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1. Internals for packed columns

Introduction

Columns packed with either random or structured packing must also include several additional key internal components that are necessary for the packing to function. These internals include vapor and liquid feed distributors, packing support and hold down plates, entrainment separators and liquid draw-off trays, all of which must be designed to suit the specific service requirements. MTE has developed basic engineering standards for the design and manufacture of high performance packed column internals based upon many years of installation experience and industry feedback. These standards are applied to custom design and manufactured internals to suit individual process and installation requirements resulting in consistent and reliable column performance.

General Arrangement

The typical arrangement of a packed column alongside shows indicative locations and space requirements for a range of internals. The internal clearances shown are the normal minimum required for access. Access manway locations should take account of future maintenance work which would typically include checking chimney trays and distributors and also possibly removal and replacement of the packing.

MTE have considerable experience in retrofitting existing columns with new internals by using unique design variations to overcome space restrictions and to use existing welded-in attachments.
1.1 Liquid Distributors

Packed tower design is based on the fundamental concept of equal liquid and gas superficial velocity across the column section. The pressure drop across the packing provides an impetus for the upward flowing gas to get uniformly distributed across the column area. The liquid flows down the packed bed by gravity and unlike a gas has poorer cross-mixing tendency. Hence it is imperative to manage a very uniform liquid distribution at the top of the bed. Distributors are internals installed above a packed bed which perform the job of providing a finite liquid distribution over the packed bed. It provides for liquid to be distributed over the packed bed in discrete streams, which could either be through orifices or V-weirs. It also provides for a separate passage for the upward flowing gas.

On entering the bed the packing tend to redistribute the liquid by virtue of dispersion and after some height the liquid profile adapts to the natural distribution tendency of the packing which generally is worse than the initial liquid distribution provided by the distributor. Hence packed beds are broken down after fixed heights and liquid redistributors are provided to collect all the down flowing liquid and redirect it uniformly over the packing.

A packed bed irrigated by a very good distributor helps one to realize the full separation potential (number of stages) of the packed bed.

Distribution Quality

Quantifying the uniformity of liquid distribution is done by calculating the distribution quality (DQ) of a distributor. It relates the liquid flux across the column area at the top of the packed bed by marking circles proportional to the liquid flow through that orifice and then considering the irrigated, overlapping and un-irrigated areas of the circles. An ideal distributor should have a DQ of 100%, but practical constructional difficulties restrict the DQ to about 96% maximum. A low DQ indicates a high degree of maldistribution and some parts of the column area may be receiving substantially different from the other parts of the cross sectional area. Also in large diameter columns proper irrigation of areas near the column wall becomes a very crucial factor in maintaining a good DQ.

A distributor with a very good DQ helps in exploiting the full separation efficiency of the bed. As the DQ decreases the number of stages that can be realized from the packed bed decreases, consequently decreasing the separation efficiency. The effect of a poor DQ is depending on the number of theoretical stages generated by the packing. For packed beds with a high number of theoretical stages the effect of a poor DQ of the distributor is much larger compared to a bed with a low number of theoretical stages.

Various factors considered in the design of liquid distributors / redistributors at MTE are:

Drip points

This indicates the irrigation points provided per square meter of the column area and are a function of mainly the size of the packing, the liquid load and the desired DQ. Smaller or highly efficient packing, that provide a very low HETP, needs a larger number of drip points and vice-versa. More important compared to the number of drip points is the drip point arrangement and equally pitch. To provide same liquid distribution across the column area.
Hydraulic Design

This forms the most important aspect of the distributor design wherein the designer decides the various dimensional details of the distributor to ensure its efficiency over the range of working conditions.

A distributor can feed the liquid to the packing top either under pressure, as in a pressure fed distributor where the liquid is fed to the distributor under pressure or due to gravity, as in a gravity flow distributor where the liquid falls thru the distributor by virtue of its head on the distributor deck.

A pressure fed distributor is either of ladder arm type or of spray nozzle type, used for very specific applications, mainly for heat transfer services. As these distributors operate under pressure, the orifice sizes in these distributors are usually small. These distributors should not be used with flashing feed. Major advantage of using a pressure fed distributor is total wetting of the surface of the packed bed; while high point to point flow variation and high cost are some of the disadvantages.

Unless otherwise requisitioned MTE always recommends a gravity flow distributor. These distributors, due to the several constructional variables available to the designer as discussed below, offer excellent uniformity and control of liquid flow to the packed bed. The gravity fed distributor could either use orifices or V-weirs to feed the liquid. Again the orifices could either be located on the floor of the deck/trough or on the side wall of a trough (single level or multilevel). Passage for gas rising upwards is either provided by riser boxes/pipes or through the gaps between the troughs.

Orifices are sized to maintain a minimum liquid head in order to handle normal turn down conditions and also avoid distributor flooding during turn up conditions having maximum flow rates. Very small orifice diameters are avoided to prevent fouling. Distributor levelness, liquid gradient due to cross flow, aeration of the liquid due to falling liquid streams and the ledge/support ring levelness are factored for during the orifice sizing, so that even at very low flows the orifice to orifice flow variation is controlled to acceptable limits. Better resistant against fouling.

For high fouling services, which can occur due to sedimentation, coking, debris, polymerization, etc. orifices on the deck floor are avoided. Depending on the service, V-weirs or orifices on the side wall are provided. The use of orifice multipliers also increases orifice size and makes the distributor.

Multilevel orifices help in the distributor operation over a wide range of flows and are typically used whenever a very high turn-up / turn down ratio is required.

Distribution Quality (DQ)

Depending on the service and separation efficiency required from the packed bed, the size of the packing and the orifices, the drip points are laid out to meet the specific drip point requirements. During this stage allowances are made for the distributor constructional details like support beams, gas risers etc. so as to maintain the required DQ.
1.1.1 MLD11/MRD21 – Pan type distributor/re-distributor

This simple looking device for small towers up to 1200mm is actually a high performance distributor consisting of critically sized orifices uniformly laid on the base of the pan for liquid down flow and adequate open area for upward flow of vapor.

Downwards of a certain size and under the corresponding operating conditions the gas risers are no longer necessary. Their absence in this case is not detrimental to the functioning of the unit.

This distributor can be made in both single and multi-piece construction. In multi-piece construction, all joints are foreseen with gaskets.

Attachment to the tower wall is mostly by bolting to cleats. It can also be mounted between body flanges or alternatively suspended from a ring sandwiched between the body flanges. The choice between these two arrangements will depend on the location of other internals and in revamp case, the type of attachments already available in the column.

For columns with diameters up to 800 mm, the supply of liquid is effected by means of a pipe which is bent downwards onto the center of the distributor. For diameters over 800 mm, we recommend a sprinkler pipe which is perforated on the underside. In both cases the exit velocity of the liquid should not considerably exceed 1.5 m/s. The feed pipe is also available together with the distributor upon request.

The re-distributor consists of riser caps and when attachment is to cleats, wall wiper is also required.

1.1.2 MLD 112/212 – Pan type distributor with raised orifices

This distributor is similar to model MLD111 only with raised orifices, created by constructing orifices with driptubes. With driptubes the distributor is able to be designed for larger T/D ratio and in combination with orifice multipliers it can be made better resistant to fouling as well.
1.1.3 MLD121/MRD221 – Riser deck distributor/re-distributor

This is a deck type distributor where orifices are located on the base of the distributor. Gas risers located between the orifices propagate liquid cross-flow thereby enhancing distribution quality.

It is generally in multi-piece construction and all joints are sealed with gaskets. Attachment is by clamping to a ledge/support ring which is welded to the column wall. This distributor can be provided with anti-migration bars in the risers and thereby eliminating the use of bed limiters. Redistributor risers are capped to prevent short circuiting of liquid

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column Diameter</td>
<td>&gt; 250 mm</td>
</tr>
<tr>
<td>Liquid Load</td>
<td>&gt;2-150 m³/m².hr</td>
</tr>
<tr>
<td>Turndown ratio</td>
<td>2,5:1</td>
</tr>
<tr>
<td>Fouling resistance</td>
<td>Low to medium</td>
</tr>
</tbody>
</table>

1.1.4 MLD122/MRD222 – Riser deck distributor/re-distributor with raised orifices

This is a deck type distributor where orifices are located on the walls of the risers of the distributor. Gas risers located between the orifices propagate liquid cross-flow thereby enhancing distribution quality.

Deck types can also be designed with driptubes like MLD112

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column Diameter</td>
<td>&lt;1200 mm</td>
</tr>
<tr>
<td>Liquid Load</td>
<td>&gt;1.5-50 m³/m².hr</td>
</tr>
<tr>
<td>Turndown ratio</td>
<td>10:1</td>
</tr>
<tr>
<td>Fouling resistance</td>
<td>Low to medium</td>
</tr>
</tbody>
</table>
1.1.5 MLD141/MRD241 – Trough type (re-)distributor with sump

This distributor is constructed of multiple tunnels called troughs with an integrated parting box called a sump. The feed enters the sump which divides it proportionally to the troughs. Orifices for liquid are located on the base or of the troughs and the sump.

Achieving adequate sealing is critical due to large number of joints at the sump to trough connection. All joints are gasketed for adequate sealing.

This distributor is appropriate for applications with higher gas capacities, as a larger free area can be created between the troughs compared to deck types.

This distributor rests on a ledge/support ring. The redistributor consists of riser caps and wall wiper. A construction with parting box can be considered for high liquid loads.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column Diameter</td>
<td>&gt; 800 mm</td>
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<tr>
<td>Liquid Load</td>
<td>2 – 50 m³/m².hr</td>
</tr>
<tr>
<td>Turndown ratio</td>
<td>2.5:1</td>
</tr>
<tr>
<td>Fouling resistance</td>
<td>Low to medium</td>
</tr>
</tbody>
</table>

1.1.6 MLD142/MRD242 – Trough type (re-)distributor with sump with raised holes

This distributor is similar to model MLD141 only with raised orifices, created by constructing orifices on the trough walls or with driptubes.

For low liquid loads, this type of distributor is constructed to hang below a support ring or support beams, so secure elevation of all troughs is possible for high distribution quality.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column Diameter</td>
<td>&gt; 800 mm</td>
</tr>
<tr>
<td>Liquid Load</td>
<td>0.5 – 50 m³/m².hr</td>
</tr>
<tr>
<td>Turndown ratio</td>
<td>10:1</td>
</tr>
<tr>
<td>Fouling resistance</td>
<td>Medium</td>
</tr>
</tbody>
</table>
1.1.7 MLD143 – Trough type distributor with parting box & V-caps

This distributor is especially developed for application with high liquid load or high tendency for fouling, without high requirements for liquid distribution quality.

It consists of long tunnels called troughs and one or more parting boxes for feeding liquid to the troughs. The parting box helps in controlling the feed velocity to the troughs and ensures proportional distribution of the liquid to the troughs.

The space between the troughs is available for vapor passage. Number and location of the parting box will depend on the column diameter. Rectangular or V-shaped notches are located on the trough walls. Notches can also be applied to deck type distributors.

<table>
<thead>
<tr>
<th>Column Diameter</th>
<th>&gt; 900 mm</th>
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<tbody>
<tr>
<td>Liquid Load</td>
<td>10 – 200 m³/m².hr</td>
</tr>
<tr>
<td>Turndown ratio</td>
<td>5:1</td>
</tr>
<tr>
<td>Fouling resistance</td>
<td>High</td>
</tr>
</tbody>
</table>

1.1.8 MLD161 – Pipe Arm distributor

This is a very simple distributor consisting of a header and a lateral assembly. It requires very little column height and provides high open area resulting in very low vapor pressure drop. It does not provide very high distribution quality and therefore it has limited applications. The main header is flanged at one end and clamped to a column wall clip at the opposite end.

<table>
<thead>
<tr>
<th>Column Diameter</th>
<th>&gt; 500 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Load</td>
<td>5 – 100 m³/m².hr</td>
</tr>
<tr>
<td>Turndown ratio</td>
<td>2:1</td>
</tr>
<tr>
<td>Fouling resistance</td>
<td>Low</td>
</tr>
</tbody>
</table>
1.1.9 MLD146 – Trough type liquid distributor with orifice multipliers

The MLD146 is a modification of the MLD142 type where a second distribution stage is introduced below the troughs. In this distribution point the liquid flowing from a single drip tube is divided in 6 streams by an overflow principle. The liquid is guided through wells down to the fingers which are set to for the distribution points and create an uniform distribution across the columns area.

The unique design of this distributor allows the designed to increase the orifice diameter in the drip tubes in case of low flows and achieve a device which is less sensitive to fouling by plugging of the orifices. This is the main principle which gave the starting point for the development of this distributor type. By implementing overflow notches in the driptubes, the distributor is proven to keep working over a huge range of flows and hardly sensitive for fouling. This distributor has proven performance in various systems varying ranging from 0.2 – 50 m³/m².hr.

For very low flows this distributor is also used in high quality systems where distribution qualities of 95% and higher are achieved for flows of 0.5 m³/m².hr with aqueous liquids and even lower in hydrocarbon systems.

The new production methods also allow MTE to manufacture this device in any material, metal alloys as well as thermoplastics. All joints are gasketed and material thickness can be designed to suit your application.
1.2 Bed Limiters

Bed limiters or Hold down plates are retaining devices used above the packed beds to prevent fluidization, which mainly occur during upset conditions and restrict packing movement.

Bed limiters are designed to provide high free area and reduce interference to liquid flow. They should withstand upward forces acting on the packed bed.

1.2.1 MBL31 – Bed limiter for random packing

This bed limiter is normally recommended for metal and plastic random packing and is designed to withstand an up thrust. The openings sizes can be varied to suit various packing sizes and the beams can be designed to support man-load. The bed limiter can be clamped on to a support ring or rests on the tower packing where no tray support ring is available.

The major advantage of using a movable anti-migration screen is reduction in crushing of tower packing during surges or bed expansions, certainly for beds with carbon or ceramic packing. The bed limiter is held in place by providing weight bars and does not require any type of clamping arrangement. Another option is to make the bed limiter construction expandable with jack screws provided to tighten on the column wall which obviates the need for ledge/support ring. This maintains good distribution near the column wall.

The MBL31 bed limiter consists of a frame backed with a screen of expanded metal. The plates, which are divided into segments, are installed into the column through the manholes and then bolted together. The materials used are carbon steel, stainless steels and thermoplastics. Please note that plates made of carbon steel are normally backed with screens made of stainless steel. Versions made of special metals are also available.

1.2.2 MHG32 – Hold down grid for structured packing

The Hold Down plate is normally used for towers using structured packing. Fluidization does not occur with structured packing, but for large diameter columns, sections of packing may be dislodged during upset conditions. Hold Down grids for structured packing are designed to reduce interference with liquid distribution. They are bolted to the column wall by vertical clips. For smaller columns, the distributor is provided with an integral retention plate, thereby eliminating need for separate Hold down Grid.
1.3 Support Plates

Support plates are provided for physically supporting the cumulative weight of the random and structured packing as well as operating liquid hold up. Support plates are shaped and designed to provide maximum open area such that there is minimum resistance to gas flow. The factors that influence the choice and design of the support plate are the column diameter, design load, packing type, liquid hold up and systems corrosivity.

Gas injection support plates provide separate pathways for gas and liquid and therefore it reduces pressure drop across the support plate. These are the most preferred type and are used in the majority of applications. Light duty support plate is used only for very small columns and where hydraulic loading is not severe.

All support plates rest directly on a support ring since the weight of the packing is sufficient to keep the support plate in place. If required however, they can be clamped to the ring.

1.3.1 MSP41 – Support plate

Model MSP41 is a support plate recommended for towers generally smaller than 900mm diameter. This type of support plate is designed using expanded metal and is constructed as a multi-piece or single piece unit depending on the column opening that will be available to install it. These support plates rest freely on, or can be clamped/bolted to, a ledge support ring.

1.3.2 MSP42 – Support plate

Model SP42 is a gas injection type support plate designed for towers generally smaller than 1200 mm diameter. These types of support beams are generally designed in multi piece or single piece construction that depends on the manhole sizing or installation through body flange. Under normal circumstances, the individual segments in the column are not bolted together. This can be provided for, however, on special request. The slot size is based on the size of packing to be supported. These support plates rest freely or can be bolted to the tray support ring.

In all cases, the free cross section of the MSP42 is more than 80% of the cross sectional area of the column.
1.3.3 MSP43 – Support plate

Model MSP43 is a gas injection type support plate designed for towers generally greater than 1200 mm diameter. The design ensures a high degree of permeability for gas and liquids. In the standard version, permeability is more than 100%. The MSP43 is designed for higher mechanical strength. The beams are made in single units that pass through a manhole. Special variants are available to handle very tall beds and are also available in thermoplastic materials.

The perforation of the plate elements is suitable for both rings-shaped and saddle-shaped packing. The minimum dimensions for the tower packing are $d \geq 15\text{mm}$ for rings and $d > 1''$ for saddles.

As a rule, all support plates are placed on a closed support ring. In order to prevent the support plates from being lifted when there are pressure surges in the column, the support plate is fixed to the support ring by means of special locking devices.

Very tall beds together with larger column diameters results in higher load, in such cases support plates are supported using I-beams in conjunction with the tray support ring.

1.3.4 MSG44 – Support grid

Model MSG44 is a support grid used in towers for supporting structured packing. It is designed to allow free passage of gas and liquid. These support grids rest freely or can be clamped to a ledge/support ring.

Very tall beds together with larger column diameters results in higher load, in such cases support plates are supported by support beams in con-junction with the tray support ring.
1.4 Liquid collectors / Chimney trays

Liquid collection between packed beds is frequently required. Liquid collectors are used in three main applications:

» For total draw-off of liquid as a product or to re-boiler or for pump-around sections
» Partial draw-off of liquid with overflow continuing down the tower
» Collection of liquid for mixing or redistributing

Liquid collectors come in different design styles to meet the needs of specific applications. The factors considered in the design of the collector trays are:

✓ Height required/available for the collector tray
✓ Column pressure (Vacuum) and permissible pressure drop (to decide the open area)
✓ Liquid and vapor loads and densities
✓ Column diameter
✓ Liquid draw-off quantity
✓ Allowable leakage rate

1.4.1 MLC51 – Liquid collector tray

This deck type liquid collector is a versatile one that can be used in all towers. Liquid volume and residence time can be controlled by having tall risers (round) on the deck. Sumps can be added on one side, both sides or across the centre to facilitate liquid withdrawal. This collector can provide 25 to 40% open area. This collector requires mid-span support beams in large columns (> 2000 mm ID).

The deck and optional sump(s) rest on tower ledges / tray support ring and the plate is seal-welded. Gas risers can be made in sections / pieces to allow installation through manhole, later they are welded to the deck.
1.4.2 MLC52 – Vane Type Collector

The model MLC52 is used in towers which process high vapor loads and low liquid loads (vacuum service). The vanes collect the overhead liquid and direct it into the annular sump, which may then be drawn from the tower or fed to a distributor below using an appropriate feeding system. It offers the minimal pressure drop (as it can provide open areas from 40 – 75%) and it avoids entrainment even at high vapor rates which otherwise would cause entrainment from conventional gas risers.

The vanes rest on an annular sump, and are fastened to cleats provided on the sump. The sump is welded to the tower wall and is generally provided for by the column vendor. For larger towers and high liquid rates, collection trough(s) are added, spanning across the annular sump to reduce liquid gradients.

1.4.3 MLC53 – Trough Type Collector

The model MLC53 is being used in a wide range of applications with column diameters larger than 1400mm. This type is normally used in applications where thermal expansion due to temperature fluctuations is of great importance. The trough type design reduces the number of welds with the column wall. The troughs can easily expand and are mounted on a support ring. An layout with a drip bar directs the liquid than into the troughs. The main collector trough in the center of the column carries the weight of the other troughs. At one side the main trough is connected to a pipeline where the liquid can be removed from the application. The other side is closed and can be used to give some additional space for expansion.

The size of the main and side troughs is determined according the required hydraulic load in the column. In general this collector type has a open area between 25 and 40%.
1.5 Feed devices

Piping systems inside the column are required to introduce feeds and in some cases to draw products. These need to be custom engineered in conjunction with all other column internals to suit the process and mechanical specifications of the column. MTE have developed a set engineering standards for the design of internal pipe work to ensure that liquid feeds are compatible with the proper functioning of liquid distributors and that inlet vapor velocities will not cause maldistribution.

Processes demand various feed to be introduced into the column at appropriate locations. The feeds being introduced could be:

- Liquid only
- Liquid and Vapor above a packed bed (flashing or mixed feeds)
- Vapor only

1.5.1 Liquid only

Liquid-only feed devices are required to introduce liquid into the column, either as feed or as reflux. The liquid is fed into the distributor and its design depends on the distributor type, liquid flow, operation range, degrees of sub-cooling etc.

In most cases a liquid only feed pipe is a piping system of headers, lateral branches and down pipes, which is used to fed liquid from outside the column onto a distributor/re-distributor. Each feed pipe meters flow to one or more appropriate feed areas, matching the hydraulic requirements of the distributor to prevent excessive turbulence and control the horizontal flow velocity in the distributor.

A liquid only feed pipe can be attached to an internal column flange and further supported by the tower wall clips.

1.5.2 Mixed or flashing feeds

For mixed or flashing feed devices above a distributor separating the two phases is the main concern. The various factors in design include the flow rate, the type of flow at feed (flashing or suppressed), turndown necessary, column height needed for flashing vapor distribution and mixing of the inlet liquid with overhead liquid.

MTE is able to design and supply all different types of mixed and flashing feed devices like flash galleries, flash feed chambers and flashing feed pipes.
1.5.3 Vapor only

Vapor only feed devices are required for re-boiler returns or to introduce vapor feed or gaseous feeds. If the column offers adequate pressure drop then the packing tends to mix the vapors. But in event of very low pressure drop across the packed beds, vapor channeling could become a serious problem. The kinetic energy of the vapor and its composition at the point of introduction are the two main factors considered in designing the vapor entry device.

A vapor distributor can be a pipe distributor or a plate distributor. The pipe distributor is used when the feed requires uniform distribution over the tower area. This type of distributor is the most simple and therefore the most cost-effective option for gas/vapor introduction. The inlet pipe is either perforated or slit on the underside or executed as an open pipe section. The gas exits downwards from the orifices, is deflected and flows into the packed bed. The arrangement of the orifices prevents the liquid from entering the gas/vapor inlet.

This distributor works by creating a pressure drop on the gas ensuring equal amounts flowing from all orifices. Hence the inlet flow and the required pressure drop would decide the operating range, but 4:1 is generally achievable. A disadvantage of this design is that at high gas or vapor velocities the pressure drop increases with possible entrainment of the liquid drops. High velocities are caused by particularly large gas volume rates or when the inlet pipes cover a significant portion of the column cross-section.

A plate distributor is a liquid collection base with gas risers permits effective and cost-effective gas distributor. This distributor plate is used when vapor enters the bottom of a column with a very high kinetic energy. This distributor will consume some pressure drop in the vapor, reduce its kinetic energy and ensure goods distribution below the packed bed. The pressure drop across this distributor could be 1-10 mbar. This model is available in any sheet metal and is supported by a ledge/support ring (mid-span beams may be required in large columns). It is provided with liquid down comers or a sump for removal of the liquid which makes it possible to handle high gas velocities.