Weir Valves & Controls 4
The Hopkinson Story 6 - 17
Company Milestones 18
Boiler Mountings & Valves 18

Parallel Slide Gate Valves
(a) Operating & Design Features 19 - 20
(b) Product Application 20
(c) Hopkinsons Product Range & Features 20
(d) Valve Construction 20
   (i) Back Seating
   (ii) Packing Under Pressure
   (iii) Seats & Discs
(e) Comparison of Parallel Slide Valve with Wedge Gate 22 - 25
   (i) Seating Principles
   (ii) Thermal Binding
   (iii) Ease of Maintenance
(f) Optional End Connections 26
(g) Bolted Bonnets 26
(h) Stuffing Box Design 26 - 28
   (i) Exfoliated Graphite Packing
   (ii) Upgrading of Conventional Glands & Pressure Seal Bonnets
   (iii) Water Sealed Glands
(i) High pressure Parallel Slide Gate Valves 28 - 33
   (i) Pressure Seal Bonnets
   (ii) Venturi Bore Design
   (iii) Follower Eye
   (iv) Seat Velocities
   (v) Product Ratings
   (vi) Relationship Between Nom. Pipe Size & Valve Seat Diameter
   (vii) Vee Port Outlet Seats
   (viii) Steam Purging with Venturi Valve Design
   (ix) Process, Petrochemical & Nuclear Market

Bypass Valves
(a) Application 33
(b) Method of Operating 34

Equalising Bypass Valves & Devices
(a) Hydraulic Lock 35
(b) Balanced Spindle Valves 35 - 36
(c) Equalising Pipes & Applications 36
(d) Over Pressure 36 - 37
(e) Alternative Equalising Devices 37
(f) Equalising Bypass 37 - 38

Types of Main Valve Operation 38 - 42

Check & Non-Return Valves
(a) Swing Check Valves 43
(b) Low & High Pressure Variants 44
(c) Feedwater Check Valves 44
(d) Vertical Lift Check Valves 45
(e) Comparative Disc Movements (Vertical Lift & Swing Check) 45
(f) Stop Check Valves (Stop & Non-Return Valves) 45
(g) Tilting Disc Check Valves 46 - 47
(h) Bled Steam (Extraction Steam) Non-Return Valves 48 - 53
   (i) Features of Hopkinson Design
   (ii) Valve Application
   (iii) Competition
Reheater Isolation Devices

Drain & Blowdown Valves
(a) Comparison of Types 56 - 58
   (i) Wedge Gate Valve
   (ii) Globe Valve
   (iii) Ball Valve
   (iv) Parallel Slide Gate Valve
(b) Rack & Pinion Blowdown Valves 58 - 59
(c) Uniflow Drain Valves 59
(d) High Performance Parallel Slide Gate Valves 60

Water Gauges (Water Level Indicators)
(a) ‘Absolute’ Type 60 - 61
(b) Plate Glass Type 61
(c) ‘Bulls Eye’ Type 62
(d) Try Valves 62

ASME Section 1 Safety Valves
(a) Definition of Safety Valve Types & Terms 63
   (i) Safety Valve
   (ii) Relief valve
   (iii) Safety Relief Valve
   (iv) Set Pressure
   (v) Simmer
   (vi) Lift
   (vii) Rated Capacity
   (viii) Accumulation
   (ix) Overpressure
   (x) Blowdown
(b) Hopkinsons Product Range & Ratings 64 - 66
   (i) Features & Benefits
   (ii) Principal Competitors
(c) Hopkinsons Steam Test Facility 67
(d) Safety Valve Mounting 67
(e) Hydrostatic Testing 68 - 69
   (i) Hopkinsons Products
   (ii) Competitors
(f) Servo Loaded Direct Acting Safety Valves 69
(g) Anti Simmer Devices 69 - 70

Feed Water Heaters 71

Feed Water Heater Bypass Systems
(a) Electrically Operated Gate Valves 72
(b) Spring Loaded Bypass Valves 72 - 73
(c) Competitors 73
(d) Atwood & Morrill 3-Way Valves 73 - 74
(e) Medium operated 2-Way Changeover Valves 75

Combined Cycle Power Plant System

Fossil Fuel Power Plant System
Weir Valves & Controls

The key to the success of Weir Valves & Controls is our capability to deliver engineering solutions that add value to the customer’s process. We offer a total package of products to meet end-to-end project requirements. Using our own analysis and configuration system, we will design and deliver the optimum valves and controls solution to protect the value of the production process.

A rigorous programme of information management means that the division is able to take a more anticipatory role in defining the future needs and expectations of the market by fully utilising the organisation’s critical resources to provide whole process isolation and control valve solutions for the global Energy sector.

With a comprehensive range of engineered valve products Weir Valves & Controls have developed an extensive global installed base and expertise across a wide range of industry sectors:

- Power Generation
- General Industrial
- Oil & Gas Production
- Refining
- Petrochemical
- Chemical
- Pulp & Paper
- Desalination

3-way valves
Check valves
Gate valves
Globe valves

Control butterfly valves
Isolation butterfly valves
High performance butterfly valves
Triple offset butterfly valves

Globe control valves
Turbine bypass valves
Choke valves
Desuperheaters
Severe service valves
Control valve actuators

Pipeline surge absorbers
Pulsation dampers
Thermal expansion compensators

Check valves
Gate valves
Globe valves
Reheat isolation devices
Safety valves

Side entry ball valves
Top entry ball valves
Subsea ball valves
Rotary gate valves
Integrated systems

Spring-loaded safety relief valves
Pilot operated safety relief valves
Two-way change-over valves
Thermal relief valves
Tank blanketing system

Pilot operated nuclear safety valves

Triple offset butterfly valves
Quality assurance

Weir Valves & Controls operates quality programmes to cover the full scope of their activities. Comprehensive quality systems have been developed to serve the power, oil and gas and industrial markets which they serve.

The company holds approvals to:

- ASME Section III ‘N’, ‘NPT’, ‘NV’
- ASME Section I ‘V’
- ASME Section VIII code UV
- BS EN ISO 9001:1994
- NF EN ISO 9001
- API Q1 TO API LICENCES API 6D (6D-0182) and API 6A (6A-0445)
- API 526
- TUV - AD MERKBLATT WRD HP 0

The Quality systems have been approved for the supply of products to meet the requirements of the Pressure Equipment Directive (PED) and compliance modules A,D1,H,B&D have been applied in categories I through IV respectively.

The company is committed to compliance with legislation and has an established environment and health and safety policy.

An ongoing commitment to customer care is met through the process of continuous improvement and the further development of our systems and processes towards meeting ISO 9001:2000.

Valve testing facilities

All pressure containing items are hydrostatically tested, seat leakage tested and functionally tested. In addition, gas, packing emission, cryogenic and advanced functional testing can be arranged.

Material testing facilities

- Non-destructive examination by radiography, ultrasonics, magnetic particle and liquid penetrant.
- Chemical analysis by computer controlled direct reading emission spectrometer.
- Mechanical testing for tensile properties at ambient and elevated temperatures, bend and hardness testing. Charpy testing at ambient, elevated and sub-zero temperatures.

Further technical information can be obtained from our Web site: http://www.weirvalve.com

Hopkinsons

Weir Valves and Controls manufacture Hopkinsons Valves and Boiler Mountings for use on steam raising plant of any size and type.

Hopkinsons brand products, renowned for long and dependable service life, can be seen on installations ranging from shell boilers for heating and process steam up to the highest capacity units on electricity generating stations.

In the nuclear power industry, the Hopkinson name is synonymous with expertise in the design and production of safety related items such as fast operating main steam and main feed isolation valves.

The Hopkinson range of products also includes valves for isolation, regulation, pressure relief, instrumentation and drain and specific plant protection duties on the new generation of Combined Cycle Gas Turbine Power Stations.
The Early History of Valves

The history of the development of valves contains very little recorded information, and cannot be said to have shown much progress beyond the most primitive stages until the beginning of the 19th century.

As far back as about 230 B.C., Philon of Byzantium described arrangements for drawing wine from casks, corresponding to present-day faucets for removing beer from barrels, and even mentioned a simple design of a two-way-cock. The Romans made use of the elementary types of valves, probably for controlling water in pipes, and among those preserved is a bronze plug cock discovered in the Palace of Tiberius in Capri (built A.D. 39). This type of valve continued to be used with little variation until the advent of steam as a motive power, when the screw-down stop valve and weight-loaded safety valve were developed.

The apparent absence of progress in valve design for two thousand years is obviously due to the fact that man had not yet appreciated the uses of steam as a source of power, and such valves as were required called for no particular technical skill in design and construction. The crude wooden plug valve (illustrated), dating from the late 17th century, was probably quite adequate for the very unexacting duties which it had to perform.

With the development of steam power, however, the importance of valves as a means of promoting efficiency and safety began to be appreciated by engineers. It is at this stage, in the early decades of the 19th century, that the Hopkinson story began.
The Hopkinson Story

Today Hopkinsons Limited is located in a 16 acre (7 hectare) factory and office complex in Huddersfield employing approx. 500 people. Its business is that of a world leader in the manufacture of valves, for power generation, the Oil & Gas industries and process and petrochemical applications. Behind these facts is a remarkable story of inventive genius, enterprise and dedication to quality that has earned the firm its unique international reputation over the years since 1843.

That story began at a time when there were still men in the prime of life who had fought at the Battle of Waterloo and before Huddersfield had a railway link with the commercial world.

Opposition to Mechanisation

Huddersfield and its neighbourhood were still affected by the Plug Riots of 1842 (so-called because men drew the plugs from factory boilers) that showed the continuing bitter opposition to the introduction of machinery in the textile industry.

However, Joseph Hopkinson believed in engineering and in the future of steam. His engineering interest obviously knew no bounds, he even patented an improved design of steel stiffener for ladies corsets!

Despite the hostile climate he started business in 1843 in an upstairs room in Huddersfield. But even as early as 1835 he was involved in tests to establish the relative strength of the copper tubes in a boiler. From this evidence it can be assumed that he was one of those engineers earnestly involved with the early introduction of steam power to the textile mills of Huddersfield and district.

By 1845 the business was firmly established in larger premises, two converted cottages, in Lockwood, Huddersfield. So, ‘Hopkinsons Huddersfield’ seen on valves in virtually every country in the world, was born.

Identifying the Market

Right from the outset Joseph Hopkinson identified his market. Indeed he left a hair-raising account of what many boilers and boiler mountings were like when he began to design and manufacture valves.

The crude equipment installed, and the light-hearted manner in which boilers were looked after caused numerous serious accidents. Frequent cases arose where boiler attendants, ignorant of the consequences, tied-down the weight lever of the safety valve in order to gain an increase in steam pressure - often with disastrous results.

In fact it was not until there was an increased sense of responsibility, fostered by the various ‘Steam Users’ Associations, and backed by reliable boiler mountings, that the boilerhouse explosion became a rarity.
Early Mountings

Those were the days of the Haystack and Wagon Boilers, simple, crude designs which remained in general use in industry until nearly the middle of the century. Arrangements for safety and control were likewise crude - where in fact they existed.

The earliest method of ascertaining the level of water in a boiler was by holes through the boiler shell each containing a wooden bung which could be withdrawn by the attendant to check if the water or steam issued from the hole. A more refined method followed in the form of two petcocks or taps situated one above and one below the normal water level. Here again the attendant had to physically open the taps to check for the presence of fluid.

The breakthrough came with the addition of a glass tube to connect the outlets of the taps, so providing a continuous indication of the water level. This formed the basis of today’s tubular water gauge.

A means of boiler pressure indication was introduced by adapting the mercurial ‘U’ tube or manometer gauge with a wooden rod resting on the mercury and moving over a scale.

Better Designs

Subsequently the primitive boiler designs were replaced by other and better types, such as the single-flued, or Cornish boiler, designed to sustain relatively high pressures, and originally introduced by Richard Trevethick in 1812. In due course that was succeeded by the Yorkshire and then the well-known Lancashire boiler, while the locomotive type of boiler was also instrumental in affecting the trend of design of boiler equipment, particularly in regard to spring safety valves, as opposed to lever or weight controlled valves.

Creating the Business - and it’s Symbol

It follows that when J. Hopkinson & Co. began operations in 1843 there was a genuine need for the design and construction of safety boiler mountings. In this regard the company adopted as its trademark the stool, or saddle, which was riveted to the boiler shell, and on which the safety boiler mountings were mounted.

One of the first major successes of the company was the Compound Safety Valve, which proved to be an outstanding invention for preventing boiler explosions. Moreover its later development, the Duad Safety Valve, became a standard fitting for Lancashire boilers and can still be seen in service today. The Compound design was among the products exhibited by the company at the Great International Exhibition in 1851 when it received a medal and certificate signed by H.R.H. Albert, the Prince Consort.
Challenging Words

Not frightened to put his money where his mouth was Mr. Hopkinson published an advertisement in 1852 headlined “Important Invention! Steam boiler explosions rendered impossible”. The copy explained the features of Hopkinson’s New Patent Compound Safety Valve and at the end carried the bold statement:

“£200 REWARD is hereby offered, and will be paid by the Inventor, to any person who shall demonstrate the possibility of exploding a boiler from pressure of steam or deficiency of water, if fitted with the New Patent Compound Safety Valve, provided that the Boiler operated upon is equal to its ordinary working pressure”.

Needless to say £200 in those days of golden guineas was no mean sum and clearly confirmed the firm’s confidence in its product just as indeed it does today.

Moreover the early Steam Users Association - which were later to become the boiler insurance companies we know today - offered a 10 per cent reduction in premium if a boiler was fitted with a Hopkinson’s Compound Safety Valve.

With these early developments, and the expansion of the firm to new premises in Leeds Road, the pattern was set whereby the history of Hopkinsons was to become that of the whole progress of valve design and manufacture.

In 1854 the Hopkinson’s type water gauge made its appearance, together with a mercurial type steam pressure gauge. Similarly, the company introduced a patented ‘Economical Self-Cleansing Boiler’ which was claimed to work with perfect safety at a pressure of 100 lb/in² - a remarkable innovation in a decade in which anything in excess of 40 lb/in² was considered a high pressure.

Three years later - in 1857 - the company’s catalogue stated “the patent transverse boiler may be used at 200 lb/in² or 250 lb/in² with greater safety than the best of the ordinary boilers at 70 lb/in²”. Actually there was considerable correspondence in the Manchester Guardian on the definition of high pressure, which closed with the view that it was 50 lb/in²!
Hopkinsons on the Indicator

At about this time - and with more than ten years research and development behind it - the company introduced the Hopkinson’s Steam Engine Indicator, which was an improvement on James Watt’s invention. Put in Joseph Hopkinson’s own words:

“What the Stethoscope is to the Physician, the Indicator is to the Engineer - revealing the secret working of the inner system, and detecting minute derangement’s in parts obscurely situated”.

His method of selling his Indicator is interesting in itself. Very simple he used his own Indicator to improve the efficiency of the engine by re-setting the valve timings. If he did not improve the horsepower by 10 per cent, then no fee was charged. If he succeeded, he was paid seven shillings and sixpence ‘per horse’ plus 25 per cent of the cost of the coal saved over two years.

This development of the Indicator was followed by the publication of a book ‘Hopkinsons on the Indicator’, which contained a great deal of additional information on the management of steam engines and boilers. At once this book was recognised as making an important practical contribution to the existing knowledge on the subject, and it ran into many editions.

It was not, however, entirely well received. There was apparently a critical review of it in The Engineer and as the Editor failed to publish Joseph Hopkinson’s reply, he wrote again to the Editor stating:

“You publish a scurrilous article, which you call a review of my book - the third edition - from which it is quite evident that the subject is one with which you are altogether at sea, and undoubtedly have a less knowledge than most operative engineers.

“Your cowardly conduct in this matter, refusing me a reply, and then withholding my property, deserves the highest censure, nay, more, such a chastisement as I shall take the liberty of giving you for your cowardice, viz., a horse whipping”.

There is no record of whether he carried out his threat, but it is indicative of the blunt and forthright manner of the man. Certainly he was not backward in coming forward and - like Brunel - was a first-class publicist. There is a reproduction of him with his “new design in valve setting” with the copy which stated:

“The prosperity of England depends upon the success of her manufacturers, and the amount of success that is accomplished in all practical sciences depends solely upon having the right man in the right place to arrange and conduct them”.

Mr. Hopkinson with his steam engine indicator.

Scale model beam engine
Taking to the Waves

The earliest mention of Hopkinsons involvement in marine engineering appears at this time in the 2nd edition of ‘Hopkinsons on the Indicator’ dated 1857. Joseph Hopkinson gives an account of tests using his Indicator instrument on the engines of the S.S. Great Britain, the first ocean going ship to be built of iron and to have screw propulsion. Hopkinson gives an account of some length in which he firstly proves the inefficiency of the original engines, then goes on to show how modifications to the engines resulted in increasing the total output from 686 to 1,663 horse power. Holding nothing back he severely raps the knuckles of the original engine constructor for perpetrating ‘such a glaring blunder as he did commit in turning out such inefficient machines’.

From that day on the name of Hopkinsons was to be associated with the best of British Shipbuilding. Through the years of the great ocean going passenger vessels - to the latest and probably the last - the Queen Elizabeth 2. The Royal Yacht ‘Britannia’ was also fitted with Hopkinson’s valves.

With the Royal Navy too, the company has a long reputation for technical expertise and product reliability. Standard and special purpose valves have been supplied for a variety of ships from the aircraft carriers and battleships of the Second World War to the smaller frigates and nuclear powered submarines of today.

Indeed it was from the company’s experience in designing and supplying rapid operating emergency closing parallel slide valves - a standard requirement on all RN steam driven ships since the 1930’s - that has enabled Hopkinsons to gain substantial orders over recent years for quick closing steam and feedwater isolation valves on nuclear power stations worldwide.
In their Fathers Footsteps

In 1867 Joseph Hopkinson was followed in the business by his two sons, John Addy and Joseph, the firm then becoming “J. Hopkinson & Co.” but the policies of good design and high-quality manufacture remained the same. So, too, did the inventive and entrepreneurial spirit.

Thus three years later, in 1870, the Hopkinson’s Deadweight Safety Valve was introduced and, with its weights contained within a lockable cover, provided a valve which overcame the problems of interference by irresponsible or incompetent operatives.

By this time the increasing reputation of Hopkinsons products meant production had to be stepped up. As a result the company moved to a relatively large factory in Viaduct street, nearer the centre of Huddersfield, in 1871. It was there over the following thirty-three years that the firm steadily advanced to become recognised as the foremost valve manufacturer in the world. It was a reputation not only for being the best, but equally for constantly producing new designs and new inventions.

These included a pressure gauge operated on the Bourdon principle, an automatic isolating valve, and a steam separator.

The Parallel Slide Valve

Most important, in 1881 the company patented the Hopkinson’s Parallel Slide Valve, an invention that greatly influenced the trend in stop valve design. So effective was the design that it remains basically unchanged even today where it accounts for the major share of the firm’s production.

Its great merit was, and is, that fluid-tightness is maintained without the aid of wedging action. No mechanical stress is exerted between the discs, and the valve is not subjected to dangerous strains in opening and closing.

Hopkinson’s premises at Viaduct Street
Originally the valves were made in cast iron and gunmetal, and were designed for pressure up to 200 lb/in². By the late 1890's they were being offered in cast steel - capable of withstanding greater mechanical stresses in the pipeline than cast iron - and suitable for steam pressures up to 250 lb/in². Today however, they may cope with superheated steam at pressures of 4,350 lb/in² at temperatures of 1085°F (300 bar at 585 °C), or, boiler feed water at 6,250 lb/in² at 500°F (431 bar at 260 °C).

1889 saw the production of the ‘Accessible’ Check Feed Valve, which was designed to enable the valve and seat to be examined while the boiler was under steam. That was followed by the ‘Absolute’ Water Gauge, which was fully automatic in both gauge arms, thus preventing the escape of steam and water in the event of breakage of the gauge glass.

With these new products and sustained growth, in March 1894 the firm was converted into a private limited company with a capital of £40,000 and trading under the name of J. Hopkinson & Co Ltd. The next milestone came in 1903 when - still innovating - the firm introduced the Hopkinson’s Centre-Pressure Valve, primarily designed as a turbine stop valve. This unit comprised two main valves and a leak-off-device - all automatically controlled in sequence. Advantages of the design - mainly that the master valve never had to close or open against full pressure - were quickly realised in the power industry, and soon added new lustre to Hopkinson’s reputation.

Even more significant, 1903 was the year when the site was prepared for the present Britannia Works in Birkby as, despite extensions, the Viaduct Street works was too small to handle the constantly expanding volume of orders. The reason Birkby was chosen was because at that time the site was in a designated Industrial area and the company was to have had a railway line, but in the event it did not materialise.

In this regard it is interesting to note that while in 1890 the number of employees totalled about 120, the new works employed some 600, a figure practically trebled before the Second World War.
Hopkinson & Ferranti

Back to 1904 and a association between Hopkinsons and another Great British innovator, Dr. Sebastian Z. de Ferranti, the pioneer of electric power. It was he who, looking at the drawings of the Hopkinson’s Parallel Slide Valve and also at the drawing of a Venturi flow meter, had the idea of combining the features of one with the other. He therefore adapted the design of a Hopkinsons valve to incorporate a converging inlet and a diverging outlet flow passage similar to that of a Venturi meter. This concept was developed and the result was the Hopkinsons-Ferranti Stop Valve, which made one more significant advance in the valve industry.

The general features, still as valid today as then, were similar to those of the parallel slide valve but embodied the Venturi principle. Owing to the reduced bore, the valve travel and fittings are proportionately smaller, the load area is less than corresponding sizes of full-bore valves and operation of the valve is therefore easier.

Underlying this development is the story that Ferranti originally offered his idea to the Hopkinson then running the business for a lump sum of £10,000. However he was told that the idea had no particular future, but that Hopkinsons was prepared to take up the patent on a royalty basis.

In the course of further negotiations the price dropped from £10,000 to £5,000 to £2,000, but still Mr. Hopkinson insisted on an agreement on a royalty basis only. Ultimately Ferranti agreed - and collected some £64,000 over the course of the life of that patent.

But hindsight is of little use, and as it was, the sustained overall progress of Hopkinsons meant that its interests soon extended internationally.

By 1910 the firm had depots and showrooms in thirty cities around the world and, to catch the eye of the relaxed industrialist, there was even a showroom on the pier at the North of England’s most popular seaside resort, Blackpool!

Naturally the First World War years 1914-18 had profound effect on the firm insofar as many employees joined the services and production was concentrated on essential war materials.

A year later in 1920, a new private company was formed with a capital of £600,000.
Throughout its history the company has produced valves to meet the highest pressure and temperature requirements of the power industry.

This graph illustrates the upward trend in water tube boiler pressures to the middle of this Century. Since then, however, UK electricity generating station practice has remained virtually level at 2,400 lb/in² (165.5 bar).

Stateside Testimonial

Hopkinsons technical excellence was still being recognised far from home as indicated by a note from the American Prime Movers Committee Report given at the National Electric Light Association convention in Chicago in 1921.

“The ‘Hopkinson’s’ English valve has been used in this country on high pressure superheated steam work with marked success... the success of these valves is due to the very careful design of body, grade of materials used throughout, and good workmanship”.

Proud of its success and anxious to increase business even more the private company exhibited at the British Empire Exhibition at Wembley in 1924. This event coincided with the firm celebrating eighty years in business so a "Monster Excursion" - as the paper dubbed it - was organised by the company. In brief, 1,300 employees and their relatives were taken from Huddersfield to London on a free, all expenses paid, visit to the Exhibition.

In 1926 the firm became public company, with a capital of £700,000 and with the title, Hopkinsons Limited.

Other examples of the success achieved by Hopkinson’s designers and engineers on the shop floor are numerous. To take one example in 1930 Hopkinsons were asked to supply a 10 in. centre - pressure turbine stop valve for an experimental turbine installation at the Delray No. 3 Power Station of the Detroit Edison Company, USA.

This valve was required to operate at 415 lb/in² maximum pressure and 1,000 °F, a temperature previously unapproached in power station operation. The arduous operating conditions necessitated the use of special steels for the body and lid. As a result the order gave Hopkinsons yet another ‘first’ and heralded the company as a manufacturer of alloy steel valves.

Six years later, in 1936, Hopkinsons produced valves for Brimsdown ‘A’ Power Station North of London. Here the safety valves had pressure of 2130 lb/in², and pressure at the turbine stop valve was 1950 lb/in² with a working temperature of 930 °F.
War Work
A few years later Britain was involved in the Second World War when the efficiency and continuous operation of the power stations and vital industrial plants were essential. Since these in turn depended on the reliability of boiler mountings and valves, Hopkinson’s products were given the highest priority. Actually for some time prior to September 1939 the firm had substantial orders for equipment for the new power and process installations in Government factories throughout the country, in addition to extensions to electricity generating stations which then acquired a new urgency.

Furthermore there was the extra production for the war effort in the form of components for armaments, aircraft, tanks and even assemblies for ‘Asdic’ submarine detection instruments.

Britain Rebuilds
Post war nationalisation of Britain’s electricity industry brought in considerable orders for Hopkinsons when the new authority commenced a national plan for the modernisation of existing plant and the construction of additional power stations. Once more, the company’s expertise was called upon to provide the best in the design and manufacture of valves and associated products to meet this challenge.

In fact, as the industry’s expansion program continued, Hopkinsons supplied practically two-thirds of the valve requirements and over a third of the sootblower systems for the fifty 500 MW electricity generating units built in the 1960’s.

Going Nuclear
Perhaps the most notable innovation in the power industry’s history has been the introduction of nuclear power, and beginning with the world’s first industrial scale nuclear power station opened at Calder Hall England in 1956. Hopkinsons has supplied both conventional and purpose designed valves for all the UK’s commercial and experimental nuclear reactors.

On the international scene too, Hopkinsons is recognised as an authority on valves essential to the safe operation of nuclear power stations. The main steam safety valves, main steam and main feedwater isolation valves made for PWR (pressurised water reactor) type nuclear power stations in the USA, Europe and Asia are notable examples. Valves for controlling heavy water have been supplied for the primary heat transfer systems of Canadian ‘CANDU’ type reactors.
Referring again to the Venturi parallel slide type main steam and main feedwater valves for nuclear power stations, at which they fulfil a requirement for the safe shutdown of the nuclear reactor in an emergency situation. The incredible fast closing speed of these 30in. (750mm) valves - a mere two seconds for full operation - contrasts sharply with the five minutes or more which would be needed for the manual operation of a much smaller valve at the beginning of the century.

The above and other examples quoted throughout this publication indicate the results of the constant research and development work by the company and, in parallel the capital investment in new buildings, plant and equipment.

**Continuing Development**

The Weir Group vigorously encourages and supports product innovation by member companies, of Weir Valves & Controls. Hopkinson's products continue their leadership of the high integrity valve industry by constant research and development. The use of highly developed materials - ceramics, plastics, carbon and graphite and new metallic alloys - are contributing to improvements in valve design. The main aims are valves having lower weight, higher strength, smaller components and longer service life, all advantageous to the valve user in reducing power plant construction and running costs.
Introduction

Most valves on a power station can be conveniently listed in two groups,

1. For safety
2. For control  (A few belong to both groups)

Group 1. Includes Safety Valves, Water Gauges, Non-return Valves and automatic Isolating Valves.

Group 2. Includes Feed Valves, Blown Down Valves, Drain Valves and all the various kinds of Stop Valves.

The following pages are intended to help newcomers to steam engineering to become familiar with the many types of Hopkinson's Valves and Boiler Mountings they are likely to come across in the course of their work.

Weir Valves and Controls Salesmen, Agents and Representatives will also benefit from a greater understanding of the various products and their applications, enabling them to provide a better service to their customers.

Boiler Mountings & Valves

In the complex equipment of a modern steam generating plant, the boiler mountings and auxiliary valves rank among the most important items, as the safety and smooth working of the whole plant depends to a great extent on their suitability and correct design.

The casual observer would hardly notice the mountings and valves, as they are usually almost indistinguishable under a thick covering of lagging. Many of them - such as Re-heater Isolation Devices - are placed in remote positions, well away from the firing floor. Some are so insignificant in size that one might easily assume that their design, construction and duties were matters of little consequence.

The power plant engineer however quickly finds out the value of these fittings. He appreciates the necessity of obtaining first class equipment, installing it correctly and maintaining it properly. He soon learns that one faulty valve can cause the most exasperating and costly shutdowns, and that a leaky valve can waste an extraordinary amount of expensive steam.

When it is remembered that in a large steam generating plant there are hundreds of items of equipment that come within the category of mountings and valves, the responsibility placed on these fittings will be fully appreciated.
Parallel Slide Gate Valves

The Parallel Slide Gate Valve (PSGV) in its various forms, accounts for some 65% of the total number of valves manufactured annually under the Hopkinson name.

First introduced in 1881 the basic design principle on which the valve operates has remained unchanged to the present day.

Before examining this important design of valve and its various applications, we should first consider basic valve construction and operation.

There are only two ways of controlling the flow of liquids and gases and all valves, whatever their complexity might be are based on one of these fundamental principles.

Fig1. Shows a simple tank from which water is flowing from an outlet near the bottom. In order to control the flow, one can either place a finger against the pipe (diagram a) or alternatively, if the pipe is flexible it can be “pinched” (diagram b).

These illustrations represent the two basic principles of valve construction, although the first principle is developed in three ways, representing the different means by which the stopper can be presented to the pipe end, or seating.

If you can think of another practical way you will have invented a new type of valve!!
## Advantages and Disadvantages of Various Valve Types

<table>
<thead>
<tr>
<th>Valve Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>Globe</td>
<td>Smaller sizes have best shut-off and regulating characteristics.</td>
<td>Very high pressure drop ($\Delta p$) through valve and rapid wear of seating faces. Larger High Pressure sizes require massive actuators.</td>
</tr>
<tr>
<td>Conical Plug</td>
<td>Quick acting, straight through flow.</td>
<td>Difficult to combine tight shut-off with ease of operation.</td>
</tr>
<tr>
<td>Ball</td>
<td>Quick acting, straight through flow, easy operation.</td>
<td>Unsuitable for regulating duties which can cause damage to the ball surface. Larger sizes &amp; higher pressures fitted with gears sometimes need as many turns of the handwheel, as a gate valve.</td>
</tr>
<tr>
<td>Butterfly</td>
<td>Quick acting, good regulating characteristics. Compact.</td>
<td>Unsuitable for very high pressures and temperatures.</td>
</tr>
<tr>
<td>Gate</td>
<td>Straight through flow, low $\Delta p$.</td>
<td>Wedge gate type unsuitable for varying temperature applications. Parallel slide design unsuitable for low $\Delta p$ conditions.</td>
</tr>
<tr>
<td>Pinch</td>
<td>Glandless, positive shut off on dirty fluids. Lends itself to linings such as glass, rubber etc.</td>
<td>Pressure and temperature limited by diaphragm material.</td>
</tr>
</tbody>
</table>

**Figure 2**

The first & simplest way of moving the stopper is by a direct thrust on to the seating. This we call the obturating movement and is the basis of the globe valve. The word “globe” being based on the shape of the first valves of this type which were like a sphere or globe.

The second method of motivation is to rotate the stopper, which is the basis of the plug cock, a principle dating back to early Roman Times.

The third way is to move the stopper across the face of the seating which is the basis of the gate valve (Both Parallel Slide & Wedge Type).

All diaphragm valves are based on the pinching/squeezing action.

To summarise, here then we have the four principal methods of valve closure:

1. **OBTURATING** - Globe Valve
2. **ROTATING** - Ball Valve, Plug Cock Butterfly Valve.
3. **SLIDING** - Wedge Gate, through Conduit Gate, Parallel Slide Line Blind.
4. **PINCHING** - Diaphragm Valve

Each has its own particular characteristics, advantages and disadvantages.

The Hopkinson’s Parallel Slide Gate Valve by definition falls into category 3.

**How does it operate?**

![Diagram of Parallel Slide Gate Valve](image)

Nominally parallel seat faces
Self aligning discs
Inlet disc lifts from seat face
Closure takes place at outlet only

**Figure 3**
In considering the operation of a Parallel Slide Gate Valve, an important fact to remember is that in its basic form i.e. without special seats or bypass arrangements, the valve is bi-directional.

Fig 3. Shows a typical Parallel Slide Valve sealing arrangement, incorporating a male and female disc held against their respective seat faces by means of an internal spring.

The purpose of the specially designed spring is to provide initial sealing of the valve under no load conditions.

When the valve is under pressure, the force of the medium (steam or water) on the inlet disks moves it away from its seat face and compresses the spring.

This action allows the medium to enter and pressurize the intergate space (i.e. that part of the valve between the seat faces) and force the outlet disk against its seat face.

Once the pressure in the intergate space is equal to the inlet pressure, the inlet disk is returned to its seat face by the action of the spring.

The intergate pressure continues to act against the back face of the outlet disk, maintaining isolation of the valve/pipeline.

THE GREATER THE LINE PRESSURE, THE TIGHTER THE SEAL.

**What is a Parallel Slide Gate Valve Used For?**

The application of a Parallel Slide Gate Valve is essentially that of providing positive isolation on the following duties:-

3. Fuel or Lubricating Oil distribution.

In certain circumstances, a parallel slide valve may be used on regulating duties - such as Boiler Feed Pump Start up - by the fitting of a “Vee Port” outlet seat. This feature will be explained in detail later on in the text.

**Product Features**

So far, we have considered Parallel Slide Gate Valves only in the most general terms. However, it should be appreciated that there are in fact, THREE specific Hopkinson designs manufactured in Cast and Forged Carbon and Alloy Steels i.e. ASTM A216-WCB, ASTM A217-WC6, ASTM A217-WC9, ASTM A105 & ASTM 182 Gr. F22. For special high temperature applications, a select range of valves is available in C-12A Modified 9% Cr.

1. Low Pressure Valves i.e. 150 & 300 Class Ratings having a Full Bore and incorporating a Bolted Bonnet.
2. High Pressure valves i.e. 600 - 3100 Class Ratings having a Full Bore and incorporating a Pressure Seal Bonnet. [NB Exception is the 600 Class Valve in WCB, WC6 & WC9, which has a Bolted Bonnet].
3. High Pressure valves i.e. 600 - 3100 Class Ratings having a Venturi Bore and incorporating a Pressure Seal Bonnet. [NB Exception is the 600 Class valve in WCB, WC6 & WC9, which has a bolted Bonnet].

The range of valves listed above are essentially in sizes 5" - 30" but there is also a complementary range of smaller sizes of valves manufactured by Hopkinsons in ASTM A105 Forged Carbon Steel and ASTM A182-F22 Forged Alloy Steel.

This range of Parallel Slide Valves is utilised on Pipeline Isolation duties and in a modified form, as a Bypass or Equalising Bypass for the larger size Hopkinson’s Parallel Slide Valves.

Let us first consider the design features of the Low Pressure Full Bore Valve; -

1. Complies with the design requirement of ASME B16.34 1998 In 150 & 300 Class Ratings.
2. Overall length in accordance with ASME B16.10
3. Flanges in accordance with ASME B16.5 with alternatives available if required.
4. Butt welds to ASME B16.25 with provision for alternative profiles should they be required.
5. Available in Nominal Bore sizes 2½" to 30".

**Valve Construction**

The valve has been designed with a bolted rectangular Body/Cover assembly incorporating an exfoliated graphite gasket.

All valves operated with a direct mounted handwheel are of the two pillar design with roller thrust bearings fitted in the bridge to provide low friction operation.

When electric, pneumatic or hydraulic actuation is required, there is provision on the standard valve cover to fit a four-pillar arrangement to provide the necessary additional support.
A substantial stem stop (together with an indicator plate on the valve pillars) provides positive indication of the degree of opening/closure of the valve and prevents rotation of the stem.

The valve is closed when the stem stop reaches the lower shoulder of the pillars and open when opposite the open mark at the opposite end of the pillars.

A Backseating facility is incorporated in the cover and is brought into effect by opening the valve beyond the ‘Open’ mark on the indicator plate until resistance is felt.

The sealing action is achieved through a seating face on the end of the disc holder contacting a Backseat bush fitted into the cover below the base of the stuffing box.

It is important to remember that irrespective of what may be written in Contract/Tendering specifications, the purpose of backseating is NOT to allow repacking of the stuffing box when the valve is under pressure.

The function of a backseating facility is to isolate a leaking stuffing box, thus preventing stem damage, until the problem can be attended to when the system is shut down and no longer live.

Failure to follow this ruling can result in serious injury to anyone attempting to re-pack a gland while the valve is under pressure.

As with all other Hopkinsons products, the stuffing box packing material in the Low Pressure Full Bore Parallel Slide Valve is Exfoliated Graphite.

The seats and discs are the very heart of a Parallel Slide Valve. Sound design and selection of the correct materials are essential to its proper functioning.

Over many years experience, Hopkinsons have developed their own proprietary material ‘PLATNAM’ for use on the wide variety of seating applications across their extensive product range.

On the Low Pressure Parallel Slide Valves, the seats are manufactured from No.12 Platinum (which is a high nickel content steel) and are a press fit into the valve body.

Discs on the smaller sizes of valve are produced from solid No.12 Platinum castings while the larger sizes (above size 4”) are manufactured from steel with a No.6 Stellite facing.

**Comparison of the Parallel Slide Gate Valve with the Wedge Gate Valve**

We learned earlier that a Parallel Slide Valve is a “position seating” valve, utilising line pressure in order to effect closure. Originally invented by Hopkinsons, it is also manufactured by a number of other Companies around the world i.e.

<table>
<thead>
<tr>
<th>MANUFACTURER</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bailey - Birkett</td>
<td>UK</td>
</tr>
<tr>
<td>Shaw Valves</td>
<td>UK</td>
</tr>
<tr>
<td>Taylor Valves Ltd</td>
<td>UK</td>
</tr>
<tr>
<td>Peter Smith</td>
<td>UK</td>
</tr>
<tr>
<td>Dewrance - Tyco</td>
<td>Germany &amp; Italy</td>
</tr>
<tr>
<td>Sapag - Tyco</td>
<td>France</td>
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<tr>
<td>TOA</td>
<td>Japan</td>
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<tr>
<td>UTSUE</td>
<td>Japan</td>
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<tr>
<td>Malbranque</td>
<td>France</td>
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<tr>
<td>Velan</td>
<td>Canada</td>
</tr>
<tr>
<td>Audco</td>
<td>India</td>
</tr>
<tr>
<td>Babcock Borsig</td>
<td>Spain</td>
</tr>
<tr>
<td>Crane Pacific</td>
<td>USA</td>
</tr>
</tbody>
</table>

There are also a number of other companies worldwide who manufacture a Parallel seating valve but this design utilises a mechanical “spreading” disc feature and cannot be considered a true parallel slide valve. In the introduction to this manual, we examined the various types of valves and their applications. Each type has its own special capability but no one particular valve can satisfy a number of functions adequately.

Such an example is a Globe Valve which has excellent regulating characteristics but at the expense of the seating surfaces. These can quickly become eroded to the point that complete isolation of the valve is impossible.

Essentially a Parallel Slide Valve is an isolation valve and performs best on systems with a high pressure differential across the seating surfaces. Where no such pressure differential exists, an alternative solution is required. A Wedge Gate Valve, which mechanically seals on both inlet and outlet seat faces without the assistance of line pressure is a suitable option.

Unfortunately Wedge Gate valves which are used extensively in the Oil, Petro-Chemical and Refinery processes are also utilised in Power Generation Industry with less than satisfactory results.

To understand the reasons for this, we must compare the relative design features of both the Parallel Slide and Wedge Gate Valve.
Positive Isolation of Seating Faces with Zero Leak

The highly effective Hopkinson’s flat disc closure mechanism is far superior to the wedging action closure used in a Wedge Gate design [Refer Fig.4] the line pressure alone causes a tight seal far superior to that of the Wedging action system.

In the Hopkinson’s design it is SYSTEM PRESSURE not mechanical force which achieves a tight seal. After moving the disc assembly to the isolation position in a Parallel Slide Valve, no additional torque is required to isolate the line.

For this reason, torque spanners, or wheel keys should never be used on a Parallel Slide Valve to effect closure. Added force once the discs are in the sealing position will result in bent stem stops and damaged spindle threads.

Additional travel of the spindle due to a bent stem stop can in extreme circumstances cause the disc holder to be forced against the bottom of the valve body causing distortion of the disc holder. If this happens, the discs will become jammed and their sealing effect lost.

The use of torque switches instead of limit switches to control the opening and closing of an electrically operated Parallel Slide Valve can also cause damage to the external and internal components as previously described.

NEVER SET AN ELECTRICALLY OPERATED PARALLEL SLIDE GATE VALVE TO OPEN/CLOSE ON TORQUE – USE ONLY THE LIMIT SWITCHES.

Conversely, the design principle on which the Wedge Gate Valve is based is that of driving a wedge between two tapered seats and effecting closure on both the inlet and outlet seat faces.

This is difficult to achieve and specification MSS SP61 acknowledges this fact by giving a leakage allowance on test of 10cc/inch bore/ hour. To achieve isolation, the Wedge Gate Valve requires extra torque to consolidate the Wedge in its sealing position, thereby placing additional stress on the valve yoke/pillars/stem/body and seat faces. Larger actuators are therefore necessary and Wedge Gate Valves are not suitable for use with air operators. (i.e. 5 – 7 bar air supply usually found in most plants would result in unacceptably sized air actuators.)

Wedge Gate Valve tries to seal on 2 seat faces which is difficult to achieve. MSS SP 61 spec. acknowledge this and gives a large leakage rate for test.

Figure 4

Incorrect angle results in leakage

The shortcomings of the traditional solid Wedge Gate design as illustrated in Fig. 4 have long been recognised by manufacturers and various ways developed as a means of overcoming the problem.
One such solution is the “Flexi-Wedge” in which the wedge has some means of permitting movement of its opposing faces to enable them to align themselves with their respective seat faces. On larger sizes of valves operating at high pressures, the extra torque required to achieve this is considerable and in reality, the Flexi-Wedge Gate Valve is only providing a complicated solution to a seating problem which a Parallel Slide Valve addresses succinctly.

A typical Flexi Wedge Gate Valve design is shown in Figure 5.

**Ease of Operation**

Because a Parallel Slide gate Valve stem is not constrained at both ends and the spring loaded discs are free to adjust themselves to temperature fluctuations, the spindle/disc assembly will never jam or seize up. [Refer Figure 6]

In a Wedge Gate valve, the stem is constrained in two places i.e. in the yoke/bridge and at the connection to the Wedge (since the wedge is forced into the tapered seating). Severe jamming, (Thermal Binding) of the Wedge can occur when the valve is isolated when hot and the system subsequently cools. In attempting to open Wedge Gate Valves from such a situation, it is not unknown for the spindle-retaining portion of the Wedge to shear [Refer Figure 7]. Acknowledging this problem, some large bore Wedge Gate Valve manufacturers (particularly where valves are required in low-pressure waterworks installations) supply their products with a jacking point for the Wedge in the bottom of the valve body. [Refer Figure 8]
The wiping action of the disks as they slide over the seat faces, removing dirt and scale deposits is a unique feature of the Parallel Slide Gate Valve. Stellite or Hopkinson’s PLATNAM seat and disc facings prevent wear under the most arduous of operating conditions. [Refer Figure 9]

Should there be evidence of a Parallel Slide Gate Valve passing once it has been isolated, the correct procedure to achieve tightness is not to reach immediately for a wheel key [Refer Page 21] but to open and close the valve a number of times to remove any possible entrapped debris between the outlet seat and disc faces. Of course, there may be damage to either the outlet seat or disc - or even both, which prevents isolation taking place. In such circumstances, remedial action can only be taken during a shut down of the plant.

The non-wiping action of a Wedge Gate Valve traps dirt and scale between the wedge and seat faces preventing correct seating and resulting in leakage. Use of a wheel key to further force the wedge into the seat taper and “squash” any entrapped debris is the traditional action of plant operatives to solve the leakage problem. It can be an effective solution but if the entrapped debris is metallic it will also ultimately damage the wedge and seat sealing faces.

**In Line Maintenance**

If properly cared for, in a well run plant, Hopkinson’s Parallel Slide Gate Valves require little maintenance. Should it be necessary to carry out lapping of the seat faces, the operation can generally be carried out while the valve is still in the pipeline. With no angles to match as with a Wedge Gate Valve, a smooth flat surface is all that is required for the lapping process.

Discs are easily removed for re-lapping on a lapping plate and as with the seats, a smooth flat surface is the only requirement.
Optional End Connections

In the Power Generation Industry, the use of flanged connection valves has diminished over the years with an increasing preference for Butt-Weld joints - even on low-pressure applications. The reason for this trend has been purely economic. Flanged connections enable a valve to be removed relatively easily from a pipeline for maintenance, but the flange joints are in themselves a potential leakage point whilst a welded joint requires no maintenance at all. Certainly in pressures above 900# it is virtually unknown to have a flanged valve in the Power Industry. Conversely, in the Process and Petrochemical Industries, flanged valves of up to 5000# are quite common.

On the Hopkinsons range of products, flanged or butt weld end connections are available in a variety of options generally up to and including 900#. Above this pressure rating, it is usual to have butt weld end connections only.

Bolted Bonnet Joints

Although the problems associated with conventional bolting have long been recognised i.e. “creep” at high temperatures and “stretching” at high pressures, correctly designed bolted bonnet joints on low pressure valves are perfectly satisfactory.

Exceptional Gland Performance

The traditional material for the packing of glands on all types of valves, was, for many years, braided asbestos covered in graphite and impregnated with molybdenum disulphide as a cohesive agent. It was marketed under various trade names, the most popular being CRANE 1066. This type of packing worked well under most circumstances but it had two fundamental flaws:

(a) The use of asbestos was considered a health hazard to plant operatives.
(b) At high temperatures, the molybdenum disulphide burned off, the packing shrank and the stuffing box leaked.

The trend towards having automated plants with fewer operatives, inevitably, meant that less daily maintenance - such as tightening gland bolts - was carried out with the results as described. A possible means of overcoming the lack of daily maintenance was the use of “live loaded” packing, which imposed a pre-determined compression on the gland packing through the use of Belleville spring washers. [Refer Figure 13]

Unfortunately, this is an expensive means of curing gland leakage problems and in today’s competitive markets does not find favour amongst original build contractors. It is more likely to be fitted to key valves - such as Main Steam Isolation Valves, by the plant operatives, once they have taken over the running of the Power Station.
Graphite has excellent mechanical properties at elevated temperatures, good friction properties, is radiation resistant and chemically inert. It also possess the necessary basic properties of a good compression packing material for Nuclear Service.

Hopkinson’s Parallel Slide Gate Valves have been designed to utilise the best characteristics of expanded graphite packing. [Refer Figure 14]

Expanded graphite provides a stable gland packing material which due to its resistance to loss of volatiles at high temperatures minimises the frequency of gland adjustment.

Packing rings on new valves are supplied whole and are also available whole as replacements. Alternatively, replacements can be supplied in two halves so they can be fitted to the stem and dropped in position without removing the handwheel assembly. It is important however that the rings are arranged so that the split between the halves of each ring are staggered as shown in Figure 14. Since less graphite is used in gland packing than conventional types, the consequent saving permits stocking of the parts at site for immediate replacement/overhaul work.

**Upgrading of Conventional Glands & Pressure Seal Bonnets**

Older valves incorporating a gland based on traditional packing may be upgraded to utilise expanded graphite. To do this it is necessary to reduce the depth of the stuffing box since less expanded graphite packing is quite critical to its effectiveness and an excess of packing would result in failure to compress the lower rings properly with the inevitable results. Figure 15 shows the basic modification to an older type of gland preparatory to changing to expanded graphite packing.

Some designs of valve bonnet closure incorporate a soft iron sealing ring as shown on the left hand side of Figure 15. The disadvantages with this type of seal are its resistance to compression and the damage it can cause to the internal valve body walls in effecting a seal under pressure. Subsequent fitting of replacement seals then becomes problematical. By modifying some of the internal components of the valve, a grafoil seal can be fitted which will accommodate at least 0.04” ovality in the body seal bore.
Water Sealed Glands

Occasionally, the requirement for valves to be fitted with a “water sealed gland” is a feature of Tender Specifications. It is little used in the Power Generation Industry these days but is still widely accepted practice in the Petroleum Industry. API standard 600 issued by the American Petroleum Institute for the design of steel gate valves gives precise requirements for a water sealed stuffing box on such valves. In the Power Generation Industry, the function of a water-sealed gland is to prevent the ingress of air into a vacuum system such as exists during turbine trips and boiler feed pump start-ups.

A metallic ring, with a recess running around its outside diameter is inserted into a specially deepened stuffing box. An external tapping point (traditionally ¼” BSP) is made from the inside of the stuffing box to the outside of the valve bonnet to which is connected a “filling cup” or piping to a central water supply. Water passes through to the lantern ring and forms a seal over the lower packing rings in the stuffing box.

Maintenance on such a feature is obviously quite high and the use of expanded graphite with all its benefits has superseded water sealed glands in the Power Generation Industry. Figure 16 below shows a typical water sealed gland layout.

High Pressure Parallel Slide Gate Valves

Although the high and low pressure designs of Parallel Slide Gate Valves manufactured by Hopkinsons serve the same function, the essential difference is that the low pressure valve is a Full Bore valve incorporating a Bolted Bonnet while the High Pressure valve may be offered in Full or Venturi Bore configuration with a PRESSURE SEAL BONNET. Figures 17 & 18 illustrate the respective designs.

Let us first examine the features of the High Pressure Full Bore Valve which apart from having welded in seats and a pressure seal closure is virtually identical to its low pressure equivalent.

Pressure Seal Bonnet

The bonnet sealing in Hopkinson’s Pressure Seal Valves is accomplished with a sealing ring of pure expanded graphite of the same material used in the gland packing.

Used as a pressure seal gasket, the seal is made onto the standard machined surface of the Body and Bonnet. Unlike valves having a metal to metal pressure seal joint, no inlay or hardfacing of the sealing areas is necessary.

Hopkinson’s valves with graphite pressure seals are therefore much easier to maintain. Any minor damage caused to the sealing faces during maintenance only requires blending into the surface. No expensive and time consuming machining, re-depositing and lapping is required.
Venturi Bore

We mentioned earlier that the Venturi Bore principle was first developed in the early 1900's by Dr Sebastian Z de Ferranti.

His experiments proved that within certain parameters, a reduced bore valve fitted with a "FOLLOWER EYE" or "CONDUIT" in the intergate space when the valve was opened resulted in very little pressure drop ($\Delta p$) across the seats. Such a design of valve has many advantages over its full-bore equivalent. Because of the reduced bore, the valve travel (i.e. distance from OPEN-CLOSE) and fittings are proportionally smaller. The disc load area is less than corresponding sizes of full bore valves and operation of the valve is therefore easier. Where electrical operation of the valve is required it is possible that a much smaller and less expensive actuator may be selected. Figure 20 shows a Venturi valve in the closed position with the follower eye located in the closed position with the follower eye located in the bowl shaped lower portion of the valve body which is a distinctive feature of the Venturi design.

The disc springs and disc clip which prevents spreading of the discs when the valve is open are clearly seen.

Follower Eye

The advantages of the follower - eye are clearly shown in Figure 21 which compares the Venturi design product with a full bore wedge gate valve.

A comparison between the Venturi valve with a follower eye and a wedge gate valve has been quite deliberate in that it demonstrates that the benefits of a follower eye are impossible to apply to a wedge gate design - at least in economical and practical terms.

However, a shrewd observer would quite rightly reach the conclusion that the shortcomings of the full bore wedge gate valve compared to a Venturi parallel slide valve, apply somewhat equally to a full bore parallel slide valve. This raises the question that if the Venturi valve is all that it is claimed to be, why do we need a full bore equivalent?

The answer to this is purely down to customer knowledge and experience: - without question, the Venturi bore valve is an exceptional design with many unique features and benefits which are recognised and appreciated in the World Power Market. By the careful selection of seat to end bore ratio, coupled with the benefits of a follower eye, a venturi valve will equal the pressure drop characteristics of a full bore gate valve - be it wedge gate or parallel slide.
However, whilst the Venturi design can represent a significant market advantage, the product may only be offered under the following conditions: -

(a) Steam velocities through the seat area must not exceed 90m/sec (Saturated Steam) 180m/sec (Superheated Steam).
(b) Water velocities through the seat area must not exceed 15m/sec.

Full bore valves i.e. valves without a follower eye are restricted to the following:

(a) Steam velocities through the seat area must not exceed 66m/sec (Saturated Steam)
130 m/sec (Superheated Steam)
(b) Water velocities through the seat area must not exceed 12m/sec.

The following formula should be used in determining seat velocities and pressure drop.

Velocity in ft/sec = \( \frac{\text{flow in lb/hr} \times \text{Sp Vol in cu.ft/lb}}{19.635 \times (\text{seat bore in inches})^2} \)

Pressure Drop = \( 'K' \times (\text{pipe velocity in ft/sec})^2 \)
9274 \times \text{Sp vol.in cu.ft/lb}

It should also be remembered that although the seat bore can be adjusted to suit a given set of design conditions for a specific pipe size, the nominal end bore size of the Venturi valve remains unchanged and compatible with the customers designated piping and butt weld end size. Even so, the benefits of a Venturi style Parallel Slide Valve are not always readily understood or accepted by customers - even after the most strenuous sales efforts coupled with technical support. This occurs most often in areas of the world, which have been exposed to American Power Technology and Consultants. Similarly European Contractors, particularly German and Italian have very conservative attitudes towards seat velocities and in spite of our own reassurances have rejected the product.

In such circumstances, it is more sensible for the Salesperson not to pursue the issue but offer a full bore Parallel Slide Valve. The sales effort can then be directed towards the benefit of the Parallel Slide Valve over the Wedge Gate, keeping the Venturi issue out of the equation. There are non-so blind as those who do not wish to see!

**Product Ratings**

The current range of High Pressure Parallel Slide Valves comply with the design requirements of ASME B16.34 in 600# 1000# 1700# 2350# AND 3100# Class Ratings. With the exception of the 600# valve, the other high-pressure valve ratings do not fall into customary defined categories.

The customary valve ratings in ASME (formerly ANSI) standards have been 300, 400, 600, 900, 1500, 2500 & 4500 classes. Up to 2500 class these have followed flange standards and were originally ‘Primary Service Ratings’.

These primary service ratings were the permissible working pressures at a particular temperature.

The first deviation from this practice was in 1964 when the manufacturers Standardisation Society of the valve and fittings industry (MSS) published Standard Practice SP66 covering pressure temperature ratings of steel butt-weld end valves. The ANSI B16 committee set up a sub-committee to study the general subject of pressure temperature ratings and to develop rational criteria for such ratings.

ANSI B16.34 standard was the outcome of these studies and the 1973 version was issued to cover steel butt welding end valves only. The SP66 type ratings were included as ‘Special Class’. Flanged valves were still included in ANSI B16.5 along with flanges.

A revision was issued in 1977 and another, the current one, in 1996 with amendments in 1998. This latest edition covers flanged and butt welding end valves in steel, nickel alloy and other special alloys. In order to cover flanged valves, rating tables have to be included for 150, 300, 600, 900, 1500 and 2500.

Since butt-welding end valves are not constrained by the flange ratings, provision was made for intermediate ratings, which can be any class within the limits of the standard.

Analysis of market requirements shows that the customary (flange) ratings are not always an economic solution to the pressure temperature requirements. For example a 2500 class valve often falls short of the requirements for main steam design conditions associated with large utility boilers.

If a 2500 class will not satisfy the requirements of pressure and temperature the next standard rating is 4500 class. Except for small sizes, the adoption of 4500 class is not practical or economic. This can be illustrated by taking an example of a valve having a 16" end bore.

Minimum wall thickness ‘tm’ for 2500 class is approx. 5 1⁄8 ".

Minimum wall thickness ‘tm’ for 4500 class is approx. 12 1⁄8 ".

Not only would the 4500 class valve be very expensive but also there would be the practical problems of support, unacceptable thermal gradients across the thick sections and the associated stress etc.

Many feed water applications require valves in excess of 1500 class and yet the required pressure-temperature rating is well short of 2500 class.

As stated earlier, provision is made in ASME B16.34 for intermediate ratings (referred to as interpolated ratings in earlier editions). To quote the standard: - “A butt welding end valve may be assigned an intermediate rating or class, either Standard or Special, providing all requirements of this standard are met”.

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On this basis Hopkinsons have adopted pressure-temperature ratings as standard, 1000 class, 1700 class, 2350 class and 3100 class. These replace the customary 900 class, 1500 class and 2500 class. Higher ratings are available as required.

The main point to remember is that these intermediate rated valves conform to the requirement of B16.34. Standard or Special as appropriate, without any qualification.

A valve designed to meet 1000 class would only be rated as 900 class standard if it had 900 class flanges. All flanged valves would be limited to the flange rating and in WC6 and WC9 would have an upper temperature limit of 1000°F.

When the required rating is 600 class or less, the advantages of intermediate ratings become marginal and tend not to be adopted by any company.

**Relationship Between Nominal Pipesize and Valve Seat Diameter (ASME B.16.34)**

One of the most frequently misunderstood aspects of the ASME design code and its intent, is the confusion some customers have in regard to the Venturi Parallel Slide Gate Valve not meeting minimum flow path criteria.

The paragraph in ASME B.16.34 to which they refer is 6.1.2 and states: “For the purpose of determining the wall thickness tm, the inside diameter d is taken as the minimum diameter of the flow passage but not less than 90% of the basic inside diameter at the valve end . . .”

It is not unusual for some customers to mistakenly interpret this paragraph as meaning a valve seat bore should not be less than 90% of the valve end bore.

Let us be quite clear on this matter. ASME B.16.34 makes no restriction whatsoever on seat bore. The purpose of clause 6.1.2 when used in conjunction with table A1 of the said code is for determining the minimum valve wall thickness tm. In determining the minimum thickness tm, the diameter used must not be less than 90% of the end bore. This 90% valve only applies to the determination of tm – nothing more.

**Market Applications**

**Power Generation Industry**

The many applications of both Low and High Pressure Parallel Slide Valves can be clearly seen in the schematic layouts of the Combined Cycle and Fossil Fuel Power Plants accompanying this text. These are purely isolation functions but there are occasions during start up of the plant where it is necessary to have a degree of regulation through the valve.

**Vee Port Outlet Seats**

Parallel slide valves are essentially isolation valves to be used either fully open or fully closed and are not designed for continuous flow regulation.

There are however applications, such as bled steam from turbine to feed water heaters, where the flow needs to be restricted during startup to avoid overloading drains. The amount of steam required is more than can be supplied through a small bypass valve and would probably require the valve in the main line to be, say, 1/3 open. For short-term use during startup this is permissible but if the ‘turn-down ratio’ is high, that is, the valve would only need to be opened a small amount, then it is not permissible.

For flow regulation and good isolation with both steam and water, a suitable valve can be produced which is essentially a standard parallel slide valve suitable for the pressure and temperature, with a modified seat and disc on the outlet side, that is, suitable for unidirectional flow only.

The seat has ‘V’ port in it as shown in Figure 22. The shaded area and inside the port is deposited with ‘Stellite’ or its equivalent, and the face of the disc is similarly deposited but over a larger area than would be the case for a straightforward isolating valve.

The port shape would normally be of a shape as shown in Figure 22 and would be such that it would fit inside a circle of the same size as one of the standard seat bore for the particular class of valve.

In all cases the minimum width of ‘Stellite’ deposit around the port area would be the same as a standard valve for the same conditions.

As will be seen from the port shape the characteristic is approximately linear but it is not intended to be a control valve with a known characteristic such that a particular stem position will give a precise pressure drop.

Its application is when a preset valve is required to balance a system rather than that where a true modulating control valve would be required to cope with constantly varying conditions.

Globe valves are often used for this application but would have a shorter life than the type described here and would certainly not provide the positive closure of the parallel slide valve when required.
Steam Purging with the Venturi Design Main Steam Isolation Valve

Common practice during the commissioning of a new boiler or after extensive repair to an existing installation, is to install a sacrificial valve in place of the Main Steam Stop Valve before commencing steam-purging operations. This procedure ensures that the main steam stop valve internals do not suffer any damage from the inevitable debris in the system but it is a time consuming and expensive operation to change and replace these two valves.

A unique advantage of the Venturi Parallel Slide Valve is that it lends itself perfectly to Steam Surging Operations without having to be removed from the boiler. Instead the valve is fitted with a temporary set of internal components which incorporate downstream seat protection, whilst the eyelet in the follower eye ensures a smooth stream flow through the intergate space in the open discharge position.

Modified spindle and actuator insert leads enable critical operating times to be achieved during steam purge sequences. Following completion of purging operations, the temporary internals may be removed and refurbished, ready for use on the next unit or held in store for future purging requirements.

Process, Petrochemical & Nuclear Market

The current range of Parallel Slide Valves have been designed to satisfy the requirements of markets for steam and associated water services. From time to time, we are asked to quote for valve requirements for other services such as oil and a variety of gases in the process and petrochemical industries. For applications where the fluid is fuel or lubricating oil there is no reason why Hopkinson Parallel Slide valves should not be offered.

If valves are required for oxygen service, we must decline to offer due to the difficulty in obtaining a gas tight seal between the seats and discs. If however gate valves are required for gas services other than CO2 services such as are employed on Gas Cooled Nuclear Reactors, we should offer our valves but making it quite clear to the customer that we are offering products: -

(a) Designed to ASME B.16.34
(b) The seat faces are ‘Stellite’
(c) The gland packing material is graphite

We are not in a position to guarantee to a customer that a ‘Stellite’ on ‘Stellite’ seating arrangement is suitable for any particular gas or combination of gases.

Hopkinson’s Parallel Slide Valves with ‘Stellite’ and ‘Platnam’ seats and discs are not suitable for modification to other seat deposit materials or combinations such as ‘Universal Trim’ i.e. Stellite seat and 13% Cr. Disc, since our design engineers have taken full advantage of the properties of ‘Stellite’ in reducing the general valve bulk and obtaining overall economies of construction.

Valves for CO2 services on Advanced Gas Cooled Reactors need seats other than ‘Stellite’ and currently the choice is ‘Fontargen E715’ with a hardness of 62 Rockwell ‘C’. Any valves for this service will need to be specially designed.

Enquiries for valves are often received in which the customer specifies API standard 600 when in fact valves to ASME B16.34 would be acceptable. There is no reason why we should not offer our products but again, we must qualify our offer with the statements given in a, b & c detailed previously. Anyone taking the trouble to read API standard 600 will understand the reasons for doing this. API standard 600 specifies a number of requirements - peculiar to the Petroleum Industry with which our products - designed to ASME B16.34 do not comply. The following list details some of the more significant requirements: -

Figure 23
1) API 600 defines Gate Valves as either Wedge (Solid, one-piece flexible and two piece split) or Double-Disc. Paragraph 2.3.6 defines a double disc gate valve as one having “parallel seats and an internal spreading device (for example, a wedging device or spring) that forces the two disks firmly against the body seats when the gate is in the closed position”. Such a statement would permit the use of our Parallel Slide Valves except where the customer wanted to “Block & Bleed” i.e. Isolate Inlet and Outlet Seats and drain the intergate space. Our Parallel Slide Valves do not conform with this requirement.

2) API 600 requires internal guiding of the gate.

3) API 600 stem diameters are greater than ASME.

4) API 600 stuffing box specifications are based on the former use of Asbestos as opposed to graphite packing, which results in a greater depth.

5) API 600 specifies a thicker body wall than ASME for certain designs of pressure seal bonnet valves.

6) For cleaning (pigging) purposes, the seat bore of an API 600 valve is required to be not less than the bore of the mating pipe.

### Bypass Valves and Equalising Devices

#### Bypass Valves

In a Hopkinson’s Parallel Slide Gate Valve, the pipeline pressure is utilised to achieve valve shut off.

When opening the valve it is necessary to overcome the forces created by the system pressure acting against the outlet disc. However it must be recognised that in effecting closure of the valve, an operator has to overcome three distinct loads, i.e.

(i) Disc Load
(ii) Packing Load
(iii) Unbalanced Spindle Load

The design of the Parallel Slide Valve is such that it is a simple calculation to accurately determine each of the above loads and ultimately their sum, in order to establish the effort required to close the valve against the design conditions of the system in which the valve will be located.

Disc Load = Disc area x design pressure x μ. N.B. μ varies between .2 and .4 depending on the design conditions. It should also be remembered that since a Parallel Slide Gate Valve is “position” seating, no additional force is required to move the disc from the seat. Experiments have shown that with a Wedge Gate Valve, an additional 20% extra effort is required. This can result in the requirement for a much larger mechanical or electrical actuator than would be necessary for a Parallel Slide Valve under the same conditions.

Unbalanced Spindle Load = Cross sectional area of the spindle x design pressure.

The unbalanced load acting on the valve spindle has a positive and negative effect during the operation of a valve. In the opening mode, the unbalanced spindle load will assist the operator whilst the reverse occurs during closure where the operator is required to overcome the effect of the unbalanced spindle load.

By far the greatest of the three loads is the disc load and when opening the valve it is necessary to overcome the forces created by the system pressure acting against the outlet disc.

On small size valves, these forces are easily overcome with our standard size handwheels or actuators.

On larger bore valves, some means of equalizing the pressure differential across the discs is desirable and this is achieved by fitting a Bypass Valve as illustrated in Figure 24. This is known as a PLAIN BYPASS and apart from reducing operating effort, the fitting of such a valve may be for a number of other reasons e.g.

1) For gradually warming down-stream metal parts.
2) For filling or priming a system.
3) Because it has been customary to do so!
If the downstream volume is of finite size and the medium flowing through the pipe is a liquid, the pressure across the main valve disc can be equalized or partly so. This will reduce the operating effort.

When the medium is steam, the equipment downstream may be capable of condensing the steam at a greater rate than it can pass through a standard bypass. In such circumstances, the pressure may not be equalized and the system may not be heated up sufficiently quickly either.

On applications such as the isolation of extraction (bled steam) pipes, the customer may ask for a bypass valve to be fitted to the main isolation valve without specifying just what he intends to do with it.

On a large unit, the heat sink beyond the isolating valve will be large and comprise not only the pipe itself, but the heater shell, tubular heat transfer surfaces and the water flowing through the tubes - as a minimum. This means that the down-stream pressure and the rate of heating may not be what is desired because of the limited amount of steam which can pass through a standard bypass.

A generally acceptable solution to the problem is illustrated in Figure 25 where a large bore bypass valve (say 100mm) is fitted to the adjacent pipework rather than the main valve body where space would be restricted.

Conversely, the same technique may be applied where a bypass valve is required on a small main valve and space is similarly restricted.

When the downstream pressure is 58% of the upstream pressure, or less, the steam will pass through the bypass at critical velocity and if this is allowed to continue for long periods, serious damage can occur. Apart from the restriction of the valve itself, there is also that of the bypass which can be significant, especially in those instances where the pipe is extended to make the bypass more accessible.

Valve damage may or may not be caused by erosion. A more likely reason is disc vibration or chatter, which may be exaggerated by disc rotation.

To minimise this potential problem, the main valve and bypass must be operated in the correct sequence: -

To open Main Valve: 1) Open Bypass Valve 2) Open Main Valve 3) Close Bypass Valve

To close Main Valve: 1) Open Bypass Valve 2) Close Main Valve 3) Close Bypass Valve

Where electric actuators are fitted, the correct sequence of operation is usually effected by utilisation of the limit switches.
Equalising Bypass Valves & Devices

When a parallel slide is used on water isolation duties - high pressure feed being a typical application, it is possible to generate a pressure in excess of the line pressure in the intergate space between the seats when the valve is being closed such that it is possible to create a “hydraulic lock”.

As the stem is moved from the open position it displaces water as a hydraulic ram. For most of its travel, the displaced water passes into the pipeline but when the disc overlaps the seat bore (Refer Figure 26) it can no longer do this should there be a differential pressure across both discs.

The valve inlet disc would not usually have a differential pressure across it at this time but it can happen, particularly on the larger bore valves where the disc spring force is greater.

During the late 1950’s, Hopkinsons developed a special range of Main Feed and Main Steam Isolation Valves, specifically designed to overcome the problems associated with “hydraulic lock.”

So successful was the range that it was extended to include isolation requirements in connection with boiler feed water circulation pumps, an illustration of which is shown in Figure 27.

The unique feature of this range of valves was the “Balanced” Spindle fitted to the lower part of the eye-follower. It served two useful functions, i.e.

1) When a Main Steam stop valve was being used to conduct a hydraulic test on a boiler or a Main Feedwater Isolation Valve was being closed, the requirement to pipe away water displaced by the introduction of the valve spindle into the body chamber was eliminated. The spindle volume in the body chamber remaining constant throughout the operating procedure.

2) the operating torque/effort of the valve was reduced by the elimination of the unbalanced load acting on the main valve spindle.

Unfortunately, whilst the design concept was sound, there were a number of practical disadvantages to its use:-

(a) It required an additional stuffing box with a potential leakage problem.
(b) It called for precise machining to ensure correct alignment of both spindles.
(c) Handling of the assembled valve on site was made more difficult with the ever present risk of damage to the bottom spindle and stuffing box.

In an increasingly competitive world, the design incurred unacceptably higher manufacturing costs and was ultimately abandoned in favour of more economical and practical methods of resolving the problem.
Such an example is shown in Figure 28 where the fitting of an inexpensive equalizing pipe enables the displaced water to be piped away.

It will be noted that in Figure 28 the pipe is connected from the intergate space to the higher-pressure side of the valve when closed. This means the valve can only be used for isolation in one direction. Should the flow be reversed with the valve in the closed position, the downstream disc would be pushed from its seat by the back pressure and the water would flow past the disc, through the equalising pipe and back into the line. A practical solution to this problem would be to fit an isolation valve into the equalising pipeline as shown in Figure 29.

On some applications such as the isolation of feed water heaters, the valves fitted to the inlet side of the heater would have an equalising arrangement as shown in Figure 28. However, the isolation valve fitted at the outlet of the Feed Water Heater would have to be fitted with an equalising pipe on the DOWNSTREAM side of the valve in order to effectively isolate the heater should a reversal of flow occur and to facilitate hydro testing of the heater during commissioning of the plant.

As feedwater applications are below 550˚F, carbon steel valves are generally used. For this reason, Hopkins fit equalising pipes to all carbon steel valves above 6” nominal bore.

**Equalising Pipe Applications**

Although we have highlighted valve operational problems on water service applications the same situation can occur under certain circumstances on steam conditions.

Consider then a valve in a vertical pipeline where the system has been shut down for some particular reason (Figure 30.)

If the direction of flow is normally upwards, it is likely that, as a result of the plant cooling, condensate will accumulate in the vertical riser.

If the valve is shut, it is possible for the weight of the condensate to compress the disk springs, push the disk away from its seat and allow the liquid to enter the intergate space.

On re-starting the boiler, the heated pipework causes the condensate to expand and the pressure inside the valve increases to such an extent that the valve cannot be opened.

This occurrence is known as “LOCKED IN PRESSURE” and can rapidly develop into a dangerous “OVER PRESSURE” situation.

N.B. (After Hydro-Test, steam valves should always be opened to release trapped water as the problem can occur in valves both in horizontal and vertical pipelines).
The fitting of an equalizing pipe enables the condensate to pass through the valve body and be safely drained away through the drain valve at the bottom of the pipe run.

**Alternative Equalizing Devices**

Two inexpensive alternatives to the fitting of an equalizing pipe, which are quite often utilised by site personnel to resolve problems associated with closure of valves on feed water applications, are illustrated in Figure 31.

The first solution is to drill a small hole in the down steam seat or alternatively the downstream disc. Both methods are highly effective but could be inherently dangerous e.g.

a) The valve could be removed from the pipeline for repair and re-installed incorrectly, even when clearly marked with direction of flow on the outside of the valve body.

b) The disc with the hole could be re-fitted incorrectly following maintenance of the valve internals.

**Automatic Equalizing Valves**

A valve fitted with an equalizing pipe will only isolate in one direction.

A possible way of overcoming this limitation is by means of an automatic equalizing device, which will enable the valve to be used on a two way flow system (see Figure 32)

The “solid” disk is free to move between the two seats, the total movement being around 10 thousands of an inch. The seat faces are stellited.

Whichever the direction of the flow, line pressure will force the disk against the other seat face and again, the intergate space is vented to the higher-pressure side of the system.

However, it should be appreciated that an automatic equalizing device is not a standard Hopkinsons product but one which could be incorporated should a customer specially require this particular feature. Of all the various equalizing options available the preferred method of providing an equalizing feature on such as Main Feed Isolation or Main Steam Stop Valves is the **EQUALIZING BYPASS**.

**Equalizing Bypass**

The equalizing bypass is basically a plain bypass incorporating the additional feature of an equalizing facility by means of connecting pipe from the intergate space of the main valve to the intergate space of the bypass valve. (Refer Figure 33)
The equalizing bypass should always be open when the main valve is being closed and under these circumstances there will be a flow through the valve [Refer Figure 34]. After the main valve disc overlaps the seat bore as previously described, any water displaced by the stem can pass along the small equalizing pipe to join the flow through the bypass.

![Figure 34](image)

When the main valve is fully closed then the bypass valve can be closed, completely isolating the system. Figure 35 shows the bypass in the closed position and it will be seen that the valve isolates in the same way as a standard valve.

The sequence of operation for an equalizing bypass is exactly the same as for a plain bypass valve.

**Types of Valve Operation**

Many of the Parallel Slide Gate Valves manufactured by Hopkinsons for every-day isolation duties are supplied with a standard handwheel as shown in Figure 36.

Such an arrangement is perfectly acceptable on small-bore valves on even larger valves providing the handwheel diameter does not exceed 750mm, beyond which an operative would have difficulty in turning the wheel.

On all manually operated valves, it is the operating effort i.e. the force required to turn the handwheel which determines the diameter of handwheel fitted. For all practical purposes, it is estimated that the average operative can apply a combined effort of 100lbs. i.e. 50lb “pull” + 50lb “push”.

![Figure 36](image)
Should this not be achievable with an acceptably sized handwheel, it is necessary to fit a reduction gearbox as shown in Figure 37.

Whilst the operating effort is reduced, the number of turns of the handwheel required to open the valve is increased which in itself can lead to operative fatigue.

The solution to this is to fit an electric actuator as shown in Figure 38. The example also shows the Main valve fitted with an electrically operated equalizing bypass and of course the two would need to be interlocked as described on page 34 for correct sequencing of operation.
Sometimes a valve may be located in such a position in the Power Plant that it is necessary to provide extension gear to a convenient operating point. Figure 39 shows a valve being operated from a floor level above with the option of either manual or electrical operation.

Where a valve is required to be operated from a floor level below, the arrangement would be as shown in Figure 40. In such circumstances it is of course necessary to fit a reversing gearbox to ensure the correct operating procedure of CLOCKWISE rotation of the handwheel to CLOSE the valve and ANTI-CLOCKWISE rotation to OPEN the valve.
Previous examples of remote operation show the valve with its stem in a horizontal position. Figures 41 & 42 illustrate similar layouts but with the stem vertical.
Figure 42

Main and Bypass Valves operated through Spur Gear Boxes

Pillar mounted actuator is used for electric operation
Check & Non-Return Valves

The various types of Gate Valves reviewed so far belong to the family of valves, which are actuated from outside of the pressure envelope.

Not only can they be opened and closed by direct force at any desired time, but in addition, the human operative can verify the degree of opening/closure by sight or by test of the actuation system.

The elementary Check Valve lacks these characteristics. Its functioning is entirely within the pressure envelope. Its opening and closing are governed by flow direction with the human operative powerless to intervene and unable to determine the position of the disc. In addition, Check valve reliability must be high. Failure to close and prevent backflow even once in a valve’s life could cause untold damage and even loss of life. Without question, the functional reliability of a check valve has to be considered in the same terms as that of an airman’s parachute.

A check valve, “reliability” is also broader than for other valve types. Not only must the valve close, it must also close according to the desired position/time relationship. A check valve that closes suddenly and late can destroy itself, along with considerable piping and supports. The pressure drop through an open check valve is a source of energy loss. Cost evaluation of the valve on certain applications i.e. Bled (Extraction) steam should include this effect, although energy loss may not be as significant in the overall picture as reliability and shock resistant closure.

A satisfying Check valve should therefore open easily and fully to pass flow with little pressure drop or disturbance to flow patterns. It should also resist damage to its seat, disc hinging or guiding means in all directions during valve life, close quickly without damage or waterhammer at the instant of cessation of flow.

How tightly a check valve should be required to seat depends on the service. Often, some leakage is permissible. Discharge lines of pumps are an example. As long as flow is insufficient to rotate the impeller or rapidly empty the overhead tank, the valve will be satisfactory. On the other hand, if the check valve is required to isolate a machine for maintenance, a leak can prevent the work from being carried out and necessitate the fitting of a separate isolation valve.

Shortcomings in the various designs of check valve, have forced many changes in and ingenious additions to the basic elements of construction.

Let us now examine each of the numerous designs of check valve utilised in the Power Generation Industry and in particular, those manufactured by Weir Valves & Controls.

Swing Check Valves

‘Swing Check’ valves is the preferred description for non-return valves consisting of a hinged disc, although they are sometimes called flap valves because of their geometric action. Their mode of working is obvious. With flow in one direction the disc hinges upwards to flow through the valve. With reverse flow, the disc is held closed. Equally, spring pressure (from an actuator) or mass effect normally holds the disc closed in the absence of a flow. In some cases, closure is also assisted by the use of a weighted lever. Figure 43 shows a Hopkinson’s 2500# Swing Check Valve with Butt Weld end connections and incorporating a pressure seal bonnet similar to that used on Parallel Slide Gate Valves. Lower pressure Swing Check Valves i.e. 150 - 600# are normally fitted with a bolted bonnet as shown in Figure 44.

Figure 43

It will be noticed also in Figure 44 that the hinge/disc assembly is of a different construction than the high pressure valve shown in Figure 43 and is typical of the design employed on lower pressure applications.

Figure 44

A requirement on this design of valve which is not immediately apparent is for the fitting of an anti rotational device to the disc/hinge assembly. Spinning of the disc by asymmetric turbulence of fluid can harm both Swing Check and vertical lift Check valves especially in non-lubricating fluids.
However, the danger is not so serious as it is for Swing Checks. Disc and hinge pin wear can be so severe as to cause complete separation of the component assembly. Also, the Swing Check valve does not have any in built anti-slam facility although it can be less expensive to produce and have lower flow losses than a globe pattern lift check valve.

Swing check valves are normally positioned for operation in horizontal pipelines although operation in vertical pipes where the flow is upwards can be accommodated.

The absence of damping means this type of valve is quite suitable for main steam line applications and other forms of compressible flow where the phenomenon of water hammer is absent. The Swing Check valve however is quite unsuitable for use in systems with pulsating flows.Whilst slamming does take place, it does not incur the same consequences to the pipework system as the compressibility of the steam tends to absorb the pressure transients.

A Swing Check valve can easily be fitted with an external damper although this does of course offset some of the price and flow loss advantages. On steam duty, a damper extends the life of wearing parts in the valve and is most useful during lengthy commissioning, prolonged periods of low flow and for numerous start-ups. Equally, a damper permits a swing check valve to be used on liquid service. The act of bringing the hinge pin out of the pressure containment involves a gland seal, which will produce the necessary damping. This is frictional damping and to ensure the valve is still capable of closing against the frictional gland resistance, a torsional spring is usually introduced.

**Feedwater Check Valve Applications**

Hopkinsons manufacture positive closing Check Valves for the discharge lines of boiler feed pumps. These valves provide positive protection for feedwater systems and can prevent damage to costly pumping equipment Figure 45 illustrates a typical feed pump/Check valve layout.

Reliable and rapid closure is achieved by means of an auxiliary spring-loaded cylinder, usually actuated by compressed air.

The positive closing cylinder acts to close the disc of the valve through a simple engaging mechanism but the engaging mechanism does not permit the cylinder to open the valve.When the piston of the closing cylinder [refer Figure 46] is pushed upwards by air pressure, the disc assembly of the valve is free to swing from a closed to a wide-open position solely in response to feedwater flow.

Figure 46
Cross Section Showing Positive Closing Cylinder & Shaft

Disc movement is completely independent of the hinge shaft. A stop on the back of the disc holds it at a slight incline into the flow when the valve is wide open normal velocities swing the disc to the full open position and the stop prevents undue flutter or movement. [Refer Figure 47.]

Figure 47
Cross Section Showing Inclined Seat & Swinging Disc
**Vertical Lift Check Valves**

The lift check non-return valve is based on the globe type of valve, where the disc moves vertically upwards during flow and gravity seats the valve when the forward flow stops.

Unlike the Swing Check, the vertical lift design has an inherent anti-slam feature which is of vital importance in liquid service and in particular feed water applications although these valves may be used on steam service also.

Damping - restricting the valve disc from changing position too quickly - is achieved by forming a dashpot arrangement with “bleed holes”. For the valve to change position fluid must flow in or out of the bleed holes and this regulates the speed at which the valve can operate. The Hopkinsons standard speed is nominally FIVE seconds from fully open to fully closed on both the angle and the straight through Globe design of valve.

The angle pattern valve is particularly useful for feed pump discharge applications where the pump outlet is vertically upwards - the angle pattern being a convenient way to bring the pipe run horizontal and is favoured when the cost and flow losses of a pipe bend are considered. Figures 48 & 49 illustrate the Hopkinson’s Globe and Angle pattern valves manufactured by Weir Valves & Controls. These are high-pressure valves and incorporate a pressure seal bonnet and complement the range of Parallel Slide valves in size, materials and pressure ratings.

**Comparative Disc Movement**

It is interesting at this stage to compare the relative movement of the disc in Swing and vertical lift pattern Check valves.

In a Swing Check valve, the disc movement from fully open to closed and vice versa is considerable. Indeed, Check valves manufactured to API specifications are required to have the disc move completely out of the flow path when fully open in order to facilitate “pigging” of the pipeline. This is not the case with ASME coded valves and caution should always be exercised in offering ASME Check valves for API applications.

By comparison, the movement of the disc in a vertical lift check valve is considerably less and follows the rule of

\[
\text{LIFT} = \frac{\text{Diameter of Valve Bore}}{4}
\]

* N.B. Where the diameter of the seat bore is equal to the diameter of the valve.

In fact this is true for all vertical lift valves including Globe and Angle pattern Isolation valves as can be illustrated by the following simple mathematical exercise.

![Figure 50 a](dashpot_with_bleed_holes)

**Figure 50 a**

![Figure 50 b](area_between_valve_head_seat_when_fully_open)

**Figure 50 b**

Effectively, when the valve is fully open, the area between the valve head and the seat face has to equal the area of the seat in order that the valve can pass the correct flow.

The flow area when the valve is open can be likened to the surface area of a cylinder of Diameter D (Seat Bore) and height L (Valve Head Lift). [Refer Figure 50a].

Therefore,

\[
\begin{align*}
\text{Cylinder area} &= \text{Seat Area} \\
\pi DL &= \frac{\pi D^2}{4} \\
4\pi DL &= \pi D^2 \\
L &= \frac{\pi D^2}{4\pi D} \\
\therefore \ L &= \frac{D}{4}
\end{align*}
\]

**Stop Check Valves**

We have stated earlier that valves generally fall into one of two categories i.e. Control or Safety although some valves actually fall into both. An example of this is a FEED CHECK VALVE.

The first duty of a feed valve is of course to enable the engineer to shut off the flow of water to the boiler when necessary, but the valve also has a ‘Safety’ feature.

It must prevent any reversal of flow through the feed pipe; in other words, if for any reason (such as the failure of the feed pump) the pressure on the ‘boiler’ side of the valve overcomes the pressure on the
‘feed’ side, the feed valve must automatically close, otherwise the hot water in the economiser would be driven violently into the feed line with disastrous results.

Of course a separate arrangement of some form of isolation valve such as a Parallel Slide or Globe Valve in combination with a Swing Check valve could be used but is an expensive option which also increases the potential maintenance levels of the plant. Such an arrangement of separate valves is however usually found on large Fossil Fired Generating Stations and Combined Cycle Power Plants.

A more practical and economical solution for the smaller industrial power plants is illustrated in Figure 51. Where a conventional globe isolating valve is adapted to incorporate a dashpot arrangement. When the valve is opened the valve head, not being connected to the spindle, is lifted from its seat by the water pressure at the inlet and is free to re-seat itself independently in the event of a reversal of flow.

With any valve of this design it is vitally important that the contact of the valve head and seat be absolutely fluid tight. A slight tilt on the part of the valve head would cause leakage. Special care is therefore taken in the machining and subsequent fitting of the guide and valve head to ensure that the valve head fits the face of the seat accurately. From the foregoing it will be understood why this type of valve should always be fitted with the spindle vertical. It will be noticed from the illustration that all guiding of the valve head is done above the latter fitting; there are no wings or guides, which would obstruct the flow passages and cause excessive pressure drop.

Hopkinson Feed Check Valves manufactured by Weir Valves & Controls are available in Globe or Angle pattern configuration for a wide range of boiler requirements. The type illustrated is often more fully described in specifications as a ‘Combined Stop and Non Return Valve’ or a ‘Screw Down Stop and Non Return valve (SDNRV)’.

Tilting Disc Check Valves

So far we have examined the operation and application of two important members of the Check Valve family i.e. Swing Check and Vertical Lift (or Piston Check) valves together with their derivatives. There is however a third design of Check valve which bears a strong resemblance to the Swing Check design and is finding increasing favour amongst designers of Power & Industrial generating plants. It is known as the TILTING DISC CHECK valve and a typical example is shown in Figure 52.

Currently, the tilting disc design of valve is not manufactured by Weir Valves & Controls but its importance is such that it is worthwhile reviewing the products design features.

As the name implies, the disc tilts around the hinge pin which is located within the disc diameter, as opposed to the Swing Check valve where the hinge pin is remote from the disc. This important design feature impacts significantly on both the physical aspect of the valve and its operational characteristics in that:

(a) The overall height of the valve and subsequent weight is reduced.

(b) The disc travel is reduced.

(c) The flow through the valve passes both above and below the disc giving a more streamlined flow than with other designs.

(d) The location of the hinge pin in the tilting disc valve results in a much reduced operating effort compared to the Swing Check design.

(e) The tilting disc valve lends itself more easily to the incorporation of a tamper proof counterweight.

(f) Seating surfaces on the tilting disc valve are conical giving seating characteristics similar to a Globe valve.
An unusual aspect of the tilting disc valve is its seating geometry. The concept of moving a conical shaped disc from a conical seating position is one, which intrigues most people - many of whom find it difficult to believe it can happen at all! The following sketches show how it is achieved.

Figure 53 is essentially a vertical section through the seat and disc. Referring now to Figure 53 if a line AB is drawn normal to line AO and another line DE is drawn normal to line CO, an area will be fixed between lines AB and DE as indicated on this sketch by angle F. If the hinge pin (pivot point) is located anywhere in this area, the disc can swing out of the seat. To reduce the torque necessary to open the valve, the pivot point is located near to the apex of the area as indicated in Figure 53. The higher this becomes the more nearly does it become similar to a swing check.

As soon as the disk begins to swing, the seating surfaces are clear all the way around the periphery. There is no rubbing.

Figure 54 illustrates the first part of the movement and Figure 55 shows the disc further open.

One very important essential point with any check valve is that it should be closed immediately the flow ceases in the normal flow direction. If it does not, a flow will be established in the reverse direction until the force on the back of the disc is sufficient to close it. When this happens, the valve will ‘slam’ shut.

If the disc was a simple shape as shown in Figure 53 then it would not close when the flow ceased in the normal direction. It would remain in a position approximately as shown in Figure 56 with the centre of gravity of the disk vertically below the pivot point.

To ensure that the disc does positively close when the flow ceases, a ‘counter weight’ is fitted as part of the disc as shown in the illustration at the beginning of these notes. If the seat was not inclined relatively to the body centre line, the weight would need to be considerably greater and the effort needed from the flowing medium to open the valve would also be greater, which in turn would cause a higher pressure drop.

The tilting disc check valve is mostly used on feed water and bled steam applications and manufactured principally by the German manufacturer ADAMS in cast and forged steel materials and also by DEWRANCE, a member of the TYCO group of companies.
Bled Steam Non-Return Valves

Alternatively known as Free Flow Reverse current Check valves (FFRC) or Extraction Steam Non Return valves (ESNR) in spite of appearing to be a simple product has its complications. The following is just one step on the way to understanding the Hopkinsons design and its application in the Power Generation Industry.

Bled Steam Check valves are required in every turbo alternator installation which utilises extraction steam for feed water heating or process requirements, irrespective of whether the fuel is coal, oil, natural gas or nuclear.

The function of the valve is quite simply to prevent flow of steam or water back into the turbine when there is a sudden change in load. For this reason, it is usual for valves on this application to be either power closing or assisted closing by operation of fire-safe pneumatic or hydraulic actuators. Pressures in the bled steam lines vary with load and at zero load i.e. with the turbine running at its normal speed but not generating any current, it will be at a pressure about 10% of the full load pressure. This means that in any line where the pressure is below 150psi (absolute) at full load, it will fall to something below atmospheric pressure at zero load.

If steam is passing to a feed water heater at a given load and the load suddenly changes, the pressure at the turbine will quickly fall and the steam already in the pipework and the heater itself being at a higher pressure will attempt to flow back into the turbine. This situation may be considered unimportant, as this is where the steam had come from in the first place. The reality is quite different. In a large turbo alternator installation designed for an output of 660MW, the rotor is transmitting more than 980,000 HP, weighs hundreds of tons and rotates at 3000 or 3600 RPM depending on the supply frequency of the country concerned. The inertia of the rotating element is very large and although the steam supply is shut off in a fraction of a second when the load is removed, its speed will begin to increase. The margin of safety is minimal so it is important that the input of additional energy into the turbine from bled steam pipes and heaters should be prevented.

In the case of the deaerator/feed water heater(s) in particular, there is a great deal of energy in the stored water at saturation temperature which immediately starts to flash into steam when the pressure is decreased.

On the other hand if there is something wrong in a feed water heater i.e. blocked drains or ruptured tubing and the water level in the steam space is unduly high, it is possible for water to be swept back into the turbine.

This is a potentially disastrous situation that can totally destroy a turbine and requires closure of the Bled Steam valves together with isolation of the defective feed water heater and diversion of the feed water flow through it. [Refer section on Feedwater Heater Bypass Systems].

There is another application, which is akin to bled steam and that is the cold reheat supply to the main steam reheater. Now that it is becoming common practice to fit steam bypass valves around the turbine HP cylinder, even when the boiler is of the drum type, it is necessary to fit a check valve(s) in the cold reheat pipework. In this situation, if the check valve does not close, high temperature steam will be fed back into the turbine and find there is no outlet. The moving blades will generate additional heat rising to point where the blades are destroyed.

Because sticking of the disc can have such severe consequences on Bled Steam applications, customers are unwilling to depend on gravity closure, no matter how reliable it may theoretically be, on those lines where the steam contains a significant amount of energy. However, on some of the very low pressure lines there are no valves at all and others have gravity closing check valves.

Generally in the USA, the assisted closing gear is required to give the disc a blow to ensure the disc is not stuck in the open position when the valve receives a signal to close. The actuation is not required to push the disc all of the way to the seat but only some 66 - 75 per cent of the distance. This is a practical consideration with most designs of Swing Check valves where the hinge pin is located above the seat. The available power in the actuator has to be such that it can be used with the plant on full load to demonstrate that the disc is not stuck in the open position.

Others require the assistance gear to have a stroke long enough to push the disc all the way from the fully open position to the seat with the pressure at full load but not to hold it closed.

With very few exceptions “Power Closing” in a specification does not mean that the operator has to be powerful enough to close the disc against a pressure differential equal to the full load pressure. A complication arises in deciding the pressure differential against which the closing gear has to push the disc to the closed position.

The differential pressure is dependent on the closing time. If the valve could be closed instantaneously there would be no pressure differential but since it takes a finite time for the disc to travel from the fully open to fully closed position there will be a differential pressure.

As the disc moves towards the closed condition, the feedwater heater will continue to condense the available steam. The available steam will be that passing through the partially closed valve, in the pipe and the heater shell.
Only the plant manufacturer or designer can determine the conditions and these may be specified as ‘X’ psi for 0.5-second closure or ‘y’ psi for 1.0-second closure.

In order to calculate the correct size of actuator for the design conditions, it is desirable to obtain from the customer, a curve showing the closing differential against closing time.

If all we are able to obtain is a pressure against a time then the design will have to be based on this. If the customer is unable to provide even this at the tendering stage, then we will have to make assumptions and state these in our quotation. We have developed a way of making a reasonably accurate assumption but it is better not to have to do this.

**The Hopkinson’s Bled Steam Check Valve**

The important role of a Non-return Valve demands a high level of reliability. The features found in all Hopkinson’s Bled Steam Non-return Valves assure that reliability. These features along with a high grade of workmanship and materials assure a superior and completely dependable valve.

**Specifications**

Design Standards ASME B16.34 and applicable international specifications as required.

- **Pressure Classes**
  - ASME 150-900

- **Sizes**
  - Cast construction 3” - 44”
  - Fabricated construction for larger sizes

- **Materials**
  - Carbon steel, alloy steel and stainless steel per ASTM specifications of applicable international standards

- **Trim**
  - Stainless steel ASTM A479 Type 410

- **Seats**
  - Stainless steel overlay or hard facing alloy

- **Bonnet Design**
  - Bolted bonnet with non-asbestos gasket

- **End Connections**
  - Butt weld or flange end

- **Power Cylinder**
  - Pneumatic or hydraulic

- **Drain Connections**
  - As required

- **Limit Switches**
  - 1, 2 or 3 SPDT or DPDT switches available

- **Cylinder Valves**
  - Solenoid operated air valves or pilot operated oil relay valves

- **Exerciser Valves**
  - Operational solenoid or manual valves available

- **Special Features**
  - Low friction stuffing boxes - standard
  - Very low friction mechanical seals - optional
  - (Can not be overtightened)
  - Non destructive examination as required by customer specification or ASME B16.34
  - Special Class

- **Installation**
  - Horizontal or vertical upflow as specified

**Free Swinging Disc**

Hopkinsons utilize a basic swinging disc Check Valve design. This uncomplicated design provides independent movement of the disc in the flow stream with fast closure upon loss of reversal of flow. The valve disc is of sturdy construction to prevent distortion under full design pressure.
**Self Aligning Disc & Disc Arm**
The disc and disc arm assembly are self aligning with the seat, assuring tight sealing. An internal stop provides the proper degree of disc opening while maintaining the edge of the disc within the flow stream, so that flow reversal will cause closure.

**Hinge Shaft & Bushing Assembly**
Large diameter stainless steel shafts, together with hardened stainless steel bushings are used on all Hopkinson Bled Steam Check Valves. The results are lower stresses, less wear and longer life.

**Balanced Shaft Construction**
The Hopkinson’s valve is designed so that the disc assembly is “pressure balanced”. This means that the disc assembly is free to swing independently of the operating shaft and therefore, is not subject to stuffing box friction or end thrust tending to force it against the side of the valve. The operating shaft which passes through the stuffing box is stationary under normal operating conditions. It is rotated only on a trip out or shutdown by the closing cylinder, which has ample power to overcome stuffing box friction or other causes of sticking. In very high-pressure installations, the operating shaft is “pressure balanced” by using a double stuffing box construction.

**Inclined Seat Design**
Hopkinson’s Bled Steam Check valves have an inclined seat to improve the performance and operating characteristics of the valve. This design offers advantages not available with other seating configurations. The inclined seat with flat disc and body seat contact provides the best configuration available in Check valve design and is easily refurbished during shutdowns. An opening angle of 75° from the vertical or 45° from the inclined seat results in low-pressure drop. The reduced swing also enables the valve to close quickly. Full opening with a vertical seat would require a greater swing and a longer closing time. The centre of gravity of the disc assembly causes a positive seating movement, therefore, the weight of the disc is always acting to seat it and hold it firmly against its seat. A portion of the disc weight can be counterbalanced in larger valves to reduce pressure drop at low flows, so the flow is not required to raise the full weight of the disc.
Valve Body & Bonnet

Hopkinsons employ a streamlined body contour designed for minimum flow resistance. Heavy body wall thickness assures rigidity and resistance to torsional and bending pipe movements. A bolted top cover is provided for ease of access to the valve internals, thus the valve need not be removed from the line for maintenance and inspection.

External Lever

Valves of all sizes are available with a shaft mounted lever to manually exercise the valve, larger size valves are supplied with a counter weight to reduce pressure drop at low flows, to maintain disc opening and reduce disc slamming.

Cylinder Operated

Spring loaded positive closing air cylinders can be provided on all Bled Steam Non-return Valves. Oil operated cylinders are also available and may be ordered with an optional oil relay valve. Both types can be exercised by a lever operated Test Valve or Solenoid Valve.

Applications for Turbine Extraction - Steam Systems (Air Actuated Valves)

Figure 65 shows an arrangement of an A & M Air Operated Free Flow Reverse Current Valve illustrating a valve operated by turbine overspeed trip and high water level in the feedwater heater.

The oil operated Air Relay Dump valve (Normally supplied by the turbine manufacture) translates oil pressure from the turbine overspeed trip system into air pressure. With oil pressure established, compressed air flows through the Air Relay Dump Valve with the atmospheric vent closed. Upon loss of oil pressure due to turbine overspeed trip, incoming air pressure is closed off, and the atmospheric vent is opened to release air pressure from the Check Valve cylinder. This action allows the spring force to assist in closing the Free Flow Reverse Current Valve. IT IS IMPORTANT THAT THE SOLENOID OPERATED 3-WAY VALVE USED ALLOWS FLOW IN THE REVERSE DIRECTION.

The Solenoid Operated 3-way Valve is installed in the air supply line to the cylinder. Upon receipt (or loss) of an electrical signal from the heater high water level alarm, the Solenoid Valve trips, closing the air supply and opening the vent to atmosphere.

Air is exhausted from the air cylinder, and the spring starts to close the valve.

The lever operated Air test Valve equalizes pressure on both sides of the cylinder piston so that the spring force moves the piston downward and exercises the valve during operation.
The system shown in Figure 66 differs from Figure 65 as the oil operated Air Relay Dump Valve is replaced by an oil pressure switch which converts the loss of oil pressure due to a turbine overspeed trip to an electrical signal. This signal is connected to the solenoid valve in series with the heater high water level alarm circuit and trips the solenoid operated 3-way valve as in Figure 65.

The quick exhaust valve shown in Figure 66 senses a loss of pressure at its inlet and will shift allowing the air cylinder to exhaust more rapidly through its vent port. This valve can be used in any control system and is recommended whenever excessive pipe is used between the air cylinder and solenoid valve or relay dump valve, and when a solenoid valve with a low Cv factor is used.

Local exercising of the Free Flow Reverse Current Valve can also be accomplished by actuating an integral test switch on the solenoid operated 3-way valve. Using this method for exercising, the solenoid valve is exercised as well as the Free Flow Reverse Current Valve.

Combinations of control system shown in Figures 65 and 66 can also be used.
DEWRANCE are part of the TYCO Group of companies although the original company has its origins in the early days of the Industrial Revolution when the founder John Dewrance was the constructor of Stephenson’s ‘Rocket’ Steam locomotive.

Extensive research was undertaken by Dewrance in the 1980’s to establish the market requirements for Bled Steam Check valves. A close collaborator in their research was Alstom Power (formally GEC). The result was the valve illustrated in Figure 69.

This is a tilting disc Check valve design with seating geometry as described previously [refer Figures 53-56]. The body is of a robust cast steel construction to withstand pipework stresses and can be either free swinging or power operated.

The product is highly regarded in the industry although there has been a tendency for the disc to stick in its seat on full power closure. A less costly alternative to the tilting disc design is the Swing Check variant shown in Figure 70. This is actually manufactured from a Parallel Slide Gate valve body and incorporates a combined seat and hinge assembly. Not being a true Bled Steam Non Return valve the disc has been known to oscillate on certain applications causing extensive wear of the hinge pin bushes.

**Reheater Isolation Devices**

The cost of closure of a power plant can run into thousands of pounds per day in lost generating revenue.

Repairs of power plant facilities are frequently part of a planned programme of maintenance where the downtime cost is incorporated into the operating budget. Even so, any innovation which can save time will also save significant amounts of money.

A traditional method for determining the integrity of repairs undertaken on pipelines and vessels is by hydrostatic testing. In one area of the plant, testing of the reheat tubes in the boiler and the pipelines adjacent to the boiler has been a time consuming and costly operation.

Isolation of the tubes from the pipeline has been done in one of two ways i.e.

(i) Mechanically forcing a blind flange between two flanges welded into the line.

(ii) Cutting an access into the pipeline and welding a temporary blank in place.

Invariably, access to a suitable location for the test blank to be inserted is difficult at best and non-existent at worst requiring complicated scaffolding to be erected before any work can be carried out.

A further consideration is the ability of the piping supports to carry the additional weight of water should the location of the test blank be some distance from the reheater tubing.

If method (ii) is selected as the procedure for testing, further costs are incurred in checking the integrity of the piping repairs required after the test blank has been removed.

The Hopkinson’s Reheater Isolation Device (R.H.I.D) however, enables hydrostatic testing to be conducted easily and efficiently on both the cold and hot reheat lines. On the cold reheat line from the high-pressure turbine, temperatures average between 600 - 700 P.S.I. The cold reheat device is available in A216-GRWC and ASME ratings Class 400 intermediate and class 600.
On the reheat line from the reheater section of the boiler, temperatures range from 900-1025 °F and pressures from 500-1200 P.S.I. Depending on the conditions, Hopkinsons are able to offer devices in ASTM A217 Gr WC9 and ASME ratings Class 600 and 900.

If these are fitted as near to the reheater as possible, the reheater pipes need not be filled with water, with all the attendant problems of supporting them. [Refer Figure 73].

The RHID also reduces the possibility of damaging the turbine intercept valve by providing a reliable seal in front of it. [Refer Figure 71].

After installation, the RHID is merely a conduit and during normal operation it is open and free from any component parts. N.B. the exception to this is where pressure drop is critical and a follower eye is fitted in the intergate space between the seat faces to promote a smooth turbulent free flow. [Refer figures 72a & b].

When hydrostatic testing is required, the system can be isolated by merely placing a closure in the path of the flow. This is accomplished by removing the bolted cover from the R.H.I.D (pressure seal on the 900# product), fitting the isolating closure in position and then re-fitting the bonnet.

The R.H.I.D is specially designed to utilise two different forces in establishing the seal. During normal plant operation, the body/bonnet joint is mechanically preloaded prior to operation. When the system is live, steam passing through the line reinforces the mechanical seal with pressure. The isolating closure used during hydrostatic testing operates in a similar manner. It is mechanically preloaded before testing and water pressure acting on the closure consolidates the seal.
The Hopkinson’s Reheat Isolating Device was developed to provide a simple means of isolating a reheat boiler section for hydrostatic test.

Such a test can be either to prove the integrity of the reheat tubing during a planned shutdown which will prevent an unplanned shutdown later, or to carry out a test after repairs. The isolator is permanently welded into the pipeline on both sides of the re heater.

The cast steel body has two parallel faces inside the centre chamber. Depending on the pressure rating, access to the centre chamber is provided by a pressure seal or bolted closure, similar to those utilised on the Hopkinson’s Parallel Slide valves.

During normal plant operation only the external body/bonnet seal is used and the isolator body effectively becomes a part of the pipe with an unobstructed passage. The Hopkinson’s RHID is simple in design and compact in its construction. It has many of the merits of a Parallel Slide Gate valve without the bulk, weight or expense. Before hydrostatic test, the top cover and bonnet are removed and the test closure assembly lowered into the centre chamber and positioned in the bore of the body [Refer Figure 74].
The test closure assembly comprises a disc with an “O” ring seal in the face, which contacts the seat face in the body and a captive preloading lever. Clockwise rotation of the nut on the threaded shaft connecting the disc and preloading lever compresses the “O” ring sufficiently to provide the initial seal. All other sealing pressure is provided by the test fluid itself. [Refer Figure 75]. Replacing the top closure isolates the reheater and it is ready for hydrostatic test.

The average time for conducting a reheater hydrostatic test from installing the closure to its removal is generally in the order of five hours.

Such service conditions are probably amongst the most severe ever likely to be encountered on a power plant, particularly as the valve has to be fluid tight after each operation. Over the years, various types of valves have been used on such duties with varying degrees of success. Following is a summary of the advantages and disadvantages of each valve type.

### Wedge Gate Valve

**Advantages**

1. Full bore with low pressure drop characteristics.
2. Relatively inexpensive.
3. Readily available.

**Disadvantages**

1. Poor regulating characteristics.
2. Prone to leakage.
3. Short operational life.

### Globe Valve

**Advantages**

1. Full bore with low pressure drop characteristics.
2. Relatively inexpensive.
3. Readily available.

**Disadvantages**

1. Poor regulating characteristics.
2. Prone to leakage.
3. Short operational life.

### Chemical Cleaning Adaptor

Being situated close to the reheater the easy access offered by the isolation device makes it an ideal point for the injection and recovery of chemical cleaning fluids. To meet this requirement, Hopkinsons can provide a specially modified top closure as an optional extra. [Refer Figure 76].

### Drain & Blowdown Valves

Drain, or Blowdown valves as they are often referred to are connected with the lowest part of a boiler. They are used on the occasion when the boiler is required to be emptied and are also regularly opened in order that accumulations of sediment may be ejected (Blowndown) from the boiler.
Advantages
1. Excellent regulating characteristics.
2. Relatively inexpensive.
3. Readily available.

Disadvantages
1. Very high pressure drop through valve.
2. Seating faces vulnerable to erosion. Flat faced seat and valve head combinations susceptible to “wire drawing”.
3. Limited effective operating life.

Ball Valve

Figure 79

Advantages
1. Full bore, low pressure drop through valve.
2. Compact size.
3. Ease of operation (¼ turn)
4. Lever operator also indicates open/closed status.
5. Seat faces are outside of the flow path giving protection from erosion.

Disadvantages
1. Special design with limited suppliers. Standard ball valves not suitable.
2. High temperature application requires metal seating which has yet to be proved efficient over long periods.
3. Ball face susceptible to erosion in partially open valve.
4. Not maintainable without removal from the pipeline.

Parallel Slide Gate Valve

Figure 80

Advantages
1. Excellent isolation valve.
2. Full bore, low pressure drop through valve.
4. Reasonable availability.

Disadvantages
1. Poor regulation
2. Discs prone to spinning leading to rapid erosion of seating faces.
3. Limited number of suppliers
4. Expensive compared to other types such as globe and wedge gates.

As can be seen from this analysis of the various valve types, there is no one particular design which incorporates all of the necessary characteristics to ensure good regulation and positive isolation.

Indeed, acknowledging this problem, many plant operators have adopted the practice of utilising two different valves in series in order to achieve both regulation and positive isolation. This is usually known as a MASTER & MARTYR arrangement whereby the MARTYR globe valve is used for regulating purposes and the MASTER parallel slide valve the isolator. [Refer Figure 81].
In order that the seating integrity of the parallel slide valve is retained, the valves must be operated in the following sequence.

**Opening Sequence (both valves closed)**
1. Open Master valve
2. Open Martyr valve.

**Closing Sequence (both valves open)**
1. Close Martyr valve
2. Close Master valve.

Excellent feed-back on product performance is obtained from many of the Hopkinson valve users, particularly in the UK Power Generation Industry.

With regard to drain and blowdown valve performance, user experience had made it quite clear that the parallel slide valve provided the best seal after blowdown operations. For this reason and where one valve only is required - perhaps for economical reasons - the parallel slide gate valve has been used successfully in the drain valve role for many years. Two examples are the rack & pinion valve and the uniflow valve.

**Rack & Pinion Blowdown Valves**

The illustrations to the left show a parallel slide gate valve operated by a rack and pinion device, a box key fitting on the square end of the pinion, taking the place of the customary handwheel. A half turn of the box key gives full opening.

An important feature of the blow-down valve is the locking gland. This is so designed that it is impossible to remove the box key unless the valve is closed. Without this safeguard a dangerous situation would arise in power plants where two or more boilers are connected to a common blow-down pipe. If a boiler was empty and under repair or inspection the opening of the blowdown valve of another boiler might result in a quantity of high temperature water being suddenly blown into the empty boiler and scalding the men working inside.
It is usual to have only one box key for the set of blow down valves so that if a boiler is under inspection has its blowdown valve in the ‘open’ position, it is impossible to remove the key for use elsewhere until this valve is first closed and the empty boiler thereby protected.

The operating spindle is fitted with a patent stop which prevents it from being rotated too far and thus straining the gear teeth on the rack and pinion.

The current range of blow-down valves manufactured is:-

**Bronze - Sizes 1 ½” & 2” Flanged to BST ‘F’ & ‘H’**.

**Steel - Sizes 1 ¼”, ½ & 2” Flanged to ASME 300 & 600 Class.**

For pressures above the rack and pinion product range, an arrangement of two ‘uniflow’ valves [refer Figure 83] in series is fitted instead of the blow down valve described above. In such circumstances, it is necessary to install a non-return valve to give protection to boilers, which discharge to a common blowdown tank.

**Uniflow Drain Valves**

The ‘Uniflow’ valve has been used for many years on drain, blow-down and other auxiliary services, especially in medium and high pressure installations. It is manufactured in sizes up to and including 1 ½” bore with flange or butt weld connections according to temperature and pressure requirements. As the name implies, the design is for one way flow only and when there is any possibility of a reverse flow, it can be used in series with a non-return valve fitted at the outlet.

The ‘uniflow’ valve is an adoption of the parallel slide valve principle but using only one disc ‘A’ [Refer Figure 83] which slides over the face of seat ‘B’, to which it is firmly held by fluid pressure in normal working conditions and by a light spring ‘C’ when not under pressure.

The valve is fully opened or closed by a half turn of the handle or handwheel. To prevent rotation beyond these limits, stops ‘D’ are incorporated in the index plate. This plate is large, clearly marked and easy to read and can be engraved to suit foreign language requirements.

No lubrication is required with this type of valve.

Maintenance and the fitting of replacement parts are easily carried out as the valve can be easily dismantled without the aid of special equipment and there are no welded joints to be broken in order to gain access to the internals. Figure 84 shows the higher pressure version of the uniflow valve with a pressure seal bonnet - identical to that incorporated in the design of conventional parallel slide gate valves.
High Performance Parallel Slide Gate Valves

The most recent development of the parallel slide gate valve for drain applications has been the ‘High Performance Drain Valve’ illustrated in its two versions in Figures 85 & 86.

In response to the higher expectations of its customers and for extreme service conditions such as on superheated drain lines, Hopkinsons developed a new range of products. They give extended service life and continued tight shut off when subject to frequent operation, two phase flow, thermal shock and large pressure drops.

The ultimate performance of these valves is achieved when they are utilised in pairs in the Master and Martyr configuration described previously.

Each valve is different and available separately, however, for ease of installation at site the valves can be supplied welded together with a short piece of joining pipework.

Martyr Valves comprise a ‘V’ port outlet seat, square bottomed discs coated with titanium nitride for enhanced wearing characteristics and ‘wings’ on the seats to give increased support to the discs [refer Figure 87].

Master Valves: similar to the Martyr valve but without the ‘V’ port outlet seat. An eye follower is however included which protects the seat faces and prevents turbulence being produced in the valve.

The advantages of square discs are well illustrated in Figure 84 which shows the relative contact area of discs from a conventional 32 mm bore valve at (a) and the high performance valve discs at (b).

A further advantage of the square discs is that they are not forced into the seat bore when handling critical flow and full pressure drop. Also, square discs do not rotate and the occasional problem of round discs eroding a half-moon shape into the seat face from flow induced vibration is therefore avoided.

The advantages of a “V” port outlet seat cannot be over emphasized for the function it performs in the Martyr valve. The sealing action is separated from the throttling/regulating function due to the V port being set back from the seat face.

Choked flow i.e. throttling occurs in a partially open valve whenever the pressure drop exceeds the critical pressure ratio. The erosion associated with such usage is therefore confined to the “V” port as it is essential with Master & Martyr valve arrangements if the seating integrity of the master valve is to be preserved. Where costs permit this, motorisation of both valves is recommended with suitable interlock arrangements to ensure the correct sequence of operation.

When the preferred solution cannot be adopted due to space or cost, then Hopkinsons can offer a combination of the two valves incorporating both sets of features i.e. follower eye, winged “V” port seat and titanium nitride square discs.

Water Gauges
[Water Level Indicators]

A water gauge, as the as the name implies is for the purpose of showing visibly, the exact position of the water level in a boiler at any given time.

Statutory requirements for steam boilers call for two sets of gauges to be fitted, one right hand and one left hand, each set comprising a steam arm, water arm, gauge glass and try valve. Hopkinsons manufacture a wide range of water gauges to suit a variety of applications.

The most basic is the bronze “Absolute” water gauge Hopkinsons figure number M645025 shown in sketch Figure 88.
This would be a useful fitting for an ordinary “Shell” type boiler for pressures up to 348 lb/in² (24.4 kg/cm²). Each arm is provided with a plug cock which can be closed when a new gauge glass is being fitted.

The try valve provides a means of testing the gauge in order to ensure that water and steam are passing through the gauge arms, that the water level seen in the gauge glass is a correct indication of the position of the water surface in the boiler and to clear away sediment which may collect in the bottom arm of the gauge.

If the glass breaks the pressure of water in the bottom arm and steam in the top arm forces the steel ball against the aperture leading to the gauge glass and will remain there, preventing the escape of scalding water and steam until the cocks in the gauge arms are closed.

To safeguard the attendant from escaping steam in the event of gauge glass breakage, the gauge is usually fitted with a specially toughened glass protector as shown in Figure 89.

**Gauge Glass Protectors**

**Figure 89**

**Water Level Indicators**

The position of water gauges on large water-tube boilers is so far above the firing floor that it is practically impossible, even with the aid of the ordinary type of water gauge illuminator to distinguish the water level at all. In these circumstances, a water level indicator, incorporating a special illuminating device is fitted. Figure 90 shows a typical arrangement together with a section through the gauge body and gauge cock.

On this type of gauge a slide valve based on the ‘uniflow’ design has replaced the more usual plug cock. The uniflow valve has proved to be the answer for the requirement of a valve which would remain fluid tight over long periods under pressure even after severe blowdown operations. The slide-down action ensures complete fluid-tightness in the closed position, due to the self-cleaning action of the disc and seat faces and the high resistance of these ‘platinum’ components to wear and tear. Index plates on both arms show whether the valve is open or closed.

The gauge possesses other features common to the equipment described on page No. 60, namely fully shut-off action in both gauge arms and the provision of the “sheltered-seat” type of try valve.

In stead of the customary glass tube connecting the gauge arms, a forged steel indicator is fitted, the steam and water space being observed through thick plate glass, faced on the inside by a sheet of mica to protect the glass from etching by steam.

The illuminator is fitted at the back of the water level indicator and is fitted with an ordinary filament electric lamp, making the meniscus of the water level appear as a brilliant concentrated spot of light which can be seen from a considerable distance.

The water level indicators illustrated in Figure 90 are designed to British Standards for a maximum boiler operating pressure of 750 lb/in² (52 bar). Flanged steam and water connections are available to either B.S.10 Table ‘R’ [Hopkinsons Product Figure No. 6806] or to B.S.10 Table ‘S’ [Hopkinsons Product Figure No. 6809].
'Bulls-eye' Water Level Indicators

This type of indicator is designed for pressures up to 1850lb/in² and can be arranged for viewing by direct vision, periscope or by a television system. The indicator is of the bi-colour type giving contrasting colours for the steam and water spaces - RED for steam and GREEN for water [Refer Figure 91]. The water level is observed through five pairs of round glasses or "bull's-eyes". Each of these glasses can be quickly removed or replaced without interfering with any of the other glasses and without removing the indicator from the boiler. The inner surface of each glass is protected by a mica disc.

Individual illumination is provided behind each port by means of a 36W vehicle headlight bulb. The light is intensified by a bi-convex lens before passing through the port. A special device to avoid the accumulation of deposits on the mica faces is an important feature of this indicator. Parallel to the main vertical bore of the indicator is another bore which is supplied with steam from a branch led into it from the upstream side of the steam shut-off valve. Side channels extend from this bore to each of the ports and are arranged in such a way that steam passing through them will sweep across the mica faces and remove any deposits that may have accumulated on them. It is usually sufficient to carry out this clearing process once daily.

Figure 91 illustrates the Hopkinson Product Figure No. 64114 Bull's Eye Water gauge with the viewing shield and illuminator removed for clarity. Changes in the boiler water level inevitably subject a water level indicator to thermal shock but this can be minimised by lagging the water arm. The indicator is protected from draughts on one side by the illuminator and on the other side by a hood.

Try Valves

Try valves are an important component of any water gauge assembly and worthy of a separate mention. It will be appreciated that this valve should remain leak-proof even after operating on a daily basis under the most arduous of conditions. It is therefore essential that it should not be rendered leaky owing to the 'scoring' action of hot water on the seat face. To avoid this happening, the try valve is fitted with a main valve and check valve as shown in Figure 92. In moving the try valve handle, the main valve is lifted from its seat and in turn lifts the check valve. As the main valve is well clear of its seat before the check valve opens, there is no scoring or cutting effect on the main valve and seat faces. Similarly, when closing the try valve as the handle is moved to the closed position, the check valve closes first, thereby cutting off the flow before the main valve makes contact with its seat.
Safety Valves (ASME Section 1)

Valves that are vital for the protection of people and plant are termed Safety and Relief valves. These valves operate automatically when a predetermined pressure level is exceeded by releasing an adjustable spring which holds a valve disc against a valve seat. There are, however, subtle distinctions between safety valves and relief valves that have been clearly defined by the major international authority on the subject - the ASME (American Society of Mechanical Engineers) Boiler & Pressure Vessel code and led to the following definitions and terminology.

Safety Valve
An automatic pressure relieving device actuated by the static pressure upstream of the valve and characterised by full-opening pop action. It is used for gas or vapour service.

Relief Valve
An automatic pressure relieving device actuated by the static pressure upstream of the valve which opens further with the increase in pressure over the opening pressure. It is used primarily for liquid service.

Safety Relief Valve
An automatic pressure-actuated relieving device suitable for use either as a safety valve or relief valve depending on the application.

There are many internationally recognised standards covering the application of both safety and safety Relief valves but in the power generation industry, the most widely recognised and used is the ASME code section I, with which the Hopkinsons A7000 series design of safety valve shown in Figure 93 fully complies.

Before examining this product in detail, it is essential to become acquainted with and understand the terms which are generic to pressure relief valve operations and which are clearly defined in the ASME code.

Set Pressure
The inlet pressure at which the valve has been adjusted to open under service conditions. The set pressure of a safety valve is generally expressed in:-
(i) lbs/in²
(ii) bar
(iii) Kg/cm²

Simmer
The audible or visible fluid which escapes between seat and disc just prior to “pop”.

Lift
The disc rise in pressure relief valves.
Rated Capacity
The percentage of measured flow at an authorised percent overpressure permitted by the applicable code.
Rated capacities are generally expressed in:-
(i) lbs/hr or Kg/hr for VAPOURS.
(ii) ft³/min or m³/min for GASES
(iii) Gallons/min or litres/min for liquids.

Accumulation
The pressure increase above maximum allowable working pressure during discharge through the safety valve, expressed as a percentage of that pressure.
ASME code Section I requires each valve, or set of valves, to discharge all of the steam that can be generated by the boiler without allowing the pressure to rise more than 6% above the highest pressure at which any valve is set and in no case more than 6% above the maximum allowance working pressure.

Overpressure
The pressure increase above set pressure during discharge usually expressed as a percentage of the set pressure.
The ASME code Section I requires valves to be so designed and constructed that they operate without “chattering” and attain full lift at a pressure no greater than 3% above their set pressure.
In parallel with the overpressure requirements the ASME code also specifies the following “popping” tolerances: -
(i) 2 psi up to and including 70psi.
(ii) 3% for pressures over 70 psi up to and including 300 psi.
(iii) 10 psi for pressures over 300 psi up to and including 1000 psi.
(iv) 1% for pressures over 1000 psi.

Blowdown
The difference between set pressure and reseating pressure of a pressure relief valve expressed as a percentage of the set pressure.
The ASME code Section I states that after blowing down, all valves set at pressures of 375 psi or greater shall close at a pressure not lower than 96% of their set pressure. All drum valves installed on a single boiler may be set to reseat at a pressure not lower than 96% of the set pressure of the lowest drum valve.
The minimum blowdown for all safety or safety relief valves shall be 2 psi (13.8kPa) or 2% of the set pressure, whichever is greater.

Mechanical Requirements for Safety & Safety Relief Valves
In addition to the requirements regarding the capacity and operation of valves manufactured to the ASME code, there are also minimum mechanical requirements covering the following subjects: -
• Spring design.
• Lifting devices to verify the free action of the valve.
• Guiding arrangements to ensure consistent operation and tightness.
• Securing the seat in the valve body.
• Drainage of the valve body.
• Sealing of external adjustments.
• Steam testing to demonstrate the popping point, blowdown, tightness and pressure containing integrity.

Additional requirements of the ASME code relate to documentation and include such subjects as: -
• A documented program for the application, calibration and maintenance of test gauges.
• Re-certification for continued use of the “V” - stamp symbol required every five years.

Having reviewed the basic requirements of the ASME code, we may now consider the design features and benefits of the Hopkinsons product.

Product Range
Sizes
2” TO 6” (50-150mm Nominal)

Pressure Rating
300 psig - 3000 psig

Materials
ASME SA 216 Gr WCB
ASME SA 217 Gr WC6
ASME SA 217 Gr WC9

Connections
Flanged or Butt Weld Inlet, Flanged Outlet.
Features & Benefits

- The product has been developed from a proven design with many years of operational experience.
- Principle design considerations were,
  (i) Simple construction
  (ii) Easy maintenance
  (iii) Simple external blowdown adjustment using one ring.
  (iv) No locking pins to remove in body steam space.
  (v) Settling position visible externally.

- Balanced distribution of spring loading on valve head and seat through 4 pillar support.
- Spring open to atmosphere to facilitate cooling.
- Simple re-furbishment of seat facing.
- Components of high grade corrosion resisting alloys.
- Seat either pressed or welded in place secured by rolled ‘V’ groove lip.
Advantages - Threats
- Widely known in the market
- Large installed population
- Established reputation

Disadvantages - Opportunities
- Complicated internals
- Two ring adjustment
- Adjusting rings difficult to set
- Locking pins in body steam space.
- Screwed in seat can be difficult to remove
- Customer requires a larger spares inventory

Dresser - Consolidated
Advantages - Threats
- Widely known and respected in the market.
- World wide installed population.
- World wide service facilities (Green Tag Centres)

Disadvantages - Opportunities
- Complicated design - similar to CROSBY HE type. Exception is that the maxiflow uses side rods instead of a cast steel yoke.
- Two ring adjustment for lift and blowdown
- Adjusting rings difficult to set
- Locking pins in body steam space
- Seat bushing difficult to remove (3 part weld on some designs)
- Customer requires a larger spares inventory

Principle Competitors
Tyco-Crosby

Crosby HE Safety Valve with educator controlled pressure-assisted blowdown for boiler drums operating from 1500 – 3000 psi.

Dresser-consolidated Maxiflow 1700 Series Safety Valve.
Hopkinson Steam Test Facility

Hopkinsons have been steam testing safety valves since manufacturing commenced at the Huddersfield works.

The improved facilities recently installed have been designed in accordance with the requirements recommended by the National Board of Boiler and Pressure Vessel Inspections in their 1992 document “VR - National Board Pressure Relief Valve Repair Symbol – Administrative Rules and Procedures”.

The facility comprises a steam generator, an accumulator vessel and a test vessel, which stores the steam at up to 120barg. The accumulator vessel in turn supplies steam to the test vessel through a control valve, which adjusts the steam pressure of the safety valve on test. Valves of up to 200mm bore and test pressures of up to 100barg can be accommodated [Refer Figure 101].

After confirmation of set and lift pressures, tight shut off can also be demonstrated at a suitable margin of steam pressure below the set pressure. The use of a “two vessel” test facility allows a high volume flow to be achieved for a duration long enough to establish the performance of the safety valve on test.

Operations are controlled through a computer based system housed in a control room within the facility. The tester can control the steam pressure in the test vessel by programming the required pressure and at the desired moment can initiate a rise in pressure to “pop” the safety valve on test. The results are collected in the data logger part of the computer and can be plotted as “engineering trends” which can be supplied to the customer as graphical evidence of the test performance of his safety valve.

Safety Valve Mounting

The correct mounting of a safety valve on a boiler is key to the smooth operation of the valve should it ever be required to discharge.

Figure 102 above illustrates the preferred alternatives for the mounting of the Hopkinsons product.

Considerable sales advantages over our competitors has been achieved, by the provision of this information to our customers along with the valve quotation. This is particularly appropriate where un-priced bids are required alongside the commercial offer to enable the customers engineering/design department to technically assess the offers received.

Due to delivery requirements, the boiler design team will often commence work on the basis of information provided, irrespective of what the commercial decision regarding choice of valves might ultimately be.

By then it can be too late to change from the Hopkinsons nozzle attachments already incorporated in the Hopkinsons boiler design.

Whenever we offer safety valves, particularly to a boiler maker, we must ensure details of the mounting of our valves is included with our quotation data package.

Figure 101

Figure 102

Nozzle attachments shown are typical only.
Hydrostatic Testing

As with all pressure vessels, there are statutory requirements covering the hydrostatic testing of boilers and associated safety related equipment - including safety valves.

All of the leading safety valve manufacturers have their own preferred procedures for hydrostatic testing their products. Whatever the method employed, all procedures involve some form of blanking off device in order that the usual test pressure of 1.5 times the valve set pressure can be achieved.

Figure 103 illustrates the Hopkinsons method of blanking off the valve, which involves the removal of the top fittings and the valve head. Of course, with a flanged inlet valve it is recommended that the valve not be installed until after the boiler hydrostatic test has been performed utilizing blank (or blind) flanges to isolate the boiler nozzles. Which involves the removal of the top fittings and the valve head. Of course, with a flanged inlet valve, it is recommended that the valve not be installed until after the boiler hydrostatic test has been performed utilizing blank (or blind) flanges to isolate the boiler nozzles.

N.B. The usual procedure when setting a complement of valves on a boiler plant is to adjust the boiler drum valves first as they are set at the highest pressure, working downwards to the superheater valves. All valves at a set pressure below that of the valve being tested must be prevented from lifting by the application of ‘GAGS’ [Refer Figure 103]

When fitting GAGS, the adjustable sections must only be turned until it is finger tight against the top of the spindle, finally giving a half turn with a spanner to secure it in position.

This method of applying overload will not damage the valve head and seat faces.

However, UNDER NO CIRCUMSTANCES SHOULD GAGS BE USED TO FACILITATE HYDRAULIC TESTS ON BOILERS AND PIPEWORK etc. AS SEVERE DAMAGE MAY BE CAUSED TO THE VALVE INTERNALS.

Hydrostatic Testing - Competitors

Tyco - Crosby

The Tyco-Crosby method of blanking off their safety valves to facilitate hydrostatic testing of a boiler, is illustrated in Figure 104.

The threaded portion of the valve nozzle, which would normally support the lower adjusting ring, is utilised to fit a cap, which holds the test plug in position.

It should be noted that there is no contact with the seating face on the nozzle - the seal is formed with an ‘O’ ring in the bore of the nozzle.
Dresser - Consolidated

With flanged inlet safety valves, Dresser are no different to most other manufacturers in recommending that the valve not be installed until after the hydrostatic test has been preformed, utilising “blind” or blank flanges to blank off the mounting stubs on the boiler.

Valves having a butt weld inlet connection are treated quite differently and incorporate a special feature, which is unique to the consolidated design. As dispatched from the factory, the high pressure 1700 series “Maxiflow” valves are fitted with a hydrostatic test plug as shown in Figure 105.

This has the effect of raising the “Set point” approximately 1.5 times the valve set pressure for hydrostatic testing purposes.

On completion of the tests, the compression on the spring is released, the valve dismantled and the hydrostatic test plug removed and replaced with the standard valve disc. In this way the seating integrity of both nozzle and disc are preserved and prevented from any possible damage during shipment. The only disadvantage to what is an otherwise excellent arrangement, is that the valve disc, which is usually fastened in a storage bag to the valve side rods are susceptible to loss once the valve reaches site!

Servo-Loaded Direct-Acting Safety Valves

In certain circumstances, the Safety Valves fitted to some Power Station boilers can be prone to simmering (passing small amounts of steam) due to the operating pressure at the boiler outlets being relatively close to the set pressure of the Safety Valves.

This is particularly so when operating pressure variations of perhaps up to 3 bar above the operating average are experienced during routine operation. In time, the passing steam at high pressure can degrade the valve seat resulting in a progressive deterioration of its sealing capability and eventually a need to ‘gag’ (clamp closed, thus remove from service) the Safety Valve.

This situation is not desirable since the Safety Valve capacity to boiler evaporation rate margin is reduced and the feed rate and unit power have to be reduced accordingly to remain compliant with design code safety case requirements.

Reducing the likelihood of the main boiler Safety Valves simmering and the need to gag them is considered a prudent measure not only from a commercial perspective but also from plant operation and safety consideration.
The most effective way of overcoming the problem of simmering is by fitting a supplementary loading arrangement to the valve concerned which provides an additional closure force on the disc/seat via a spring and pneumatic cylinder acting on the Valve Spindle. (Refer Figure 107)

The supplementary load is removed automatically when the measured boiler pressure reaches the desired set pressure of the Safety Valve enabling the valve to open instantly at the set pressure eliminating any premature simmering. Figure 108 illustrates a typical installation of servo-loaded drum Safety Valves. The control cubicle should be located conveniently close to the Safety Valves taking care the ambient temperature does not exceed 50°C.

An air supply in excess of 3.5 bar is required to the cubicle with two air lines from the cubicle to the Safety Valve. It is recommended that the tubing for the air lines be a minimum of 12mm outside diameter with flexible connections adjacent to the entries at the air cylinder on the Safety Valve to allow for thermal expansion. Since an automatic draining filter is incorporated in the cubicle no other filtration is necessary.

An electrical supply of 110v.50Hz single phase is normally utilised but other inputs can be accommodated. The 15mm nom. bore impulse tube take-off point should be as remote as possible from the Safety Valves to avoid the effect of localised pressure drop in the tube when the Safety Valves are operated.

It is also essential to ensure the impulse tube incorporates a syphon bend to collect condensate and protect the pressure transmitter from steam temperature.

A hydraulic pump connection/pressure test connection is incorporated in the isolation manifold in the control cubicle, to check or adjust the electrical switch settings prior to raising of boiler pressure and verifying the pressure settings displayed. Figure 109 shows a simplified schematic diagram of the control cubicle.

The servo air system is controlled by an electronic trip amplifier.

Boiler pressure is sensed by a pressure transmitter from which a signal, proportionate to the boiler pressure is fed to a trip amplifier. There, the signal is interpreted and compared with preset trip points.

When the trip points are reached, the air control valve is actuated allowing air to the cylinder on the Safety Valve thereby applying or removing a supplementary load. The trip amplifier displays the pressure signal as measured pressure in Bar Units.
Feedwater Heaters

To improve the thermal efficiency of steam operated power generating plant the condensate leaving the condenser at about 80°F is heated to about 500°F before it reaches the boiler. This is called regenerative feed heating.

Heat is added to the water from a number of sources. The main source is steam extracted from various stages of the turbine, after it has done some work, (bled steam), but there are others such as the turbine lubricating oil system, gland sealing steam and the alternator cooling system. This latter source on a 50 MW unit could amount to 5 MW.

If water at too low a temperature reaches the economiser section of the boiler, which extracts heat from the flue gas going to the chimney, a very corrosive regime will be created which cannot be tolerated for long. The current tendency is to increase the water temperature leaving the last feed water heater, from say 500 to 560°F, because of the use of flue gas de-sulphurisation plant to reduce atmospheric pollution.

Feed water heaters are classified into two groups, those installed between the condenser extraction pump and the boiler feed pump are described as low pressure heaters and those after the boiler feed pump are described as high pressure.

The heater immediately before the feed pump, is called the deaerator, and has a dual function. It is used to heat the water and at the same time to remove as much of the dissolved oxygen from the water as possible. This heater is usually combined with a water storage vessel to act as a buffer in the system and to ensure enough water is available to maintain the desired water level in the boiler if all else fails.

With the exception of the deaerator, feed water heaters are usually of tube and shell construction with water inside the tubes being the higher pressure fluid, and bled steam in the shell outside the tubes. Sometimes the first one or two heaters, using bled steam at around atmospheric pressure or less, are fastened directly to the turbine low pressure cylinder without any piping or valves. This can be both an efficient and economic solution.

Pressures of the various bled steam supplies vary from sub-atmospheric to more than 1000 psi. the pressures and number of heating stages are different with each turbine design and predicted load cycle. A base load station will have more heating stages, typically 6 or 7, than one designed for peak loads.

If a heater is of simple tube/shell construction, without any special sections within it, the condensate produced would be at the same temperature as the saturation temperature of the steam and the water leaving the heater would be approx. 10°F less than the saturation temperature.

This is because a temperature difference is necessary for heat to be transmitted through the tube wall and this is dependent on the tube material and the conditions existing on the tube surface. At the low temperature end of the system this could be acceptable but as the pressures and temperatures increase this would not be efficient.

Some of the higher pressure bled steam supplies are superheated but if the heater is not specially constructed no increase in water temperature would be attained than if the steam was saturated. The outlet water temperature would still be approx. 10°F below saturation temperature.

Similarly with the condensate drains. Even though the water entering the heater is lower than the drain temperature, drains will still leave the heater at about the saturation temperature. This too is not efficient as the pressures and temperatures increase.

High pressure heaters particularly are constructed with separate sections for de-superheating, (to take advantage of the superheat), condensing and drain cooling, (to sub-cool the drains). Heat transmission rates are very much less in the desuperheating and drain cooling sections than in the main condensing section so this type of construction makes the heater physically much larger. It need not concern us here what the detailed construction is like.

In spite of the feed water being deaerated and chemically treated to absorb as much of the free oxygen in the water as possible all the steam contains a mixture of gases. When the steam is condensed in a heater these incondensible gases are left behind and tend to accumulate in the heater if they are not vented off, usually to the condenser which has very powerful extraction equipment to remove accumulations of air and other extraction equipment to remove accumulations of air and other incondensible gases. Gas accumulations in a heater can, in the limit, stop heat transfer and cause tube corrosion problems.

Problems in heaters are usually concerned with tubes or tube fixing. Tube failures are rarely, if ever, associated with a complete fracture although this is often the basis of calculating how quickly the water level can rise in the heater body. More often than not it is a tube perforation, caused by basic manufacturing defects, which produce unacceptable water levels in the shell. Perforations usually erode into a hole 4 or 5mm in diameter and the jet from such a hole erodes adjacent tubes. With this mode of failure the water level tends to initially rise very slowly. Early detection of such a situation is important if the potential destruction of the turbine is to be prevented through ingress of water into the Bled Steam (Extraction Steam) pipework.
There are a number of ways in which this situation can be addressed. Each heater is fitted with a device to detect a high water level long before it reaches the danger point and a signal from this device is used to initiate the operation of valves to isolate the feed water from the defective heater train (or string) with the problem. Water is still required by the boiler so same means of by passing the flow is required.

The most basic arrangement is to have five electrically operated parallel slide gate valves as illustrated in Figure 109 but such an arrangement has three basic faults.

1. If the bypass pipe is the same bore as that entering the heaters, most of the water would pass through the bypass and would not be adequately divided between the bypass and the remaining heaters. To increase the pressure drop through the bypass, an orifice plate or some similar device is usually required.

2. If the bypass valve failed to open, all the water would try to pass through the remaining heaters and could cause a drain problem (see below).

3. If in the unlikely event there was a problem with both ‘trains’ simultaneously and the bypass failed to open, the boiler would be starved of water which would cause another form of disaster.

Ideally when one train of heaters is isolated, about 60% to 70% of the feed water should pass through the remaining heaters to keep the water temperature to the boiler as high as possible. This helps with the overall efficiency on one hand and helps to prevent corrosion on the exhaust gas side of the economizer on the other. (This latter point is equivalent of ‘acid rain’ forming on the tube surface).

One of the limitations in the maximum percentage flow through the heaters is the capacity of the heat drain system to handle the condensate from the increased quantity of bled steam which will be absorbed because of the increase in feed flow and a rise in thermal conductivity across the heater tubes.

**Spring Loaded Bypass Valve**

One solution to the shortcomings of the system shown in Figure 110 is the Spring Loaded Feed Water Heater Bypass Valve shown in Figure 111.

It is essentially a low pressure relief/check valve inside a high pressure rated body with seals of the same type as a high pressure parallel slide gate valve. It is used in combination with gate valves as shown in Figure 112.

Loading from the valve spring must ensure that water will not pass through the bypass under normal operation therefore the set pressure will be determined by the pressure drop across the heaters, valves and piping for each particular installation.
To compensate for any operational variation in the pressure differential, compared with initial calculations, the valve can be provided with an external spring adjustment as an option. This enables the set pressure to be adjusted without disturbing the high pressure seal.

A dangerously high water level in any of the heaters would be detected by an electronic alarm which initiates operation of the valves to isolate the feed water from the heater bank with the problem.

The frictional forces caused by the increased flow of water through the remaining operational heater bank results in an increase in the pressure differential across the system. The effective loading of the spring is overcome and the Bypass Valve opens.

**Competitors**

Credit for the original concept of utilising a Spring Loaded Bypass Valve on Feed Water Heater Bypass applications probably rests with the former turbine manufacturer GEC (now Alstom Power).

From the mid 1970’s until recent times, this was the preferred method for Feed Heater Bypass for GEC in the UK and is the reason why DEWRANCE are also able to offer this particular product. At the time of writing, there are no other manufacturers of this valve type.

The countries in which it is known – apart from the UK are:– China, Canada, India and South Africa.

**Atwood & Morrill 3-Way Valves**

A further option for the bypassing of feed water heaters is the Atwood & Morrill 3-way Valve shown in Figure 113.

(N.B. Low Pressure Design).

First introduced as far back as 1925, its unique benefit is its ability to save costs on individual heater isolation by the elimination of two gate valves and a ‘tee’ piece.

Figure 114 illustrates a typical feed water heater bypass arrangement for a single heater utilising motor operated gate valves.

Under normal operating conditions, Valve ‘A’ would be closed and Valves ‘B’ and ‘C’ open. If isolation of the heater was required, Valve ‘A’ would open while ‘B’ and ‘C’ would close, thus diverting the flow around the defective heater.
The Atwood & Morrill 3-Way Valve enables the same pipework configuration to be utilised with the cost saving advantage of eliminating two of the isolating gate valves together with the ‘tee’ piece. Figure 115 illustrates the 3-Way Valve installation.

The inherent disadvantage of such a system is one which is common to all electrically operated valves in that they do not provide a ‘fail safe’ isolation. Should either of the motors fail, the defective heater would have to be isolated by manual operation of the valves and in such circumstances, time really would be of the essence!

Happily, the reliability of modern electric actuators is very high indeed and the system is used extensively in the United States on both fossil and nuclear power plants. The valve has also been used on systems in the Far East and China but appears to have found little or no applications elsewhere in the world. In this particular market, Atwood and Morrill has no immediate competitors although the Japanese manufacture OKANO has been known to offer 3-Way Valves into the Chinese Market with limited success.
Medium Operated Two-Way Changeover Valves

A natural development of the Atwood & Morrill 3-Way Valve system of bypassing feed water heaters took place in Germany during the 1960's when Sempell, Deutsche Babcock and Zikesch each pioneered a fail-safe medium operated system of Changeover Valves.

C. A. Parsons, the UK turbine manufacturer (now owned by Siemens) adopted the concept for their own feed heating plants which resulted in Hopkinsons rival Dewrance developing a product to suit when Parsons engineering director R. U. McCrea joined Dewrance in the early 1970's.

Preliminary tests with the Dewrance design were held at Pembroke P.S. and were so successful that the type was ultimately installed as a permanent feature. In later years, the Dewrance system was also adopted for the 660 MW units at Peterhead P.S. near Aberdeen in Scotland and Isle of Grain Power Station in the South of England.

**Operation**

This system is designed to be “Fail Safe”. Failure of the controlling electric or pneumatic supplies will cause the main changeover and outlet valves to close and so isolate the feed side of the feed heater or heater bank.

Float switches on feed water heaters are intended to have contacts normally made and to break with rising water levels. Relays and Solenoids are normally energised and of the continuously rated type.

Assuming the unit to be in normal operation, the Changeover Valve will be in the position shown i.e. with the bypass line isolated.

The out of balance forces acting on the disc caused by a combination of the differential area between the bottom and top of the disc and the pressure drop across the heater bank will hold the disc in this position.

The Solenoids on the Quick Acting Valve will be normally energised allowing air pressure on the top of the diaphragm to keep the valve closed.

Rising water level in a heater will cause the float switch contacts to break, de-energising the Solenoids on the Quick Acting Valve causing it to open. When the Quick Acting Valve opens, water is exhausted from the lower Chamber ‘A’ of the operating cylinder of both the changeover valve and the 2-way outlet valve at a far greater rate than it can enter through the small filling orifice for the piston cylinder (Refer Figure 116).

Feed water passes through the adjustable orifice into Chamber ‘B’ and the resulting pressure difference on the pistons causes both valves to isolate the heater or heater bank.

Control of the speed of operation to reduce the effects of hydraulic shock is by means of the adjustment orifice over the major part of the stroke and finally by the patented specially profiled stem and port arrangement which any tendency for the disc to slam onto the seat face.

During the above closing process, the electrically operated Dump Valve has also opened allowing the Safety Relief Valve to operate and reduce the pressure in the heater tubes and feed piping to ensure that both valves are held firmly closed under all conditions.

Any increase in pressure from whatever source in the isolated section of feed water piping between the two main valves will be automatically reduced by the Safety Relief Valve.

At the point of main valve closure the Quick Acting Valve will also close to prevent unnecessary loss of feed water to the plant drainage system.
The illustration shows a typical modern power plant with a Bi-Drum boiler system burning either oil or coal. The boiler consists of a large number of tubes extending the full height of the structure and the hearth producing the fierce heat. The temperature of the water circulating in the tubes is raised to almost the boiling point of water. On UK Power Stations, the turbine shaft rotates at 3,000 revolutions per minute.

As the steam passes through the turbine, its temperature and pressure fall and it expands. Because of this expansion, the turbine blades are much larger and longer than the low pressure cylinders. In the High Pressure (HP) section of the boiler, steam is heated to 540˚C before being directed into the High Pressure cylinder of the turbine (HP) where the steam is expanded to about 10 Bar. The steam will be hot enough (300˚C) to make the steam pipe glow to a dull red.

The steam is then passed through the primary and secondary superheaters and thence through the Main Steam Stop Valves (4) to the high-pressure cylinders of the turbine (HP). The steam is then heated further in the primary and secondary superheaters and fed through the Main Steam Stop Valve (5) to the high pressure cylinder of the steam turbine (HP). The steam will be hot enough (540˚C) to make the steam pipe glow to a dull red. When the steam has been through the HP cylinder of the turbine it is returned to the Reheat section of the boiler and reheated before being passed through the intermediate (IP) and low pressure (LP) cylinders of the turbine.

As the steam gives up its heat energy to drive the turbine, its temperature and pressure fall and it expands. Because of this expansion, the turbine blades are much larger and longer than the low pressure cylinders.

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