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Dry Screw Vacuum Pumps for clean process applications in API Industry

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ABSTRACT
Dry screw vacuum pumps are widely used in manufacturing, pharmaceutical, nuclear research and petrochemical industries. The major advantage of dry screw vacuum pump is that it generates no oil and gas during operation, which increases its reliability. Everest Vacuum Pumping Systems are noted for their dependability and unique design, as well as their unmatched quality, value and performance. They are also simple to use and maintain. The present paper describes a particular case of distillation and drying operation of N-Methyl 4-Chloro Piperidine (NMCP) which is used as an Intermediate of Loratidine which is an Anti Hystaminic Drug. The advantage of replacing an ejector vacuum system with a dry screw vacuum pump is analyzed for various parameters. It is observed that use of dry vacuum systems results in reduction in man hours and maintenance cost. In addition, a clean product is obtained with the use of a dry screw vacuum pump.

Keywords-Superscrew, Dry screw vacuum pump, Chemical, Pharmaceutical, API

I. INTRODUCTION

Vacuum pumps come in two basic varieties: the 'wet' kind, which is essentially a hydraulic pump, and the pneumatic i.e., 'dry' variety. Both are used to create suction, which is imparted onto a dynamic substance in order to 'pull' more of that substance from the far end of a tube and generally, to use that same substance in order to perform some sort of work at the tube's far end.

Everest Vacuum, a brand of Everest Blower Systems Private Limited brings to its customers, hybrid combined variable pitch Dry Screw Vacuum Pumps. These are widely used in chemical, pharmaceutical, petrochemical, food processing, plastics, CD-DVD manufacturing, thin-film & wiped film evaporation and many other applications which require a clean and stable vacuum in general and as a central vacuum facility.

In our recent experience, we have seen more and more explorations and experimentation by process companies with different Vacuum technologies on existing processes. The conventional wet vacuum pumping is being replaced by the relatively newer dry vacuum pumping using pumps such as Roots Booster Vacuum Pump, Dry Screw Vacuum Pump and Claw Vacuum pumps. The typical wet vacuum pumps are Water jet Ejector Vacuum Pump, Steam Jet Ejector Vacuum pump, Liquid Ring Vacuum Pumps, Rotary/Reciprocating Oil Ring Vacuum Pump etc. This switch has yielded in many cases success stories and in some cases unexpected challenges, we still believe that such experimentation & trials are not only healthy to challenge the status quo, but also necessary to push the boundaries of vacuum application to drive innovation and cost saving in different industries and processes.

Vacuum Specialist when choosing the right Vacuum pumps & Systems, typically considers the following parameters to make the best choice:

1. Process Vacuum Requirement (mBar)
2. Process Pumping Capacity (m3/hr)
3. Process Carry Over vapor & its behavior when it passes through the Vacuum Pump
4. Process Carry Over discharge contamination after the vacuum pumping & its disposal with environmental regulatory compliance.
5. Utilities applicable & their availability.
6. Total Cost of Ownership over product life cycle.
7. Power Requirement and Optimisation.
8. Return on Investment (ROI).

As you see, the list of the above dynamic parameters goes beyond the mere vacuum pump selection based on the level of vacuum & capacity to rather a more holistic approach needs to be taken even though multiple vacuum pump technologies can be a possible interim solution, but the most cost efficient long term solution can be identified by making a product selection matrix which will weigh all parameters and help us in making a more

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holistic decision considering the Total Cost of Ownership over product life cycle. The parameters that constitute this matrix are as follows:

1. Total Power Consumed (Pumps & Direct Utilities)
2. Solvent Recovery and Collection Post Pump
3. Cost of Utilities
4. Cost of Treatment of Process Carry Over Contamination.
5. Production Uptime or Loss of Production by Pump Downtime.
6. Saving in Batch Cycle Time by making the right selection of Vacuum Pump
7. Increase in Process Vacuum Level leading to enhanced Product Quality/ Purity Levels
8. Cost & Ease of Maintenance, Cost of Spares.

As you see that the decision to make the right selection involves so many dynamic parameters, however to simplify & summarize this decision making process, we shall be discussing real case scenarios using a particular case study.

II. LITERATURE REVIEW

Ravindra &Ashutosh [1] performed a parametric study on the effect of root filet radius of helical gear in dry screw vacuum pumps. Several mathematical models highlighting various aspects of Dry Screw vacuum pumps have been studied by researchers around the world [2-4]. An overview of comparison between Dry and Wet technologies has been presented by Dhruv Malhotra [5]. Few case studies have been presented for a better understanding of the technology. Various technical aspects associated with Dry Technology have been presented by Everest Vacuum [6]. From the literature, it can be understood that the dry vacuum technology is still in its nascent stages and awareness needs to be created for customers to understand the benefits from an energy, exergy, economic and environmental point of view.

Research methods

The EVEREST ESPH Dry Screw Vacuum Pump (Superscrew) is a hybrid variable pitch screw, dry running non-contact type vacuum pump. Two parallel screws operate rotating in opposite directions, having a highly sophisticated surface profile consisting of an Archimedean, Quimby and an Arc curve. The driveshaft rotation is clockwise (CW) when viewed from the motor end (Drive End) of the pump. Helical timing gears position these screws relative to each other. The pumped gas is compressed into the discharged port by the synchronous rotation of the screws. The advanced screw design results in lower energy consumption compared to standard screw design. This also results in lower heat generation during the compression of the gasses/vapors.

Superscrew is the newest development in the vacuum pump industry (Fig 1). They offer a number of advantages over traditional vacuum pump designs. There is No Oil / No Water in contact with the process vapors, therefore they are considered as extremely environment-friendly. As these pumps are completely dry, the process vapor can pass through the pump without any contamination and be collected at the discharge of the system by a vent condenser. This offers the customer a very efficient vapor recovery management system and an environment friendly vacuum ecosystem.

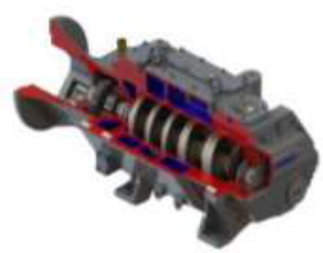

Fig 1: Everest Dry Screw Vacuum pump (Superscrew series)

Various applications of Superscrew Dry Vacuum pump are listed below:

- **Chemical & Pharmaceutical**- Degassers, Vacuum Distillation, Evaporators, Crystallizers, Vacuum filters, Vacuum Dryers
- **Vacuum Furnace Industry**- Heat Treatment, Hardening, Optical coating, Metallizing, Degassing in metallurgical furnaces
- **Electrical Industry**- Vacuum Impregnation of Transformers, industrial motors, Transformer Oil Purifier, Vacuum Phase Drying
- **Industrial Processing**- Impregnating Windings, Drying Textiles Mills, Sterilizing re-circulation through Ethylene Dioxide, Incandescent CFL and Tube Light Manufacturing, TV Tubes Manufacture
- **Food Processing Industry**- Vacuum Packaging of Fresh & Cooked Meats, Freeze Drying, Deodorization of Vegetable Oil (FFA Distillation), Sugar Refining, Vacuum Evaporative Cooling, Vacuum Tray Drying, Flash Drying

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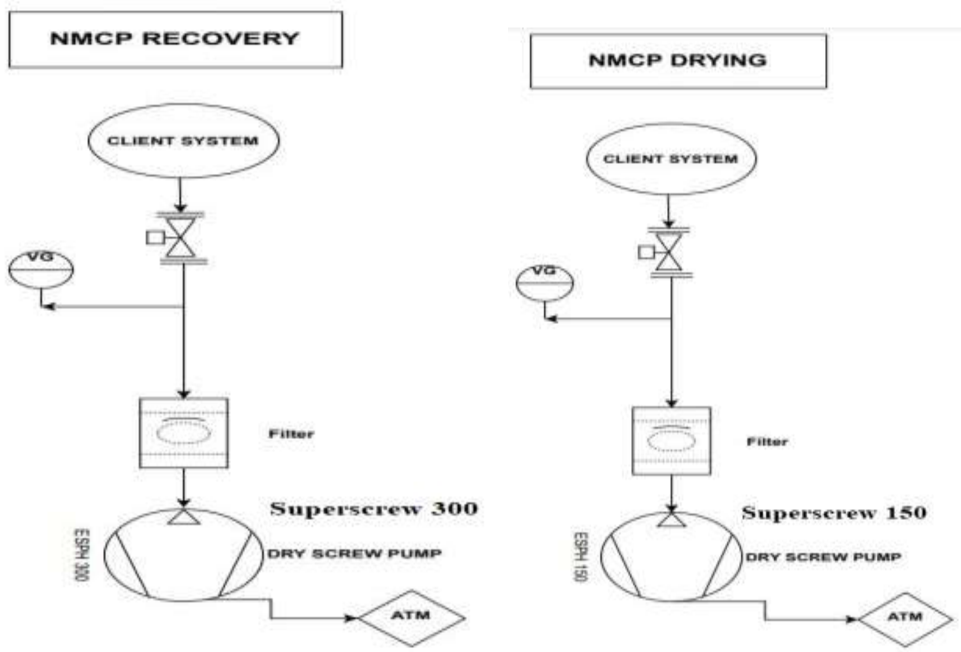
III. DATA ANALYSIS & INTERPRETATION

Let us take a case study of Distillation and Drying operation of N-Methyl 4-Chloro Piperidine (NMCP) which is used as an Intermediate of Loratidine which is an Anti Hystaminic Drug. The schematic diagrams of the distillation and Drying operations are presented below. The client system denoted in Fig 2a is the distillation reactor while that in Fig 2b is Vacuum Tray dryer. The operation in both the processes is briefly described below:

Vapor coming from the client system passes through a filter (1 micron size) and enters the Dry screw vacuum pump (Superscrew). The vacuum gauge connected measures the vacuum level of the complete package of Superscrew. At the exhaust of the screw pump, the condensate is collected by a drum.



(a) (b)

Fig 2: (a) Distillation & (b) Drying operation of N Methyl 4 ChloroPiperidine using Dry Screw Vacuum Pump

Traditionally, the distillation process has been carried out with the help of an oil ring vacuum pump. However, it has been observed that problems like oil contamination with solvent, high maintenance cost etc are occurring during every batch process. Similarly, for the drying process Steam and water jet systems have been used and significant variation in vacuum level and high maintenance cost have been observed.

Dry screw vacuum pump offers the following advantages compared to systems working on wet technology when analyzed for distillation and drying operations:

- Efficient solvent recovery from Vacuum systems
- Lower power consumption
- Low Maintenance
- Better optimization thereby reducing the manufacturing cost
- No contamination of output product
- Zero load from Effluent Treatment Plant

IV. RESULTS & DISCUSSION

A comparative study has been performed for two different cases of N-Methyl 4-Chloro Piperidine (NMCP) processing. One case uses the Oil Ring Pump for the distillation and the Water/ Steam jet ejector system for the drying process whereas in the second case, a Superscrew Dry vacuum pump is used for the distillation and drying operation. The dry vacuum system was supplied to a major manufacturer of NMCP and the results provided for various parameters by them are tabled below.

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Table 1: Comparative study of output parameters for Dry and Wet Technology

S NO	Particulars	Unit	Wet Technology (Steam/Water jet Ejector)	Dry Technology (Superscrew Dry Vacuum pump)	Remarks
1.	MFG Cost	Rs/Kg	5500	5000	Reduced By Rs 500/Batch
2.	Power Consumption	kW	11	7.5	Reduced By 3.5 kW/5 HP
3.	Effluent	KL/Month	10	0	Reduced to Zero Load on ETP
4.	ETP Treatment	m3/hr	5.5	0	Totally vanished. Cost of Treatment is zero
		Rs./Ltr	0.16	0	
5.	Solvent Recovery	Kg/Hr	0	20	Increased by 20 Kg/Hr
6.	Yield	Kg/Batch	730	780	Increased by 50 Kg/Batch
7.	Batch Time	Hr/Batch	12	8	Reduced By 4 Hrs Per Batch
8.	Man-hours	Per Batch	12	8	Reduces By 4 hours/man
9.	Maintenance Cost	Rs/yrs	50000	15000	Reduced by Rs.35000

From the table, it can be observed that Effluent generation is not present in Dry vacuum technology due to the absence of water circulation. Further, we are able to recover the solvent which in the earlier case (wet technology) was mixing with water. In addition, the cost of Effluent treatment is saved which results in overall reduction of production cost. It is observed that the overall yield of the final product increases (approx 6 % in the present case) with the Dry vacuum Technology.

Further, the batch processing time decreased significantly when Dry vacuum technology was introduced. This can be attributed to the fact that in earlier processes, maintenance of uniform vacuum over the entire process was difficult thereby resulting in fluctuations and degradation of circulating water. This aspect was taken care of with the advent of the dry vacuum system. Further, the level of vacuum and throughput can be dynamically controlled as per process requirement, using variable drive which also saves energy.

A major aspect which every organization focuses on is the maintenance cost. The replacement of the Ejector system with Dry vacuum pump resulted in significant reduction in yearly maintenance cost. In wet technology, the constant interaction between circulating water and product vapors results in the acidic nature of circulating fluid which tends to corrode the inner components of the pump. This results in regular servicing of the wet vacuum system thereby increasing the maintenance cost. All these aspects are absent in Dry vacuum systems thereby reducing the maintenance cost.

A brief cost benefit analysis in terms of various parameters is presented. The plant is operated for 300 days per year. As the batch time is reduced to 8 hours, 3 batches are possible on each day.

Table 2: Cost Benefit Analysis on using Dry Screw Vacuum Pump

S.No	**Parameter**	**Savings**
1	Effluent Cost saving (Annually)	Rs 4,80,000/- Annually (**Four Lakh Eighty Thousand rupees**
2	Value of Solvent (Pyridine) Recovery (Annually)	Rs 2,88,000,000/- Annually (**Two crore Eighty Eight lakh rupees)**
3	Additional revenue generation due to increase in yield (Daily)	Rs 37,50000/- **(Thirty seven lakh fifty thousand)**
4	Annual additional revenue due to increase in number of batches (Annually)	Rs 3,75,000,000/- **(Thirty seven crores fifty lakh)**.
5	Power Consumption saving (Annually)	Rs 2,48,220/-. **(Two lakh forty eight thousand two hundred and twenty)**

For any customer, the return on investment (ROI) is a major factor. It provides a performance measure used to evaluate the efficiency or profitability of an investment. In the present case ROI can be defined as the ratio of cost of Equipment (Superscrew systems) and total savings (Solvent recovery+Effluentcost+power savings). In the present case, the total cost of the equipment is about **Rs 20 lakhs** and the total savings amount to about **Rs 295 lakhs** resulting in an ROI of **0.067**. This means that the investment into a Dry screw vacuum system will result in better output along with faster payback of the investment.

Research Implications

Dry Screw Vacuum Pumps are known for generating vacuum in any industry where the requirement of clean vacuum exists, as the name suggests there is no lubricating/sealing fluid in the working chamber and no contact between the parts even with tight clearances within the pump. Thus, producing an oil free dry pumping is an unique characteristic to this type of pumping technology, ideally suitable for modern technologies.

The cornerstone of recognizing the potential of any technology is to provide global outreach of the phenomena. As part of this endeavor, Everest Vacuum has been granted 2 patents and 2 Design protection on Dry Screw Vacuum Pump and Mechanical Booster. A brief overview on the scope of the patents is presented below:.

Patent 1 & Patent 2 (Fig 3): This invention relates to the technical field of Dry Screw Vacuum Pumps. More Particularly, the invention relates to the Dry Screw Vacuum Pump having rotors uniquely designed to minimize premature bearing failure and a combination of sealing arrangements to avoid leakage in order to enhance the performance of the pump.

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Fig 3: Patents granted to Everest Vacuum on Dry Screw Vacuum pumps

Further, we have been granted Design Protection (Fig 4) for the Dry Screw Vacuum pump.

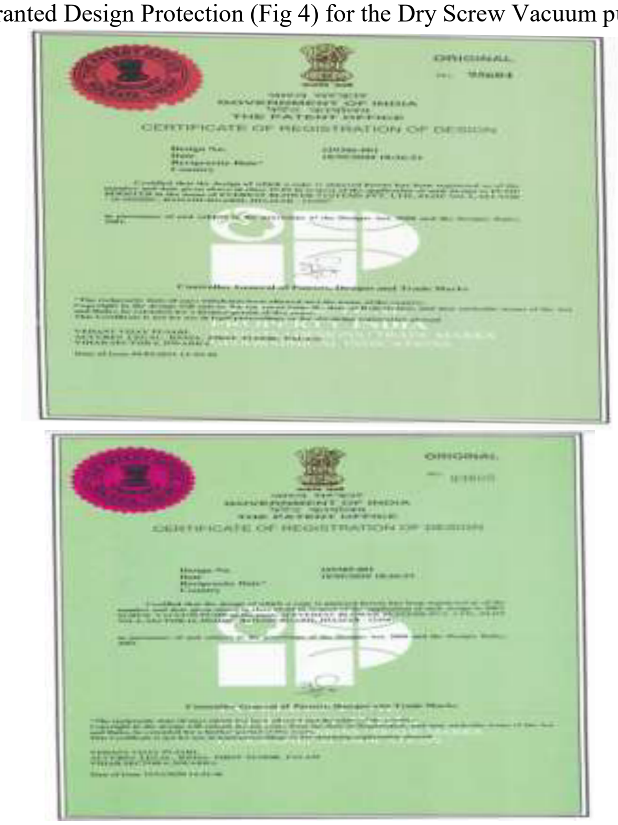

Fig 4: Design Protections granted to Everest Vacuum on Dry Screw Vacuum pumps

V. CONCLUSIONS

When choosing the right vacuum pump for your process application, it becomes very important to look beyond the vacuum level & the pumping speed. A well sought after design/ selection should consider the following aspects while making the selection:

Parameters playing a critical role in making the right choice:

1) Process Vapor/Gas Carryover: Dust, Powder, Liquid, gas, Vapor etc?

How to filter/separate/condense incoming process carryover? How will ingested process carry-over interact with the pump's internal components or seal fluid?

2) Environmental Constraints: What are the regulatory restrictions and what is the cost of

treatment of contaminants at the discharge of the vacuum pumps?

3) Utilities Available: Compressed Air/Nitrogen Cost, Chilled Water /Cooling Water Cost and Capacity availability, Water Treatment Cost & Capacity Availability etc.
4) Total Cost of Ownership Over product Life Cycle: Service Interval, Cost of Spares & Consumables, Labor Cost, Equipment downtime Cost, etc..
5) Other important Factors: Noise Limitation, Housekeeping, Central v/s Decentralized Vacuum Systems, Preventive Maintenance Schedules, Spare Parts & Consumable Inventory management, etc.

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