WATER RESEARCH

WRc

ENGINEERING

TR 238

The Performance and Selection of Pressure Reducing Valves

Part 1

B Ratcliffe

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Engineering TR 238

The Performance and Selection of Pressure Reducing Valves

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I OBJECTIVE

To define and measure the performance parameters of various types of pressure reducing valves and to present the results in a uniform manner.

To produce guidelines for the selection of pressure reducing valves.

II REASON

Previous work by WRc, reported in the NWC/DoE Report 'Leakage Control Policy and Practice', demonstrated that the effect of pressure on leakage was far greater than previously thought. A given reduction in pressure was shown to produce a proportionately greater reduction in leakage.

The most common method of pressure control is the use of pressure reducing valves (PRVs); however in parts of the Industry doubts existed about their efficacy and reliability. The unsatisfactory performance of some valves may be attributable to design limitations or incorrect valve selection, installation or operation.

The correct selection of PRVs is difficult as comprehensive and comparative performance data is not generally available. This is in part due to the complex nature of PRVs and has resulted in the lack of a performance specification for such valves.

III CONCLUSIONS

(i) For all practical purposes pressure reducing valves (PRVs) can be classified according to one of 4 types depending upon their outlet pressure and their control and activating mechanism.

(ii) The performance of pressure reducing valves, although complex, can be expressed by two measures:

Rangeability, which is the range of flows and inlet pressures over which the valve can satisfactorily operate can be expressed in a series of rangeability maps.

Controllability, which is the valve's accuracy in maintaining the downstream set pressure over the given range, can be classified.

(iii) The rational selection of PRVs using the guidelines and performance data in this report is essential in order to realise the full benefits from pressure control at a reasonable cost.

Summary

IV RECOMMENDATIONS

It is recommended that those engineers responsible for implementing pressure control schemes should follow the guidelines for valve selection using the independently derived performance data contained in this report.

V RESUME

This report, TR238: Part 1, contains information on the functional performance of pressure reducing valves (PRVs) and provides guidelines for their rational selection. Both traditional constant outlet PRVs and also the recent developments of flow modulated valves which aim to produce a constant pressure at a critical point within the distribution system are described.

PRVs are classified according to one of 4 types depending upon their outlet pressure and method of control and actuation. The operating principles of these 4 types of valves are discussed.

The report defines the performance of PRVs as being rangeability and controllability and gives details of the test programme carried out on nine 150mm fixed outlet PRVs to determine these performance parameters. Full results of the performance of these valves together with the manufacturers' comments on them are contained in a companion report TR 238: Part 2 entitled the 'PRV Performance Atlas'. This is issued in a loose leaf format so that subsequent issues of valve data can be filed as they become available.

Finally the report contains guidelines for valve selection. Major selection criteria are discussed and full details of the methodology for using the performance data to select the type, make and size of valve is given.

This document covers:

1. A general description of the operation of all the types.

2. The test method used to produce performance maps for fixed outlet PRVs.

3. The general characteristics of water distribution systems which affect the choice of suitable methods of pressure control.

4. The collection of site data for all the types.

5. Applying this data to rationalise the choice of fixed outlet PRVs using the performance maps.

Summary

6. Recommendations to the Water Industry of the detail and type of information required by manufacturers to specify valves other than 150mm fixed outlet styles.

Introduction

1

It has long been known that the reduction of system pressures could reduce leakage levels and burst rates. A comprehensive investigation of this effect by WRC, reported in 'Leakage Control Policy and Practice' and elsewhere[1,2] demonstrated that the benefit was far greater than previously thought from purely theoretical considerations. A given reduction in pressure was shown to produce a proportionately greater reduction in leakage.

In view of the fact that pressure control does not involve any labour intensive location of leaks, but is a relatively quick and inexpensive method of leakage control it was recommended that pressure control should always be considered as a first step in any leakage control policy.

There are various ways of reducing system pressures but this report is concerned solely with the most commonly used and versatile method, namely the use of pressure reducing valves (PRVs).

Unfortunately there were some doubts in parts of the Industry about the efficacy and reliability of currently available pressure reducing valves. A preliminary study showed that it was not clear whether the unsatisfactory performance shown by some valves was due to design limitations or whether it was attributable to incorrect valve selection, sizing, siting or lack of maintenance.

The correct selection of PRVs is difficult as comprehensive and comparative performance data for all valves is not available. This is in part due to the complex nature of PRVs which makes it difficult to fully express their performance in a simple manner. This has also resulted in the lack of a functional specification for PRVs so that manufacturers do not know the Industry's requirements for valve performance, e.g. the limits within which the downstream pressure should be maintained.

In order to eliminate these shortcomings a programme of work was defined with the following objectives:

(i) To define and measure the performance parameters of various types of pressure reducing valves agreed by their manufacturers as typical products in an ex works condition. The manufacturers' agreement with the methodology to be sought and obtained.

(ii) To present the resultant data in a uniform manner so that all valves can be compared on the same basis.

(iii) To produce guidelines for the selection of pressure reducing valves.

(iv) To compare the valve performance data with measurements on installed valves to check the validity of the measurements.

(v) To use the above data to identify poor performance and to discover and if possible eliminate the reasons for it. Examples could include poor sizing, siting or lack of maintenance.

In addition, to ensure the correct and appropriate application of pressure control a further objective is:

(vi) To produce a consistent methodology for the design, installation and operation of pressure control schemes, taking proper account of the costs and benefits.

This report is concerned with the first three objectives and is designed to ensure that the Industry selects PRVs in a rational manner in order to realise the full benefits from pressure control at a reasonable cost.

Types of Pressure Reducing Valve

A pressure reducing valve can be defined as a device which will maintain a reduced, generally constant, outlet (downstream) pressure for a range of flow rates and inlet (upstream) pressures.

Recently there have been several developments of traditional, constant outlet PRVs as defined above such that their outlet pressure is affected by the flow rate through the valve. These valves, generally referred to as flow modulated PRVs, can be defined as devices whose outlet (downstream) pressure is varied in such a manner that a constant head can be maintained at a target point in the distribution system for the range of flow rates and inlet (upstream) pressures expected.

Figures 1(a) and (b) demonstrate the effect of these two basic types of valve on a critical point in the downstream distribution system. Constant outlet PRVs produce a constant pressure immediately downstream of the valve.

There are a variety of valves on the market, both constant outlet and flow modulating kinds, in a range of different styles and operating principles. These all consist of two major components, the valve element, which is responsible for causing the pressure drop, and the controlling and actuating mechanism, responsible for maintaining the desired pressure.

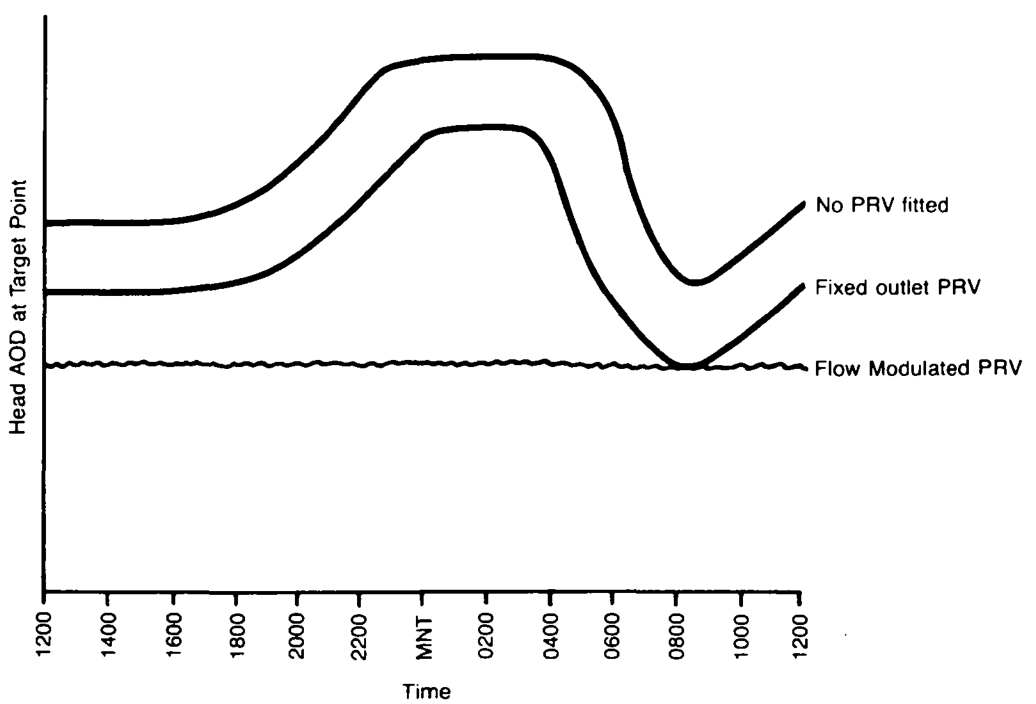

Figure 1(a) Diurnal pressure variation at target point

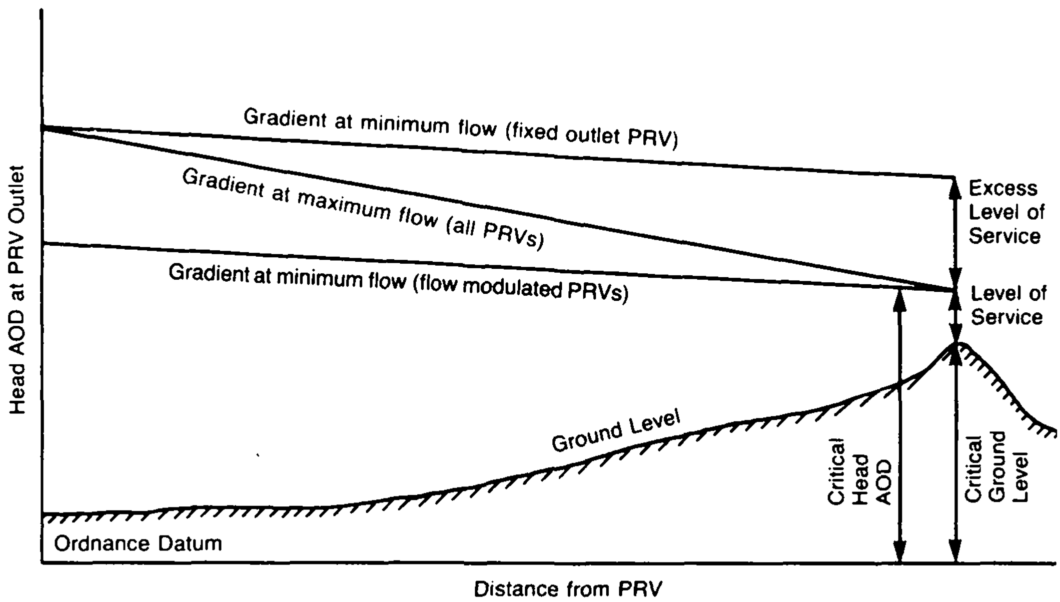

Figure 1(b) Pressure gradient to target point

The type of valve element used classifies the style of the valve i.e. globe, plug, gate and diaphragm. PRVs are available in all of these styles. Figure 2 illustrates the operating principles and gives some examples of manufacturer's products in different styles.

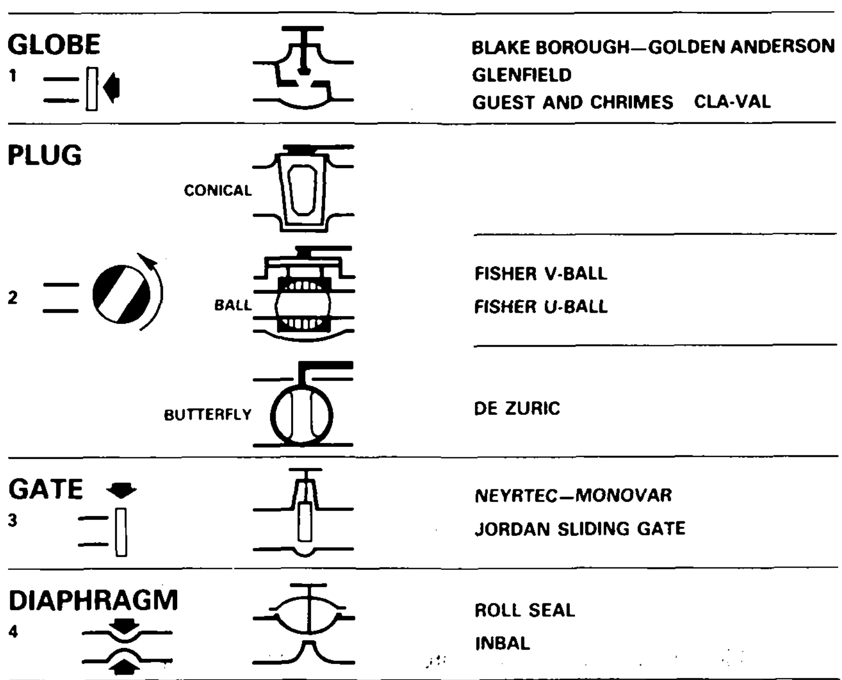

Figure 2 Valve styles

The method of deriving control feedback signals for any style of valve can be either mechanical or electronic. Mechanical systems depend on reactions to reference masses such as springs and weights. Electronic systems depend on transducers to provide data for control.

The valve element can be moved by either line fluid pressure or external electrical or hydraulic positioners.

However for all practical purposes it is convenient to classify valves into 4 basic types depending upon their:
(i) outlet pressure regime,
(ii) control mechanism, and
(iii) actuation.

Table 1 lists typical examples of PRVs characterised in this way. The major differences and operating principles of these 4 valve types are discussed in the following sections.

Type	Outlet Pressure Characteristics	Valve Control Mechanism	Valve Actuation	Typical Example
1	Constant	Spring loaded diaphragm valve.	Hydraulically self actuated.	Guest and Chrimes 6DC Talbot Bailey
2	Constant	Spring loaded external pilot valve.	Hydraulically self actuated.	Glenfield 1301 Guest and Chrimes 6DR Inbal Claval Roll Seal
3	Flow modulated	Spring loaded external pilot valve, diaphragm modulated.	Hydraulically self actuated.	Blakeborough Variducer Glenfield 1350 Inbal Modulator
4	Flow modulated	Electronic.	Externally actuated.	DTS/De Zuric Blakeborough/DTS

Table 1 PRV Classification

Types of Pressure Reducing Valve

2.1 Type 1 PRVs

These are spring loaded diaphragm valves which are self actuated by line fluid pressures. They are designed to produce constant outlet pressure but in practice can have outlet pressure characteristics which are higher at low flows than high flows. Figure 3 illustrates a typical Type 1 PRV which consists essentially of a spring acting on a diaphragm the underside of which is connected to a bottom guided stirrup. Integral with the stirrup is a valve plug with a sealing seat the position of which controls the headloss across the valve. The value of the downstream (constant) pressure is adjusted by changing the compression of the spring.

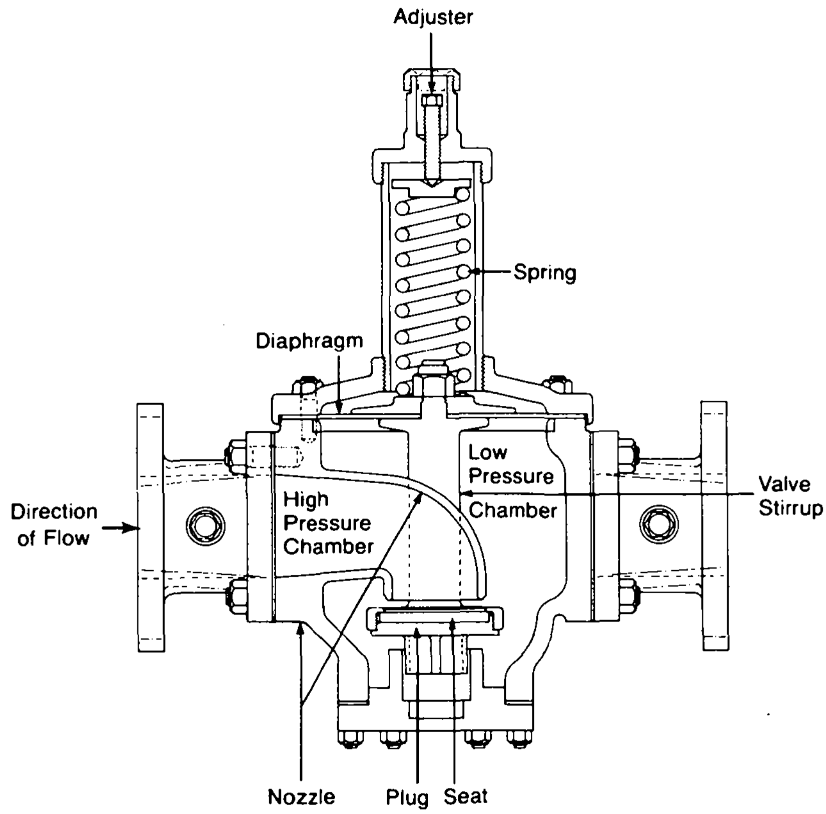

Figure 3 Type 1 PRV : Guest and Chrimes 6DC

The gap between the nozzle and the seat represents the variable hydraulic resistance part of the total hydraulic resistance of the valve. The size of this gap, in equilibrium conditions for any flow rate, is set by the pressure gradient of upstream pressure to downstream pressure. The lower end of which is kept constant by the equilibrium of the downward force of the spring and the upward force of the product of diaphragm area and pressure in the downstream chamber.

A change of flowrate and, consequently, upstream pressure temporarily overcomes the equilibrium forces and induces either a higher downstream pressure (reducing flowrate) or a lower downstream pressure (increasing flowrate) since there is now a new pressure gradient across the valve element.

If we consider an increase in flow through the valve then an initial fall in pressure occurs in the downstream chamber. This upsets the equilibrium and allows the spring force to overcome the pressure on the underside of the diaphragm. The resultant downward movement of the diaphragm moves the stirrup downwards and allows a larger gap between the seat and the nozzle. The larger gap, having less hydraulic resistance, enables the downstream pressure to rise and this process will continue until the valve opening adjusts such that the lower end of the hydraulic gradient is the equilibrium position of the diaphragm.

A decrease in demand will initiate a similar process except that an initial rise in pressure is sensed by the diaphragm leading to relative closure of the seat to nozzle gap.

2.2 Type 2 PRVs

These valves are characterised by being hydraulically self actuated and controlled by a spring loaded external pilot valve. They produce a constant outlet pressure.

Figure 4 shows a typical Type 2 PRV having a globe body and the typical external pilot valve. The pilot valve has connections to the outlet pressure (P2) end of the valve body, to the inlet pressure (P1) end via a fixed orifice and to the intermediate pressure (P3) chamber via a needle cock.

The moveable part of the pilot valve is connected to a diaphragm, one side of which is subjected to the outlet pressure (P2) and the other side to the compression force of an adjustable spring.

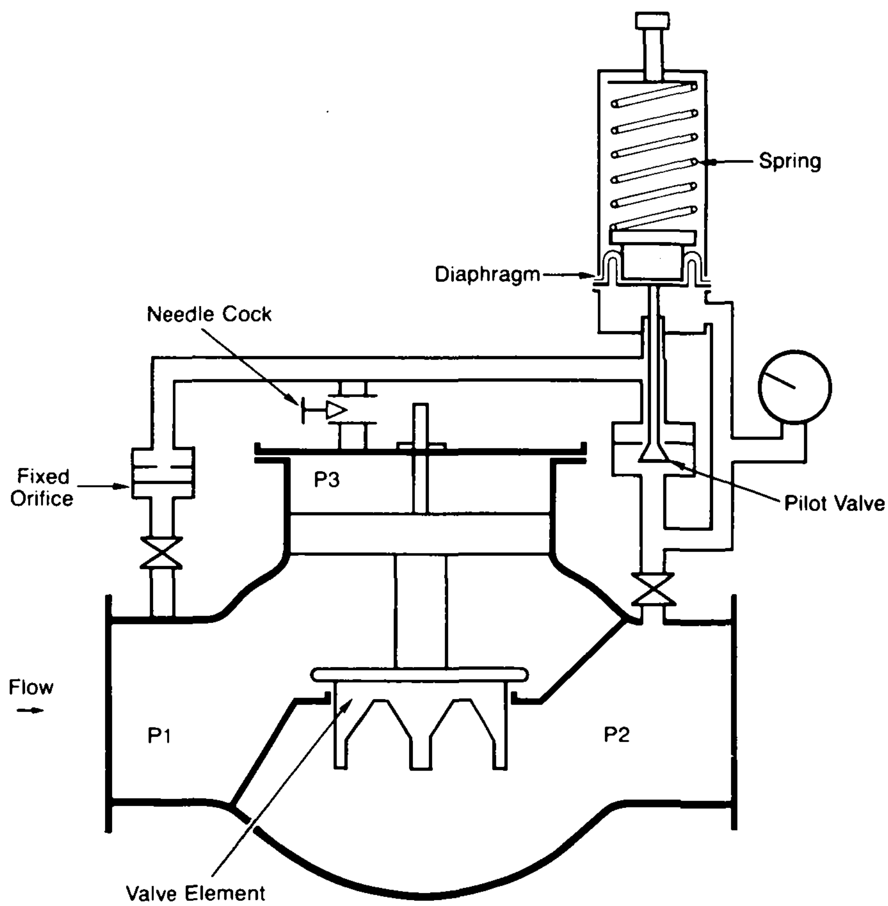

Figure 4 Type 2 PRV : Glenfield 1301
Blakeborough
Guest and Chrimes 6DR.

Pressure P3 controls the position of the valve element. The value of this pressure depends upon the relative pressure drops generated across the fixed orifice and the pilot valve which is a variable orifice. The position of the pilot valve and hence the current position of the valve element is controlled by the equilibrium of forces of the compression spring and the product of downstream pressure and the area of the diaphragm.

For any particular flow and inlet pressure and set downstream pressure there will be a pressure gradient across the valve such that the valve element opening will be fixed. A change in flow and consequent change in inlet pressure (P1) will induce a change in the outlet pressure (P2) and disturb the equilibrium of the valve.

If we consider a decrease of flow and increase in inlet pressure (P1) then the resultant increase in downstream pressure will tend to close the pilot valve causing an increase in the intermediate pressure (P3). The increase in P1, P2 and P3 acting upon the valve element and piston will close the valve element. This increases the hydraulic resistance across the seat and reduces the outlet pressure (P2) until equilibrium is regained. The speed of response is determined by the setting of the needle cock. An increase of flow would set up the opposite process to the one described.

This same hydraulic control system is also applied to styles of valve other than the globe pattern. Examples of its use on diaphragm pattern valves are shown in Figures 5 and 6. Figure 7 shows a globe pattern valve that transmits the force to the valve element via a diaphragm.

Type 2 PRVs can also have 2 pilot valve systems with a clock changeover mechanism. These are used, for example, to institute greater pressure reduction at night than during the daytime.

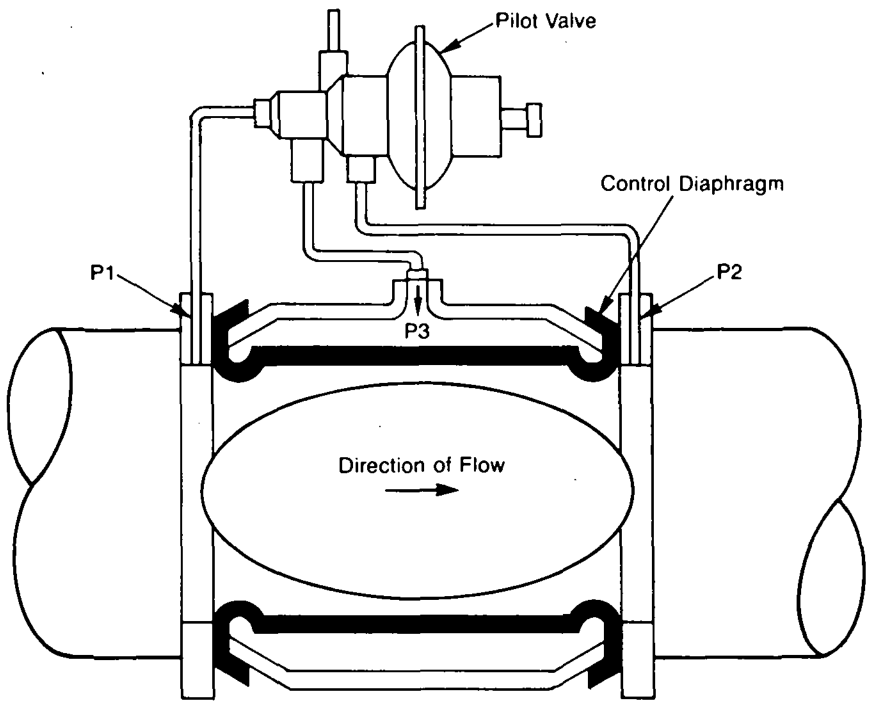

Figure 5 Type 2 PRV: Inbal.

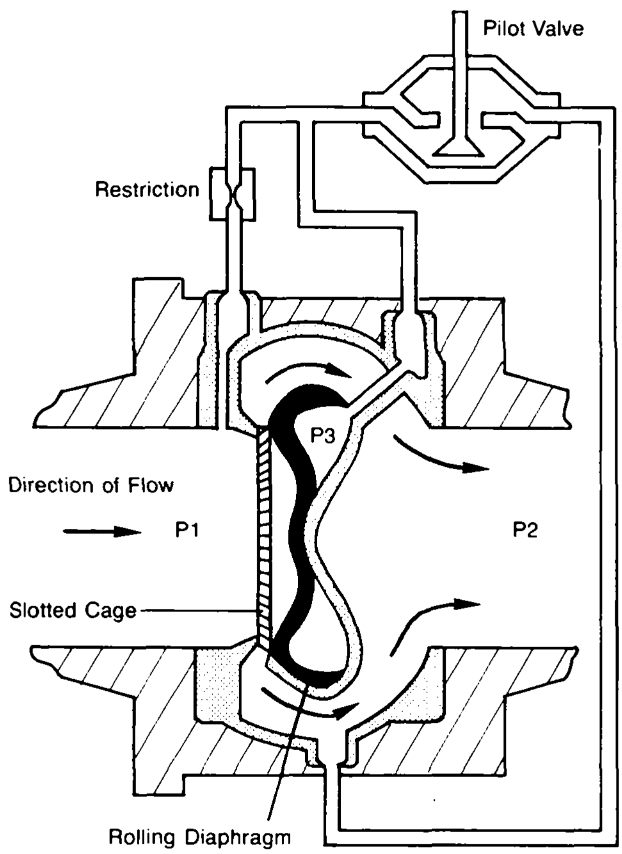

Figure 6 Type 2 PRV: Rollseal

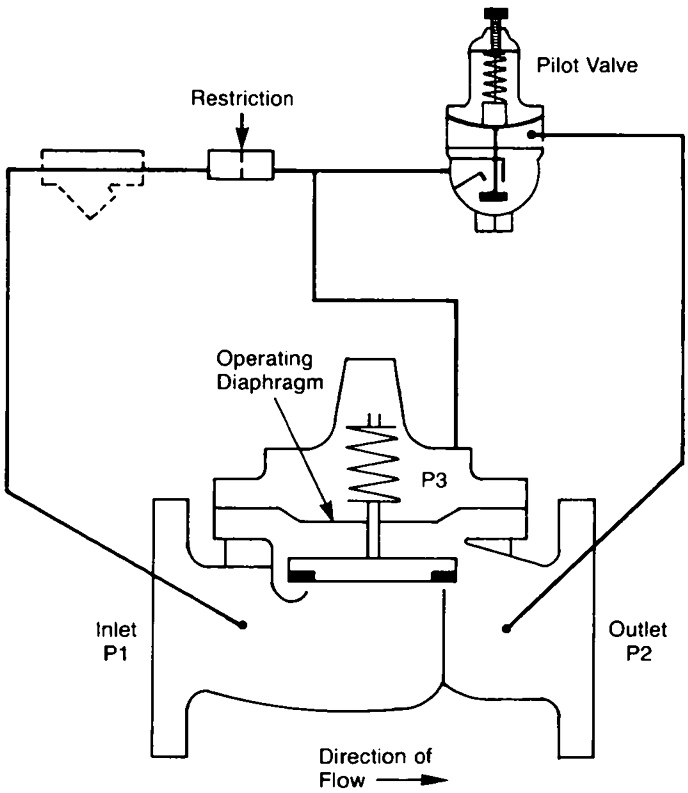

Figure 7 Type 2 PRV: Claval.

2.3 Type 3 PRVs

These valves are basic modifications of Type 2 PRVs and are characterised by supplementary diaphragm control of the external pilot valve in order to achieve a flow modulated outlet pressure or utilising the pressure recovery properties of orifice plate, nozzle or Venturi devices.

A schematic drawing of a Type 3 PRV is shown in Figure 8. It has two additional features over a Type 2 PRV, an orifice plate mounted either upstream or downstream of the valve and a supplementary diaphragm acting on the bottom of the pilot valve. The purpose of the orifice plate is to derive a pressure differential signal related to flow rate which is used to modulate the external pilot valve and thus the outlet pressure.

At very low flow rates the PRV behaves like a Type 2 valve. Normal equilibrium exists between the spring force and the upward acting force of the downstream pressure on the area of the relay valve diaphragm.

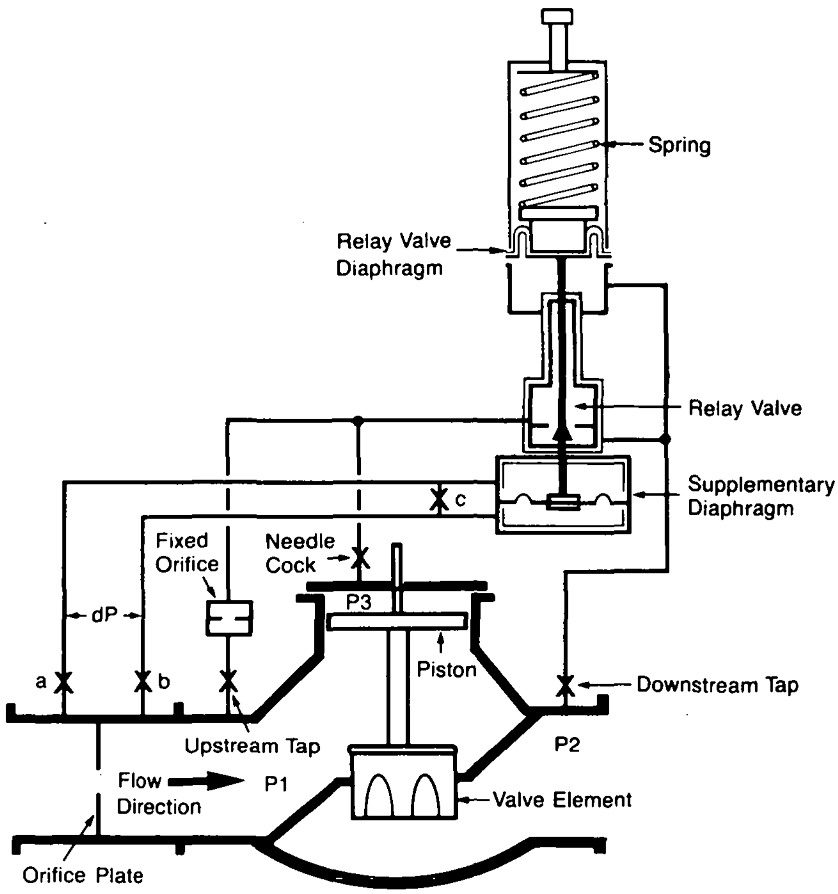

Figure 8 Type 3 PRV: Blakeborough Variducer
Glenfield 1350
Inbal (diaphragm style valve).

At other flow rates a larger differential pressure will be developed across the orifice plate. This pressure is applied to the supplementary diaphragm which will cause the normal equilibrium position of the relay valve, compression spring combination to be modulated. The degree of modulation will be the product of orifice plate differential pressure, (proportional to the flow rate) and the area of the supplementary diaphragm which is mechanically connected to the underside of the relay valve.

If the flow rate increases, the outlet pressure (P2) falls and the valve attempts to restore equilibrium. The increase in flow and consequently in the differential pressure (dP) is such that the new equilibrium position of the external pilot valve is slightly more open than before. This causes an additional decrease in P3 and consequently an additional opening of the valve element over that required to regain the previous set outlet pressure.

The outlet pressure P2 thus increases with increasing flow rate, and falls with decreasing flow rates.

The modulation compensates for the system headloss characteristics downstream of the valve owing to the similarity of the relationship between:

(i) the differential pressure (dP) and the flow (Q) through the orifice plate ($Q \alpha \sqrt{dP}$).

(ii) the system headloss (HL) downstream and flow rate (Q).

This latter relationship is complicated by the distribution of demand across the system but approximates to a square law ($H_L \alpha Q^2$).

The modulation thus compensates for the system headloss characteristics in such a way that an approximately constant pressure is maintained at the critical point in the system.

In some valves the size of the orifice plate and the size of the area of the supplementary diaphragm are adjusted to match the compensation to the particular downstream distribution system hydraulic characteristics. In other valves cocks, a, b and c in the diagram, are used to achieve the match. Some network characteristics may require judicious alteration of all.

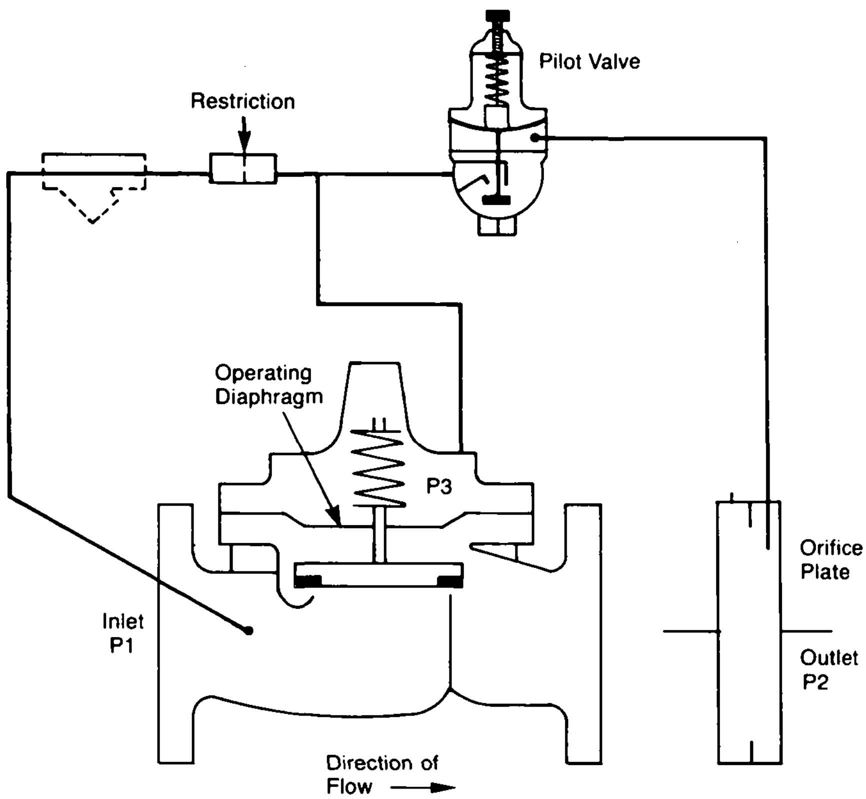

Figure 9 Type 3 PRV: Claval.

Figure 9 illustrates the pressure recovery principle of flow modulating pressure. An external pilot valve, instead of controlling the pressure in the downstream chamber of the valve, is connected to the downstream tap of an orifice plate, nozzle or Venturi device. This controls the minimum pressure level of the vena contracta at a reference level. At low flows there is very little loss developed across the control device so that the pressure recovery is correspondingly small.

Higher flows develop more losses across the control device so that more recovery can take place thus producing the desirable characteristic of increasing outlet pressure with increasing flow.

The dimensions of the control device are used to match the downstream system characteristics. This limits the useful modulation range of the system as a higher modulation range of pressures requires a smaller orifice and this will eventually choke the valve performance by reducing the effective flow capacity. These difficulties can be partially overcome by using a low loss Venturi in place of the orifice plate.

2.4 Type 4 PRVs

These valves are characterised by being electronically controlled and externally actuated and produce a flow modulated outlet pressure.

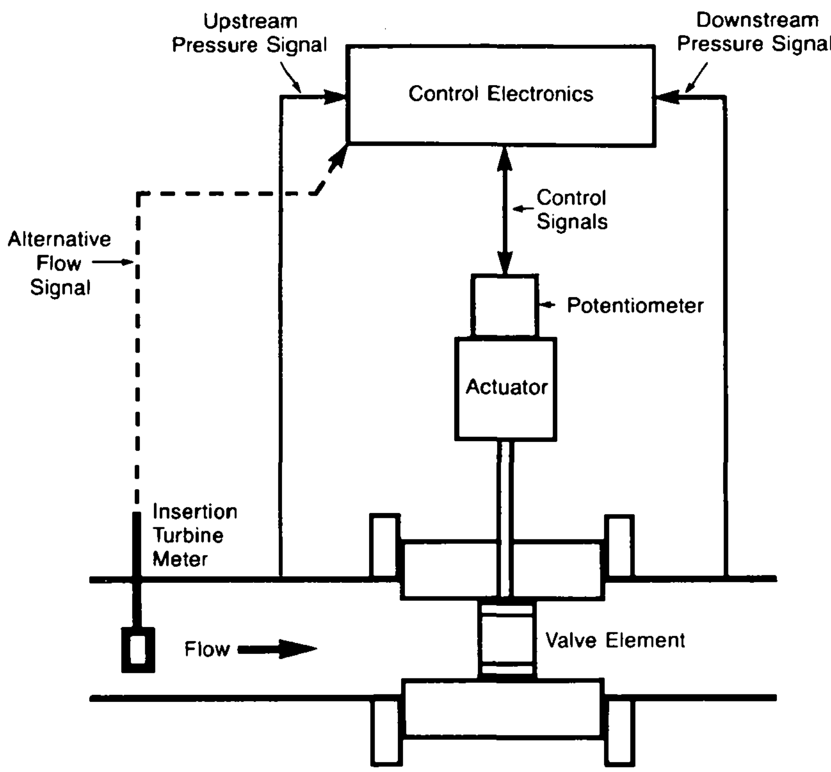

Figure 10 Type 4 PRV: DTS DeZuric valve.

Figure 10 shows the components of one Type 4 PRV which utilises an electrically actuated eccentric plug valve. The electronic control system records upstream pressure, downstream pressure and the valve position and emits control signals to the valve actuator in order to maintain the desired downstream pressure.

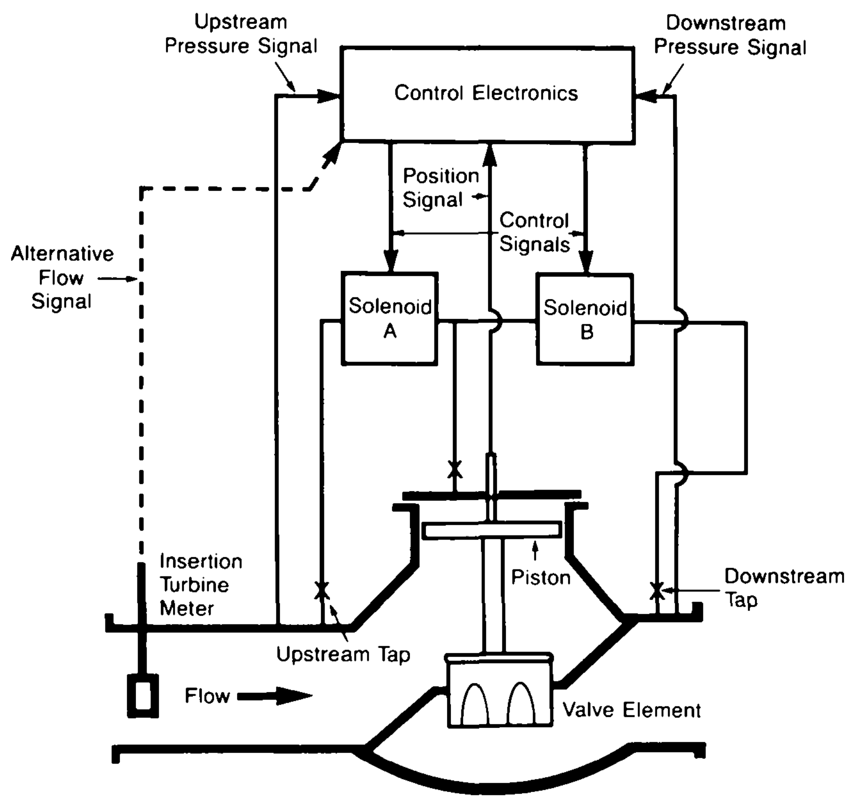

Figure 11 Type 4 PRV: Blakeborough/DTS valve.

Figure 11 shows the components of a second Type 4 PRV. This is a modification of a Type 2 PRV with electronically controlled solenoid valves replacing the external pilot valve. This valve also measures downstream pressure, upstream pressure and valve position. Alternatively these latter two measurements can be replaced by a single measurement of flow rate. This valve can also incorporate a mechanical fail safe to fixed outlet pressure device in case of power failure.

The operation of these valves is simply explained by reference to Figure 12. Measurements of upstream and downstream pressure and valve position and knowledge of the valve characteristics enable an estimate of the flow rate to be calculated using the valve as a variable orifice flowmeter. The system headloss characteristics are then used to determine the desired downstream pressure and the valve actuated until this is achieved. Where flow rate is measured directly the first calculation is unnecessary.

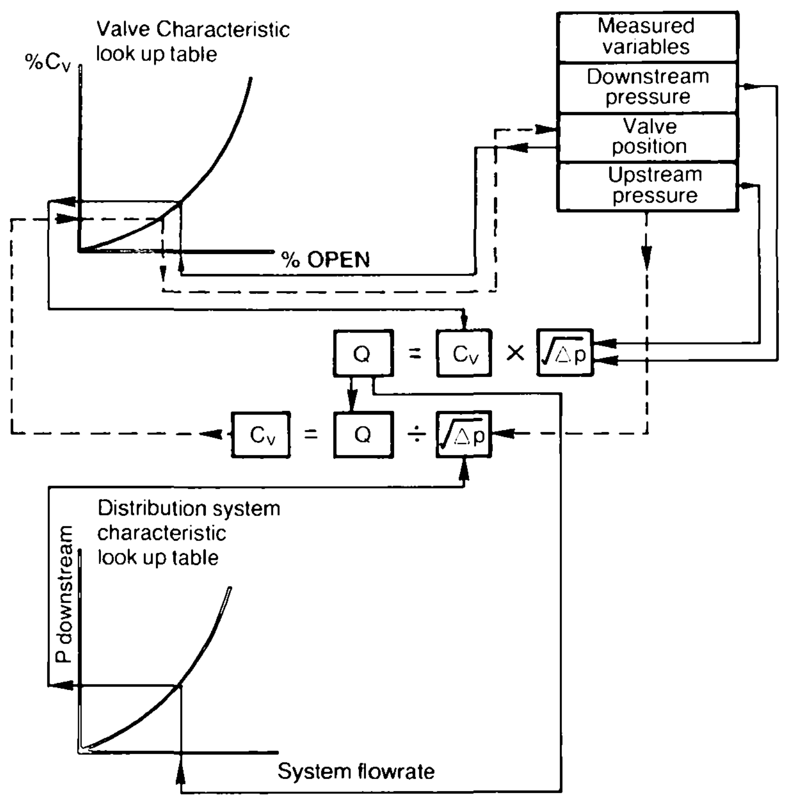

Figure 12 Control system operation of Type 4 PRVs.

The versatility of the electronic controller means that any system headloss characteristics can be incorporated rather than being constrained to a square law as with Type 3 valves which is an advantage for more sophisticated control schemes.

Type 4 PRVs need not be 'stand alone' and control signals can be obtained and distributed by telemetry schemes. One example is a central mainframe computer which sends information to control valves from stored pressure patterns. In another example the control valve receives control signals from a pressure transducer installed at the critical point. If time of day accurately reflects daily pressure patterns then Type 4 PRVs can be controlled by clock signals.

PRV Test Programme 3

3.1 Introduction

In order to determine the performance of the PRV types discussed in Section 2 a PRV test programme was initiated by WRc at the British Hydro-Mechanics Research Association (BHRA). BHRA's expertise and knowledge of valves is well known.

The objectives of this work were to develop a suitable test procedure and specifically to provide data on the functional performance of 150mm (6″) PRVs. This size was chosen as being representative of the majority of installed valves. Prior to commencing the test programme it was necessary to define the relevant performance parameters in view of the lack of published information in this area. In addition a practical method of presenting comparative results was devised.

Valve performance was ultimately defined as:

(i) rangeability – which is the range of flows and inlet pressures over which the valve can operate without violating mechanical limits.

(ii) controllability – that is the valve's accuracy in maintaining the downstream set pressure over the range of flows and inlet pressures which map within the boundaries defined by rangeability.

3.1.1 Rangeability

This is defined as the region of flows and pressures where the valve can function although it may not maintain the same level of controllability over the whole of this range.

Inside this range the valve will function without hunting. Hunting is a condition of unstable operation frequently met when the valve is required to operate at low flows and high pressure drops.

The valve will also function without being damaged by critical cavitation, a condition caused at high pressure drops across the valve although the range of pressure drops representing the onset of cavitation shown by the map boundary labelled'possible noise nuisance' in Figure 13 is a legitimate area of operation.

In addition to these criteria there is also the limitation imposed by the hydraulic loss across the valve when fully open.

These limitations on performance have been expressed as rangeability maps for various set control pressures an example of which is given in Figure 13.

3.1.2 Controllability

This is the valve's ability to either maintain a constant outlet pressure – fixed outlet valve styles – or follow a set head/flow relationship – flow modulating valve styles. There are, however, difficulties in presenting a particular parameter to describe controllability since pressure control is not only dependent upon the valve and its setting, but it is also related to both the demand pattern and supply system head/flow characteristic.

Controllability is expressed by the deviation of the value of the outlet pressure from the set downstream pressure at a set flow rate. Only those flow/pressure combinations which fall within the recommended operating envelope of the rangeability map are included in the classification. Additionally, any specific manufacturers recommendation for a particular product to have a minimum pressure drop across the valve is taken into account in assessing controllability. This has the effect of reducing the area of the envelope by moving a new boundary inside the fully open C_V line and is labelled on the rangeability diagram as 'minimum differential pressure' (see Figure 13 – Example of rangeability map).

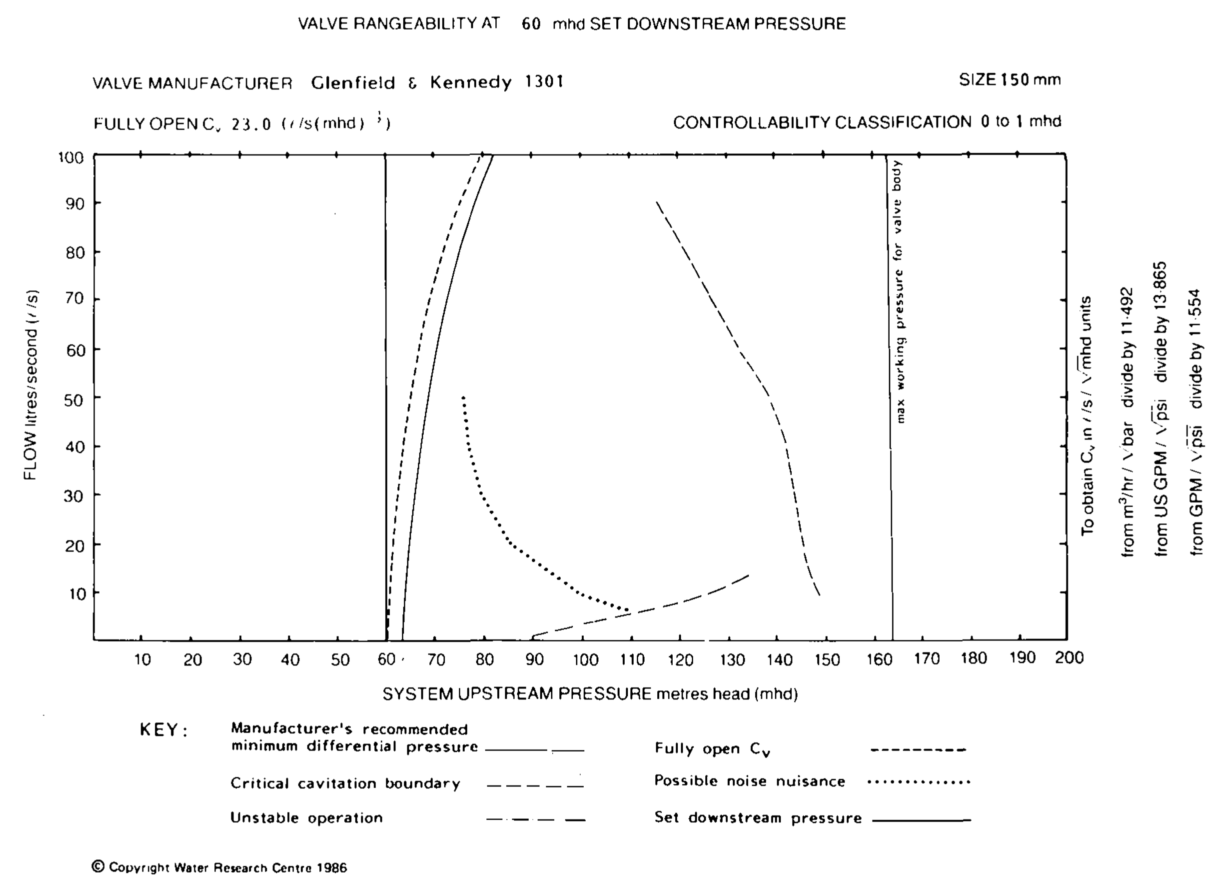

Figure 13 Example of rangeability map.

Controllability has been classified according to the experimental data and the categories are shown on each individual performance map in 'The PRV Performance Atlas', TR238 Part 2.

The test data and plotted results are discussed in Appendix 2.

3.2 Experimental Facility

A schematic diagram of the test rig facility is given in Figure 14.

The rig consists of a 150mm water pipe loop and bypass connected to a 32,000 litre open top reservoir. A pump with a duty of 90 litres/second flow and 120 mhd delivers water to the rig.

Flows through the test section were determined by the settings of the pump regulating valve, bypass butterfly valve and the demand regulator valve, which was used to simulate demand.

Noise generated by the pump and cavitating valve combinations was prevented from entering the test section with flexible pipe connectors and an acoustic decoupler.

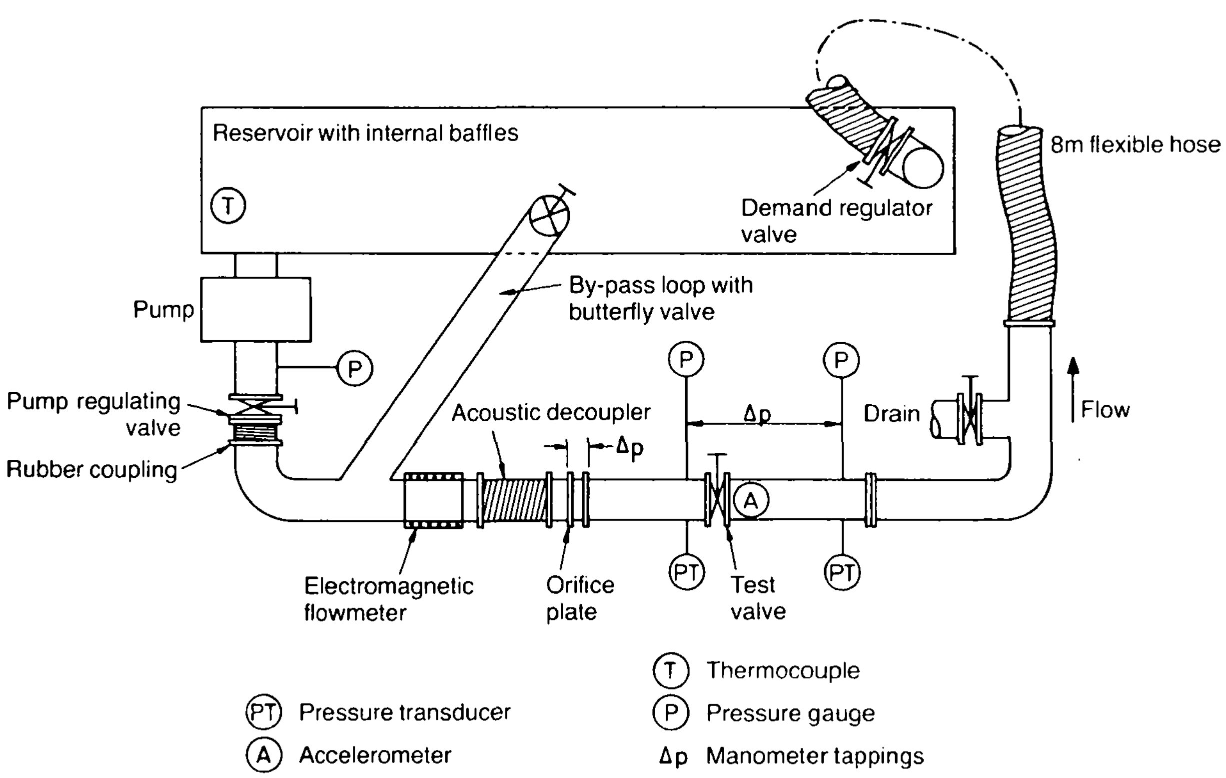

Figure 14 Schematic representation of the PRV Test Rig.

Flows into the test section were measured with an electromagnetic flowmeter installed to manufacturers' recommendations.

Downstream of the electromagnetic flowmeter a 108mm orifice plate provided an in situ check on the electromagnetic flowmeter and also conditioned the flow structure for measurements taken at the test valve. Pressure measurements taken two diameters upstream and six diameters downstream of the test valve were made with piezo resistive pressure transducers and 10 inch dial standard test gauges.

Pipe wall vibrations were measured with an accelerometer mounted on the pipe downstream of the test valve. These measurements were used to discriminate between the various cavitating states.

Flexible hose returned the flow of water via a gate valve to the reservoir. Although the gate valve is not considered ideal as a control valve, its installed flow characteristic proved satisfactory for this series of tests.

The vast quantity of data required for the characterisation of any particular valve necessitated a computer logging system. With the exception of noise measurements all data from the instrumentation was collected by mini computer.

Noise data was taken manually using rms meters, although provision was made for more detailed analysis with a frequency analyser.

3.3 Test Procedures

3.3.1 Valve Installation

At installation the test valve was inspected to ensure no damage had occurred in transit and no dirt had entered into its parts, care being taken to observe each manufacturers' installation and setting up instructions.

Where appropriate, connections were made between the valve position indicator and a position transducer. The attachment of this transducer did not interfere with the natural operation of the valve.

For self actuating valve styles a hand operated bleed valve was connected directly to the control space. This greatly simplified the process of bleeding air from the control space and pilot assembly. The attachment of this valve in no way interfered with the natural operation of the test valve.

Once installed the rig was pressurised and any leaks from either the pilot assembly or main flanges cured.

3.3.2
Test Preparation

The following check procedure was observed prior to the commencement of any particular test:

(a) The pipework was completely filled with water and the discharge pipes were fully submerged in the reservoir so as to minimise air entrainment which would adversely effect cavitation measurement.

(b) All free air was bled from the test valve.

(c) The test valve was confirmed in the fully closed position.

(d) A check of zero flow and pressure readings at the digital display unit was made.

(e) A check of background noise level from the accelerometer was made.

Only when these checks had been satisfactorily completed did testing begin.

3.3.3
Test Methods

In the following section the four tests used to assess rangeability and controllability performance of the valve are described. These are:

(i) Fully open valve testing.
(ii) Inherent valve characteristic testing.
(iii) Controllability testing.
(iv) Cavitation testing.

All valves were tested in the same way for a range of system head/flow characteristics so that the results are directly comparable and applicable to any distribution system. In conducting these tests, the manufacturers' cooperation was sought and obtained in setting up their valves and agreeing the test criteria.

3.3.3.1
Fully Open Valve Test

The purpose of this test was to define the hydraulic loss through the valve when fully open. This loss can be expressed by the valve flow coefficient (C_v) a term used by valve manufacturers. In this report it expresses the flow rate (Q) in litres/second passing through the valve at a loss of one metre head. At other flow rates the headloss through the valve is equal to the flow divided by C_v all squared, $(Q/C_v)^2$, enabling the fully open headloss boundary on the rangeability maps to be produced for any set downstream pressure. It is important to realise that the magnitude of the fully open C_v value is dependent on the units used and published C_v values should be carefully checked to determine which flow and pressure units are expressed.

3.3.3.2
Inherent Valve Characteristics

The inherent valve characteristic is the relationship between valve position, expressed in terms of percentage opening and the valve flow capacity expressed in terms of percentage of fully open C_V.

3.3.3.3
Cavitation Testing

The purpose of these tests was to determine the limits of cavitation within the valve so that both noise and the risk of physical damage to the valve can be avoided.

Cavitation is a phenomenon which occurs within PRVs when the water pressure immediately downstream of the valve element falls to the vapour pressure of the liquid. When this occurs vapour bubbles appear. As these move away from the valve element they collapse back into the liquid. This initially causes noise within the valve and ultimately erosion of the metal of the valve element.

Two cavitation limits have been included in the rangeability maps.

Incipient cavitation is the point at which noise is first generated. Although this does not pose a problem as regards physical damage it denotes the onset of significant noise generation which could be important in residential areas.

Critical cavitation is the point at which minor damage to the valve or pipework would be expected to occur. Valves should not be operated beyond the critical cavitating condition for any significant time.

3.3.3.4
Controllability Testing

The main purpose of these tests was to establish:

(i) the accuracy and manner in which the valve controlled its outlet pressure.

(ii) the point at which persistent hunting took place, i.e. the valve was unable to maintain a stable outlet pressure.

Noise measurements were also taken in these tests and used to supplement the cavitation testing data.

Constant outlet PRVs

For these valves, tests were conducted for accuracy of control of set downstream heads of 20, 40, 60, 80 and 100 metres head over the five upstream head/flow characteristics given in Figure 15.

This resulted in fifteen controllability tests per valve (fewer tests were possible at higher set pressures).

In conducting these tests the upstream head flow characteristic was set on the test rig and the valve adjusted to produce the chosen downstream pressure at a chosen point on the system characteristic curve. The flow through the rig was then slowly altered, by varying the demand regulator valve, so that the valve was subjected to a different flow rate and upstream pressure on the system characteristic curve and the valve allowed to stabilise.

If stability was not achieved within 5 minutes the valve was considered to be hunting and the flow and upstream pressure at which this occurred was used to construct the hunting boundary.

If the valve did stabilise the new downstream pressure was recorded and used to produce the controllability tables.

New flows, by demand regulator valve adjustments, changed the upstream head for the particular upstream head/flow characteristic and the test was repeated. The other simulated upstream head/flow characteristics were tried in turn and the tests repeated.

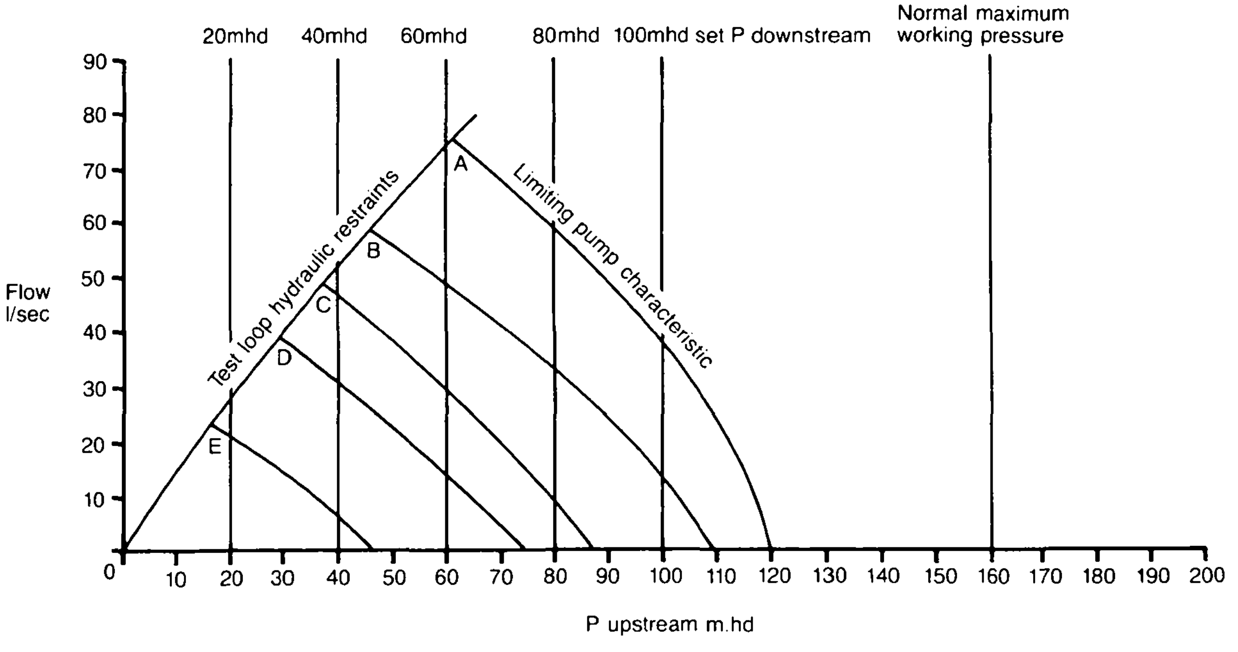

Figure 15 Upstream head flow simulated system characteristics used for controllability testing.

3.3.4 Results of the Test Programme

To date tests have been completed on the following valves:

Type 1 PRVs	Guest and Chrimes 6DC.
Type 2 PRVs	Glenfield 1301 Blakeborough/Golden Anderson Guest and Chrimes 6DR Inbal 500R Rollseal 110 PR Claval Hytrol Jordan 67 DeZuric 100

The results for the above valves are in 'The Performance Atlas', TR238: Part 2.

Selection of Pressure Control Valves 4

4.1 Introduction to the Selection of Pressure Reducing Valves

The selection of the most appropriate PRV for a given installation is dependent upon a number of criteria. It is first necessary to choose from engineering data in the 'PRV Performance Atlas', TR 238: Part 2, the most suitable models of PRV for a particular application. This shortlist of potentially suitable valves should be checked against such factors as price, installation and maintenance requirements as well as operating costs.

This process allows the most suitable make and size of valve to be selected using the performance data discussed earlier confident that the valve will perform satisfactorily and at minimum cost.

The manner in which the performance data can then be used to make the final selection of make and type of valve is described in Section 4.2.

4.1.1 Use of Performance Data

For any PRV, performance data is presented on two diagrams:

(a) The rangeability map.

(b) The inherent valve characteristic, a plot of % opening versus % of fully open C_v.

These two diagrams form the basic tool which enables the correct size and type of valve to be selected for the upstream range of flows and pressures. The selection process is described for both fixed outlet head, types 1 + 2, as well as flow modulated, types 3 + 4, PRVs.

The maps can also confirm the correct sizing of existing PRV installations.

4.2 Data Collection

4.2.1 Characterising the Network

The characterisation of the distribution network is best achieved by network analysis, as described in WRc publication TR177[(4)], TR237[(5)] and TR242[(6)]. An inferior method would be pressure and flow surveys. The network features that need to be identified are:

(a) The AOD ground level of critical points for consumer supply, usually the high spots or the most distant supplies but can also be the tallest building.

(b) The headloss in the distribution system between the proposed PRV site and the critical point for the range of flows.

(c) The range of flows and upstream pressures that the valve will have to cope with.

(d) The minimum supply pressure at the critical points.

(e) The AOD ground level at the proposed PRV site.

The variation in AOD head, pressure plus ground level, at the target node compared to that at the proposed PRV site over a daily cycle will show whether or not the network is characterised by high hydraulic resistance. High hydraulic resistance characteristics would show large pressure variation from minimum flow to maximum flow. As a guide, if the pressure variation is less than 10m, this would indicate a low hydraulic resistance network.

A low hydraulic resistance network would indicate the use of a Type 1 or Type 2 fixed head PRV.

A high hydraulic resistance network would indicate the use of a flow modulated PRV, Type 3 or 4 provided it was economically justified. The cost of water is a major factor when contemplating type 3 or 4 valves.

4.2.2 Field Data – Type 1 and 2 Fixed Head PRV

The only prerequisite to use the maps is a knowledge of the supply (upstream) pressure and flow at the proposed PRV site and a histogram of flow class against frequency. The pressure/flow data can be obtained from the network analysis model by running the model at minimum, maximum and intermediate demands. Simulation programs can also be used for this purpose. Analysis of a 24 hour flow pattern yields the histogram data.

Other methods demand the measurement of daily simultaneous flow/ pressure patterns at the proposed PRV site. This can be achieved by the use of insertion meters, with tappings in the gland for pressure transducers. The arrangement can be connected to a data logger and the simultaneous pattern recorded. Details of the methods of installing a Quadrina turbine insertion meter, both standard and mini versions are described in WRc publication 'District Metering Part 1 System Design and Installation', ER180E[3].

Any alternative method of obtaining a synchronised flow and pressure pattern such as existing flow meters and nearby fire hydrants is equally satisfactory.

The data can be analysed to obtain the histogram of flow class and frequency. The flow class can be 0–1 litres/second or 0–5 litres/second, for example, depending on the range of flow rates. The frequency would normally be the time in hours that a particular flow class occupies. If logged data is used then analysis of the flow/time graph yields the required diurnal flow distribution. This transformation is illustrated in Figure 16.

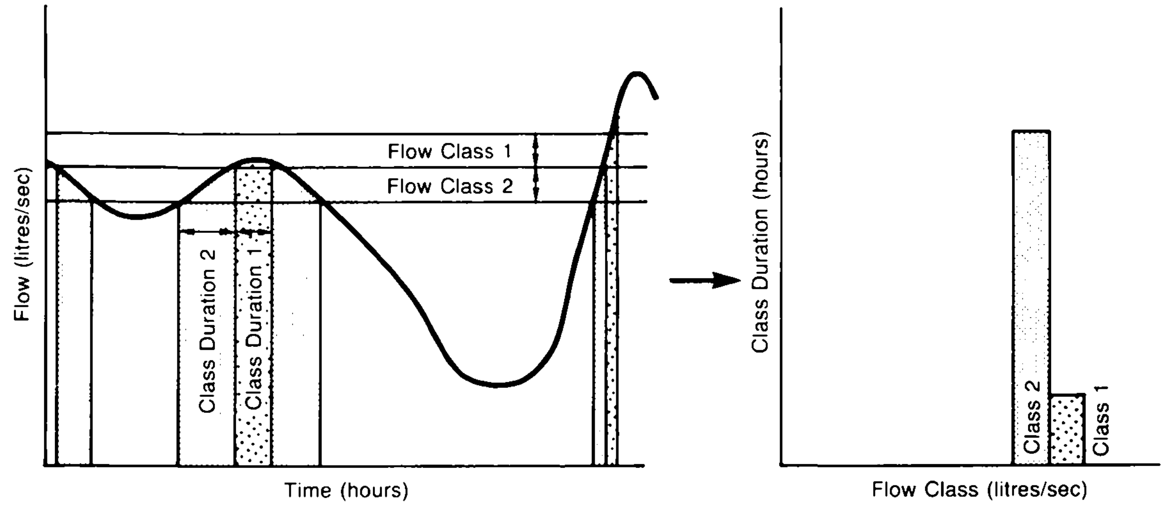

Figure 16 Transformation of FLOW/TIME data to HISTOGRAM form.

The synchronised flow and pressure data is plotted on to translucent graph paper. Supply pressure, metres head, versus flow, litres/second, equally scaled so that one centimetre represents both 10 metres head or 10 litres/second. This scaling matches the published PRV data. If the recorded data does not include the highest seasonal flow or the lowest night flow these should be extrapolated and included in the pressure/flow plot. These extrapolations should not include far future predicted flows since this will result in oversizing the PRV. PRVs are best thought of as plug-in devices with an operational life of 5 years maximum. The PRV will not be worn out at this stage and can be used on another scheme when the new demands require the next larger size. The civil engineering of the pit should include provision for fitting a larger PRV.

Fire fighting flows should not normally be included in the pressure/flow plot because most fires are put out using the contents of the tanks of the attending engines. Major fires will require alterations to the distribution system to provide cooling water for surrounding buildings so that installation of PRVs on bypass arrangements will cope with this situation. The balance of advantages for satisfactory pressure reducing valve operation lie with decreasing the size of the valve rather than the other way about. If an area has a particularly severe risk then this may limit the scope for pressure reduction.

The required downstream head AOD can be determined by the sum of:

The head AOD required at the critical node.

The maximum headloss between the proposed PRV site and the critical node.

The downstream head is normally set so that peak flows are catered for at the minimum target head. The downstream set gauge pressure is obtained by subtraction of the ground level at the PRV site.

It is useful to remember that the set downstream pressure of a PRV has a controllability error and this is minimum at the flow at which the pressure was set. This can be exploited by carefully studying the flow pattern of the data and choosing to set up the PRV at the flowrate to minimise the effects of this controllability error. This might be the flowrate that most often re-occurs or may be the most critical flowrate. The histogram of flow distribution is invaluable in these circumstances.

The downstream pressure of the PRV is obtained for the critical flow say Q_{max} by $P_{out} = GL_{target} + SL_{target} + H_L - GL_{PRV}$

where P_{out} = downstream gauge pressure of PRV (m hd)
GL_{target} = AOD level at critical (target) point in network (m)
SL_{target} = minimum pressure service level at target (m hd)
H_L = friction loss in pipes connecting PRV to target (m hd)
GL_{PRV} = AOD level at PRV site (m)

4.3 Valve Selection using the Valve Performance Data

4.3.1 The Rangeability Map Type 1 + 2 PRV

As can be seen from the example in Figure 17, the rangeability map is plotted as system upstream pressure in metres head against flows measured in litres per second. The useful range of PRV performance is circumscribed by flow capacity, inherent unstable operation and critical cavitation. The flow capacity is described by the fully open CV boundary defined as the set downstream pressure plus the inherent headloss through the valve. The maps are based on a fixed series of set downstream pressures from 20 metres head to 100 metres head at 20 metre head intervals. The actual position of the boundaries varies with the style of the valve and the particular set downstream pressure. Two other boundaries can occur and these represent areas which indicate caution in selecting a valve for a particular duty. The first is a boundary labelled 'possible noise nuisance'. Data which maps over this line towards the critical cavitation boundary has reached the incipient cavitation stage and could give noisy operation although not being physically damaged by this stage of the cavitation process. Hydraulically operated valves have another boundary placed inside the fully open CV representing a manufacturer's recommendation for the minimum operating differential pressure. The rangeability map titles show the particular set downstream, the size of the valve, the numerical value of the fully open CV and the controllability classification. Fully open CV is defined in Section 3.3.3.1 and the controllability classification in Section 3.1.2. Each type of valve has its own set of maps which are contained in the 'PRV Performance Atlas, TR238: Part 2'.

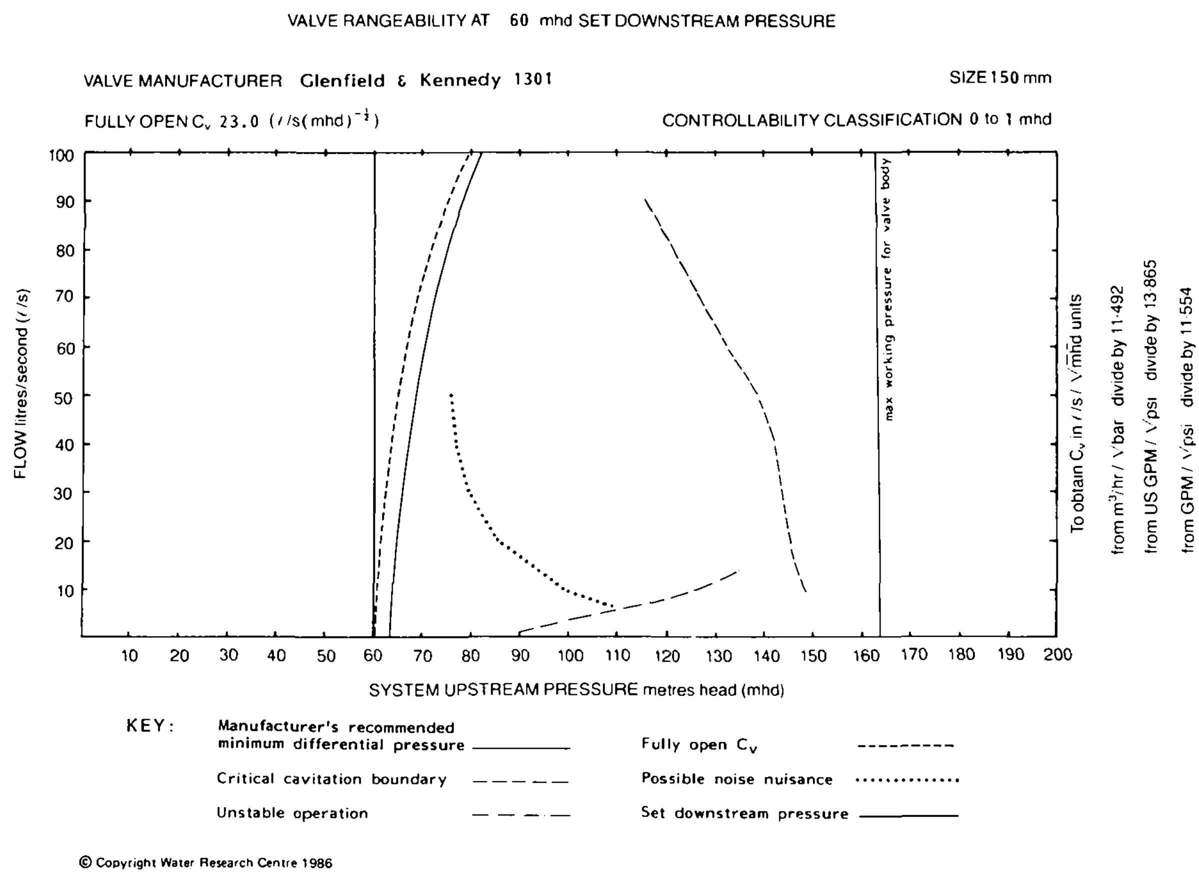

Figure 17 An example of a Rangeability Map.

Figure 18 shows an example of the measured upstream pressures and flows plotted on translucent graph paper. A vertical line is drawn to represent the nearest mapped downstream pressure. The translucent paper is laid on each valve model's map in turn aligning the vertical with the appropriate set downstream pressure point.

Using the interpretation guidelines discussed in 4.3.2 a shortlist of suitable valve styles is drawn up. When selecting the nearest downstream pressure, choosing the lower map set pressure predicates a more pessimistic set of conditions. This may be an advantage under some circumstances.

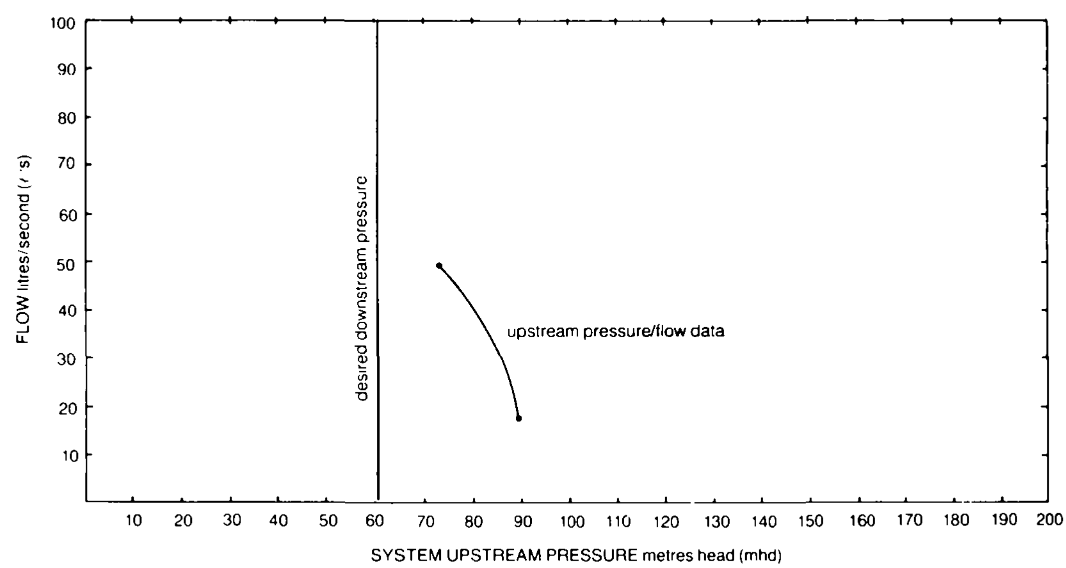

Figure 18 *Plot of measured data on translucent graph paper.*

4.3.2 Interpretation of the Rangeability Map

Figures 19 to 25 are to guide engineers in the interpretation of data applied to maps.

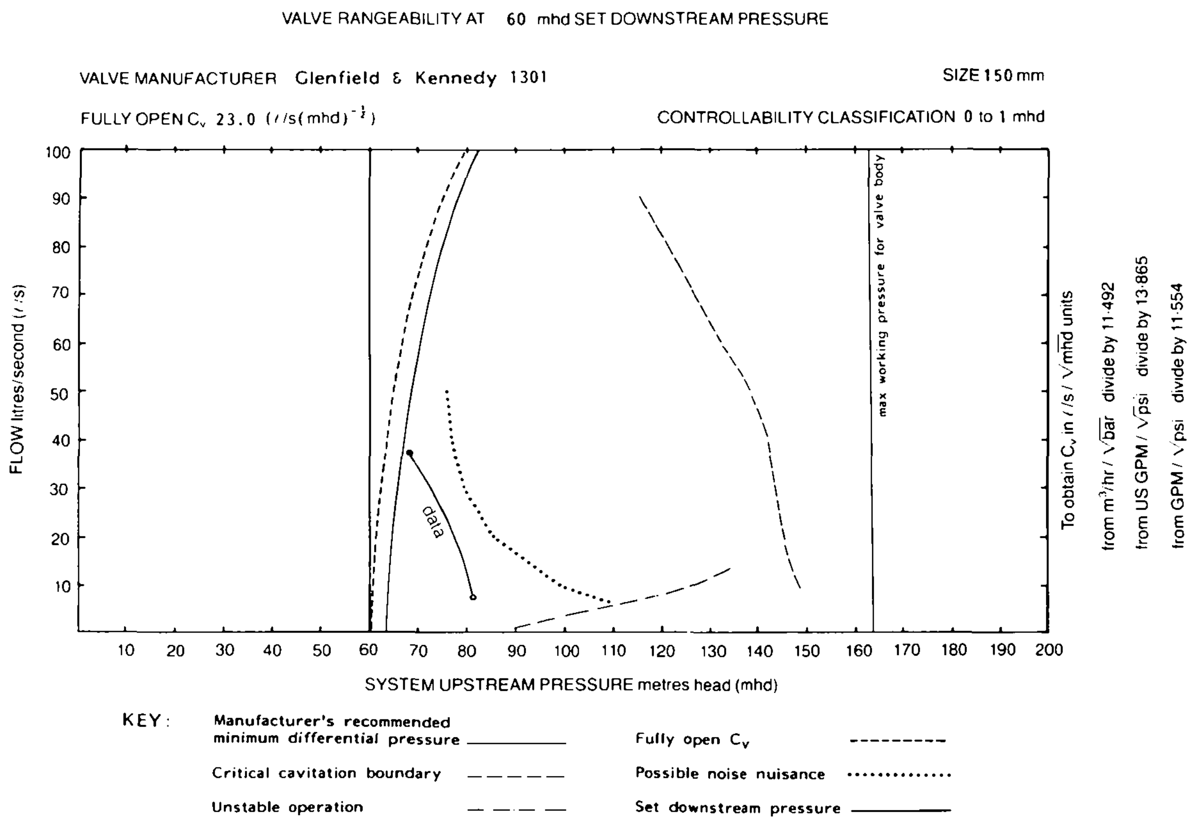

Figure 19

The data maps within the boundaries – valve suitable for the purpose.

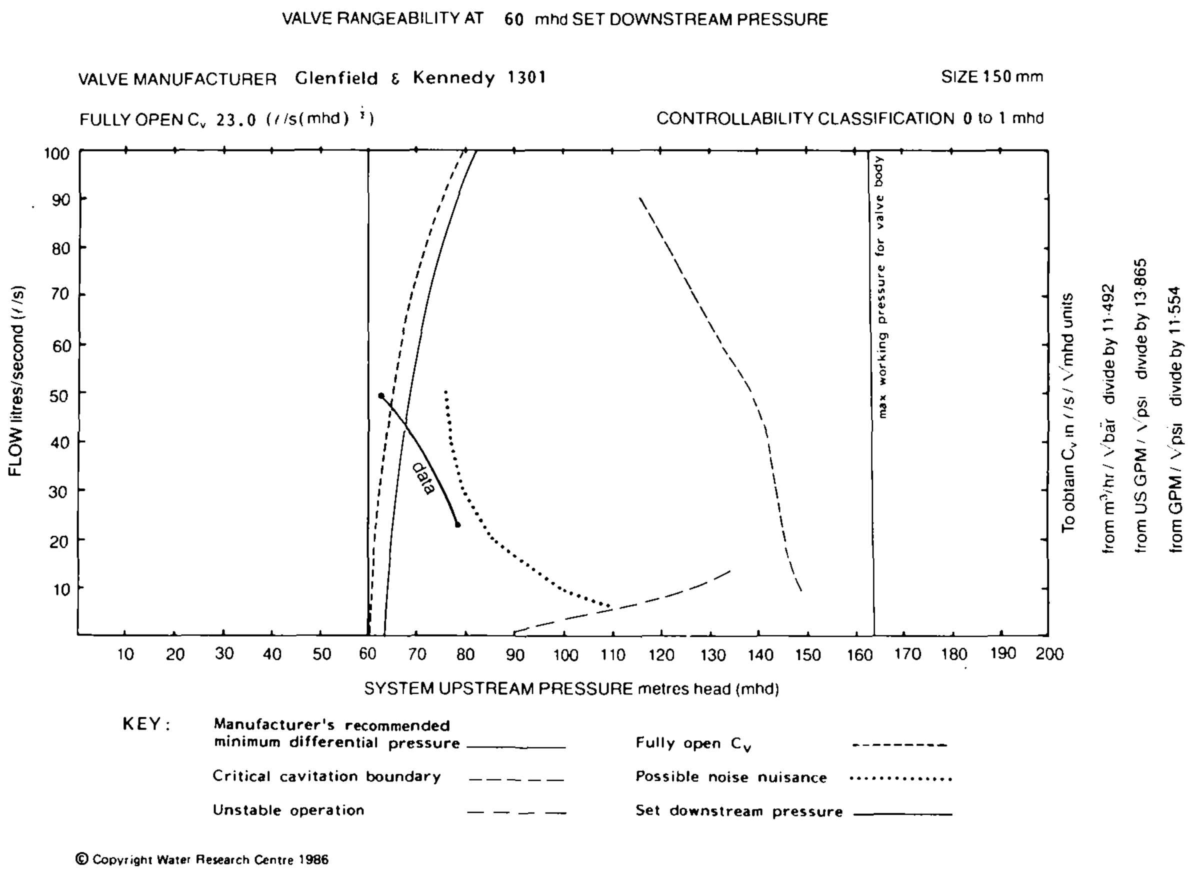

Figure 20

The data maps over the fully open C_V boundary – larger valve required. The histogram may indicate that the range of flowrates that have exceeded the fully open C_V boundary occupy such small periods of time that it may be possible to allow the valve to open fully. If this latter case is true then the manufacturer should be informed of the intention.

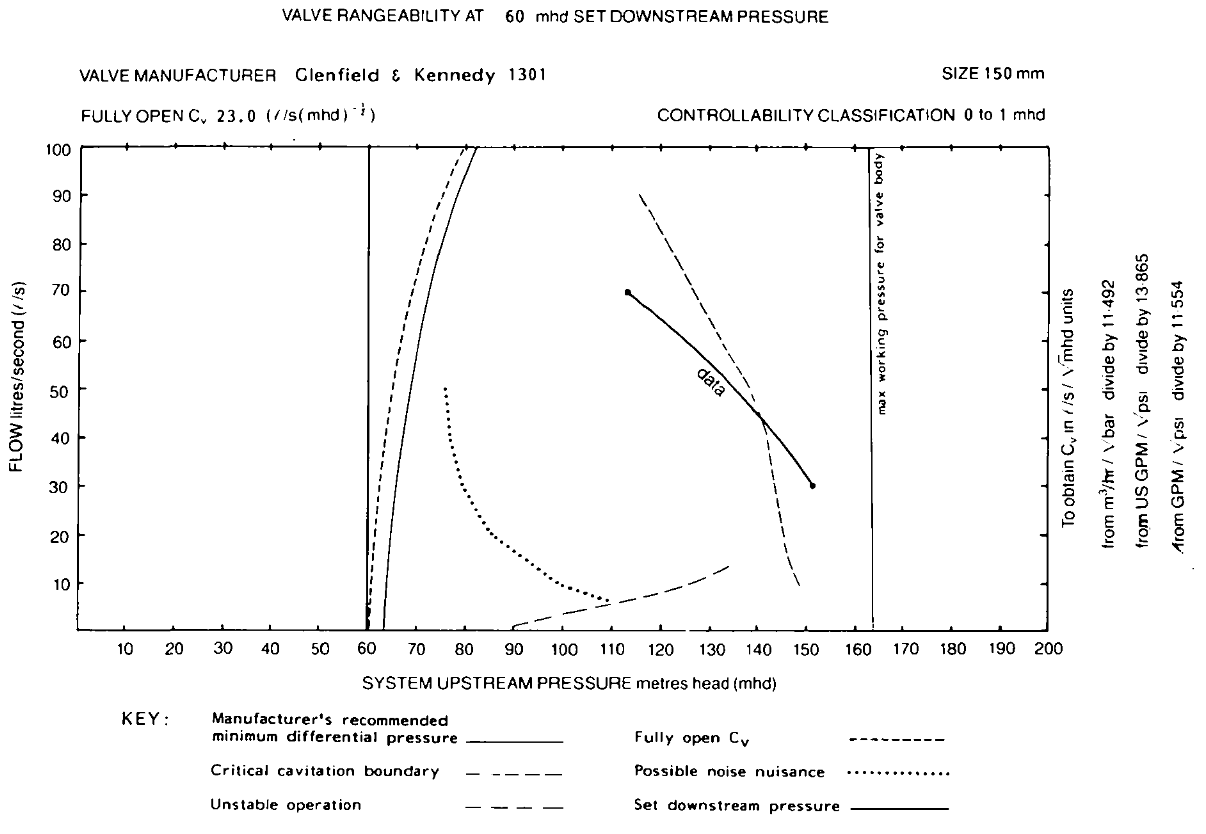

Figure 21

The data maps over the critical cavitation boundary – larger valve or different style required.

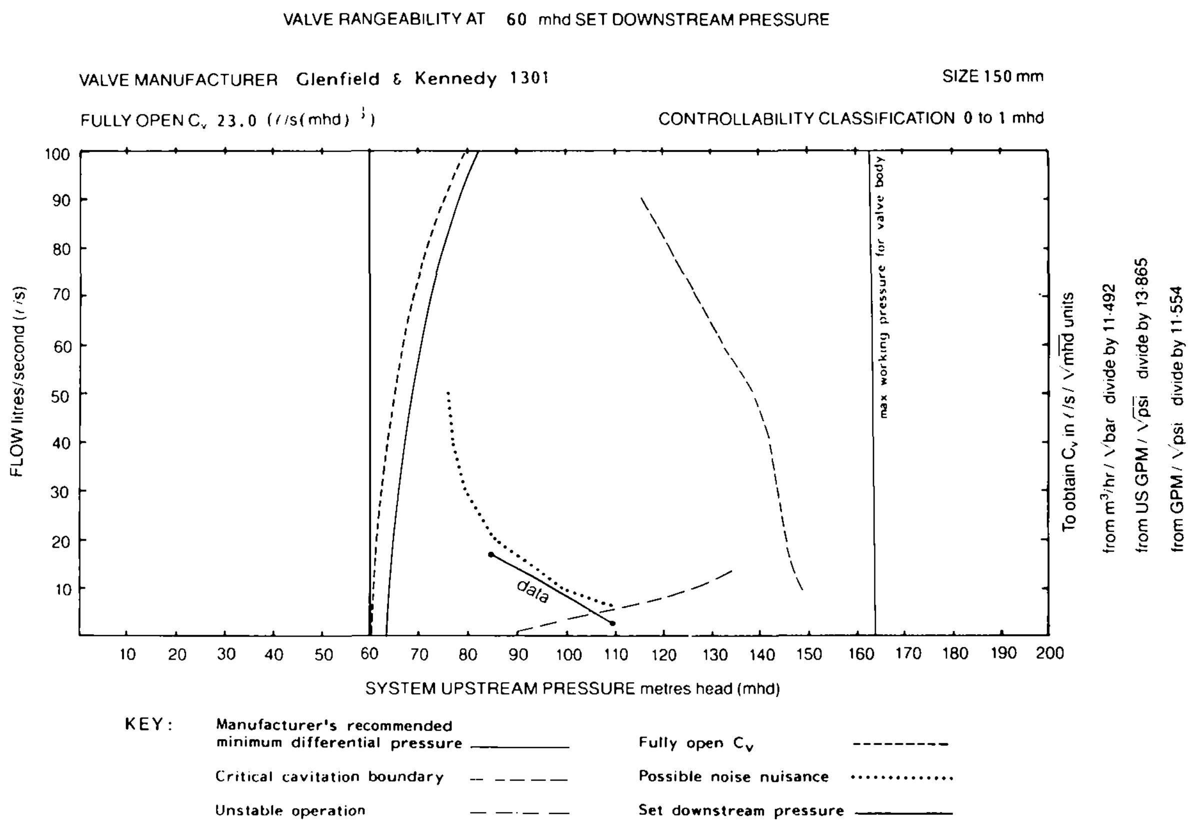

Figure 22

The data maps in the region of unstable operation – smaller valve required.

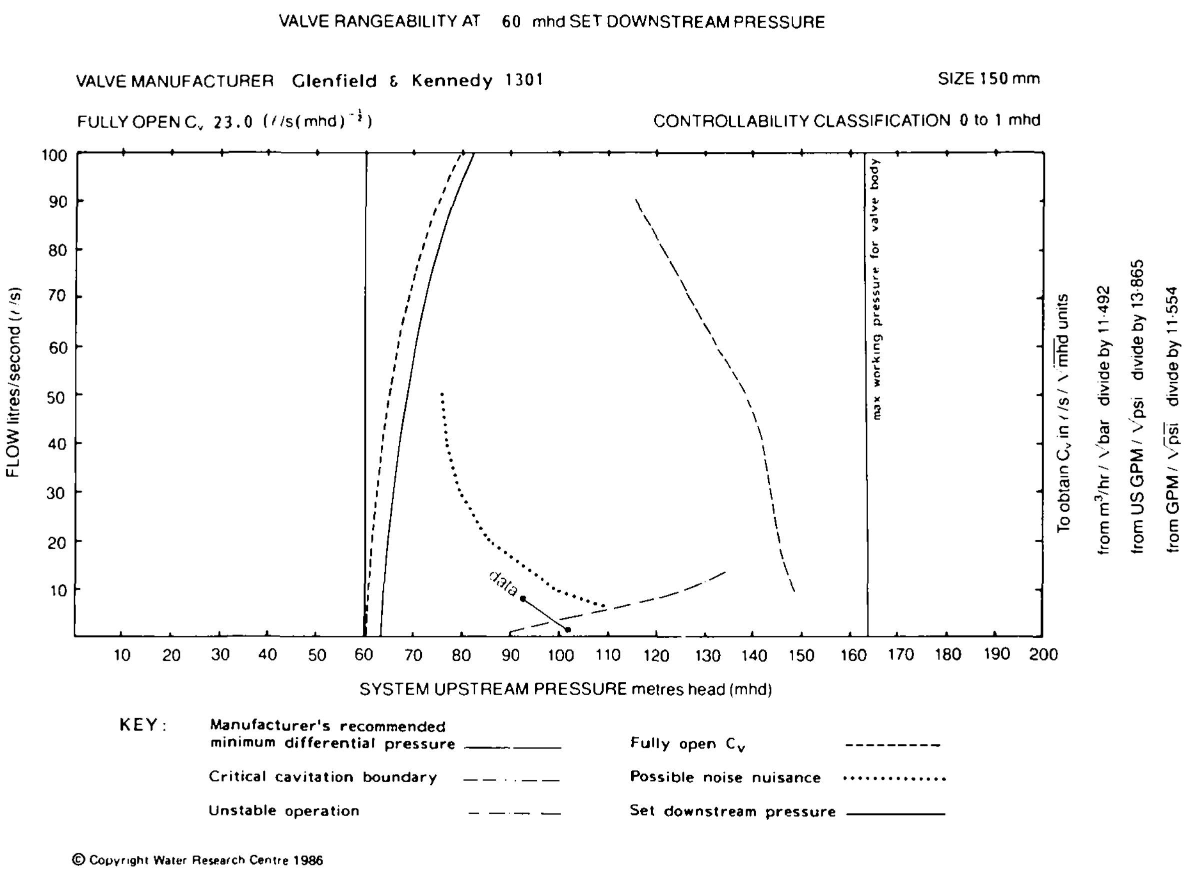

Figure 23

The data maps in the region of low flows and crosses the region of unstable operation – smaller valve or different style required.

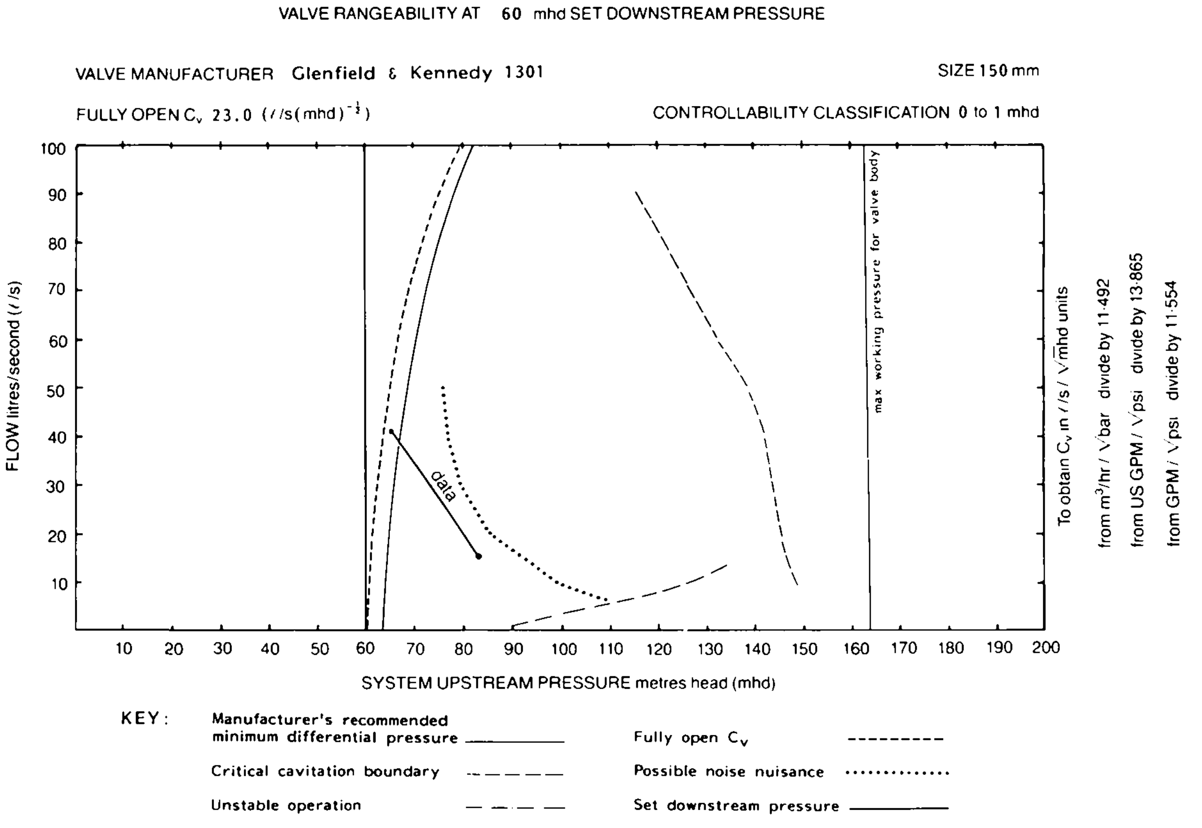

Figure 24

The data maps within the minimum differential pressure line – consult manufacturer about proposed service conditions.

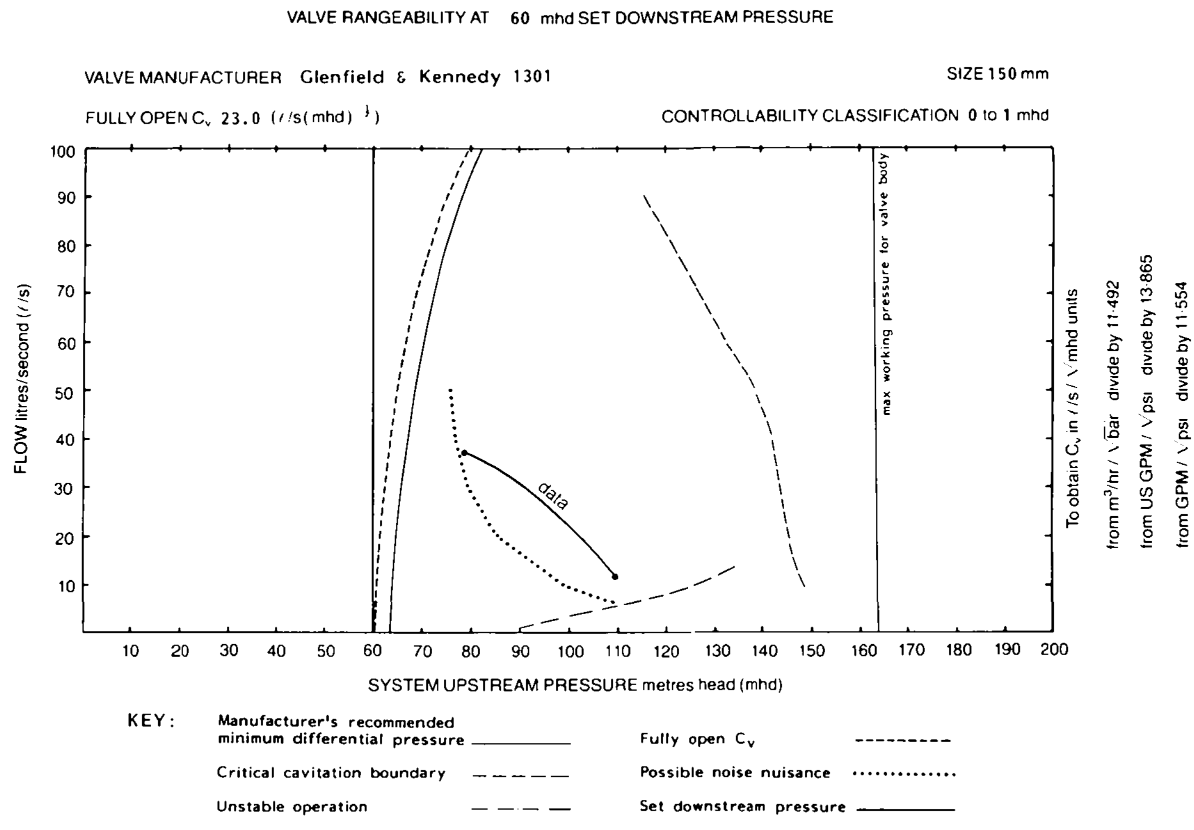

Figure 25

The data maps beyond the noise nuisance boundary and could be troublesome in built-up areas.

4.3.3 The Inherent Valve Characteristic

The previous section ended with a shortlist of valve candidates. The inherent valve characteristic, a plot of % C_V versus % opening, is used to re-examine the candidates. Figure 26 shows a typical plot which is supplied for every valve type except diaphragm types.

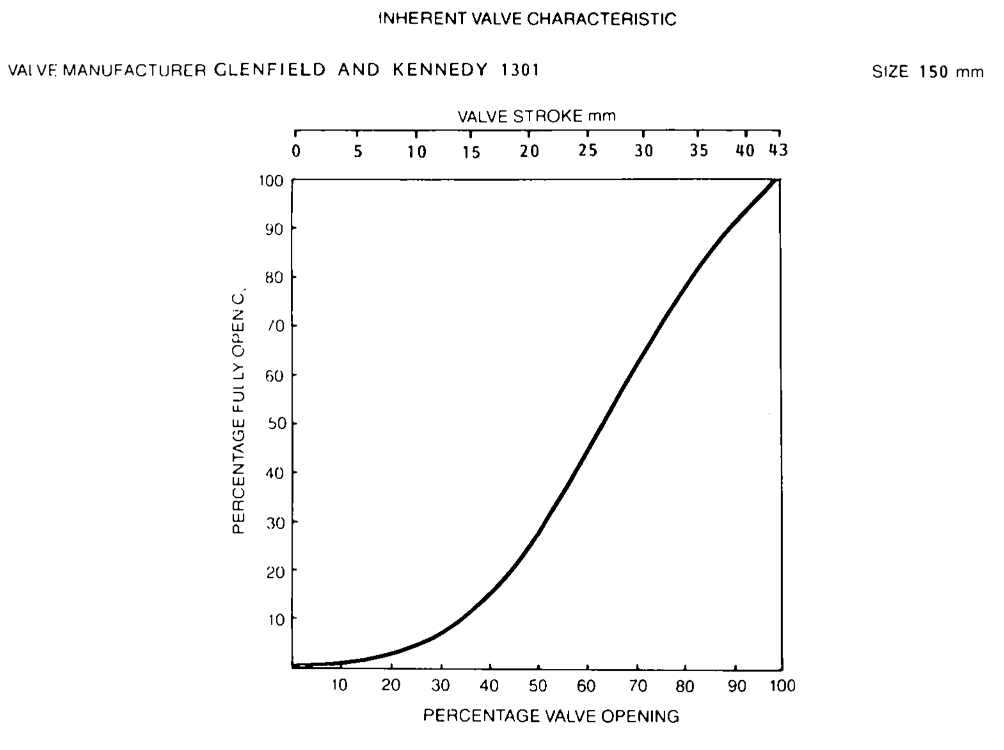

Figure 26 An example of a plot of inherent valve characteristic.

The shape of the characteristic and the value, (in litres/second, (m hd)$^{-1/2}$) units, of the fully open flow coefficient (100% C_V) will both vary from one valve to another.

The fully open C_V value has been found during the test for each valve and is written on the rangeability map for each valve type. An example is shown in Figure 27. The relevant fully open C_V test value is shown on every rangeability map published in 'The PRV Performance Atlas', TR 238: Part 2. Conversion factors allowing C_V to be expressed in flow and pressure units other than litres/second and m hd are printed in the right margin of the rangeability map. Manufacturers' data should be treated with caution until the units have been established.

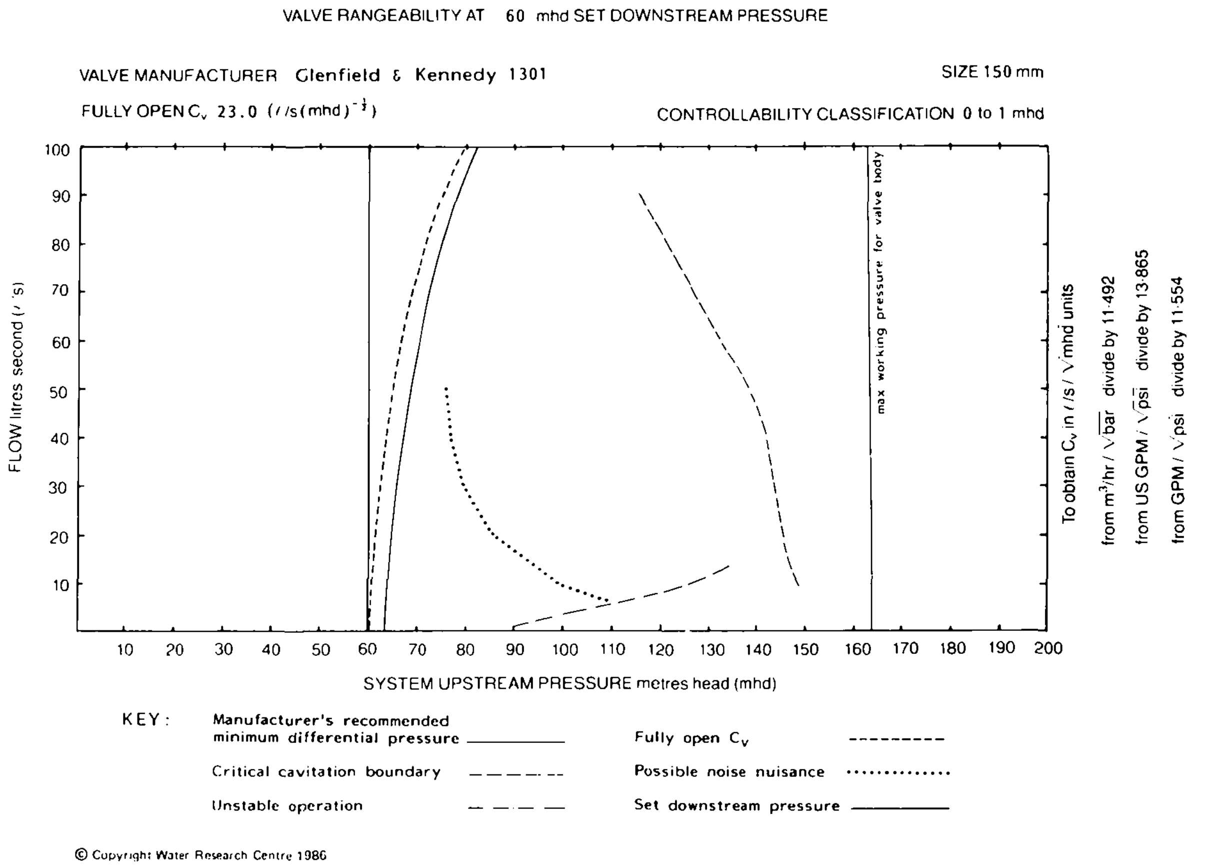

Figure 27 An example of fully open C_V value (litres/second (m hd)$^{-½}$)and conversion factors.

The percentage valve opening can be transformed to the rangeability map format by use of the percentage opening curves, an example of which is shown in Figure 28. The Performance Atlas, TR238: Part 2 contains detailed curves for every model tested except for diaphragm types.

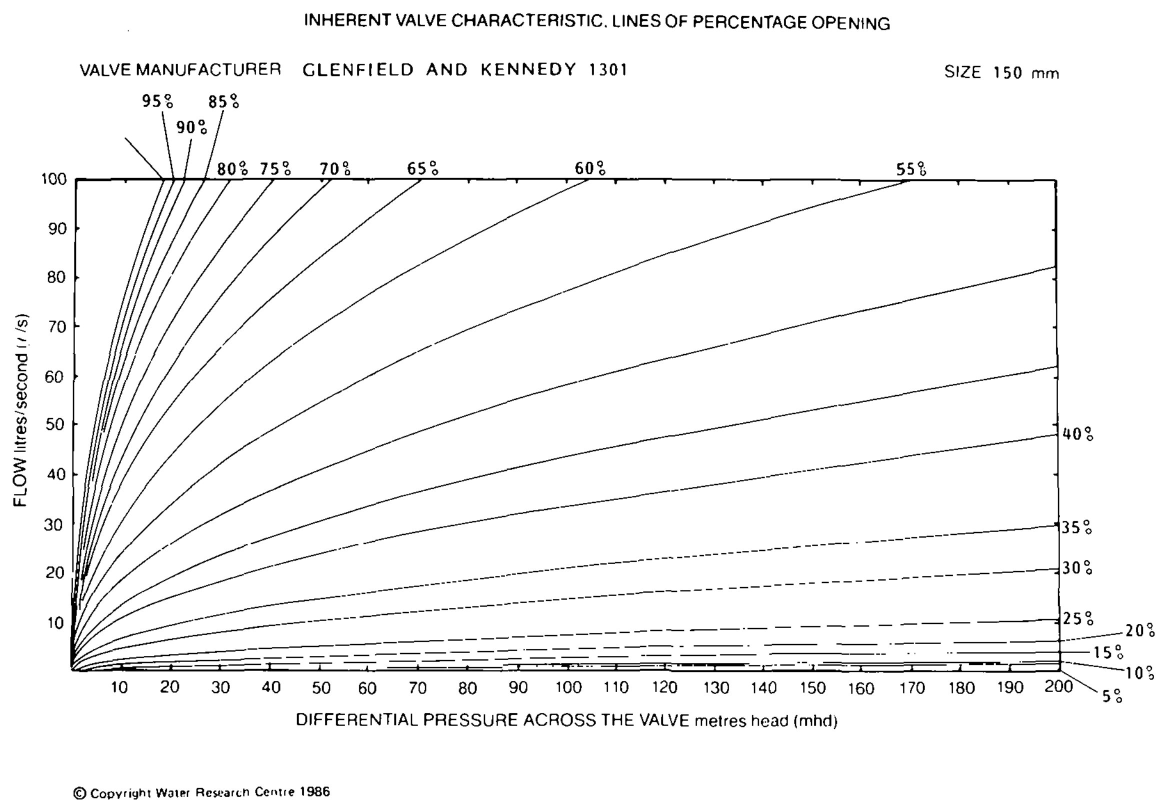

Figure 28 Example of plot of inherent valve characteristic, lines of percentage openings.

The data plotted on translucent paper can be applied to the percentage inherent valve characteristic, lines of percentage opening diagram and the range of percentage opening found. The marked position of downstream set head must be lined up with origin of the graph shown in Figure 28. This range of lift can be transposed to the inherent valve characteristic shown in Figure 26 and the position and maximum and minimum value of percentage C_V can be easily checked. The range of C_V in numerical terms can be calculated by reference to the fully open C_V value which is the same as 100% C_V.

The working range of valve stroke can now be checked for each candidate. Valves with the best range should be retained for further selection. Good and bad examples of the working range are shown in Figures 29 and 30.

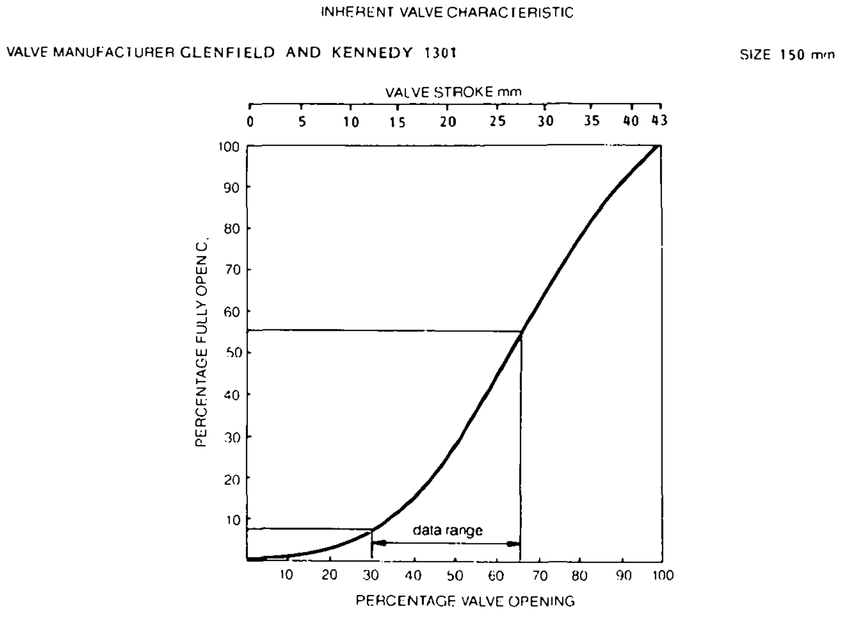

Figure 29

The measured data gives a range of percentage opening that occupies a desirable part of the inherent valve characteristic.

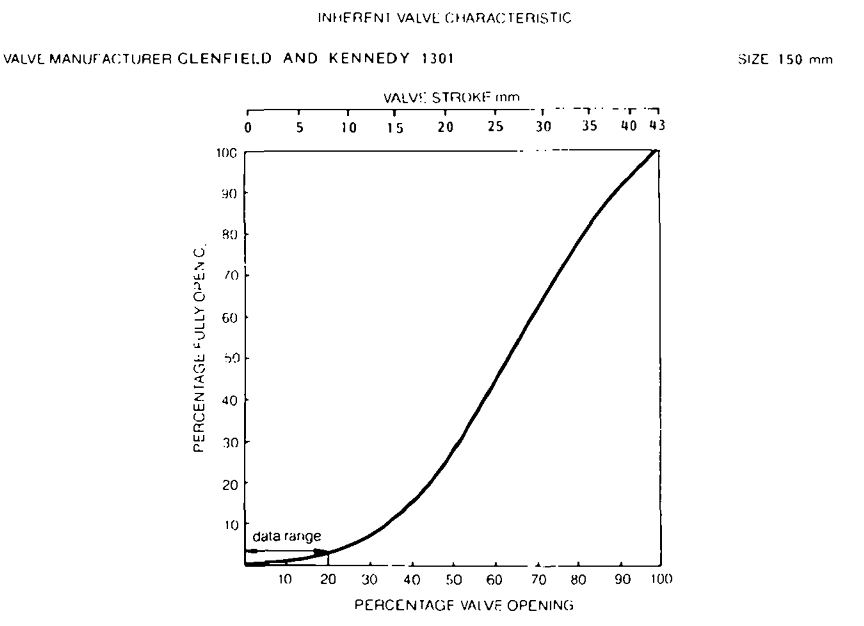

Figure 30

The measured data gives a range of percentage opening that occupies an undesirable part of the inherent valve characteristic. Smaller valve required.

A control valve should be chosen so as to use the largest range of valve opening as possible. Further, the stroke should not spend long periods at the low end which means that the valve is operating much too close to its seat and will almost certainly be unstable. The histogram is used to determine the hours that particular flow rates occupy. A valve that fully opens for a small portion of the day or year need not be rejected if it is desirable on other grounds.

This again points to use of the smallest sized valve that will cope with the measured flows.

The valve should also work, as far as possible, on the most linear portion of its characteristic.

In the unusual event of a valve having to work fully open during part of its duty cycle, the fully open hydraulic loss has to be considered. The loss can be read from the appropriate rangeability map at the point of intersection of the downstream system curve at the fully open C_V boundary. The size of the loss is given by the difference in pressure between the set downstream pressure line and the fully open C_V line as shown in Figure 31.

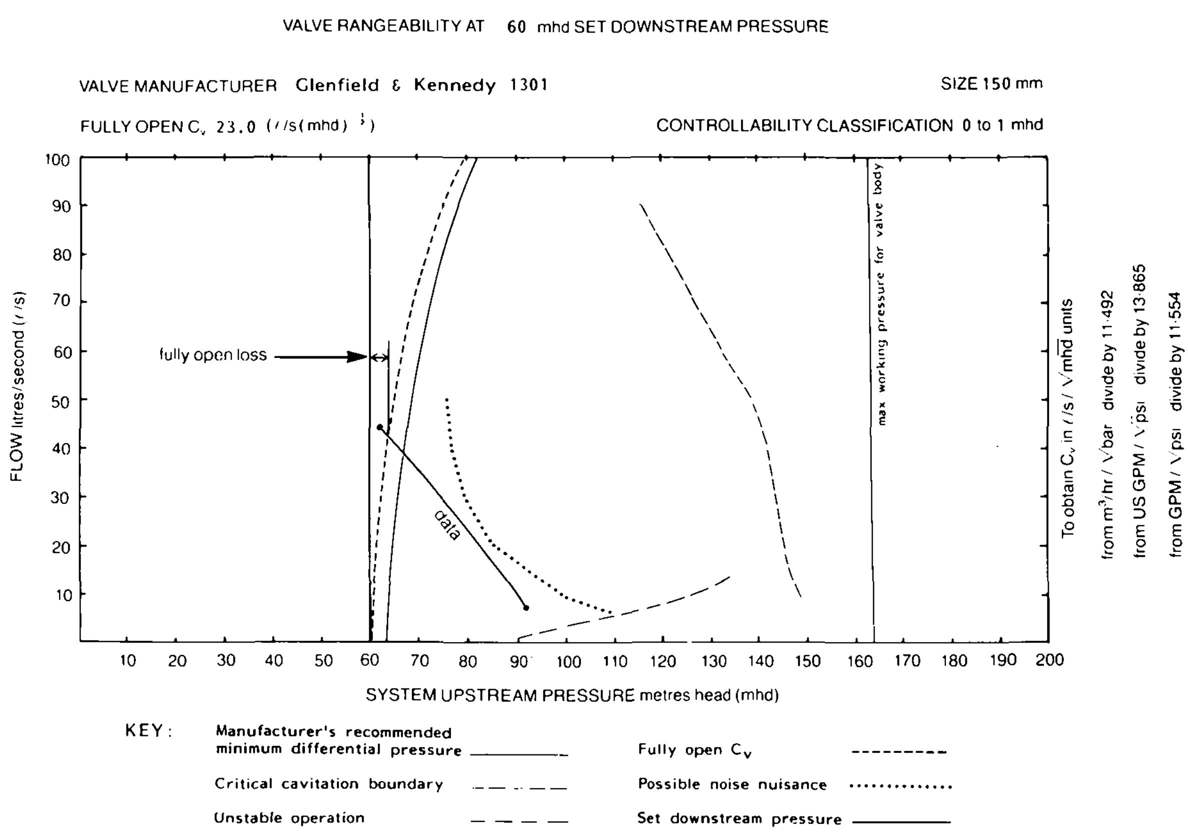

Figure 31 Example of fully open valve loss.

Some styles of valve have a lower inherent loss than others. The higher the value of fully open C_V the lower its inherent or insertion loss. The valve with the lowest insertion loss is not necessarily the best controller. These styles of valves have a control element in an unobstructed body. Virtually all of the required pressure differential has to be dropped across the control element itself. These high differential pressures mean that relatively small valve openings are required to produce the desired control and can result in the PRV working too close to its seat. Low loss valves are most suited to distribution systems which only need small differential pressures across the valve.

Valves with high loss bodies, such as globe styles, lose a proportion of the incoming pressure in friction leaving less to reduce in the vicinity of the valve element. The resulting smaller differentials allow larger valve openings for the same control described above.

4.3.4 Controllability Classification

The remaining candidates are now tested for their controllability characteristics, that is the valve's ability to maintain the set downstream pressure. Each rangeability map has written on it the controllability range, in metres head, of deviation from the set head. This information relates to the experimental results which are discussed in detail in Appendix 2. This is illustrated at the top right of Figure 32.

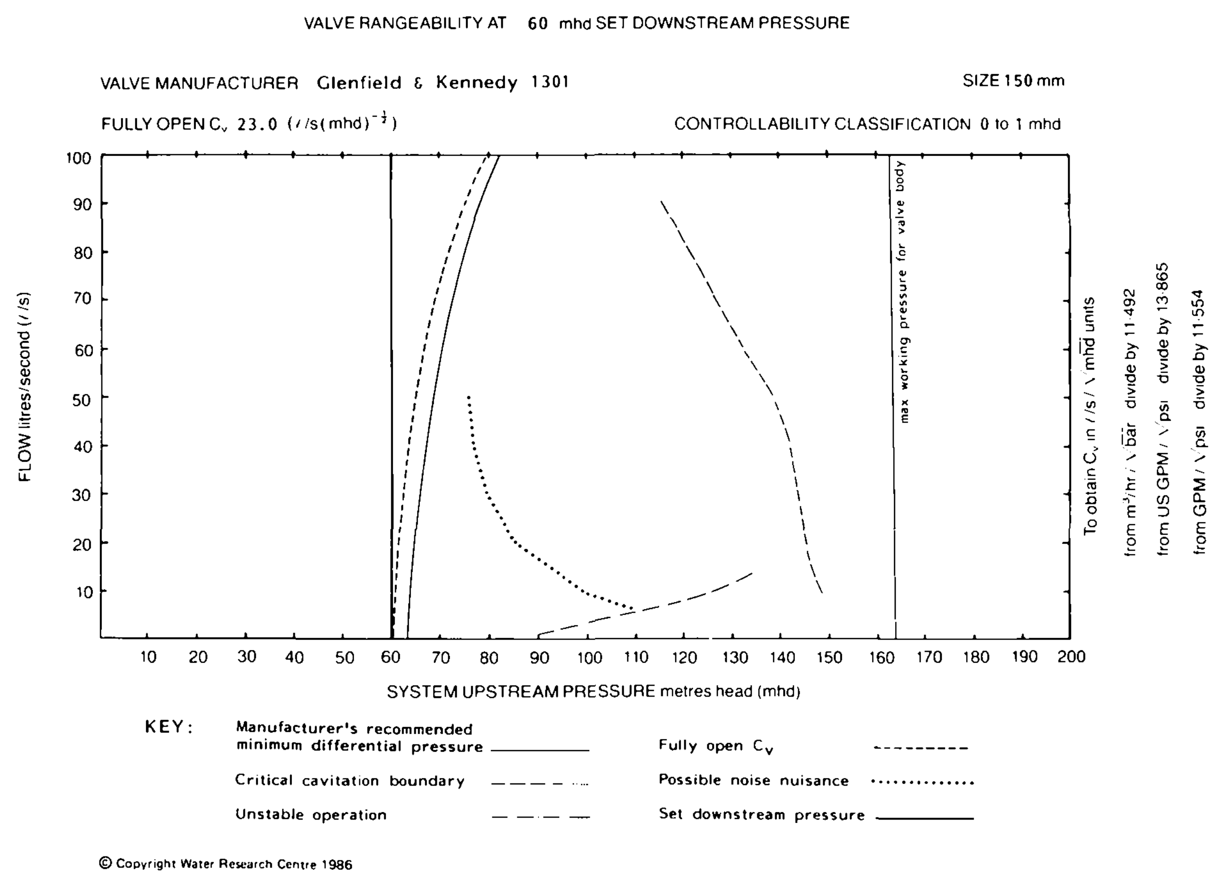

Figure 32 The controllability classification.

The need for accuracy of control of output pressure of PRVs is a function of present or intended level of pressure service at a target consumer. The lower the proposed pressure service level then the greater the need for more accurate control.

The following factors should be borne in mind when deciding on the desirable control constraints for particular networks:

(a) The nature of the target point. This could be either a high point in the topography with no dwellings nearby or a high point with consumers on it. The first case could imply that a degree of fluctuation, providing the hydraulic gradient did not go below ground level, would be acceptable but the second case implies much more attention is needed to maintain a constant pressure. The first case could also be solved by a very accurate controller set to maintain a lower target pressure.

(b) The need to minimise night pressures. Spring loaded diaphragm valves have a tendency for the output pressure to increase with low flows. Spring loaded diaphragm valves could be reserved for situations where a narrow diurnal range of flows is experienced.

(c) Additionally, other factors in the level of service concept for water distribution networks also impinge on the choice of PRV. These other factors include continuity of supply with its attendant considerations of PRV reliability and maintenance. Dirty water and taste and odour problems can relate to materials used in the PRV design as well as the maintenance of the design upstream and downstream network conditions. Changes in either network operation or expansion of services should prompt a measured reassessment of the flow and pressure conditions relating to PRV performance.

Any rejections from this process will have shortened the list again and this will now represent the PRVs that fit the hydraulic performance criteria that have been applied. The shortlist is now looked at from the viewpoint of site requirements.

4.4 Siting the PRV

4.4.1 Site Requirements

It is desirable to minimise pressure differential across the PRV particularly at low flows as this can lead to instability and noisy operation. At the same time a minimum pressure differential at highest flows is required to ensure reliable operation of a hydraulically operated PRV. If this is less than 10m hd then the manufacturer should be consulted.

The simplest savings implications of pressure reduction schemes dictate that the lowest outlet pressures (gauge) be used. Pressure reducing valve rangeability maps increase the area of satisfactory operation available as the set downstream pressure (gauge) increases. This can be seen by comparing the examples of 20 metre head and 40 metre head set downstream pressure rangeability maps in Figures 33 and 34.

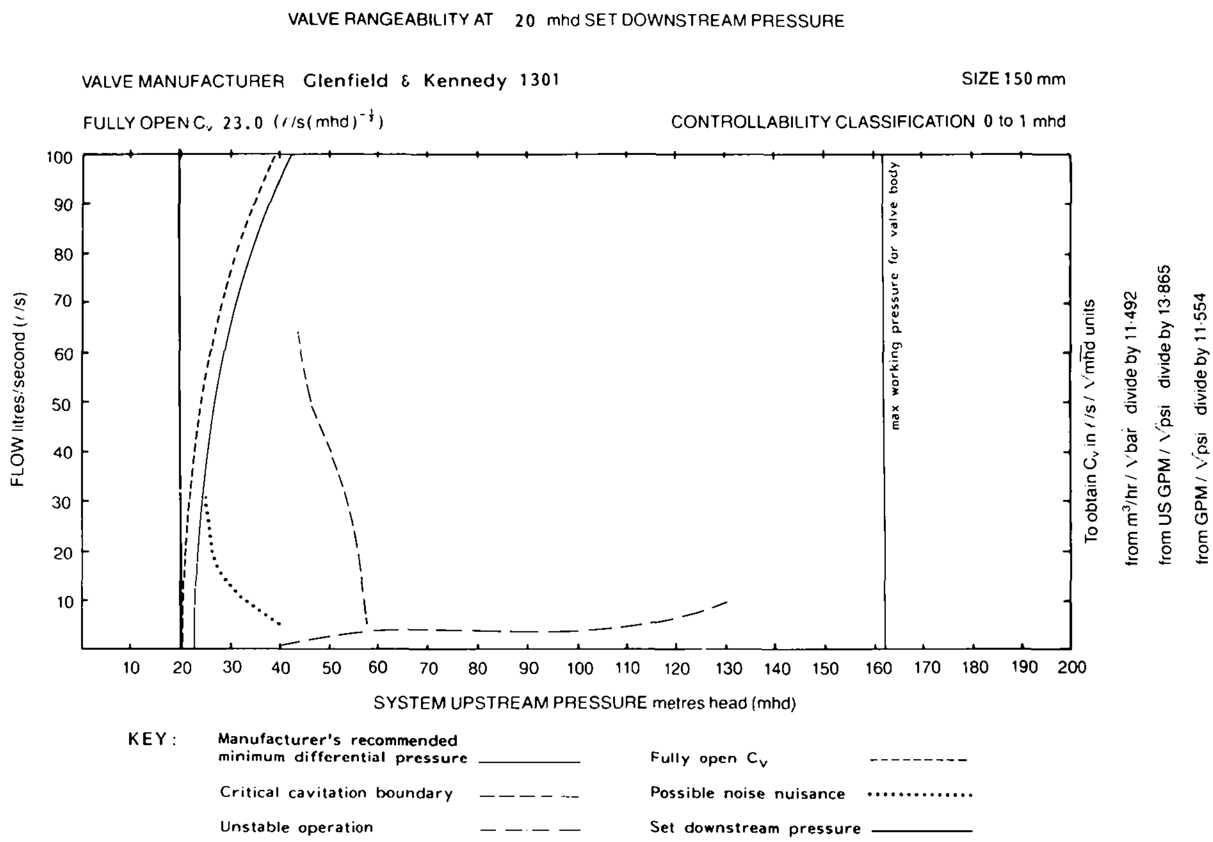

Figure 33 Rangeability map at set downstream pressure of 20 m.hd narrow area of satisfactory operation.

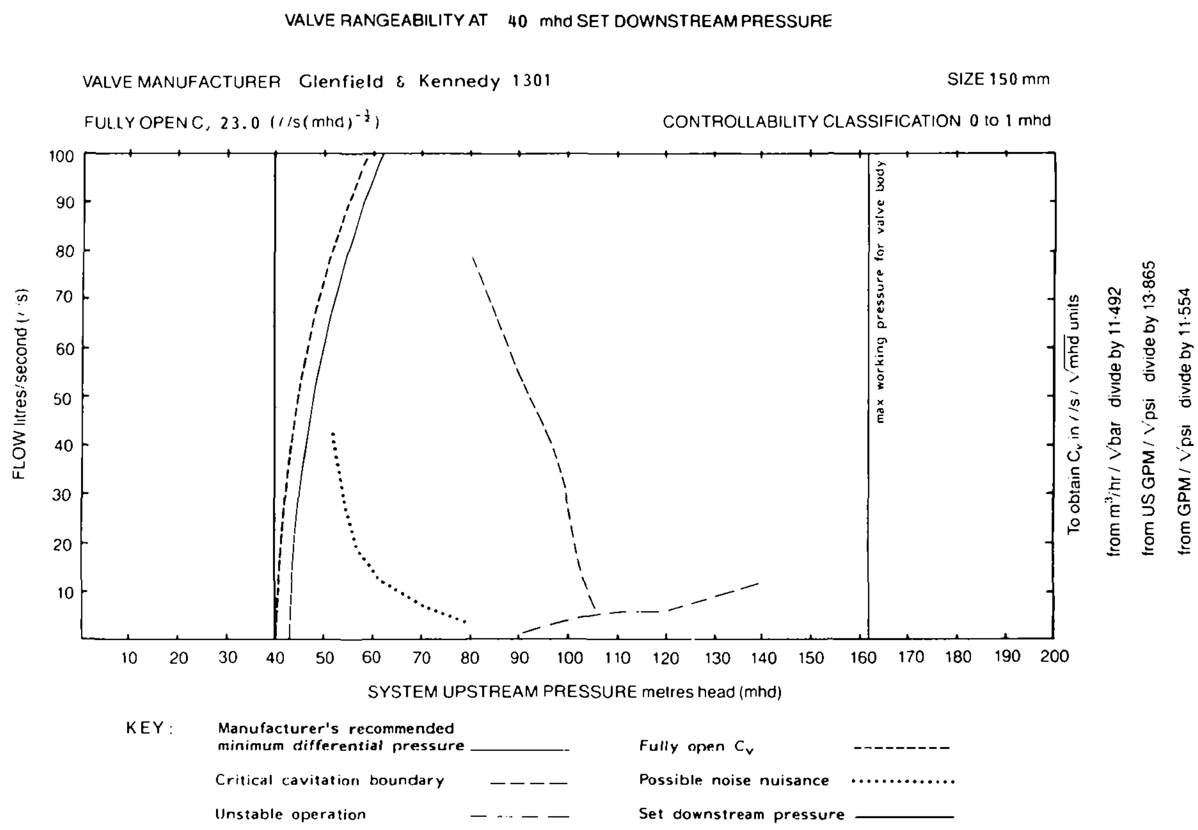

Figure 34 Rangeability map at set downstream pressure of 40 m.hd wider area of satisfactory operation.

A compromise must be struck between the savings indicated by Chapter 5 of 'Leakage Control Policy and Practice'[(1)] and a satisfactory hydraulic duty for the valve.

Figure 35 shows how the gauge pressure component of the set downstream pressure can be raised by siting the PRV at a lower ground level. The GL_{PRV} component influences P_{out} because:

$$P_{out} = GL_{target} + SL_{target} + H_L - GL_{PRV}$$

where P_{out} = downstream gauge pressure of PRV (m hd)

GL_{target} = AOD level at critical (target) point in network (m)

SL_{target} = minimum pressure service level at target (m hd)

H_L = friction loss in pipes connecting PRV to target (m hd)

GL_{PRV} = AOD level at PRV site (m)

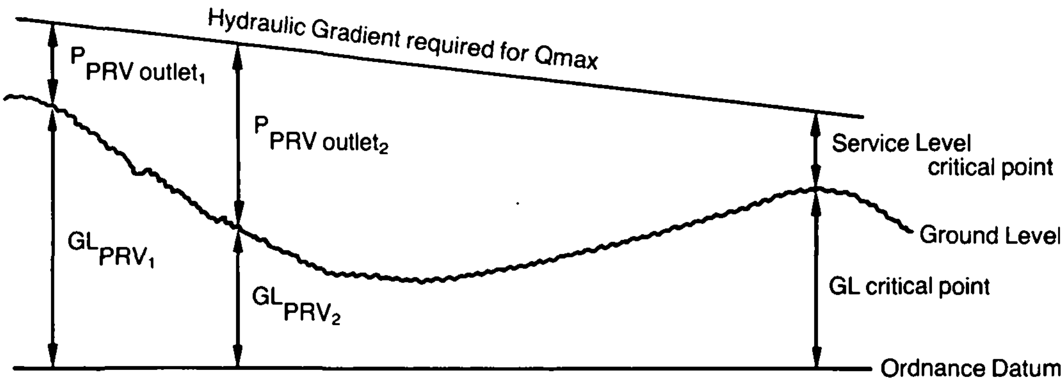

Figure 35 An example of siting a PRV at a lower ground level to raise the value of the set downstream pressure.

The valve should be sited in a free draining pit. The pit should be sized and placed so that the valve is central and enough access is available for all maintenance procedures including stripping the valve completely. It is important to remember that some valve styles, for example the Guest and Chrimes 6DC, require the valve mechanism to be removed from the bottom so that ample clearance beneath the valve is also necessary.

Provision for measuring and data logging the flow, upstream and downstream pressures should be built into the pipework.

This can be in the form of a suitable upstream combined flow and pressure tapping and a separate downstream pressure tapping for use with measurement systems based on insertion meters. If a separate small pit is contemplated to house the pressure tapping point then the tapping should be made about 6 inches away from one wall of the pit. This enables simpler access for the operator to connect the pressure housing to the gate valve.

The pit could have a combined use as a district or wastewater meter site. In this case the pulse output of the meter can be logged directly and just upstream and downstream pressure tappings are required. In the case of telemetered flow or pressure information provision should be made for local connection to a logger. This enables the subsequent combination of flow/time data with instantaneous pressure/time data into more useful forms such as flow/pressure plots or flow histograms. Where both measurements are telemetered then translation programs can be incorporated into the telemetry computer system. These provisions allow routine performance testing to be carried out.

Pit covers should be the lightest that service conditions allow and large enough to allow simple access and egress.

Enough open area should be available so that oxygen deficiency problems are minimised when the pit is being worked in.

Full account should be taken of working in confined spaces and a working triple gas detector should be used when the pit is occupied. All other precautions for safe working should be observed.

The question of placing the PRV on bypass piping has already been discussed in Section 4.2.2 where it concerned fire flows. A bypass can also make temporary shut offs for maintenance purposes much easier. For vital mains a spare parallel PRV may be considered.

4.4.2 Economic Considerations

The method developed in Report 26 [1] establishes the benefits of pressure reduction. The costs include the price of the PRV, the price of the installation and the annual maintenance cost.

Weighing the costs and benefits allows a sensible choice of fixed outlet PRVs to be made from the final shortlist of valves chosen up to now purely for engineering considerations.

4.5 The Procedure for Flow Modulated PRVs

The procedure for choosing a flow modulated PRV differs from that of fixed outlet PRVs and will be discussed in a later report. However, the methods of measuring distribution system parameters are included so that appropriate data can be offered to manufacturers for them to quote for the correct device.

4.5.1 Field Measurements for Flow Modulated PRVs

The range of downstream pressures at the valve for the range of flows needs to be established. The required downstream head AOD at the valve for any flowrate is the sum of the AOD ground level at the critical point, the required level of service and the headloss in the intervening distribution system.

This data is best obtained from the network analysis but can be obtained by measurements. The degree of complexity of the intervening distribution system determines the measurement method.

A single pipe with no take offs between the proposed PRV site and the critical point would enable hydraulic resistance to be measured.

The ground levels at both the proposed PRV site and the critical node are levelled in. The flow and pressure at the PRV site and the pressure at the critical node are recorded during periods of high flow. The appropriate ground levels are added to the pressures and the pressures subtracted to find a value for headloss H_L. The value of hydraulic resistance in litres/second, metres head units is calculated from the relationship $R = H_L/Q^{1.85}$.

Thus for any flowrate the headloss can be calculated using the established value of hydraulic resistance.

Intervening distribution networks which have more complex connections between the proposed PRV site and critical node can have their behaviour measured by continuous recording over a period sufficient to reveal the full flow pattern.

Field data are taken at the point in the system where the modulating pressure reducing valve is to be installed as well as selected target nodes.

P_{up}, Q = pressure AOD (m hd) and flow measurements (litres/second) taken at the proposed valve site.
P_{target} = pressure AOD (m hd) at any target point.

For any flow $P_{mod} = GL_{target} + SL_{target} + H_L$

where
P_{mod} = modulated pressure AOD (m hd)
GL_{target} = AOD level at target (m)
SL_{target} = minimum pressure service level at target (m hd)
H_L = friction loss in pipes connecting input to target (mhd)

The pressure gauge on the downstream tap of a PRV does not read in m hd AOD. The gauge pressure is obtained by subtracting the ground level at the PRV site.

4.6 Limitations of Presented Results

The maps relate to stated valve styles. No data is available at the moment on sizes other than 150mm. No data is available on flow modulating styles of valve. Whether the performance maps are used or not the request for a tender from a manufacturer should contain the following information:

(a) The range of upstream pressures (m hd).

(b) The set downstream pressure or range of downstream pressures if a modulating style (m hd).

(c) The range of flows (litres/second).

(d) The histogram of distribution of flows (frequency versus flow classes in litres/second).

(e) Any special hydraulic consideration e.g. small differential pressure.

(f) Existing pipe size (mm).

(g) Details of flange connections.

(h) Pressure specification for the body.

(i) Confirmation that all materials comply with all requirements for potable water use.

Conclusions 5

(i) For all practical purposes pressure reducing valves (PRVs) can be classified according to one of 4 types depending upon their outlet pressure and their control and activating mechanism.

(ii) The performance of pressure reducing valves, although complex, can be expressed by two measures.

Rangeability, which is the range of flows and inlet pressures over which the valve can operate satisfactorily, can be expressed in a series of rangeability maps.

Controllability, which is the valve's ability to effect pressure control can be expressed by measured deviations from the set downstream pressure.

(iii) The rational selection of PRVs using the guidelines and performance data in this report is essential in order to realise the full benefits for pressure control at a reasonable cost.

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3. M J FARLEY. **District Metering Part 1, System Design and Installation.** WRc ER 180E.

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5. K R STIMSON. **Analysis and simulation of water networks and a guide to the WATNET simulation computer program.** WRc TR 237.

6. J G DEVINE. **Network Analysis – implementation and application.** WRc TR242 (to be published).

Appendix 1 – Manufacturers and Agents for Pressure Reducing Valves

1	Glenfield and Kennedy Glenfield and Kennedy Works Kilmarnock Ayrshire KA1 4DF Tel: (0563) 21150	PRV Types 2 and 3
2	J Blakeborough and Sons Ltd P O Box 11 Brighouse West Yorkshire HD6 1NH Tel: (0484) 715511	PRV Types 2, 3 and 4
3	Guest and Chrimes Ltd P O Box 9 Don Street Rotherham South Yorkshire S60 1AQ Tel: (0709) 382035	PRV Types 1 and 2
4.	De Zuric International Ltd Wrotham Place Wrotham Sevenoaks Kent Tel: (0732) 884889	PRV Type 4
5.	Delta Technical Services Asser House Airport Service Road Portsmouth Hants PO3 5RA Tel: (0705) 697321	PRV Type 4
6	Cla-Val Aztec Engineering Ltd Goods Station Road Tunbridge Wells Kent TN1 2DH Tel: (0892) 39588	PRV Types 2 and 3
7	Inbal Magisco Valves Unit 16, Fordhouse Road Industrial Estate Steel Drive Wolverhampton WV10 9XB Tel (0902) 781673	PRV Types 2 and 3

8	Rollseal Sihi-Ryaland Pumps Ltd Bridgewater Road Broadheath Altrincham Cheshire WA14 1NB Tel: (061) 9286371	PRV Types 2 and 3
9	Jordan Tamo Ltd St Lawrence House Uxbridge Road Hillingdon Middlesex UB10 0NW Tel: (01) 5731597	PRV Type 2
10	Fisher Controls Ltd Medway House Knight Road Strood Rochester Kent Tel: (0634) 736972	PRV Type 3

Appendix 2 – Controllablity Test Results

A.2 Introduction

Controllability is defined as the valve's accuracy in maintaining the downstream set pressure over the range of flows and inlet pressures which map within the boundaries defined in rangeability. Rangeability is defined as the range of flows and pressures over which the valve can operate without violating mechanical limits. These terms are more fully defined in Sections 3.1.2 and 3.1.1 respectively.

A2.1 Limitations of Tests

Figure 36 shows the pump curves, labelled A, B, C, D and E, used to simulate the characteristics of the upstream system. Curve A represents the maximum pump curve limited by pump performance and electricity tariff constraints. The lowest pressure at any flow that the pump can deliver to the loop is limited by the hydraulic characteristics of the test loop itself and this boundary is also indicated on Figure 35.

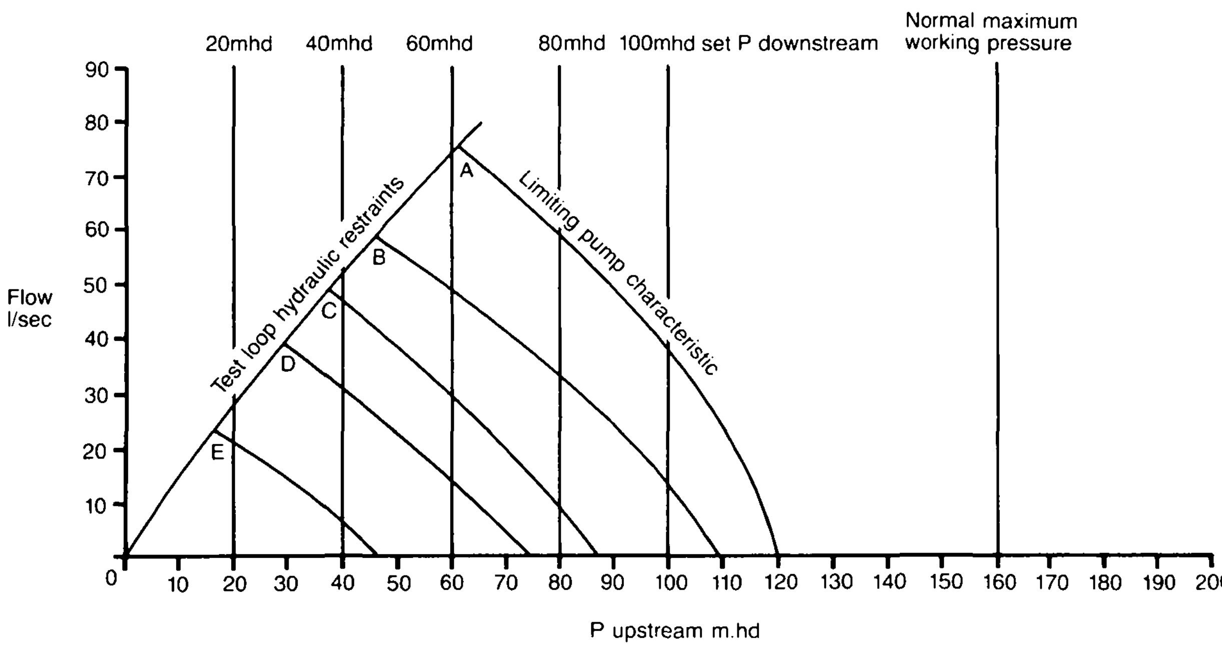

Figure 36 Range of Tests.

Matrices of results are formed by setting the downstream pressure of the PRV at successively 20, 40, 60, 80 and 100mhd for each of the upstream supply characteristics. The downstream characteristics are represented by the vertical lines on Figure 35.

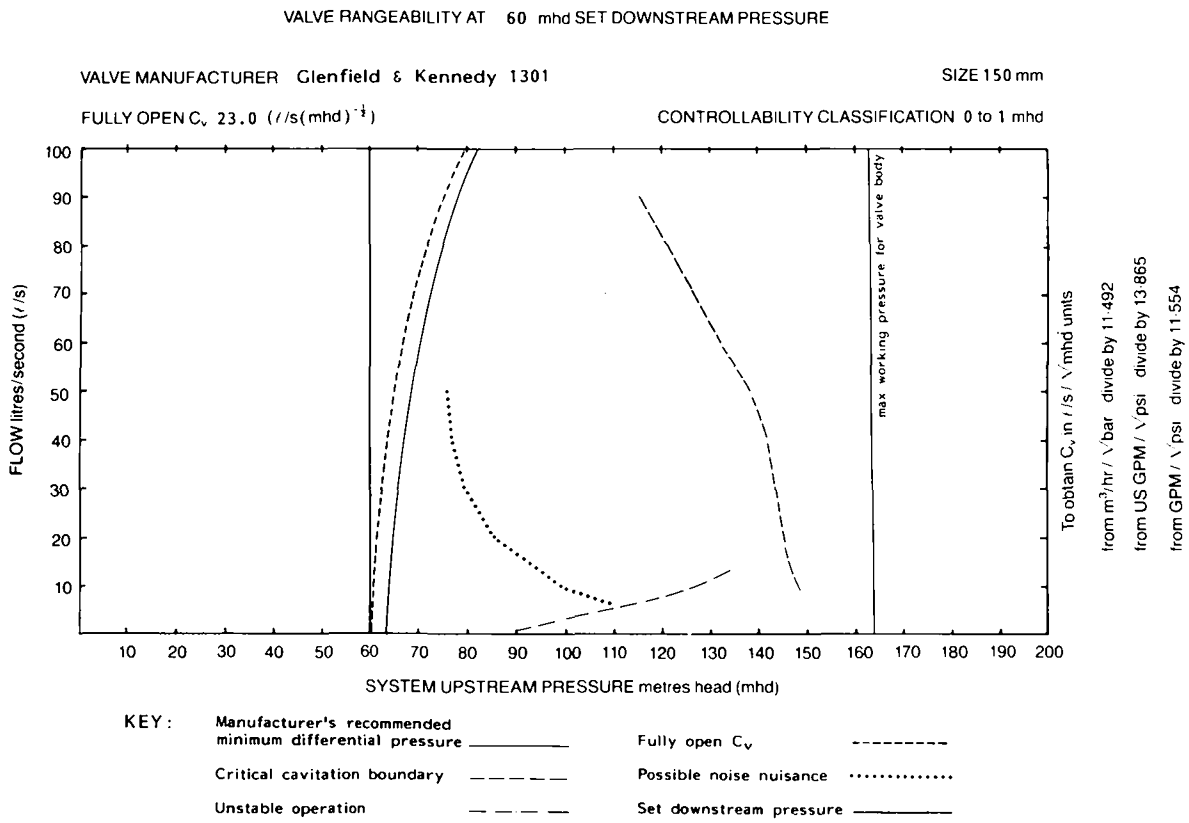

Figure 37 Example of rangeability map.

Figure 37 shows the normal boundaries of a performance map and the controllability classification, defined in A2.2, is derived from data mapping within the boundaries including the manufacturers minimum differential pressure.

It can be seen from Figure 36 that a valve with a set downstream pressure of 40m hd will include more points on the pump test curves than any other set downstream pressure. This means that the maximum quantity of controllability test data will be available from the 40m hd rangeability map for any test PRV.

A2.2 Method of Conducting the Controllability Test

The required upstream system characteristic is set up by manipulating the pump regulating valve and the bypass valve to defined positions. The demand regulator valve is then set for a particular initial flow rate. At this flowrate the downstream pressure of the PRV is set to one of the required values.

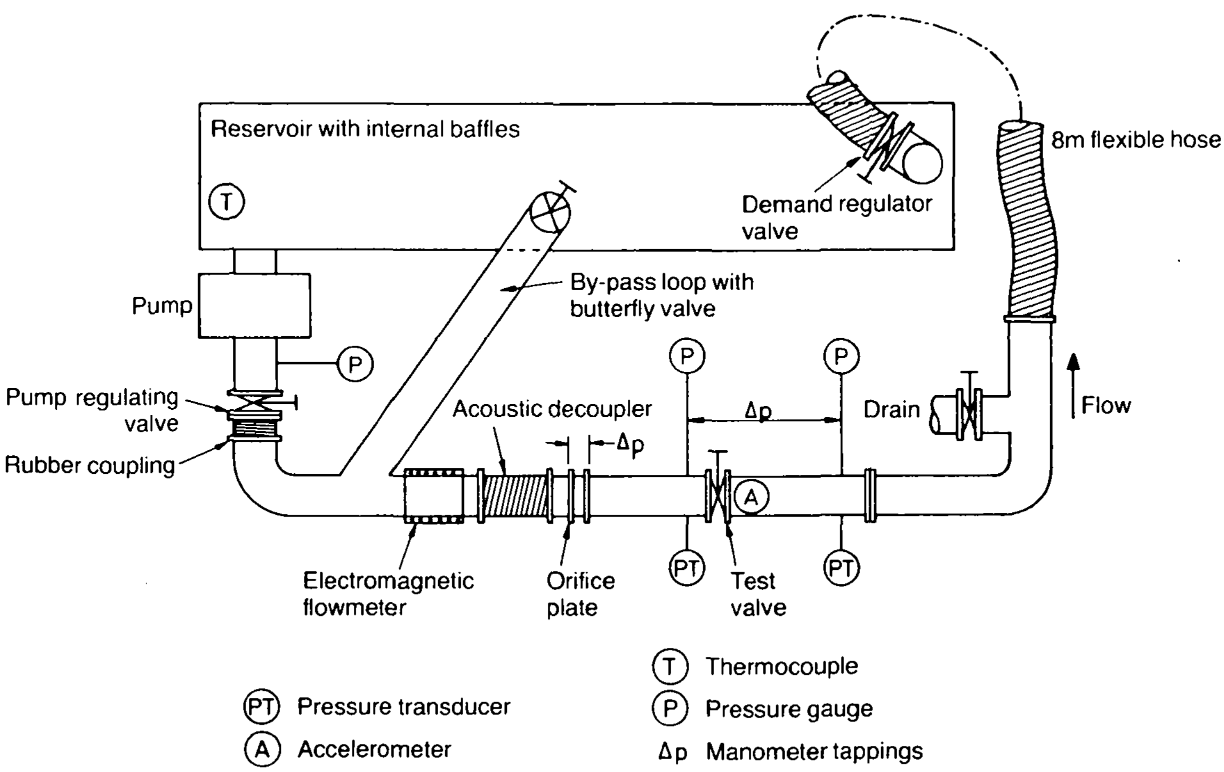

Figure 38 Diagram of Test Loop.

The flowrate through the valve is varied by the demand regulator valve so that various points obtain on the upstream characteristic. The downstream pressure at each of the points is recorded and compared to the set pressure. The magnitude of the difference both positive and negative with respect to the set pressure is recorded as the controllability error. This process is repeated for all appropriate combinations of upstream and downstream characteristics.

Appendix 2

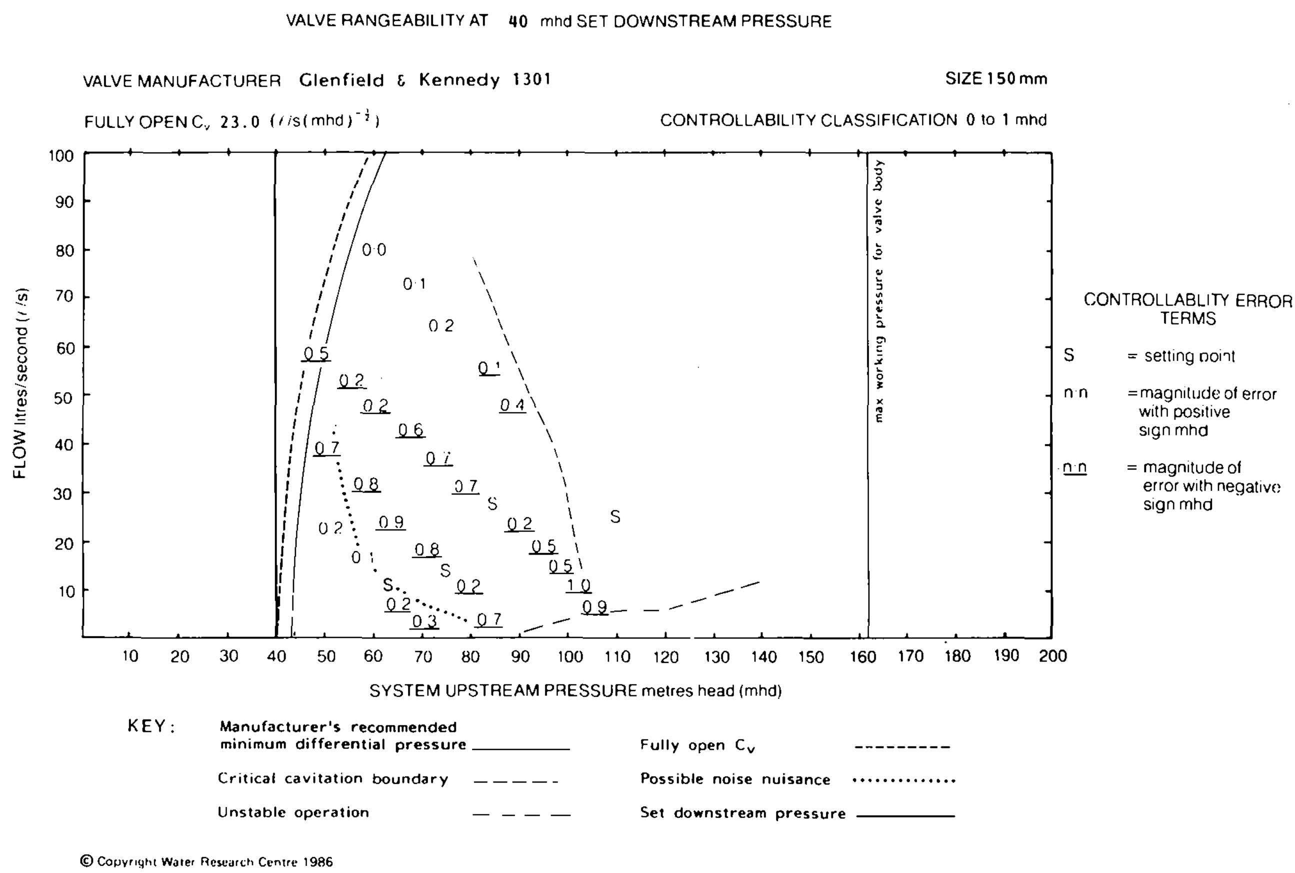

Figure 39 The plotted controllability errors.

Figure 39 shows how these errors are plotted on the appropriate performance map with the setting flow/upstream pressure point designated by the letter 'S'. The sign and magnitude of the value of controllability error is plotted at the measured flow/upstream pressure coordinate. Controllability classification, as recorded on the rangeability maps in the 'Performance Atlas', is the range of these magnitudes for that set downstream head.

A2.3 Results

The Guest and Chrimes 6DC, the only Type 1 valve tested, clearly demonstrates controllability errors typical of spring loaded diaphragm PRVs. The results show larger negative errors and therefore decreasing downstream pressure as flow rates are increased from the setting point. As flow rates decrease from the set flow the downstream pressure errors are positive and result in rising downstream pressures.

The Type 2 PRVs show much less variation in output pressure as flows are increased and decreased from the set point. The exception to this was the Jordan 67 pattern PRV which showed considerable droop in the output pressure. this phenomena is discussed in the appropriate section of the 'Performance Atlas'. A summary of the controllability classifications is set out in Table 2.

Valve Type	Deviation from Set Head 20m hd	Deviation from Set Head 40m hd	Deviation from Set Head 60m hd	Deviation from Set Head 80m hd	Deviation from Set Head 100m hd
DeZuric 100	0–10m hd	0–20m hd	Not tested	Not tested	Not tested
Blakeborough Golden Anderson	0–2m hd	0–2m hd	0–5m hd	0–5m hd	Not tested
Guest & Chrimes 6 DR	0–2m hd	0–2m hd	0–5m hd	0–2m hd	Not tested
Guest & Chrimes 6 DC	0–10m hd	0–10m hd	0–10m hd	0–10m hd	Not tested
Rollseal 110 PR	0–2m hd	0–2m hd	0–2m hd	0–2m hd	Not tested
Inbal 500R	0–1m hd	0–2m hd	0–2m hd	Not tested	Not tested
Claval Hytrol	0–1m hd	0–1m hd	0–1m hd	0–2m hd	0–2m hd
Jordan 67 Series	0–10m hd	0–10m hd	0–10m hd	0–10m hd	0–10m hd
Glenfield 1301	0–1m hd	0–1m hd	0–2m hd	0–1m hd	0–1m hd

Table 2 Controllability classification