Instructions for use of INFLATABLE PACKERS
IPI's inflatable packer range is available in a variety of sizes ranging from 12 mm up to more than 2 metres in diameter and with pressure ratings from a few kPa (psi) up to 138 MPa (20,000 psi). Many of these packers form parts of specialized tools and each of these is offered complete with comprehensive instructions for use, however, there are also simpler uses of IPI packers for which specific instruction manuals are not offered. The intention of this document is to offer general use information and instructions applicable in these cases. It is worth noting that these general instructions, for the most part, will also be applicable to packers used in specialized tools as well.

PRESSURES AND SIZES

Inflatable packers, as mentioned above, offer a wide variety of sizes and pressure ratings. In general, for a specific packer, the pressure rating decreases as the hole size increases.

Each IPI packer is supplied complete with a pressure rating chart that specifies the maximum allowable inflation pressure with respect to hole size. These ratings must be respected in order to avoid premature failure of the packer elements.

The rated pressure of a packer is its allowable inflation pressure not the differential pressure it can support. The differential pressure will always be lower since inflation pressure must be sufficiently higher to inflate the packer to the required hole size and create a seal to support the applied differential pressure. The difference between inflation and differential pressures is specific to each packer design and application as it also largely depends on friction. Contact IPI with your specific application details for more information.

INFLATION FLUID

Inflation with Water

Most inflatable packer manufacturers recommend inflation with water whenever possible. Generally the only time it is not possible is in a dry hole or where the water table is too low. In these circumstances the column of water in the inflation tube is too great to allow complete deflation of the packer. Even then, use of special deflation valves (which may require running two inflation tubes) makes use of water inflation possible.

The reason water inflation is preferred, is that a water inflated packer, after establishing an initial seal, will remain inflated up to the burst pressure of the packer owing to the incompressibility of the water. This phenomenon is normally referred to as “dynamic sealing”. In contrast a gas inflated packer can only provide a seal if the gas pressure is maintained at a level above the sum of the sealing and differential pressures. Leaks, relaxation, soil movement, excess differential pressure, etc, can all lead to bypass of a gas inflated packer without the operators knowledge. Bypass is detrimental not only to the accuracy of the test but can also affect the ability to retrieve the tool. If, for example, grout bypasses a gas inflated packer and sits above the packer for any length of time, the packer will become difficult or impossible to retrieve.

In fact, any liquid will provide the same inflation benefits as water and in sub-zero temperatures other liquids or water/anti-freeze solutions must be used. When possible however, water is the preferred liquid since it's non-polluting, readily available and will not damage the rubber. (Note: that many packers are made of natural or SBR rubber and thus are not suitable for oil inflation.)
The major drawback with using water for inflation is the deflation is slower than when using gas and it may be more inconvenient to operate a water inflation pump in some circumstances. On the plus side, water is far better logistically and from a safety viewpoint.

**Inflation with Gas**

If inflating with gas, the operator must be aware that rubber is gas permeable to a greater or lesser extent depending on the type of rubber, the temperature, the length of exposure time, the differential pressure across the rubber and other factors. This fact means that, while inflated, the packer rubber will absorb gas which is not a problem while the packer remains pressurized. When deflated and retrieved to surface however, this absorbed gas will slowly come out of solution in the rubber and build up in any local discontinuities within the packer element construction – typically along the reinforcement. If sufficient gas gathers in this way then it can cause delamination of the outer cover of the packer with the subsequent forming of large bubbles in the cover making the packer unusable. IPI recommends against the use of gas for inflation for all but short term applications – a few hours maximum.

Where gas inflation is used, the gases preferred are compressed air or nitrogen. Under no circumstances should oxygen be used as it may cause explosive failure of the packer. Other gases should be checked with IPI for compatibility with the packer elastomer.

Gas inflation pressures, as already mentioned, are of critical importance and must be carefully calculated and monitored during operations. For any particular application, the minimum inflation pressure required (in units of kPa), as read on a surface pressure gauge can be calculated as follows:

\[
\text{Min gas inflation pressure} = (\text{pressure to inflate out to hole diam}) + (\text{sealing pressure advised by manufacturer}) + (\text{max applied pressure})
\]

**Note:** that the “maximum applied pressure” is the pressure at the packer, not the surface pressure. This is determined as follows:

\[
\text{Max applied pressure} = (\text{depth to packer (m)} \times 10 \times \text{S.G. of well/injected fluid}) + (\text{surface pressure}) - (\text{packer depth below water (m)} \times 10)
\]

The pressure to inflate the packer to the hole diameter is not normally given by IPI as it varies considerably depending on packer inflation history and environmental factors such as temperature. It can and should be checked on site before starting operations. If the sealing pressure (really a safety factor to assure adequate sealing) has not been provided by IPI a figure of around 10-20% of the maximum applied pressure should be used.

**Safety Considerations**

Another prime consideration with gas inflation is the safety aspect of dealing with high pressure gas. A gas inflated packer is basically a bomb and should be treated as such. If ruptured it has the potential to do lethal damage – we have seen the centre pipe from such a packer driven through the engine block of a truck! Under no circumstances should gas be used to test inflate packers free-in-air. Test inflations should always be conducted in a pipe with adequate protection to personnel against potential injury by projectiles ejected from the pipe should the packer fail.
INFLATION CONTROL

Regardless of the type of packer or the inflation method it is critically important to have an inflation system that provides sufficient control and monitoring functions. The assembly shown in the Figure below (or an equivalent setup) is considered to be the minimum for safe, efficient operation.

The system basically requires:

- A pressure source
  - An isolation valve
  - A vent valve
  - A pressure gauge
  - Suitable hose/tube to connect to the packer and between the other items.
  - A high pressure gas regulator (for gas inflation)

The Inflation Set shown combines the isolation and vent valves into one 3-way ball valve for more compact packaging.

Using this type of inflation control and monitoring assembly ensures that, for example:

- The pressure gauge cannot be accidentally isolated from the packers and so always indicates packer pressure.
- The pressure source is independently isolated from the packer. This is of great importance with gas regulators since they can easily be set at very high pressures or not be properly shut down. (In fact, the temptation is to leave the regulated gas supply connected to the packer at pressure which may lead to packer over-expansion and subsequent failure.)
- The separate vent valve (or vent function) ensures the packer can be safely vented for deflation.
- Being small, self contained and portable (if provided with suitable hose length) the Gauge Set can be moved to the most convenient location to control and monitor the packer during inflation and subsequent operations.

Clearly, all components used in the inflation control system must be of adequate pressure rating. In the case of gas inflation, if operating deep in a water filled hole, the surface gas pressure may easily be over 1,000 psi (70 bar) and adequate precautions are required. The pressure gauge should be chosen such that the maximum inflation pressure lies in the middle third of the gauge’s scale. Pressure gauges are delicate instruments that require careful treatment and regular calibration to ensure their reliable operation.
Inflating the packers

Once the packer has been chosen along with the suitable inflation fluid and inflation control and monitoring system it's time to connect it all up and trial inflate the packer/s. If gas inflating, trial inflations should only be performed in a pipe of adequate strength and with appropriate safety precautions. If inflating with a liquid, trial inflations may be performed free in air but are more usefully done in a pipe as per the gas inflated packers to get accurate pressure and time data.

Trial inflation allows the operator to check for system performance and leaks. Specifically, the operator should be checking inflation pressure required to inflate the packer to firm contact with the test pipe wall, and packer integrity at the maximum in-hole pressure. Note that the latter may be considerably less than the surface inflation pressure for a gas inflated packer owing to the fact for a surface inflation there is no “depth below water” term in the inflation pressure calculation. This may mean that a separate pressure test with the packer disconnected and the inflation hose/tube plugged off is warranted to assure the inflation system.

It is best to perform trial inflation with the full length of inflation tube that will be run in the hole with the packer. This allows the operator to time inflation and deflation, get an indication of pumping pressures during different stages of inflation and, for a liquid inflated packer, primes both the packer and the inflation tube.

The general characteristic of packers whether inflated with liquid or gas is that the bulk of the inflation volume is placed into the packer at relatively low pressure and it is only the last little bit of volume that is placed at increasingly higher pressures. Charting inflation pressure against time leads to a curve showing low, steady pressure increase over an extended period followed by a rapid pressure increase (after wall contact is achieved) in a relatively very short time. This characteristic takes some getting used to and operators should be encouraged to use the trial inflations to accustom themselves to the pressures, volumes and times involved.

Deploying the Packer

The usual deployment methods are via rigid pipe or via hose. The latter is quicker but provides limited depth control, no packer hold-down capacity and limited support for inflation tubes. It is also depth limited by the self supporting capacity of the hose and its connection to the packer for which reason a safety wire is sometime used along with the hose. Depth limitation may also be due to the handling capacity of the hose raising and lowering system which is frequently manual.

Using a rigid pipe for running the packers offers good depth control, good support for inflation tubes and some hold down capacity. However, it generally requires a mechanized system (drill rig or crane) to handle the rods due to their length and weight and thus is much slower and more cumbersome.

Concerning hold down capacity, this is related to the inflatable packer's ability to anchor itself in the borehole against the up-lift force generated by the differential pressure below a single packer. It has been calculated that for normal open hole situations, where L/D ratio (packer contact length to hole diameter ratio) is 10 or more the packer should be self-anchoring against all differential pressures up to burst. If the L/D ratio is less than 10, whether or not the packer is self-anchoring would depend on the specifics of the application. Advice should be sought from IPI in these circumstances.
### PACKER DAMAGE + SERVICE LIFE

Packer damage during downhole operations is generally due to one of the following factors:

<table>
<thead>
<tr>
<th>Damage Factor</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Over-expansion</strong></td>
<td>Caused by inflating in too large a borehole or a washed out section of the hole or, occasionally, in a yielding soil such as weak clay.</td>
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<tr>
<td><strong>Outer cover rubber cutting</strong></td>
<td>Caused by any sharp object in the borehole, eg end of casing or a casing joint, perforations or sharply fractured rock.</td>
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<tr>
<td><strong>Moving a partially inflated packer</strong></td>
<td>Can damage it either by excessive wear against the hole wall or by pulling the steel ends off the rubber, either partially or completely. This action can also deform internal reinforcing which will affect the packer’s ability to recover to its original form.</td>
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<tr>
<td><strong>Over Pressurization</strong></td>
<td>Packers are rated for specific pressures in specific diameter holes and over-pressurization normally is caused by using the packer’s pressure rating in one hole as the rating in a much larger hole. Always refer to manufacturer’s diameter vs. pressure rating chart before deciding on an inflation pressure.</td>
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<tr>
<td><strong>Sliding End Fouling</strong></td>
<td>Fouling of the sliding end packer mandrel can prevent the packer end from sliding and/or damage the sliding end seals. Such fouling could be due to, for example, cement grout or corrosion.</td>
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<tr>
<td><strong>Sliding End Damage</strong></td>
<td>Damage to the sliding end of the packer mandrel may damage the sliding end seals or prevent them from sealing.</td>
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<tr>
<td><strong>Rubber Deterioration</strong></td>
<td>Direct sunlight or high temp. conditions or exposure to solvents or ozone gas from such sources as arc welding operations.</td>
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<tr>
<td><strong>Inflating with Oil</strong></td>
<td>Inflating natural or SBR rubber packers with oil will cause excessive swelling and associated softening of the rubber.</td>
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<tr>
<td><strong>Long Term Gas Inflation</strong></td>
<td>Often causes rubber blistering and delamination after the packer is removed from the borehole as gas which has been absorbed into the rubber under pressure is desorbed and collects in pockets formed within the packer reinforcement carcass.</td>
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With the exception of failure due to one or more of the causes outlined above and assuming that the packers are well maintained and adequately stored between uses, and when they are used in accordance with the guidelines given in this article, then inflatable packers should provide long term reliable service.

There is no intrinsic reason why many hundreds of operations may not be performed with a single packer. When such service life is not realized it is frequently due to one or more of the factors highlighted above which stem from inadequate operator knowledge and training or incorrect borehole data. It is hoped that these instructions will serve to remedy the first of these detriments and that, with such knowledge available, Contractors will ensure that their operators are appropriately trained.