVELOPMENT AND THE CONCEPT ITSELF

The concept itself has been described in section 4, page 136. The development of this system was iterative, an initial solution was developed, changed and improved, further developed and so on. The final solution is therefore the result of an evolutionary process The calculations in this section refer only to the final solution. ie, those used as a basis for the prototype.

Referring to the layout drawing in 5 18 of this section, page 194 the concept can be clearly understood.

5.4 THE DETERMINATION OF THE RACK AND PINION/HELICAL COMPRESSION SPRING MECHANISM CHARACTERISTIC AND PRELOAD

For the purpose of this calculation the following assumptions were made :-

- i) The door closer arm length was 350 mm
- ii) The pivot axis of the pinion lay 190 mm from the door hinge axis as measured along the face of the door. It was then proud of the door by 26mm.



1 .

'DESIGN' POWER CURVE.

•

The pinion pitch circle diameter (p.c.d) was .875" or 22 225 mm.

iii) The channel width was 26 mm therefore the door closer arm roller axis was proud of the door face by 13mm

The arm length and position of the pinion axis evolved during the design development phase. The pinion p.c.d is based on one of NTEL's standard rack and pinion tooth patterns. This particular pattern gave the largest p.c.d and so the largest root diameter which means it was strongest. Strength was necessary because the combined forces in the Bowden Mechanism would be larger than those of an equivalent sized rack and pinion system and also the double bore system would require a long pinion shaft which would be more inclined to flex than those in the existing NTEL products.

This calculation is based largely on the geometry of diagram 19, page 144. The scale of these diagrams have been reduced to fit into the thesis). The calculations were actually performed on full size diagrams for accuracy.

The door angle has been measured from -5° to 175° of opening The 5° allows for the movement of the arm from its resting position, or preload position, to the door closer primed or datum position, approximating to door angle 0°. If 0° position of the door was the same as the preload or resting position of the door closer any slight inaccuracies on fixing positions, where the door closer is proud, would prevent the door closer functioning correctly The 175° door angle is chosen because it is the BS 6459 minimum door opening angle for a class 'C' door closer.

Diagram 19 shows the relationship of the door angle to door closer arm angle. This in turn enables the spring compression and so spring load to be calculated (through knowing the p.c.d). So an arm torque can be related to a door torque because the line of action of the arm torque, and its point of contact relative to the door hinge, is known.



Diagram 19



-- - *-*

Consequently a torque versus door angle characteristic may be plotted, the powercurve.

The following equation relates the helical compression spring load to door torque through the rack and pinion mechanism, see diagram 19

$$\frac{L_1 \cdot r \, d. \, \cos \alpha}{1} = T_1 \qquad \text{eqn (1)}$$

Where :

L ₁	= Helical compression spring load	(N)
r	= Pinion radius	(m)
1	= Door closer arm length	(m)
d	= Distance from hinge to arm contact point	(m)

X	Angle at which force acts on the door	(degrees)
т	= Door torque due to helical compression spring	(Nm)

The ratio of 'l' and 'r' remain constant, independent of the door angle so can be replaced by a constant (.03175).

Similarly for each of the door positions -5° to 175° both the 'd' and 'cos α ' are constant. so L₁.d.cos α_{x} ,03175 = T₁

where $L_1 \dot{R}_{\theta} = T_1$ where \dot{R}_{θ} = constant for each door angle

Table 2, page 146 shows these values for different door angles. The helical compression spring load L_1 is a function of its compression which equates to piston displacement in the door closer. The angle turned by the door closer arm, therefore, can be related to piston displacement because the p.c.d. of the pinion is known. Referring to diagram 19 it can be seen that when the door angle is 0° then the door closer arm angle is also 0°, ie, the primed or datum position, and when the door angle reaches 175° the door closer arm has turned 168°. The corresponding compression on the spring can be calculated as a proportion of the pinion's circumference.

DOOR ANGLE (degrees)	∝ (degrees)	d (m)	kθ	
- 5	5	. 542	1.7208 x 10-2 =	к ₋₅
0	3	. 540	$1.7122 \times 10-2 =$	ĸ
45	25	.435	1.2509 x 10-2 =	К 45
90	30	.276	.7589 x 10-2 =	к ₉₀
135	17	. 180	.5465 x 10−2 =	K 135
175	4	.158	.5004 x 10−2 =	к ₁₇₅

TABLE 2

		SPRING		
DOOR ANGLE	ARM ANGLE	DEFLECTION	L ₁ (N)	T ₁ (Nm)
(degrees)	(degrees)	a(mm)	-	-
- 5	- 7.5	- 1.455	720 03	12.390
0	0	0	752.00	12.876
45	68.5	13.286	1043.89	13.058
90	117	22.692	1252.67	9 507
135	149.5	29.000	1391.26	7,603
175	168	32.584	1470.00	7.356

-

/

TABLE 3

So spring deflection, $a = \frac{168}{360}$ p c.d. circumference 360 = 32.58 mm per 168° or .1939497 mm/°

The helical compression spring to be used in this application was an off-the- shelf spring (SPEC Associated Spring DI 3820 L) This was chosen because it had a high peak load capacity for a small outside diameter enabling a single spring to be used rather than a spring nest which simplifies the calculations. The spring's characteristic was :-

f ₁	3	Free length	=	180 0	mm
f ₂	3	Loaded length	#	109.0	mm
P ₁	=	Maximum load	=	1569	N
Hole	Ħ	Outside clearance diameter of spring	-	30 7	mm
R	=	Spring rate	Ŧ	21.97	N/mm

As already described the concept may be divided into the two energy storage components, the rack and pinion/helical compression spring and the detente cam/die spring. Because the detente cam/die spring acts over only the first few degrees of the door opening the closing torque specified by BS 6459 for the 90° door opening position is achieved by this rack and pinion/helical compression spring part of the arrangement.

Using $L_1 \not R_{90} - T_1$ in reverse, where T_1 is the BS torque requirement for 90° a value for the spring load at this point can be generated.

 $L_1 = 11Nm = 1449.5N$ k_{90}

Unfortunately this value is too close to the peak load of the spring so a lower value must be chosen, ie, at 175° or higher the spring will be compressed beyond its limit and risks being damaged.

Instead a maximum load for the spring of 1470 N was chosen applied to the 175° door open position. Here some 4.5 mm safety factor was included on its compression equating to 99 N force The nominal torque on the door at 175° was therefore 7.35 Nm, and at 90° 9 51 Nm. The characteristic is shown in Graph 15 page 149.

This means that the torque value at 90° falls below that of the design powercurve but is still well clear of the BS minimum torque requirement of 5 Nm (for a size 3). It is a compromise which must be struck in order that a standard, off-the-shelf, spring may be used. No larger spring (ie peak load on the spring) of this sort of size is available commonly.

Additional spring information :-

Preload spring length = $147 \ 23 \ \text{mm} \ (-5^{\circ} \ \text{door} \ \text{angle})$.

5.5 THE GENERATION OF THE RACK AND PINION/HELICAL COMPRESSION SPRING MECHANISM CHARACTERISTIC FROM -5° TO 45° IN 5° INCREMENTS

To aid subsequent calculations of detente cam/die spring characteristic and blend cam characteristic it was necessary to calculate a characteristic for the rack and pinion/helical compression spring mechanism of more accuracy between -5° and 45°.

The procedure used for this calculation was identical to that of the previous calculation. Refer to diagram 20 page 150 for the geometry and tables 4 and 5 for the data page 151, Graph 16 page 152 shows the characteristic.





Diagram 20

DOOR ANGLE	R	d(m)	h	
(degrees)	(degrees)		ĸө	
- 5	- 5	. 5420	1.7208 x 10-2 =	= K5
0	3	5400	1.7122 x 10-2 :	= K
5	5	5365	1.6969 x 10-2 =	= K_5
10	8.5	. 5295	1.6627 c 10-2 =	= K ₁₀
15	11	. 5205	1.6222 x 10-2 =	= K ₁₅
20	13.6	.5100	1.5738 x 10-2 =	 [∗] ^K 20
25	16	4985	1.5214 x 10-2 =	= K ₂₅
30	18	.4840	1.4615 x 10-2 =	= K ₃₀
35	20.3	.4683	1.3945 x 10-2	= K ₃₅
40	23	.4500	1.3152 x 10-2	$= \frac{K_{40}}{K_{40}}$
45	25	4347	1 2509 x 10-2 -	= K ₄₅
				45

TABLE 4

		SPRING		
DOOR ANGLE	ARM ANGLE	DEFLECTION	L ₁ (N)	T ₁ (Nm)
(degrees)	(degrees)	a(mm)	-	-
- 5	- 7.5	- 1.455	720.03	12.390
0	0	0	752.00	12.876
5	7.6	1.474	784 38	13.310
10	16	3.103	820.17	13.637
15	24.5	4.752	856.40	13.893
20	32.5	6.303	890.48	14 014
25	39.5	7.661	920.31	14.002
30	46.5	9.019	950.147	13.886
35	54.5	10.570	984.223	13.725
40	62.5	12.122	1018.32	13.393
45	68.5	13.286	1043.89	13.058

TABLE 5



5.6 THE DETERMINATION OF A CHARACTERISTIC FOR THE DETENTE CAM/DIE SPRING MECHANISM

The detente cam was used instead of a conventional cam system for the following reasons \cdot -

In a conventional cam the follower rides up an often changing, or variable, gradient where the normal to the gradient, if it does not pass through the central axis of the cam, creates a torque. If the follower is sprung loaded then as the cam action compresses the follower the load from the spring is increased, this in turn increases the torque on the door closer arm. In the door closer application the highest torque is required when the door is just opening, which is where there is least load from the spring. So that the torque is largest at this starting point then the cam angle must be steep, tailing off to practically nothing, at the cam's largest radii where the torque is required to be small. Because the spring load at this position is largest the cam must compensate for this so that the resulting torque is small. The cam angle, therefore, compensates for a rising spring rate; but to result in a falling torque rate the compensation must be large. Diagram 9 page 90 helps to show this so the conventional cam is not ideal for this application. This 'limitation' may be seen in practice. The Geze TS 5000/5500 described on page 47 uses a cam system of this type. The powercurve, although improved (see discussions), is still not ideal, but it must be presumed that Geze have optimised the system.

The detente cam works on a different principle. Diagram 21 page 154 helps explain the mechanism. The line of action of the load passes from the central axis of the roller follower through the centre of the lip radii of the detente cam and, due to its distance from the central axis of the cam, generates a torque. In this type of 'cam' the displacement of the line of action of the load from the central axis of the cam starts off largest and decreases as the cam turns and this initial displacement is large compared to a normal/ conventional cam



Diagram 21

which compensates for the rising spring rate where the high torque is required

The detente cam is not as adjustable as a conventional cam. The resulting characteristic is a product of choosing and setting the following variables :-

Lip radii
Detente depth or overlap
Gam dwell diameter
Roller follower diameter

Diagram 22 page 156 helps to explain how changes in the above affect the resulting characteristic. In this application, providing the characteristic peaks and spreads over a reasonable angle (explained later), then it may be considered adequate.

Knowing exactly what blases to place on each of the variables described, in order that the resulting characteristic be optimised, is difficult to judge, however most of the variables did have other limitations imposed.

- 1 The lip radii was as large as was reasonable without compromising the peak torque. See diagram 22. This kept wear to a minimum in what is a high wear area
- 2 The detente cam dwell diameter was large to gain both strength and stiffness, as well as to reduce wear. Its diameter was ultimately limited by the maximum bore diameter of the rack and pinion piston bore so that the prototype was kept reasonably small. It was also governed by the diameter of the roller follower because of the effect a larger detente cam dwell diameter has on the characteristic, relative to the roller follower diameter. ie, the characteristic becomes wider if the detente is smaller, again diagram 22 helps to explain this.



1

- -

Diagram 22

3 The roller follower was an off-the-shelf item determined by the strength of the bearings within it (needle rollers) and the bore size which in this case is the same as the spring 'hole' dimension.

With these three variables determined the only major adjustment of the detente cam/die spring characteristic came in the choice of depth, or overlap, with the follower. A larger depth has the following effect on the characteristic :-

- (a) It increases the angle over which the detente is in operation which in turn widens the resulting characteristic. This is an important feature when considering fitting the door closer arm to the pinion shaft. The narrower the characteristic the greater the number of potential arm to pinion shaft fixing positions necessary to guarantee that when the door closer arm is in its primed position (theoretically 0° but could be more or less) it is not turned too far beyond its peak. The result of this would be a loss of closing torque at the latch position of the door.
- (b) It increases the peak torque because the line of action of the load passing through the detente lip radii is displaced further.

The only limiting factor was that as the detente becomes deeper so the strength and stiffness of the detente cam and pinion shaft reduces. ie, the second moment of area of the pinion decreases.

A die spring was used in this application because it is one of the only types of spring which can achieve a preload high enough for the application in the limited space available. Refer to double bore prototype drawing section 5.18 page 194.

The final detente cam arrangement was as follows :-

Detente dwell diameter	=	29	mm
Lip radıi	=	2	mm
Roller follower diameter	=	30	mm

The calculation for determining the detente cam torque characteristic is similar to that used for determining the helical spring characteristic

The following equation relates die spring load to door torque through the detente cam mechanism according to the geometry shown in diagram 21 page 154.

L _z .y cos /3	≃ T ₂	
Where	:	
L ₂	-	Die spring load (N)
ß	-	Angle between line of action of the die spring load and
1-		pinion centre (degrees)
Ч		Perpendicular distance between the line of action of the
Ŭ		die spring load and pinion centre (m)
^т 2	-	Door torque due to die spring (Nm)

It can be seen that the 'cos β ' and 'g' functions are constant for any <u>set</u> angle of the door so the die spring load and door torque can be related by a constant, k_{Θ} , for each door position, in the same way as the compression spring.

Finally, the angle turned through by the door closer arm can be related to that turned by the door. Refer to diagram 20 page 150. It was found that the relationship of door angle turned to arm or cam angle turned was almost constant throughout the first 45° door opening and in this calculation it is treated as such. The angle turned by the door closer arm, and so the cam, when the door is opened to 45° is 68.5°. So 1° arm movement = .6569° door movement.

Table 6 page 160 relates detente cam angle to door angle by the constant k_{C} in each of these positions Where -

 $L_2 \cdot k_{\theta'} = T_2$

The die spring load, L_2 , is a function of its compression and is shown in diagram 21.

The die spring to be used in this application was an off-the-shelf spring (SPEC Associated Spring St52680 BQ). Its specification was .-

f ₁	=	Free length	=	76.2 mm
f ₂	=	Loaded length	=	53.3 mm
P_1	=	Maximum load	=	3827 N
Hole	=	Outside clearance diameter of spring	Ŧ	32 mm
R	=	Spring rate	=	166.7 N/mm

The preload for this die spring is defined at the 2° R_2 ' position The torque requirement at this point in the final door closer should be 42.7 Nm * (Design powercurve) 17Nm BS 6459. From graph 17 page 161 it can be seen that 13.096 Nm of this torque is actually supplied by the rack and pinion/helical compression spring mechanism at 2° where

 $T_1 + T_2 = 42.7$ Nm So $T_2 = 29.604$ Nm

This value was originally 37 4 Nm but the formulae on page 158 has been corrected and all subsequent calculations and graphs have been altered to reflect this change.

DOOR ANGLE

ARM ANGLE	ß	$y^{(m) \times 10^{-3}}$	i . 1		
(degrees)	(degrees)	•	ROXIC)	
0	33 1	12 40		_	L2
0	33.1	12.40	1.480	-	~ -5
2.5	31.1	12.20	1.425	*	^К -3 36
5	30.0	12.00	1.385	=	^K -1.72
10	26.2	11.30	1.259	=	^K 1 56
10.65	25.2	11.17	1.234	=	к ₋₂
15	23.5	10.47	1.142	-	^К 4.85
20	19.6	9.22	.979	=	K 8 14
25	16 0	7.90	.822	=	^K 11.42
30	12.4	6.34	.649	=	^K 14 71
35	8.85	4.60	.466	=	^K 17 99
40	53	2.80	.281	3	^K 21.28
45	1.6	. 95	.095	=	^K 24.56
47 5	0	0.00		=	^K 26.2

TABLE 6

1





The rest of the detente cam characteristic may be determined from this point. The largest deflection is also safely within the limits of the die spring.

Table 7 page 163 shows the torque that the detente cam/die spring produces (T_2) . Added to the rack and pinion helical compression spring torque, (T_1) , the torque 'felt' by the door may be calculated.

The preload of the die spring was 1952.2N. Its initial preload length was 64.49 mm (-5° door angle).

:	DIE SPRING DEFLECTION		× た ⊖ from table 6 to give		COMBINED TORQUE
DOOR ANGLE	(mm)	LOAD	\overline{T}_{2} (Nm)	T ₁ (Nm)	T (Nm)
(degrees)	aı	$L_2(N)$	*	•	
- 5	0	1952.18	28.89	12.390	41.28
- 3.36	.70	2068.87	29.48	12.58	42.06
- 1.72	1.23	2157.22	29.88	12.73	42.61
1.56	2.50	2368.93	29.82	13.02	42 84
2.00	2.71	2404.67	29.67	13.10	42.77
4.85	3.56	2545.63	29.07	13.31	42.38
8.14	4 52	2705.66	26.49	13.46	39.95
11.42	5.30	2835.69	23.31	13.68	36.99
14.71	5.95	2944.05	19.11	13.91	33.02
17.99	6.50	3035.73	14.15	13.98	28.13
21.28	6.80	3085.74	8.67	14.01	22.68
24,56	6.96	3112.41	296	14.00	16.96
26.2	7.00	3119.08	0	14.00	14.00

-

TABLE 7

5.7 BLEND CAM DESIGN

It is quite obvious from graph 17 that some form of blend is required between the detente cam/die spring characteristic and the rack and pinion/helical compression spring characteristic to smooth out the door motion. This is possible by introducing a cam from the outside of the lip radii to a larger diameter than the .029 m already specified for the dwell of the detente. See diagram 23 page 165.

The first stage of the design of the cam is to find the angle at which the detente lip radii is in relation to the central axis of the detente itself. See diagram 24 page 165.

Using the trigonometric equation $a^{2} = b^{2} = c^{2} - 2bc \cos A$ for triangle ABC $\cos A = \frac{b^{2} + c^{2} - a^{2}}{2bc}$ $A = 48.394^{\circ}$

The cam begins before 48.39° blend cam angle at a tangent to the lip radii.

To calculate this the torque value at the point at which the cam starts is required. See graph 18 page 166. This is 10.95 Nm above the rack and pinion/helical compression spring torque at this point The point on the lip radius where its angle equates to that necessary to give this torque with the corresponding compression of die spring, is the point where the blend cam begins. See diagram 25 page 167.

From the diagram the following equation may be used to generate angle $oldsymbol{\beta}$

Torque = Load x displacement (Nm) $T_3 = (P_r + R.a) \tan \beta (A_1 + A_2)$ (Nm)



Diagram 23



Diagram 24





Diagram 25



where :

 P_r = Die spring preload(N)R = Spring rate (die spring)(N/m) a_1 = Cam radius at an angle (at arm angle 0° a_1 = 7.5 mm)(m)a = Die spring displacement(m) T_3 = Door torque due to blend cam(Nm)

The trigonometric rule states :

so
$$\beta = \left(\frac{T_2}{(P_r + R.a)(a_1 + a_1)}\right)^{n-1}$$

Referring to diagram 26 page 167 it is also possible to define β geometrically. This formulae is again based on the trigonometric equation for a triangle ABC

$$a^2 = b^2 + c^2 - 2 bc \cos A$$

so

 $(a_1 + a_1)^2 = .0125^2 + .002^2 - 2(.0125 \times .002.cos (180 - \beta))$

$$/3 = \left(\frac{(a, +a)^2 + 0.002^2 - 0.0125^2}{2.(a, +a).0.002}\right) \cos^{-1}$$

Because β in the above equations is the same by choosing a value for the $(\alpha_i + \alpha)$ function values for β may be generated. When β in both is the same then this is the angle of the cam face at its start, the angle necessary to generate the required torque of 10.95 Nm.

The following is the final loop of the iterative calculation by way of an example.

let $(a_1+a_1) = .01434m$ so $a_1 = .006934m$ so $P_r + R_{,a} = 1952.18 + (006934 \times 10-3) 166.7)$ = 3108.08 N

From the equations used before

$$\beta = \left(\frac{10.95}{3109.74 \times .014 4}\right) \tan^{-1}$$

 $\beta = 1372^{\circ}$ L1kewise . $\beta = \left(\frac{(a, +a)^2 + 0.002^2 - 0.014434^2}{2.(a, +a).0.002} \right)^{\circ} \cos^{-1}$

Because these angles are the same then this is the angle of the blend cam face measured at normal to the radius of the detente at this point which is the same as the angle of the lip radius measured from the line passing through the centre of the detente to the lip radius centre line.

So the angle at which the cam takes over from the detente, measured radially, is .-

 $a^{2} = b^{2} + c^{2} - 2bc \cdot \cos U$ $\cos U = \frac{01434^{2} + .0125^{2} - .002^{2}}{2x \cdot .01434 \times .0125}$ $U = 2 \cdot 174^{\circ}$

Therefore cam starting angle = $48.394 - 2.174 = 46.22^\circ$

It is also assumed that the end point of the cam = 75° (detente radial angle). So the blend cam stretches over 75 00 - 46.22 = 28.78° of the detente cam/pinion shaft.

The calculation so far has assumed that the point of contact of the roller follower on the cam face, the detente cam central axis and the roller follower central axis are in line throughout the cam's rotation. This is, in fact, not the case except during the detente dwell. The point of contact of the roller follower on the cam face is displaced defining an angle between it, the central axis of the detente cam, and the roller follower. This also causes a corresponding error in the extension 'x' of the die spring and so load. The practical effect of this is that the torque on the arm, due to the cam begins taking effect before 46.22° is turned by the arm. The angle at which this effect takes place is the arm angle. The best way to compensate for this is to calculate a correction factor graphically.

Graph 18 shows the combined detente cam/die spring and rack and pinion/helical compression spring characteristic. When the cam begins as opposed to the detente cam, at 46.22° arm movement, the torque should be 10.95 Nm greater than the rack and pinion/helical compression spring torque alone; 14.00 Nm. The door angle is .6569 times the detente cam or arm angle. Allowing for the preload angle of -5° , is subtracting 5° from the door angle, the 46.22° detente cam equates to a door angle of 25.36°. By reading off graph 18 it can be seen that this point does not touch the detente cam characteristic but is 5.84° clear. This is where the correction factor must be taken into consideration. It is assumed that the correction factor for the other angles of cam arm rotation are proportional, reducing to zero when the cam reaches the dwell (75° detente cam angle). So the cam begins when the arm rotation is 46.22° and operates for a further 28.78° to 75°. In terms of door angle the cam starts at 25.36° finishing in the dwell after 18.96°, ie, at 44.27°. So a correction factor of $5.84^{\circ} = .3086^{\circ}$ must be added to every degree of door opening 18.96

along the cam. See table 8 page 171.

The torque values necessary for the T_3 cam at each of these corrected angles may be calculated by subtracting the helical compression spring torque T_1 from the absolute torque at each angle. See table 9 page 171.
DETENTE CAM	DOOR ANGLE	CORRECTION FACTOR	NEW DOOR
ARM ANGLE	FROM -5*	(DEGREES DOOR ANGLE)	ANGLE
(degrees)	(degrees)		
46.22	25.36	5 850°	19 <i>5</i> 2°
50	27.84	5.069°	22 77°
55	31.13	4.055°	27.08 [°]
60	34.41	3.043°	31.37°
65	37.70	2.028°	35.67°
70	40.98	1.015°	39.97°
75	44.27	0	44.27°

TABLE 8

	CORRECTED			
DETENTE CAM	DOOR ANGLE			~
ARM ANGLE	$(FROM -5^{\circ})$	T ₁ (Nm)	T(Nm)	T ₃ (Nm)
(degrees)	(degrees)	-		-
				10.04
46.22	19.52	14.00	24.96	10.96
50	22.77	14.09	23.11	9.02
55	27.08	14.00	19 60	5.60
60	31.37	13.85	16.64	2.79
65	35.67	13.70	15.4	1.70
70	39.97	13.40	14 51	1.11
75	44.27	13.10	13.10	0

TABLE 9

-- --

5.8 GENERATION OF THE CAM PROFILE

The starting point of the cam profile and the required torques for each angle of the cam have been defined. It now remains for the actual cam profile to be generated which may be calculated using the following procedure ·-

From section 5.7 At 46.22° detente cam or arm angle $T_3 = 10~96$ Nm and $A_2 = .014434$ m This gives a cam face angle β of 13713°

A new value for (a_1+a_1) can, therefore, be calculated geometrically for the 50° arm angle position See diagram 27 page 173 where X = a fraction of the circumference (m) Z = further cam deflection which is added to the (a_1+a) function to

give a larger (a, +a) function at increasing arm angles.

$$\frac{\text{Increase in arm angle}}{360^{\circ}} = \frac{\mathbf{X}}{2\pi(a_1 + a_2)}$$

$$\frac{(50^{\circ} - 46.22^{\circ})}{180} = \chi$$

$$= .9528 \times 10^{-3} \text{m}$$

and

 $Z = x \tan \beta$ = .9528 x 10⁻³ tan 13.713 = .2324 mm

so the new (a_1+a_2) function = 14.44 mm + .23 mm = 14.67 mm

$$\left(\frac{T_3}{(P_r + R.a)(a_1 + a)}\right)^{tan^{-1}} = \beta$$

where T_3 at 50° = 9.02 Nm and $P_r + R.A = 1952.18N + (166.7N/mm x 7.17mm)$ = 3147.25N so $\beta = 11.23^\circ$



Diagram 27

So a new value for $(\alpha, +\alpha)$ can be calculated as before for the arm angle of = 55°

$$\frac{5^{*} \times \pi(a_{1}+a_{2})}{180} = 1.2802 \times 10^{-3} \text{m}$$

$$Z = \chi \tan \beta$$

$$Z = 1.28 \times 10^{-3} \tan 11.23^{\circ}$$

$$Z = 7.254 \text{m}$$

therefore $(a_{,+A})$ at 55° = 14.92 mm (P_r+ R.a) = 3189.1N

so
$$\tan^{-1}\left(\frac{5.60\,\text{Nm}}{3189.\,\text{IN} \times .01492\,\text{m}}\right) = 6.71^{\circ}$$

So a new value for $(\alpha, +\alpha)$ can be calculated as before for the arm angle at 60°

$$\mathcal{X} = 1.3020 \times 10^{-3} \text{m}$$

So $Z = \mathcal{X}$ Tan 6.71°
 $Z = .153 \text{mm}$

therefore (A_1+A) at $60^{\circ} = 15.07$ mm

Table 10, page 175 shows the continuation of this method up to 75° cam angle.

The final dwell radius is 15.24 mm so the outside diameter of the detente is 30.48mm. See diagram 28 page 176.

AM/		
CAM TORQUE	CAM FACE ANGLE	(a,+a)
T ₃ (Nm)	(degrees)	(mm)
10.96	13.71°	14.43
9.02	11.23°	14.67
5.60	6.71°	14.92
2.79	3.30°	15.07
1 70	1,99°	15.16
1.11	1.29	15.21
0	0	15.24
	CAM TORQUE T ₃ (Nm) 10.96 9.02 5.60 2.79 1 70 1.11 0	CAM TORQUE CAM FACE ANGLE T ₃ (Nm) (degrees) 10.96 13.7/° 9.02 11.23° 5.60 6.71° 2.79 3.30° 1 70 1.99° 1.11 1.29 0 0

TABLE 10

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Diagram 28 Cam Profile

5.9 THE DETERMINATION OF A PREDICTED POWERCURVE FOR THE PROTOTYPE See graph 19 page 178.

The resulting powercurve for the Concept 2000 is the result of adding together all the previously generated constituent characteristics. It assumes 100% efficiency so is more comparable to the design curve. Again, actual torque values are less important than the characteristic shape.

The predicted powercurve for the prototype is the sum of the three torques T_1 , T_2 and T_3 .

 T_1 Torque due to Helical Compression Spring through the rack and pinion system.

T, Torque due to the die spring through the detente cam system.

 T_2 Torque due to the die spring through the blend cam system.

This predicted characteristic is as close as possible to the design powercurve, page 142. Differences are due to the limitations of standard parts, particularly the springs, and calculation errors due to the graphical techniques used. In production custom parts would be used so the characteristic could be tailored that bit more. But the shape of the characteristic is correct.

This characteristic, and that of the 'Design' powercurve, is for the opening torque. The efficiency of the prototype, which is assumed to be 50%, plus a further 10% for the tolerance of parts and calculation errors, means that the closing torque characteristic should be such that the torque at 2° and 90° approximates to the BS minimum requirements and the shape that determined in the P.D.S



Graph 19

5.10 DETERMINATION OF THE CRITICAL JAMMING LENGTH FOR THE PISTON BORE SLIDE ACTION

As well as determining the theoretical powercurve that this prototype could generate calculations were required to determine the practical elements of the prototype such as sizes, strengths, stiffnesses, feasible assembly, manufacturability and so on.

The jamming length is the minimum length that the piston can be without the risk of jamming. See diagram 29 page 180

Let :-

F	=	Force	(N)
e	3	eccentricity of load	(m)
2	=	bearing length	(m)
R ₁	=	reaction	(N)
л	=	coefficient of friction	
r ₁	3	bore/piston radius	(m)

The piston will jam in the bore if -

F<(2×µ×R)

by taking moments about '0' the following expression may be obtained .-

$$(F_{x}e) + (u_{x}R_{1} \times r_{1}) = (R_{1} \times l_{2}) + (u_{x}R_{1} \times r_{1})$$

 $F_{x}e = R_{1} \times l_{2}$

Substituting into the first equation jamming will occur when

$$F \leq \frac{(2 \cdot \mu \cdot F_{x} e)}{l_{2}}$$

or
$$l_{2} \geq (2 \cdot \mu \cdot e)$$

In appendix 9 a value of $\mu = 0$ 4, maximum, for the materials used in this application was obtained. So



Diagram 29

So $l_2 \ge .8r_1$ because where e is at its maximum it equals the piston radius r_1

This ratio was used for both the pistons in the prototype, the rack and pinion and detente follower.

5.11 <u>SUMMARY OF THE PROPERTIES OF MATERIALS USED BY NTEL FOR COMPONENT</u> PARTS

There were two BS steels which NTEL use for the component parts of its door closers, both of which were used in this prototype :-

ENIA. To BS 970 (c1955) a mild steel with added lead. Nominal stress values are :-RM (U.T. Stress) 460 N/mm² RE (Yield Stress) 380 N/mm²

EN33. To BS 970 (c1955) a 3% Nickel cose hardening steel, Nominal stress values are :-RM 754.2 N/mm² RE 638.6 N/mm²

These are values for when the steel is carburised.

The mild steel ENIA is used for the piston parts and the high carbon steel EN33 is used for pinion shafts including the teeth. These were the values used in determining the strength of the component parts.

5.12 FACTORS OF SAFETY. SOME GUIDELINES

Factors of safety 'N' are extremely important for the correct running of machine elements. The guidelines given below are based on values suggested by Robert L Mott, P.E. University of Dayton in his book (c1985) <u>Machine Elements in Mechanical Design</u> - Merrill Publishing Co.

- N=2 Where in calculation or practice the loads, material properties and operating conditions are well known and ductile materials are used (these redistribute stresses better than non ductile materials so may be loaded to a higher percentage of their yield).
- N=3 For ductile materials where the adequacy of material properties data, loads, or the stress analysis, such as in stress concentration areas and so on, is in some doubt.
- N=4 As in N=3 above but for brittle materials where stress concentrations are not so readily redistributed and so on.
- N≈5 When conditions are uncertain concerning all of material properties data, loads and stress analysis.

5.13 SHAFT DESIGN

The shaft design calculations and the following stress calculations are based largely on methods outlined in two books :-

- 1 R L Mott, PE (1985) "Machine Elements in Mechanical Design". C E Merrill Publishing Company
- 2 K Smith (1981) "Mechanical and Engineering Principles. Vol 1 Satics and Dynamics". Pitman

Refer to the final component drawing and to diagram 30 on page 183.

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Diagram 30 Pinion Shaft

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The p.c.d. = 22.225 mm for the pinion teeth) a standard NTEL profile) The dwell diameter of the cam = 30.48 mm The length over which the pinion may be treated as a beam is 67.5mm The peak loads on the pinion part of the shaft due to the helical compression spring is 1470 N at a door angle of 175°. The peak load on the detente cam blend cam due to the die spring is 3242N beginning at a door angle of 44.77 onwards. The axis of these peak forces are shown in diagram 30. It is assumed EN33 will be used here, necessary for the hard wearing properties required.

The shaft is supported in bearings by shafts of diameter 16mm.

5.13.1 Calculation

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The reaction at the bearings must first be calculated.

First find R, by taking moments about R.

 $(1479 \times 14.25) + (3242 \times 54.25) = R_2$ 67.5 x 10⁻³

 $R_2 = 2916 N$

 $R_1 = 1470 + 3242 - 2916$ $R_1 = 1796 N$

By constructing a shear force and bending moment diagram, see diagram 31 page 185, the maximum bending moment may be calculated.



Diagram 31 Shear Force and Bending Moment diagram

Using the equation for circular bending

Where :-

I = Second moment of area for a beam (m^4)

In this case

$$I = (\frac{\pi_{\star} r^{4}}{4}) = \frac{\pi_{\star} . 01125^{4}}{4} = 1.203 \times 10^{8} (m^{4})$$

From diagram 31 the maximum bending movement is 38.63 Nm

so

$$O^{-}$$
 max = 38 63 x 0 011125 = 35.7 N/mm²
1.203 x 10⁻⁸

This is well within the maximum ultimate and yield stress for EN33. The safety factor is, in fact, greater than N=4. But the large safety factor will :-

(i) Allow for stress concentrations due to the change of section ie, the two different diameters.

- (i1) Allow for the component being fabricated, with the inherent join weaknesses, rather than being manufactured from one piece which is probable because of the complexity of the part.
- (i1i) Allow for the stress concentrations associated with the sharp change of section to the detente slot.
- (iv) Allow for fatigue problems which may occur due to the large number of cycles that the door closer is required to make.

Next consider the shear strength.

The weakest shear point is at R_2 across the 16mm spindle diameter.

Shear stress = $\frac{(R_2)}{Area}$

 $\overline{0}$ max = 14 5 N/mm²

Again this is well within the necessary shear strength. ie, a safety factor in excess of N=4.

5 14 DETERMINATION OF PIVOT DIAMETER

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The minimum size of pivot diameter for the roller follower in the detente system is the only other manufactured part which needs checking for strength. The standard parts, such as bearings and the roller follower, discussed later are specified using trade literature calculations not basic engineering formulae. Parts such as the pistons or body are substantial with no associated strength problems and are, therefore, not considered. Similarly end plugs which use 20 TPI Imperial screw threads have little risk of tear out.

The minimum shear diameter of the pivot using EN33 can be calculated using the equation :-

$$\overline{0} = \underline{F}$$

so

 $d = 2\sqrt{\frac{F}{(\sigma, \pi)}}$ where 'd' is the pivot diameter and σ is the $\sqrt{(\sigma, \pi)}$ yield stress of the material.

The maximum force of 3242N on the roller follower is spread over two shear planes The force is, therefore, half this value on each plane.

so

 $d = 2 \sqrt{\frac{1621N}{(638 \times \pi)}} = 1.80 \text{mm minimum diameter}$

5.15 CHOOSING A ROLLER FOLLOWER

The roller follower size was limited by the detente bore diameter (the die spring 'hole' diameter). The outer diameter of the follower should be as large as possible to lessen wear. Using the INA Rolling Bearings 305 catalogue 1989, a standard roller follower was found with an outside diameter of 30 mm and a thickness of 12 mm with integral needle rollers and no inner race so no axial guidance. The outer race will, in fact, be axially guided by its location in the detente piston itself so was not necessary on the component. The face of the roller follower is crowned, ie, is slightly rounded which, in practice, causes even wear over its surface ⁻¹ when compressed.

5.15.1 Calculation for the Life of a Bearing

The life of a bearing is calculated using the following formulae

Life =
$$\begin{pmatrix} \underline{C} \\ L \end{pmatrix}^p$$

where :-

Life is measured in millions of revolutions and is the life expected to be reached, or exceeded, by 90% of a sufficiently large group of apparently identical bearings before the first evidence of material fatigue develops.

C = Basic dynamic load rating. For radial bearings it is that load of constant magnitude and direction which a large group of apparently identical bearings can endure for a basic life rating of one million cycles. (N)

L = Equivalent Dynamic bearing load. (N)

p = Life exponent: p = 10/3 for needle rollers which are used in all the bearing applications of this door closer.

The roller follower chosen was STO10 with the dimensions already described. Its basic dynamic load rating C = 8400 N

So

Life =
$$\left(\frac{8400}{3242}\right)^{\frac{10}{3}}$$
 = 23.89 million cycles

This bearing system is overstrong because BS 6459 only requires a half million cycles of the door closer for compliance. This over specification would warrant the custom design of a roller follower in mass production. A great saving could be made by only achieving say 2.5 or 3 million cycles (including a safety factor) but was not justifiable for the prototype 1 Advised by T Davis, Reader and Lecturer, Department of Mechanical Engineering, LUT.

5.16 CHOOSING BEARINGS FOR THE PINION DETENTE SHAFT

The bearings for the main pinion detente shaft were chosen for their strength and their small width. If they were wide then the longer the pinion shaft would be and the larger the body necessary to accommodate them.

Drawn cup needle roller bearings with open ends were used in the prototype. Other than just a cage containing needles the drawn cup type are the cheapest variety being housed in a drawn steel housing. The machined equivalent would cost more than 2.5 times as much, with only fractional performance improvements. The cage type require greater tolerances and surface finish of the hole they fit inside, which is aluminium in this application, a poor bearing surface.

Finally, because the outer race, the drawn cup, is so thin the bearing diameter is not much larger than for needles alone.

Again these bearings are specified by Life, the INA HK1612 drawn cup closest to the detente side of the shaft. ie, at position R₂ in diagram 30 page 183 has the larger peak loading. Its dimensions are outside diameter 22mm, width 12mm, fitting to a shaft diameter of 16mm. Using the same formulae for life.

Life =
$$\begin{pmatrix} C \\ L \end{pmatrix}^{\frac{10}{3}}$$

L = $\begin{pmatrix} \frac{7600}{2916} \end{pmatrix}^{\frac{10}{3}}$. = 24.36 million cycles

This was again high but to be expected in a prototype.

5.17 SPECIFICATION OF SEALS

Radial seals were necessary at either end of the pinion/detente shaft. By placing these seals on the outside of the bearings then the hydraulic damping oil could also be used to lubricate them.

- Whenever the pinion/detente chamber oil 1s compressed the seal tightens against the shaft creating a firmer seal.
 See diagrams 32 page 192.
- (i1) It was dimensionally small so does not increase the shaft or body size unnecessarily.
- (111) There were no high pressures in the internal cavity of the door closer so a seal with this interference was adequate.

(1v) It was a low cost type.

The seals and bearings required particular shaft chamfers and tolerances for correct assemply and functioning. These are shown on the shaft drawing "Pinion/Cam Shaft" page 196. For the seals the tolerance was hll for the bearings h5 (ISO specification). The chamfer which guides the shaft into the seal and bearings is 20° which prevents any damage during assembly.



Diagram 32 · Seal Profile

5.18 ASSEMBLY OF THE PROTOTYPE

The calculations in the previous section were those essential for the detail design of the door closer. It was during visits to NTEL on 14 March 89 and 7 April 89 and during numerous telephone conversations with A Bishop and Dave Evans of NTEL as well as regular liaison with supervisors that the author was able to develop the door closer concept to the prototype stage. The author was able to establish just what parts could be cannibalised from existing NTEL products and what their manufacturing capabilities were with its corresponding influence on design. The drawings shown on the next pages show the layout drawing of the door closer concept, the double bore system, and the detailed component drawings for the custom parts.

The author, as project manager, ordered the off-the-shelf/ standard parts and organised the collection of NTEL parts, (ie, those cannibalised from other NTEL products).

The Prototype Double Bore System dated 24 Apr 89 was agreed for manufacture in a meeting convened on 10 May 89 at Loughborough Those attending were Dave Yates, Syd Pace, Alan Underhill and the author Detail drawings were supplied to NTEL after this meeting, the last being sent on 23 May 89. On 18 May 89 a letter was sent to NTEL advising the necessary cannibalised parts to be collected together, the parts were listed by drawing name, number and the quantity required. All the custom parts were finished by 16 Jun 89 except for the hardening and tempering of the "Pinion/ cam shaft". The standard components were sent to NTEL on 20 Jun 89 by the author having been collected together at Loughborough. The door closer assembly was finished on 27 Jun 89.

The prototype was herein called the 'concept 2000' since it was a new system based on NTEL's 2000 series door closers



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• 76 30 7/ NOWINAL 10 00 FOR NTYS . . 16 10 MOMINAL IO TON H7-36 45 8 5 IX45 WHOUTSIDE 45 NTLON WASHER NONUMAL NOR NT- ps (MESS ITT) 15 MONINAL FOR ATT APRESS FIT LOCATING PIN (MATL EN 33) 585 TO SLIDE FREELY W BORE 16 25 **31 80** 17 15 DE-TENTE CAM PISTON HOUSING ROLLER FOLLOWER INA STOLO (NOT WARN) 12 10 TOLERANCE UNLESS OTHERWISE STATED \$ 0.05 MM MATL STEEL EN LA UNLESS OTHERWISE STATED OIM MM DRAWN & BOWDEN DATE 9" MAY BY SCALE: Z I 1 TITLE DE-TENTE CAM PISTON ROLLOWER ARRANGEMENT

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The author then visited NTEL on 29 Jun 89 to test the door closer and generate a powercurve and efficiency characteristic. The door closer, being adjustable, has a maximum and minimum setting so two powercurves and efficiency characteristics are shown graphs 20 and 21 pages 202 and 203. These are discussed in more detail in the evaluation section.

Figure 6, page 204, shows a photograph of the prototype in position on the door while being tested.

5.19 COMPLETE CONCEPT PROTOTYPE PARTS LIST

DRAWING TITLE	DRAWING NUMBER	QUANTITY
End plug Regulator (General and	1986 162 75	l end plug + 2 seals
Latch)	23 009 00	2 Regulators + 2 seals
Piston (Operational		l Piston (opened out
Sequence)	25 002 03	to 30.7 as shown in
		layout)
Channel (as used for 2030	D	
series 460 mm)		1
Arm (350 roller centre to	o	
piston shaft centre)		1

NTEL PARTS CANNIBALISED





a s main

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Fig.6 Prototype testing at NTEL

STANDARD PARTS

PART	COMPANY	ORDER NO	QUANTITY
Halical Compression	CDEC Agenciated		
	SPEC ASSociated	D12920	,
Spring	Spring	D13820	Ţ
Die Spring	SPEC Associated		
	Spring	St52680	1
Seals (pinion/cam shaft) Simrit	16246 Bl	2
Drawn Cup Needle	INA	HK1612	2
Roller Bearings			
Roller Follower	INA	ST010	1
Ό'ring seal	Superior Seals	ID11	1
'O`ring seal	Superior Seals	ID38	1
Circlip (for "Screw" on	SPEC Associated		
preadjust)	Spring	N71120	1
CUSTOM PARTS			
DRG TITLE		DATE	QUANTITY
"Body"		23 05 80	1
"Douy"		16 05 80	- ,
"Pinion/Cam Shart"	10 03 89	1	
"Cam Profile"		08 05 89	-
"Detente cam piston folle	ower arrangement"	09 05 89	
Includes :- End plug			1
Slider			1
Screw			1
"Bearing Housing and bus	h" Includes :-	18 05 89	
Bearing hou	eina		1
	arng		-

NB : The bush is required because the outside diameter of the seal 1s greater than that of the bearing. So the order of assembly would be to fit the seal, then the bush and then the bearing to the bearing housing (or body).

5.20 THE DEVELOPMENT OF A SINGLE BORE SYSTEM

Because the concept prototype worked, that is generated the correct powercurve characteristic while maintaining a high efficiency, further measures had to be taken to establish how viable the product was. Dave Yates asked that a single bore system be developed, or at least some ideas be generated for reducing the foot print size of the unit. The large foot print of the concept prototype was expected, as discussed in section 5.1 'Prototype Development'. Prior to the concept being proven it is not worth developing or optimising the constituent parts but rather maximising the use of existing parts to reduce cost and time.

A single bore system was developed and a scaled layout drawing sent to Dave Yates at NTEL prior to the final meeting at NTEL on the 20 Sep 89. The single bore system was based exactly on the proven concept prototype except that the detente cam and rack and pinion systems were combined. This was an unengineered layout and although realistic, it was expected that the engineering be carried out by NTEL engineers in terms of optimisation. The concept was drawn as a Layout, including a parts list, enabling a comparison to be drawn, in terms of necessary parts, between this and NTEL's internal solutions to the same door closer problem.

Quite obviously a single bore system massively reduces the size of the foot print but a lot more of the parts become peculiar to the individual product rather than standard. Springs, for example, require designing to fit, perhaps the pinion tooth pattern, piston etc. Machining becomes more complex because of
off centre bores which enable one mechanism centre to slide past another, although the design does still allow for grinding on centres which is necessary to produce the high tolerances required for the sliding members.

The "Single-Bore Concept Overhead Door Closer Parallel Arm Application (Unengineered)" drawing dated 28 Jul 89 is shown on page 208.

5.21 OVERHEAD DOOR CLOSER AESTHETICS

The aesthetic proposals fall into two categories, those for a single bore system and those for a double bore system (shown on pages 209 to 212). This was because the aesthetic development was run in parallel to the engineering development when either the single or double bore engineering solution could have been developed. The reason for this was that all too often the practical or performance criteria of a product are designed first and then a box designed to fit over the resulting 'functional' object. By interweaving the two the 'functional' object may be altered or rearranged in some way that vastly improves the potential aesthetic of the product with no detrimental effect on performance, resulting in a better product.

Referring to section 3.3 'Factors Influencing Architects' Choice of Door Closers' and 3.6B 'Discussion of Door Closer Aesthetics' a 'check list' of desirable visual features from which aesthetic proposals may be generated has been given, a method of combatting the subjectivity problem associated with aesthetics. Beyond this the proposals are self explanatory offering NTEL some options to the aesthetic system currently used. These range from being an obvious progression to the existing aesthetic, or to proposals which are quite different.











The aesthetic is achieved in all cases by an injection moulded or high pressure formed cover fitting over the body casting. In all cases the cover is a two part moulding. The channel section is achieved using a purpose built extrusion profile with injection moulded end plugs. All the covers enable the door closer body casting to fit either way round to suit different fitting applications.

6.1 EVALUATION

Concept 2000 Prototype

The evaluation of the door closer is carried out directly against those sections outlined in the Product Design Specification. See Appendix 1 page 229.

Two points must be remembered, firstly, the door closer is a prototype so some of the factors required by the BS, for example those concerning endurance testing, are unrealistic to test at this stage, due to time and because such testing is aimed at production products not prototypes. The concept was developed to a single bore system which is more desirable in terms of viable mass production. In terms of performance, and from an analysis point of view, it is assumed that the single bore system would be identical although smaller.

1 Performance

- 1.1 The door closer complies with BS 6459 regarding the categorisation of power. The door closer built satisfies the size 3 rating, but being adjustable, would be equally applicable to the range of BS power sizings.
- 1.2 The door closer conforms to BS 6459 performance requirements in the following:-
 - (a) Variable power, although considered of secondary importance in the PDS, is included since specifiers consider it important. Door closers can be adjusted on site to suit the application rather than being specified for each separate application.

A preadjust is shown in the single bore concept drawing which adjusts each of the two springs independently, yet in the same bore.

- (b) Closing times.
- (c) Closing moment.
- (d) Efficiency, which is higher than necessary, but lower tolerances in bearings, seals and between bore and piston, which are inclined to be over specified in a prototype, would obviously be reduced in production to save costs in production.
- (e) Latching action, ie the high torque at latching, is where the concept excels. Because the latching action is the result of the detente die spring, which is separate from the closing action, ie the rack and pinion/helical compression spring, it may be adjusted independently. Likewise the closing torque can be adjusted separately so the resulting torque characteristic can be variable.
- (f) Back check resistance, again regarded in the PDS as being of secondary importance, is not included presently. By simply increasing the cam radius at the appropriate point on the dwell it may be facilitated.
- (g) Fluid leakage during the endurance tests was not evident. At the end of the testing there should be no leakage around external seals which could damage door furniture Similarly there should be no leakage between the pistons and bores which would affect the closing speed adjustment. Although such endurance testing couldn't be conducted in the time to see the effects of wear on fluid leakage it stands to reason that if the piston/bore and seals currently used in NTEL products suffice then they will in this.

- (h) Damage is concerned with the fracture of any of the door closer parts during the testing, including in the door impact test and by fatigue in the endurance tests. Fixings should also be secure. The same applies here as for (g) above. Although testing wasn't carried out present NTEL door closers satisfy this requirement so it is safe to assume this will, not being significantly different. It is, however, an area where engineering optimisation is needed and testing required, because some components are specific to this concept such as the pinion shaft, so not yet tested. This is only really worthwhile at the mass production stage.
- 1.3 Marking a door closer for identification according to BS 6459 is again only concerned with the final production run.
- 1.4 The prototype is a class C, as required, which means the door on which it is mounted could open to greater than 175° and the door closer can close, and control, the door from a minimum of 115° down to the closed position. It does, in fact, control from the fully open position.
- 1.5 The door closers torque characteristic is of the shape described in the PDS, which indicates that the solution in terms of engineering is viable. Referring to Graph 22, page 217, and the graphs in section 5.18 page 201, it can be seen that in both the maximum and minimum settings the characteristics from approximately 35° upwards are the same, which is similar to that of the predicted powercurve, perhaps some 35% stronger. The part of the characteristic which is significantly different is the latch to 35° position which is due primarily to the detante/die spring mechanism. This must be because the die spring was stronger than specified or, and this is most likely, the die spring preload was too high. Other more general errors can only be due to :--



2. -1

(i) The over specification of parts for the prototype, a factor which would be reduced as the unit is further developed for mass production where purpose built components are used.

(ii) Errors in assessing the mechanical advantage of the system. The system is stronger, geometrically, than first assumed.

Such discrepancies are to be expected in the first prototype and would be ironed out in further generations as the product is developed to mass production.

The absolute torque values are high compared to BS 6459 requirements. This is mostly the result of the design powercurve which was used as a basis for designing the unit as described in section 5.2 "Generation of a 'Design' Powercurve". On no account should the characteristics go below the BS requirements so that the unit be seen to fail, despite the characteristic being the correct shape.

- 1.6 The damage occuring to the door by the door closer is minimal, ie only that associated with fixing, which is acceptable, so it doesn't compromise the fire resisting door standards or BS
- 1.7 The magnitude of the noise levels of the door closer in operation is the same as that already existing in NTEL's door closers and therefore acceptable. It was possible that disc springs, were they to be used, may give off undue noise which could be detrimental to perceived quality and so sales.
- 1.8 When in situ there is no part of the door closer which projects when the door is closed which minimises the opportunities for vandalism or misuse.

Environment

- 2.1 The door closer would withstand a drop of 7 feet without suffering any subsequent loss of performance, although the casing would be damaged which is acceptable.
- 2.2 The door closer was not, as a prototype, tested to see if it was able to withstand abuse subject to the BS requirements of abuse testing, in reaching its maximum throw (or backcheck were it incorporated). Present NTEL door closers satisfy this requirement so it is also assumed this would once developed to a finished product.
- 2.3 The materials used would :-
 - (a) withstand prolonged exposure to damp_
 - (b) withstand the above in conjunction with cleaning by normal household cleaners
 - (c) resist attack by atmospheric pollution existing in industrial locations
 - (d) exhibit no adverse reaction to long exposure to sunlight such as ultraviolet degradation leading to discolorations, cracking etc.

- all without corrosion, loss of performance or shortening of the product life.

- 2.4 It is assumed, again because NTEL's existing products would satisfy this criteria, that when the door closer is stored or in position subject to a temperature range of -20° to 40° that no creep, detrimental to performance or product life, would occur.
- 2.5 Differential expansion should not be a problem over the above temperature range when in use, although there was no direct testing of compliance with this factor, ie, tolerances are large enough for no jamming to occur, no cracking, freezing and other temperature associated problems. This factor was introduced because of the potential marketing of the product in countries as far apart climatically as Norway and Spain.

Maintenance

3.1 The door closer is designed to need no maintenance other than annual oiling and tightening of fixings.

Size and Weight

4.1 The size, or footprint, of the <u>single bore system</u> is only slightly larger than that of the existing NTEL product. Its weight, therefore, would be comparable due to the use of similar materials. It would be easily handled for installation.

Aesthetics, Appearance and Finish

5.1 For the purpose of the evaluation the single bore visual concept page 209 should be referred to.

The visual proposal successfully incorporates the following factors indicated in previous sections to be desirable. (3.3, 3.6B and 5.21).

- (a) Consistency, by using similar edge radii, shapes, colour and materials on the various constituent parts. This helps the viewer see the door closer as a single, complete product, not as a collection of parts; channel, arm and body.
- (b) Visually blending the channel, arm and body together. Running lines and shapes through all the parts makes the result look more 'product' like and less an engineering solution.
- (c) Care has been taken not to design the product in orthographic elevations which often leads to a square looking product. Instead the product has been designed in the view it would most commonly be seen, ie, the interplay of the front, sides and underneath have been carefully considered
- (d) The visual size of the product has been <u>reduced</u> by utilising lines within the product. These come, not only from natural breaks in the product between channel, arm and body but also in -

(i) the relief in the body face giving horizontal lines and the sides almost vertical lines This reduces the visual height of the product and, in the case of the sides, the distance it appears to be from its mounting surface.

(i1) the use of matt finishes on upwardly facing surfaces, a more subtle way of introducing lines, although primarily to disguise dust.

- (e) By varying the colours of the parts, the lighter colours stand out distracting the viewer from the dark parts Seeing only the lighter part the viewer perceives the product to be smaller
- (f) Using the logo to balance visually heavy areas as well as giving a focus of detail, interest and asymmetry.
- (g) The proposal creates interest in what has mostly been a visually uninteresting product area. Unobtrusive does not mean uninteresting and with the correct colour for its location greater unobtrusiveness can be achieved while remaining interesting and original, certainly different from the existing door closers and certainly more desirable.

The cost of the cover and extrusion profile, in terms of tooling, is large, however, NTEL's current product is considerably cheaper than its two competitors, Dorma and Geze. This difference gives NTEL room to absorb the tooling costs in the 'new' product price and still remain competitive. The author believes this to be a wholly justifiable expense and, in the long run, lead to improved product sales.

Because the mechanism is adjustable the same body may be used for different sizing applications, so the problems of a family resemblance, or lack of consistency throughout a building, would not occur. Use of plastics, such as perspex, for the body means that a full range of colours compatible with office furniture and general building interiors is immediately available. Plastics also lend themselves to invisible/snap fixings which, in the analysis of existing door closers, the author felt would be an area for improvement. Fixings are usually hidden or covered in most domestic and public products from computers to kettles In that the aesthatic objectives have been realised in the proposal, the evaluation can only conclude that it must be successful. Beyond this the analysis becomes one of personal preference. Dave Yates of NTEL was pleased with the proposal offered giving an alternative to NTEL's present aesthetic, perhaps a second yardstick by which to judge the success of the aesthetics.

Materials

6.1 The PDS requires that the materials used in the prototype should be conducive to generating a manufacturable design. All the materials used are identical to those NTEL use presently, so one may assume that this factor is fulfilled.

Standards and Specifications

7.1 All necessary BS and other standards are satisfied with particular reference to performance or the requirements for closers used on fire resisting doors. The only exception being endurance testing not applicable to the prototype.

Ergonomics

8.1 The door closer, when in position, in no way obstructs or creates a hazard, or potential hazard, to the door user Being surface mounted it offers no ergonomic installation problems. It is proposed that a template be used, supplied in the packaging, to make the installer's task easy and trouble free.

Testing

9.1 Prototype tests were carried out as and when necessary (not BS tests at this stage). Such as to generate the powercurve and efficiency characteristics.

7 CONCLUSION

The evaluation fully assesses the door closer in terms of the Product Design Specification against which it was designed. The prototype proved that the concept was viable achieving the desired characteristic shape with a suitably high efficiency. The visual proposals suggested an aesthetic suitable for the 'top-of-the-range' product. The project can therefore be seen as a success.

8 FURTHER WORK

Further work is required in terms of development. The engineering requires optimisation for manufacture The injection moulded cover and extruded channel profile require rationalising and detailing. All these requirements are well within Newman Tonks Engineering Ltd capabilities should they wish to pursue the project. In the author's capacity as a Design Consultant this is how far the author can sensibly take the project before his skills are duplicated, so it is a suitable point for the author to finish and hand the project over to Newman Tonks Engineering Ltd.

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TRADE LITERATURE

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INA Rolling Bearings 305 (1989). INA Bearing Company Ltd.

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Simrit Catalog No 100 Simmerring Radial Shaft Seals (1989). Freudenberg Simrit Ltd.

SPEC Springs and Spring Washers Straight From Stock (1988). Associated Spring.

APPENDICES

1	Draft 2:27/10/88 'Product Design Specification : Door Closer.
2	List of Door Closer Manufacturers Included in Trade literature search.
3	Standard Letter - Literature Search. 3/11/88.
4	Briton 2030 Non Projecting Sliding Arm Serles October 1988 Ref A-12-3.
5	Dorma TS 93 Cam action overhead door closers with slide arm assembly (Please refer to the author's copy)
6	Geze Brochure Exhibitions 1988. TS 5000 TS 5500. (Please refer to the author's copy).
7	Gibcloser Automatic Door Closers. Closes doors automatically in the home, office and industry. (Please refer to the author's copy).
8	Chasmood Hinge Systems. 1988. (Please refer to the author's copy).

9 Determination of the coefficient of friction for Aluminium on Steel

PRODUCT DESIGN SPECIFICATION : DOOR CLOSER

DRAFT 2:27/10/88

1 PERFORMANCE

- 1.1 The door closer should comply with the appropriate British Standard (BS 6459) regarding the categorisation of power and class.
- 1.2 The door closer should conform (where applicable) to the following performance requirements of BS 6459 regarding :-
 - (a) Allowance for variable power (secondary importance; need not necessarily be one device.
 - (b) Closing times.
 - (c) Closing moment.
 - (d) Efficiency.
 - (e) Latching action.
 - (f) Back-check resistance (secondary importance).
 - (g) Fluid leakage.
 - (h) Damage.
- 1.3 The door closer should be marked for identification according to BS 6459.
- 1.4 The door should be class C as defined in BS 6459.
- 1.5 The door closers torque characteristic should, as far as possible, be as in Fig 1.
- 1.6 No damage to the door should be made by the door closer in use other than that associated with the attachment/fixing of the door closer to the door and frame and this should be minimal.
- 1.7 The magnitude of the noise levels of the door closer in operation should be comparable to already existing door closers.
- 1.8 When in situ there should be no part of the design of the door closer that projects, with the door closed, so minimising the opportunities for vandalism and misuse eg, projecting arms and other projecting parts.

2 ENVIRONMENT

2.1 The door closer should withstand a drop of 7 feet without suffering any subsequent loss of performance. ie, surface damage such as scratches, small dents etc are acceptable but misalignment of parts, buckling, fracture of parts etc is not.



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- 2.2 The door closer should be able to withstand abuse subject to the requirements of the abuse testing both in closing and in reaching its back-check (secondary importance) or maximum "throw" without detrimental effect on performance ie, it should withstand foreseeable abuse.
- 2.3 The materials used should -
 - (a) Withstand prolonged exposure to damp.
 - (b) With stand the above in conjunction with cleaning my normal household cleaners.
 - (c) Resist attach by atmospheric pollution existing in industrial locations.
 - (d) Exhibit no adverse reaction to long exposure to sunlight such as ultraviolet degradation leading to discolouration, cracking etc.
- 2.4 The door closer when stored or in position should withstand the temperature range of -20 to 40 degrees centigrade without undergoing any amount of creep detrimental to performance or product life (secondary importance).
- 2.5 The design of the door closer and materials used must be such that differential expansion is not a problem over the above temperature range when in use.

3 MAINTENANCE

3.1 The door closer should only require minimal maintenance other than annual oiling and the tightening of the door closers fixings/method of attachment to the door.

4 SIZE AND WEIGHT

- 4.1 The size and weight should be kept to a reasonable minimum for easy handling of the product in both the manufacture and in the installation by the user.
- 5 AESTHETICS, APPEARANCE AND FINISH
- 5.1 Aesthetics, appearance and finish should be such that the feeling of quality already associated with Newman Tonks Engineering Ltd's products is maintained or promoted.

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6 MATERIALS

6.1 The materials specified in the concepts/prototypes should be such that they would be conducive to generating a manufacturable design.

7 STANDARDS AND SPECIFICATIONS

- 7.1 The door closer should comply with BS regarding :-
 - (a) Performance (as stated in section 1 above)
 - (b) The requirements for closers used on fire resisting doors (ie, the fitting of the door closer to the door should not significantly reduce the door's fire resistance).

8 ERGONOMICS

8.1 The door closer, when in position, should in no way obstruct or in any way create a hazard or potential hazard to the door user.

9 TESTING

9.1 Prototype tests will be carried out as and when necessary (not BS tests at this stage).

THE FOLLOWING IS A COMPLETE LIST OF THE COMPANIES INCLUDED IN THE TRADE LITERATURE SEARCH. THE LETTER 'R' IN BRACKETS AFTER THE COMPANY ADDRESS INDICATES THAT INFORMATION WAS RETURNED.

AMERICA

Schlage Lock Co 2401 Bayshore Boulevard, San Fransisco, California, USA (Part of Ingersoll-Rand Door Hardware, Mississauga, Ontario LSE-1E4). (R)

AUSTRIA

Grundmann Ges m/b/H., Gebr., A-3130 Herzogenburg.

BELGIUM

Metalchimex SA-NV Ruse de Houtain 31, B-4296 Grand-Hallet.

CZECHOSLOVAKIA

Merkuria, Argentinska 38, CS-17005 Praha-7.

FINLAND

Oy Wortsila, Box 230, SF-00101 Helsinki-10

Saajos Ky, J Puistokatu 17-21, SF-08150 Lohja-15

FRANCE

Fontaine SA, 181 rue Saint-Honorè, F-75001 Paris

Liob SA BP 33, F-69650 Saint-Germain-au-Mont -d'Or.

Maloigne & Cie S.A R.L., G.,6, rue de la Rèpublique, F-80210 Feuquières-en-Vimeu.

GERMANY, FEDERAL REPUBLIC OF

Ahrent, Wolfgang, Kehrwieder 16, D-2000, Hamburg-Schenefeld.

BKS GmbH, Postfach 100210, D-5620 Velbert-1. (R).

Bremicker Söhne KG, August, Postfach 210/220, D-5802 Wetter-2, Volmarstein. Brennenstuhl GmbH & Co, KG, Hugo, Seestr. 1-3, D-7400 Tubingen-9, Pfrondorf Dannert, Fritz, Postfach 4046, D-5828 Ennepetal-14.

Dictator-Technil Berlin, K.u.J. Stech GmbH, Postfach 360427, D-1000 Berlin-36. (R) Dictator-Technik Ruef & Co., Gutenbergstr. 9, D-8902 Neusa B-1. Dorma GmbH & Co KG, Postfach 4009, D-5828. Ennepetal-14. (R)

Dowaldwerke, Postfach 106123, D-2800 Bremen-1. Gartner GmbH & Co KG., Josef, Postfach 40, D-8883 Gundelfingen (R) Geze GmbH & Co, Postfach 1363, D-7250 Leonberg. Ischebeck, Karl, Postfach 33, D-5828 Ennepetal-14, Voerde Wiemann & Co., Herm., Mühlenstr. 39, D-5820 Gevelsberg. Zimmermann GmbH, Am Gilligert 14, D-7632 Friesenheim - Heiligenzell.

GREAT BRITAIN AND NORTHERN IRELAND

Aardee Spring & Lock Co Ltd, 36 Clyde Place, Glasgow, G5 8AN (R) Adams James & Son Ltd, 26 Blackfriars Road, London, SEl 8NY. Adrenalin Co., Unit 3, Nefyn Ind Est, Pwellheli, North Wales, LL53 6EG (R) Appleton Jack (Willenhall) Ltd., Meadowdale Wks, Dimminsdale, Willenhall, W. Midlands, WV13 2BE (R)

Avenue Spring Co (Metal Workers) Ltd., 58 Southgate Road, London, Nl 3JG Boyd (George) & Co Ltd., 300 Crownpoint Road, Glasgow, G40 2UP.

Buck & Hickman Ltd., Bank House, 100 Queen Street, Sheffield, Sl 2DW. (R) Budden (Thomas) Ltd., Unit 14 Works, Manford Ind. Estate, Manor Road 5 7JH Erith DA8 2AJ.

Chasmood, Patgro Ho., Middleton Estate, GB-Guildford, Surrey, GU2 5XR. (R)

GKN Crompton Ltd, Gerard Street, Ashton-in-Makerfield, Wigan, Lancs, WN4 9AN. (R)

Dictator (UK) Ltd, Sherborne Works, 141 Sherborne Street, Ladywood, Birmingham, B16 8DA.

Door Controls Ltd, 19/21 The Broadway, Herne Bay, CT6 8LG.

Door Spring Supplies Co, 1-2 Adams Yard North, Finedon Road, Wellingborough, Northants, NN8 4EB. Dorma Door Control Ltd, Dorma Trading Park, Staffa Road, London, E10 7PU Dryad Simplan Ltd, Frog Island, Leicester, LE3 5DP (R). Forson Design & Engineering Co Ltd, Commerce Way, Lancing, W Sussex, BN15 8TQ. (R) Gibbons (James) Format Ltd, Coliery Road, GB-Wolverhampton, WV1 2QW. (R). Groom, G.W. 420 Kingsland Road, London, E8 4AA. Group Sales Ltd, 18 Tresham Road, Orton Southgate, Peterborough, PE2 OSG. (R). Heath & Sons, plc, Samuel, Cobden Wks, Leopold Street, Birmingham, B12 OUJ. Holmes Brothers (Lytham) Ltd, Freckleton Street, Lytham Sy Annes, Lancs, FY8 5DY. Industrial Devices Ltd, 309 West End La, London, NW6 1RG (R) Jebron Ltd, Wednesbury, West Midlands, WS10 9HY (R). W&R Leggott Ltd, Silens Works, East Parade, Bradford, BD1 5HA MacKinnon & Bailey, 72 Floodgate Street, Birmingham, B5 5SJ (R) Magnet Joinery Sales Ltd, Royd Ings Avenue, Keighley, West Yorkshire, BD21 4BY. New Defiant Products Ltd, 23-41 Northwood Street, Birmingham, B3 ITX (R) New Defiant Products Ltd, Nairn Road, Deans Ind Estate, Livingston, West Lothian, EH54 8AL. (R) Parkes (Josiah) & Sons Ltd, Union Worksm Gower Street, Willenhall, WV13 1JX. (R) Perkins & Powell, Cobden Works, Leopold Street, Birmingham, B12 OUJ. PLC Peters Ltd, Pasadena Close, Hayes, Middleton, UB3 3NS. Peters-Bradbury, Springwood Industrial Estate, Rain Road, Braintree, CM7 7ET. Reiler Ltd, Blackpool Road, Preston, PR2 2DN (R). SAL (UK) Ltd, PO Box 312, London, SE3 7TS Skeldings Ltd, 126 Oldbury Road, Smethwick, Worley, West Midlands, B66 1JB. Slingsby plc, HC., Preston Street, Bradford, West Yorkshire, BD7 1JF (R) Stokes Adrian (Overseas) Ltd, 39-42 Burnt Mill, Harlow, CM20 2HZ. Titon Hardware Ltd., International House, Peartree Road, Stanway, Colchester, CO3 5JX. WET Engineering Co Ltd, 23 Northwood Street, Hockley, Birmingham, B3 1TX. Worcester Parsons Ltd, Lifford Lane, Kings Norton, Birmingham, B30 3JR.

Yale Security Products Ltd, Wood Street, Willenhall, WV13 1LAS.

HUNGARY

Ferunion, PO Box 612, H-1051 Budapest (R) Finomszerelvenyguar, Postfach 2, H-3301 Eger. Mogurt, Postfach 249, H-1391 Budapest.

ITALY

C.I.S.A. SpA, C.P.170, I-8018 Faenza (RA) Industrial Briantea Ferramenta c Minuterie, S.a.s. Marco, Via Don G Verita, 5, I-20052 Monza (M1) Marchesi & C., A, Viale Val Rendena, 93, I-38079 Tione di Trento (TN)

<u>JAPAN</u>

Chikura Kogyo, Kabushukikaisha, 38-5 Chidoriz-Chome, Ota-ku, Tokyo-to. Santo Industries Co Ltd. 23-24 Furvichi 3-Chome, Koto-ku, Osaka.

NETHERLANDS

Ankerslot BV, Postbus 521, NL-7550 AM Hengelo (Ov) Dictator Productie BV, PO Box 57, NL-8300 AB Emmeloord. (R) Etrometa BV Postbus 132, NL-8400 AC Gorredijk (R) Kramahan BV, Postbus 212, NL-3702 AR Zeist. (R)

PORTUGAL

Hipólito, S.A.R.L. Rua Serpa Pinto, P-2651 Torres Vedras-Códex.

<u>SPAIN</u>

Cubells, Camino del Rochs, 6Z, E-46013 Valencia Jardi, S A Sardana, 7, E-08150 Parets del Vallés, Barcelona. Trepat, La Llacuna, 105, E-08018 Barcelona. (R)

SWEDEN

de Jong Ltd., A.M. Box 506, 5-16215 Vällingby

SWITZERLAND

Mechanik-Norm, Postfach, CH-8036 Zurich.

Mewo A.G Bahnhofstr. 18, CH-8832, Wallerau (SZ) (R)

Schmidt A.G., C. Eugen, Postfach, CH-8033 Zurich.

TAIWAN

Ching Ho Shi, No 31 Fan She St., Ilan, Fan She Tseng, Fu Shin Hsiang, Chang Hua Hsien.

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DEPARTMENT OF DESIGN AND TECHNOLOGY

Professor K.W. Brittan

N.G.R.Bowden. Ext.2664. 3/11/88

Dear Sir,

I am a research assistant working for Loughborough University of Technology and I am conducting a review of door closers with particular reference to the principle of their operation (eg. rack and pinion, torsion springs etc.); the torque characteristic of the door closer; and the measures taken to meet the efficiency requirements of British Standard 6459 or an equivalent standard.

The sort of door closer that I am reviewing should not be an integral part of the door but rather one which would fasten to the door.

Please send me any information available on your current product range.

Many thanks for your cooperation in this matter.

Yours faithfully,



on 2030 Non Projecting Sliding Arm Series

ption

n 2030 sliding arm series are n 2030 sliding arm series are ured to give a slimline door closer of ally pleasing design. This single action hounted rack and pinion door closer aulic check and adjustable latch action ra single arm to close the door. e arm being unobtrusive there is a risk of vandalism. As an option the 30 can also be supplied with ck. ries provides a cushioning effect when is forcibly thrown open but-does not a substitute for a door stop).

ction 30 series door closers are constructed ast L.M.9 aluminium body, steel rack on (heat treated and ground) with needle roller bearings, extruded n channel and nylatron roller.

30 series door closer covers are sprayed silver, gold or brown bronze Steel covers are zinc coated steel for n against rust. Alternative covers and polished brass, imitation bronze, satin d stainless steel. Briton 2030 series are lable in a range of colours to match the Tonks Hardware's Normbau range. rm and channel are sprayed black.

mance

nended door size and weight limitations al doors

ze	Max. Door	Max. Doo
28.1	Width	Weight
32	830mm	45Kg
33	930mm	60Kg
34	1070mm	80Kg

g (or ball bearing) butt hinges will ensure closer performance.

ity

on 2030 series is manufactured to standards that have earned Briton door a worldwide reputation for quality and

Adjustments

All closers in the series incorporate two basic regulators:

- Door Speed-to control general speed 1 of closing.
 - Latch Action-to accelerate door in final stages of the closing cycle to overcome stubborn latch bolts.
- Back-check (Briton 2530) provides retardment to the opening swing of the door over a wide range of the opening angle and can be turned off if not required.

Concealed Controls

Briton controls are concealed. This is a requirement being insisted upon by fire officers the world over. A door closer is an important link in the control of fire and smoke and could help save lives. It is therefore important that its efficiency is not reduced by unauthorised adjustment.

Additional Safeguard

Briton regulating screws are retained in position and cannot be removed either accidentally or by vandals

Coil Strengths

Experts have calculated the coil spring specifications so successfuly that we have as yet to hear of a breakage in the field.

Rack and Pinion

A special design feature of the mechanisms is that the rack is cut out to take the pinion giving two important advantages over most arrangements:

- 1. The overall projection of the closer is considerably reduced.
- 2. The pinion rotates on the centre line of the piston, a geometrically perfect action giving less wear

Applications

Fixing

Briton 2030 series can be surface mounted in three alternative applications, ie Door Mounted (pull side) Transom Mounted (pull or push side) Detailed instructions supplied with each closer.

Stand Open

Briton 345 friction stand open device is available on Briton 2032/3/4 door mounted pull side closers

Handing

Closers are self handing

Angle of Opening 110° max.

A door stop should always be used to prevent door opening beyond the limit of the closer.

Maintenance

All internal working parts of the Briton 2030 series are completely immersed in oil to ensure long working life of closer.

When used as part of a fire precaution system, check correct functioning of unit during the periodic fire test procedures, check quarterly to ensure correct setting of door closing and latching speeds and that fixing screws are tight. A small quantity of light machine oil applied to the roller and door hinges will maintain optimum performance

Guarantee

A 10 year guarantee with a free replacement exworks of any closer proved defective by reason either of faulty manufacture or defect in material.

Supply and Quotations

Available through architectural ironmongers and builders merchants.

Technical Services

Newman Tonks Engineering Ltd have technical consultants covering all areas throughout the U.K.







Door Mounted (pull side)







Transom Mounted (push side)







The products shown herein are designed for use on doors in normal building construction. Where a customer wishes to use the products for special applications outside the criteria mentioned, reference should be made to the manufacturer to enable him to make recommendations which the buyer should follow in the interests of development and policy of continued improvement the manufacturers reserve the right to change the specification in this brochure without notice.

Briton door controls are manufactured under a stringent quality control system monitored by the British Standards Institution



2 on estable
THE DETERMINATION OF THE CO-EFFICIENT OF FRICTION FOR ALUMINIUM ON STEEL

Determination by experiment was considered the most effective and accurate method to find the coefficient of friction for aluminium on steel \neg the bore and piston materials respectively.

A steel marking block, the finish of which compared to that of the piston, was used as a slope and various finishes of aluminium block were placed on it. The tangent to the angles at which they began to slide is the coefficient of friction. The highest values were obtained for 'as bought' aluminium, although many types were tested.

Tan U = M where U = 20.75 (the worst case)

so /L = 0.3789

By choosing $\mathcal{M} = .4$ a safety factor is introduced because the bore surface would be better than that of the 'as bought' aluminium, and the system_would_be_fully_lubricated.__Once_the_piston_begins_to-move______ in the bore, and not before, a fluid bearing is generated where oil passes between the piston and bore. The friction at this time becomes that of the shear strength, or viscosity, of the oil itself, which is minimal. • -• •