

EMERGENCY PIPELINE REPAIR SYSTEMS DEVELOPED TO FACILITATE PIPELINE REPAIR OF UNPIGGABLE DEFECTS

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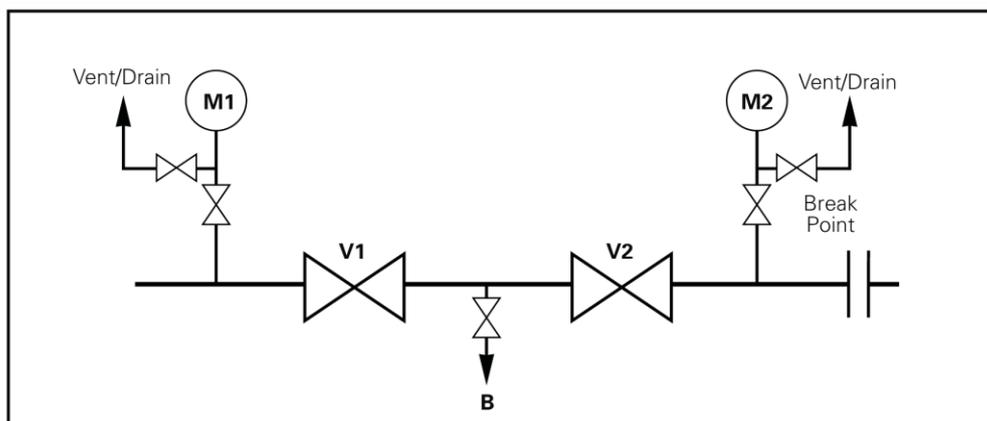
Introduction

The term “Double Block and Bleed” is mostly used to define a level of isolation provided by valves in a pipeline or process system. The term is used to describe a safe method of isolation from a pressurised or hazardous medium to facilitate breaching of the pressure system for maintenance and modifications. This terminology is also utilised to identify the relative integrity of temporary isolation systems.

However, although “Double Block and Bleed” is a universally used term to specify a level of isolation, the definition of the term is by no means universal. For example:

The UK Health and Safety Executive guidance document, The Safe Isolation of Plant and Equipment, defines double block and bleed (DBB) as “an isolation method consisting of an arrangement of two block valves with a bleed valve located in between.”

DBB Isolation Integrity Test (Two Valves)



Key

- V1 First (upstream) isolation valve from live system.
- M1 Live side monitoring point (pressure gauge or vent/drain).
- V2 Second (downstream) isolation valve from live system.
- M2 Monitoring point between valves and break point (pressure gauge or vent/drain).
- B Bleed point between the isolation valves.

Figure 1: Double Block and Bleed Diagram – Two Valves

Testing and monitoring the effectiveness of the isolation is specified in this guidance document which states:

“Prove the integrity of **all** isolation points of an isolation scheme **before** proceeding with intrusive work (unless your risk assessment has indicated that the use of non-proved isolation is acceptable):

- each part of the isolation should be proved separately, e.g. prove each valve in a double block and bleed scheme;
- each part should be proved to the highest pressure which can be expected within the system during the work activity
- where possible, each part of the isolation should be proved in the direction of the expected pressure differential” [1]

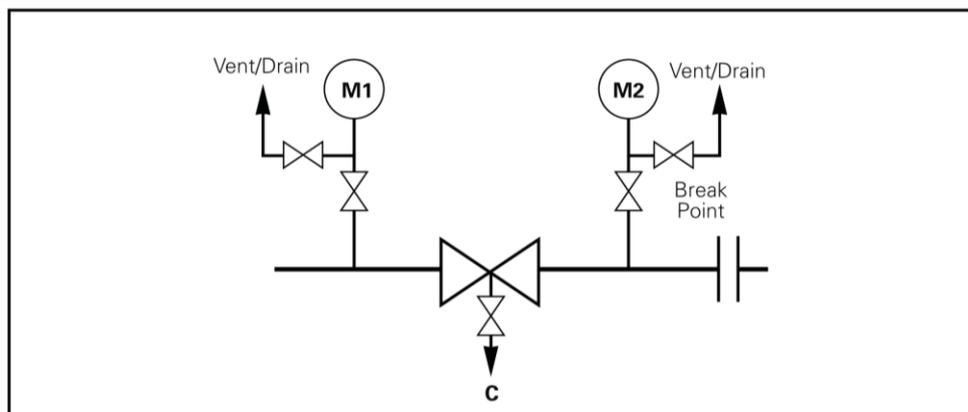
BP – Guidance on Practice for Safe Isolation and Reinstatement of Plant specifies Double Block and Bleed as:

“Double Block and Bleed consists of the closure of two block valves in series with an intermediate bleed valve. The integrity of both valves shall be tested separately and the bleed valve will then be left in the closed position between periodic integrity checks.” [2]

Most other operators have similar specifications, however there is an acceptance on many that the bleed can be left open to accommodate acceptable upstream valve leak rates. Some even specify the size of the vent to ensure that the acceptable leak rate will not generate pressure in the void between the valves.

The BP Guidance then goes on to explain which types of single body valves can be assessed to provide the same level of isolation.

(BP-approved Double Sealed, Single Valve)



Key

- M1 Live (upstream) side monitoring point.
- M2 Monitoring point between valve and break point (downstream).
- C Cavity drain (between seals).

Figure 2: Double Block and Bleed Diagram - Single Valve

Before we can look at how temporary isolation tools can be assessed to provide an equivalent “Double Block and Bleed Isolation” we need to define a consistent definition which covers the high end intent while accommodating the practicalities of pipeline systems in which valves have acceptable leak rates.

Double Block and Bleed – Definition

The baseline definition for incumbent valves is two valves, tested and proven to full line pressure in a direction consistent with the required isolation with the void between them vented and monitored for pressure rise. Although this is idealistic other than on brand new plant, it does form a starting point for assessment.

The intent of this level of isolation is that no single failure can invalidate the isolation.

Failure (or inadvertent operation) of the primary valve would only allow pressure to enter the bled zone between the valves. The second valve would prevent any hydrocarbons (or other pipeline pressure) from affecting the worksite.

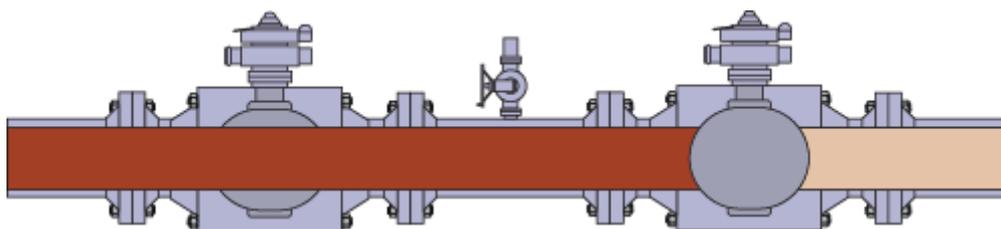


Figure 3: Double Block and Bleed Valve Arrangement – Primary Seal Failure

Failure (or inadvertent operation) of the secondary valve would only open the ambient void to the work site offering no direct risk. The primary valve would prevent any hydrocarbons (or other pipeline pressure) from affecting the worksite.

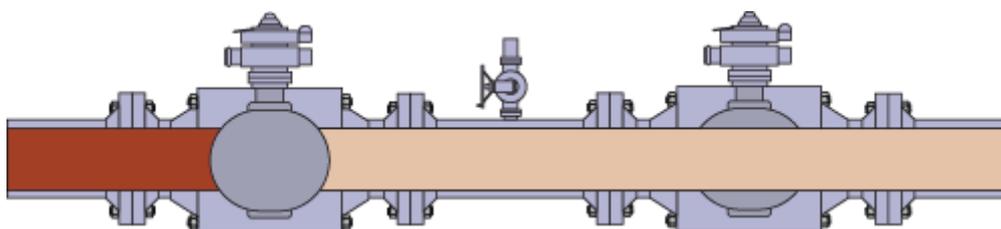


Figure 4: Double Block and Bleed Valve Arrangement – Secondary Seal Failure

The requirement for the secondary valve to be tested to verify the isolation capacity is key to ensuring that any bypass of the primary valve is retained.

The requirement for the void between the valves to be vented to ambient is necessary to ensure that any pressure build up from a passing primary valve will be detected and that it can be vented to a safe area, whilst being retained by the secondary valve. Preventing any hydrocarbons or pressure from affecting the worksite.

This is a simple concept which is complicated by the reality of plant design and valve wear. The result is that most of the time two leak tight valves are not available.

As a result some practical compromise is usually required when incumbent pipeline valves are used to provide double block and bleed isolation. The first part of this is the definition of acceptable leak rates on valves. Most operators have an acceptable leak rate criteria based on pipe diameter, pressure, and hazardous nature of the fluid being isolated. Other factors such as available vent capacity and even fire fighting capacity can also be used when assessing what leak rate can be safely accommodated. With this compromise, the secondary valve (downstream) is tested using pipeline pressure to validate it is sealing within the documented acceptable leak rate. The void between the valves is vented and locked in to measure the primary valve (upstream) leak rate. Once the leak rates

are accepted as within allowable levels, the bleed is opened to flare to ensure no differential pressure builds across the downstream valve.

Where a single valve is to be used to offer equivalent isolation, the same rules should be applied. Where the valve design energises both the upstream and downstream seals with the upstream pressure, the valve can be considered for double block and bleed. However the single modes of failure require to be assessed to ensure that sufficient safeguards are put in place to mitigate against these failure modes.

One of the main single failure points is that a single actuator function can remove both the primary and secondary seals at once, it is critical that inadvertent or accidental operation of the valve actuator must be prevented from occurring, preferable by removing or locking the actuator, while the isolation is in place.

Another potential single point failure is the ball or gate. With a single double block and bleed valve, there is normally a single closure, with a seal on either side. However the pipe is a single skin and a blind flange is similar to a gate which is bolted in place, so this can be mitigated against by ensuring the valve design is to the same factor of safety as a blind.

As most pipeline valve seats are pressure assisted, it is important that the valve integrity is tested in the correct direction, although we still see too often the valve cavity being depressurised to check both the seats of a DBB valve at the same time.

Double Block and Bleed Isolation Tooling

Double Block and Bleed is a valve definition, so all temporary isolation techniques and devices require to be risk assessed to validate that they offer an equivalent isolation level in the required application. In order to assess the comparison of isolation provided, we need first to identify the requirements.

Temporary isolation techniques offer different challenges to valves so can't be assessed in a directly equivalent manner.

Valves are designed to be installed in pipes for many years and a high number of operations between maintenance. As a result they are normally provided with acceptable leak rates higher than those of a new valve. This, results in minimum bleed capacities being specified where an open bleed is used. The wear, erosion and corrosion associated with old valves can cause many concerns, although valves in good condition should always at a minimum provide a secure mechanical restraint.

Temporary isolation devices on the other hand are not permanently connected to the pipework and can be inspected and tested immediately before use and tend to be maintained after very few operations. The seals can be replaced for every deployment so offering a consistent level of seal integrity. The only limitation on this is pipe bore condition where the temporary isolation device seals against. All the high pressure isolation devices identified here do apply some local stresses to the pipe at the set location which need to be assessed.

The ability of the isolation integrity to be monitored is critical in the temporary isolation assessment. With valves, where an open bleed is used, the monitoring of the isolation is minimal, as a rise of pressure would indicate a loss of control over the isolation rather than an indication of deterioration of either the primary barrier or vent capability. The high specification of the BP requirement above, with the bleed locked in will offer the full monitor but may not be viable with valve leak rates.

The independence of control systems to ensure no single operation could invalidate both barriers, which is a cause for concern in the single double block and bleed valve, must be addressed in the assessment of temporary isolation devices.

Accidental operation, which causes restrictions in the use of ESDV valves in double block and bleed, is easier to control in temporary isolation systems since they tend to be independent of automated plant systems, however needs to be covered in a risk assessment.

Where assessing the integrity of an isolation, we therefore need to assess the following:

- Two independent barriers
- Ability to test both barriers in the correct direction to verify the isolation integrity
- Any single failure modes are understood and addressed. E.g. single bulkheads such as in double block and bleed valves
- Bleed limitations
- Monitoring capability
- Seal integrity
- Restraint integrity
- Exposure to single seal
- Stability of isolation under unstable loading from pressure fluctuations
- Effect on the piping system

These are all assessed initially in a FMECA for the tooling then a HAZID on the deployment for STATS supplied equipment.

Tecno Plug™

The current Tecno Plug™ is derived from the dual seal tethered isolation plug. The basic concept is for two compression seals mounted in series outboard of a taper lock array. There are several configurations from single to triple module with the multi module configurations being connected by structural ball joints. The basic loading and operation is the same for all varieties.



Figure 5: Remote Control Tecno Plug™ in Pigging Configuration

The most compact plug is the single module dual seal Tecno Plug™. This plug is designed to be set in tight spaces, e.g. between two valves or between a pig trap valve and production tee to allow production to be maintained while the valve maintenance is progressed. This plug can however, be pigged round 3D bends so can also be used for long distance pigging jobs.

The single module Tecno Plug™ has two compression seals in series, supported by an array of 6 or 8 lock segments arrayed around a single lock bowl. The advantage of arraying the contingent lock segments in a single array is that both seals are fully energised by the differential across the plug. In this configuration, the loading across the plug from the differential pressure which energised the seals and locks does not change with a change in annulus pressure, unlike the alternative design with two separate lock rings.

The Tecno Plug™ is normally deployed with a remote control system which comprises a control module pigged in with the plug that sets and monitors the plug under instructions communicated through the pipe wall with ELF communications. The assessment of the isolation integrity needs to cover both the isolation plug and control system.

When deployed, the isolation plug is hydraulically activated by the control module. This causes the internally mounted hydraulic cylinder in the Tecno Plug™ to contract so setting the locks and seals to create the initial barrier. Once the plug is confirmed as set, the pressure inboard (portion of the pipe to be isolated) is vented generating a pressure differential across the plug module. As the pressure differential is applied, the trapped fluid in the annulus between the seals is compressed due to the seal compression. The other effect is that the hydraulic pressure in the actuation system drops. The remaining hydraulic set pressure once the pipe is fully vented is locked in by pilot operated check valves to ensure it is maintained, even with loss of power in the control module.

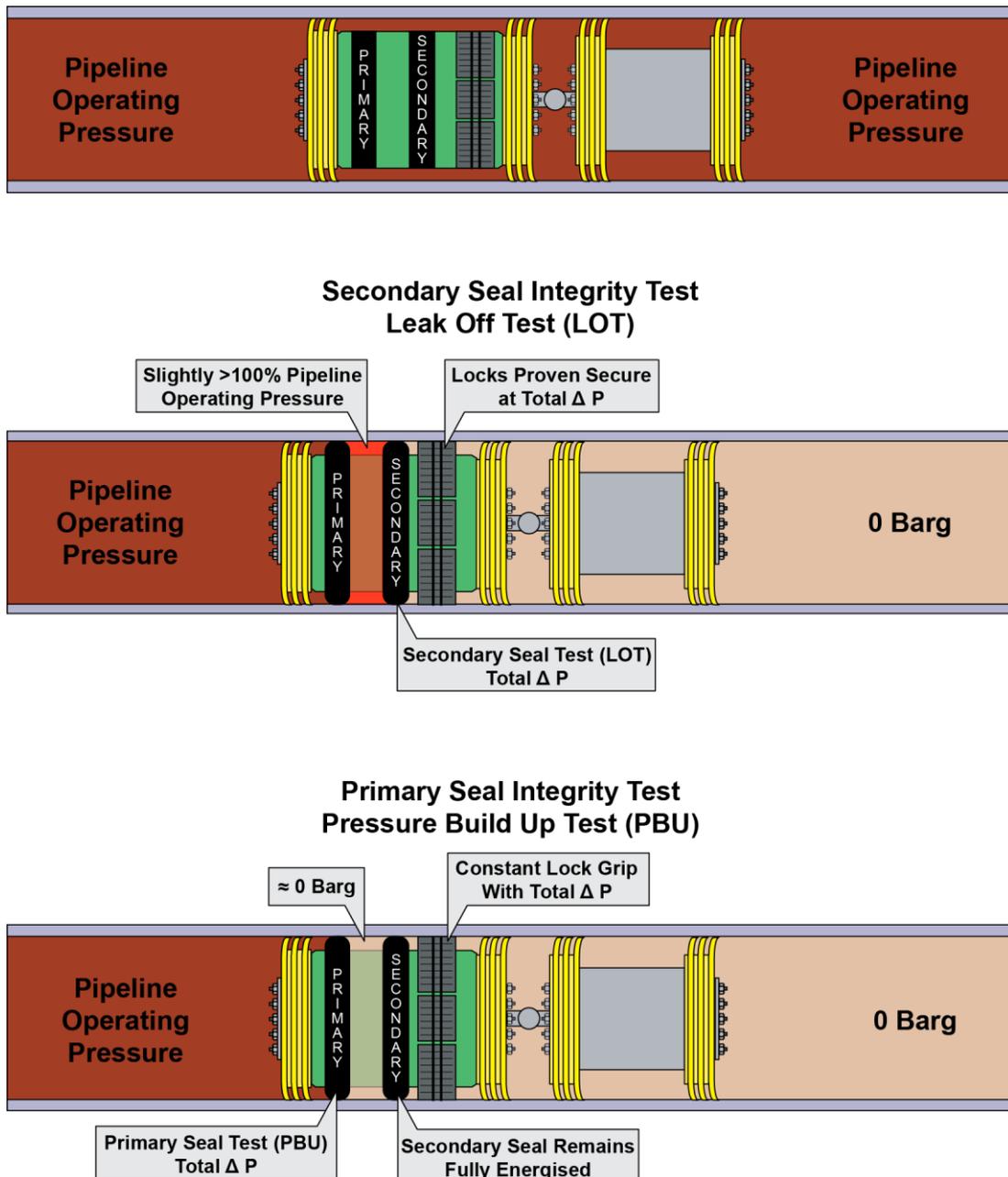


Figure 6: Tecno Plug™ Seal Verification Cycle

Once inboard pressure is fully vented the Tecno Plug™ secondary barrier is tested in situ to above the pipeline pressure in the correct orientation. This proves the integrity of the secondary seal. The annulus is then vented to the tail pressure and locked in. This allows the primary seal to be tested to the full differential pressure. Although the annulus will settle at a few bar above the small volume (~3 litres for a 30" plug) combined with the low pressure (~5 bar/ ~70 psi) does not offer a substantial risk.

The isolation is then monitored for an extended period prior to breaching the pipe integrity. The standard period is 12 hours for a high pressure isolation.

This offers the closest monitoring to the valve scenario. Both barriers are proven in-situ to full pipeline pressure and the void between the seals is bled to ambient and locked in for monitoring. As the isolation plugs offer high integrity sealing, this annulus pressure is not anticipated to require venting during the isolation. However, if the annulus pressure did rise, then the loading on the seal would be

unchanged and the system has already been tested to the secondary seal loading so does not go outside the tested condition.

Once the isolation certificate is issued, the control system is put in watchdog mode which automatically monitors the Tecno Plug™ sensors and transmits changes to alert the operator. The plug will not accept any command which will change the status while in watchdog which locks the system from inadvertent operation. The hydraulic unset is also limited and high pressure isolations can't be unset hydraulically without equalising the pressure first.

Single failure assessment of this plug is to the extent that the ¼" outboard monitor is protected by a shuttle valve to protect from a leaking fitting.

Comparing this to the Double Block and Bleed Criteria

- Both primary and secondary seal are capable and tested to the pipeline pressure in the correct direction during the deployment
- Annulus between the seals is vented and locked in minimising exposure from loss of secondary seal integrity
- Effect of the loading on the pipe is well understood and engineered for the application. All plugs are tested in equivalent pipe to Hydro-test pressures
- Both seals and the locks are fully activated by the differential pressure and by hydraulic activation pressure. Two totally independent actuation systems
- Control system locked from inadvertent operation
- Automatic monitor of outboard pressure, inboard pressure, annulus pressure, hydraulic set pressure, hydraulic unset pressure. These sensors would give advance notice of any change of status in the system. There is the ability to intervene in a controlled manner if required

Tecno Plug™ Failure Modes

The pressure head is a steel disc similar in design to a blind flange with the design to 1.5 times the isolation plug design pressure. As the standard Tecno Plug™ working pressure is in excess of 3000 psi and most deployments are less than 2000 psi, then this offers additional contingency. Every isolation tool is tested in similar pipe to the code hydro-test pressures prior to deployment. This compares to valve gates which only require a 1.1 times MAOP test pressure.

The front compression seal is the primary barrier. This seal is held activated by both the differential pressure and hydraulic set pressure, both of which would require to be lost to invalidate the activation. Failure modes assessed are a leak developing and a catastrophic loss of seal. These are highly unlikely events, however the consequences need to be assessed. A leak past the primary seal would only restore the annulus pressure to the pre-vented plug status which had already been tested. The secondary seal is proven as a full barrier. The Tecno Plug™ control system allows controlled venting of this pressure if required. A catastrophic failure of the primary seal could allow movement of the pressure head towards the taper locks. The Tecno Plug™ is therefore designed to accommodate this movement to the extent of the full loss on the primary seal rubber volume. However, additional to this defence, the seal would not extrude onto the pipeline pressure as the pipeline pressure is acting against it. Extrusion towards the secondary seal would be limited by the free volume around the annulus ring so a full seal loss is not possible. The plug design has however been designed to accommodate total loss of this seal.

The annulus ring is a solid steel plate under compression which is supported across the surface with the compression seals and is designed of sufficient thickness to retain rigidity.

The rear compression seal is the secondary seal. This seal activation is maintained by both the differential across the plug and the hydraulic set pressure, whether there is pressure between the seals or not. The seal is tested as part of the Tecno Plug™ deployment and held during the isolation with minimal pressure locked in the annulus. This seal is assessed for two failure scenarios. Firstly a leak developing. A leak in this seal would be identified by the loss of the small pressure in the annulus. The small volume and pressure minimises the potential hazard. The second hazard assessed is the catastrophic loss of the secondary seal. Like the primary seal the Tecno Plug™ stroke is designed to accommodate this movement. However like the primary seal, the seal movement is limited. For the seal to move forward into the annulus, the limited free annulus volume would prevent seal loss. If the seal moved backwards, the movement would be limited by the locks. Hence the catastrophic seal failure also protected against by the nature of the design.

The lock bowl is a solid steel ring designed to take the full test pressure in a similar manner to the annulus ring and pressure head.

The taper lock segments have more than 100% contingency arrayed around the lock bowl. This ensures that eccentric pipe surface degradation (e.g 6 o'clock corrosion) can be accommodated. The locks are fully engaged by both the hydraulic set pressure and the differential pressure across the plug in a similar manner to the seals. These locks are tested to the full pressure during the isolation plug deployment and the loading from the differential pressure is constant with pipeline pressure. The alternative of axially separating the contingency locks, placing a set between the seals, would result in the loading on the lock grip changing if the annulus between the seals changes- offering the potential on an untested condition being generated during an isolation. STATS have assessed this risk as being more hazardous than a single fully tested and stable grip.

Tecno Plugs™ have been accepted by most major operators over the last 20 years.

Tecno Plug™ Examples



Figure 7: 38" Tecno Plug™ after Sour Gas Deployment

- 38" Remote Tecno Plug™, Ras Laffan Facility, Doha, Qatar. Gas pipeline isolation facilitates removal of 2" bypass branch connected to a 38" ESDV.
- 2 off 36" Remote Tecno Plugs™, MLNG-Dua, Bintulu, East Malaysia. Pipeline isolation operations facilitates Kumang Cluster onshore tie-in project.
- 36" Remote Tecno Plug™, Dol 2 Platform, North Field, Qatar. Double-block isolation facilitates 36" valve maintenance activities.
- 24" Remote Tecno Plug™, Dunlin Alpha Platform, North Sea, UK. Double-block isolation facilitates valve change out activities.



Fig 8: 38" Tecno Plug™ Deployment Malaysia

BISEP™ – Branch Installed Self Energised Plug

The BISEP™ is the Double Block and Bleed isolation tool which has been developed and patented by STATS Group. It uses Tecno Plug™ seals mounted on a spherical head to provide the dual barrier isolation.

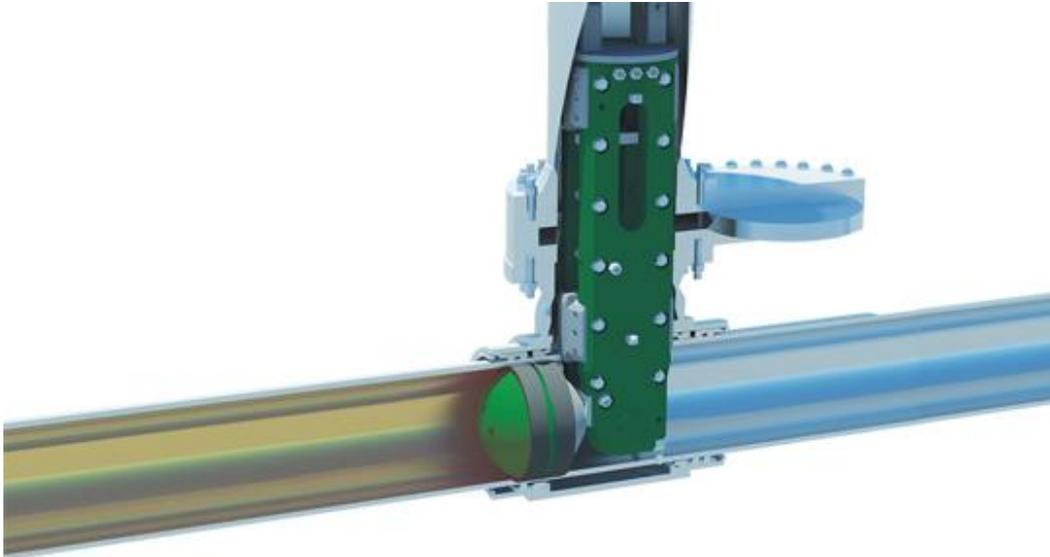


Figure 9: BISEP™

The BISEP™ offers all the dual seal advantages of a Tecno Plug™ but with some additional features.

- The pressure head, primary seal annulus ring and secondary seal operate in a similar manner to the Tecno Plug™.
- The BISEP™ is however installed through a hot tap penetration so instead of the taper locks, the BISEP™ is restrained by two solid clevis arms, each of which can resist the full test pressure.
- The BISEP™ also has a secondary leak tight pressure head mounted to the rear of the secondary seal.
- The BISEP™ had permanent hydraulic connection through the launcher. This would allow continuous safe venting of any primary seal bypass.
- The BISEP™ can accommodate back pressure to test the completed pipework.
- The BISEP™ can be utilised in conjunction with a Tecno Plug™ to allow hot tap fittings to be removed so removing the hazard of welding onto live lines and the long term security of split welded fittings.

STATS have developed a system, first used to remove an 18" dead leg for BP in the UK, where a mechanical hot tap clamp is used to provide a cold work branch. The clamp is a dual seal variety which allows the assembly on the pipe to be pressure tested. A hot tap machine and valve then generates a penetration in the pipe for the deployment of the BISEP™.

The BISEP™ is then deployed to provide double block and bleed isolation so facilitating the removal of the dead leg. Once the dead leg is removed, a temporary launcher complete with Tecno Plug™ is attached and pressure tested against the back of the BISEP™. This new verified boundary allows the BISEP™ to be removed leaving access to deploy the Tecno Plug™. The Tecno Plug™ is then deployed outboard of the mechanical hot tap clamp and set to provide Double block and bleed isolation.

The clamp and pipe with hot tap penetration can then be removed under the Tecno Plug™ isolation. In the 18" application there was a flange break immediately on the 36" by 18" tee allowing a quick and permanent solution. This Tecno Plug™ was designed with a mechanical lock and retention which allowed the plug to be abandoned in the branch and blinded behind it. The length of the plug was designed to fill the branch so effectively removing the dead leg.



Figure 10: BISEP™ Deployment During Testing



Figure 11: BISEP™ Isolating Pipeline On-Site with Dead Leg Cut Away

The whole operation was conducted under cold work conditions with double block and bleed isolation throughout.

BISEP™ and Tecno Plug™ seals are rated for leak tight operation. The picture below shows a BISEP™ head where the seals were set on hot tap swarf and attained a leak tight seal. The swarf can clearly be seen on the BISEP™ seals.



Figure 12: BISEP™ Head after Successful Set on Hot Tap Swarf

BISEP™ Features

- Pipeline differential pressure acting across BISEP™ head activates seals independent of hydraulics
- Hydraulic set pressure to ensure two independent activation mechanisms
- Seal support head bears on two solid clevis arms, each one capable of taking the full load (100% contingency)
- Clevis arms are axially retained by the hot tap penetration and fitting

BISEP™ Examples

- 30" BISEP™, Cassia A Platform, Trinidad. Riser isolation allows replacement of 30" ESD Valve.
- 18" BISEP™, Sullom Voe Terminal, Shetland, UK. Isolation of 18" crude oil bypass line allowed removal of dead leg.
- Two 14" BISEP™, Galeota Point Terminal Facility, Trinidad. Crude oil pipeline isolation allows piping spool tie-in.
- 10" BISEP™, Brent Bravo and Delta Platforms, North Sea, UK. Thirty-two cell fill line replacements within utility shaft of platforms.
- 6" BISEP™, Theddlethorpe Terminal, England, UK. Isolation facilitated valve replacement.
- 3" BISEP™, Piper Bravo Platform, North Sea, UK. Isolation facilitated replacement of piping system.



Figure 13: 30" BISEP™ Launcher Rigged into Position

References

[1] Health and Safety Executive, 1997, The safe isolation of plant and equipment

[2] BP, Dec 2009, Guidance on Practice for Safe Isolation and Reinstatement of Plant

BISEP™ and Tecno Plug™ are trade marks of STATS (UK) Ltd