

Cocoa Drying with the Lister Moisture Extraction Unit. Addendum: Drying Trial on an 800 sq. ft. Floor.

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Results from a single trial in which 5½ tons dry bean equivalent were dried on a floor area of 800 square feet at a depth of approximately 8 inches. The trial was conducted at the Lowlands Agricultural Experiment Station, Keravat, between 16th December, and 23rd December, 1963.

PRINCIPLE.

IN an earlier paper, summarizing the results of a series of ten drying trials with the Lister M.E.U., a physical description of the dryer was given and the principle of drying with this machine outlined (Newton, 1963). In this outline it was pointed out that, "theoretically the machine should have a greater capacity to dry when operated at maximum air volume and minimum temperature rise than when lower volumes at higher temperatures are used. However, this assumes that the drying air is exhausted at a relative humidity of 94 per cent. which is a difficult level to achieve with a large volume at low temperature unless the load is spread at a shallow depth over a large area; e.g., assuming that an airflow through cocoa beans at 20 feet per minute allows the drying air to approach 94 per cent. R.H. when exhausted, then 34,000 c.f.m. would have to be pushed up through 1,700 square feet of floor space at a total water gauge of 1 inch at the fan (equivalent to a load of approximately 3-4 inches of wet fermented beans) to achieve maximum drying efficiency. This system would probably handle the equivalent of five tons of dry beans maximum load".

With the completion of the first series of trials on a relatively small platform (216 square feet) there remained a requirement to test this theoretical argument that the machine would have a greater capacity to dry over a larger floor area with beans at a shallower depth. For this reason the following trial was conducted on a specially designed 40 ft. x 20 ft. platform.

DESIGN OF THE PLATFORM.

The design of the drying platform is given in *Figure 1*. This shows that the exact measurement of the floor itself was 40 ft. x 20 ft. and

that the construction of this floor was based on the utilization of a steel pipe framework over which 3 in. x 2 in. A.R.C. mesh and cocoa wire were laid. Steel pipe was used for reasons of durability, low resistance to airflow and in order that the area of contact between the framework and the A.R.C. mesh and cocoa wire would be as low as possible.

A 3 in. x 2 in. wooden framework around the edge of the floor was incorporated to support a 1 inch marine plywood facing board around the perimeter of the dryer. This was to prevent any contact between cocoa beans and the concrete wall.

Care was taken in design and construction of the dryer to ensure that the internal walls of the plenum chamber and fishtail duct were finished smooth and flush with a minimum degree of obstruction to airflow. The drawings indicate how this fishtail or expansion duct was used to connect the fan outlet on the M.E.U. to the drying floor. As will be explained in more detail in a later paper, this type of duct is the most efficient one for use in the connection of drying units to platform dryers. Design of these ducts is of paramount importance as the relationship between duct length, width and height can have a significant effect on the percentage static regain of velocity pressure. An incorrectly designed duct can give a regain as low as 30 per cent., whereas a correctly designed duct can give a regain of 70 per cent. For the floor under discussion duct length was 20 feet, width 20 feet and height 2 feet, a relationship calculated to give a 65 per cent. recovery of velocity pressure as static.

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A sliding roof was fitted to the platform although this remained closed over the floor during the trial to eliminate a variable factor in fuel consumption due to the effect of sun drying. In addition, provision was made in the design for the construction of a square concrete deck over the fishtail duct to carry a series of fermenting boxes, thus bringing fermentation and drying processes together into a practical unit.

DRYING.

1. Method.

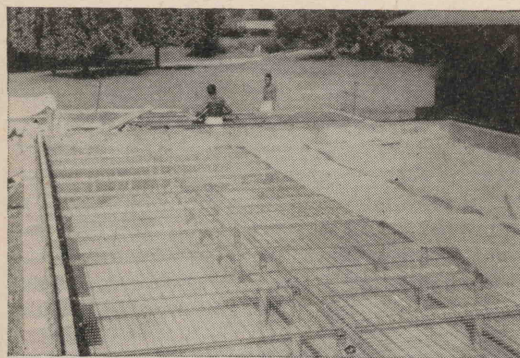
In this trial a total of 520 cubic feet of wet fermented beans weighing 25,595 lb. (i.e. approximately $11\frac{1}{2}$ tons) were loaded onto the platform for the purpose of continuous and complete artificial drying with the M.E.U. Throughout the drying period the machine was run at full throttle and blanking pieces were used to effect a temperature rise where indicated. The aim was to test the effectiveness of a large volume of air at low temperature in drying cocoa beans. No sun drying was incorporated in the trial, the sliding roof being closed over the floor throughout.

2. Trial Results.

Details of all recordings taken during the trial are shown in *Table 1*.

3. Temperature Rise Above Ambient.

Average temperature rise above ambient with no baffle pieces fitted was 5.3 degrees F. while the average with baffles fitted over the two top quadrants of the fan guard was 8.2 degrees F.

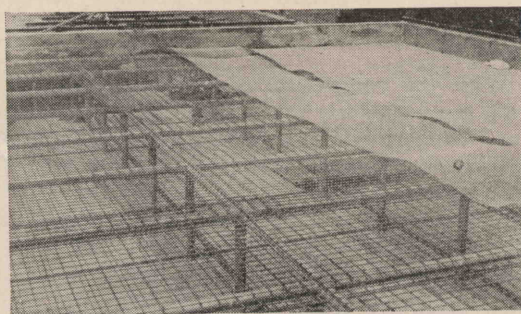


4. Airflow.

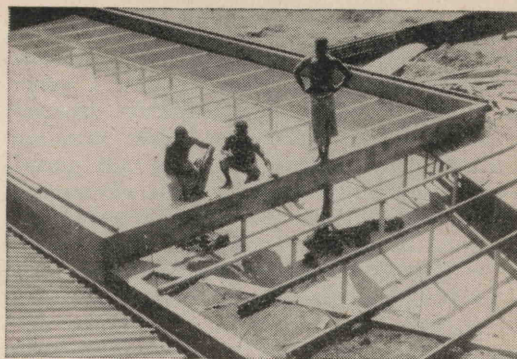
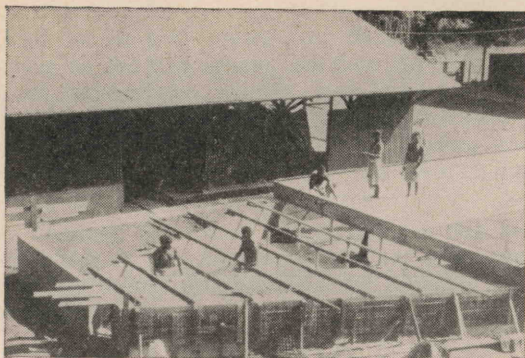
Measurement of airflow through the floor which were taken on the first day within $1\frac{3}{4}$ hours of the commencement of drying are shown in the results. The indication from these is that airflow at this stage was greater than 24,000 c.f.m. and could have approximated the rated output of 34,000 c.f.m. at 1 inch total water gauge; the highest pressure recorded at the commencement of drying. Distribution of airflow readings as shown schematically in the results indicate that airflow through the whole floor area was relatively even when these readings were taken. This effect was probably resultant to some extent from the use of a fishtail expansion duct.

5. Time to Surface Dry.

The anticipated reduction in the time taken for this $5\frac{1}{2}$ ton dry bean equivalent load to reach a stage of surface dryness on the 800 square feet floor did not occur. In an earlier trial on the 216 square feet floor, an 11,109 lb. dry bean equivalent load did not become surface dry until 75 to 91 hours after the commencement of drying, by which time a "foul" odour had developed. In the current trial beans did not become surface dry until the fifth day or approximately 90 hours after the commencement of drying and a "foul" odour was again apparent although not severe. Just how much of this odour would be carried through in the manufacturing process and emerge as a flavour defect in chocolate is difficult to assess. However, it is an established fact that the odour can emerge as a flavour defect and as a consequence any



Plates I and II.—Details of construction showing steel pipe framework supporting A.R.C. mesh and cocoa wire drying floor. Note steel bolts set in concrete around the edge of the floor to take the 3 in. x 2 in. framework and marine plywood facing board.



Plates III and IV.—Details of construction showing expansion duct and end wall of drying floor. Expansion duct was later covered with concrete floor to carry fermenting boxes.

system of drying in which there lies the danger of development of "foul" or "foreign" odours cannot be supported. It must be clearly understood however that this is in reference to a $5\frac{1}{2}$ -ton dry bean equivalent load and that the Lister M.E.U. has ample capacity to safely dry at least a three-ton dry bean equivalent load as has been proven in previous trials.

The weakness in drying a $5\frac{1}{2}$ -ton D.B.E. load with large volumes at a 5 degrees F. temperature rise appears to lie in the fact that the drying rate is never quite fast enough to remove all moisture from the surface of the bean and then draw moisture from within the bean to the surface and remove it immediately so that the bean surface remains dry. Rather, it would seem that moisture is removed from the bean surface at a rate which is so slow that migration of moisture from within the bean to the surface can keep pace with removal from the surface, so that, although drying is continuing, the bean surface remains moist for a prolonged period until the rate of migration from within the bean to the surface falls to such a low level that the surface can become dry. It is obviously not a matter of air volume, which is ample, but of air temperature which is too low. Without the supply of an additional source of heat, the problem of drying five-ton loads can only be overcome by using the Lister M.E.U. to rapidly surface dry small loads and to complete drying in a deep bin. It may be argued that a 20 to 25 degrees F. rise could be obtained by restricting airflow with flow control vanes in front of the fan and this in fact could be done. There is

the weakness however, that on an 800 square feet floor a minimum airflow of 20 to 25 feet per minute means a minimum requirement of 16,000 to 20,000 c.f.m. from the fan and restriction of airflow down to this rate with control vanes would only allow a temperature rise above ambient of 8 to 12 degrees F. The ability of air at this temperature to rapidly surface dry a $5\frac{1}{2}$ -ton D.B.E. load is very doubtful. Consequently the approach to correct utilization of the machine must be through the agency of a shallow tray/deep bin system. The basic requirement with such a system would be that the floor area of the deep bin would be no greater than 200 square feet so that either the bin could be loaded to such a depth that airflow was restricted to about 5,000 c.f.m. and 25 degrees F. rise above ambient or else control vanes in front of the fan could be closed down to restrict airflow to 5,000 c.f.m. with a 25 degrees F. rise above ambient. The area of the pre-drying floor would not be so important as it is obvious that small loads can be rapidly surface dried by the Lister M.E.U., e.g., on a 216 square feet floor, 3,940 lb. D.B.E. were surface dried in $5\frac{1}{2}$ hours; 1,830 lb. D.B.E. in $6\frac{3}{4}$ hours and 2,730 lb. D.B.E. in $8\frac{1}{4}$ hours. As a consequence, innumerable combinations of shallow tray-deep bin systems could be designed around a basic 200 square feet bin unit.

6. Fuel Consumption.

Perhaps one of the most interesting results to come out of this trial is the tremendous reduction in fuel consumption with the $5\frac{1}{2}$ ton D.B.E.

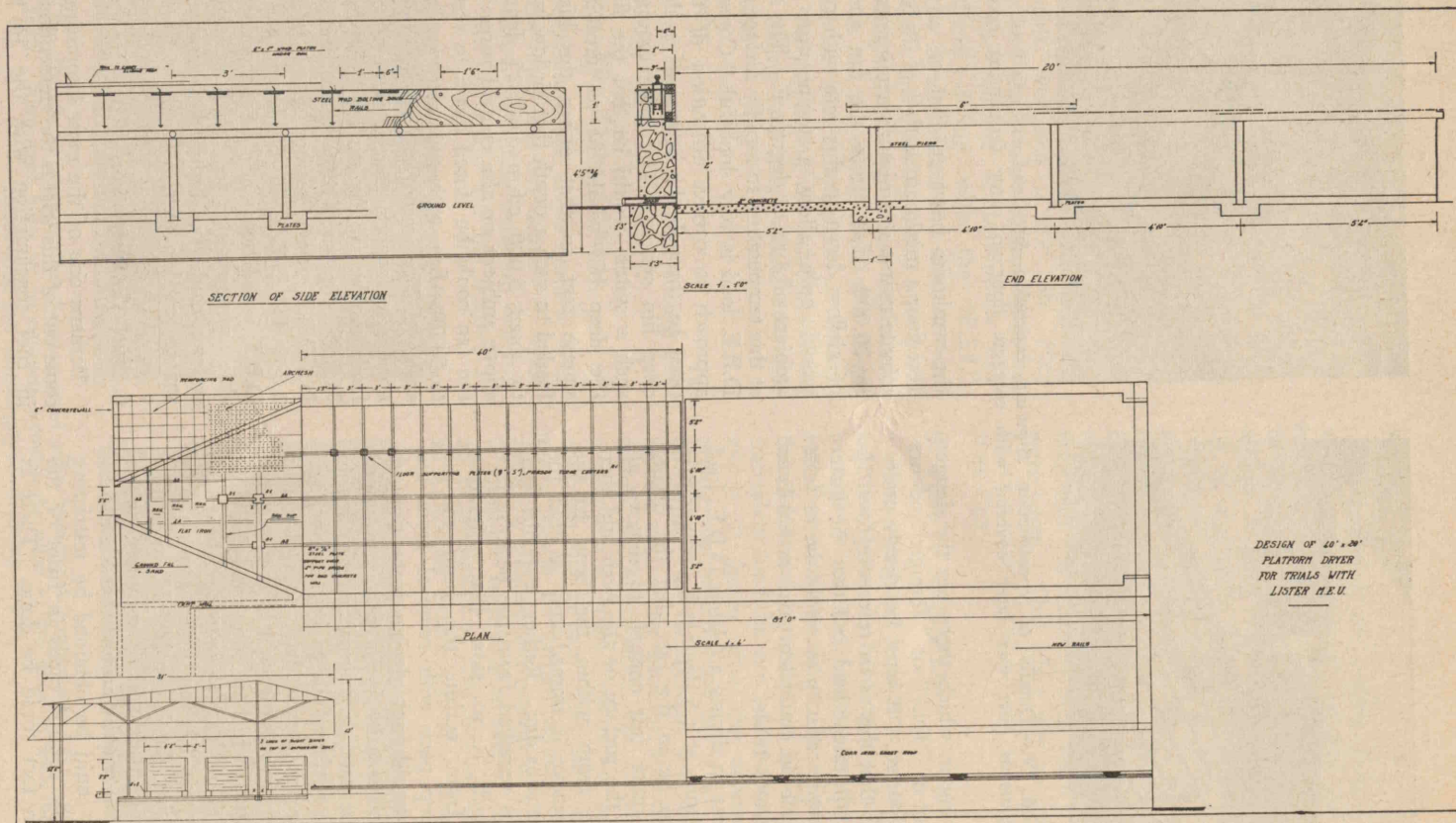


Figure 1.—Design of Platform Dryer.

load on an 800 square feet floor. In earlier trials on the 216 square feet floor the graph of fuel consumption against load indicated that a 5 ton D.B.E. load would require approximately 55 gallons of fuel per ton for complete and continuous artificial drying. The new figure from this trial is 35.8 gallons/ton.

Locating the factor responsible for this big reduction in fuel consumption is not a straightforward matter although there are probably only two factors involved.

(a) *Drying efficiency.* As pointed out earlier there is a theoretical argument that the machine should have a greater capacity to surface dry when operated at maximum air output with minimum temperature rise than when lower air volumes at higher temperatures are used. In practice this has been shown to occur, as is illustrated by a comparison between this trial and trial No. 5 in the earlier report. In trial No. 5, 11,109 lb. D.B.E. were dried in $139\frac{1}{2}$ hours on an area of 216 square feet at a fuel consumption rate of 48.3 gallons/ton. In the current trial 12,300 lb. D.B.E. was dried in $132\frac{3}{4}$ hours on an area of 800 square feet at a fuel consumption rate of 35.8 gallons/ton. Therefore, drying efficiency appears to be greater with higher air volumes at lower temperature rise above ambient.

(b) *Dryer design.* Reference has been made to the importance of fishtail expansion duct and plenum chamber design on the efficiency of drying units. As the platform dryer used in this trial had a plenum chamber and fishtail duct designed specifically for the Lister M.E.U. it would be reasonable to assume that the efficiency of conversion of velocity pressure to static pressure was approaching maximum and that as a consequence drying efficiency was improved.

Obviously the contribution made by either or both of the above two factors to improve drying efficiency cannot be assessed at this juncture.

SUMMARY.

NEWTON, K. (1963). Cocoa Drying with the Lister Moisture Extraction Unit, *Papua and New Guinea agric. J.*, 16: 91.

In a single trial aimed at testing the efficiency of the Lister M.E.U. when used on a 40 ft. x 20 ft. platform dryer, $5\frac{1}{2}$ tons D.B.E. of cocoa was dried in a total time of seven days at a depth of 8 inches. Drying was effected at a cost of 35.8 gallons of fuel and 4.4 pints of oil per ton of dry beans.

For the purpose of this trial a sliding roof platform dryer was constructed as shown in *Figure 1*. The dryer incorporated a correctly designed fishtail expansion duct to allow for maximum static regain of velocity pressure. During the trial the average maximum temperature rise above ambient which was used was 8.2 degrees F. while for much of the time an average rise of 5.3 degrees F. was used. Approximately 90 hours elapsed after the start of the trial before the beans became surface dry. A foul odour was detected during drying and although this was not severe, its presence indicated that drying was too slow with such a large load on the floor. From a consideration of the factors involved the indications are that the Lister M.E.U. can be used most efficiently as a cocoa dryer when fitted to combinations of shallow trays and deep bins.

Using the machine on the larger floor area resulted in a marked improvement in drying efficiency as measured in terms of fuel consumption. This increase in efficiency was either due to a greater rate of removal of water by larger volumes of air at low temperatures or else to the design of the dryer, or a combination of both factors.

Table 1.—Notes and Records.

LISTER DRYING TRIAL No. 11.

Ferment No.—1,271.

Harvested.—4th December, 1963.

Broken.—9th December, 1963.

Weights of one cubic foot wet beans (lb.)—

$58\frac{1}{2}$ — $58\frac{1}{4}$ — $60\frac{1}{2}$ — $58\frac{1}{2}$ — $57\frac{1}{4}$ — $58\frac{3}{4}$ — $57\frac{3}{4}$ — $56\frac{1}{4}$.

Average weight per cubic foot (lb.)—58.2.

Total volume wet beans.—300 cu. ft.

Total weight wet beans.—17,460.

FERMENTATION NOTES.

Day 1.—

	Depth.	Volume C.F.T.
Boxes filled—4 p.m. A	36 in.	60
B	36 in.	60
C	36 in.	60
D	36 in.	60
E	36 in.	60
		300 cu. ft.

F

G

H

Day 2—Turned 8 a.m.

Day 3—Turned 8 a.m.

Day 4—Turned 8 a.m.

Day 5—Turned 8 a.m.

Day 6—Turned 8 a.m.

Day 7—Turned 8 a.m.

SUN DRYING.

Day 8.—

Samples were taken as follows for sun drying and flavour assessment :

HOT AIR DRYING.

Day 8.—16th December, 1963.

- (1) Portion of total ferment used.—Whole ferment.
- (2) Equivalent volume of wet beans.—300 cubic feet.
- (3) Equivalent weight of wet beans.—17,460.
- (4) Moisture content at end of fermentation.—Not recorded.
- (5) Weights of one cubic foot of fermented beans.—50—49½—47½.
- (6) Average weight of one cubic foot of fermented beans.—49.

(7) Total weight of fermented beans (2x6).—14,700 lb.

(8) Volume of additional fermented cocoa beans brought in from outside sources.—220 cubic feet.

(9) Approximate weight of additional fermented cocoa (8x6).—10,895 lb.

(10) Total weight of fermented beans to dryer (7+9).—25,595 lb.

(11) Total volume of fermented beans to dryer (2+8).—520 cubic feet.

(12) Depth of beans on dryer floor.—Approximately 8 inches.

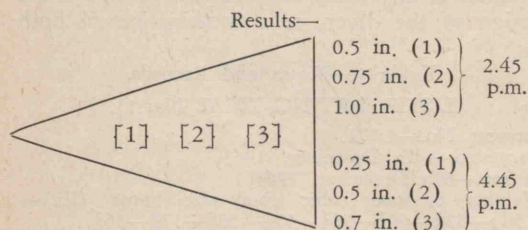
Start Stop	Time	Fuel	Amb. Temp.	Air Chamber	Engine Speed	Blanks	Total W.G.	Add Oil	Turning	Moist Per cent.
Start	2.45 p.m.	28½	....	....	Full	Nil	0.8	....	....	....
	3.30	....	85	95	Full	Nil	....	....	....	....
	4.30	....	84½	93	Full	Nil	0.5	....	....	....
	9.30	16¾/43	75½	81½	Full	Nil	0.3	2	....	....

Day 8 (Continued). COMMENTS.

1. STATIC WATER GAUGE MEASUREMENTS.

At the commencement of hot air drying (2.45 p.m.) and again two hours later (4.45 p.m.), static water gauge measurements were taken at three positions along the fish-tail duct as shown:

2. R.H. MEASUREMENTS.

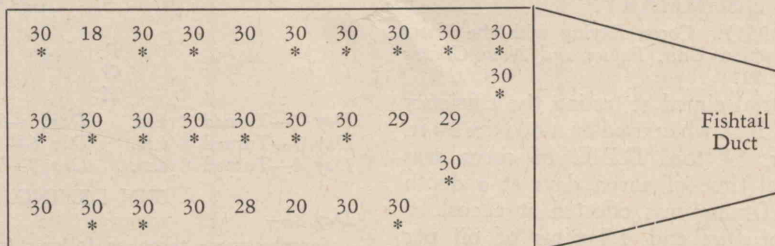


—	3.30 p.m.	4.30 p.m.	9.30 p.m.
Per cent.	Per cent.	Per cent.	Per cent.
Ambient R.H.	68	74	90
R.H. in duct at Position (3)	61	67	78
R.H. of air leaving the Bed	89	93	97

3. AIR FLOW MEASUREMENTS.

The rate of airflow through the beans was measured at 4.30 p.m., i.e., 1¾ hours after the commencement of drying, using a Cassella airflow meter which had a scale of 5 to 30 feet per minute. Readings taken are shown schematically on the diagram below in relation to their approximate location on the drying platform.

As so many of the readings were greater than 30 ft./minute an average figure for airflow cannot be calculated. At an average of 30 ft./minute over the whole bed, airflow would have been $800 \times 30 = 24,000$ c.f.m. The M.E.U. is rated to produce 34,000 c.f.m. at 1 inch total water gauge and it is probable that actual output was close to this when the above readings were taken.



* Indicates a speed of more than 30 ft./minute.

Day 9.—Tuesday, 17th December, 1963.

Start Stop	Time	Fuel	Ambt. Temp.	Air Chamber	Eng. Speed	Blanks	Add Oil (Pints)	Turning	Moist Per cent.
	a.m.								
	8.30	....	77	82.4	Full	Nil	Nil	2M.H.	....
	12.30	....	81	86	Full	Nil	Nil	 4M.H.	....
	p.m.								
	2.30	....	81	85	Full	Nil	Nil	.... ....	....
	2.45	Two upper baffles fitted.							
	3.30	....	80½	88½	Full	2/0	Nil	.... ....	....
	4.45	....	80	87.8	Full	2/0	Nil	.... ....	....
	5.45	13/46	78	86.9	Full	2/0	Nil	.... ....	....
	9.30	....	75	83.3	Full	2/0	Nil	2M.H.	....

COMMENTS.

N.B. 2.45 Attachment of two upper baffles raised R.H. of air leaving the beans from 80 per cent. to 90 per cent. at 3.30 and temperature rise above ambient from between 4 degrees F. and 5 degrees F. to approximately 8 degrees F.

R.H. MEASUREMENTS.

—	8.30 a.m.	12.30 p.m.	2.30 p.m.	3.30 p.m.	4.45 p.m.	5.45 p.m.	9.30 p.m.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Ambient R.H.	83	72	78	81	86	90	90
R.H. in Duct at Position (3)	77	69	70	65	68	71	72
R.H. of Air leaving the bed	97	94	80	90	93	93	95

Day 10.—Wednesday, 18th December, 1963.

Start Stop	Time	Fuel	Ambt. Temp.	Air Chamber	Eng. Speed	Blanks	W.G.	Add Oil (Pints)	Turning	Moist Per cent.
	a.m.									
	8.00	....	76.5	84.2	Full	2/0	....	2	....	....
	10.00	....	84.0	91.4	Full	2/0	....	....	....	....
	11.00	....	77	87.8	Full	2/0	....	....	....	....
	12.00	....	79	87.8	Full	2/0	....	....	....	....
	p.m.									
	1.00	....	83	89.6	Full	2/0	....	....	....	....
	2.00	....	82.5	90.5	Full	2/0	....	....	....	....
	3.30	....	80.0	88.0	Full	2/0	....	....	....	....
	4.30	....	80.0	88.0	Full	2/0	....	....	....	....
	5.30	....	78.0	87.0	Full	2/0	....	....	2M.H.	....
	6.30	9/45 Baffles removed to increase airflow				....	....	....	4M.H.	....
	7.00	....	76.5	83.5	Full	Nil	....	....	....	....

COMMENTS.

R.H. Measurements (Percentages) :

	8.00 a.m.	10.00	11.00	12.00	1.00 p.m.	2.00	3.30	4.30	5.30	7.00
Ambient R.H.	81	84	87	80	78	77	81	82½	85	91
R.H. in Duct at Position No. 3	70	62	70	63	62	61	64	63	67	70
R.H. of Air Leaving the Bed	96½	91	91	90	90	90	91	91	88	88

Day 11.—Thursday, 19th December, 1963.

Start Stop	Time	Fuel	Ambt. Temp.	Air Chamber	Eng. Speed	Blanks	W.G.	Add Oil (Pints)	Turning	Moist Per cent.
	a.m.									
	6.30	....	72	77	Full	Nil	Nil	....	....	....
	7.30	....	71½	78	Full	Nil	Nil	....	....	....
	p.m.									
	1.00	....	77	82.4	Full	Nil	Nil	2	....	....
	4.30	12½/45	78½	84.2	Full	Nil	Nil	2	....	....

Day 12.—Friday, 20th December, 1963.

Start Stop	Time	Fuel	Ambt. Temp.	Air Chamber	Eng. Speed	Blanks	W.G.	Add Oil (Pints)	Turning	Moist Per cent.
	8.30	....	81	86	Full	Nil	Nil	2	2M.H.	....
	At 8.30 a.m. two upper baffles fitted.									
	11 a.m.	....	84	94	Full	2/0	Nil	....	....	....
	5.30 p.m.	9/42	77	85	Full	2/0	Nil	4	....	....

COMMENTS.

8.30 a.m. Beans were mostly surface dry although some 30 to 40 per cent. still retained some dampness on the skin. Internal free moisture was low to absent at this stage. External mould had developed on some beans but was not serious. Two upper baffles were fitted.

Day 13.—Saturday, 21st December, 1963.

Start Stop	Time	Fuel	Ambt. Temp.	Air Chamber	Eng. Speed	Blanks	W.G.	Add Oil (pints)	Turning	Moist Per cent.
	8.30 a.m.	....	84	89	Full	2/0	Nil	2	2M.H.	....
Stop	6.00 p.m.	6	79	88	Full	2/0	Nil	2	....	....

COMMENTS.

6 p.m. At this stage drying was stopped although it had not been completed.

Day 14.—Sunday, 22nd December, 1963.

No drying was carried out.

Day 15.—Monday, 23rd December, 1963.

Drying was completed with the machine running for 9½ hours. Fuel consumption was 14 gallons and oil consumption 4 pints.

RECORDS.

Total time beans in dryer 7 days.
 Total drying time 132¾ hours.
 Total Fuel Consumption 197 gallons.
 Av. consumption/hour for engine 1.484 gallons/hr.
 Engine oil consumption 24 pints = 4.4 pints/ton.
 Wt. dry beans produced 12,320 pounds = 5½ tons dry.
 Fuel consumption/ton 35.8 gallons per ton.
 Total man hours for turning 12M.H.