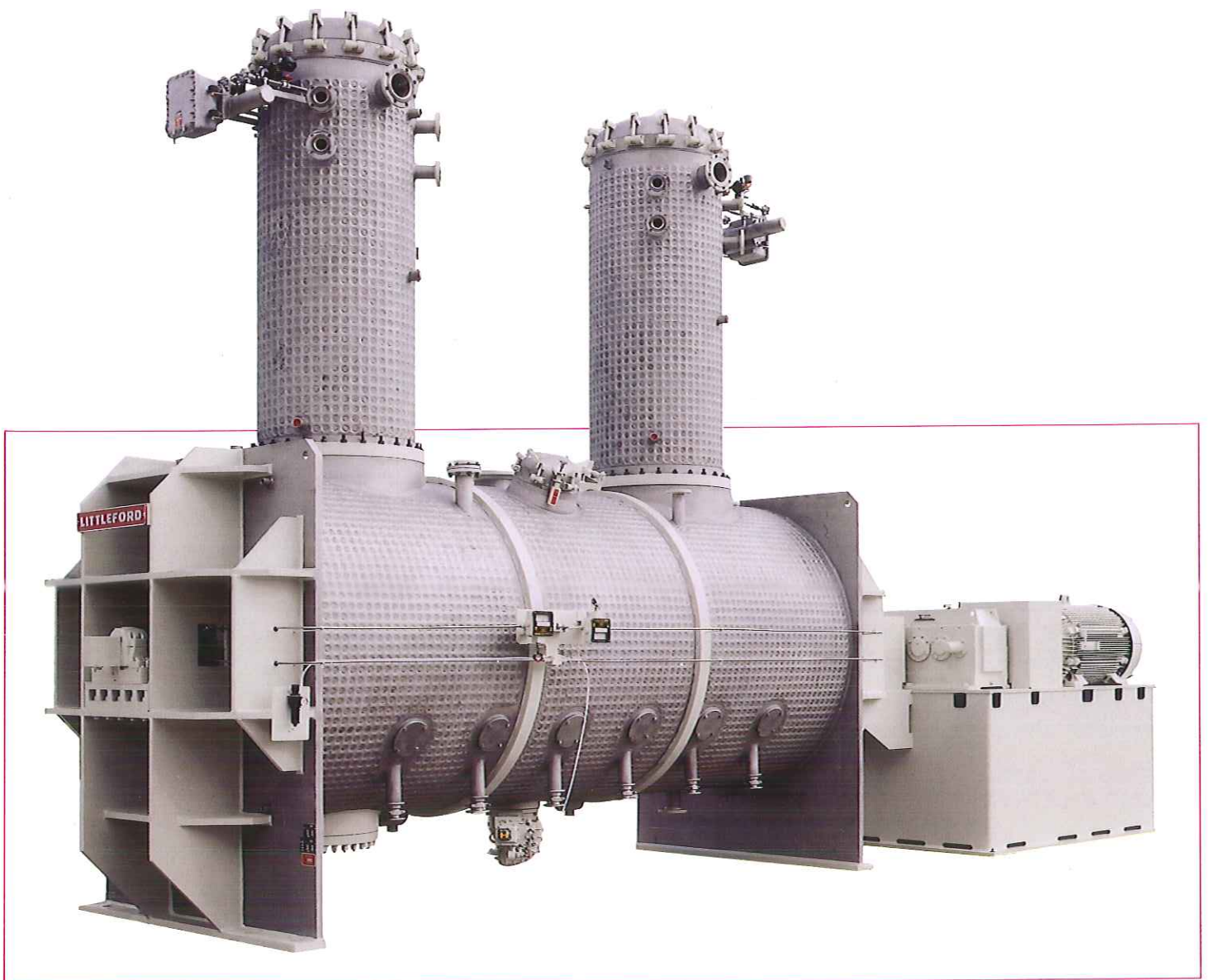


Littleford

Advanced Drying Technology



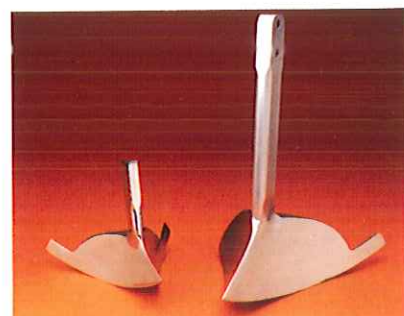
Littleford Advanced Drying Technology

Littleford drying technology brings unmatched efficiency and economy to the drying function

- Offers high-efficiency drying of suspensions, pastes, and bulk materials
- Provides complete dispersion of agglomerates, lumps, and fiber bundles
- Allows homogeneous mixing of dissimilar ingredients
- Offers the capability of drying the product from a liquid state to a free-flowing powder in one process vessel
- Permits liquid addition during processing
- Adapts itself to effective recovery of costly solvents
- Facilitates batch control sampling
- Offers fast drying cycles and discharge
- Provides easy clean-out, along with minimum maintenance
- Meets FDA and USDA sanitary design, if required
- Allows efficient, complete drying of temperature-sensitive materials at low temperatures
- Eliminates need for additional processing equipment and expense
- Offers methods and designs which minimize explosive conditions, oxidation of the product, and overwetting the product during mechanically agitated drying



*Littleford VT Ploughshare Vacuum Dryer.
Capacity: 4,200 Liters*



Littleford Unique Plow Shaped Mixing Tools

COVER PHOTO:

Littleford 20,000 Liter Ploughshare Vacuum Dryer with 5,280 Gallon Capacity, 400 HP Drive and two 150 FT.² Pulse Back Filters

Overview of Drying Technologies

Effective drying is often the crucial step in many production operations. In addition to its obvious importance in generating an attractive and usable product, it is frequently utilized to facilitate product handling, reduce shipping costs, increase other process equipment capacities, and optimize product integrity during shipment and shelf life during storage.

Merely placing a wet solid material in an oven and applying heat will eventually produce a dry product. A low or high speed tumbling device will, after sufficient time, have the same result. Tray drying is yet another time-consuming method of drying a product. All of these materials focus on one objective – drying – without respect to temperature sensitivity of the product, volatility of the materials, flammability of the volatiles, friability or shear sensitivity of the product, cycle time considerations, environmental constraints, and pre- or post-drying processing steps.

In simple terms, there are just two conditions for drying materials – atmospheric and vacuum. In either condition, the objective is to remove volatiles from a wet solid material.

Littleford Ploughshare® Dryer

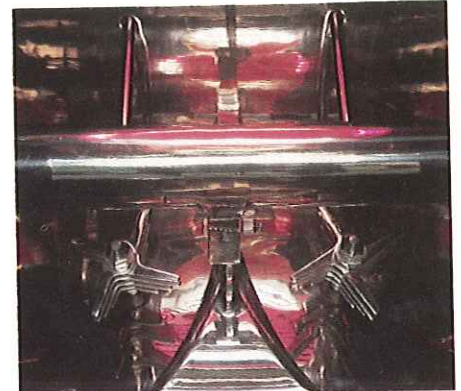
The key to Littleford state-of-the-art drying technology is the unique, mechanically fluidized ploughshare action which agitates and individualizes the solid particles to be dried. This ploughshare action within the horizontal, cylindrical Littleford vessel forces the product into a three-dimensional motion that individualizes each particle, continuously exposing tremendous particle surface area for drying. The particles constantly contact one another and the heated interior walls of the jacketed Littleford vessel, furthering the drying process.

Additionally, Littleford Ploughshare Dryers, equipped with independently operated, high shear "chopper" devices, reduce the particle size of the lumps or agglomerates

to expose undried materials and ensure thoroughly dried particle interiors. Deagglomeration further shortens the drying time required.



Fluidized Bed Mixing Action
(shown at 1/200 second exposure)
Inside Littleford Ploughshare Dryer
(mixing plow and choppers)



Drying Comparison

A comparison of operational parameters of atmospheric and vacuum drying is helpful in selecting the most effective dryer for your product.

ATMOSPHERIC DRYING IN A LITTLEFORD PLOUGHSHARE DRYER (with dry gas purge)

Batch temperature during drying cycle is near the atmospheric boiling point of the volatiles being removed. Atmospheric drying is excellent for many materials but usually not suitable for temperature-sensitive materials.

Large volume of gas/air in the vapor stream makes solvent recovery expensive. Atmospheric drying is not recommended for flammable solvents or where environmental restrictions are imposed.

Non-saturated atmosphere works very well with shear-sensitive materials.

Drying cycles are substantially shorter than with other types of dryers but are not as efficient as vacuum drying because of smaller temperature differential (jacket to product) available for drying.

VACUUM DRYING IN A LITTLEFORD PLOUGHSHARE DRYER

Batch temperature during drying cycle is much lower than the atmospheric boiling point of the volatiles being removed. Vacuum drying is excellent for temperature-sensitive materials.

Entirely enclosed system makes solvent recovery very easy, and works well with flammable solvents or where environmental restrictions are imposed.

Saturated atmosphere necessitates parameter changes to the process including speeds to avoid over working shear-sensitive material.

Drying cycles are shorter because of larger temperature differential (jacket to product) due to the lower boiling point under vacuum conditions.

Both the Littleford atmospheric and vacuum drying processes are based on state-of-the-art mechanically fluidized bed mix action augmented by the high shear chopper, the combined effect of which leads to Littleford efficient thermal processing technology. Although the atmospheric dryer is efficient in drying shear-sensitive materials which are not temperature limited, a vast number of drying applications require lower temperature processing and/or shorter cycle times. Thus, in most applications, the highly efficient Littleford Ploughshare Vacuum Dryer is the recommended drying process.

Littleford Advanced Drying Technology

Stages of Drying

An examination of the physical stages in the drying process will reveal why the action of the Littleford Ploughshare Vacuum Dryer is so efficient.

Materials go through several physical stages during the drying process – Paste, Granule, and Powder. During the early portion of the Paste Stage (see Figures 1 and 2), the product is a thickening slurry which is readily put into turbulence by the action of the plows. This is because the Littleford Ploughshare Dryer has been designed and engineered to achieve the critical Froude number (the point at which the plows force the batch into turbulence and thus maximize the heat transfer capability of the dryer), as shown in Figure 3. The Littleford

Ploughshare Dryer's attainment of the critical Froude number enables fast, efficient transfer of the BTU's required to satisfy the latent heat of vaporization, thus generating a much shorter drying cycle.

Conventional dryers do not begin to achieve Littleford drying rates, even in this Liquid Stage of the drying curve where drying is most easily accomplished. Figure 4 compares the heat transfer coefficients attainable in several dryers. As can be seen, the Littleford Ploughshare Dryer exhibits superior heat transfer coefficients, often two or three times higher than those of a ribbon or paddle dryer. In the case of tumble or tray dryers, the Littleford Ploughshare Dryer can provide coefficients ten times higher.

As the slurry thickens at the end of the Paste Stage (end of the constant

rate period), the batch thickens to a mud-like consistency, which in conventional dryers causes the batch to ball or cake. This makes drying exceedingly difficult, since moisture (volatiles) must migrate from inside through capillaries to the particle surface before it can be flashed off. This point on the drying curve is where the limited drying rate of conventional dryers gets even worse, as internal particle drying replaces efficient external drying.

In the Granule Stage, Littleford Ploughshare Dryers, utilizing both the action of the turbulent plows and the high shear choppers, reduce the forming lumps to smaller granules, thus exposing large amounts of new surface area for drying. Choppers are high-speed (3600 RPM) impact devices composed of four or more blades mounted upon the rotating shafts of independently operated motors. The chopper action allows

Figure 1—STAGES OF DRYING

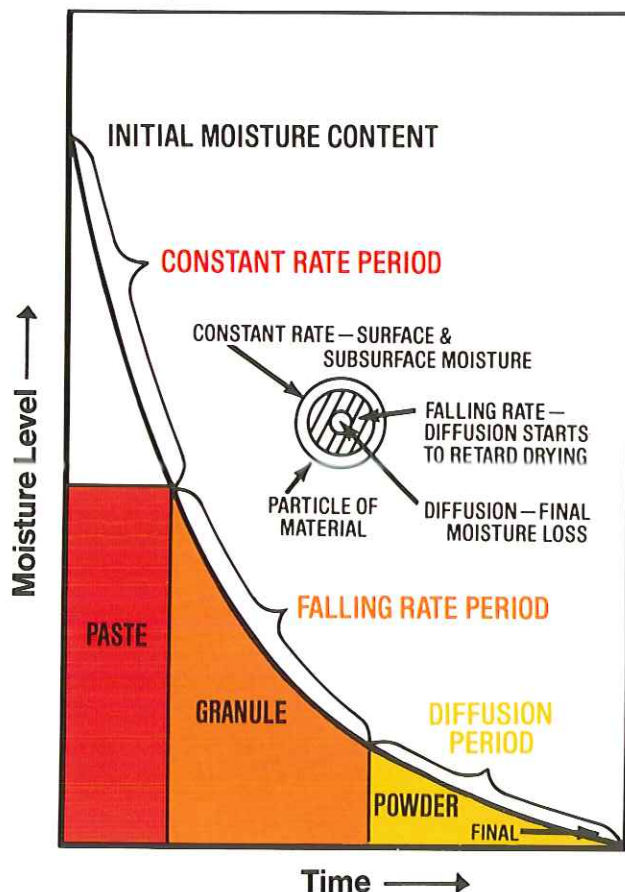


Figure 2—CLASSIC DRYING CURVE

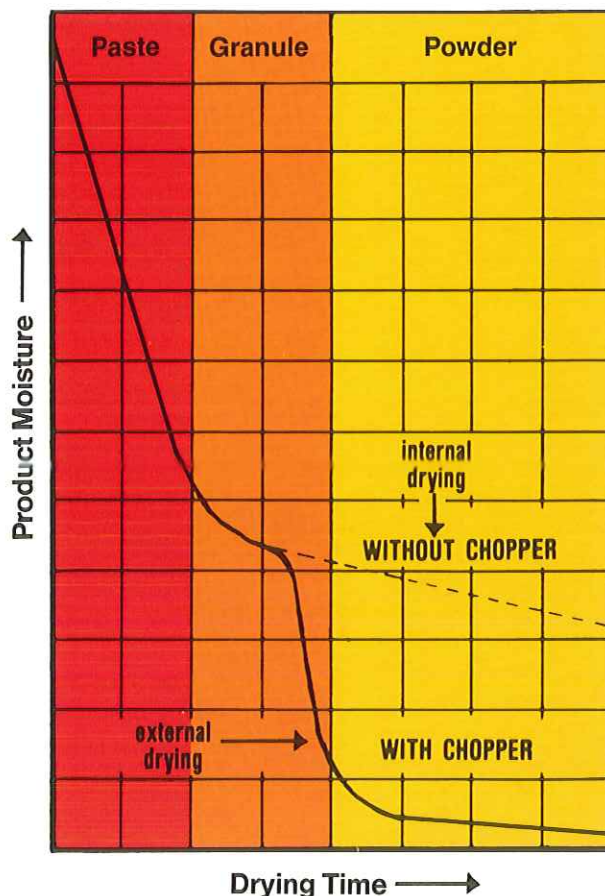


Figure 3—HEAT TRANSFER CAPABILITY

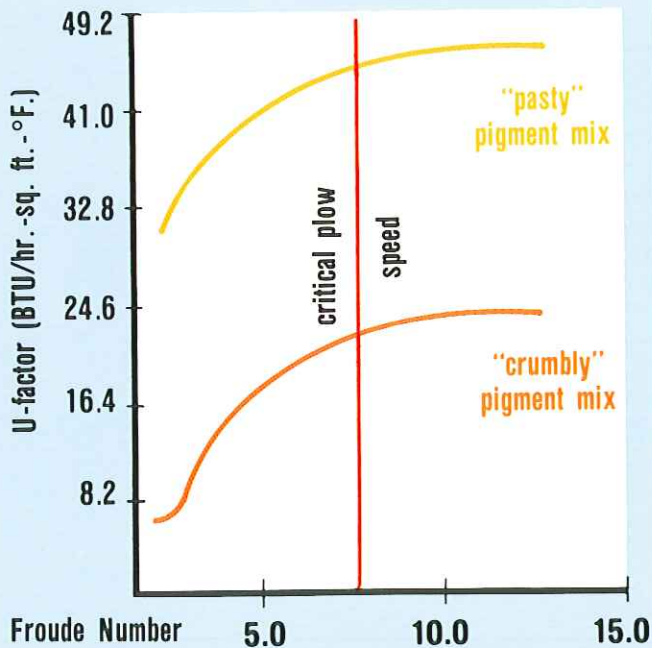
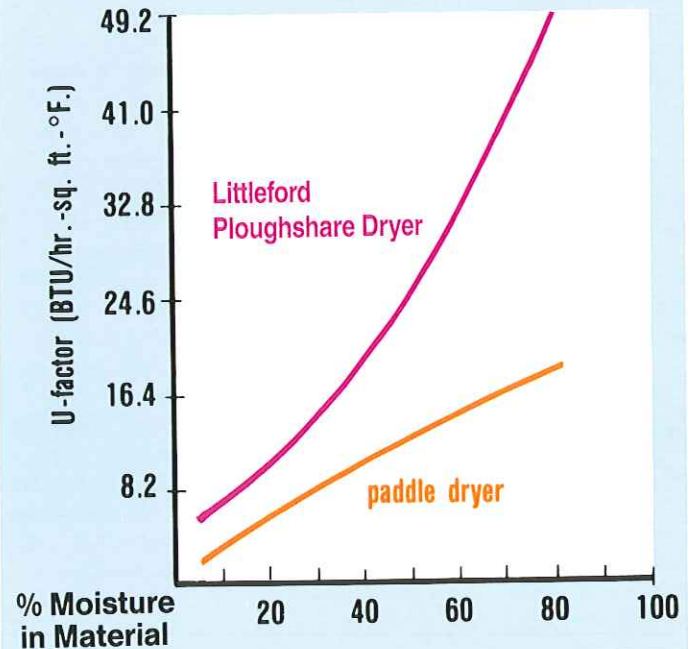


Figure 4—HEAT TRANSFER COEFFICIENTS

(Comparative example: aqueous pigment paste—highly plastic)

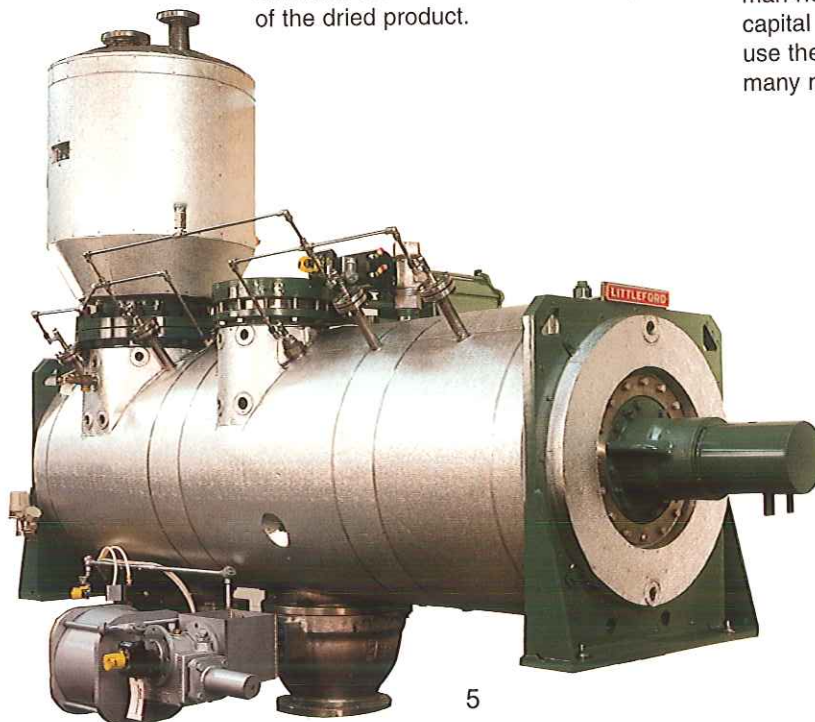


the faster external drying mechanism to remain in effect, thus shortening the drying time. As seen in Figure 2, the slower internal drying rate caused by the formation of lumps is driven back to the faster external rate by the action of the chopper on the lumps.

As the product moves from the Granule to the Powder Stage, continued use of the high shear chopper will break the drying granules into a fine powder.

Depending upon the friability of the lumps, use of the choppers may eliminate the need for further milling of the dried product.

In summary, the efficiency of the Littleford Ploughshare Dryers, due to the turbulent action of the plows combined with the high shear dispersive action of its choppers, generates much shorter drying cycles compared to conventional equipment. Shorter cycles means not only less cost in man-hours and energy, but also less capital cost, since the processor can use the Littleford Ploughshare Dryer many more cycles per day.



Littleford Advanced Drying Technology

Littleford Dryers Go Beyond One Function

The versatility and economies of a Littleford Ploughshare Dryer result from its ability to do more than just effectively dry materials. For example, when specific process needs dictate, a Littleford Ploughshare Dryer can perform efficient homogeneous mixing prior to, during, or after the drying process.

Optionally available add-ons can increase its versatility and economy even further. These include:

The Littleford patented Filtorr® liquids-solids separator, which facilitates washing and extracting prior to the drying process. The internally-mounted Filtorr® allows the consecutive processing steps of mixing, reacting, filtering, washing, and drying – all carried out in a single process vessel instead of in the several process vessels previously required.

Pulse Back Filters can be added to effectively handle the vapor stream created during drying. In a typical application, a Pulse Back Filter is used to filter the vapor stream from the dryer in order to prevent product carry-over into the condenser. The filter is heated slightly higher than

the dew point of the vapor, thus preventing condensation. The filter housing is constructed of material to meet customers' specifications and is equipped with a removable head and an ASME code constructed jacket. Filter bags of proper porosity are mounted over stainless steel cages and can easily be removed through the top section of the filter housing. A pneumatic pulse jet system provides continuous automatic bag cleaning down through a venturi at the top of the bag. Since this pneumatic shock wave clears only one row of bags at a time, there is no interruption of vapor flow through the filter. This provides a smoothly operating dust control system.



Fast Vacuum Drying Cycles Save Time and Money

Compared to other drying methods in use today, the Littleford Ploughshare Vacuum Dryer is several times faster (and more efficient), thus greatly reducing man-hours, energy requirements, and associated costs, while increasing productivity. Under most circumstances, a Littleford Ploughshare Vacuum Dryer is at least two to three times faster than a ribbon or paddle dryer. Compared to a tumble dryer, it is six to ten times faster. It is many times faster than tray drying – and without the mess.

Environmentally Clean/Safe/Controlled Drying

Since a properly equipped Littleford Ploughshare Vacuum Dryer is a totally enclosed cylindrical vessel, there is no chance of toxic gases or solvent vapors escaping to the atmosphere and contaminating the workplace. Moreover, a properly sealed Littleford Ploughshare Vacuum Dryer, fully evacuated, refilled with inert gas, and reevacuated to full vacuum, will prevent oxidation of products, even at elevated working temperatures. Unlike other dryers, the Littleford Ploughshare Vacuum Dryer does not require physical contact with the material – critical when drying toxic materials. The Littleford Ploughshare Vacuum Dryer equipped with rupture disc and explosive venting greatly reduces the hazard associated with drying under explosive conditions.



Optimum Operation At High Temperatures/Pressure

A Littleford Ploughshare Dryer can operate safely at temperatures up to 450°F. Units are available for even higher operating temperatures, depending upon the specific application. Littleford Ploughshare Vacuum Dryers are structurally designed and constructed to operate at full vacuum. Littleford Day designs and manufactures vessels that operate under both pressure and vacuum conditions.

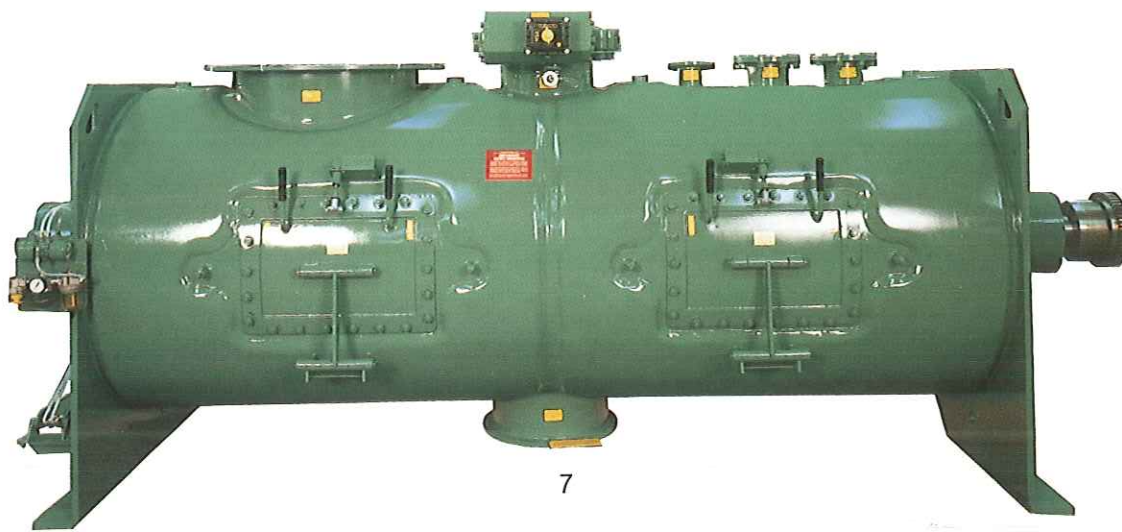
ASME code constructed heat transfer jackets on Littleford Ploughshare Dryers are normally designed to operate at 75 p.s.i.g. pressure rating. Higher pressure jackets are available. A standard 75 p.s.i.g. jacket allows the use of steam at a maximum temperature of 320°F, or recirculating water or hot oil for temperatures above or below the capabilities of steam.

Optional Solvent Recovery Systems

Littleford Day provides sophisticated Solvent Recovery Systems to match their dryers. These systems include a heat exchanger, recovery tank, vacuum pump, and all of the associated controls, accessories, and hardware.

Littleford Day Specifically Designed Seals

For many drying applications, conventional packing type seals are adequate. However, all Littleford Ploughshare Dryers can be equipped with either special nitrogen purge seals or with double-face mechanical seals on the main shaft and chopper shafts. Seal integrity is an integral part of Littleford Ploughshare Dryer performance.



Littleford Advanced Drying Technology

Littleford Day Provides State-Of-The-Art Controls

Monitoring and analyses of process data generated by the drying product enables precise control of the entire drying process. At the start of the drying cycle, the product temperature and vapor temperature both level out at a given temperature equilibrium. During the early cycle, the power (watts) required slowly increases as the batch thickens. At the onset of the Granule Stage, the power rises markedly on the viscous batch and does not start to drop until the batch breaks over into Granules. From this point in the cycle the power continues to drop while the batch temperature rises slowly. As the final few percent of volatiles are removed from the batch, the power drops slowly until it eventually becomes level. Finally, the vapor temperature in the vacuum lines decreases and without evaporative cooling, the batch begins to heat up very rapidly, indicating that drying is completed.

With the proper state-of-the-art instrumentation, it is not only feasible to insure that a processing cycle as involved as drying meets the established criteria for that process, but also to ensure that the same product quality is reproducible from run to run. This is utmost importance in meeting government standards on Process Validation in the pharmaceutical industry.

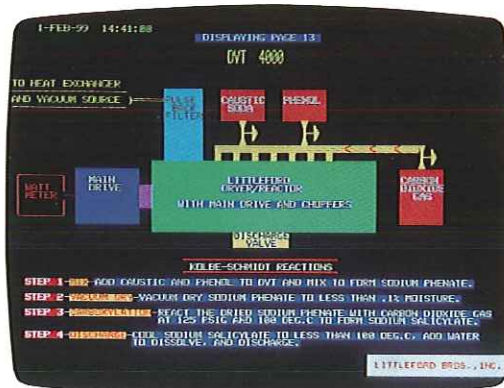
Total control of the entire drying process can be facilitated with a programmable controller (PLC). With the PLC the customer is able to regulate and control vacuum levels, jacket heating, chopper timing, and duration, plus control and documentation of any number of required process steps.

Partial instrumentation of the drying process can also be extremely valuable.

Recording Watt (power) meters can be used to accurately measure total energy (KWH) usage and to detect when the material passes through the various stages of drying; i.e., Paste, Granule, and Powder.

A Temperature Chart Recorder device can be added to record temperature profiles, thereby documenting completion of the drying process.

Littleford Ploughshare Dryers can also be entirely mounted on load cells to detect volatile loss by monitoring change in the mass weight of the unit and its contents.



Process Testing And Development Begin At Littleford Day

For many customers, a partnership with Littleford Day begins in our unique Process Testing and Development Center at our headquarters in Florence, Kentucky. Your company will quickly discover the advantages of the Littleford Day technologically-advanced dryers which will help you achieve superior results.

The technical center is staffed by Littleford Day engineers, chemists and technologists who understand your specific applications and can recommend the best drying equipment and solutions for your needs. Once you build a working relationship with us during your Process Testing and Development Program, we are confident Littleford Day will become your choice for the right technology.

FKM Series Atmospheric/Vacuum Dryers

Littleford FKM Series Ploughshare Atmospheric/Vacuum Dryers produce uniformly dried products in economical drying times. These vessels promote drying much more efficiently than conventional dryers. They are designed to operate at levels down to 125mm of Hg absolute (25" Hg. reference vacuum). For increased levels of vacuum, pressure, or temperature, Littleford Day offers the VT and DVT Series Ploughshare Vacuum Dryers described below.

VT Series Vacuum Dryers

Littleford VT Series Ploughshare Vacuum Dryers operate on the same principles as the FKM Series Dryers, but are designed to meet more rigorous requirements of increased vacuum and higher temperatures. They also provide efficient and thorough drying at lower temperatures. VT Series Dryers are designed to operate up to full vacuum and 50 p.s.i.g.

DVT Series Vacuum Dryers

For applications which require pressure ratings greater than 50 p.s.i.g., Littleford Day offers the DVT Series Ploughshare Vacuum Dryer. Like other Littleford Dryers, the DVT Series Dryer operates on the mechanically fluidized bed principle to yield an extremely high solid surface area per pound of dry solid.



STANDARD SIZES OF FKM PLOUGHSHARE DRYERS

Total Capacity				Total Capacity			
Model No.	Liters	Gallons	Cu. Ft.	Model No.	Liters	Gallons	Cu. Ft.
FKM-300D	300	79	11	FKM-4200D	4200	1109	148
FKM-600D	600	159	22	FKM-6000D	6000	1584	212
FKM-1200D	1200	317	42	FKM-8000D	8000	2113	283
FKM-1200E	1200	317	42	FKM-10000D	10000	2642	353
FKM-2000D	2000	530	71	FKM-15000D	15000	3960	530
FKM-2000E	2000	530	71	FKM-20000D	20000	5284	706
FKM-3000D	3000	792	106	FKM-25000D	25000	6605	883



STANDARD SIZES OF VT AND DVT PLOUGHSHARE DRYERS

Total Capacity				Total Capacity			
Model No.	Liters	Gallons	Cu. Ft.	Model No.	Liters	Gallons	Cu. Ft.
VT/DVT-300	300	79	11	VT/DVT-6000	6000	1584	212
VT/DVT-800	800	211	28	VT/DVT-8000	8000	2113	283
VT/DVT-1250	1250	330	44	VT/DVT-10000	10000	2642	353
VT/DVT-2000	2000	530	71	VT/DVT-15000	15000	3960	530
VT/DVT-3000	3000	792	106	VT/DVT-20000	20000	5284	706
VT/DVT-4200	4200	1109	148	VT/DVT-25000	25000	6605	883

Littleford Advanced Drying Technology

Littleford Day Drying Applications

Below are listed a few of the many applications for which Littleford Ploughshare Dryers have been providing excellent results. Consult your Littleford Day Sales Engineer or the Littleford Day Technical Center for information and/or specific details on these or other applications.

A-B-C

Acetquanamine
Acetyl Salicylic Acid
Acrylic Powder
Agricultural Herbicides
Aluminum Hydroxide Slurry
Animal Byproducts
Animal Feed Products
Animal Waste for Fertilizers
Barium Stearate
Boric Acid Solution
Brewer's Yeast
Cadmium Oxide
Calcium Stearate
Carbon Black
Carbon Fibers
Carboxy Methyl Cellulose
Carrageenan
Catalyst
Cellulose
Cetylpyridinium Chloride
Chemical Dye Intermediate
Chocolate
Citric Acid
Coal Ash Slurry
(removal of anthracene oil)
Cocoa (Dutching)
Cocoa (Processing)
Coffee (Decaffeinating)

D-E-F-G

Dental Adhesive
Dextrose
Dye Intermediates
Enzymes (Temperature Sensitive)
Ethyl Cellulose
Fillers
Fish Meal
Flammable Sludges
Flour (toasting)
Friction Material
Graphite Filter Cake

H-I-J-K-L

Herbicides
Inks
Inorganic Filler Powders
Iron Oxide Filter Cake
Lead Phthalates



Lead Stearates
Lecithin Oil Extract
Liquid Fungicides
Lithium Fluoride

M-N-O-P

Magnesium Stearates
Metal Binders
Metal (Precious) Reclaim
Methyl Cellulose
Modified Protein Powder
Molybdenum Disulfide
Paint Sludge Slurry
Para Toluene Sulfonate
Paraformaldehyde
Peat Moss (Vermiculite Mix)
Penicillin Powder
Pesticides

Pharmaceutical (Intermediates)
Photographic Process Sludge
Pigments
Plastic Resin Beads
Polyethylene
Polymers
Polyvinyl Alcohol
Potassium Boro Fluoride
Potassium Phenate
Printing Inks
Protein Modifications
Psyllium Seed

Q-R-S-T

Refracting Powders
Resin Beads
Selenium Metal Filter Cakes
Silicon Dioxide
Sodium Methylate
Sodium Phenate
Sodium Stearates
Specialty Chemicals
Starch Powder
Sulfonated Polystyrene
Temperature Sensitive Enzymes
Tungsten Carbide Slurry
Toxic Sludges

U-V-W-X-Y-Z

Vitamin Mix
Wet Friction Lining
Wheat Bran (Stabilization)
Wheat Farina (Instantization)
Wheat Germ (Stabilization)
Winnofil Filler Powder
Zinc Diacrylate



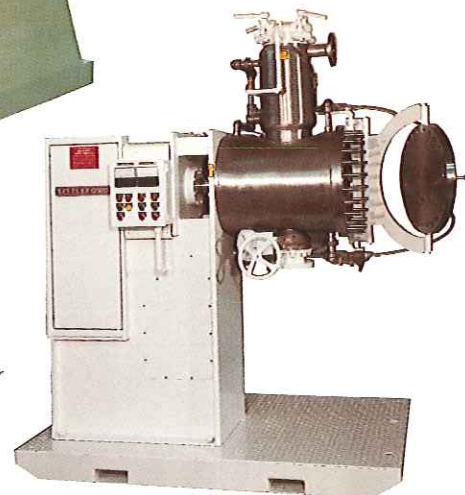
Littleford DVT-800 Ploughshare



Littleford FM-130 Ploughshare Dryer



Littleford DVT-130 Ploughshare Dryer



Littleford Day Testing Program

In keeping with its pioneering work in advancing drying and thermal processing technology, Littleford Day maintains a modern, sophisticated Technical Center wherein customers' and prospective customers' products can be dried in both atmospheric and vacuum dryers. These test dryers range in size from 5 liters, 130L, 800L up to 1200L.

The high efficiency labyrinth design jackets on the test dryers are hooked up via plumbing manifolds to sources of chilled, warm and hot water, steam (up to 75 p.s.i.g.) and hot recirculating heat transfer oil. The piping in and out of the jacket is equipped with thermocouples to monitor both the incoming and outgoing jacket temperatures. Instrumentation and support equipment for the test dryers is typically set up to monitor at least the following parameters: profiles on product temperature ingoing and outgoing jacket temperature,

recovery of jacket condensate, power consumption of the plows and chopper, vapor temperature in the vacuum lines, condensate recovery of the volatiles, % volatiles in representative samples, vacuum levels during drying, air/gas purge rates during drying, and the final material balance on all the components of the starting materials. If the drying test also involves filtration then the additional parameters of filter design, filter placement, choice of filter media, utilization of decanting, plow design, etc. will also be investigated in order to optimize the filtration/drying process.

The scope of drying tests may range from the very simple all the way to filtering, washing and drying a slurry down through a granule to a lump-free powder – followed by higher temperature drying cycle to remove the final chemically bound water (moisture of hydration) from the product.

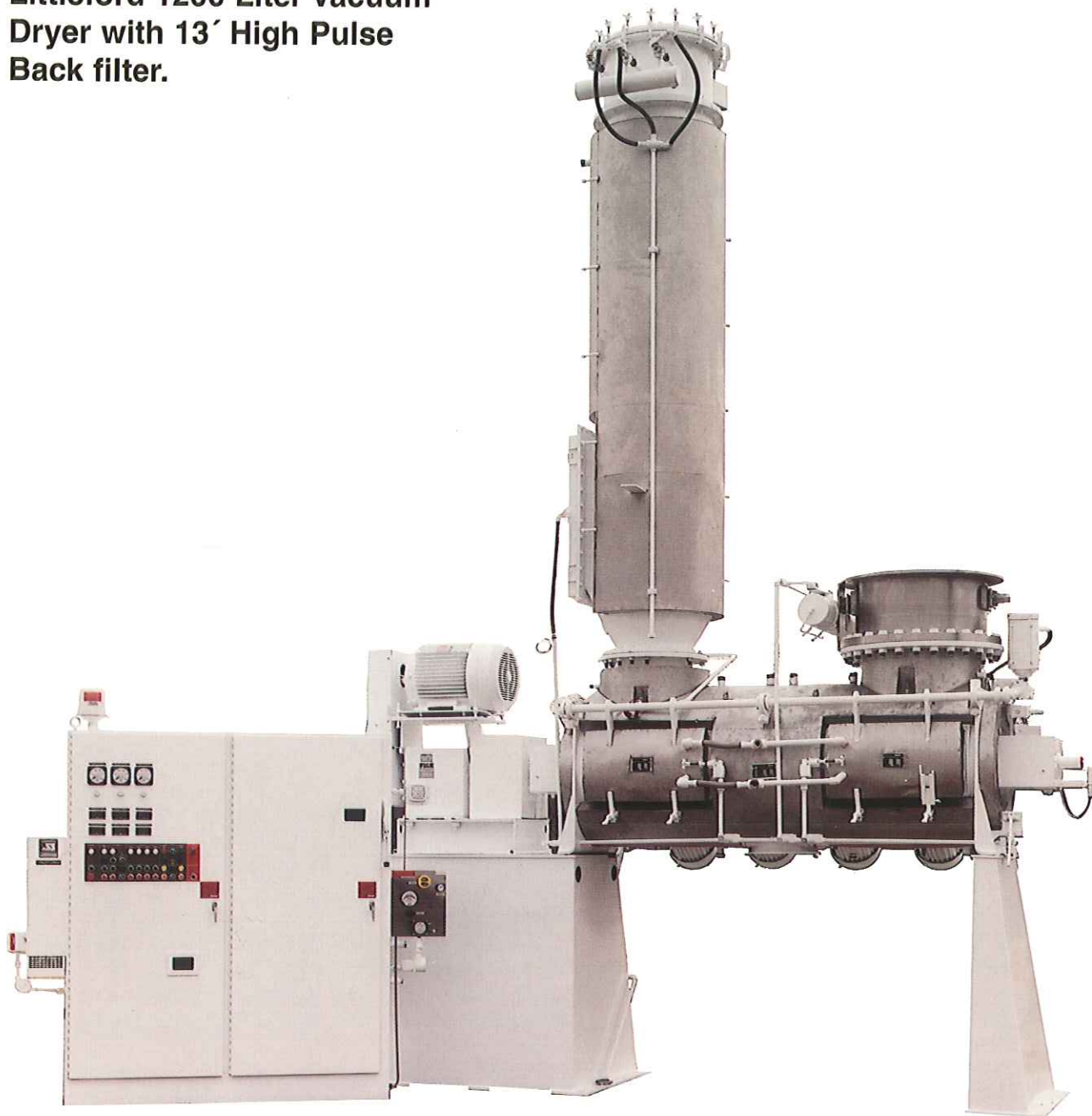
Littleford Day is confident that you will find the data compiled during the test program to be valuable and useful in assessing Littleford Day drying equipment for your application

Littleford Day Trial Demonstration Program

Your Littleford Day Sales Engineer can arrange for the rental of a trial demonstration mixer or dryer (FKM, VT, or DVT Series in the 130L, 800L and 1200L size) for testing in your own plant. Our Trial Demonstration Program offers potential customers in the processing industry a unique opportunity to test Littleford Day equipment in their own manufacturing environment.

Through the Trial Demonstration Program, you are able to determine the processing advantages and efficiencies of the Littleford Day equipment without large commitments of research and development funds.

**Littleford 1200 Liter Vacuum
Dryer with 13' High Pulse
Back filter.**



You can visit us on the Internet.

URL Address: <http://www.iac.net/~littlefd>

E-mail Address: littlefd@iac.net

Littleford Day
Where Processing Ideas Become Reality

Dimensions, weights, production capacities and other specifics cited in this literature are illustrative only and may be subject to many variables. The only warranty applicable is our standard written warranty. We make no other warranty, expressed or implied.

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