THE LABORATORY FLUID BED DRYER

INSTRUCTION MANUAL

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INSTRUCTION MANUAL

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1. INTRODUCTION

1. THE BASIC PRINCIPLES OF FLUIDISED BEDS

When a stream of gas is passed upwards through a bed of material at a certain velocity the bed will first expand, then become suspended and agitated by the gas stream to form a fluidised bed. This has the appearance of boiling liquid due to the formation of many small bubbles - the so-called "bubbling fluidisation".

At higher gas velocities, larger bubbles and plugs of material are formed resulting in a more violent type of fluidisation called slugging or spouting. Although smooth bubbling is preferred, some materials - especially those of uniform size - may be more amenable to spouting fluidisation. The optimum operating gas velocity for bubbling fluidisation lies above the minimum fluidising velocity but below the velocity of entrainment of the material.

1.2 THE DRYING PROCESS

If a bed of wet material is fluidised by a heated air stream, as in the laboratory batch dryer, the conditions are ideal for drying. The very efficient contact between gas and solid particles due to the turbulence of the bed results in high heat transfer rates causing rapid evaporation (mass transfer) of moisture which is carried away with the exit air. This process has a high thermal efficiency because most of the heat input is used in vaporising the moisture and the exit air only rises in temperature as drying nears completion.

Because of the very good mixing of particles in the fluidised state, the conditions of temperature and moisture content are uniform throughout the bed, therefore a uniform product is obtained. Also the product is not affected because fluidisation causes very little abrasion and the temperature can be adjusted to ensure no loss of properties for heat-sensitive materials.

The same principles apply for industrial fluid bed driers - both batch and continuous types, therefore the laboratory fluid bed dryer can be used to assess the feasibility of different materials for large scale fluidised drying.

2. THE LABORATORY FLUID BED DRYER

The dryer is of simple compact design conveniently portable and easy to operate, the only requirement being a mains power supply. The cabinet contains the air distribution system and electrical controls. Air is drawn in through a mesh filter in the base of the cabinet and blown by the centrifugal fan over a 2 kw electrical heater and through a stainless steel filter gauze at the base of the dryer body.

The tub unit consists of a container with a fine mesh nylon gauze air distributor and stainless steel support gauze. This channels the air uniformly and support the bed. A filter bag which fits over the top of the tub retains any particles expelled from the fluidised bed. Filter bags are available in nylon, terylene and polypropylene to suit a range of process conditions.

2.1 DRYING TUBS

The tub unit locks into position within the cabinet by a simple bayonet fitting and the base of the tub is removable to allow replacement of the distributor gauze. The filter bag for the exit gases has a retaining ring which slips over the top of the tub.

Tubs are available in two sizes: 2 litres and 5 litres and two materials - stainless steel and glass.

High grade stainless steel is used where the process requirements are for high product purity and good chemical and corrosion resistance at high temperature.

Glass tubs are particularly useful for observation of the fluidising process and condition of the material, and determinations of the optimum fluidising velocity, which gives the required smooth type of bubbling fluidisation.

The multi-tub head - using four small capacity tubs - is a useful addition to the dryer. It enables small quantities of material to be dried simultaneously and rapidly, either as a preliminary to further processing, as may be required in research laboratories, or for moisture determinations in analytical and process control laboratories.

2.2 THE DRYER SYSTEM

The dryer cabinet incorporates an electrical heater, temperature controller, timer and air blower fan.

The air blower is controlled by a thyristor circuit to give a smooth variation over a wide range of motor speeds. This enables efficient fluidisation to be achieved for different materials, and gives fine control of the drying temperature.

Some materials, particularly uniformly size materials like peas or lentils, may be difficult to fluidise smoothly. However, the more violent slugging or spouting type of fluidisation may be obtained which also has good heat transfer characteristics, and has applications in drying of granular materials and foodstuffs, coating of tablets, and granulation of fertilisers.

The heater is a 2 kw finned element which gives air inlet temperatures to the fluidised bed of up to 200oC. A two term temperature controller gives an accuracy of $\pm 1\ ^{o}C$ over the complete operating range. Adjustment is made by a simple thumb wheel movement for both analogue and the optional digital temperature display.

Air velocity is variable using the blower speed control, which is graduated from 1 to 10 for ease of operation. Table 1 show the relationship between blower speed and air velocity.

BLOWER SETTING	metres/sec	ft/min	litres/sec	cu ft/min
1/2	1.80	360	14.86	31.42
3	1.85	370	15.28	32.30
4	2.03	405	16.73	35.36
5	2.25	450	18.58	39.29
6	2.45	490	20.23	42.78
7	2.75	550	22.71	48.02
8	3.10	620	25.60	54.13
9	3.50	700	28.90	61.11
10	3.65	730	30.14	63.73

Table 1

The unit can be used in either manual or automatic mode. The sequence timer allows the user to pre-set any cycle time between 6 seconds and 6 hours duration. An audible alarm will sound at the end of each drying cycle and the unit will automatically switch off to allow weighing of the sample. After each timed cycle the unit must be reset using the stop-reset control button.

2.3 RANGE OF MATERIALS

The wide range of materials which can be dried includes fine powders, coarse particles, crystals, granules, slurries or pastes (after decanting, or pre-drying or by spraying into bed of initially dried material). Materials with moisture content up to 80 per cent such as some polymers, dyestuffs and molecular sieve catalysts can also be accommodated. In addition, heat sensitive materials including foodstuffs such as peas, wheat and lentils, may be dried at relatively low temperatures. The dryer is equally able to vaporise solvents like heptane and methanol from polymers, pharmaceutical products, etc. For inflammable or hazardous solvents, drying should be conducted in a fume cupboard.

Because of the high heat and mass transfer rates obtainable, drying times for the Laboratory Fluid Bed Dryer are much less than for the more traditional methods available in laboratories such as oven or vacuum drying. Many materials can be dried in less than 15 minutes including those with high "bound" moistures content e.g. resins. The more volatile solvents such a methanol are vaporised even quicker. Typical drying curves for materials eminently suitable for fluidised drying are shown in Fig 1 of the product data sheet.

2.4 OPTIMUM BED DEPTH

The optimum bed depth is that which can be fluidised at the required temperature by relatively high air velocity, bearing in mind that as drying proceeds the bed becomes easier to fluidise i.e. the air velocity can be progressively reduced. This optimum bed depth will vary appreciably with the material - an initial bed depth of about 75mm is typical and a trial and error procedure is generally used to identify the optimum. Particle sizes in the range 0.1mm to 5mm are most suitable and the size ratio largest: smallest should not be more than 8.

3. TYPICAL APPLICATIONS FOR THE FLUID BED DRYER

1. Simple drying of a material to give moisture content and the drying time (or residence time) required.

2. Fluidising curves give the variation of pressure drop with air flow rate showing the feasibility of fluidisation and the conditions for minimum and operating fluidisation velocity.

3. Determination of drying curves - to assess feasibility of fluidised bed drying of a material on an industrial scale. Drying curves are relevant to the mechanism of drying. They may be used as a basis for heat and mass balances, thermal efficiency of drying and dryer design.

4. Calculation of heat transfer coefficients for different conditions - relevant to dryer design and comparison of fluidised beds with other drying methods.

4. OPERATING PROCEDURE

4.1 DRYING OF MATERIAL & DETERMINATION OF MOISTURE CONTENT

Remove any excess water from the sample by decanting and/or using a filter pump. Place the sample in the dryer at a pre-determined bed depth compatible with the operating range of the dryer as previously indicated. In some cases the moisture content may be too high for immediate fluidisation to be effected, but after some initial drying fluidisation becomes possible.

- Weigh container empty, then with the material.
- Fit a clean bag over the container, locating the sealing ring into its groove on the tub.
- Switch on the mains supply.
- Select the drying temperature.
- Select manual or automatic mode of operation. Push cycle start button.
- Select blower and heater settings. Adjust blower speed to achieve good fluidisation - as determined by observation.
- The blower speed will correspond to the fluidisation velocity required which will normally be above the minimum fluidisation velocity ^{U}mf and in the range of 1-2 ^{U}mf.

In normal mode, when drying nears completion as judged by rise in temperature of outlet air or visual observation, push stop button to stop cycle. Remove the tub with contents and re-weigh, continue repeating the drying cycle until a constant weight is obtained. For each weighing the dryer is stopped and then restarted. The difference in initial and final weights of the material can be expressed as the moisture content on wet or dry basis. This is the equilibrium.

In the automatic mode, once the pre-set time has elapsed the cycle will automatically stop and the alarm will sound. This can be reset by means of the red stop button.

The total drying time for the material can be calculated by multiplying the interval cycle time by the number of cycles required. The dry material is removed from the dryer and may be stored for further analysis or processing.

4.2 DETERMINATION OF DRYING CURVES

Drying curves are obtained by a similar procedure to that used for a simple drying operation. They establish the drying characteristics of the material including drying rates, constant rate and falling rate periods, drying times, equilibrium moisture content and critical moisture content and heat transfer coefficients.

Procedure:

As for simple drying, place the sample of material in the tub to an appropriate bed depth as determined by trial. Weigh the tub alone then with the material. Fit a filter bag over the tub locating the sealing ring into the groove.

Switch on the mains supply and select the drying temperature required as in (1).

Using a suitable form of hygrometer note the wet and dry bulb temperatures (and thus humidity) of the inlet air to the fan and outlet air from the fluidised bed.

Weigh the tub with material at 2 minute intervals for about 15 minutes (or as long as it takes to attain constant weight) recording the wet and dry bulb temperature before removing the tub for weighing. Then weigh at 5 minute intervals until constant weight is achieved indicating that the equilibrium moisture content has been reached. Record the drying time and moisture content.

From the results plot drying curves of moisture content vs. time and drying rate vs. moisture content.

Some interpretations of the drying process are shown in Figs 2 and 3 in the product data sheet.

4.3 CALCULATION OF HEAT TRANSFER COEFFICIENT

4.3.1 CONSTANT RATE PERIOD

heat lost by entering gas = heat transferred to solids to vaporise the liquid

Therefore $\left(\frac{dw}{dt}\right)_C . L = -h_c A(T_a - T_s)$ log mean ...... (1)

Where $\left(\frac{dw}{dt}\right)_C$ = constant drying rate (kg/s)

L = Latent Heat of vaporisation (J/kg)

h_c= heat transfer coefficient (W/M^2 ^{o}C)

A = surface area (m^2)
T_a= dry bulb air temperature ^{o}
T_s= wet bulb air temperature ^{o}

Equation (1) can be integrated to give

$$h_c = \frac{(W_o - W_c) . L}{t_c . A . (T_a - T_s) \text{ log mean}}$$

Where W_o = initial moisture content
W_c = "critical" moisture content at end of constant rate period
t_c = constant rate drying time

4.3.2 FALLING RATE PERIOD

For resins and other materials where the moisture is bound strongly in the particle, diffusion of the moisture to the surface is slow and will therefore control the rate of drying. This may be represented by:

$$\left(\frac{dw}{dt}\right)_f = K(w-ww_e)\text{......(2)}$$

Where $\left(\frac{dw}{dt}\right)_f$ = falling period drying rate (kg/s) at time t from start of falling rate.

W = moisture content at time t (kg)
W_e= equilibrium moisture content at temperature and humidity of air (kg)

$$K = \frac{\left(\frac{dw}{dt}\right)_c}{W_c-W_e}$$ substituting for K & $\frac{dw}{dt}$ in (2) and integrating

$$hc = \frac{(W_c-We)L\ \ln(W_c-W_e)}{tA(T_a-T_s)m\ (W-W_e)}$$

where t=time from start of falling rate period.

FLUID BED DRYER

5. GENERAL MAINTENANCE

BEFORE STARTING ANY MAINTENANCE PROCEDURE ON THE FLUID BED DRYER MAKE SURE THAT IT IS DISCONNECTED FROM THE ELECTRICAL SUPPLY AND READ ALL THE INSTRUCTIONS THOROUGHLY. THIS IS FOR YOUR SAFETY AND TO PREVENT DAMAGE TO THE INSTRUMENT.

5.1 DISASSEMBLY

In order to carry out any of the maintenance procedures explained below the instrument has to be disassembled. This is carried out in the following manner:

1. On a clear worktop cover the surface with a soft cloth to prevent scratching the instrument's painted finish. Lie the Fluid bed dryer on its side on this surface. Undo the 3/8" bolt in the base of the machine.

2. Place the instrument upright and undo the screws fixing the case together (no.8x3/8" self-tap, 5 per side and 2 on the top).

3. While facing the front of the instrument carefully remove the Dark Brown top cover by gently pulling out the sides to clear the base and lifting until completely clear of the base section. Lie the top section on its side to the left of the base. Note: the wires do not have to be disconnected if the two parts are kept close together.

4. Support the weight of the casting hanging inside the top cover by placing a suitable block between the casting and the inside of the top cover.

At this stage all the internal components should be accessible.

5.2 REPLACEMENTS

5.2.1 BLOWER MOTOR

Remove the top cover and four screws holding motor to housing and disconnect two wires from terminal block. Reverse the procedure to fit replacement.

5.2.2 BRUSHES

Remove blower motor, as per above instructions, disconnect red lead and withdraw through side of motor casing. Remove three screws holding motor casing together and prise apart. Remove screw holding the brush housing to casing and withdraw brush.

5.2.3 HEATER ELEMENT

Remove top cover, remove four screws holding housing on to the base plate, disconnect wires and remove heater housing. Remove screws securing the heater into the housing and withdraw the heater. Reverse the procedure to fit replacement.

5.2.4 TEMPERATURE CONTROLLER

Withdraw controller from its sleeve by pulling from the front panel.

5.2.5 BLOWER SPEED CONTROLLER

Remove knob by slackening small screw. Remove top cover, unscrew two screws securing controller to fixing bracket. Disconnect three wires and withdraw controller. Replace using reverse procedure.

BLOWER SPEED

As both motor and speed controller are subject to variations in voltage and frequency, variations in speed/control ratio will occur and are more apparent at the lower settings.

Dryers are normally set and tested at 240V 50Hz unless otherwise specified.

5.3 REMOVAL OF AIR INLET FILTER FOR CLEANING

Remove top cover. Remove heater housing by withdrawing the four screws securing it to the base plate. Remove two screws and secure clip holding filter to the housing. Lift out heater housing of blower motor. Replace using reverse procedure.

6.0. THE LABORATORY FLUID BED DRYER – DIGITAL CONTROLS

SUPPLEMENT TO THE INSTRUCTIN MANUAL

TEMPERATURE CONTROLLER

The temperature controller is located on the right hand side of the sloping control panel on the front of the instrument.

The digital fluid bed dryer features a self-optimising PID controller for the range 0 – 200°C. The fascia has LED digital temperature indication, LED indicators for deviation, mode and operation of outputs, setting keys and temperature indication switching key (the positions of these are shown on the diagram below).

The temperature controller regulates the heater which raises the temperature of the air fed to the sample by the dryer. It will only operate if the heater switch is in the ON position. When first energised there is a short self-check procedure and then the display shows the process air temperature.

To set the control temperature press the switching key (the left one of the three) once. The letters SP appear in the bottom left corner of the display and the two arrowed keys can now be used to change the display to the desired value. Press the switching key twice and the display reverts to process temperature.

On the left hand side of the display are the three deviation indicators; a red down-arrow indicates that process temp. is below set temp., a green square that temp. is near to set temp., and a red up-arrow for over temperature.

The output operation indicator is a red square in the top right of the display.

TIMED CYCLE MODE

The process timer is located on the left hand side of the sloping control panel on the front of the instrument.

The timer fitted to the digital FBD can be set to any time in the range 1s to 99m 59s. It has push button rotary switch setting and a 4 digit LED display indicating elapsed time period. The time is set using buttons for each digit, + (for increment the set time) and – (decrement), and displayed in the windows of the rotary switches (see the diagram below).

The timed cycle is started either when the manual/timed cycle switch is changed to the timed cycle position or, if timed cycle is already selected, when the start button is pressed. At the end of the cycle the timer resets, the audible alarm sounds and the dryer is automatically turned off. To cancel the alarm either switch back to manual operation or switch off the mains switch.

Sherwood Scientific Limited
Warranty Statement

Product Warranty

Serial Number ____________________

Warranty Term: **12 Months**

Sherwood Scientific warrants, subject to the conditions itemised within this document, through either Sherwood Scientific personnel or personnel of its authorised distributors, to repair or replace free of all charges, including labour, any part of this product which fails within the warranty time specified above, appertaining to this particular product. Such failure must have occurred because of a defect in material or workmanship and not have occurred as a result of operation of the product other than in accordance with procedures described in the instructions furnished with this product.

Conditions and specific exceptions that apply to the above statement are as follows:

1. End-user warranty time commences on the date of the delivery of product to end-user premises.

2. 'Free of all charges' statement applies only in areas recognised by Sherwood as being services either directly by its own personnel, or indirectly through personnel of an authorised distributor. Products purchased outside these areas requiring service during the warranty period will incur charges relative to the travel/transit costs involved. However, products purchased in such areas will be serviced during the warranty period free of all charges providing they are returned, carriage paid, to either Sherwood or by pre-arrangement to an authorised Sherwood distributor.

3. All maintenance (other than operator maintenance as described in the instructions), repairs or modifications have been made by Sherwood or Sherwood authorised personnel.

4. This product has, where applicable, been operated using Sherwood specified supplies and reagents.

5. Sherwood reserves the right to make any changes in the design or construction of future products of this type at any time, without incurring any obligation to make any changes whatsoever to this particular product.

Warranty Statement (continued)

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6. Reagents, supplies, consumables, accessories and user maintenance items are not included in this warranty.

7. Repairs or replacement of any part failing due to abnormal conditions including the following, are excluded from this warranty:
   a) Flood, lightning, earthquake, tornado, hurricane, or any other natural or man-made disaster.
   b) Fire, bombing, armed conflict, malicious mischief or sprinkler damage.
   c) Physical abuse, misuse, sabotage or electrical surge.
   d) Damage incurred in moving the product to another location.

8. User agrees to permit Sherwood personnel or personnel of its authorised distributor to make changes in the product which do not affect results obtained, but do improve product reliability.

Representations and warranties purporting to be on behalf of Sherwood Scientific made by any person, including distributors and representatives of Sherwood, which are inconsistent or in conflict with the terms of this warranty (including but not limited to the limitations of the liability of Sherwood as set forth above), shall not be binding upon Sherwood unless reduced to writing and approved by an officer of Sherwood Scientific.

Except for the obligations specifically set forth in this warranty statement, in no event shall Sherwood Scientific Limited be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort or any other legal theory and whether advised of the possibility of such damages.

Neither Sherwood nor any of its third party suppliers makes any other warranty of any kind, whether expressed or implied, with respect to Sherwood Products.

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