Adriano Giacomel, Managing Director, AGE Developments Pty Ltd
Clem Rowe, MIEAust CPEng, Engineering Director, AGE Developments Pty Ltd

INFLATABLE PACKER FUNDAMENTALS

SUMMARY: The basic construction details and operating characteristics of inflatable packers and inflatable packer based systems are presented and discussed in the light of general application requirements. Those criteria which are most relevant to the selection of packers are highlighted.

INTRODUCTION

Inflatable packers have been used in the oil industry for more than forty years. With the increasing availability of these packers designed specifically for economical use in other industries the areas of application have extended to include the water well, mineral, geotechnical and foundations drilling industries. Typical applications include:

- permeability testing,
- fracture testing;
- chemical injection;
- formation fluid sampling;
- casing/pile grouting;
- borehole plugging;
- downhole fishing tools

A drilling contractor's first introduction to inflatable packers is often when called upon to perform so called "packer tests" as part of a drilling program. In this case "packer test" is used as a generic term to cover a multitude of different downhole testing programs using inflatable packers. Usually when applied in a mineral drilling or investigation project the term means permeability testing using inflatable packers. In this case the packers are used to isolate a section of the hole to allow controlled pumping into this zone to enable the permeability of the formation to be determined. See Figures 3 and 4 for typical packer configurations used for testing.

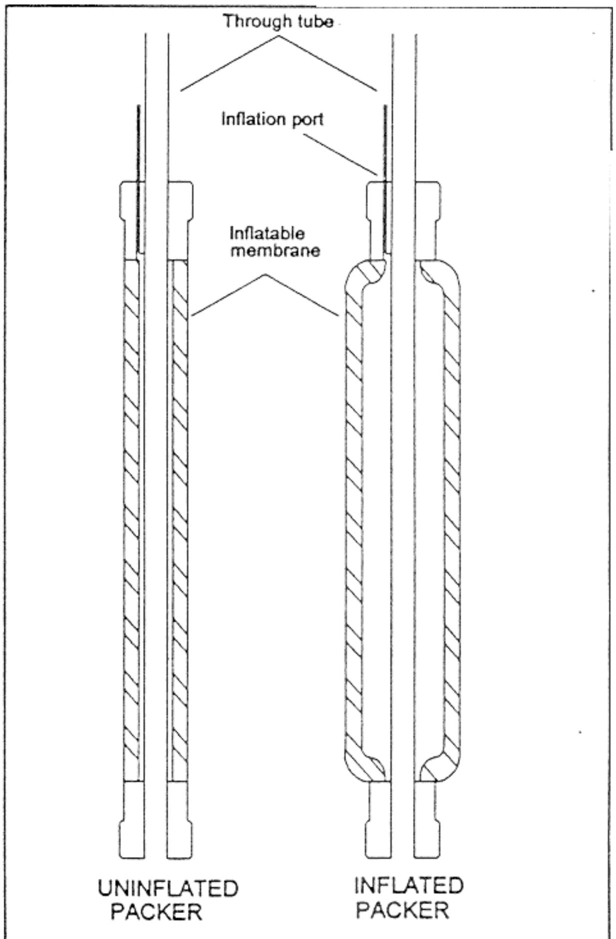

FIGURE 1 - Simple packer configuration

The term "packer testing" is also applied to fracture and so called stress testing, selective pump testing operations and on any particular project may be applied to any specific activity involving the use of inflatable packers.

Testing is by no means the sole or even the major use of inflatable packers. As indicated in the above list they also find application in a number of grouting procedures whether for foundations work, completions, casing repair operations, etc.
To gain a better understanding of the type of activity that may be addressed with packers and the advantages and limitations that may apply in any particular case it is helpful to understand the way in which inflatable packers work and the factors that effect their operation.
This paper is aimed at providing that basic knowledge and then showing how it is applied in several practical applications.

2.0 INFLATABLE PACKERS

An inflatable packer in the simplest form is a cylindrical, elastic membrane that is sealed at the ends and that when internally pressurized inflates radially. The radial inflation is used to seal and anchor the packer in place in the hole or pipe in which it is inserted.
In pratice, a packer looks like a short length of hose with steel end fittings and, usually, a central through pipe as illustrated in Fig. 1. The inflation medium is introduced between the central pipe and the inside of the membrane.
The membrane itself may be anything from a simple rubber tube to a fabric and wire reinforced rubber element to even a thin metal sheath. Obviously, the membrane type has a large bearing on the pressure rating for the complete packer and on the applications for which it is suitable.
A packer with an unreinforced rubber membrane will have a very low pressure rating, say 200-300 kPa. 'It will be relatively delicate, not capable of withstanding rough handling or even inflation in open hole where there is danger of cutting the membrane on sharp formations. A typical application would be for use in very shallow groundwater monitoring operations.
Similarly, packers manufactured with a metal sheath as the inflating membrane are for a limited range of very specialized applications. In this instance though we're looking at the opposite end of the pressure specturm to that addressed by the previous type. Typical applications are, very high temperature sealing systems, casing or pipe internal patches, etc.
For the main part, most inflatable packers used in the drilling industry employ fabric or wire reinforced rubber elements. These offer a broad range of operating characteristics which can be engineered to suit most applications.
Regardless of membrane type, all inflatable packers exhibit an unique characteristic with regard to their response to inflation pressure which is discussed in the following.

2.1 Packer Pressure Ratings

Inflation pressure rating is a decreasing

function of inflated diameter. That is, for any particular packer, the allowable inflation pressure at small expansion ratios will be lower than that at larger expansions ratios. (The expansion ratio is

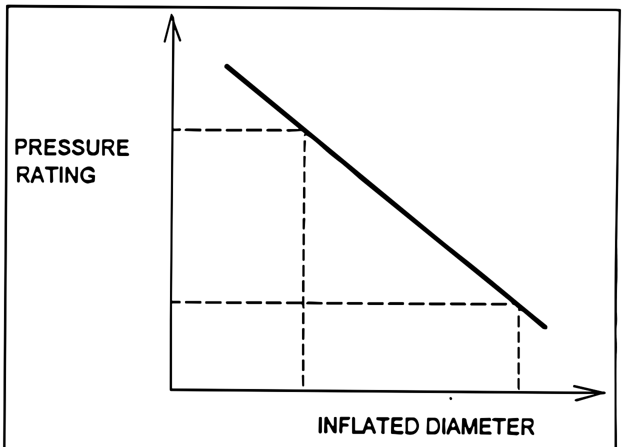

FIGURE 2 - Typical Pressure vs Diameter Chart
for Inflatable Packers

the inflated diameter divided by the uninflated diameter.) This relationship is illustrated in Figure 2.

Depending on the packer type and construction method the slope of rated pressure curve may be more or less severe.

With low expansion ratio packers this pressure/diameter characteristic is of minimal importance but since packers are now available with expansion ratios of up to 3:1 an appreciation of this aspect of packer pressure rating is essential.

As a general rule, if you run into a hole with only a small clearance your pressure rating when inflated to the hole diameter will be several times higher than if your packer has to expand an appreciable percentage of its uninflated diameter prior to reaching the wall.

The specification of inflatable packers for a particular job should make allowance for this characteristic. The consequence of not including such information in the specification is that you can end up paying a lot of money for something you don't really need.

For example, a "standard" oilfield packer to run on Y' API casing would typically be approx. 61/2" O.D. and be rated for 1000 psi when inflated in a 91/2" hole. To use such a packer for a shallow casing grouting job, e.g. 200m deep, 1W diameter with no restriction on run-in diameter, would be uneconomical since a low pressure packer, rated at 300psi and run-in at, say, W' O.D. would do the job equally well.

2.2 Differential Pressure Rating

A common misconception with inflatable packers is that the packer pressure rating indicates the packer's ability to support a differential pressure of this magnitude. A packer's pressure rating is the same as any other components' pressure rating. It's the pressure which the packer may safely support under the quoted conditions.

A packer's capacity to support a differential pressure, although related to the packer pressure rating is as much a function of the in-hole and support conditions.

The in-hole conditions, ie, fluid type, temperature, sealing surface type and condition, determine the frictional resistance to sliding which the inflated packer can generate. The support conditions, eg straddle configuration (two packers “straddling” a test zone), single packer run on pipe or wireline, etc., determine what contribution is required from the packer/hole friction.

The frictional component is best assessed by testing in conditions which as closely as possible mimic the worst of expected downhole conditions. Usually the support component may be readily calculated from the structural conditions.

2.3 Packer Types

Another unique characteristic of inflatable packers is related to the type of membrane end fixing employed. Two types are available, namely fixed end and moving end.

The fixed end type is the simplest kind of packer, with an unreinforced rubber element clamped at each end representing the simplest of all. Reinforced rubber or all metal membranes are also available in fixed end configurations. Regardless of membrane, the packer expands radially by axial stretching of the membrane.

Restricting attention to standard reinforced rubber elements, the fixed end packer offers low initial inflation pressures, moderate pressure capability, high expansion ratios and relatively simple construction. They are generally well suited to cased hole applications where packer over expansion into unconsolidated or washed out regions is not a consideration.

Moving end packers achieve radial expansion by allowing the packer element to shorten axially. Usually, one end is fixed and the other end slides on a central mandrel which doubles as the through pipe.

This type of packer typically has higher initial inflation and final pressure ratings. It is more suitable for open hole applications, particularly in soft or fractured formations.

The existence of mechanical seals at the sliding end presents a potential leak path, absent in the fixed end type. Also the fact of the moving end and subsequently the exposed sliding surface of the mandrel must be considered in the overall application. For example, for long term inflation, is the sliding surface subject to corrosion or in a grouting application, could grout set in the sliding region preventing the packer from returning to the deflated condition.

3 PACKER SYSTEMS

Many criteria concerned with the selection and use of inflatable packers relate to 'the total application system rather than just the packers themselves. Matters to be examined in this light include:

a) Geometrical constraints;.

b) Inflation fluid type;

c) Inflation method;

d) Deployment method;

e) Ancilliary operations.

3.1 Geometrical Constraints

This is perhaps the most basic of all criteria when assessing any downhole equipment. Will it fit in the hole? With inflatable packers, the question becomes "will it fit in the hole and inflate to seal at the required pressure".

Due to the pressure/diameter relationship discussed previously the answer to this question may not always be obvious. The effect of hole size restrictions such as intermediate casings or no-go nipples and suchlike must also be considered.

Often an open hole is assumed to be in gauge and downhole components are sized accordingly. On the day it is discovered that

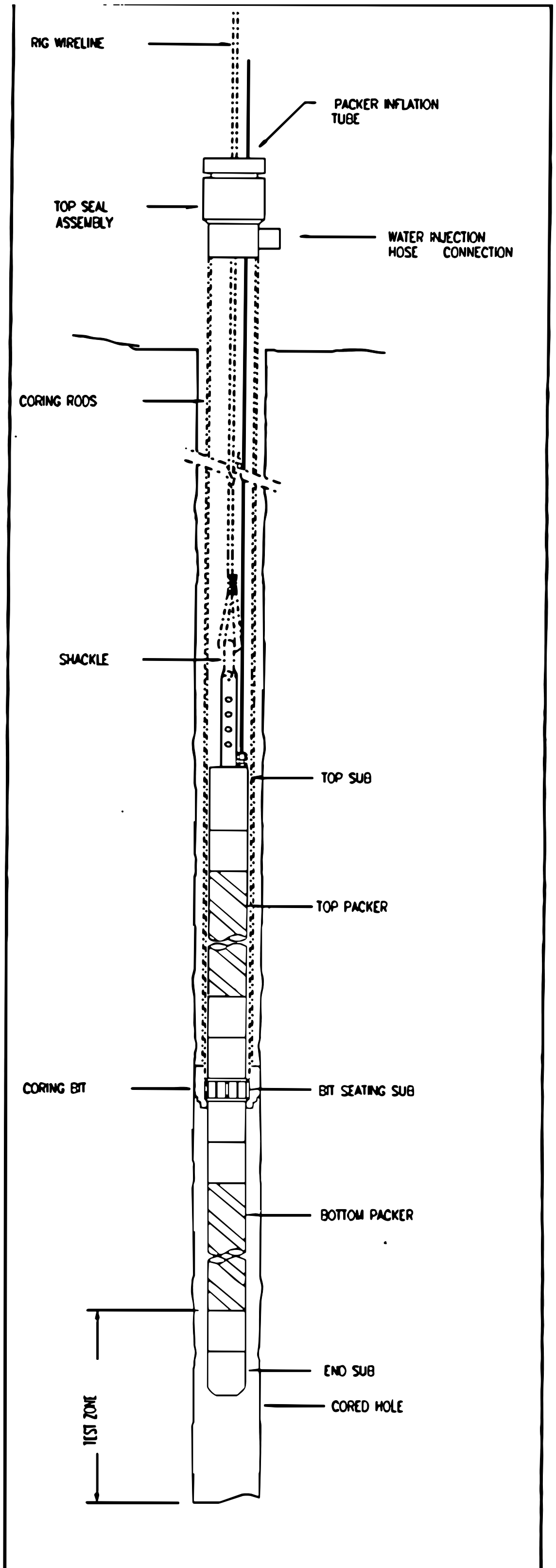

Figure 3 - Typical wireline system

the very zone where packers are to be set is washed out, thus making their use suspect or even impossible.

Where inflatable packers are to be used, careful attention must be paid in the planning stages to a realistic assessment of hole diameters and clearances.

3.2 Inflation Fluid

In general, packers may be inflated with. either a liquid or a gas. Oil, water, nitrogen gas and air are commonly used.

The choice of gas or liquid is often influenced by the packer's response to applied pressure. If inflated with a liquid, the packer inflation pressure will respond positively to any applied differential pressure owing to the essential incompressibility of the inflation volume.

This characteristic of liquid inflated packers is often made use of in grouting and fracturing applications to avoid initial high inflation pressures. As an example consider a fracturing job.

Two packers are inflated to isolate a test zone between them. The fracture pressure is expected to be around say, 20 MPa. In order to observe the fracturing process during fluid injection into the test zone, the last thing you want is for the packers to initiate fracture before you even start the test. To guard against this eventuality the packers would be inflated to only 10 MPa, say. As the test zone injection pressure increases, the packer pressure will increase in parallel so avoiding premature fracture.

In addition to this criteria the choice of inflation fluid should be carefully considered with respect to several other factors as follows:

- chemical compatibility with the packer materials;
- setting depth;
- hole conditions;
- the period for which the packers will remain inflated;
- availability.

3.2.1 Chemical compatibility

The question of chemical compatibility is an obvious one which more often becomes a problem where packers are used in an application other than that for which they were originally designed and purchased. The two most common pitfalls are inflation with oxygen gas which leads to explosive failure of the packer element and inflation of a natural rubber packer with a hydrocarbon liquid which leads to premature failure due to swelling and chemical attack.

3.2.2 Setting Depth

The influence of setting depth on choice of inflation fluid is not so obvious. It strictly relates more to the static pressure at the setting depth than to the actual depth and is best illustrated by considering an example.

Consider a packer located at 100 meters below the SWL. To initiate inflation with gas the 100 meter static head must first be overcome. So if the required inflation pressure is, say, 2000 kPa above static, the gas pressure required at surface is approximately 3000 kPa. This may be a problem if using a compressor for inflation.

In a more extreme case, if the setting depth were increased to 1000 metres below SWI, the required surface gas pressure becomes 12,000 kPa even though the actual packer inflation pressure is still only 2000 kPa. This sort of pressure requirement has consequences for the pressure ratings of both surface and downhole inflation equipment.

Use of a liquid, say water, as the inflation fluid in the above examples, reduces the maximum inflation system pressure rating to 2000 kPa in both cases by balancing the static head with an equal liquid head in the inflation system.

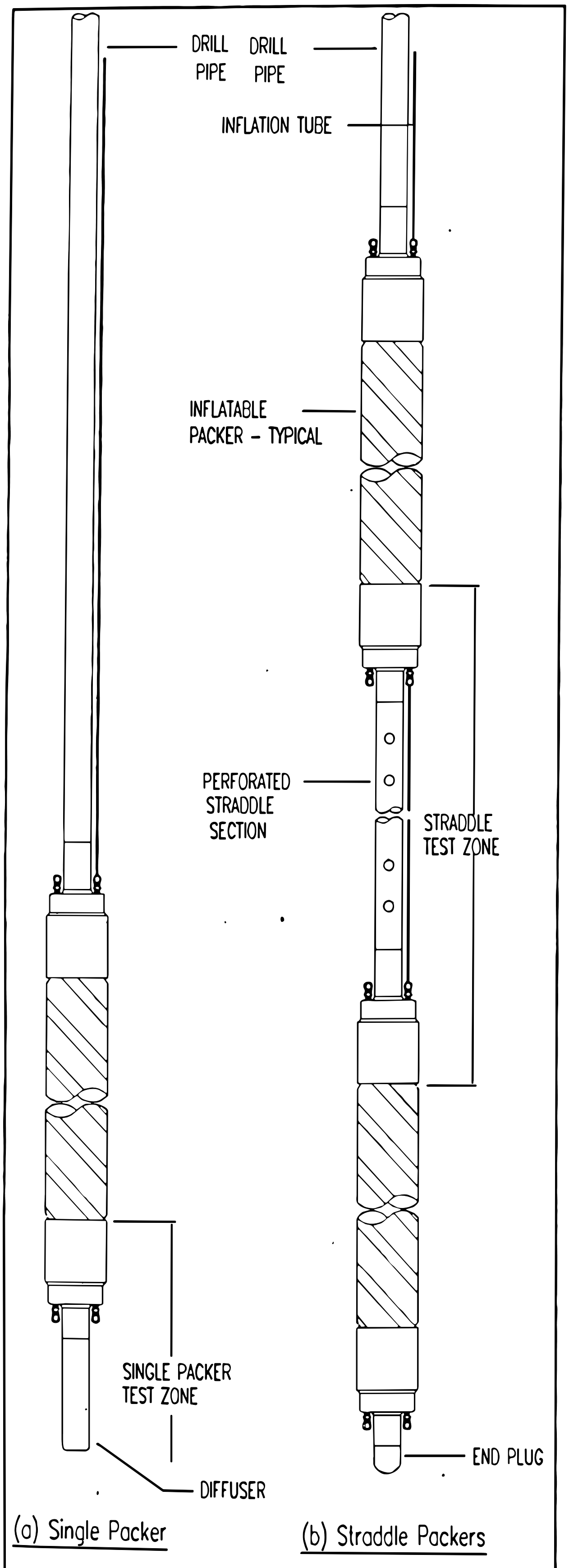

Figure 4 - Typical drill string deployed packer configurations

In some instances the static head due to a liquid inflation fluid can be a disadvantage. For example, if a packer is to be set in a hole where the SWL is, say 50 metres below surface, two problems may arise with liquid inflation.

First, the static head of the inflation fluid, if applied to the packer prior to reaching the setting depth may be sufficient to cause premature inflation. Secondly, for the packer to deflate it must be able to expel the inflation fluid via action of elastic rebound of the rubber. This action would be insufficient to eject the inflation fluid against a static head of 500 kPa.

A consequence of these two criteria is that additional equipment is required downhole to both protect against premature inflation and to allow dumping of inflation liquid downhole.

3.2.3 Hole conditions

The nature of the formation in which the packer is to be set influences packer inflation fluid selection.

A gas inflated packer can experience large volume changes without showing significant pressure variations at the surface owing to the compressibility of the gas. This situation is exacerbated where the packer volume is only a small percentage of the total inflation system volume e.g. in deep holes with larger inflation tubes..

As a consequence, a gas inflated packer may over expand and burst in a soft sand or clay formation without registering significant pressure drop (prior to burst) on surface instrumentation.

Another environmental condition to consider is the temperature. For example, water inflation is not a particularly attractive option if the downhole temperature exceeds 100°C owing to the danger of steam generation. At the opposite end of the spectrum, where very low surface temperatures are expected ie less than O°C, water is equally unsuitable.

3.2.4 Inflation period

The period of time for which the packer will remain inflated has a large bearing on the choice of gas or liquid as the inflation fluid. This is due to the gas permeability of the rubber membrane.

When inflated with gas over an extended period, the gas permeates the rubber membrane leading to a loss of inflation fluid and subsequently pressure. Rather than have an inflation monitoring program in place to keep topping up the losses, it is usually more convenient to use a liquid for inflation.

3.2.5 Availability

Often, the choice of inflation fluids boils down to whether to use a gas or a liquid with the particular type often being a matter of availability.

In remote locations, particularly where higher pressures are required, the only practical inflation fluid may be water. Even if this is not ideal, by consideration of the foregoing criteria, equipment or procedural allowances may be made to accommodate this situation.

3.3 Inflation Methods .

Two main inflation methods are available, namely, through the string or via an external tube.

The first of these uses the pipe string to which the packer is attached to inflate the. packer. Inflation pressure is retained by means of downhole valves of one sort or another. Many such systems are single set only. Resettable systems require a setting tool activated by either pipe string manipulation or drop or pump down plugs to inflate, deflate and allow resetting. It should be noted that this system of inflation does not readily permit gas inflation of the packers.

The external tube inflation system uses a small bore tubing run alongside the deployment pipe as a direct conduit to the inflatable packer. Such systems are naturally resettable and also allow continuous monitoring of packer inflation pressures during grouting or testing operations. On the minus side, the inflation tube is potentially subject to damage during installation and retrieval and, owing to the small tube diameter, inflation and deflation times may be excessive.

Each of these systems has advantages and disadvantages with the latter one generally being better suited for shallower applications where annular clearance is not a problem whereas the first system tends to suit deep applications with tight clearances and higher environmental stresses. This is reflected in that the through string inflation system is favoured by oilfield operators whereas water and geotechnical operators prefer the external tubing inflation system.

3.4 Deployment Method

The packer deployment methods in common use are via wireline, pipe or hose. The most common "wireline" method is illustrated in Figure 3. The wireline being in this case that usually used for core barrel retrieval on a wireline coring rig. Other wireline methods, both mechanical and electrical are also available though their use tends to be for specialized applications only.

The basic drill string deployment method with external tubing inflation is indicated in Figure 4. With few changes, this is also representative of hose deployment methods.

The deployment method dictates the packer connection detail. There is also some influence on inflation systems. For example, you usually can't have through string inflation if the packers are run on a wireline; through string inflation is also problematic for reusable packers deployed on hose owing to the limitations on downhole tool manipulation with the hose.

The required differential pressure capacity of the packer system may influence deployment method selection. For example, pipe weight may be required to hold a single packer (see Figure 4) down against an applied differential pressure.

Another criteria to be addressed in the choice of deployment methods is that of depth control. Packer applications often call for very precise depth control. In such circumstances hose or wireline deployment without rigorous external controls on depth measurement may be inappropriate.

3.5 Ancillary Operations

These criteria relate to how the packer interfaces with other elements in the application - both equipment and procedural consequences should be considered.

An example of this is where two or more packers are used on a single pipe string. Some procedures would require separate inflation and deflation of each of the packers. This requires each packer to have a through tube if using external inflation or separately operable valves for through string inflation.

Another example is where an annuluar grouting valve is to be used in conjunction with a casing packer to place grout in the annulus above the inflated packer. In this instance the activation and operating parameters of the grouting valve must be compatible with those of the packer. It may be that the operational requirements of the valve require a re- think of the type of packer, the inflation method, inflation fluid, etc. Say the valve is operated by shear off lugs activated by a pump down plug. If the packer is also operated by pump down plugs some interference may result.

4.0 CONCLUSIONS

There are a number of factors that effect the choice and operation of inflatable packers. These factors are generally well defined and relatively simple when approached in a logical manner.

When planning work involving the use of inflatable packers due consideration of these factors will lead to a better work program with equipment and procedures well suited to the application at hand.