APPENDIX 1

(referred to in paragraph 2.3)

BTR: Principal products

Conveyor Belting	Natural or synthetic rubber and PVC belting. Textile or steelcored reinforcement. White food and special profile belting. Technical, installation, maintenance and repair services.
Industrial Hose	Mandrel built and continuous moulded hose. Wire braided, spiral, multi-spiral and textile reinforced for hydraulic and pneumatic applications. Large bore specialist hose. Reinforced PVC hose.
Engineering	Design, fabrication and erection of pipework, tanks, non-coded vessels, castings and valves. Exotic metal fabrication. Fabrication and hook-up of offshore rig modules and full back-up maintenance and repair service to offshore industry. Marine piping heating/cooling systems. Surface treatment equipment. Ball valves and actuators.
Reinforced Plastics	Custom manufactured sheet or dough moulded GRP components. Foam reservoir moulded and pultruded continuous profile products for industrial markets. Standard range of meter boxes, sectional storage tanks and water cisterns.
Aerospace Products	PTFE, rubber and Metalflex hose assemblies. Rigid pipe assemblies and fluid filters. Electrical harnesses, magnetic chip detectors, metallic seals. De-icer assemblies.
Hydraulic Equipment	Wire, nylon, textile reinforced and PTFE hydraulic hose, fittings and assemblies. Swaging equipment. Rigid tube assemblies. Worldwide distribution service.
Automotive Components	Moulded rubber and rubber-to-metal bonded products. Rubber extrusions including weatherstrips. Flock coated weatherseals. Polyurethane bumpers. Car carpets. Press and vacuum moulded rubber matting.
General Rubber Products	Inflatables, respirators and structural gasketing. Specialised footwear, stereo rubber, typewriter platens, escalator handrails. Anti-vibration mountings, bridge bearings. Segmental bearings. General and precision mouldings. Pipe seals, gas leakage control kits, diaphragms. Air sea rescue equipment.
Medical Products	Rubber anaesthetic tubes, haemodialysis blood lines, blood pressure bags and veterinary sundries. Processed plastic extra corporeal sets, syringe fillers, tubing lengths, catheter packs, aerosol and dip tubing, flame retardant ducting.
Paper/Textile Products	Elastomeric and plastic roll coverings for pressing, drying and carrying. Rolls for spreading webs, automatic web handling equipment, weft straighteners and guiding and tension control systems. Forming fabric.
Anti-corrosion	Specialist corrosion-proof lining service for pipework, fittings and vessels. Fluoroline KF coatings, solid PV2 pipe. PFA lined centrifugal pumps and KF lined diaphragm valves. PTFE chemical transfer hose and flexible joints.
Consumer	Squash balls and equipment. Kitchen utensils. Wet suits, lifejackets and showerproof clothing. Airbeds. Swimming pools. Camping and garden equipment. Hot water bottles. Artificial ski slopes and synthetic surfaces for a variety of sports.

Source: BTR Publication 'The Anatomy of Growth'

APPENDIX 2

(referred to in paragraph 2.10)

BTR: Principal acquisitions in the period 1971–80

Year	*Company*	*Country*	*Product Range*	*'Contiguity' Features*
1971	Miles Redfern	United Kingdom	Rubber and rubber-to-metal, automotive carpets	Processes, products and markets
1972	Fatati SA	Switzerland	Automotive carpets	Processes, products and markets
	Charlton Leslie Engineering	United Kingdom	Contract engineering, conveyor belting	Products and North Sea new market opportunity
1973	Hopkins Odlum	Australia	Mouldings, extrusions and engineering	Processes and products
1974	Peter-BTR Gummiwerke AG	W Germany	Conveyor belting, mouldings and extrusions	Processes and products
1975	Permali	United Kingdom	Reinforced plastics, laminates and mouldings	Technology and processes
	Lonstroff AG	Switzerland	Mouldings and extrusions	Technology and processes
1976	SW Industries Inc	USA	Rolls, rubber and rubber-to-metal	Technology, processes and markets
1977	Andre Silentbloc	United Kingdom	Rubber, rubber-to-metal, metal	Processes and markets
1978	Allied Polymer	United Kingdom	Rubber and plastic mouldings and extrusions	All
	Worcester Controls	USA/United Kingdom	Engineering, components in fluid control ball valves and actuators	Markets and applications processes
	Kencord Holdings	Australia	Automotive carpets	Technology, processes and markets
1979	Campbell & Isherwood	United Kingdom	Contracting, electrical	Markets, contracting service
1980	Adamas Carbide Corporation	USA	Carbide tipped tools	Markets
	Huyck Corporation	USA	Paper machine clothing	Markets
	Gummi A/S K Lund	Norway	Rubber products distribution	Products
	Gummiwerke Becker	W Germany	Rolls, rubber and rubber-to-metal	Technology, processes and markets

Source: BTR

APPENDIX 3

(referred to in paragraph 2.17)

BTR: Principal subsidiaries and associated companies

(percentages, where shown, indicate size of BTR holding)

Country of incorporation	*Name*		*Main activity*
United Kingdom:	Andre Rubber Co Ltd		Bonded mouldings
	Beaufort Air-Sea Equipment Ltd		Safety equipment
	BTR Belting Ltd		Belting
	BTR Fatati Ltd	(80%)	Automotive carpets
	BTR Hose Ltd		Hose
	BTR-Permali RP Ltd		Reinforced plastics
	BTR Silvertown Ltd		Polymeric fabrications
	Campbell & Isherwood Ltd		Electrical contracting
	Charlton Leslie Engineering Ltd		Engineering
	Charlton Leslie Offshore Ltd		Oil industry fabrications
	Concargo Ltd	(83%)	Insulated containers
	Cow Industrial Polymers Ltd		Mouldings and extrusions
	Cow Proofing Ltd		Graphic arts
	Gandy Belting Ltd		Belting
	Greengate Industrial Polymers Ltd		Hose and mouldings
	Greengate Polymer Coatings Ltd		Coated fabrics
	Hertfordshire Polymer Products Ltd		Mouldings and extrusions
	Hi-Flex International Ltd		Hydraulic components
	Huyck Ltd		Paper machine clothing
	Leyland & Birmingham Rubber Co Ltd		Mouldings and extrusions
	Leyland Medical International Ltd		Medical products
	London Artid Plastics Ltd		Mouldings and extrusions
	Malone Precision Tool Co Ltd		Toolmakers
	Miles Redfern Ltd		Mouldings and extrusions
	Mount Hope Machinery Ltd		Web control devices
	Palmer Aero Products Ltd		Aerospace components
	Peradin Ltd		Bonded mouldings
	Permali Gloucester Ltd		Laminates and mouldings
	R Blackett Charlton Co Ltd		Metal fabrications
	Silentbloc Ltd		Bonded mouldings
	Stowe-Woodward BTR Ltd		Roll coverings
	Vacu-Blast Ltd		Surface treatment
	Worcester Controls (UK) Ltd		Ball valves and actuators
Austria:	Huyck Fez GmbH		Paper machine clothing
Denmark:	BTR Industries A/S		Hydraulic components
Finland:	Hi-Flex OY		Hydraulic components
France:	Worcester France sarl		Ball valves and actuators
Italy:	Huyck Italia SpA		Paper machine clothing
Norway:	Gummi A/SK Lund & Co	(60%)	Distribution
Sweden:	BTR Industries AB		Hydraulic components
Switzerland:	Fatati SA		Automotive carpets
	Lonstroff-BTR AG		Mouldings and extrusions
West Germany:	BTR Hi-Flex GmbH		Hydraulic components
	Gummiwerke Becker AG	(81%)	Roll coverings
	Peter-BTR Gummiwerke AG	(91%)	Belting, mouldings etc
	Worcester Armaturen GmbH		Ball valves and actuators
Argentine:	Huyck-Mati SAIyC		Paper machine clothing

Brazil:	Huyck do Brasil IeC Ltda		Paper machine clothing
	Permali do Brasil Ltda		Laminates
	Stowe Woodward Elastomeras Ltda		Roll coverings
Canada:	Canadian Worcester Controls Ltd		Ball valves and actuators
	Huyck Canada Ltd		Paper machine clothing
	Permali (Canada) Ltd		Laminates
	Stowe Woodward Co Ltd		Roll coverings
USA:	BTR Inc		Holding
	Adamas Carbide Corporation		Carbide tipped tools
	Hamilton Kent Manufacturing Co		Extrusions and mouldings
	Huyck Corporation		Paper machine clothing
	Mount Hope Machinery		Web control devices
	Permali Inc		Laminates and mouldings
	Stowe Woodward Co Inc		Roll coverings
	Vacu-Blast Corporation		Surface treatment
	Worcester Controls Corporation		Ball valves and actuators
Japan:	Huyck Japan KK		Paper machine clothing
Australia:	BTR Australia Ltd		Holding
	BTR Hopkins Ltd	(69%)	Holding
	Apex Belting Pty Ltd		Belting
	Beaufort Air-Sea Equipment Pty Ltd		Inflatables
	BTR Apex Pty Ltd		Hose
	BTR Industrial Products Pty Ltd		Hose and linings
	BTR Silentflo Pty Ltd		Exhaust equipment
	Empire Rubber (Australia) Pty Ltd		Mouldings and extrusions
	Fusion Engineering Pty Ltd		Metal fabrication
	Injectapak Pty Ltd		Mouldings
	Johnson Engineering Pty Ltd		Cryogenic vessels
	Pacific Piping and Equipment Pty Ltd		Metal fabrications
	Rubberflex Pty Ltd		Rubber products distributor
	Silentbloc/Legget Group		Bonded mouldings
	Kencord Holdings Ltd	(52%)	Automotive carpets
	Huyck Australia Pty Ltd		Paper machine clothing
South Africa:	BTR South Africa Ltd	(62%)	Holding
	BTR Power Products (Pty) Ltd		Engines and transmissions
	Laursen Brothers (Pty) Ltd		Engineering components
	Lesteel Spring Co (Pty) Ltd		Rail fasteners
	Permali (South Africa) (Pty) Ltd		Laminates
	Rubber & Wheel Industries (Pty) Ltd		Mouldings
	Sarmcol (Pty) Ltd		Belting, hose, mouldings etc
	Victor Kent Holdings (Pty) Ltd		Engineering products
United Kingdom:	Bestobell Ltd	(23%)	Engineering
	Blyth, Greene Jourdain & Co Ltd	(26%)	Trading and engineering
	BTR Vitaline Ltd	(50%)	Vessel lining
France:	Gerland SW Industries BV	(50%)	Roll coverings

Source: BTR Annual Report 1980

APPENDIX 4

(referred to in paragraph 3.3)

Serck: Principal subsidiaries and associated companies

Country of incorporation	*Name*	*Main activity*
United Kingdom:	Serck Industries Ltd, comprising:	Manufacturing and trading company
	Serck Audco Valves	Industrial stop valves and actuators
	Serck Glocon	Industrial control valves and actuators
	Serck Heat Transfer	Heat transfer equipment
	Serck Services	Exchange parts for motor vehicles
	Serck Controls	Supervisory control systems
	Serck Baker	Water processing systems
	Wilson's Foundry and Engineering Co Ltd	Steel castings
Switzerland:	Serck AG	Investment holding company
West Germany:	Serck GmbH	Heat exchangers and desalination plant
	Deutsche Audco GmbH	Industrial stop valves
France:	Audco Serck SA	Industrial stop valves
The Netherlands:	Serck Audco NV	Marketing of valve products
Belgium:	Serck Audco SA	Marketing of valve products
Australia:	Serck Audco Pty Ltd	Marketing of valve products
	Audco Manufacturing Pty Ltd	Industrial stop valves
South Africa:	Serck Southern Africa (Pty) Ltd	Industrial stop valves
USA:	Serck Incorporated	Marketing valve products
	Baker Filtration Company	Water filtration equipment
Sharjah, UAE:	Serck Services (Gulf) Ltd	Exchange parts for motor vehicles
Associated Companies		
India:	Audco India Ltd	Industrial stop valves
Saudi Arabia:	Almutlaq Serck Services Ltd	Exchange parts for motor vehicles
Bahrain:	Kanoo Serck Services WLL	Exchange parts for motor vehicles
France:	Compagnie Auxiliaire Industrielle sarl	Actuators
Kuwait:	Radiator Repair Company WLL	Exchange parts for motor vehicles
Oman:	Serck Services (Oman) Ltd	Exchange parts for motor vehicles
Italy:	Audco Rockwell Italiana srl	Industrial stop valves

Source: Serck

Appendix 5
(referred to in paragraph 3.13)

Serck: Operating divisions

Serck Limited Board

Group Chief Executive

Functional heads:
Accounting
Legal and Secretarial
Personnel
Corporate Development

	Managing Director:	Managing Director:	Managing Director:	Managing Director:	Managing Director:
	Serck Audco Valves International	Serck Heat Transfer	Serck Services	Serck Controls	Serck Baker
Business	Industrial valves and actuators	Heat transfer equipment	Exchange parts for motor vehicles	Supervisory control systems	Water processing systems
Locations	Newport Shropshire, Gloucester, Bishop Auckland, Hamburg, Paris, Pau, Bergen-op-Zoom, Brussels, Melbourne, Johannesburg, Houston and Madras.	Birmingham, Manchester and Hamburg.	Redditch and 73 branches throughout the United Kingdom. Units in the Middle East.	Coventry and Leamington Spa	Gloucester, Los Angeles and Houston.
Products and services	Plug valves; ball valves, butterfly valves; control valves and instrumentation; power actuators; ring joints; pressure-reducing equipment steel castings.	Tubular heat exchangers, plate heat exchangers; air cooled heat exchangers; desalination plant; waste heat recovery systems; thermostatic valves; heat exchanger repair.	Replacement and remanufactured parts for static plant and vehicles.	Electronic supervisory systems.	Oilfield water injection systems; refinery waste-water systems; filtration systems; dissolved air flotation; drum screens.
Principal applications	Oil industry gas industry; steel industry; chemical and petrochemical industries; water industry; power stations; mining process plant.	Marine & naval industries; locomotives; aircraft power plants; heavy vehicles; power generation; process plant; general engineering.	Motor trade fleet and plant operators.	Oil industry; gas industry; electricity industry; water and sewage control; chemical and petrochemical industries.	Oil industry; manufacturing industries; municipal water and wastewater; mining; aquaria.

Source: Serck

APPENDIX 6

(referred to in paragraph 4.1)

Types and uses of industrial valves and actuators

Industrial valves

1. The term 'industrial valves' is recognised in the Standard Industrial Classification (SIC) as last revised in 1968. The SIC defines the category by exclusion of 'valves for use in hydraulic and pneumatic systems, actuators not forming an intrinsic part of the valve, . . . inlet and exhaust valves for internal combustion engines, valves for use in aircraft systems, aerosol, bicycle and similar valves, sanitary taps and fittings and domestic gas cocks'. The remaining types of valves are those suitable for the control of fluids used in industrial processes. Industrial valves include:

Automatic process control valves (that is automatic flow regulators);
Pressure reducing valves;
Relief and safety valves;
Check or 'non-return' valves;
Other valves.

The British Valve Manufacturers' Association (BVMA) considers that each of the above categories can be regarded as distinct from or insignificantly substitutable with the others. The 'other' valve category includes gate, globe, diaphragm and quarter-turn valves, all of which can act as on/off devices (that is they can open or close a line of piping).

Valve actuators

2. A valve actuator is a mechanism for operating a valve. A handle or a wheel linked to a gearbox and thence to the valve is described as a manual actuator, whereas a device operating from a power source such as electricity, compressed air (pneumatic) or hydraulics is classified as a powered actuator. It is common for powered actuators to be capable of remote control. An actuator designed for control of valves can serve to power other devices; for example, bus doors are commonly actuated by pneumatic actuators.

Choice of valve and actuator types and substitutability

3. It has been estimated that of the valves sold in Europe about three-quarters are supplied for new projects, the remainder replacing valves in existing plant. Replacement is usually undertaken when valves are life-expired or defective. However, in some cases it may pay to replace a line of piping and valves with new equipment which would be cheaper to maintain or would permit alterations to the industrial process.

Replacement choices

4. The range of choice of valves as replacements is more constrained that that for new plant. In particular a replacement valve must have the shape and dimensions of its end connections compatible with those on the piping. In general for a valve of any given type designed to an approved Standard

specification only replacement with a valve of the same type designed to the same standard will be economic.[1] The most important standards are those of the American National Standards Institute (ANSI), the German DIN and the British Standards Institution (BSI). In addition to standards for flange and threaded connections, there are standards concerned with basic design details, materials of construction, some dimensions, marking, testing and quality control, but in some circumstances users may replace with a non-standard valve provided it has standard end connections.

Choice of valves for new plant

5. In principle the team of architect/engineers responsible for a plant's design have to take a large number of considerations into account when specifying the type of valve required. These include technical considerations such as the nature of the medium, pressure and temperature. Other considerations are space and weight limitations, the requirement for remote operation, the need to maintain continuous production, and requirements for high reliability and safety. Many of these factors are constraints on choice: for example, a valve designed to resist not more than 200°C cannot be used in a 300°C line. However, in cases where a variety of valve types would serve, the choice becomes one of economics, in which the relative importance of purchase cost, valve life and maintenance costs must be assessed.

Choice of valve size

6. One aspect of choice which is nearly always clear-cut is that of size. Valves are designed to fit a specified diameter of piping, and except in extremely rare cases the piping diameter determines the valve size rather than *vice versa*. One user told us: 'the valves ordered by us relate to the line size. If a 6-in line is necessary to meet flow and design parameters then obviously we order a 6-in valve. Wherever possible . . . we design to the smallest size.' This particular user was designing for processes where weight and space were at a premium, but we understand that the great majority of other users follow similar policies. Thus each size of valve (as measured by the piping diameter for which it is designed) is in practice barely substitutable for any other size of valve.

Characteristics of various types of valves

7. Various distinctions between valve types can be made, but one of the most important is between on/off and control valves (whose primary purpose is to modulate flow). In some cases an on/off valve can be used as modulator, and a control valve can shut off a line, but in general valves are designed to perform one function or the other. As noted in paragraph 1, the BVMA's category 'other valves' includes the main types of on/off valves. Another distinction is that between multi-turn and quarter-turn devices. Multi-turn valves act by the insertion of some form of blockage into the line, the insertion being made by the turn of a screw through several revolutions. Quarter-turn valves in contrast have a member inserted in the line of flow which when facing the flow head-on blocks the passage but which opens the line when turned through 90°.

[1] This is because a section of piping would have to be cut away, giving space for an insertion at either end of the valve of a section of piping with the appropriate faces.

8. There are three main types of quarter-turn valve: plug, ball[1] and butterfly. All are quick acting in comparison to multi-turn valves and versions of all three give tight shut-off. Moreover, the need for only a 90° turn gives these valve types an intrinsic superiority for applications where powered actuation is desired. The three types are illustrated in Figures 1 to 5. It can be seen that plug and ball valves contain a hollow member, which when in the open position offers a port through which flow can take place. When the port is turned away from the line the flow is prevented. The size of the port can be either of the same diameter as the piping ('full-bore') or smaller ('reduced bore'). A multi-port valve can allow a separation and diversion of flow into several lines of piping. Butterfly valves have a disk which prevents flow when facing the line; when the disk ('butterfly') is parallel to the line flow is permitted on either side of the butterfly.

Materials

9. Most valve manufacturers produce their basic design of valve in a variety of materials. Valves are offered in a range of metals and indeed in some cases also in plastic. The seat or sleeve (that is the surface layer inside the valve body in contact with the moving part) can similarly be in one of a variety of substances, often fluorocarbon based (known as 'soft' seating, in contrast to the 'hard' seating offered by a metal).

Quarter-turn valves

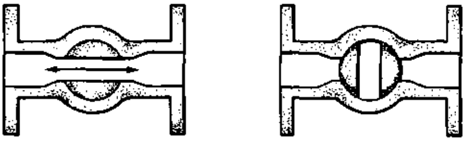
Plug valves

10. The operation of plug valves requires considerably more torque than that of either ball or butterfly valves because the area of contact between the surfaces of the plug and sleeve is greater. One consequence is that plug valves are more expensive to actuate by power. The basic plug valve design is easily adapted to give a multi-port construction, providing two, three or even four different flow ways. A basic plug valve can also be used for coarse modulation on some low flow services. They are the bulkiest of the quarter-turn valves. Their advantage is their tight seal, with no cavity where solids can accumulate, and versatility. Plug valves also give a straight-through flow, and thus loss of line pressure is low. Both lubricated and soft-sleeved types are available. A lubricated version in a suitable material can be specified for high pressure duty (up to 10,000 pounds per sq inch), whereas sleeved plug valves are limited to about 400 pounds per sq inch and 230°C with the present range of fluorocarbon sleeving materials. The lubricated type are relatively expensive to maintain. Of the three basic shapes of plug taper plug valves give a tighter seal than either parallel or cylindrical.

11. Plug valves share many of the characteristics of the other two main types of quarter-turn valves, but have more in common with ball than butterfly valves. The combination of plug valve plus power actuator (which must be specially adapted for a lubricated valve) is more expensive than actuated ball or butterfly, and this limits the range of applications for which it is used. In general sleeved plug valves can be competitive with ball valves in sizes such as 4-in to 6-in where a tight shut-off is required, and where the slightly

[1] Plug and ball valves are developments of the simpler 'cock' valve.

FIGURE 1
How a ball valve works



Sources:

FIGURES 2 AND 3: **British Valve Manufacturers' Association Ltd**

FIGURE 4: **Xomox Ltd**

FIGURE 5: **McGraw-Hill Book Co**

FIGURE 2
One piece ball valve

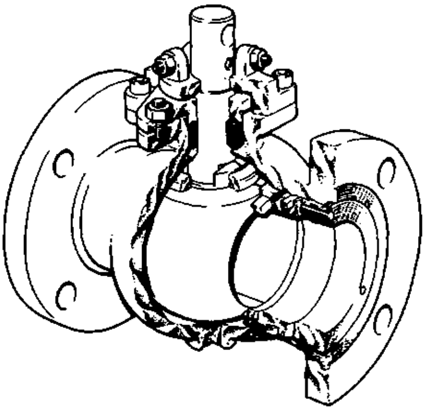


FIGURE 4
Sleeved taper plug valve

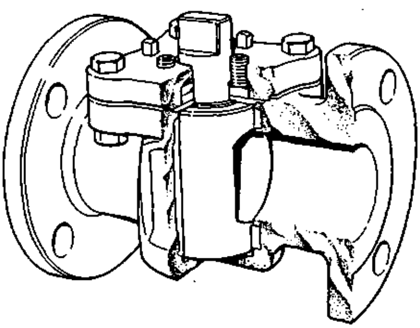


FIGURE 3
Flanged butterfly valve

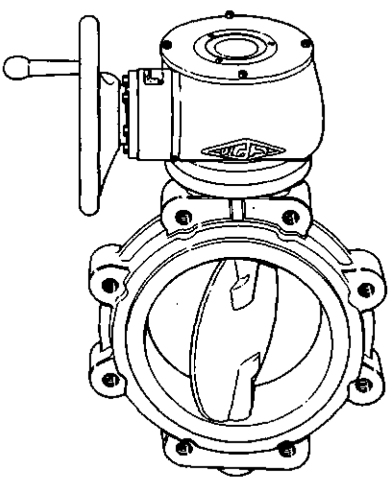
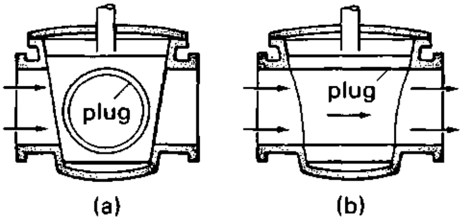


FIGURE 5
How a plug valve works



(a) closed (b) open

more restricted flow of the plug valve is not important. The absence of a cavity where solids can accumulate can also be important, and plug valves are often chosen where multi-port valves are required. Lubricated plug valves are competitive where very difficult temperatures and pressures are encountered.

Ball valves

12. Ball valves are made in one, two or three pieces, depending upon the need for robust construction (one piece being the most rigid). Both top entry valves, whose ball can be replaced while the valve is in situ, and end entry constructions are produced. Screw thread, flanged and welded end connections are available. Ball valves are cheaper than plug valves, almost as versatile, and offer a tight shut-off with a lower operating torque. Full bore ball valves provide straight through flow with a minimum resistance, and have the advantage that 'pigging'[1] is possible.Reduced bore ball valves are more economical, and where pigging is not necessary would usually be preferred as the increased pressure drop across the valve is not significant for most applications. Ball valves can be used as coarse modulators but are first and foremost on/off valves. Some three port ball valves are made. Standard ball valves have temperature ranges from −30°C to 230°C, at pressures from a coarse vacuum to 700 pounds per square inch, but specialised versions are made with a range almost as wide as the lubricated plug valves. Seating materials are usually types of fluorocarbon such as polytetrafluoroethylene (ptfe) but other materials are used. The ball can be made of any of a number of materials including brass, cast iron, mild steel, cast or carbon steel, stainless steel, monel and titanium (in ascending order of cost). The choice depends on the medium, temperature and pressure duty. Ball valves are easy to maintain, and in general are considered highly reliable. Fire-safe and anti-static versions are available.

13. Serck suggested to us a classification of ball valves into four main types: relatively cheap non-ferrous, general purpose, high specification, and pipeline valves. Worcester proposed a similar classification and those users of ball valves who described to us the factors in their choice of valves confirmed that this classification was in general consistent with their purchasing. However, any classification of such heterogeneous products will inevitably be less than clear-cut.

14. In more detail the distinctions are as follows:

(i) Cheap non-ferrous (mainly brass) valves are those used for undemanding applications (eg air and water). They are produced mainly in sizes up to 2-in.

(ii) General purpose ball valves are valves made either of cast iron or steel, and are of medium pressure ratings. Generally such valves have three piece bodies with ptfe seats and are made in sizes up to 2-in, or 6-in at most. These valves are available in both ferrous and non-ferrous metals, but most are of carbon and stainless steel versions. This

[1] Pigging is the insertion of a mechanical plug or inflatable sphere into a line and allowing the fluid to drive it from one end to the other. It is a technique for cleaning piping or for separating fluids.

valve type is the main-stay of many process industries and is used in a very wide range of applications. Valves conforming to BS 5159 would be included in this category.

(iii) High specification ball valves are those which meet standards of wall-thickness, fire-safety and static-proofing and are hence suitable for relatively demanding use in petro-chemical, chemical and pharmaceutical applications. They tend to be made in sizes from ½-in to 12-in in one or two pieces, of various types of steel or more expensive metals. Valves conforming to BS 5351 and to BS 5146 would be included, as would non-standard variants.

(iv) Pipeline (or high pressure) ball valves are generally large valves (over 12-in) for use on gas and oil transmission pipe lines. These valves are invariably in carbon steel and usually in pressure ratings higher than ANSI 300.

Butterfly valves

15. Butterfly valves are the most compact type of quarter-turn valve. They are rarely if ever made in sizes below 2-in diameter; this is because for small sizes the disk would occupy a disproportionate part of the flow shaft and produce substantial pressure loss. They are quick acting and have good modulating characteristics for a purpose-built on/off valve. Butterfly valves with metal-to-metal contact are difficult to make leak-tight, and thus most are made with rubber moulded or fluorocarbon seating. It is common to cover iron disks with a coating, but such valves are still regarded as relatively low performance devices. However, cast iron butterfly valves are the cheapest quarter-turn valve for use in piping of 3-in diameter and above and are ideal for undemanding pressure and temperature ratings where a quick acting or power actuated valve is required. Stainless steel, ptfe-seated high performance butterfly valves are a relatively new product in the United Kingdom, although they have been available for some years in the USA. They are an economical alternative to high specification ball valves in 2-in to 12-in diameter lines, especially in the larger diameters. Their compactness and lightness are advantages, but their telling advantage is the cost saving because of lower material content. Butterfly valves are made in a wide range of sizes and materials.

Multi-turn valves

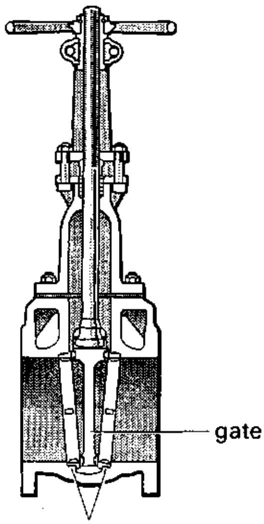
16. The three main types of multi-turn valves which serve for on/off applications are gate, globe and diaphragm. Because these valves require several rotations of the handle to completely open or close, their action is intrinsically slower than that of quarter-turn valves.

Gate valves

17. Gate valves are valves which provide a straight-through passage for the flow of the fluid when open; closure is effected by the insertion of the gate (metal plate or wedge) between body seats (see Figure 6). There are many variants of the basic gate valve design currently available including parallel slide valves. All give straight-through flow when open and hence cause minimal loss of line pressure; but they are the slowest acting of all valves because of the distance through which the gate must be moved, and are difficult to actuate. Further they are bulky in construction, are not considered

to give very positive shut-off, and are unsuitable for any modulation (velocity of flow against the partly opened gate can damage the mechanism). Nevertheless gate valves are the most common type of valves in industrial use, partly because of their cheapness. They are predominantly used in less demanding applications, where automatic actuation and speedy shut-off are not required. They are commonly used to control the flow of water or steam.

FIGURE 6 **Gate valve (view looking at pipeline)**

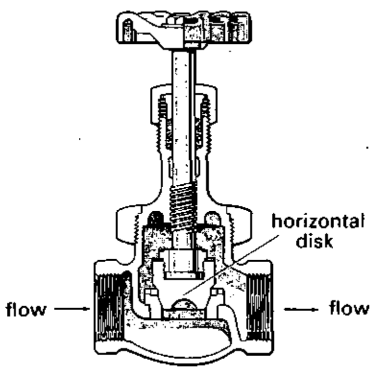


Source: British Valve Manufacturers' Association Ltd.

Globe valves

18. Valves of the globe type have a stem at right angles to the piping which raises or lowers a disk on to the body seat; the disk itself is horizontal to the piping. When the valve is open the flow is directed up through the gap and then redirected to its former course. Figure 7 illustrates a globe valve in the closed position.

FIGURE 7 **Globe valve (in closed position)**



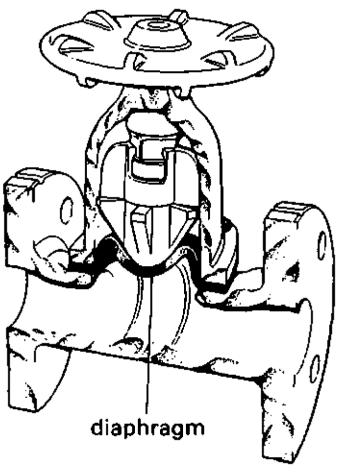
Source: British Valve Manufacturers' Association Ltd.

19. Globe valves in principle give the tightest shut-off of any type of valve; they also have reasonably short up and down movement of the disk and are not therefore particularly slow acting. However, the resistance to flow of globe valves is higher than that of most other valves because of the changes in direction of the fluid as it passes through the valve. This may be significant, in that the power required to drive the fluid is increased. Variants of globe valves can serve as modulators only, or as primarily on/off valves. However, as on/off valves they face a number of disadvantages: manual versions are relatively expensive, and actuated versions still more so, and their shut-off speed is slower than that of quarter-turn valves. Therefore globe valves are used for those on/off applications where a tight shut-off is required but where these actuation disadvantages are not of great account.

Diaphragm valves

20. Diaphragm valves have a flexible diaphragm of an elastomeric material (usually rubber) which is compressed by the turning of a screw thread stem (see Figure 8). The effect is in principle similar to cutting the flow through a garden hose by standing on it.

FIGURE 8 **Diaphragm valve (straight through flow variety)**



Source: British Valve Manufacturers' Association Ltd.

21. Because the fluid comes into contact only with the diaphragm and the body, and therefore there is no part which can become clogged, diaphragm valves are ideal for use with viscous fluids and those containing deposits and thick slurries. In the straight-through version the stroke of the diaphragm is relatively long, which slows the action and limits the choice of materials for the diaphragm to elastomers. The weir type requires a shorter stroke and hence ptfe with an elastomeric backing can be used, but the resistance is greater. Diaphragm valves are limited to medium temperature ranges (depending on the cost of the elastomer used) and the stresses induced in the diaphragm give diaphragm valves a shorter working life than other valve types. Diaphragm valves can be used as modulators, but are primarily on/off valves.

The shut-off is tight and the purity of the line fluid is guaranteed by the separation of the mechanism from the line, which is important in hygienic applications, eg edible or pharmaceutical production processes. In other circumstances diaphragm valves are not usually favoured for use in applications where quick acting automatic actuation is required.

Control valves

22. These are valves whose purpose is to change the nature of a flow rather than to shut it off. Some of the types of on/off valve which were described in paragraphs 10 to 20 can be used for such purposes, but only the globe type would serve as a fine modulator, and hence can properly be described as a control valve. However, there are control valve types which are based on the basic butterfly valve principle. In general a valve designed for control purposes would not be specified for an on/off application, as control valves are more sophisticated and expensive. Conversely quarter-turn valves are not competitive with control valves.

Survey information about on/off valve sales

23. Figures 9 to 12 illustrate some of the findings of a BVMA survey of the sales in 1979 of its members. The BVMA has estimated that the survey had a coverage of 50–60 per cent of the United Kingdom market. Detailed figures of diaphragm valve sales were unavailable.

24. Figure 9 shows the sales of various types of on/off valves, and also distinguishes between sales of ferrous and non-ferrous versions. The figure shows that gate valves had the largest sales, followed by ball valves. Sales of ferrous valves were more than three times those of non-ferrous.

25. Figure 10 shows the purchases of on/off valves by industry. The chemical and petro-chemical, water and sewerage and mineral oil production industries had the largest purchases.

26. Figure 11 shows the purchases of the three main types of on/off valve by industry. For ferrous gate valves the largest purchaser was the water industry, but the oil and chemical industries were also important. Ferrous ball valve sales were largely to process users (that is chemical, petro-chemical, oil and gas industries), whereas ferrous butterfly valve sales were more diffuse.

27. Figure 12 is an analysis of the main using industries by the type of on/off valve used. This shows that the water and sewerage industry predominantly bought gate valves, and that in the chemical, oil, and gas industries the ball valve had the largest share. In both the chemical and oil industries it was followed by the gate, globe, butterfly, and plug valves in that order, although the proportions varied. The electricity and the heating, ventilation and air-conditioning industries bought relatively few ferrous ball or butterfly valves.

FIGURE 9 **Sales of on/off valves in the UK 1979 (£ millions)**

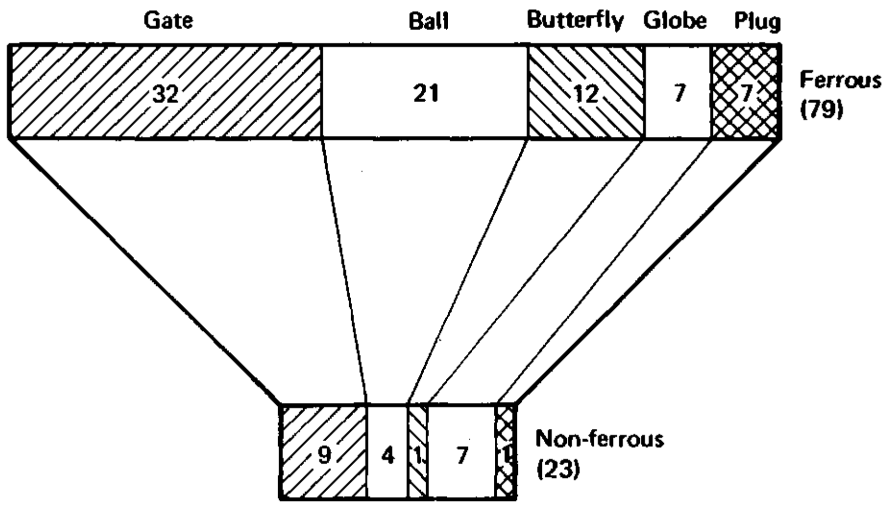


FIGURE 10 **Purchases of on/off valves in UK, 1979 (£ millions) Analysis by industry**

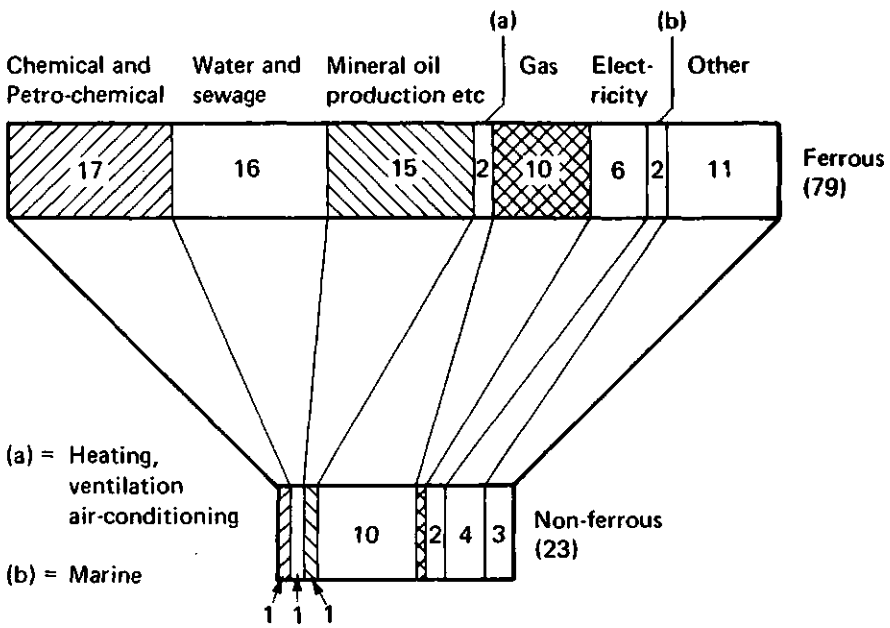


FIGURE 11 Main valve types—by customer industry (sales, £ million)

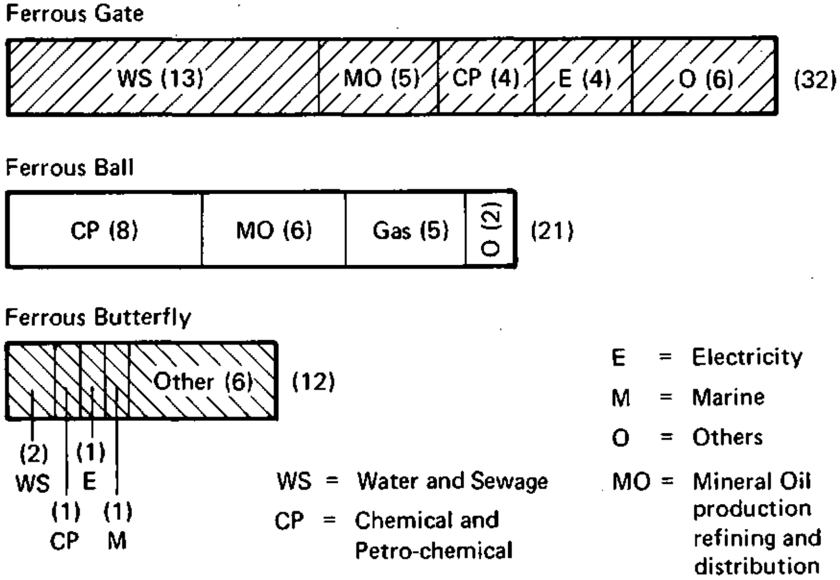
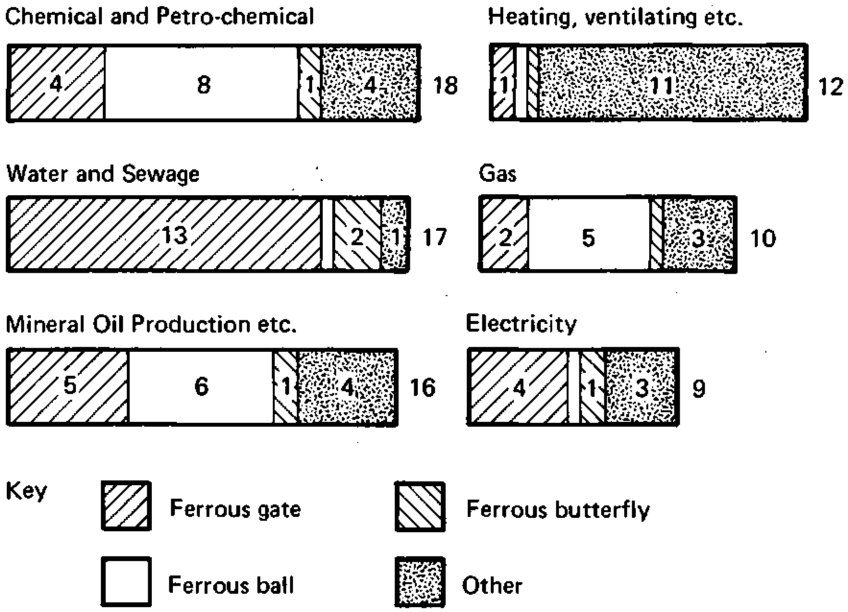


FIGURE 12 Main customer industries—by type of valve (purchases, £ million)



Source: British Valve Manufacturers' Association Ltd.
NOTE: All figures rounded off.

Types of powered actuators

28. Actuators can be powered by electricity, compressed air, hydraulic equipment or the pressure of the gas flowing in the line of piping. We refer to these four types as electric, pneumatic, hydraulic and gas. It is usual nowadays for the actuator to be designed so that the tripping of a switch on a remote panel will send an electronic signal to the actuator, which is then actuated using its power source.

Substitutability of actuator types

29. Actuators for on/off valves are designed to produce either a multi-turn, so that the screw thread stem of a multi-turn valve is raised or lowered, or a quarter-turn (for quarter-turn valves). A multi-turn actuator cannot serve for use with a quarter-turn valve; conversely a quarter-turn actuator is not capable of giving a multi-turn. The two types are quite distinct.

30. Actuators are rated by torque, that is the extent of the rotational force required (in units of lb-inches or newton-metres). The larger the valve to be operated, the greater the torque required; torque required also increases with the pressure in the line which is to be shut off. In general the cost of an actuator increases with its torque rating; as a result a higher torque device is not a substitute for one with a lower torque. There is no clear-cut dividing point at any particular torque rating separating actuators for general process applications and those for pipeline valves.

31. Another distinction between quarter-turn actuators is that between those which are single acting and those with a double action. The former are designed to give powered actuation in only one direction (either to open or to close), whereas the double acting variant offers powered actuation for both opening and closure. Any supplier of a single acting actuator would also make a double acting version. Actuators are often supplied with fail-safe devices (usually springs), so that when the supply of power (whether air or electricity or hydraulic) is disrupted the valve is automatically operated to close down the line.

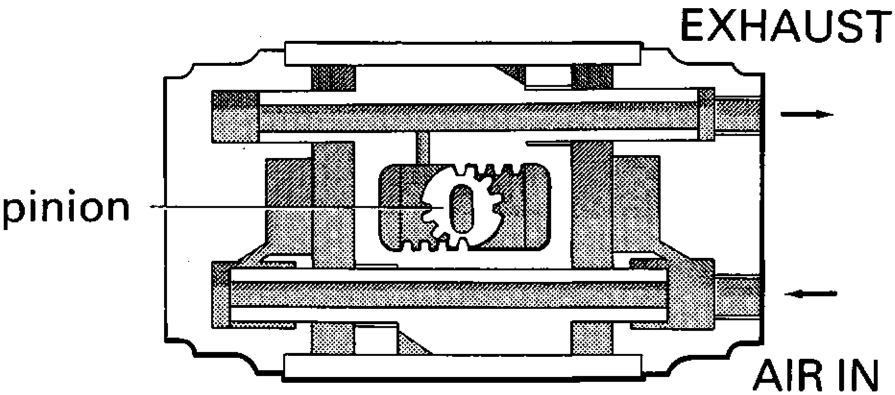
32. Electric actuators tend to be used only where another type is not suitable. On a pipeline in a desert or on top of an oil platform it is much easier to supply a cable than it is to supply compressed air; where space is restricted electric actuators are preferred as they are smaller than hydraulic (which are themselves smaller than pneumatic). Otherwise pneumatic or hydraulic types are preferred as they are inherently safer and are sold at a lower price.

33. The choice between pneumatic and hydraulic is also clear cut. In sites where hydraulic power is to be installed for other purposes a hydraulic actuator will be preferred for its economy, but otherwise a pneumatic is chosen as nearly every process plant will have compressed air supplies. In practice hydraulic power is available on oil platforms and in ships but in few process plants; hence the pneumatic type predominates in industrial use.

Pneumatic quarter-turn actuators

34. The two main types of pneumatic quarter-turn actuators are vane and piston. A vane actuator has a vane (not dissimilar to a weather vane) in a casing; compressed air from either its left or right blows it from closed to open or *vice versa*. A piston actuator operates by one or two pistons driven by air moving a rack or crank mechanism against a cogged pinion and turning it through 90°. When two pistons are employed they act in opposite directions to provide the rotation as illustrated in Figure 13.

FIGURE 13 **Double acting piston pneumatic actuator**



Source: BTR Ltd.

35. In circumstances where fail-safe features are required the piston type is nearly always preferred, as the fail-safe mechanisms offered are recognised to be more reliable as well as substantially cheaper. The dominance of the piston type for fail-safe use gives it an advantage in the market, as many companies see advantages in standardisation on a single actuator type for both fail-safe and less demanding applications. However, a user who does not require a fail-safe actuator can choose between the lower price of vane type actuators and the greater reliability of piston devices. To such users the vane type is a substitute for piston pneumatic actuators. The vane type captures segments of the market where its price advantage outweighs any performance disadvantages, and in particular it is used increasingly with general purpose valves.

Users and purchasing arrangements

36. In the course of inquiry we were assisted by various users of valves and actuators who told us of the influences upon their choice, and the nature of their purchasing arrangements. These users ranged from a brewer who expected to spend £2,000 per annum on valves to an oil company who might spend about £1 million on valves for a single North Sea platform (the platform in total costing around £500 million). The larger users typically had a central purchasing department which was responsible for establishing what products were available, their quality and the reliability of the supply, and for the

negotiation of terms for purchase. The discretion given to the operational management varied. In practice all these users produced something akin to a list of approved vendors, although in some cases only informally.

37. Several large companies had separate buyers responsible for valves and for actuators. Valves came under the heading 'valves and piping', actuators under 'instrumentation'. Every user expected the valve supplier to arrange the supply of actuators under sub-contract, although to the user's specification and with his agreement.

38. Some users had a formal policy of preference for British products, but the large multi-nationals and international plant contractors had established sources of supply from much of the industrialised world. The heterogeneity of valves weakens any advantages of standardisation, and typically users had a policy of ensuring multiple sources of valves. In contrast several users had standardised on actuator types.

39. All the users bought both from distributors and directly from manufacturers. In general more specialised items would be ordered directly, as would large orders for a new plant. Some told us distributors and manufacturers charged common prices; others said that negotiation secured some flexibility. Most users secured some volume-related discount from list prices.

40. Users placed a high value on achievement of delivery promises. It was explained that valves are often one of the last items ordered by a user, and that their cost is insignificant in comparison with the costs of construction delays. Nearly all users clearly preferred established suppliers, although some explained in detail the efforts they would make to approve new suppliers, and the extent to which they were willing so to do.

41. For a choice between an acceptable valve and a more expensive but possibly better product it seemed that plant contractors buying on behalf of clients tended to prefer low purchase cost more often than buyers who were end users. The rationale was that the product bought need only meet rather than exceed the required specification. We were told that on reimbursable (cost-plus) contracts clients would be free to override the contractor's recommendation, but that on fixed price or lump sum projects a bid made against foreign competition had to be on a low first cost basis.

42. None of these users saw any advantage to them in a valve manufacturer being able to supply a package of different valve types. One international plant contractor told us that, since its orders for ball valves and other valve types were placed at different times because the detailed design for plant was undertaken during construction, it always placed orders item by item. This was perhaps an extreme case, but item by item ordering seemed to be the norm. On the basis of this evidence it would seem that a supplier of packages would not have any significant advantages over a single product producer. However, one valve manufacturer gave us examples of users who preferred packages and pointed to the existence of packaging agents as evidence of the demand from some users for packages.

FIGURE 14 Volume of UK market (1975) prices

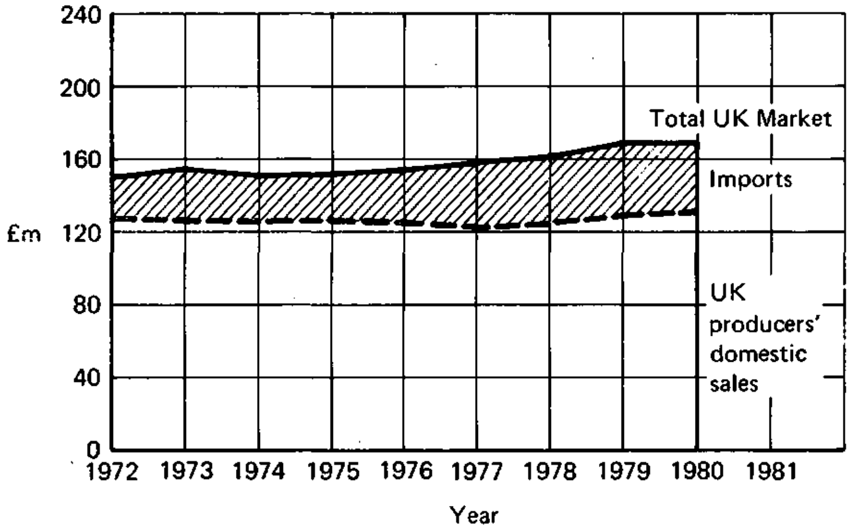
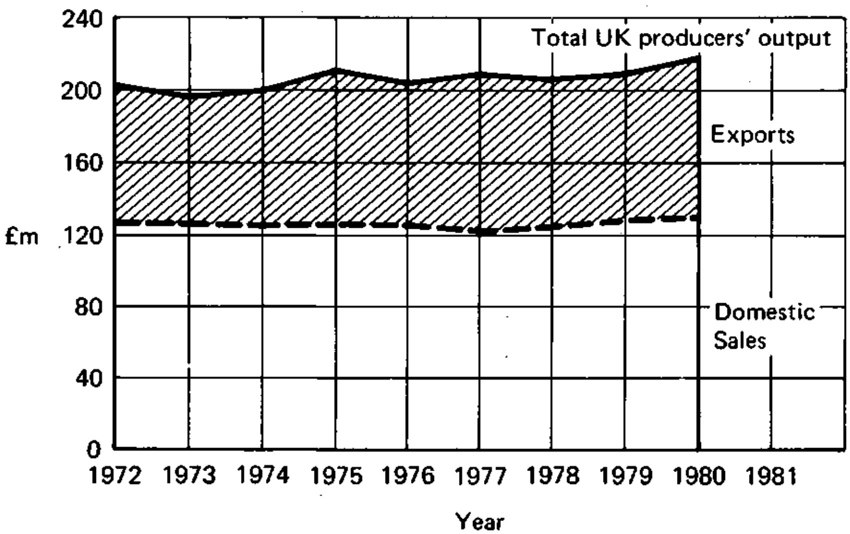


FIGURE 15 Volume of sales by UK producers (1975 prices)



Source: Business Statistics Office

Changes in the demand for and use of valves in the United Kingdom

43. Figures 14 and 15 show the fluctuations in the size of the domestic market and the volume of sales by United Kingdom producers. They are calculated using monetary value of sales, adjusted for changes in valve prices. The figures are for the principal products of firms in MLH 333.2 ('manufacturers of industrial valves and cocks including pneumatic control valves'). They show that the size of the United Kingdom market has varied little during the 1970s but that import penetration has increased. The United Kingdom was a net exporter of valves throughout this period, and the volume of exports grew although not greatly. The onset of the recession, as the combination of domestic slump and rising exchange rate depressed the market, is not shown. We understand that the trade cycle in valves lags somewhat behind the economy as a whole. Owing to the 1981 industrial dispute in the Civil Service, detailed figures of trade in valves were unavailable to us, but we were able to obtain data showing changes in the volume of sale by United Kingdom producers in SIC Order VI, Mechanical Engineering, of which MLH 333.2 is a part. Between 1980 and 1981 sales (allowing for price change) of these producers fell by about 12 per cent, with the domestic sales contracting somewhat more than exports.

44. Quarter-turn valve sales have been more buoyant than valves in general in the last few years. The BVMA estimated that the proportion of ferrous ball valves sold through distributors rose over this period; it noted that above 6-in butterfly valves had 'moved in on the ball valve market', that there was a trend towards sales of ball valves for higher pressure uses and towards use of plastics in lower pressures. 'Lined iron ball valves were tending to replace steel, and an increase in interest in corrosion had stimulated more use of exotic metals'. The proportion of full bore ball valves was increasing, and these were encroaching upon applications for which gate valves had been used. Lined plug valves took share from both lubricated plug and ball valves, but the ball valve was also gaining from the lubricated plug and compact gate valves. We understand that forecasts for the USA of average annual growth rates of over 10 per cent per annum for quarter-turn (with butterfly faster than ball), a decline of 1 or 2 per cent per annum for gate, and a growth of about 5 per cent per annum for diaphragm are regarded as plausible, and that United Kindgom prospects are believed to be similar. Many users told us they expected sales of butterfly valves to grow most swiftly, because of the development of high performance variants which have substantial cost advantages compared with valves with a higher material content. It is noteworthy that in 1960 quarter-turn valve sales represented only between 1 and 2 per cent of the total industrial on/off market, but that in 1981 the proportion was more than 50 per cent.

45. The cost of valves and actuators as a proportion of the cost of a new process plant is rarely as high as 10 per cent. Most users thought that 1–5 per cent was the range for most process applications. The implication is that any change in the price of all valves relative to other goods is unlikely to affect the rate of ordering greatly, or indeed at all.

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