In today’s rescue many different types of airbags are offered, each of them with its own benefits and specific applications. At the same time it is the lifting bag that does not get a lot of attention from rescuers, nor is it often used by them.

The lack of regular use and insufficient knowledge on how to use lifting bags make them even less popular in rescue operations. Nevertheless, the airbag, when used properly, can be a real lifesaver.

This document will provide an overview of the different lifting bags available, its (dis) advantages and a specification comparison. With the information in this document, you are able to make the right decision when in the process of buying lifting bags. It will help you to focus on the true application of the lifting bag and to step away from making a sale based on specification comparison only.

RESQTEC Zumro
June 12, 2013
**LIFTING BAGS: THE MAIN BUYING REASON**

‘To free entrapped persons from underneath heavy or large objects’

This single buying reason actually comes with different target groups:

1. Fire Brigades with Heavy Rescue vehicles
2. USAR
3. Railway or tram heavy rescue

The main benefit of these target groups is that they all understand the need for lifting bags. In ‘normal’ rescue a spreader or ram may be sufficient to create space and free a victim, but when lifting heavy objects these tools simply become useless.

**THE PRINCIPLES OF LIFTING**

In rescue lifting bags are used to lift an object or to spread one or more objects away from another to free an entrapped victim. Lifting bags can deliver high lifting capacity allowing them to lift or move very heavy objects.

Note: Lifting bags are not used for stabilizing a vehicle. For stabilization cribbing is used.

**LIFTING CAPACITY**

The lifting capacity of a lifting bag is obtained by multiplying

- The functional area of the airbag. That is the area that is in contact with the object being lifted,
- The internal air pressure

\[
\text{Lifting capacity} = \text{Pressure} \times \text{Area}
\]

Example: lifting bag with dimensions 55x55 cm

According to the formula the lifting capacity of this lifting bag equals to (55x55cm)

\[
8 \text{ bar} = 3,025 \text{ cm}^2 \times 8\text{bar} = 24.2 \text{ tons.}
\]

The lifting capacity of a lifting bag is obtained by multiplying

- The larger the contact area in contact with the object being lifted, the higher the lifting capacity
- More internal pressure increases the lifting capacity

**POWER CURVE**

When the lifting bag is fully deflated the total surface area of the lifting bag can be utilized for lifting. This is called the functional area. When the bag is inflated and gains height, the functional area gets smaller; the lifting capacity of the airbag decreases.
This means that the lifting capacity has a direct relationship with the functional area. The assumption is that we lift at constant pressure. From this we can conclude that:

- High pressure bags (especially the pillow-shaped bags) have a diminishing power curve (less functional area equals less lifting capacity).
- At maximum lifting height the bags will lift no weight (point load at top). The result is that the lifting height is determined by the required area needed to lift a specific load. Basically the larger the bag, the more lifting capacity it offers. However, often limited insertion space makes it impossible to use larger sized bags.
- The functional area of low pressure bags remains constant causing the lifting capacity to be constant too. On the contrary to high pressure bags the sidewalls of the low pressure bags are not very stable.

### HOOP STRESS

Hoop stress is the stress on the material of the lifting bag caused by the internal pressure and which has a direct relation to the size of the lifting bag. The bigger the lifting bag, the more stress is put on the material even when the pressure remains constant.

To accommodate this problem high pressure bags are made of high quality materials (Kevlar) and the operating pressure of the low pressure bags is reduced.

### LIFTING HEIGHT

Although many textbooks on vehicle extrication will tell you to lift only as high as needed, it is highly recommended to lift 60 – 80 cm to create a safe environment for both the victim and the rescuer. The background for this is that a person’s average shoulder width is 45 cm. Having a bit more space simply allows you to operate under better circumstances and to avoid any additional injuries to the victim. When your customer is looking into lifting bags, it is to be advised to set the minimum height for safe rescue at 60 cm.

### ADDITIONAL NOTES

In rescue there are several functions that require good understanding about lifting, stabilizing and even moving a load:

1. Center of gravity
2. Load stability
3. Estimated load weight

The center of gravity (CG) is the center of an object’s weight distribution, where the force of gravity can be considered to act. It is the point in any object about which it is in perfect balance no matter how it is turned or rotated around that point. It is also the heaviest point of an object.

Lifting straight up is not advised in rescue operations as it will create a floating load. To avoid such floating load, the object to be lifted must be secured at one side. Doing so a pivot point is created which simultaneously creates a lateral or ARC movement. In case of an ARC movement side loads occur on the lifting equipment.
The main reason for estimating the workload is to ensure one uses the right lifting bag. Each single bag comes with its own specifications which determine the lifting capacity of the bag. Estimating the load first, calculated by \( L \times W \times H \) times the weight for the material in m\(^2\), gives you a good estimation which lifting capacity is required and thus which bag(s) to use.

**TYPES OF LIFTING BAGS**

Lifting bags are classified in two ways based on the air pressure classification: low and high pressure bags. Each single lifting bag operates in the exact same manner; air inflates the bag and the air pressure multiplied with the bag surface area gives you the lifting force available for your rescue operation. Almost any lifting bag in the market offers a safety factor of 4:1 which means that the bursting pressure is 4 times bigger than the working pressure allowing a safe environment for the rescuer.

**HIGH PRESSURE LIFTING BAGS**

The traditional high pressure lifting bags can be recognized by its square or rectangular shape and high-quality (Kevlar) material used. High pressure bags are thin and therefore require only a small insertion height. Different sizes are available where the lifting capacity increases as dimensions increases. Another advantage is the stacking possibility to create more height.

More advantages:
- High pressure bags are strong and very durable
- The bags inflate quickly and are silent in their use
- The bags can be used on soft and uneven ground
- Relatively small insertion space required
- Good lifting capacity at the beginning of the lift

Some disadvantages:
- Maximum lifting height is less than that of low pressure bags
- Stability decreases when half of maximum lifting height is reached and tend to roll out when close to full inflation
- The more air is inflated, lifting capacity decreases
- Relatively stiff and heavy to handle
- Difficult to repair
- High stress on sides

Another disadvantage is the limitation of high pressure bags when stacking. The rule is that you can only stack 2 bags of dissimilar size and where:
- the larger lifting bag must always be placed on the bottom
- the air pressure of the larger bag must be kept lower than that of the smaller bag on top

By doing so the smaller bag is cradled by the larger bag and cannot slip free or even worse, shoot out.
SUB-CLASSIFICATION HIGH PRESSURE BAGS

The high pressure bags can be classified in 4 different types; the square bag, the flat bag, the ultra-flat bag and the NT Bag. The square bag is the most common in rescue operations and already explained in the previous paragraphs.

FLAT BAG

On the contrary to the square bag, the flat bag is designed in such that it keeps its flat surface in the center even when being inflated. This decreases the chance of rolling or shooting out. Unlike the square bag, the maximum stack is 3 bags. The dimpled surface prevents the bags from slipping and the side-straps assist in aligning the bags and prevent the bag from shooting out.

More advantages

- A maximum of 3 bags can be stacked creating more height
- Bigger surface area for lifting while retaining the lifting capacity
- Relatively thin insertion space required

Disadvantages

- The flat bag cannot be used on soft ground without the support from a solid support or fiberboard
- When there is more than 70mm space between the ground and the object to be lifted, a firm and high enough foundation must be built first. The reason for this is that the maximum lifting height is 66 cm (3 bags stacked)
- A common misunderstanding is that stacking (one upon another) lifting bags increases the lifting capacity; stacking will only increase lifting height capacity.
- Unable to lift objects with unusual shapes such as an l-beam or pipe. A fiberglass board or steel plate should be inserted between the bag and the object to be lifted.

ULTRA-FLAT BAG

Like the flat bag, the ultra-flat bag is designed to keep a very flat surface in the center. The contact area is bigger resulting in higher lifting capacity. It’s very small insertion height makes it ideal for confined space rescue. The main disadvantage is the limited lifting height due to the lack of stacking of bags.

NT BAG

The NT bags are designed in such that it combines the lifting capacity of high pressure bags with the height offered with low pressure bags. The threaded connector in the middle allows for secured stacking of bags (maximum 3 bags). The oval shape retains a large surface that does not affect the lifting capacity when fully inflated.

More advantages

- A maximum of 3 bags can be stacked together creating maximum height
- Load Capacity Enhancer (LCE) enlarging the effective area and thus distributes the load of the lifted object more equally.
- Optional PowerPlate for lifting pointed object
- ARC (lateral displacement) capability
- The bags can be used on soft and uneven ground

Disadvantages

- Thick insertion height at the effective area in the center
- Relatively stiff and heavy to handle
- Higher cost
LOW PRESSURE LIFTING BAGS
A significant difference between low and high pressure bags is that they require a high volume of airflow for inflation. Therefore the air hoses come with a larger diameter with a relatively thin skin. The hose is easily bent and compressed to the point that airflow is restricted. Another notable difference is the shape and flexibility of the low pressure bag. Unlike the high pressure bags the side walls of the low pressure bags are made of very flexible material to allow in- and deflation.

More advantages:

• Low pressure bags reach more height which creates more clearance in rescue operations
• Ideal to use against sheet metal and on soft underground
• More surface contact than high pressure bags
• Easy to repair
• Flexible and light-weight

Disadvantages

• Limited / very low lifting capacity
• Very unstable during inflation (outer sides)
• Limited ARC capability
• Bags cannot be stacked to create more height
• Large volumes of air are required.
• Weak material, sensitive to damage

HIGH OR LOW PRESSURE BAGS?
The choice of low or high pressure bags is dependent on the anticipated problems. Low pressure bags will give a higher lift than high pressure, but will not have the lifting capacity of high pressure bags. High pressure bags usually need a greater opening for insertion than the low pressure bags. High pressure bags, as stated, will lift a tremendous amount of weight, but do not have a great lifting distance. However, high pressure bags offer a distinct advantage in the direct lift of heavy loads in the rescue of trapped persons. Lifting of floors and beams after the collapse of a building, lifting a locomotive or carriage, lifting a truck in the separation of vehicles or a capsized forklift, are to name a few.

In the next paragraphs you will find a specification overview of the lifting bags available. It will provide you with sales arguments that will help your customer in making the right decision when considering the purchase of a lifting bag.
**SPECIFICATION OVERVIEW**

The choice of low or high pressure bags is dependent on the anticipated problems. Low pressure bags will give a higher lift than high pressure, but will not have the lifting capacity of high pressure bags. High pressure bags usually need a greater opening for insertion than the low pressure bags. High pressure bags, as stated, will lift a tremendous amount of weight, but do not have a great lifting distance.

To ensure a fair comparison similar sized bags have been selected. Except for the ultra-flat bag where the largest square sized bag has been selected from its product range. Note that the size of the NT

<table>
<thead>
<tr>
<th>TYPE</th>
<th>ULTRA FLAT BAG</th>
<th>FLAT BAG</th>
<th>SQUARE BAG</th>
<th>NT BAG</th>
<th>LOW PRESSURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (cm) L x W or Ø</td>
<td>37 x 37</td>
<td>55 x 55</td>
<td>55 x 55</td>
<td>52 Ø</td>
<td>1020 Ø</td>
</tr>
<tr>
<td>Surface area deflated (cm²)</td>
<td>1369</td>
<td>3025</td>
<td>3025</td>
<td>2205</td>
<td>8167</td>
</tr>
<tr>
<td>Surface area inflated (cm²)</td>
<td>unknown</td>
<td>841</td>
<td>250</td>
<td>1288</td>
<td>Unknown</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>16</td>
<td>28</td>
<td>28</td>
<td>45</td>
<td>100</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>2.4</td>
<td>8</td>
<td>8.1</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>Insertion height (mm)</td>
<td>16</td>
<td>30</td>
<td>29</td>
<td>45/10**</td>
<td>100</td>
</tr>
<tr>
<td>Max. lifting height (cm)</td>
<td>20.3</td>
<td>17</td>
<td>27</td>
<td>27.5</td>
<td>450</td>
</tr>
<tr>
<td>Max. lifting capacity (kg)</td>
<td>9.6</td>
<td>20,000</td>
<td>20,250</td>
<td>23,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Max. lifting capacity at max. lifting height (kg)</td>
<td>unknown</td>
<td>7,000</td>
<td>Approx. 2,000*</td>
<td>4,000</td>
<td>unknown</td>
</tr>
<tr>
<td>Size of flat area at max. lifting capacity (cm)</td>
<td>unknown</td>
<td>29 x 29</td>
<td>15 x 15</td>
<td>40.5</td>
<td>unknown</td>
</tr>
<tr>
<td>Max. inflation pressure (bar)</td>
<td>10</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>0.5</td>
</tr>
<tr>
<td>Number of max. bags to be stacked</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: the formula for calculating the surface of round bags = pi times r² (where r = radius)

*= taken from manufacturer’s graphs

All items in italic are calculated items. These figures are not presented by manufacturers in such.

**GUIDELINES FOR BUYING LIFTING BAGS**

In any sales process your customer prefers to compare the product specifications and sales prices as this allows for an easy apple to apple comparison. Unfortunately, buying lifting bags demands for a bit more research and good understanding of its applications in order to make the right decision.

In order to best support your customer in this process, the following considerations need to be looked into:

1. Insertion height
2. Maximum lifting capacity
3. Puncture resistance
4. Maximum lifting height
5. Functional area
6. Stackability
7. ARC movement

**INSERTION HEIGHT**

In order to lift objects a certain insertion height and area is required. But, on the contrary to what manufacturers may want you to believe, this specification is merely a method to sell the product. In rescue where lifting is required, there is always enough insertion height to position your lifting bag.

Rescue is all about freeing an entrapped person. If in such case, there is not enough insertion height, it is likely we are dealing with ‘body recovery’ instead of rescuing a person.
LIFTING CAPACITY
As explained in the previous paragraphs, the actual lifting capacity is related to the effective area placed against the object to be lifted. The larger the effective area more lifting capacity is available. From the highlighted specifications below one would assume the flat bag offers more capacity at maximum lifting height. However, less is true…

The maximum lifting height of the flat bag is 17 cm, whereas the NT bag offers 27.5 cm; 10.5 cm more height. To make an apple to apple comparison you would need to calculate the lifting capacity of the NT bag at 17 cm height, which is about 8.3 ton (see appendix A) and yet with more lifting height left than the flat bag.

<table>
<thead>
<tr>
<th></th>
<th>FLAT BAG</th>
<th>NT BAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (cm)</td>
<td>55 x 55</td>
<td>52 Ø</td>
</tr>
<tr>
<td>Surface area inflated (cm2)</td>
<td>841</td>
<td>1288</td>
</tr>
<tr>
<td>Advertised max. lifting height (cm)</td>
<td>17</td>
<td>27.5</td>
</tr>
<tr>
<td>Max. lifting capacity (kg)</td>
<td>20,000</td>
<td>23,000</td>
</tr>
<tr>
<td>Advertised max. lifting capacity at max. lifting height (kg)</td>
<td>7,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Actual calculated lifting capacity at similar height being 17 cm (kg)</td>
<td>7,000</td>
<td>8,300</td>
</tr>
<tr>
<td>Size of flat area at max. lifting capacity (cm)</td>
<td>29 x 29</td>
<td>40.5</td>
</tr>
<tr>
<td>Max. inflation pressure (bar)</td>
<td>8</td>
<td>10</td>
</tr>
</tbody>
</table>

PUNCTURE RESISTANCE
Except for the NT Bag all manufacturers state in their operation manual never to put a pointed load on top of the bag without the intervention of steel plates or fiberglass board. Since these plates must hold heavy loads the thickness of such plates is likely to be around 3 cm.

Important note:
The table below shows a quick overview of alternative solutions to handle with pointed loads. Even though a steel or fiber plate may look like a good alternative such solution in fact creates a more dangerous environment. When making a lift the lateral displacement or ARC movement creates side loads which may result in the plates to shoot out. It is therefore highly recommended to have plates directly connected to the bag.

The NT Bag offers a PowerPlate that can be connected on the top and/or bottom of the NT bag. Its threaded connector eliminates the possibility of the PowerPlate to slip out.

<table>
<thead>
<tr>
<th></th>
<th>PUNCTURE RESISTANT</th>
<th>SOLUTION ADVERTISED IN USER MANUAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat bag</td>
<td>NO</td>
<td>Steel plate / Fiber plate (3cm thick)</td>
</tr>
<tr>
<td>Square bag</td>
<td>NO</td>
<td>Steel plate / Fiber plate (3 cm thick)</td>
</tr>
<tr>
<td>Ultra flat bag</td>
<td>NO</td>
<td>None</td>
</tr>
<tr>
<td>NT Bag</td>
<td>YES</td>
<td>Integrated PowerPlate</td>
</tr>
</tbody>
</table>

LIFTING HEIGHT
In rescue you always want to be best prepared for whatever the rescue operation. On the contrary to what many text books claim, the minimum safe height for rescuing an entrapped person is 60 cm. This statement eliminates the square bag immediately from the buying process. Even though manufactures and text books claim a maximum of 2 square bags to be stacked, the recommended lifting height will never be achieved. The reason for this is that the bags are not allowed to be fully inflated minimizing its lifting height and also its lifting capacity (see types of high pressure bags / square bags).
With the square bags being eliminated from the buying process, it leaves your customer with the choice between the flat bag and the NT bag.

<table>
<thead>
<tr>
<th></th>
<th>FLAT BAG</th>
<th>NT BAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (cm)</td>
<td>55 x 55</td>
<td>52</td>
</tr>
<tr>
<td>Surface area deflated (cm2)</td>
<td>3025</td>
<td>2205</td>
</tr>
<tr>
<td>Surface area inflated (cm2)</td>
<td>841</td>
<td>1288</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>28</td>
<td>45 (10 from outer side)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Insertion height (mm)</td>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>Max. lifting height (cm)</td>
<td>17</td>
<td>27.5</td>
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<tr>
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<tr>
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<td>29 x 29</td>
<td>40.5</td>
</tr>
<tr>
<td>Max. inflation pressure (bar)</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Number of bags stack</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Different bag sizes can be stacked</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>

**Important note:**
Even though the minimum lifting height is recommended at 60 – 80 cm, some rescue scenarios demand for higher lifting.

**EXAMPLE**
In bus accidents where the bus is on its side and victims are trapped underneath, often 60 cm lifting height is not sufficient to get even near the victim. Victims close to the floor of the bus cannot be reached. In such cases more lifting height is required. It is therefore recommended to look into lifting bags that can create as much height as possible.

In the next paragraph you will find that stacking bags allows for more height and that the NT bag offers the highest lifting height among all high pressure bags.
When reading various text books one will notice the many times mentions not to stack more than 2 square bags as it creates a very unstable stack. Yet, the flat bag and the NT bag states that a maximum of 3 bags can be stacked. What makes them different from the square bag?

The flat bag offers a dimpled surface preventing the bags from slipping and the side-straps assist in aligning the bags and to prevent the bag from shooting out. The NT bag has a threaded connector in the middle guaranteeing a secured stack of bags.

The main difference between the flat bag and the NT bag is that the latter offers the possibility to stack different sizes of NT bags offering a greater variety in lifting heights to be achieved. Where the flat bag can only stack same sizes of similar lifting heights, the NT bags offer a variety of lifting bags.

Compared to the flat bags the NT bag offers a range in lifting height between 275 mm and almost 2 meters, whereas the flat bag offers a maximum lifting height of only 3x 22 cm = 66 cm.
**ARC MOVEMENT**

Ideally one can make a good decision based upon comparing the different specifications of bags offered. However, in rescue one cannot only make a good judgment based on specifications only. It is the application and features that count. In addition to lifting height and lifting capacity, another important feature to look into is the possibility to follow the ARC movement.

Lifting an object straight up is not possible or advised as it will result in an uncontrollable floating load. When lifting an object one side needs to be blocked creating a pivot point. A pivot point creates a lateral displacement or ARC movement. When an ARC movement is created side loads are created on the lifting equipment. This side load makes equipment unstable and limits the height of the lift.

**SQUARE BAGS**
- Bags become round when being inflated and create an unstable stack
- Bags can easily shoot out due to missing connection

**FLAT BAGS**
- Dimples surface preventing the bags from slipping
- The side-strap assist in aligning the bags and prevent the bag from shooting out

**NT BAGS**
- LCE (the Load Capacity Enhancer) on top and bottom create stable connection
- Connector in the middle creates a stable stack
- LCE and connector follow the load
CONCLUSION

When in the buying process of lifting bags it is highly recommended to take your time and get a good understanding about the real application of lifting. It may look as simple as to comparing the different specifications of lifting bags; it is the different aspects to be considered during a lift that make the buying process complicated.

Basically there are 4 simple guidelines to follow when choosing your lifting bag:

1. What is the main application? Rescue or recovery?

2. Understand the different aspects of lifting
   • Insertion height
   • Lifting capacity
   • Lifting height
   • Stacking
   • …

3. Avoid specification comparisons

4. Always ask to set up a demo; seeing = believing