A SMART ACID DISTRIBUTOR

FOR SULFURIC ACID PLANT TOWERS

by

Gordon M Cameron P. Eng.
Cecebe Technologies Inc

ABSTRACT

At present a number of types of distributor are being offered to sulfuric acid plant owners. Many of these designs have evolved as opposed to being based on new design. This paper reviews a number of conventional approaches, sets out suggested criteria for assessing distributor offerings, reviews materials available, and offers a simpler solution.

INTRODUCTION

Sulfuric acid manufacture by the contact process is a very old process but is not frozen in its development. Originally there was little freedom on the materials side and the changes came on the process side. Now, while the desirable processes are well understood, there have been many advances in the fields of materials and equipment which the operator can incorporate in his plants.

In the materials area, there have been many changes over the last twenty years. Our traditional sources of thick walled grey cast iron have mostly dried up with the shift of water pipe to much thinner and more ductile nodular iron. The number of foundries is also decreasing, compounding the problem. The decreasing numbers of foundries affects us both in terms of pipe and even more so in terms of specialized castings.

Alloys which can be fabricated have increased drastically in number and have become much more competitive. The old CA20-Cb3 has now been joined by HASTALOY, SARAMET, SX, and LEWMET. At the same time the cost of the regular stainless grades such as 304L and 316L has dropped to the point where these materials are standard designer choices for many applications. With the decrease in the foundry industry, cast alloy development has not proceeded to the same degree but the LEWMET family of alloys are a notable exception.

A further and increasingly useful field is that of the non-metallics. Here we have the ceramics which are key in the towers and packings. We also have a whole family of fluoropolymers such as PTFE, PFE, FEP, PFA, HALAR, and a number of co-polymers. These materials show very good corrosion resistance to sulfuric acid and can be very useful once their properties such as coefficients of expansion and cold flow are acknowledged and accommodated.

This paper is concerned with the use of these materials in design of distribution systems for sulfuric acid plant towers where a variety of the above materials have a potential place.

PRESENT TECHNOLOGY

Over some thirty years, the author has been exposed to tower designs using a wide variety of tower packings ranging from quartz rock to ping pong balls and almost anything in between. Plate towers have also been a subject of frequent interest.

With the exception of several of the Lurgi plants which have used Venturi scrubbers, packed towers have been used for gas drying, SO_3 absorption, or for SO_2 stripping in almost all cases. Here the industry has now settled on two to three inch saddle packings although mini-rings are advocated by one designer. With few exceptions, the towers have carbon steel shells with an acid brick lining and with ceramic packing support and packing. Metallic towers in SARAMET, SX, and in 309 or 310 stainless steel also have been introduced but only form a small minority of the applications. All towers typically have about 14 feet of packing and can have diameters as large as 30 feet. Acid flows can run as high as 10,000 gallons per minute.

A variety of distributors have been used in these towers. Included are:

1. full diameter cast iron pans with vertical downcomers
2. quadrant sized cast iron pans with overflow weirs
3. trough type units in stainless with overflow notches
4. trough type units in cast iron with cast iron downcomers
5. buried pipe type cast iron distributors
6. buried pipe type distributors in stainless steel
7. buried pipe cast iron units with PTFE inserts
8. SARAMET pipe type distributor

ACID SPREADING

As a starting point, what must a distributor do in an acid plant? Consider first the proper wetting of the packing. In any given tower, there are a number of discrete points at which liquid is introduced and the liquid is expected to spread quickly across the packing. The force of gravity is unfortunately much stronger and the angle of the cone used to describe the spreading at most is 45 degrees. If the liquid feed points are wide spread, the fraction of packing needed to ensure wetting will be large and the tower performance will suffer. Figure 1 shows several different cases of liquid spreading. Clearly if a packing does not do a good job of spreading the liquid in the horizontal plane, then more closely spaced distribution points will be required or a greater depth of packing. Distributor design therefore depends to some degree on the nature of the packing

For the saddle packing, the cone angle is around 45 degrees. Table 1 shows the lateral spreading which results from that angle and the number of points per unit area which are associated with that spreading:

TABLE 1

Depth (")	Spread (")	Points/sq ft
6	2.4	6
8	3.2	3.8
10	4.0	2.3
12	4.8	1.6
15	6.0	1
18	7.2	0.7
24	9.6	0.4
36	14.4	0.2

Many studies of distribution have been carried out and many of the recommendations for the density of irrigation points give numbers even higher than those shown here. These other evaluations have also had to allow for packings with worse spreading characteristics than saddles.

It should also be obvious that a large number of irrigation points not uniformly distributed will perform like a distributor which has many fewer points and will waste packing. One of the unfortunate aspects of the pipe unit without downcomers is that distributor points are spaced as much as fifteen inches apart in one plane. The table suggests that this will leave a significant part of the packing, (18 inches), dry.

TOWER BLOCKAGE

The distributor in a tower should not bottleneck the tower. In sulfuric acid plants we now need to differentiate between two types of tower. First is the drying tower. Here the pressure loss per unit height is essentially the same at the top of the tower as it is at the bottom. Since traditionally the tower is designed to a fraction of flooding at the bottom, it follows that the same fraction of flooding will apply at the top. The distributor therefore can not block off packing.

In the absorbers there is a significant difference in gas flow between the bottom and the top of the tower. Part of this difference is due to the SO_3 removed from the gas and the other part is due to the gas cooling that takes place on passage through the tower. Here there is a significant difference in loading between the top and the bottom of the tower. In a number of cases this difference in loading has allowed smaller packing to be used in the top of the tower as a means of increasing mass transfer surface. The gas flow difference also reduces the potential blocking caused by a buried distributor. Table 2 shows

TABLE 2

TOWER	DRY	INTERMEDIATE	FINAL
Gas Flow lb/hr			
- in	431000	486000	383000
- out	431000	383000	373000
Temp in (F)	250	390	300
Press ("wg)	200	120	30
Acid Flow lb/hr	2570000	4900000	2000000
Diameter (ft)	17.0	20.33	18.33
Flooding (%)			
- Bottom	60	60	60
- Top	59.4	45	49
Available Blockage (%)	0.6	15	11

In the case of the drying tower clearly any buried pipe distributor will create a bottleneck. In the absorbers it may create a bottleneck. Trough and distributors with the liquid distribution headers out of the packing do not have this problem nor do pipe type units with downcomers.

Buried pipe distributors without downcomers typically block anywhere from 15 to 45 % of the tower cross-section, the blockage increasing with acid flow and tower diameter. Such blockage can cause acid mist carry-over and extra pressure losses in the tower. Even accepting that all of the acid is not present between the arms in the packing , the correction is quite small and does not invalidate the conclusion.

The previous discussion concerned a process bottleneck. Another bottleneck of importance is that of physical access. Such access is needed for a variety of reasons including (1) removal of packing for washing (2) addition of or changing of packing (3) removal of sulfate and (4) inspection of the tower shell. For good access to packing, the number of and spacing of troughs or distributor pipes or headers should allow easy passage to maintenance personnel in acid suits through large openings. Present standards of separation are very acceptable provided one has a number of <u>very</u> small maintenance personnel. A good target for such gaps between troughs or headers would be to ask for a minimum clearance of at least 3 feet and a trough or header should serve five feet of tower cross-section. Such a spacing is much larger than anything at present in service.

POSITIVE DISTRIBUTION

With towers increasing in size and capacity there is a need to ensure that the liquid distribution is not sensitive to poor levelling, hydraulic surge, acid flow or gas flow. Positive measures need to be taken to make this result. Let us consider first the feed to the individual distribution point.

INDIVIDUAL DISTRIBUTION POINTS

Here the designer can using overflow weirs or submerged orifices.Flow through an overflow device is very sensitive to liquid level and can also be affected by the manner in which the acid is introduced to the header feeding the point. If one has a very large tower the headers feeding the overflow points must be level across its length when erected as well as after the tower has been in service for many years.

If a submerged hole is used, there normally will be significantly greater head and the submergence of the hole will be at least an order of magnitude greater than any possible deviation from level. The submerged hole is thereby much less sensitive to acid flow and turndown should be better. We ran tests on one such distributor in a drying system at Copper Cliff in which we cut back the acid flow to 30 % of design without affecting drying.

HEADERS

Troughs, pipes, and pans have all been used to feed individual distribution points. Pans can be ignored. Cast Iron, various grades of stainless steels, and higher alloys such as HASTALOY or CA20-Cb3 have been used. Comparing pipes and troughs, the pipe is a much better conveyer of liquid in terms of weight and availability while the trough allows easier cleaning as it is open at the top. Where troughs are used in cast iron, the wall thicknesses can be set conservatively to give long life. Where pipes are used, if one wishes long life, one has a choice between such materials as the expensive silicon stainless steels SARAMET and SX on the one hand and quality cast iron (if one can find it).

ACID SUPPLY TO HEADERS

The incoming acid needs to be split among the headers or pipes which feed the individual points. Where pipe is used, it is possible to set up the system such that all headers are part of a common plenum and equalization between headers is possible. Where troughs are used, the acid must be split upstream of the troughs and no easy equalization is available. Typically this upstream equalization is carried out by the use of orifices. The trough design therefore requires two stages of flow splitting, one involving relatively high pressure drop orifices in the lines to the troughs and a very low pressure drop in the individual overflow weirs. The pipe type does not need the primary orifices and can use all of the pressure drop across the final distribution orifices where distribution is critical.

DISTRIBUTOR CLEANING

Thirty years ago when I first became involved in this industry, most acid plants produced acid containing 15 to 20 ppm iron and corrosion of cast iron was expected. These plants then deposited the iron sulfate corrosion product in distributors, piping, and packing, and cleaning out of sulfate was a common chore.

Trough and pan distributors were suited to this situation as they were very accessible to the maintenance personnel. The introduction of the anodically protected stainless steel acid cooler and the introduction of non-corroding stainless acid pipe have resulted in lowering the iron content in product acid in many cases below five ppm. While sulfate is still formed, it tends to stay in the acid and sulfating of distributors is only an occasional nuisance for most operators.

Sulfate is not the only material which can find its way into distributors. Packing chips, pieces of brick, and even sulfur have been observed here and have required cleaning. In many cases separate filters have been installed using LEWMET or SARAMET screens to protect the system from such tramp materials.

Pipe designs which are accessible for cleaning from outside the tower are not present in existing distributors but could offer a possible alternative. With separate cleaning and no sulfate formation it is also a moot point as to how much concern needs to be paid to ease of cleaning if other advantages have to be sacrificed to get it.

MATERIALS

CAST IRON

Classically, cast iron shapes such as pans, troughs, downcomers, and pipe and fittings have been required for each plant. The troughs or pans and the downcomers were typically custom for each size of tower and the patterns were kept by the foundry that supplied them. The parts were therefore on special order and one had to hope the foundry was still in business when one needed them. These shapes are also heavy and difficult to install.

The cast iron fittings are sand cast and normally come with thick walls. The standard fittings are also normally held in stock and thus readily available. The designer challenge when he considers cast iron systems is therefore to avoid designs which use non standard fittings.

Cast iron pipe has already been mentioned. Good quality thick cast iron pipe is no longer as available because of the change in foundry practice and utility switching to nodular iron. To add to the problem, corrosion rates in concentrated sulfuric acid increase as the iron content of the acid decreases. The use of non-corroding acid coolers has dropped iron content in the acid and increased the corrosion rate of the cast iron, further shortening pipe life.

One possible alternative by which good quality pipe might be available would be to pool orders to the point that one or more foundries might be interested. Since this would require commitments for 100 tons of pipe at a time no one user is likely to have enough volume to justify this expense.

Unless carefully specified, cast iron has limited resistance to corrosion in high velocity regions. My first experience with buried pipe distributors in cast iron involved pipe with drilled holes. These holes grew from 0.75 to over 1 inch in two years. We did solve the problem with inserts but the sensitivity to erosion was clear. One exception would be the pipes used by Lewis to carry acid from their submerged pumps to the external piping. These lines have high velocity and give reasonable service as far as I can tell.

On grounds of availability and economics, cast iron still has to be considered as one of the best alternatives open to the distributor designer.

STAINLESS STEELS and ALLOYS.

One of the original wrought alloys for use in sulfuric acid service was Carpenter Alloy 20-Cb3 which offers good corrosion and erosion resistance over a broad range of sulfuric acid concentrations and temperatures. This alloy is now frequently used in cast form in pumps and valves. Since that time the number of stainless steels has grown and highly resistant steels and alloys are now available in many forms. The ordinary stainless steels are also now relatively less expensive and are replacing steel and cast iron in many duties where the stainless steel weight is much less than the conventional alternate. The stainless and alloy developments include:

(1) The use of anodically protected stainless steel
(2) The development of the LEWMET series of cast alloys
(3) The introduction of the silicon containing stainless steels for use in strong acid
(4) The definition of the MEC strong acid window
(5) The introduction of ferritic stainless material.

As far as distributors are concerned, SARAMET, SX, ferritic stainless steel, CA20-Cb3, and cast iron are now used for complete designs. PTFE, Lewmet, and CA20-Cb3 have been used for inserts.

PLASTICS and other NON-METALLICS

There are now a broad range of plastic and ceramic materials available for use in acid plants. Here we are concerned only with distributors so acid brick and the ceramics are of lesser importance. Plastics are newer, less understood, and thereby offer more opportunity.

The prime family of plastics which are of interested for concentrated sulfuric acid distributors are the fluoropolymers, a group which includes PTFE, FEP, PFA, and many related polymers and copolymers. Some of these materials are thermoplastic while others are not. All are machinable and usable to temperatures which vary with the specific polymer. Dimensional stability is also quite variable as some will cold flow (e.g. not sustain long term stress when cold).

PTFE tubing has been used for downcomers in some cases and glass-filled PTFE has been used for threaded inserts with good success.PTFE is not thermoplastic. FEP and PFA on the other hand are thermoplastic and will soften when heated but are commonly used as pipe and tubing. PFA which is more expensive, is used among other duties for fittings where dimensional stability is important as well as in the form of tubing. It also has better strength at higher temperature.

DISTRIBUTOR DESIGN TARGETS

In the light of the previous discussions the targets for an improved liquid distributor design are as follows:

1. Frequent and well spaced distribution points
2. Distributor must not create a process bottleneck
3. Distribution must be positive
4. Distribution must be insensitive to level,liquid flow
5. Distributor materials must offer long life
6. Distributor must use readily available shapes
7. Distributor must be easy to assemble and repair
8. Distributor must allow easy access to packing
9. Distributor must be easy to clean
10. Distributor must be economical

CONCEPTUAL DESIGN

With the above criteria for design a concept has been involved in which pipe headers are used, fed from outside the tower. The individual distribution is through adapters which connect to fluorocarbon tubing which leads the acid into the packing below the level of the distributor pipes. With the exception of the pipe to tubing adapters, all components are available from stock, eliminating the need to maintain spares.

The concept is illustrated in Figures 2 to 5. Here the figures are

2. A distribution grid in a tower
3. Plan view of distributor showing tubing
4. Cross-section of header showing downcomers
5. Connection of tubing to adapter to form downcomer

Consider now our distributor design targets in light of these four drawings.

Figure 2 shows a distribution grid which is essentially completely uniform and satisfies criterion No 1. Clearly also, even closer spacing could be available if needed.

With the piping out of the packing as shown by Figure 4, it does not create a process bottleneck. In fact, in the tower shown it blocks less of the open tower area than any existing header. The target No 2 is therefore fully met.

The distributor offers a single plenum feeding the individual points through orifices in the adapters and the head of liquid fully fills the pipe system. This design clearly

With a significant head of liquid over the distributor holes, sensitivity to poor levelling is small and the use of a common plenum makes sensitivity to flow small as well. The previously mentioned tests using a similar design concept in a drying tower at Copper Cliff cutting flow to one-third of design without affecting drying indicates Criterion 4 is satisfied.

For the pipes in this header I have chosen L-14 Iron pipes from the Chas S Lewis & Co Inc. This material now gives good life in much hotter and turbulent service in most of your plants. In addition, it is available with relatively thick walls and Lewis maintains it in stock. It is hard to predict life in this environment but what test results I have seen suggest ten years at a minimum. The adapters will be cast out of LEWMET or a similar resistant alloy and are likely life of plant items. The fluorocarbon tubing does not corrode in this environment and it is difficult to assess when it will need replacement. It is more likely to be damaged by maintenance personnel with heavy boots than by the process fluids. Criterion 5 is in my view therefore satisfied.

With the exception of the adapters which are specially cast, all other components are stocked and require little time for procurement. If the cast iron pipe fails, it is simply a question of pulling material out of stock and carrying out the necessary flanging, drilling, and tapping. Fluorocarbon tubing is stocked and information to date suggests delivery in a week or two. Cast iron fittings for either internal or external headers can be standards which are held in stock, again easing maintenance headaches. For the adapters, two sizes are proposed so appropriate molds will be available and it is not a difficult job to cast such parts once the mold or pattern is available. Criterion 6 calls for the unit to use readily available shapes which this design satisfies.

With an external header, the assembly will require the cast iron pipes to be drilled and tapped prior to being placed in the tower. At the same time, the plastic tubing can be cut to length , heated, and mated to the adapters. With the pipes installed in the tower the next step is to screw the adapters into the pipes inside the tower and tighten with a simple wrench. Once the external header is connected, the distributor is complete. For maintenance or repair, no welding is involved and only threaded parts need to be separated. If a new pipe is needed, the downcomers need not even leave the tower. It may be possible to generate a simpler concept but at this time I do not know how.

Criterion 8 calls for easy access to the packing. For a sixteen foot tower, the design calls for three twelve inch pipes as primary distributors, leaving approximately four feet clear between pipes. Maintenance personnel will however have to avoid walking on the plastic tubing. The design again satisfies the criterion.

Criterion 9 calls for the distributor to be easy to clean. Here it is my belief that this criterion is reasonably satisfied. It is our suggestion that a filter be placed upstream using either LEWMET or SARAMET to catch any tramp packing or brick as a

One plant I know generates sulfur in large quantities and cleaning is very difficult. If the plant generates large quantities of sulfate, the ease of sulfate removal in the pipe by access to the pipe end would require investigation. Clearly a vacuum hose could be used from outside the tower as could rakes. This cleaning criterion is in my view only reasonably satisfied.

Criterion 10 calls for an economical design. Cost estimates for this design suggest that the design is extremely cost effective by comparison with any other concept using downcomers. As far as comparison with units using buried pipe, the concept avoids the bottlenecks, has a greater concentration tolerance as a result of the materials used, and offers better value. We would also expect it to be less expensive but only time will answer this question.

For ease of comparison, Table 3 has been prepared:

TABLE 3

CASE	TROUGH	BURIED PIPE	CECEBE
Materials			
Headers	C. I.	Alloy	C. I.
Orifices	None	None	LEWMET
Downcomers	C. I.	None	FEP/PFA?
Header Location	Clear	In Packing	Clear
Tower Blockage	No	Yes	No
Packing Access	Poor	Poor	Good
Distribution Device	Overflow Weir	Submerged Hole	Submerged Hole
Specialty Castings	Troughs Downcomers	None	Adapters
Self-equalizing	No	Yes	Yes
Cleaning	Manual from Inside tower	Manual Difficult	External Simple
Simplicity	Complex	Simple	Simple
Ease of Maintenance	Fair	Good	Good
Corrosion	Base Case	None	Better than Base case
Assembly	Most complex	Simple	Simplest
Acid Strengths	Insensitive	Sensitive	Insensitive
Capital Cost	Highest	Intermediate	Least

CONCLUSIONS

From the review of existing designs and the newer materials available, it is possible to an effective distributor for acid plants which is easy to fabricate, install, and clean, and which is likely to cost less. The design uses proven materials and principles and offers little risk to the user and significant benefits.

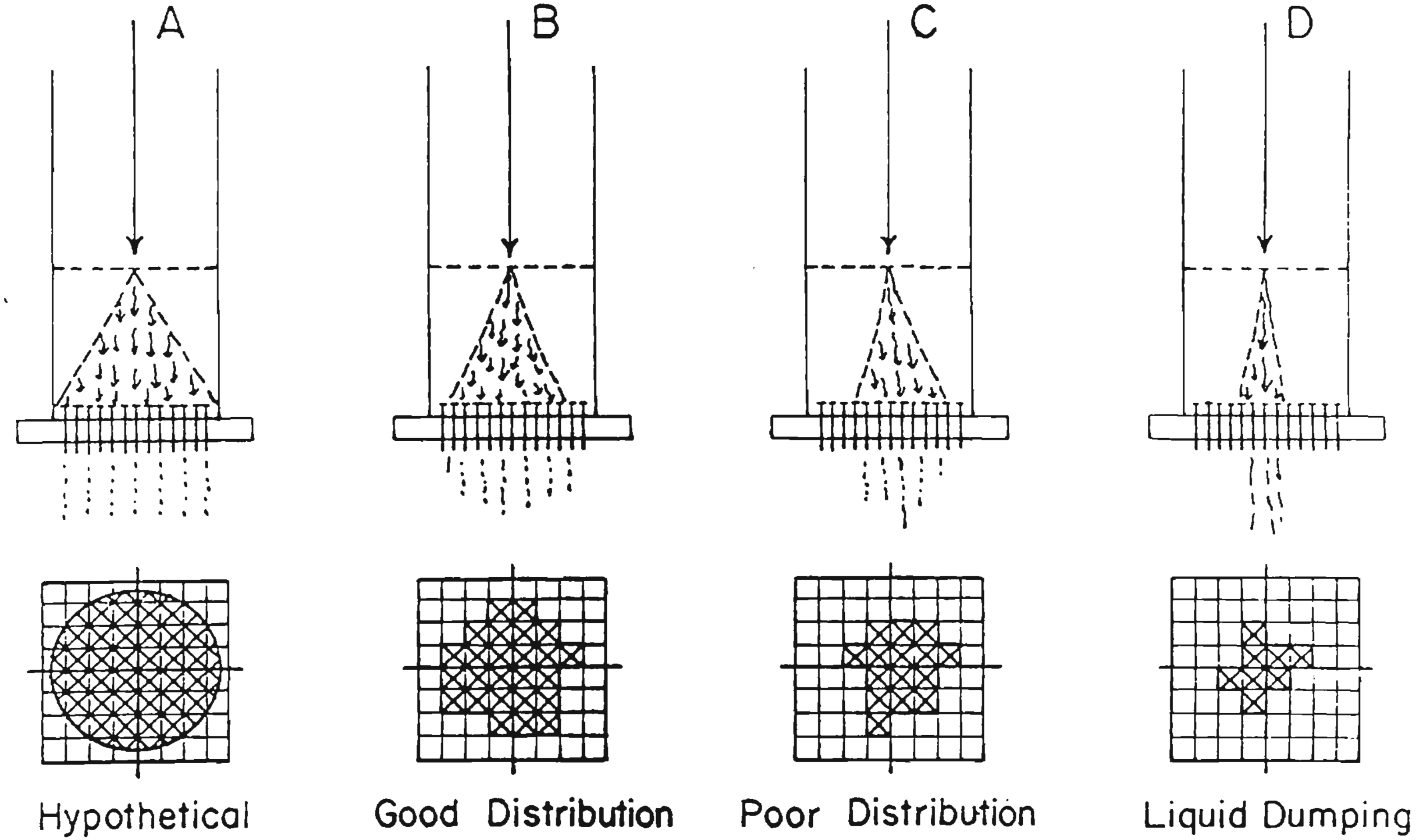
FIGURES

1. Liquid Spreading in Packing
2. Distribution Grid
3. Top view of Distributor
4. Section of Distributor Arm showing Downcomers
5. Adapter-Tubing Assembly

Acknowledgments

1 SARAMET is a trademark of Chemetics International Co
2. LEWMET is a trademark of the Chas S. Lewis & Co Inc
3. SX is a trademark of Edmeston Co Inc
4. HASTALOY is a trademark of Haynes Alloys

FIG. I LIQUID DISTRIBUTION QUALITIES OF RANDOMLY DUMPED PACKINGS



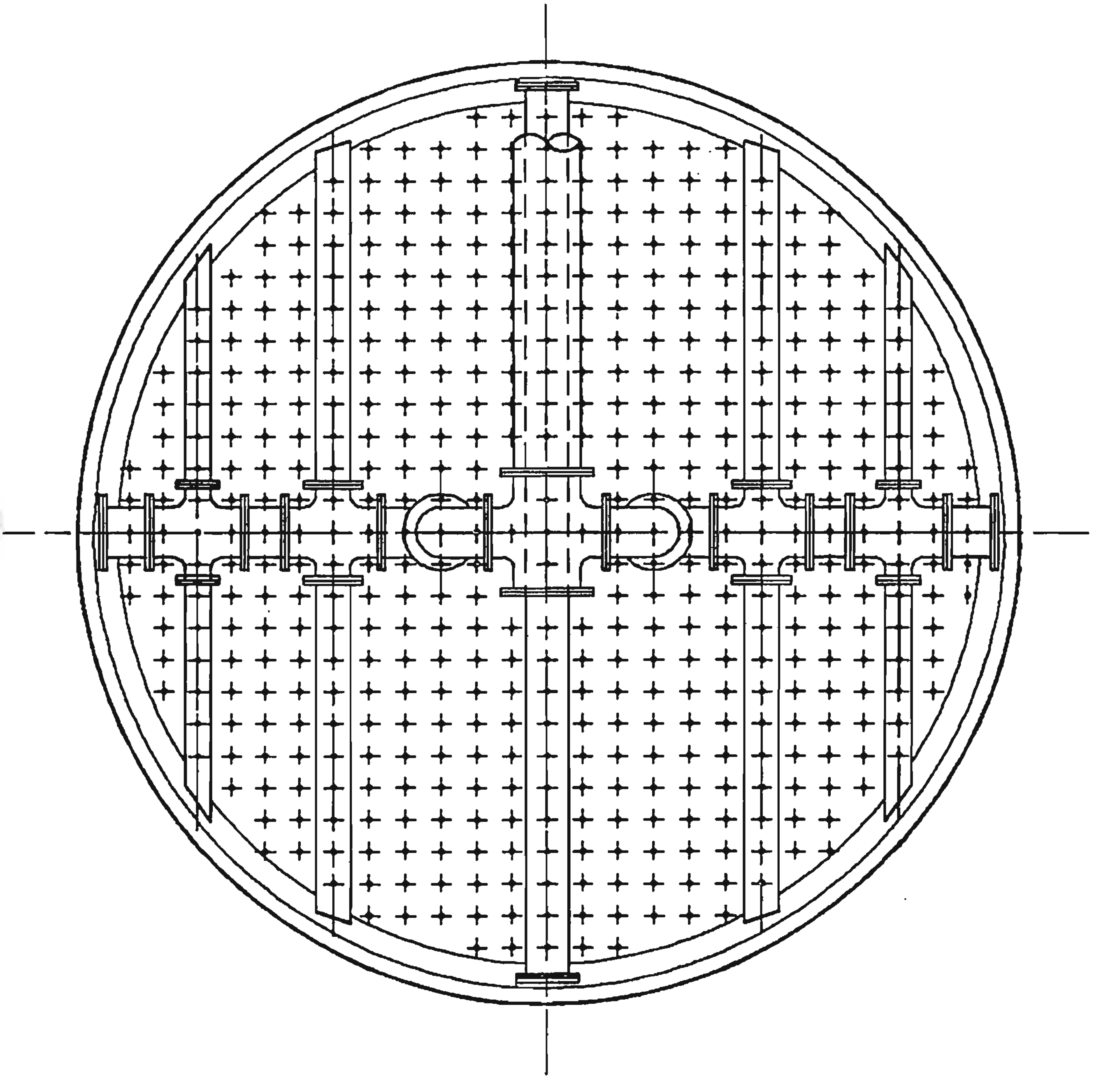


FIGURE 2

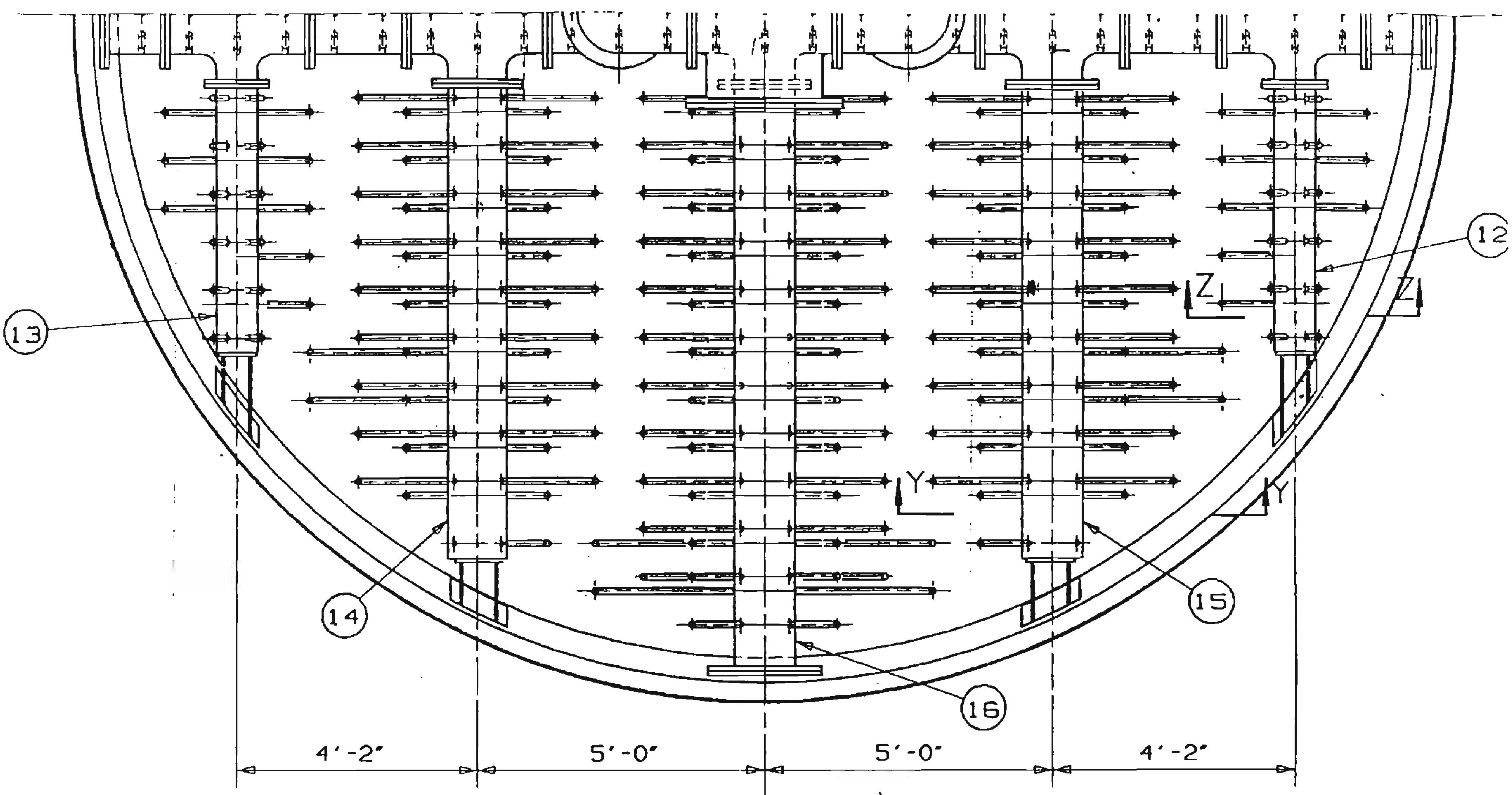
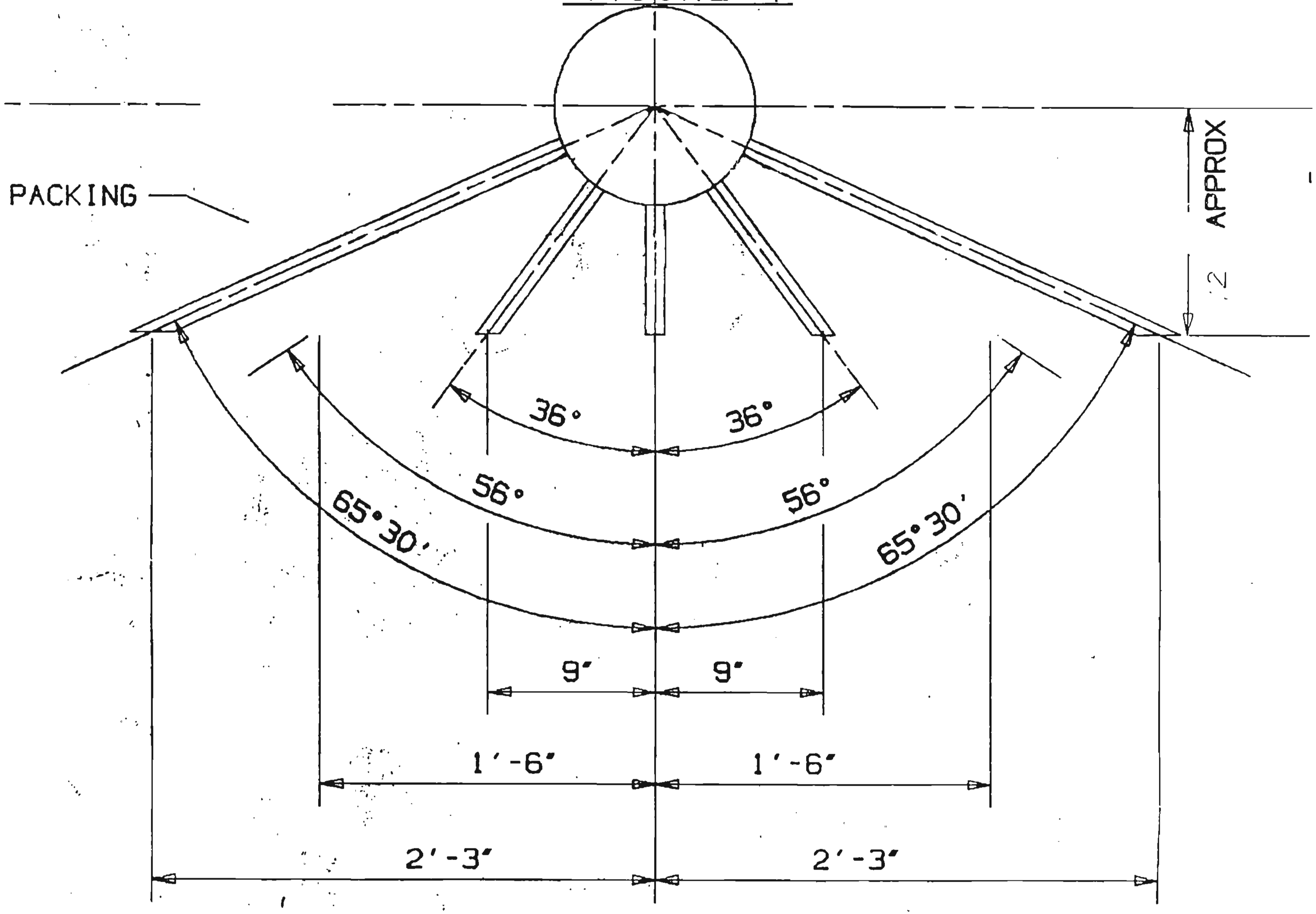


FIGURE 3

FIGURE 4



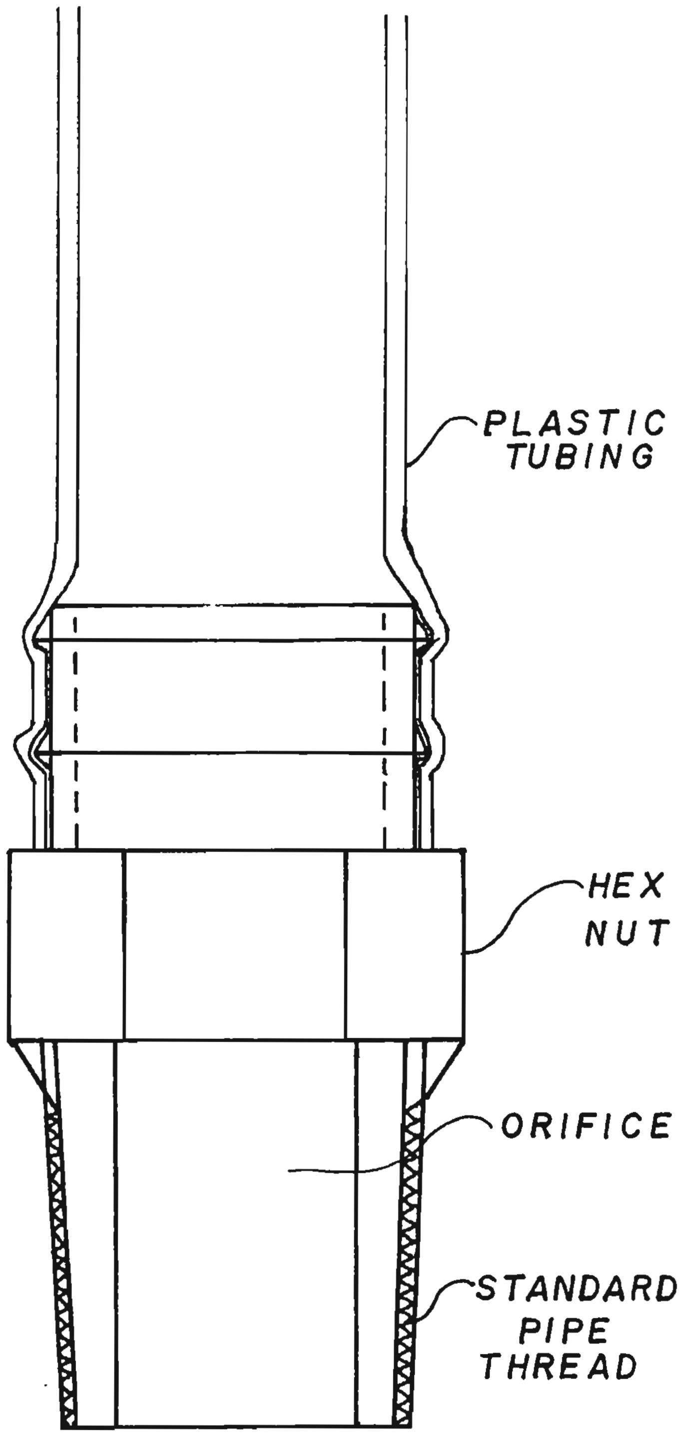


FIGURE 5