Table of contents

Introduction .......................................................................................................................2

1.1 Liquid distributors........................................................................................................3
  1.1.1 MLD11/MRD21 – Pan type distributor/re-distributor ....................................................6
  1.1.2 MLD 112/212 – Pan type distributor with raised orifices.................................................7
  1.1.3 MLD121/MRD221 – Riser deck distributor/re-distributor ..................................................7
  1.1.4 MLD122/MRD22 – Riser deck distributor/re-distributor with raised orifices .....................8
  1.1.5 MLD141/MRD241 – Trough type (re-)distributor with sump ...........................................8
  1.1.6 MLD142/MRD242 – Trough type (re-)distributor with sump with raised holes ...............9
  1.1.7 MLD143 – Trough type distributor with parting box & V-caps .........................................9
  1.1.8 MLD161 – Pipe arm distributor .......................................................................................10
  1.1.9 MLD146 – Trough type liquid distributor with orifice multipliers ..................................11

1.2 Bed limiters ................................................................................................................12
  1.2.1 MBL31 – Bed limiter for random packing .....................................................................12
  1.2.2 MHG32 – Hold down grid for structured packing .............................................................13

1.3 Support plates ............................................................................................................13
  1.3.1 MSP41 – Support plate ..................................................................................................13
  1.3.2 MSP42 – Support plate ..................................................................................................14
  1.3.3 MSP43 – Support plate ..................................................................................................14
  1.3.4 MSG44 – Support grid ....................................................................................................15

1.4 Liquid collectors / Chimney trays ...............................................................................16
  1.4.1 MLC5 – Liquid collector tray ..........................................................................................16
  1.4.2 MLC52 – Vane type collector .........................................................................................17
  1.4.3 MLC53 – Trough type collector .......................................................................................17

1.5 Feed devices ...............................................................................................................18
  1.5.1 Liquid only ...................................................................................................................18
  1.5.2 Mixed or flashing feeds ................................................................................................19
  1.5.3 Vapor only ....................................................................................................................19
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 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 has 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. Therefore, it is imperative to manage a very steady liquid distribution at the top of the bed.

Distributors are internals installed above a packed bed, which perform the job of providing a liquid distribution over the packed bed in discrete streams, which could either be through orifices or V-weirs. It also separates passage for the upward flowing gas.

When the liquid enters the bed, the packing tends to redistribute the liquid by the principle of dispersion. As the liquid flows through the distributor, it adjusts to its natural flux. In general, this liquid flux is far less effective than at the start of the process by entering the liquid through the distributor. To optimize this process, several redistributors are placed in the column to interrupt the natural flow of the liquid and redirect it uniformly onto the packed bed.

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

Distribution quality

To determine the uniformity of liquid dispersion over the packed beds, the calculation of distribution quality (DQ) of the distributor is required. These calculations relate to 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. Furthermore, the irrigated, overlapping and un-irrigated areas of the circles are calculated as well.

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. 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

Drip points indicate the irrigation points provided per square meter of the column area. Drip points are inherent of mainly the size of the packing, the liquid load and the desired DQ. Smaller or highly efficient packing, that provide a very low height equivalent to a theoretical plate (HETP), needs a larger number of drip points and vice-versa. Besides the amount of drip points, the arrangement and equal flow provide same liquid distribution across the column area.

Hydraulic design

This is the most important aspect of the distributor design. 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 into a fed distributor under pressure, or in a gravity flow distributor where the liquid falls through the distributor due to gravity.

A pressure feed distributor is either a ladder arm type or a spray nozzle type, used for very specific applications, like heat transfer services. As these distributors operate under pressure, the orifice sizes in these distributors are usually small. The major advantage of using a pressure feed distributor is total wetting of the surface of the packed bed. Some of the disadvantages are high point-to-point flow variations and high costs.
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 column. 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.

The orifices in a gravity flow distributor are sized to maintain a minimum liquid head in order to handle normal turn down conditions and to prevent distributor flooding during turn up conditions having maximum flow rates. Larger orifices prevent fouling of the liquid. Distributor levelness, liquid gradient (due to cross flow), aeration of the liquid (due to falling liquid streams) and the ledge/support ring levelness are factors for calculating the sizes of the orifices. This provides; even at very low flows, the orifice - to - orifice flow variation is controlled to acceptable limits.

Distribution Quality (specifics)

Depending on:

» application of the gravity flow distributor;
» separation efficiency required for the packed bed;
» size of the packing;
» size of the orifices.

The drip points are laid out to meet the specific drip point requirements. During this stage constructional details are designed for the distributor like support beams, gas risers etc. This allows to optimize and to maintain the required distribution quality.
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 clamps. 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 centre of the distributor. For diameters over 800 mm, we recommend a sprinkler pipe which is perforated on the bottom. 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. When attached to clamps, wall wiper is also required.

<table>
<thead>
<tr>
<th>Specifications</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Column diameter</td>
<td>&lt; 1200 mm</td>
</tr>
<tr>
<td>Liquid load</td>
<td>2 – 100 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>
1.1.2 MLD 112/212 – Pan type distributor with raised orifices

The pan type distributor is similar to model MLD111 only with raised orifices, created by constructing orifices with drip tubes. With drip tubes 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.

<table>
<thead>
<tr>
<th>Specifications</th>
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<tbody>
<tr>
<td>Column diameter</td>
</tr>
<tr>
<td>Liquid load</td>
</tr>
<tr>
<td>Turndown ratio</td>
</tr>
<tr>
<td>Fouling resistance</td>
</tr>
</tbody>
</table>

1.1.3 MLD121/MRD221 – Riser deck distributor/re-distributor

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

In general, this is a 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>Specifications</th>
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<tbody>
<tr>
<td>Column diameter</td>
</tr>
<tr>
<td>Liquid load</td>
</tr>
<tr>
<td>Turndown ratio</td>
</tr>
<tr>
<td>Fouling resistance</td>
</tr>
</tbody>
</table>
1.1.4 MLD122/MRD22 – Riser deck distributor/re-distributor with raised orifices

This deck type distributor have orifices which 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 drip tubes like MLD112.

### Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</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 liquid enters the sump which divides it proportionally to the troughs. Orifices for liquid are located on the bottom or on the troughs and the sump.

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

The trough type 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.

### Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Column diameter</td>
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</tr>
<tr>
<td>Liquid load</td>
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<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. The raised orifices are created by constructing orifices on the trough walls or with driptubes.

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

**Specifications**

<table>
<thead>
<tr>
<th>Column diameter</th>
<th>&gt; 800 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid load</td>
<td>0,5 – 50 m³/m².hr</td>
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<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

A through type distributor with parting box and V-caps is especially developed for application with high liquid load or high tendency for fouling, without high requirements for liquid distribution quality.

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

The space between the troughs is constructed 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.

**Specifications**

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<th>Column diameter</th>
<th>&gt; 900 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid load</td>
<td>10 – 200 m³/m².hr</td>
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<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>Specifications</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Column diameter</td>
<td>&gt; 500 mm</td>
</tr>
<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 of the so-called spider arms. These arms provide liquid flowing towards the distribution points and create an uniform flux across the columns area.

The unique design of this distributor allows the through type to increase the orifice diameter in the drip tubes in case of low flows and 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. This distributor has proven performance in various systems varying ranging from 0.2 – 50 m³/m² per hour.

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 per hour with aqueous liquids and even lower in hydrocarbon systems.

This new production methods also allows 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.

<table>
<thead>
<tr>
<th>Specifications</th>
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<tbody>
<tr>
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<tr>
<td>Turndown ratio</td>
</tr>
<tr>
<td>Fouling resistance</td>
</tr>
</tbody>
</table>
1.2 Bed limiters

Bed limiters (or hold down plates) are retaining devices used above the packed beds to prevent fluidization. This mainly occurs 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 opening 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. Sometimes 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 so 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.

A 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. This 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 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 larger 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 as well as saddle-shaped packing. The minimum dimensions for the tower packing are d ≥ 15mm 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 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 conjunction with the tray support ring.
1.4 Liquid collectors / Chimney trays

Liquid collection between packed beds is frequently required. Liquid collectors are used in 4 main applications:

» For total draw-off of liquid as a product;
» For 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 calculate the measurements of the open area);
✓ Liquid and vapor loads and densities;
✓ Column diameter;
✓ Liquid draw-off quantity;
✓ And allowable leakage rate.

1.4.1 MLC5 – 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 rings and the plate is seal-welded. Gas risers can be made in sections / pieces to allow installation through manholes. Eventually, 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 surplus of liquid and directs it into the annular sump. The liquid is 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 occur in conventional gas risers.

The vanes rest on an annular sump, and are fastened to clamps 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.

A layout with a drip bar directs the liquid into the troughs. The main collector trough in the centre 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 an 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 has developed an engineering standard for the design of internal pipe work. This ensures liquid feeds are compatible with the proper functioning of liquid distributors and 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);
- And 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. They are used to feed liquid from outside the column on to a distributor/re-distributor. Each feed pipe meters flow to one or more appropriate feed areas, matching the hydraulic requirements of the distributor. This prevents excessive turbulence and controls 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, to introduce vapor feed or gaseous feeds. If the column offers adequate pressure drop, the packing tends to mix the vapours. But in event of very low pressure drop across the packed beds, vapor channelling 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, either slit on the bottom, 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, 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. 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 commers or a sump for removal of the liquid which makes it possible to handle high gas velocities.