"Design And Fabrication Of Agitated Thin Film Dryer"

Bhushan M. Thengre[1], Sulas G. Borkar[2]

[1](Currently pursuing masters' degree program in Heat Power Engineering in Guru Nanak Institute Of Technology
Kalmeshwar Road, Dhahegaon, Nagpur, Maharashtra, India- 441501)
Contact No. 09422172963
bhushanthengre102@gmail.com
[2](Professor, Mechanical Engineering Department in Guru Nanak Institute Of Technology
Kalmeshwar Road, Dhahegaon, Nagpur, Maharashtra, India- 441501)
Contact No. 09403870375
borkarsulas@gmail.com

ABSTRACT

Agitated thin-film dryers (ATFDs) are used to produce dry free-flowing powder from slurry/solution-type feed and widely implemented in pharmaceutical, chemical, food industries and metal industries. The feed passes through the ATFD in several forms such as solution/slurry and successively becomes paste, wet powder, and dry powder. The flow of feed in the ATFD undergoes a helical path (combination of rotational velocity imparted by the agitator/blade and axial velocity of feed) while flowing through the annular part of the dryer. The ATFD is described stage-wise and the parameters such as physical properties, scraped surface heat transfer coefficient, and evaporation rate (drying rate) are derived using stepwise model equations.

Keywords: - *Heat Transfer, ATFD, Fouling & Effluent.*

1. INTRODUCTION.

Evaporators are used in a wide range of processes including Pharmaceuticals, foods and beverages, metal industries, pulp and paper, chemicals, polymers and resins, inorganic salts, acids, bases, and a variety of other materials. There are many types and variations of evaporators and the best for a particular application depends on the product characteristics and desired results. Evaporation is an operation used to concentrate a solution of a nonvolatile solute and a volatile solvent which in many pass is water. A portion of the solvent is vaporized to produce a concentrated solution, slurry or thick & viscous liquid. An evaporator consists of heat exchanger or a heated bath, valves, manifolds, controls, pumps, and condenser.

The most common designs are jacketed pans, tubular heat exchangers, and plate and frame heat exchanger and agitated thin film evaporator. An **AGITATED EVAPORATION MACHINE** is one of the most significant steps towards it. An agitated thin film evaporator is a recent technology used to dry the concentrated solution of essential solids so that moisture is evaporated & dry powder of solid is obtained.

2. A PROPERLY DESIGNED EVAPORATOR.

- **a.** Be designed to effectively transfer the heat at a high rate with minimum surface area to be cost effective for installation, operations and maintenance.
- **b.** Effectively separate the vapors from the liquid concentrate meet the conditions required by the product being processed.
- **c.** Produce a product that needs the required quality.
- **d.** To be energy efficient, where possible making effective use of steam with multiple effect evaporation or vapor recompression.
- **e.** Minimize the fouling of heat transfer surfaces.

f. Be constructed of materials that are adequate to minimize.

3. LITERATURE SURVEY.

3.1 Sanjay B. Pawar , A.S. Mujumdar , B.N. Thorat – Article 2011

The design of agitated thin film dryer (ATFD) is difficult both mechanically and process engineering point of view. The present work describes the basic flow pattern in ATFD in terms of bow wave and its transformation along the dryer height. The effect of flow rate, jacket side heating medium temperature and speed of the rotor has been studied for a pilot scale ATFD. The effect of rotor speed was found less significant for water as a feed material than for sugar and ammonium sulfate solutions over the studied range of speed. The scraped side heat transfer coefficient was obtained using the penetration theory and its value was found in the range of 3000–7000W/m2 ◦C.

3.2 Nicholas P. Cheremisinoff.

We may organize water treatment technologies into three general areas: Physical Methods, Chemical Methods, and Energy Intensive Methods. Physical methods of wastewater treatment represent a body of technologies that we refer largely to as solid-liquid separations techniques, of which filtration plays a dominant role. Filtration technology can be broken into two general categories - conventional and non-conventional. This technology is an integral component of drinking water and wastewater treatment applications. It is, however, but one unit process within a modern water treatment plant scheme, whereby there are a multitude of equipment and technology options to select from depending upon the ultimate goals of treatment. To understand the role of filtration, it is important to make distinctions not only with the other technologies employed in the cleaning and purification of industrial and municipal waters, but also with the objectives of different unit processes.

3.3 Freeze H.L., and Glover W.B.

Agitated thin film evaporators are attractive for the concentration, distillation, stripping or deodorization of liquids in broad variety of chemical-process-industries (CPI) applications where the process streams are temperature sensitive (and must have only brief exposure to heat), viscous, or tend to foul or foam. When this type equipment does seem to be the right choice in a given situation, the common, and sound, approach is to ask an evaporator manufacturer to conduct an evaluation and make an equipment quotation. The quality of such an evaluation will depend on the type and quality of the data that the manufacturer receives from the potential customer’s engineers and perhaps to some extent, on those engineers’ familiarity with the evaluation process itself.

The thin-film process - That familiarity begins with an understanding of what a thin-film evaporator is and how it works. A vertical thin-film evaporator consists of two major assemblies: a heated body and a close-clearance rotor. The process fluid enters the unit tangentially above the heated zone, and is distributed evenly over the inner surface of the body wall by a distribution ring mounted on the rotor. The rotor blades spread the product over the en- tire heated wall, and generate highly turbulent flow conditions in the thin layer of liquid.

The product spirals down the wall, while the turbulent conditions developed by the rotor blades generate optional heat flux, rapidly evaporating volatile components. The resulting vapors flow upward through the unit into a centrifugal separator, which re- turns entrained droplets or froth directly back to the heating zone. Clean vapors pass through the vapor outlet ready for condensing or further processing. Meanwhile, the concentrated liquid stream leaves the evaporator through its bottom conical outlet. Continuous washing by the bow waves generated by the rotor minimizes surface fouling of the thermal wall, where the concentrated liquid or residue is most prevalent.

Thin-film evaporators are commercially available in various basic or standard versions. They can have vertical or horizontal designs, with cylindrical or tapered bodies and rotors. The rotor can employ any of several zero clearance designs, or a rigid fixed clearance design, or an adjustable clearance type. The basics for scale up from the manufacturer’s pilot testing program are the same or similar for all.

3.4 Sulzer Chemtech ltd.

In 20th Century the growth in the Chemical Sector was increased due to World War II and Cold War. Due to Chemical industries increasing there was tremendous increasing in Chemical Waste and sub-product. It was difficult to collect and store these chemicals. It was also harmful to nature and humans. It was necessary to reduce the increasing rate of chemical and dispose it properly by order of chemical of united nation, that why which convert liquid chemical into solid powder. Lateran, some improvement implemented on the evaporator design to make its more efficient and reliable. In India Sulzer Chemtech introduced the agitated thin film evaporator in chemical Industries.

4. PROBLEM DEFINITION.

Technical problems can arise during evaporation, especially when the process is applied to the food industry. Some evaporators are sensitive to differences in viscosity and consistency of the dilute solution. These evaporators could work inefficiently because of a loss of circulation. The pump of an evaporator may need to be changed if the evaporator needs to be used to concentrate a highly viscous solution.

Fouling also occurs when hard deposits form on the surfaces of the heating mediums in the evaporators. In foods, proteins and polysaccharides can create such deposits that reduce the efficiency of heat transfer. Foaming can also create a problem since dealing with the excess foam can be costly in time and efficiency. Antifoam agents are to be used, but only a few can be used when food is being processed.

Corrosion can also occur when acidic solutions such as citrus juices are concentrated. The surface damage caused can shorten the long-life of evaporators. Quality and flavor of food can also suffer during evaporation. Overall, when choosing an evaporator, the qualities of the product solution need to be taken into careful consideration.

5. EXPERIMENTAL SETUP.

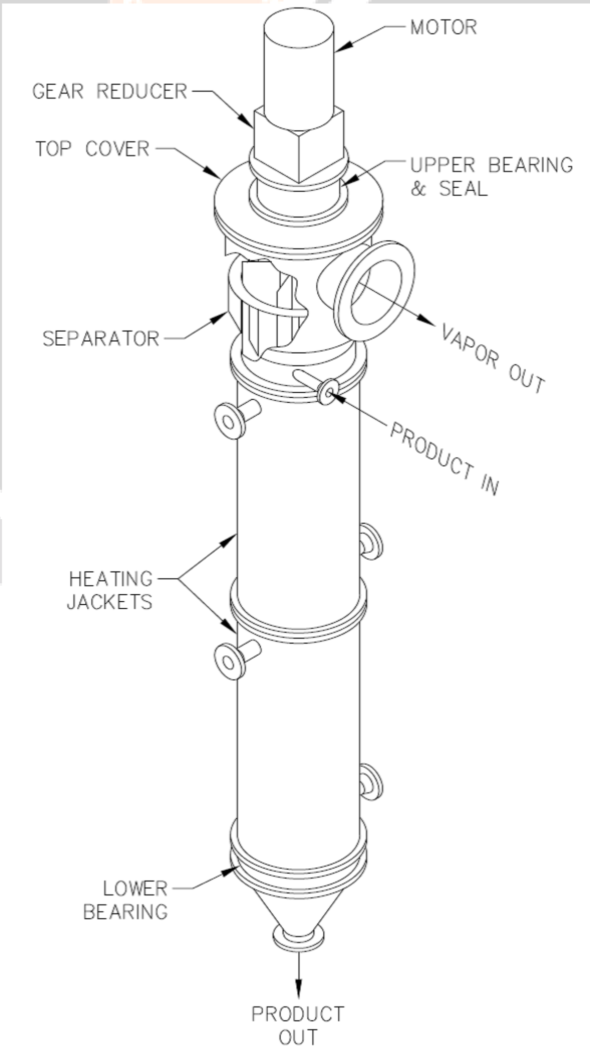

Fig-1: Agitated thin film dryer

A schematic diagram of the experimental setup is shown in the figure 1. The main components of the ATFD are sequentially 1. Motor 2. Gear Reducer, 3. Top Cover, 4. Upper Bearing, 5. Top Plate, 5. Separator, 6. Vapour Out, 7. Product In, 8. Heating Jacket, 9. Lower Bearing & 10. Product In. Agitated thin-film evaporation has been very successful with difficult-to-handle products. Simply stated, the method quickly separates the volatile from the less volatile components using indirect heat transfer and mechanical agitation of the flowing product film under controlled conditions. The separation is normally made under vacuum conditions to maximize ΔT while maintaining the most favourable product temperature, and to maximize volatile stripping and recovery.

6. CRITICAL OPERATIONAL AND PRODUCT CHARACTERISTICS.

6.1 Heat Sensitivity

Many foods, pharmaceuticals, chemicals & resins are heat or temperature sensitive & require either low heating temperatures or a short residence time exposed to the heat, or both. This can be accomplished by a combination of minimizing the volume of product in the evaporator at any one time, minimizing the time in the evaporator, & reducing the products' bulk boiling temperature by operating the evaporator at reduced pressures. Reducing the internal operating pressure may also allow operation at lower heating temperatures, while still maintaining a reasonable heat-transfer driving force (the temperature difference between the boiling point of the bulk product and the temperature of the heating medium).

6.2 Fouling

Fouling of the heat transfer surfaces is usually caused by solids in the feed, precipitating solids in the concentrate, or degradation of the product. A slow build up of a film on the heat transfer surfaces will cause a gradual reduction in the overall heat transfer coefficient. Eventually this will require shutdown of the process and cleaning of the heat transfer surfaces, which results in production downtime and additional maintenance labour.

6.3 Foaming

Product foaming during vaporization is common. It may range from a small amount of unstable foam that breaks easily to a very stable foam that is difficult to break and tends to fill the entire void of the evaporator system. Foaming can often be minimized by special designs for the feed inlet (separation of feed from the vapour stream) and the vapour/liquid separation area (special disengaging designs). Also, reducing the boiling intensity of the liquid on the heat transfer surface (by operating at lower temperature or at a higher pressure) and reducing the vapour velocity in the tubes may significantly reduce foaming. Where the product purity specifications allow, introduction of antifoam may solve or greatly reduce the problem.

6.4 Solids

The properties of the concentrate may change as the solid concentration increases. Solids may plug tubes, causing loss of heat transfer surface, in turn resulting into reduced heat transfer rates and requiring downtime for cleaning. Solids increase the tendency to foul the heating surface, which reduces the heat transfer coefficient boil-up rate. An increase in solids may also increase the concentrate viscosity, which affects the overall heat transfer coefficient, reducing capacity.

6.5 Viscosity

Any increase in the viscosity of the concentrate will reduce the overall heat transfer coefficient.

6.6 Heat Transfer Medium

The heat transfer medium (hot oil or steam) may impact the selection of the type of evaporator. Liquid heated evaporators typically have lower overall heat transfer coefficients and require more heat transfer area. If the product is temperature-stable, then hot oil heating may allow higher temperatures and overcome the lower heat transfer coefficients. This, in some cases, could allow the use of smaller evaporator.

7. WORKING PRINCIPLE

Agitated Thin Film Evaporator- Vertical In a vertical dryer, the rotor blades are hinged. The feed enters the shell tangentially and gets spread along the inside surface of the shell into a thin film. The hinged rotor blades keep the film under intense agitation preventing any scale formation. The feed progressively passes through different phases like liquid, slurry paste, wet powder and finally powder of the desired dryness. The vapours flow counter current to the film. The powder gets collected in a powder receiver at the bottom.

Agitated Thin Film Dryer- Horizontal orientation is required when the feed is in the form of a thick slurry, paste or wet powder. The fixed clearance rotor with screw elements prevent scale formation and convey the material from the feed end to the powder discharge end in a continuous fashion.

Agitated Thin Film Evaporators- The Agitated Thin Film Evaporator comprises two major assemblies a jacketed shell precision machined from the inside. A rotor assembly has revolves at high speeds while closely fitting the shell. The feed enters the shell tangentially and spreads along the periphery ought the distributor. The rotor blade tips slides with a close clearance with the wall and spread the feed uniformly on the heated surface into a thin film and then agitate it. The heating medium provides the necessary heat for evaporating t he volatile component of the feed. The vapour transmits counter current t o the film and gets cleared in the entrainment separator before being left through the vapour nozzle. The concentrated product leaves the evaporator bottom through the concentrate nozzle

8. DESIGN OF AGITATED THIN FILM EVAPORATOR

Process Design-Among the needed physical-property parameters are the latent heat of vaporization, viscosity, thermal conductivity, specific heat and density, of both the heating medium and the process fluid. Additional process-fluid data needed are its solids content, fouling tendencies, & thermal sensitivity.

8.1 Design Calculation for Evaporator:

8.1.1 Feed Condition for ATFE

Feed inlet flow Rate F	= 600 kg/hr	= 0.519m3/hr = m_f,
Temperature	=70°C	=273+70 = 343 K,
Solid %	=28.57 %,	
Total Solids in Feed = m'	=136 kg,	
Remaining Water = m_v	=464 kg,	
Inorganic Salts in Feed,		
Ammonium Chloride	=44.8 kg,	
Sodium Chloride	=43.8 kg,	
Magnesium Bromide	=47.4 kg.	

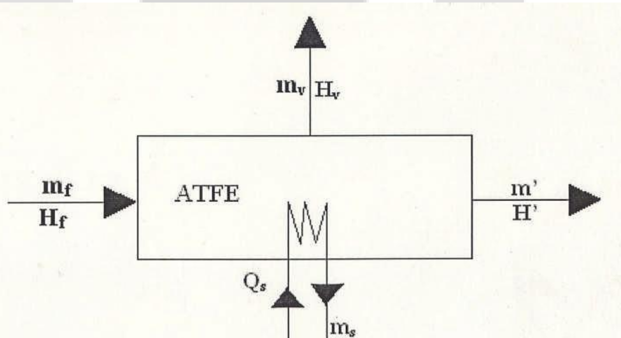

Fig -2: Enthalpy balance

8.1.2 Enthalpy Balance over the ATFE

$m_f H_f + m_s \lambda_s = m_v H_v + m'H'$....................(1)

Now, $H_r=(C_p)_f * T_f$…………………………….(2)

$(C_p)_f=\Sigma x_i \, C_{pi}$……………………………….(3)

8.1.3 Weight Fractions:-

X_{NH4Cl} = 44.8/600-0.075 **X_{MgBr2} = 47.4/600 = 0.079**

X_{NaCl} = 43.8/600 = 0.073 **X_{H2O} = 464/600 = 0.7733**

8.1.4 Heat Capacity of Components:

For NH4Cl

C_p = 9.80 + 0,0368 T
= 9.80 + 0,0368 (343)
= 22.4224
$(C_p)_{NH4Cl}$ = 22.4224 cal/(mole.K) = 5.02128 Kj/kg.K

For NaCl

C_p =10.79+0.00420T
=10.79+0.00420(343) ,
= 12.2306
$(C_p)_{NHCl}$ =12.2306 cal/ (mole.K) = 2.995 KJ/ (kg.K)

For MgBr2

C_p =17.3+0.00377T
=17.3+0.00377(343)
= 18.5931
$(C_p)_{MgBr2}$ =18.5931 cal/ (mole.K) = 14.33 KJ/ (kg.K)

For H20

$(C_p)_{H2O}$ = 4.1967 KJ/(kg.K)

Hence from equation (3), '

$(C_p)_f$ = $\Sigma x_i C_{pi}$
= 0.075(5.02128) + 0.079(14.33) + 0.073(2.995) + 0.7733(4.1967)
$(C_p)_f$ = 4.9726 KJ/(kg.K)

Also from equation (2),

H_f = $(C_p)_f * T_f$
= 4.9726 * (343-373)
H_f = -149.178 KJ/kg

Now,

λ_s at 70°C = 2163.22 KJ/kg

H_v at 70°C = 561.44 KJ/kg

Now, for dried solids,

$C_p' = \Sigma x'_i * X(C_p)_i$

Where,

X'_i = Weight Fraction on Moisture Free Basis.
X''_{NaCl} = 44.8/136 = 0.329
X_{MgBr2} = 43.8/136 = 0.322 = 47.4/136 =0.349

Now,

C_p' = $\Sigma x'_i$ * $X(C_p)_i$
= 0.329 * 5.02128 + 0.322 * 2.995 + 0.349 * 14.33

C_p' = 7.618

H' = 7.618 * (343-373)
= - 228.54 KJ/kg

Hence, from equation (1),

$m_f H_f + m_s \lambda_s = m_v H_v + m'H'$

600 * (-149.178) + ms * (2163.22) = 464 * (561.44) + 136 * 7.618 * (343-373)

Hence,

M_s = 147.43 kg/hr

Hence, Steam required is approximately 150kg/hr.

8.2 Designs for Agitator

F = 0.5190 m^3/hr
A = 3.14 * d^2/4 = (3.14 * $(0.2)^2$) / 4 = 0.0314 m^2

Velocity of feed stream is,
V = F/A = 0.5190/0.0314 = 16.53m/min = 0.27m/s

Now,
Reynolds Number is given as,

N_{Re} = ρ v d/μ.
N_{Re} = (1.156* 0.27 * 0.2) / (13.61 *10^{-3})

NRe = 4.2468

Now,
Power Number is related to Reynolds Number as,

N_P = 203 * $(N_{Re})^{-1}$ for 2< N_{Re}< 60
= 203*$(4.2468)^{-0.1}$
N_P = 47.8

Power Number is given as,

N_P = P / (ρ * N^3 * d^5)
P = N_P x ρ * N^3 * d^5
= 47.8 * 1156 * 33 * (0.21)5
P = 609.32 watts = 0.82 hp

Hence,
Power required is approximately 1 hp.

8.3 Designs for Shell

Working Pressure = 3 kg/cm2 + vacuum
Now, Thickness is given as,

t = PR / (SE-0.6P)

Where,

P - Design pressure, R - inside radius,

S = allowable stress, E = joint efficiency

Assuming design pressure is 20% of Working Pressure.

P =1.2 * 3 = 3.6kg/cm2

Now,
Assuming mild steel as a material of construction,
S = 1200 kg/cm2 •
E = 0.7,

Let the Diameter of Shell be 200 mm & Corrosion allowance as 3 mm.

Radius R = [200+ (2 * 3)] / 2 = 103 mm = 10.3 cm
t = (3.6 * 10.3) / [(1200 * 0.7) - (0.6 * 3.6)]

t = 37.08/(840-2.16) t = 0.04426 cm = 0.4426 mm
t = 3+0.4426 mm = 3.4426mm

t = 3.4426mm

Hence, Thickness of shell is approximately 5 mm.

8.4 Designs for Jacket

Assume Pressure = 5 kg/cm2

Gap between Shell and Jacket is 20 mm.

Internal Diameter = 200+ (2 * 5) + (2 * 20) =250 mm
Radius R_j = 125 mm = 12.5 cm

Hence Thickness of Jacket is,

t = (5*x 12.5) / [(1200 * 0.7) - (0.6 * 5)]
t = 62.5 / (840-3)
t = 0.07467 cm = 0.7467 mm
t = 3+0.7467 = 3.7467 mm
t =3.7467mm

Hence, Thickness of Jacket is approximately 5 mm.

8.5 Designs for Spring

We select the helical Torsion spring.

θ= 30° = 0.5235 radian
T = m = 534.4191 N.mm
6b = 201.624 N/mm2
Spring Index = 21

$$Kw = \frac{C *(4C-1) - 1}{C * (4C-4)} = \frac{21 (4 x 21-1)}{21 * (4*21-4)}$$

Kw = 1.037

6b = Kw * (32m) / (π*d^3)
201.624 = 1.037 * (32 * 534.4191) / (3.14 * d^3)
d^3 = 27.99947
d = 3.036 mm
D/d = 21
D/3.036 = 21
D = 63.766 mm

(We select standard helical spring. 3mm (d) and 62 mm (D).)

9. CAD – DRAWING.

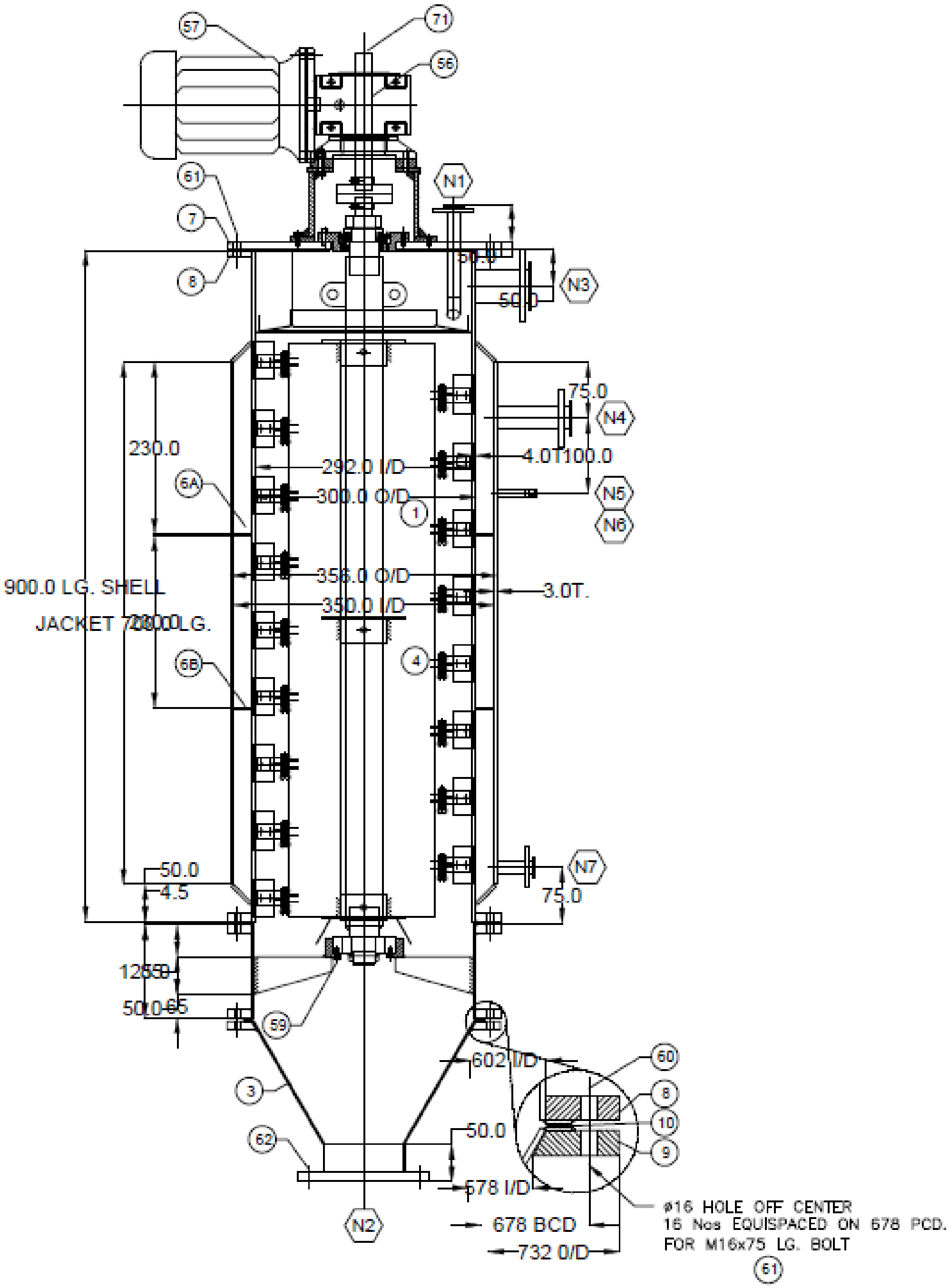

Fig-3 : CAD ATFD

10. CONCLUSIONS

The mechanical & process design for agitated thin film evaporator is proven & reliable, and should be considered whenever an application proves difficult for conventional evaporators. Currently they are often used as "finishers" when high concentration of solids required. Thus, in future AGITATED EVAPORATION MACHINE "will find applications in various processes.

Agitated thin-film evaporators are attractive for the concentration, distillation, stripping or deodorization of liquids in a broad variety of chemical process-industries (CPI) applications where the process streams are temperature sensitive (and must have only brief exposure to heat), viscous, or tend to foul or foam.

The suitability of the ATFE for the various parameters such as viscosity, high capacity, & temperature variations puts it in front of various other conventional evaporators.

Applying numerical techniques is not as simple as it appears on surface. There are problems with the stability & accuracy of solutions. In both the areas there are plenty of opportunities in chemical industry for research & application on ATFE.

11. OBJECTIVES.

a. When solids are dried, they obtain a longer best-before date as the water activity in a product is reduced by means of heat. This is done in a controlled environment. The dry product must meet specific requirements for instance with respect to being free flowing or dust free, average particle size and distribution, solubility or active-component preservation. The right drying process determines the quality of our final product and is therefore an important component for cost price.
b. The Agitated Thin Film Drying (ATFD) can simply be described as an indirectly heated continuous dryer. The feed can be varied and may be a solution, suspension, wet cake or paste. Depending on the application and client's wishes, drying in a vacuum is possible.
c. The vertical ATFD has a jacketed cylinder with a closely fitting rotor at the centre. During operation the rotor revolves at high speed. The feed distributor spreads the incoming feed uniformly over the top of the cylinder. The rotor blades pick up the material and spread it in a thin film over a heated surface. The product transforms from solution to a dry powder as end product. The generated vapour rises and are captured in a condenser.
d. Eliminates preparatory steps such as concentration, filtration or centrifugation.
e. Feeds can be processed without pre-concentration or dilution.
f. Mild drying technology because of indirect heating and drying in absence of air.
g. Energy efficient drying technology with a thermal efficiency exceeding 90%.
h. Final product is a fine powder that can often render a pulveriser in a downstream step superfluous.
i. Different rotor configurations possible for a variety of applications.
j. No impact on surrounding soil salinity, groundwater pollution or ecology of river bodies
k. Conservation of water resource through recovery and reuse of treated effluent
l. Recovery and reuse of salt used in the textile dyeing process.

12. FUTURE SCOPE.

Thermal separation in an evaporator may be conveniently characterized by the viscosity of the non volatile stream the concentrate. Typical viscosity ranges for their useful applications. Unless other considerations are important (thermal stability, fouling tendencies), the terminal viscosity frequently dictates the type of evaporator selected. By far, most evaporation applications involve no viscous (less than 100 centi-poise) fluids. Mechanically agitated evaporators are usually specified for terminal viscosities exceeding 1,000 centi-poise and for heat-sensitive, foaming, or fouling products with lower viscosities Applications. The long tube vertical evaporator offers several advantages like low cost, large units, low holdup, small floor space, good heat transfer over a wide range of services.

Disadvantages include like high headroom, recirculation is frequently required, and they are generally unsuited for salting or severely scaling fluids. They are best applied when handling clear fluids, foaming liquids, corrosive fluids, large evaporation loads. Falling film units are well suited for heat sensitive materials or for high vacuum application, for viscous materials, and for low temperature difference.

Mechanically Agitated Thin-Film Evaporators Thin-film evaporators are mechanically-aided, turbulent film devices. These evaporators rely on mechanical blades that spread the process fluid across the thermal surface of a single large tube. All thin-film evaporators have three major components: a vapor body assembly, a rotor, and a drive system. Product enters the feed nozzle above the heated zone and is transported by gravity and mechanically by the rotor in a helical path down the inner heat transfer surface. The liquid forms a highly turbulent thin film or annular ring from the feed nozzle to the product outlet nozzle.
Only a small quantity of the process fluid is contained in the evaporator at any instant. Residence times are low and gases or vapors are easily disengaged. The blades may also act as foam breakers. Typically about a half-pound of material per square foot of heat transfer surface is contained in the evaporator. A variety of 51 basic or standard thin-film evaporator designs is commercially available today. They are either vertical or horizontal, and can have cylindrical or tapered thermal bodies and rotors. The rotor may be one of several "zero-clearance" designs, a rigid "fixed clearance" type or, (in the case of tapered rotors) an adjustable clearance construction may be used One vertical design includes an optional residence-time control ring to manipulate the film thickness to some extent. The majority of thin film evaporators are the vertical design with a cylindrical fixed-clearance rotor.

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