AN ECONOMIC ANALYSIS OF THE ARTIFICIAL DRYING OF WHEAT ON OKLAHOMA FARMS

By

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CHAPTER I

INTRODUCTION

Objectives of the Study

The objective of this study is to determine the economic feasibility of on-farm drying of wheat with unheated air.[1] Included in this objective is a consideration of the nature and importance of physical factors related to grain spoilage and recommendations for operating procedures to farmers equipped with facilities to dry grain with unheated air.

Grain Storage in Oklahoma in 1954

In 1954 one hundred thirty-six million bushels of permanent commercial storage were available in Oklahoma. This consisted of 61 million bushels in terminal elevators, 10 million in interior merchant mills, and 65 million in country elevators. In addition, there were approximately 35 million bushels of on-farm storage, 3 million of temporary storage, and 500 thousand of government (Commodity Credit Corporation) owned storage. Total grain storage capacity available on December 31, 1954, amounted to ap-

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[1]Unheated air has been defined in this study as unheated, unmodified atmospheric air at the particular location.

proximately 174½ million bushels.[1]

There is a trend to store less wheat on the farm in Oklahoma and to store more in country and terminal elevators than in the past. This trend is shown in Figure 1. The trend was slowed down in 1942 and 1954 when many farmers, because of the large state-wide carry-over supplies of wheat, had no alternative except to store on the farm. The trend toward the use of elevator storage rather than farm storage has been faster in Oklahoma than in the Northern Great Plains wheat states. In Oklahoma, temperature, moisture, and humidity conditions average higher and aggravate the problem of controlling grain spoilage more than in the Northern Plains states. Risk of damage and shrinkage is high, particularly in farm bins or granaries.[2]

Approximately 30 million bushels of grain were actually stored on farms in Oklahoma in 1954.[3] Most of this grain was stored in reasonably good condition because of the favorable harvesting conditions in 1954.

Weather conditions in Oklahoma vary from year to year. High rainfall and high humidity often occur during the harvest season. These conditions affect the state of maturity and the moisture content of the grain at harvest. The use of combines has resulted in the storage of wheat with a higher moisture content than desirable for safe storage.

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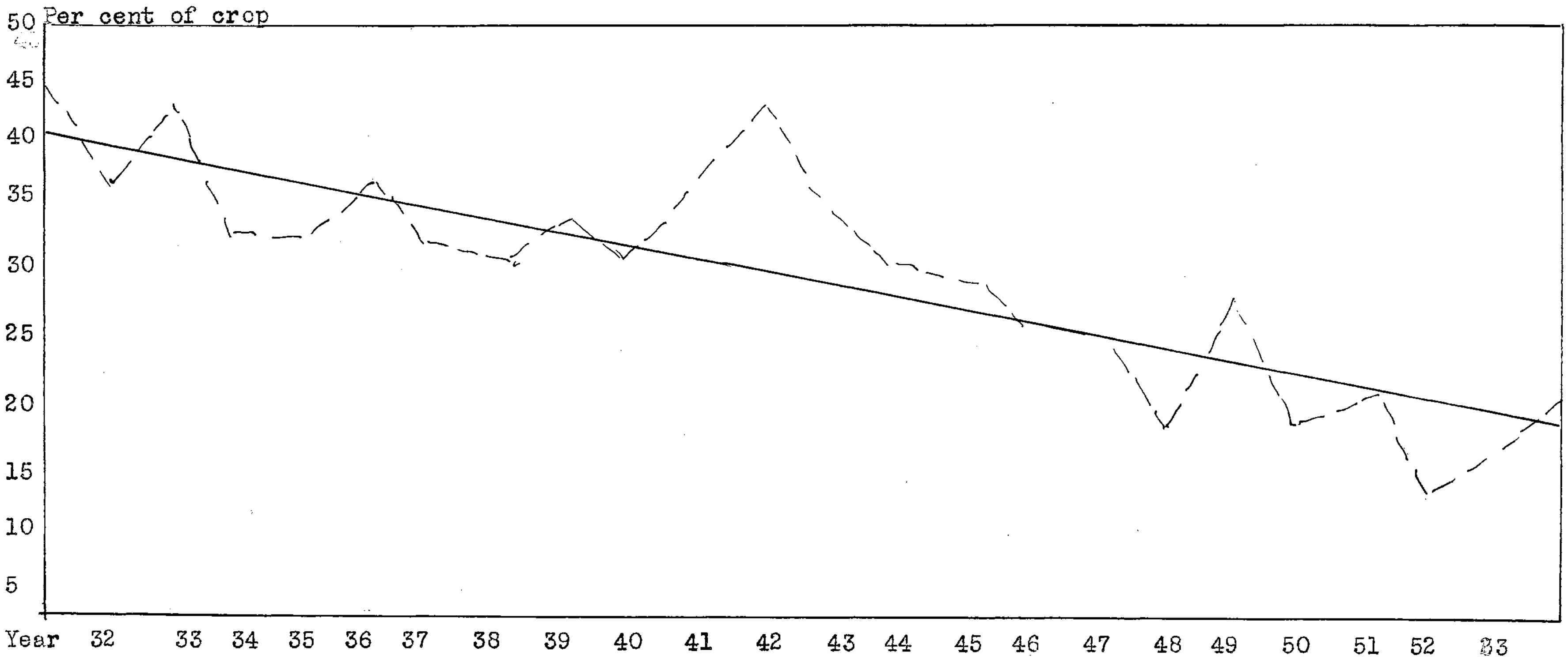
[1]Total storage capacity arrived at by storage data obtained from United States Department of Agriculture, Agricultural Marketing Service, Office of Agricultural Statistician, 318 Federal Building, Oklahoma City, Oklahoma, and Oklahoma Agricultural Stabilization and Conservation Office, Stillwater, Oklahoma.

[2]The use of combines has resulted in wheat going into storage with higher moisture levels than desired. Thomas E. Hall, Adlowe L. Larson, Howard S. Whitney, and Charles H. Meyer, Where and How Much Cash Grain Storage for Oklahoma Farmers (Farm Credit Administration, Bulletin No. 58, May, 1950.)

[3]United States Department of Agriculture, Stocks of Wheat and Feed Grains, (October 1, 1954) Agricultural Marketing Service, 318 Federal Building, Oklahoma City, Oklahoma.

Figure 1 TREND IN WHEAT STORED ON FARM IN OKLAHOMA 1931-1954



Source: Stocks of Wheat and Feed Grains Reports,
United States Department of Agriculture,
318 Federal Building, Oklahoma City, Oklahoma

Grain with high moisture is discounted in the market because of loss-risks or because it must be dried before it can be safely stored. The amount of the discount varies directly with the amount of excess moisture. A moisture discount schedule used for wheat in Afton, Oklahoma, in 1954 is shown in Table 1.

Potential Benefits of On-farm Grain Drying

Oklahoma wheat is harvested mechanically in a very short period of time and must be sold or moved directly into either elevator or farm storage. If this wheat is sold or placed in elevator storage, the farmer is not directly responsible for many storage problems. However, if the wheat is stored on the farm, the farmer assumes full responsibility for the storage problems. The primary consideration in the use of farm storage of grain is the marketing of the grain at a subsequent time when the additional returns from storage may be greater then the cost of the storage.

In stored grains, chemical changes, some of which have a profound effect on nutritive values, are continually taking place regardless of how they are stored. With very few exceptions these changes tend to be detrimental to the quality of the grain. Under the most favorable conditions, grain stored for many years may undergo relatively minor changes in composition and may still be used as a source of nutritious and palatable food or animal feed. Very unfavorable storage conditions, on the other hand, can result in the complete spoilage of the grain for food or feed within a few days.

Until recently farm grain drying has not been practiced very extensively. With electric power more widely available, and farm machinery

Table 1. A MOISTURE DISCOUNT SCHEDULE FOR WHEAT, AFTON, OKLAHOMA, 1954[1]

Per cent moisture[2]	Cents per bushel[3]
14.0	0
14.1 to 14.25	1
14.26 to 14.50	2
14.51 to 14.75	3
14.76 to 15.0	4
15.01 to 15.25	5
15.26 to 15.50	6
15.51 to 15.75	7
15.76 to 16.0	8
16.01 to 16.25	9
16.26 to 16.50	10
16.51 to 16.75	11
16.76 to 17.0	12
17.01 to 17.25	13
17.26 to 17.50	14
17.51 to 17.75	15
17.76 to 18.0	16

[1]Taken from discount schedule card 1954, Afton Cooperative Association, Afton, Oklahoma.

[2]Wet basis.

[3]A bushel of wheat consists of 60 pounds regardless of the moisture content.

of more kinds being used, on-farm grain drying is coming into some use. Some Oklahoma farmers have become interested in grain drying with unheated air. In 1954 sixteen farms in Oklahoma were equipped to dry grain with unheated air; only one farmer was equipped to dry grain with heated air.[1] Limited research information is available on drying grain mechanically under Oklahoma conditions. Most research information available on grain storage on the farm has been done in other states and under climatic conditions quite different from those existing in Oklahoma.

In general, farmers with drying equipment named several potential benefits to be derived from drying grain on the farm.

The first of these is that loss in quality of the grain is prevented or minimized. Two principal types of losses are due to harvesting grain too high in moisture content. The first and most familiar of these is recognized through such grain grading terms as tough, heat damage, total damage, and sample grade. These types of losses cost farmers and grain handlers many thousands of dollars each year. The drying process may improve the grade of the grain. According to Federal Grain Standards, the percentage of moisture in wheat must not exceed 14 per cent for the grade Number 1 to Number 5. A special grade of "Tough Wheat" is designated for wheat which contains more than 14 per cent but not more than 15.5 per cent of moisture. Wheat containing in excess of 15.5 per cent moisture is graded "Sample Grade."[2]

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[1]Owned and operated by Robert W. Buster, Guymon, Oklahoma, who lives one and one-half miles east of the city of Guymon, Oklahoma.

[2]United States Department of Agriculture, Handbook of Official Grain Standards of the United States (Production and Marketing Administration, Grain Branch, Revised 1951.)

Farmers equipped to dry their grain may be able to take advantage of seasonal price changes. Wheat prices are usually lowest at harvest. Prices usually rise as the marketing season progresses and prices usually reach their highest level in late spring. The farm price change in Oklahoma from harvest until a typically high month of the years 1940 to 1954 is shown in Table 2. In the United States in 14 of the last 15 marketing years, the monthly average hard winter wheat cash price was lowest of the year in June, July, or August. In 9 of the last 15 years, the price averaged highest in March or later. In other years, except in 1952 when the price averaged highest in November, the high occurred in December-February. Prices exceeded the price support loan at some time during the season in every year except 1952-53 and 1953-54. Except for 1946-47 and 1947-48, when demand for wheat was exceptionally strong, prices averaged around the "effective" loan level for the season--the announced rate less an allowance for storage, which was assumed by growers beginning in 1951.[1]

Also grain drying on the farm may permit the harvesting of more grain per day. Drying with unheated air may permit starting the combine a few hours earlier in the day and also permit its operation a few hours longer in the day than possible if it were necessary to wait before starting the combine until the grain was dry in the field to a point considered safe for farm storage.

As a result of earlier harvesting this may increase the flexibility of the total farm operation. Some farmers in Eastern Oklahoma located on Arkansas River bottom land double crop if weather conditions are favorable. In this area a few days earlier harvest of wheat might permit double crop-

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[1]Data published currently in The Wheat Situation (Agricultural Marketing Service.)

Table 2. WHEAT: FARM PRICE CHANGE FROM HARVEST UNTIL TYPICALLY HIGH MONTH DURING CROP YEAR, OKLAHOMA, 1940-1954

Year	June 15	April 15	Change by April 15	Per Cent Change
1940	.62	.72	.10	16
1941	.79	1.01	.22	28
1942	.96	1.20	.24	25
1943	1.20	1.40	.20	16
1944	1.38	1.47	.09	6
1945	1.43	1.55	.12	8
1946	1.70	2.43	.73	43
1947	1.96	2.22	.26	13
1948	2.02	2.03	.01	--
1949	1.72	2.05	.33	19
1950	1.90	2.21	.31	16
1951	2.15	2.26	.11	5
1952	2.01	2.12	.11	5
1953	1.86	2.12	.26	14
1954	1.91	2.17	.26	13
Average	1.57	1.80	.23	15

Source: Oklahoma Agriculture. Annual Report of The Oklahoma State Board of Agriculture and the Agricultural Marketing Service, United States Department of Agriculture, 1953, 1954.

ping the same land with soybeans or vegetable crops.

Grain drying on the farm may permit harvesting grain earlier in the season. Wheat drying with unheated air may indirectly affect the amount of wheat harvested by permitting farmers to operate their combines a few days earlier in the season than would be possible if it were necessary to depend entirely on weather conditions to dry the grain in the field before starting the combine. A few days gained by starting the harvest earlier could result in saving a crop which might otherwise be lost should a storm occur during the harvest.

On-the-Farm Drying with Unheated Air

Mechanical ventilation with unheated air is potentially an inexpensive method of drying grain under many conditions.

Wheat is dried by this method in circular steel bins or general purpose structures by installing duct systems to insure proper distribution of the air in the grain. Illustrations of some of the common structures and systems in use in Oklahoma are shown in Figures 2, 3, and 4.

Wheat is harvested in late May or early June when the atmospheric conditions in Oklahoma are usually favorable for drying grain with unheated air. Recommended minimum air-flow rates for drying wheat from various moisture levels are given in Appendix C. Table II.

Unheated air drying of grain has certain merits. There is no expense for fuel other than for the operation of the motors; the initial equipment cost is low; little supervision is required; and the fire hazard is small.

However, the process has some disadvantages. There is extreme dependence on weather conditions; the rate of drying is slow and, as a result, during the weeks which may elapse, the grain may be damaged by mold growth.

Figure 2. Circular metal bins prepared for drying wheat and equipped with fan and duct system to supply unheated air.


BUTLER

Figure 3. General-purpose building equipped with air duct and fan unit for drying wheat with unheated air.

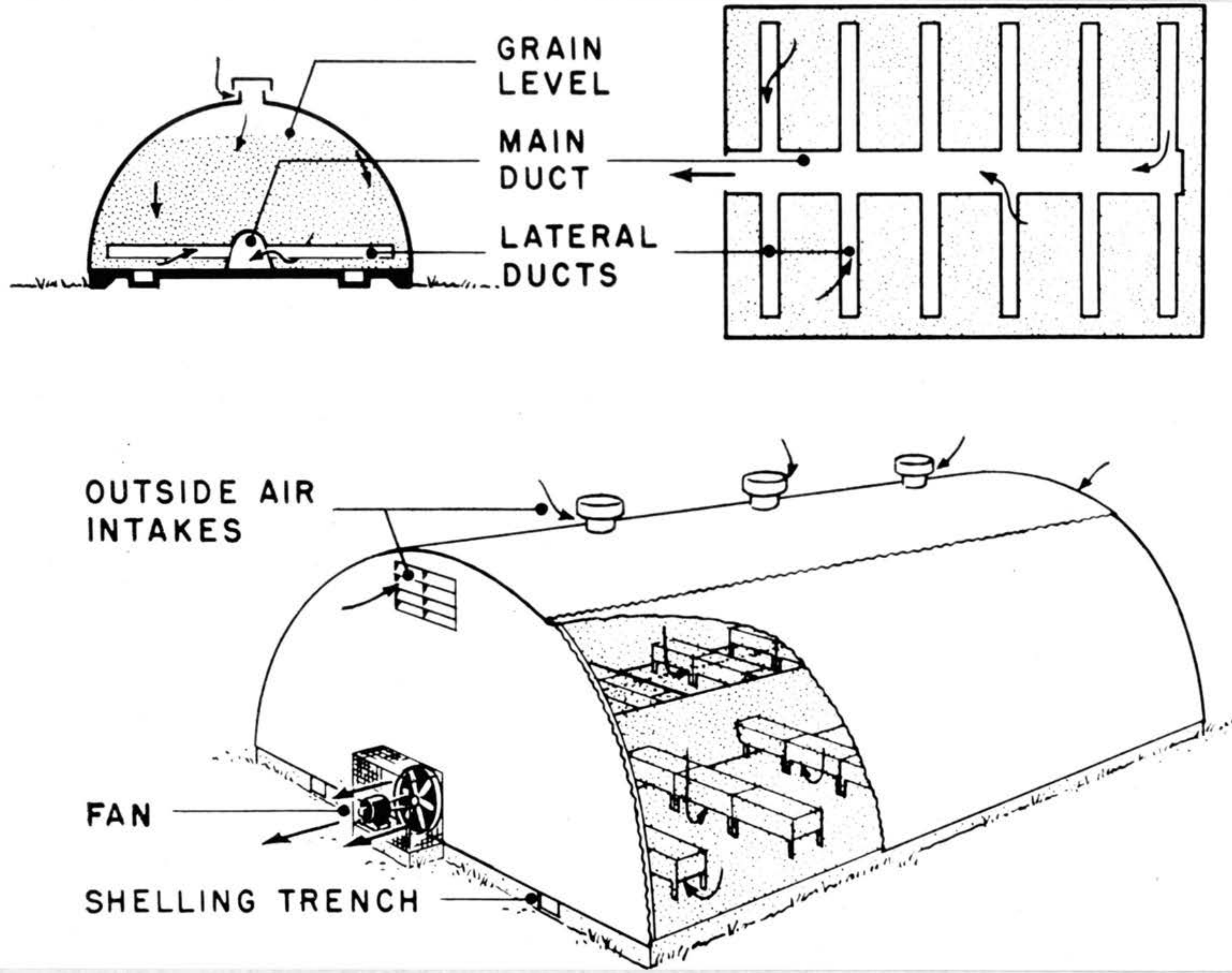
GRAIN LEVEL
MAIN DUCT
LATERAL DUCTS
OUTSIDE AIR INTAKES
FAN
SHELLING TRENCH

Figure 4. Circular metal bins equipped for drying grain with unheated air.


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CHAPTER II

Sources of Data and Procedure

The data on drying wheat with unheated air were secured by personal interview from all Oklahoma farmers who were known to have facilities for drying wheat by this method in 1954. In an attempt to locate these farmers, letters were sent to County Agricultural Agents throughout Oklahoma requesting names of farmers using grain drying equipment.[1] Replies were received from about 60 per cent of the County Agents. In those counties where no replies were received from the County Agent, a similar letter was sent to the County Office Manager of the County Agricultural Stabilization Committee. Between these two agricultural agencies, replies were received from all 77 counties in the state.

From the replies received it was determined that 17 farms in the state were equipped to dry grain on the farm. These farms were visited and detailed questions were asked the operators concerning the drying installation and its operation.

One farm using artificially heated air for drying was discarded because it was the only installation of its kind in operation in the state. Three farms did not complete their drying installations in time for the 1954 harvest; therefore, they were not used in this study.[2]

Location of the grain drying structures were well distributed

[1] See Appendix A.
[2] See Appendix B.

throughout the state as shown in Figure 5.

All the installations were made in 1954. Since the weather during the 1954 harvest season was very favorable, permitting the grain to be harvested in a reasonably dry condition, this study will need to be continued in order to be more representative of average Oklahoma climatic and storage conditions.

Engineering data were taken from the United States Department of Agriculture and state Agricultural Experiment Station publications.

Data on grain spoilage and handling in storage were based on information obtained from: (1) lecture notes and personal interviews with Dr. Max Milner, Department of Flour and Feed Milling Industries, Kansas State College, Manhattan, Kansas; (2) a book recently published, Storage of Cereal Grains and Their Products, American Association of Cereal Chemists, Monogram Series, Volume II; (3) correspondence and personal interview with Dr. Majel M. MacMasters, Chemist in Charge, Starch Granule Section, Starch and Dextrose Division, Northern Regional Laboratory, United States Department of Agriculture, Peoria, Illinois; (4) tests by J. W. Sorenson Jr., G. L. Kline, and L. M. Redlinger on drying and storing sorghum grain in farm storage bins in South Texas, the Agricultural and Mechanical College of Texas, College Station, Texas;[1] (5) the experience of the author who operated a country grain elevator for eleven years and was Commodity Loan Supervisor for the Production and Marketing Administration, United States Department of Agriculture in Oklahoma for three years.

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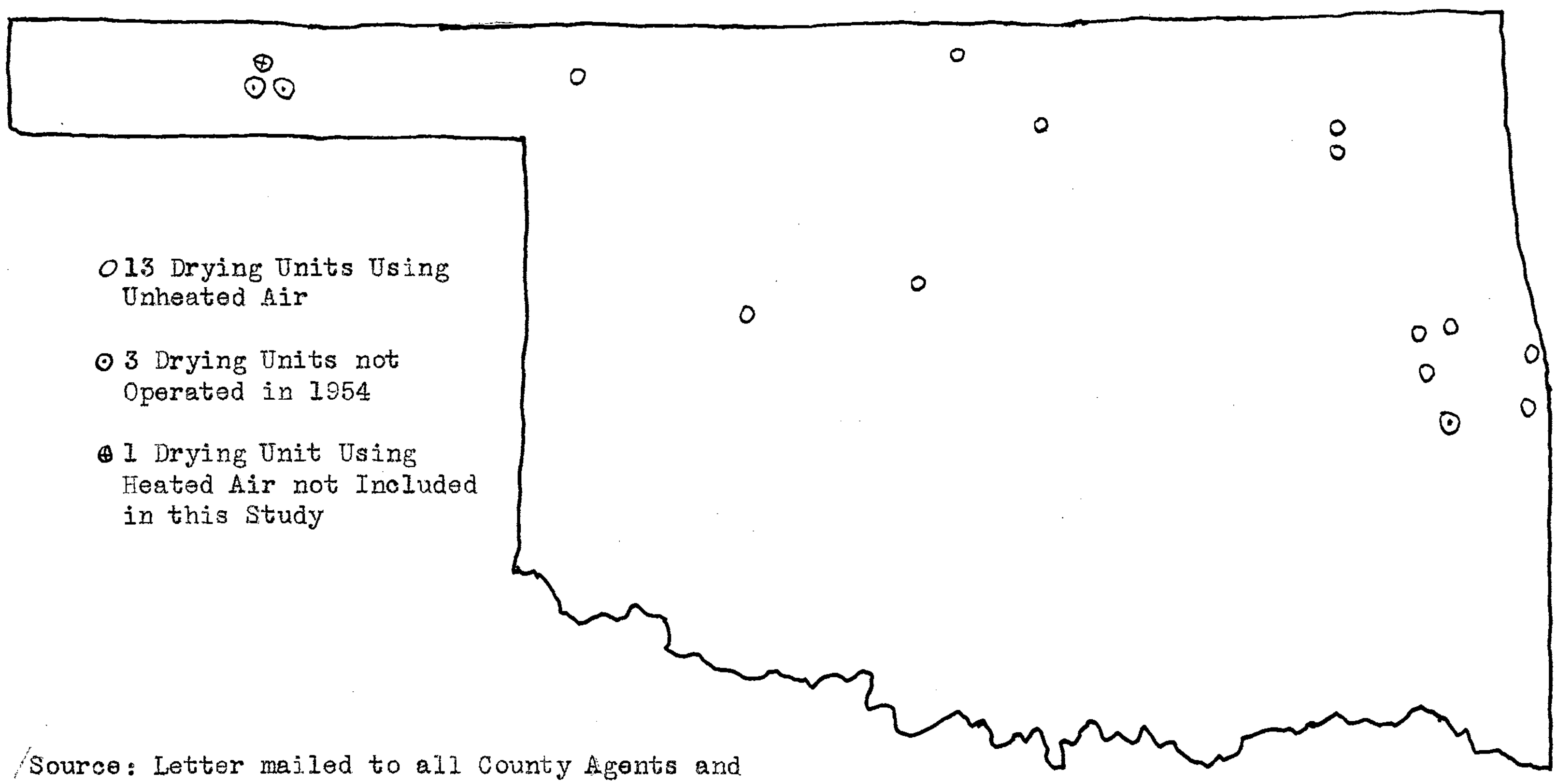
[1] J. W. Sorenson, Jr., G. L. Kline, and L. M. Redlinger, Drying and Storing Sorghum Grain in Farm Storage Bins in South Texas, the Agricultural and Mechanical College of Texas, Progress Report 1685 (College Station, Texas, May, 1954.)

Figure 5. LOCATION OF 17 SURVEY FARMS EQUIPPED TO DRY GRAIN IN OKLAHOMA, 1954



/Source: Letter mailed to all County Agents and County Agricultural Stabilization Committee. Se Appendix A.

CHAPTER III

ECONOMIC FACTORS IN ON-FARM DRYING

Description of Farms Studied

Ten of the 77 counties in Oklahoma were represented by at least one farm in the 13 survey farms studied. One-third of these farms are located in the central and western part of the state and two-thirds are located in the eastern part of the state.

The range and average of total acres, total tillable acres, and wheat acreage for the 13 survey farms are shown in Table 3.

Table 3. Acreage Per Farm on 13 Survey Farms

Items	Range	Average
Total acres	540-7000	1552
Total tillable acres	100-1300	762
Wheat acreage	0-750	284

The tillable acreage, wheat acreage, and capacity of storage equipped for drying for the 13 survey farms is shown in Table 4. The wheat acreage allotments were in effect in 1954 and all the survey farms seeded within their acreage allotment.

Two farms did not plant wheat in 1954. Their drying units were used primarily to dry grains other than wheat, such as, grain sorghum, oats, barley, and other grains.

Thirty-six per cent of the farmers reported they installed drying equipment "to be sure wheat would keep" while twenty-five per cent installed drying equipment specifically "to get the government loan." Only fourteen per cent indicated "earlier harvest." Other farmers indicated that they dried their wheat for the following reasons: (1) to provide insurance against loss of moist grain, (2) to gain a better bargaining position at the elevator, (3) to avoid "dock", (4) to benefit from higher quality, or (5)to protect certified seed. Others bought high moisture grain for livestock feed.

None of the farmers had moisture testing equipment. All indicated they took samples to the elevator for moisture testing. One farmer said he operated his dryer when the humidity was 50 per cent or below. Another watched the local television station for weather reports and operated his dryer when the humidity was 65 per cent or lower. The balance operated their dryers when the air was "dry". No clear explanation could be obtained from them concerning what they considered "dry" air. Most of them felt that lowering the temperature helped keep the grain in better condition. However, no special effort was being made to operate the dryer with temperature reduction as the principle objective.

Ten of the farmers said the installation of their drying equipment did not affect their farm cropping program. Two of them indicated intentions to grow more grain and soybeans. One farmer indicated he would plant winter crops for harvest in the spring rather then plant spring crops for harvest in the fall. Another indicated intentions to plant more late maturing wheat varieties instead of all early maturing varieties. One farmer intends to grow more crimson clover, rye grass,

Table 4. TILLABLE ACREAGE, AND CAPACITY OF STORAGE ON 13 FARMS EQUIPPED FOR DRYING

Number	Total Acres	Tillable Acres	Wheat Acreage	Bushels Capacity 1000's
1	1320	1200	540	17.6
2	1235	950	286	8.8
3	1050	900	150	13.2
4	7000	800	142	4.4
5	630	600	121	18.3
6	1280	1000	535	7.2
7	980	600	108	2.0
8	2200	100	0	3.0
9	540	520	164	2.0
10	800	760	500	34.0
11	583	375	42	4.0
12	1600	1300	750	15.0
13	960	800	350	18.0
Total Average of Positive Items	1552	762	284	11.2

vetch, and fescue. Two farmers stated they harvested earlier than before they had grain dryers. The range indicated was from one to fourteen days earlier. None used his drying equipment for purposes other than drying grain.

Direct Costs of Drying Wheat with Unheated Air

Capital investment

The original average investment in the drying installations, including all necessary equipment, was $857 with a range of $345 to $1800. The investment in the drying equipment for the 13 survey farms is shown in Table 5. All installations were made in 1954.

Fixed costs

As shown by Table 6, fixed costs per year averaged $245.52 on the 13 farms. This represented 91.5 per cent of the total costs.

Depreciation in per cent of purchase price was figured on the basis of actual estimates given by the farmers. All survey farmers used a depreciation rate of 20 per cent. Although each item included in the drying installation may have a different life expectancy, farmers gave only one rate for their entire installation. The 20 per cent depreciation rate reported is the authorized amortization rate allowed under the 1954 Internal Revenue Code permitting accelerated "write-off" rates to encourage the expansion of grain storage facilities. Undoubtedly some of the drying equipment has a life expectancy of more than five years. If a depreciation rate more nearly in line with the actual life expectancy of the drying equipment were used, the farmer's actual annual costs might be lowered in proportion to the added years of life of the equipment.

Table 5. INITIAL INVESTMENT IN DRYING EQUIPMENT ON SAMPLE FARMS IN OKLAHOMA, 1954

Farm No.	Fans (Dollars)	Motor (Dollars)	Wiring (Dollars)	Ducts (Dollars)	Total (Dollars)
1		700	100	1000	1800
2		700	120	565	1385
3		714	114	774	1602
4		700	70	500	1270
5		700	100	500	1300
6	125	145	40	200	510
7	175		10	160	345
8		125	40	184	349
9		108	70	200	378
10	125	150	120	300	695
11	110	135	0	112	357
12		350	100	195	645
13		385	35	85	505
Range		108-714	0-120	85-1000	345-1800
Average					857

Most farmers were not familiar with their insurance rates. Several carried no insurance. Since very little information was received, the customary flat 0.4 per cent of the initial cost of the drying equipment was used for insurance for survey farms. The following rates in per cent of initial investment in the drying equipment were used in determining fixed costs; interest, 5 per cent; taxes, 2 per cent; and maintenance, 1 per cent. Fixed and variable cost data for the 13 survey farms are shown in Table 6.

Of the 13 survey farms only four farmers filled their storage bins to capacity. Eight utilized more than 50 per cent of the capacity, and one used less than 50 per cent.

Fixed costs per bushel for the bushels dried ranged from 1.6 to 8.9 cents per bushel. The average fixed cost was 3.4 cents per bushel for the bushels dried. The fixed cost per bushel of the total capacity of the farms equipped for drying, and the fixed cost per bushel for the bushels dried of the 13 survey farms is shown in Table 7.[1]

If the total storage on the 13 farms equipped for drying had been used to capacity and if total fixed costs had remained unchanged, the fixed cost per bushel would have ranged from 0.6 to 8.2 cents per bushel. The average would have been 2.3 cents per bushel.

Variable costs

Variable costs in the study include only the electrical energy to power the fan. Other variable costs such as labor and repairs were of such minor importance in 1954 that no amount was included to cover these items. However, if farmers keep the records recommended on page 53 and

[1] These costs are limited to direct drying costs only. They contain no allowance for bins or other storage facilities.

Table 6 FIXED AND VARIABLE COST DATA OF 13 FARMS DRYING WHEAT WITH UNHEATED AIR IN OKLAHOMA 1954

		FIXED COSTS						VARIABLE COSTS
No.	Initial cost	Depreciation 20%	Insurance 0.4%	Interest 5%	Taxes 2%	Maintenance 1%	Total	Cost of Electrical & Fuel Energy Used
1	1800	360.00	7.20	90.00	36.00	18.00	511.20	29.36[1]
2	1385	277.00	5.54	69.25	27.70	13.85	421.04	22.50
3	1602	320.40	6.41	80.10	32.04	16.02	454.97	40.00
4	1270	254.00	5.08	63.50	25.40	12.70	360.68	19.00[1]
5	1300	260.00	5.20	65.00	26.00	13.00	369.20	38.50[1]
6	510	102.00	2.04	25.50	10.20	5.10	144.84	30.00
7	345	69.00	1.39	17.25	6.90	3.45	97.99	33.60
8	349	69.80	1.40	17.45	6.98	3.49	99.12	5.00
9	378	75.60	1.51	18.90	7.56	3.78	107.35	18.00
10	695	139.00	2.78	34.75	13.90	6.95	197.38	34.00
11	357	71.40	1.43	17.85	7.14	3.57	101.39	6.00
12	645	129.00	2.58	32.25	12.90	6.45	183.18	9.00
13	505	101.00	2.02	25.25	10.10	5.05	143.42	11.00
Total	11,141	2,227.40	44.58	557.05	222.82	111.41	3,191.76	295.96
Average	857	171.34	3.43	42.85	17.14	8.57	245.52	22.77

[1]Electric meter attached separate and total fuel costs taken from meter readings.

Table 7. FIXED COST FOR CAPACITY USE OF STORAGE EQUIPPED FOR DRYING, AND PER BUSHELS ACTUALLY DRIED IN OKLAHOMA, 1954

No. of Farm	Bushels Storage Capacity Equipped For Drying	Bushels Dried	Total Fixed Costs	Fixed Cost of Drying Per Bushel for Capacity Use of Storage Equipment For Drying	Fixed Cost Per Bushel Dried in 1954
			$	cents	cents
1	17,600	16,000	511.20	2.90	3.2
2	8,800	8,800	421.04	4.8	4.8
3	13,200	11,100	454.97	3.4	4.1
4	4,400	4,400	360.68	8.2	8.2
5	10,600	10,600	369.20	3.5	3.5
6	7,200	7,200	144.84	2.0	2.0
7	2,000	1,200	97.99	4.9	8.2
8	3,000	1,800	99.12	3.3	5.5
9	2,000	1,200	107.35	5.4	8.9
10	34,000	12,000	197.38	0.6	1.6
11	4,000	3,200	101.39	2.5	3.2
12	15,000	11,000	183.18	1.2	1.7
13	18,000	4,550	143.42	0.8	3.1
Totals	139,800	93050	3191.76		

Average Fixed Cost Per Bushel Dried 3.4 cents.

Range 1.6 to 8.9 cents

Average Fixed Cost per Bushel assuming complete utilization of storage and drying capacity and total costs as given, 2.3 cents

Range, assuming complete utilization, 0.6 to 8.2 cents generally observe the recommended operating procedures for grain drying, labor and maintenance costs will be incurred. The cost of fuel for the one gasoline motor reported and for electricity for the other farms were taken from farmer estimates. Variable costs per bushel of grain dried in 1954 are shown in Table 8. Variable costs averaged $22.77 with a range of $5.00 to $40.00. The variable costs per bushel averaged .32 cents with a range of .18 to 2.8 cents per bushel.

Total direct costs.

Total costs discussed here are the total fixed and variable outlays for drying only and do not include shrinkage cost. Table 9 shows that costs for the 13 drying units were 3.7 cents per bushel based upon a total volume dried of 93,050 bushels. This 3.7 cents per bushel would be subject to individual variations for almost any particular farm because of the different costs of the input factors. Total costs per bushel ranged from 1.7 cents to 11.0 cents. Individual farm cost data of 13 survey farms are shown in Table 10.

Total costs of drying grain for these 13 farms averaged $268.29 with a range of $104.12 to $540.56. Of this amount total fixed costs were $245.52 with a range of $97.99 to $511. 20, and total variable costs of $22.77 with a range of $5.00 to $40.00. Of the total, fixed costs averaged 91.5 per cent and variable costs averaged 8.5 per cent. Due to favorable weather conditions for drying grain in 1954, these figures may be out of proportion to operating costs for average or usual weather conditions.

Variations in Drying Costs by Location and Size of Storage Capacity

The average costs of drying wheat per bushel on the survey farms grouped by volume dried in 1954 are shown in Table 11.

Table 8. VARIABLE COSTS PER BUSHEL WHEAT DRIED IN OKLAHOMA, 1954[1]

No. of Farm	Bushels Dried	Total Variable Costs	Variable Costs per Bushel cents
1	16,000	$29.36	.18
2	8,000	$22.50	.26
3	11,100	$40.00	.36
4	4,400	$19.00	.43
5	10,600	$38.50	.36
6	7,200	$30.00	.42
7	1,200	$33.60	2.80
8	1,800	$5.00	.27
9	1,200	$18.00	1.50
10	12,000	$34.00	.28
11	3,200	$ 6.00	.19
12	11,000	$ 9.00	.82
13	4,550	$11.00	2.42
Totals	93,050	$295.96	
Average	7,158	$ 22.77	.32
Range per bushel			.18-2.80

[1]Fuel or power costs only.

Table 9. PER BUSHEL COSTS OF 13 DRYING UNITS OPERATED IN 1954

No.	Bushels Dried	Fixed Costs	Variable Costs	Total Costs	Cost per Bushel
		Dollars	Dollars	Dollars	Cents
1	16,000	511.20	29.36	540.56	3.4
2	8,800	421.04	22.50	443.54	5.0
3	11,100	454.97	40.00	494.97	4.5
4	4,400	360.68	19.00	379.68	8.6
5	10,600	369.20	38.50	407.70	3.8
6	7,200	144.84	30.00	174.84	2.4
7	1,200	97.99	33.60	131.59	11.0
8	1,800	99.12	5.00	104.12	5.8
9	1,200	107.35	18.00	125.35	10.4
10	12,000	197.38	34.00	231.38	1.9
11	3,200	101.39	6.00	107.39	3.4
12	11,000	183.18	9.00	192.18	1.7
13	4,550	143.42	11.00	154.42	3.4
Total	93.050	3,191.76	295.96	3,487.72	--
Average	7,158	245.52	22.77	268.29	3.7

Table 10. DRYING COST DATA FOR 13 FARMS DRYING WHEAT WITH UNHEATED AIR IN OKLAHOMA, 1954

Farm Number	1	2	3	4	5	6	7
Initial investment[1] (dollars)	1,800	1,385	1,600	1,270	1,300	570	345
Year installed	1954	1954	1954	1954	1954	1954	1954
Total Fixed Cost (dollars)	511.20	421.04	454.97	360.68	369.20	144.84	97.99
Total Variable Cost (dollars)	29.36	22.50	40.00	19.00	38.50	30.00	33.60
Total Cost (dollars)	540.56	443.54	494.97	379.68	407.70	174.84	131.59
Bushels Dried	16,000	8,800	11,100	4,400	10,600	7,200	1,200
Moisture content (Start) % cents	15	15	18	18	14	17	17
Total Cost per Bushel	3.4	5.0	4.5	8.6	3.8	2.4	11.0

Farm Number	8	9	10	11	12	13
Initial investment[1] (dollars)	349	378	695	357	645	505
Year installed	1954	1954	1954	1954	1954	1954
Total Fixed Cost (dollars)	99.12	107.35	197.38	101.39	183.18	143.42
Total Variable Cost (dollars)	5.00	18.00	34.00	6.00	9.00	11.00
Total Cost (dollars)	104.12	125.35	231.38	107.39	192.18	154.42
Bushels Dried	1,800	1,200	12,000	3,200	11,000	4,500
Moisture Content (Start) % cents	15	13	16	13	17	15
Total Cost per Bushel	5.8	10.4	1.9	3.4	1.7	3.4

[1] Because all units were new in 1954, the depreciated value is the same as initial investment.

Table 11. Average Costs of Drying Wheat per Bushel on 13 Survey Farms Grouped by Volume Dried in Oklahoma, 1954.

Group	Volume Range Bushels	Number	Ave. Volume Bushels	Ave. Cost per Bushel
				Cents
I	1200-4,999.9	6	2725	6.1
II	5,000-9,999.9	2	8,000	3.9
III	10,000- or more	5	12,140	3.7
Total Average		13	7,158	3.7

Group I dried an average of 2725 bushels with a range in volume from 1,200 to 4,550 bushels. Average drying costs were 6.1 cents per bushel. Costs in this group were rather high due to fixed costs. Depreciation and interest were the largest items of the fixed costs even though the investment in equipment was about $230.00 below the average for all farms.

Group II dried an average of 8,000 bushels with a range of 7,200 to 8,800 bushels. Average drying costs were 3.9 cents per bushel. The fixed charge, as in Group I, was the largest item of cost. Depreciation and interest were also the largest fixed cost items.

Drying an average of 12,140 bushels, Group III had a range of 10,600 to 16,000 bushels. Average drying costs of 3.7 cents per bushel were the lowest of the three groups. Even in this group with higher volume, the fixed cost per bushel dried was high. Depreciation and interest were again the largest costs in the fixed items.

Relationship of Drying Costs to Location

Tables 12 and 13 show drying cost data for individual survey farms

Table 12. PER BUSHEL COSTS OF EIGHT DRYING UNITS IN EASTERN OKLAHOMA, 1954

No.	Bushels Dried	Fixed Costs Dollars	Variable Costs Dollars	Total Costs Dollars	Costs per Bushel Cents
1	16,000	511.20	29.36	540.56	3.4
2	8,800	421.04	22.50	443.54	5.0
3	11,100	454.97	40.00	494.97	4.5
4	4,400	360.68	19.00	379.68	8.6
5	10,600	369.20	38.50	407.70	3.8
7	1,200	97.99	33.60	131.59	11.0
9	1,200	107.35	18.00	125.35	10.4
11	3,200	101.39	6.00	107.39	3.4
Totals	56500	2,423.82	206.96	2,630.78	--
Average	7073	302.98	25.87	328.85	4.6

Table 13. PER BUSHEL COST OF FIVE DRYING UNITS IN WESTERN OKLAHOMA, 1954

No.	Bushels Dried	Fixed Costs	Variable Costs	Total Costs	Costs per Bushel
		Dollars	Dollars	Dollars	Cents
6	7,200	144.84	30.00	174.84	2.4
8	1,800	99.12	5.00	104.12	5.8
10	12,000	197.38	34.00	231.88	1.9
12	11,000	183.18	9.00	192.18	1.7
13	4,550	143.42	11.00	154.42	3.4
Totals	36,550	767.94	89.00	856.94	---
Average	7,310	153.59	17.80	171.39	2.3

in Eastern Oklahoma and Western Oklahoma. Eight of the farms are located in Eastern Oklahoma and five are located in Western Oklahoma.

Total per bushel cost, exclusive of shrinkage costs, in Eastern Oklahoma were two times as great as were the costs in Western Oklahoma. (See Tables 12 and 13.)

The difference in cost per bushel appears to be in the large capital investment in drying equipment. These investments are greater in Eastern Oklahoma. The difference in capital investment between these two areas may be a reflection of the differences in farmers' expectations concerning the problems of on-farm storage.

Weather conditions in 1954 were favorable, both in Eastern and Western Oklahoma, for grain storage on the farm. Greater variation in per bushel cost may be anticipated between these two areas during seasons more nearly normal to Oklahoma climatic conditions. Based on thisassumption the difference in operating costs and/or grain conditioning costs between these two areas is likely to be much greater than this study indicates.

Farmers in Eastern Oklahoma all gave the following reasons for installing their drying equipment: (1) to protect the quality of the grain, (2) lack of commercial storage space, and (3) to be eligible for the government price programs. Farmers in Western Oklahoma were also concerned about the reasons listed above, but indicated other reasons for installing their drying units. Some of these reasons were: (1) to avoid a "dock" at the elevator, (2) to avoid delay in unloading at the elevator, and (3) to purchase high moisture grain from other farmers for use as livestock feed.

Shrinkage as an Indirect Cost of Drying Wheat

Shrinkage cost per bushel depends on the amount of moisture removed, the number of bushels dried, and the price of the wheat, and may amount to more than the direct cost of drying.

The greater the amount of moisture, the greater is shrinkage cost and, therefore, total drying cost. The shrinkage cost will also vary with the price of the wheat. Figure 6 shows shrinkage costs, taking into account the effect of price and the amount of moisture to be removed. This Figure points up the influence of price on shrinkage cost.

The moisture content of the wheat dried on the farms covered in this study averaged 15.8 per cent at the time the wheat was placed in storage. It was assumed that the wheat was dried until the moisture content was reduced to 12.5 per cent, the maximum allowable for safe storage on the farm in Oklahoma. A few farmers dried their grain below the 12.5 level.

Drying wheat from 15.8 per cent moisture to 12.5 per cent moisture brought about a decrease in weight of 4.3 per cent. This reduction in weight was obtained by the following formula:[1]

$$100 - \frac{84.2 \text{ X } 100}{87.5} + .5$$

The 84.2 figure was the percentage of dry matter before drying and the 87.5 figure was the percentage of dry matter after drying. The 0.5 figure was the estimated percentage of invisible loss, such as dust and

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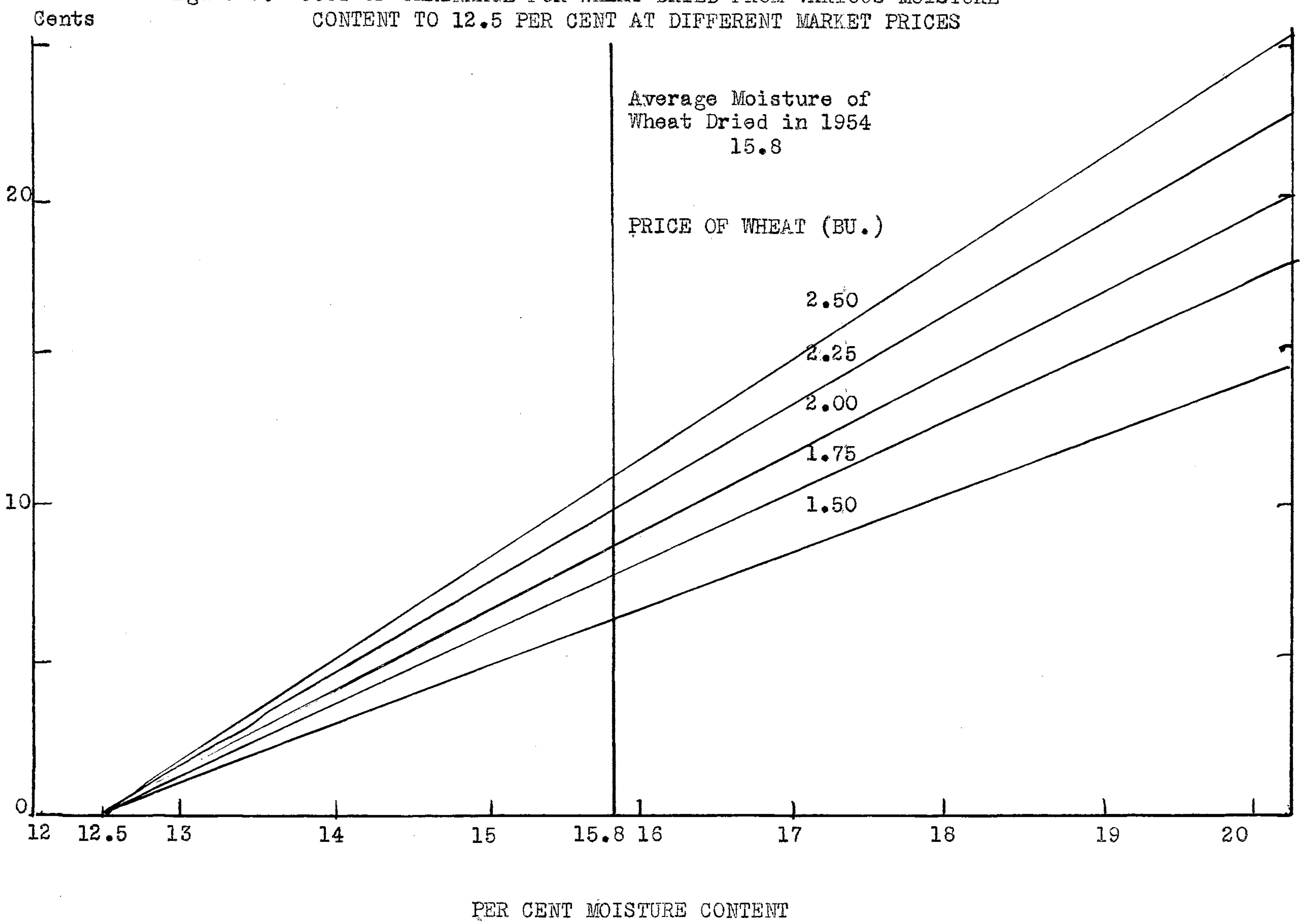
[1]Reduction in weight can also be obtained by an interpolation of Minary Table Series S, <u>Shrinkage Cost of Drying Grain</u>, T. E. Minary, Jr.

Figure 7. COST OF SHRINKAGE FOR WHEAT DRIED FROM VARIOUS MOISTURE CONTENT TO 12.5 PER CENT AT DIFFERENT MARKET PRICES



foreign material blown out of the wheat by the large volume of air circulated. Solution of this equation gave 4.3 per cent decrease in weight of the grain. This 4.3 per cent multiplied by the price of Number 1 Wheat ($2.25 X .043) gave a shrinkage cost of 9.7 cents per bushel as illustrated in Figure 7.

No attempt was made in this study to compare shrinkage costs in Eastern Oklahoma with shrinkage costs in Western Oklahoma. Weather conditions for storing grain on the farm during 1954 were unusually favorable in Eastern as well as Western Oklahoma. Generally, however, rainfall and humidity conditions are higher in Eastern Oklahoma than in other parts of the state. Higher shrinkage costs may be expected in Eastern Oklahoma than in Western Oklahoma under these conditions.

Further research is needed in this area to determine more accurately effects of the differences of these climatic conditions on shrinkage costs.

Economic Feasibility Under Present Operating Conditions

Total fixed and variable costs of 3.7 cents per bushel plus 9.7 cents per bushel shrinkage cost equalled 13.4 cents a bushel. Overall discount of 8 cents per bushel to the farmer for his wheat (as shown in Table 1 for 15.8 per cent moisture content) at the elevator included shrinkage, cost of drying if dried, and a risk charge for handling the high moisture wheat.

The difference of 13.4 cents per bushel when artificially dried on the farm with unheated air, as compared with 8 cents per bushel discount in price at the elevator, raises serious doubt about the practicability of drying grain on the farm. A summary of cost and other information on the 13 survey farms appears in Table 14. However, it is difficult to conclude that drying is or is not profitable on these survey farms. Each farmer has his own costs of drying and his own direct and indirect returns from drying depending upon his operating conditions and alternative storage opportunities. All the farmers surveyed said they intended to keep on drying grain. This indicates that each farmer thought drying was a desirable activity on his farm.

The majority of the farmers surveyed indicated that they installed on-the-farm drying either to protect their grain or to be eligible for government price support loans. In addition, commercial storage was critically short in Oklahoma in 1954. Some farmers sold their wheat at harvest because they did not have on-farm storage or did not wish to assume the storage risk. Government loan support prices on wheat in 1954 averaged $2.25 per bushel for Number 1 Wheat stored on the farm. The market price of wheat dropped as low as $1.85 per bushel during harvest. Some of the farmers who used dryers no doubt would have been forced to sell at a lower price had they not provided on-farm storage.

Earlier harvest, as it affects field losses, a more flexible cropping program, higher quality of grain for storage, and insurance against risk of losing the entire crop in an extremely wet season were advantages frequently attributed to drying. It is difficult to place a monetary value on these items because the value varies with each farm situation and year-to-year variations in weather conditions.

In any harvest dituation, some field losses will occur. The amount of the loss will be affected by weather conditions prior to harvest and at the time of harvesting. It is difficult to arrive at a value which might be placed on field losses prevented by installation of drying equip-

Table 14 SUMMARY OF SELECTED ITEMS OF DRYING INSTALLATION AND OPERATION ON 13 SURVEY FARMS IN OKLAHOMA, 1954

Number of farms	13
Acres per farm	
Range	540-7000
Average	1552
Tillable Acres per farm	
Range	100-1300
Average	762
Wheat acreage per farm	
Range	0-750
Average	762
Bushels dried	
Range	1200-16,000
Average	7158
Per cent moisture per bushel	
Range	13-18
Average	15.8
Fixed cost per farm	
Range	\$97.99-\$511.20
Average	\$245.52
Variable cost per farm	
Range	\$5.00-\$40.00
Average	\$22.77
Cost per bushel (cents)	
Range	1.7-11.0
Average	3.7
Average shrinkage cost per bushel (cents)	9.7
Average total costs per bushel including shrinkage (cents)	13.4

ment.

Presumably, if harvesting at an earlier date and drying the grain would make possible the production of soybean or vegetable crops in rotation, then the value of owning drying equipment would be the net returns of soybeans or vegetables added to wheat, less the cost of drying the wheat.

No attempt was made to place a monetary value on the value of drying equipment as insurance against a complete loss in wet years, or any of the other numerous reasons not already discussed which were mentioned on page 32 in answer to the question asked individual farmers, "For what reason did you install drying equipment on your farm?"

CHAPTER IV

PHYSICAL FACTORS IN SAFE GRAIN STORAGE

The previous chapter was an attempt to evaluate the important economic considerations in the adoption and use of grain drying equipment as found on Oklahoma farms in 1954. Costs, both fixed and variable, have been analyzed and evaluated. It must be remembered, however, that these operations and costs were associated in large part with the most desirable weather conditions for drying grain that might be expected in any given year in Oklahoma. Many of the operators interviewed were not aware of the conditions and limitations of drying their grain prior to their purchase of such equipment. Furthermore, the weather conditions in 1954 were so favorable that operators were not forced to give consideration to what minimum physical conditions might be required for drying grain for safe storage. The size of farms studied suggests that they were probably large enough to assume the economic risk of pioneering with grain drying equipment. For small farmers the risk of impairment to their financial position from such pioneering would be relatively greater. The coincidence of good weather and good drying conditions might mislead the farmers who utilized such equipment in 1954 as well as neighboring farmers who might have been impressed by the results of such drying operations under such favorable conditions.

This chapter is an attempt to clarify some of the physical phenomena associated with drying grain under usual (not optimum) weather conditions in Oklahoma. The economic analysis in this study suggests that for 1954 farmers would have benefited financially by storing their grain in elevators. However, it is recognized that many factors were not taken into consideration in this study. Among the factors omitted were:

1. The fact that upon occasion farmers cannot find elevator storage even for acceptable moisture level wheat. (14 %.)
2. Wheat harvested at higher than the minimum acceptable level must be reduced to the safe storage level by some means to be accepted at local elevators.
3. This represents only the first year of operation on the part of the operators and it is possible that they did not make optimum use of their equipment.
4. Changes in price relationships could possibly change the relative profitability of storage on farms with drying equipment and in elevators.

In spite of the apparent disadvantages of on-farm drying as compared with commercial storage, there may be many farmers who still feel that it is in their best interest to have grain drying equipment on their individual farms. For such farmers, an understanding of the physical requirements for drying grain should reduce the chance of loss.

Conditions for Safe Storage

There are five important factors to consider as conditions for safe grain storage. These are as follows:

1. Moisture content of the grain.
2. Temperature of the grain.

3. Cracked grains and foreign materials or trash.

4. Insects.

5. Age of the grain.

Moisture

In Oklahoma, low moisture content of the grain is one of the principal factors in safe storage. It is usually impracticable to attain a level of moisture content sufficiently low to completely stop all kinds of deterioration, but it is widely recognized that certain levels of moisture content are more or less "safe" for storage. The safe levels of moisture content vary according to the conditions and duration of storage, but there is fairly general agreement, based on past experiences, on what levels are safe in particular circumstances. In Oklahoma, the following are generally considered relatively safe levels of moisture content for the storage of several kinds of grains in farm-type bins for a period of one year:[1]

Kind of Grain	Moisture Content (% wet basis)
Wheat	12.5
Oats	11.8
Barley	12.1
Corn	12.9
Sorghum	12.0
Soybeans	9.7
Flaxseed	7.9

For grains stored as seed stock, or for long-time storage, from three to five years, the moisture level should be 2 per cent lower.

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[1] D. A. Coleman and H. C. Fellows, Hygroscopic Moisture in Cereal Grains, Cereal Chemistry 2:275-287 (1925)

Moisture levels not in excess of those mentioned above are desired. Further, no portion of the grain in bulk, from the storage stage through the marketing channels, should contain a moisture content higher than the level cited.

Average moisture content sometimes does not give a true picture of moisture distribution in bulk stored grain. In a bin with an average moisture content of 13 per cent, it has been found that some of the grain may test as high as 18 per cent. Also there is considerable shifting of the moisture, especially if different portions of the bulk are at different temperatures or if the grain has gone into storage at fairly high temperatures. Broadly speaking, the storage life of a bulk of grain is determined by its dampest part.[1]

Wheat can be stored in some of the Northern Plains States with a moisture content about 2 per cent higher than in Oklahoma because the mean air temperature is about 10° F lower during the summer.

Chemical changes are continually taking place in all grain regardless of how it is stored. A primary objective in the storage of grain, in addition to economic considerations, should be to control conditions, wherever practicable, so that the original quality of the grain is maintained or the deteriorative changes are held at a minimum. How grain is handled before storage is most important. If it has deteriorated in quality because it has been stored with too high moisture content, or if damaged by weather conditions, its prime condition can never be restored.

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[1] C. F. Kelly, B. M. Stahl, S. C. Salmon, and R. H. Black, <u>Wheat Storage in Experimental Farm Type Bins</u>, (United States Department of Agriculture, Circular No. 637, Washington, D. C., April, 1942.)

The moisture content of grain is important because it controls the relative humidity of the air surrounding the grain. Very wet grain provides excellent conditions for the growth of molds, bacteria, or other micro-organisms. Usually the first evidence of spoilage is visible mold growth. In some cases, it may be sourness which results from bacterial fermentation, but mold growth is most common. Mold growth occurs rapidly when the relative humidity is above 74 or 75 per cent, and some kinds of mold will grow well when the relative humidity is as low as 65 per cent. Wheat containing 12.5 per cent moisture at room temperature (approximately 77°) is surrounded with air having a relative humidity of 60 per cent.[1] At this low relative humidity level, molds may take months or even years to develop.

Migration of moisture from the warmer grain in the center of the bulk to that in the cooler surface layer directly above has been observed in the fall. This condition occurs during the fall as the outer and top layers cool faster than the grain in the center of the bin.[2] In late fall, for example, temperatures of grain in the center of the bin may be 20° F higher than those near the outside wall. This difference in temperature causes a circulation of air within the bulk of grain. Air next to the outside wall cools and settles to the floor and moves toward the center where it takes the place of the rising warmer air. As the warm column of air passes through the cool surface layer of grain in the center of the bin, some of its moisture is transferred to the grain by virtue of the greater water vapor pressure in the air as compared with that of the grain. This transfer may increase the moisture content of

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[1]American Association of Cereal Chemists, Storage of Cereal Grains and Their Products, Monogram Series, Vol. II, p. 405.

[2]Ibid. pp. 326, 327.

the grain by 4 to 6 per cent in the upper 10 inch layer of grain. The deeper the bin and the higher the moisture content of the grain, the greater the surface moisture accumulation will be.

"Sick" wheat is a vexing problem to the grain trade. The studies which have been reported indicate that "sick" wheat may be the end result of any one of several different processes, or combinations of them. If the seed is stored moist, or if it becomes moist in storage, fungi (and sometimes bacteria) invade and kill the embryo, and soon after death it turns brown. The embryos of seed stored under atmospheres of carbon dioxide or nitrogen at moisture contents of 18-20 per cent die and turn brown in the apparent absence of active growth of microorganisms. The germs of seed stored dry for years gradually die and turn brown. The nature of this pigmentation remains to be determined. At the present, however, the available evidence indicates that fungi are major cause of of the "sick" wheat condition.[1]

The moisture content of grain is also an important factor in the activity of insects. When the moisture content is as low as 9 per cent in wheat, most of the destructive insects become inactive.

Perhaps the simplest step taken to control the spoilage of grain in storage is turning the grain or drying the grain with a forced draft of unheated air. This may give good results if the grain is not very much above the moisture levels for "safe" storage (12.5 per cent moisture content for wheat) to start with, and if the relative humidity of the air is in the safe area or not in excess of 60 per cent.

Chemicals to inhibit mold growth or chemical drying agents have

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[1] Ibid., p. 212.

been investigated to some extent. These show some promise over a short storage period.

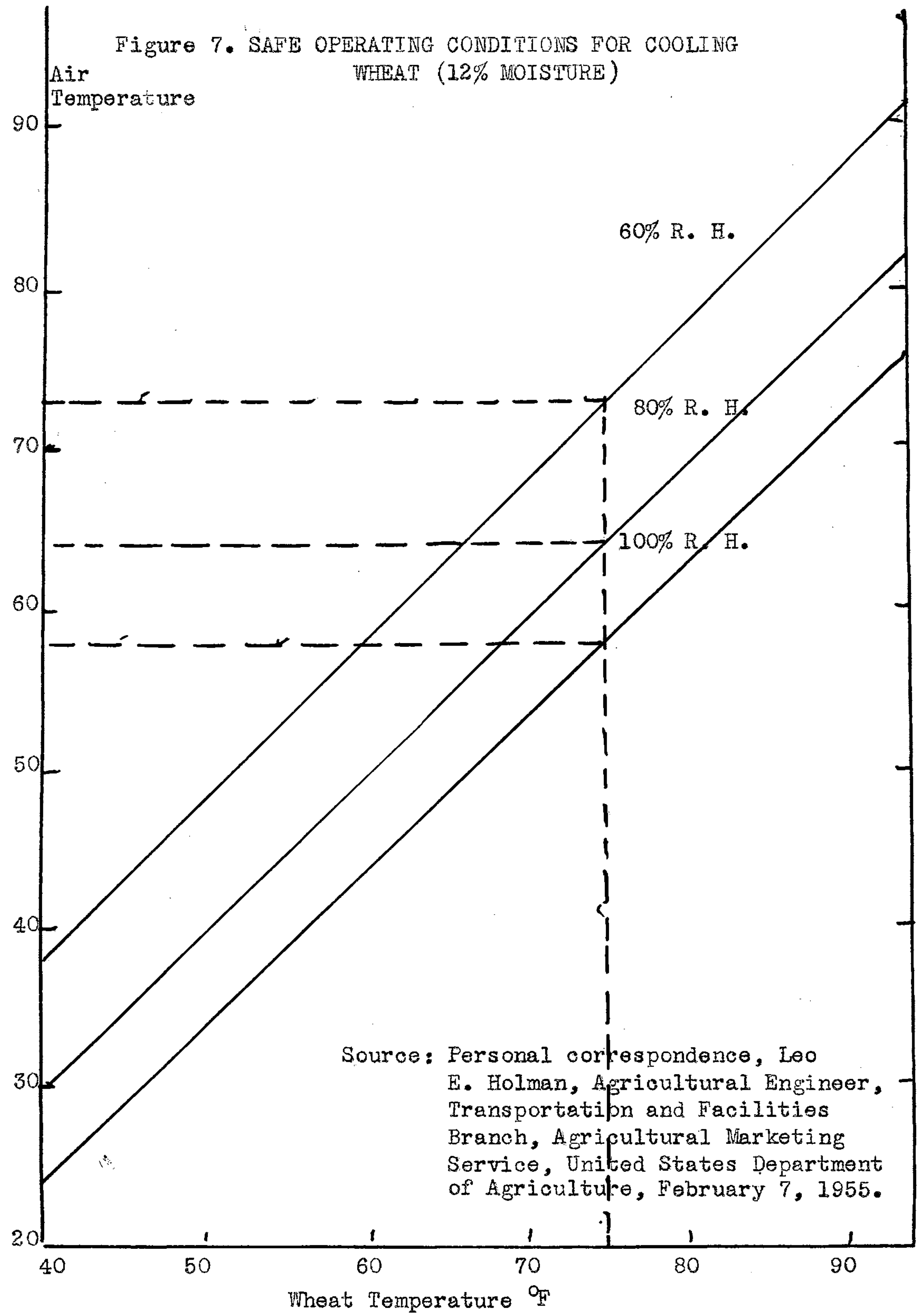
Temperature

Temperature is another important factor in the storage of grain. When grains in storage are cool, there is less likelihood of spoilage. Low temperature offsets the effects of high moisture with respect to the hazards of mold growth and insect development. Hence, grains in cooler climates may be stored safely at moisture levels 1 or 2 percentage points higher than in warmer climates. A noticeable rise in temperature may be the result of heating and evidence of grain spoilage. Molds can heat grain to a temperature of at least 122° to 132° F. Temperatures as high as 142° F have been reported to be caused by mold growth. Bacteria can grow at temperatures that are too high for molds, and have been reported to heat stored grain to a temperature as high as 155° to 159° F. Temperatures of 55° to 60° F seem to be the breaking point for all three of the life processes in the storage of grain, namely, (1) respiration of the grain, (2) respiration of molds, bacteria, and fungi, and (3) insects. Moreover, the recent and rapid adoption of methods of cooling stored grain by mechanical ventilation makes it possible to extend appreciably the safe storage period of high moisture grains. Safe operating conditions for cooling wheat (12 per cent moisture) are shown on Figure 7.

Cracked Grain and Foreign Material

Cracked grain and foreign materials in excessive amounts are also

Figure 7. SAFE OPERATING CONDITIONS FOR COOLING WHEAT (12% MOISTURE)



Source: Personal correspondence, Leo E. Holman, Agricultural Engineer, Transportation and Facilities Branch, Agricultural Marketing Service, United States Department of Agriculture, February 7, 1955.

considered to be important factors in grain storage. They provide favorable conditions for the development of the "non-boring" type of stored grain insects known as bran or fungus beetles. These insects do not develop readily in clean grain but feed primarily on grain dust, broken kernels, and molds. Moreover, it is extremely difficult to fumigate grain which has a high percentage of cracked grain, broken kernels, and foreign materials.

Insects

Insects may be an added cause of grain spoilage. Even a few insects concentrated in a pocket in the grain can heat that area considerably. The heat which they produce provides a suitable climate for them and attracts other insects to join them because of the moderate temperature. In addition to causing the grain to spoil, some stored grain insects feed upon the grain kernels causing loss in weight of the grain as well as damage to the grain. When the respiration of the growing insect colony increases the temperature so much that they become uncomfortable, they move out to the edge, forming an ever-increasing circular zone of heating.

Age of Grain

The age of the grain is a factor in safe storage for long periods of time. Research has been done with grains concerning the length of time they may be stored and maintain germinability. Kanred wheat, stored in a dry unheated room at Fort Collins, Colorado, germinated after a period of 22 years.[1] In an anonymous publication in Colorado A & M News[2] the following germinabilities after storage for the indicated period in a dry, unheated, farm type storage at Fort Collins, Colorado, is reported; Marquis, Kanred, Kubanka wheat average 10.4 per cent after 27 years; barley varieties, average over 25 per cent after 28 years; corn, 16 per cent after 26 years; Rosen rye, 5.6 per cent after 15 years; and Black Amber Sorghum, 92.8 per cent after 23 years. It is stated in the abstract that most seeds show a sharp decline in germinability after the tenth year of storage.[3]

Recommended Operating Procedures[4]

Tests have been conducted at the United States Department of Agriculture Station, Beeville, Texas, since 1949 to determine the practicability of drying and storing sorghum grains on the farm in south Texas. The following recommendations are based on these tests as they apply to the use of unheated air for drying wheat, and its storage on the farm. Since the conditions for grain sorghums drying is similar to conditions found in drying wheat, practical procedures can be obtained from these tests. Climatic conditions are also similar in many respects. These recommendations may be followed as a guide and may be changed as additional

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[1]C. C. Fifield and D. W. Robertson, "Milling, Baking, and Chemical Properties of Marquis and Kanred Wheat Grown in Colorado and Stored 14 to 22 Years." Agronomy Journal of the American Society of Agronomy, Vol. 37, No. 3, pp. 233-239, (1945).

[2]Seed Grains are Tested for Longevity, Colorado A & M News, Vol. 6, No. 7, Vol. 5, (1951).

[3]Biological Abstracts, Vol. 26, 11470, (1952).

[4]J. W. Sorenson, Jr., G. L. Kline, and L. M. Redlinger, Drying and Storing Sorghum Grain in Farm Storage Bins in South Texas, Progress Report 1685, Agricultural and Mechanical College of Texas Experiment Station, College Station, Texas (May, 1954).

results are obtained on drying wheat with unheated air in Oklahoma.

Before Drying

Do not attempt to dry wheat that contains excessive amounts of foreign material or "trash". This material accumulates in pockets, causes air to channel, prevents free air circulation, and results in musty and heat-damaged grain. Proper adjustment of combines at the time of harvest will reduce the amount of foreign material or "trash".

Fill the drying bin to a depth of not over 8 feet with grain containing not more than 18 per cent moisture. As the bin is filled, distribute the grain evenly to prevent cracked grain and foreign material from accumulating in spots.

Select drying equipment that will provide a minimum air-flow rate of 2.0 cubic feet per minute per bushel (3.5 cfm per 100 pounds), with a recommended rate of 2.5 cfm per bushel (4.5 cfm per 100 pounds).

Information required by fan manufacturers in selecting fans for drying include the total air volume and the static pressure requirements. Static pressures required to develop air-flow rates of 2.0 and 2.5 cfm per bushel are:

Air-flow rate per bushel, cfm	Grain depth, feet	Static pressure, inches water column[1]
2.0	6	1.3
2.0	8	2.3
2.5	6	1.7
2.5	8	2.8

[1]Includes an estimated o.25 inch pressure drop in duct system.

During Drying

Start the fan as soon as the air distribution system is uniformly covered with grain. Push air through the grain continuously until the moisture content of the top foot of grain is reduced to about 15 per cent. Then reverse the position of the fan and pull air down through the grain until the moisture content is not more than 12½ per cent in any part of the bin. During the drying period when air is pulled through the grain, operate the fan only when the relative humidity is 75 per cent or less (usually during daylight on clear bright days).

Take samples of grain for moisture content at least twice a week during the drying operation. The bin should be probed at intervals of not more than 6 feet over the surface of the grain and samples drawn from three levels as follows; bottom foot, center foot (halfway between bottom and top) and top foot. The grain from each level should be thoroughly mixed and a moisture check made for each level.

Check grain temperatures at least twice a week. This may be done by forcing 1/8 inch metal pipes at 6 to 8 foot intervals the full depth of the grain and leaving them in the grain throughout the storage period. Temperature checks for warm spots can be made as the pipes are pulled out of the grain. If the pipes are warm to the touch it may indicate heating.

Low grain temperatures during drying do not always insure that the grain is in good condition during the drying period. Therefore, samples obtained for moisture content should be checked for mold growth.

Uniform distribution of air throughout the bin is essential for a successful job of drying. Keep operation records on fan operation, grain temperatures, and moisture content of each bin.

After Drying

Once the grain is considered safe for storage, the temperature of the grain during storage is a good indication of its condition. The temperature should be checked at least once a week during warm weather and every two weeks during the winter. Observations also should be made for insect activity, especially in high temperature areas. Full depth probe samples should be taken monthly in all parts of the bin to determine insect population.

When grain is artificially dried with heated air, or when field dried and loaded into the bin direct from the field, pull air through the grain as soon as possible after the bin is filled to cool the grain to as near average atmospheric temperature as possible. Further aeration during the summer usually is not necessary unless needed to eliminate "hot spots" that may develop. Operate the fan during these periods only when the relative humidity is below 80 per cent. When cool weather starts, aerate each bin as often as necessary to cool the grain to as near average atmospheric temperature as possible. During cool weather, start the fan when the outside temperature is 10° F or more below the average grain temperature, and the outside relative humidity is 80 per cent or less. Continue aeration until the average grain temperature and the outside air temperature are about the same. One thermometer should be placed between the fan and the bin and another on the outside to determine when the air leaving the grain and the outside air are approaching the same temperature. Operate the fan to pull air through the grain during periods of aeration. The fan should not be operated during rain or fog.

Check the moisture content and condition of the grain at least once a month during the storage period. Separate checks should be made at the bottom, center and top foot of the grain.

Records

Previous mention has been made about the importance of maintaining records of the grain drying operation. Figure 8 is suggested as a form suitable for keeping such records. One of the survey farms, operated by Mr. Spencer Littlefield, Spiro, Oklahoma, maintained such a record of his grain drying operations in 1954. Mr. Littlefield stated that keeping a record as provided by this form was helpful to the proper operation of his grain dryer. Since this was a single record, no long time answers could be provided by one year's operation. However, Mr. Littlefield stated, "Everyone operating an on-farm dryer should keep such a record. It helps me to know what's happening to my grain." As additional number of farms provide records of their operations, more detailed and accurate information will be available on grain drying in Oklahoma as represented by average storage and weather conditions.

Figure 8 STUDIES ON FARM GRAIN STORAGE

County ______________ Name of Farmer ______________ Address ______________

Bins and Equipment ______________

BIN NO. ________ (Use separate record sheet for each bin)

Beginning of Study: Date ________

(1) Date bin loaded ________ (2) Kind of grain ________ (3) Wt. of grain ________

(4) Depth of grain in bin ________ (5) Per cent of moisture ________

End of Study: Date

(1) Wt. of grain ________ (2) Per cent of moisture ________ (3)Total hrs. fan operation ________

Record Information

Date	Fan Operation			[1] Grain Temperature [2] Level in bin			[1] Per cent moisture [2] Level in bin			[3] Outside		Other Bins in Operation	Remarks (use back of sheet if needed)
	Time on	Time off	Hrs.	a	b	c	a	b	c	Temp.	Humidity		

[1] Readings at beginning of day before fans are started.
[2] a-Near bottom; b-Middle; c-Near top.
[3] Local weather bureau, if available.

CHAPTER V

Summary and Conclusions

The primary objective of this study was to determine the economic feasibility of on-the-farm drying of wheat with unheated air on Oklahoma farms. The secondary objective was to examine the physical conditions requisite to on-the-farm drying and to recommend operating prodedures, based on research tests.

Because commercial storage was critically short in supply in 1954, some farmers elected to store their grain on the farm. Storing wheat on the farm in Oklahoma involves considerable risk of spoilage. In some seasons rainfall, humidity, and temperature conditions during harvest create a problem of storing wheat containing a high percentage of moisture.

Artificial drying of wheat with unheated air is one possible solution to the problem of moisture in the storage of wheat on the farm.

Oklahoma farmers do not have cost data on drying grain with unheated air under Oklahoma conditions. Generally they have limited knowledge of the reasons why grain spoils in storage. Practical operating procedures for on-farm drying units are not generally known by farmers. For the successful operation of on-farm dryers using unheated air, it is important for the farmer to be aware of the causes of grain spoilage, the practical operating procedures, and the economic feasibility of on-farm drying operations.

In 1954, 17 farms located in Oklahoma were equipped to dry grain.

One farm used artificially heated air for drying and was discarded from the study because it was the only installation of its kind in operation. The other 16 units were designed for the use of unheated air. Three farms did not complete their drying installations in time for the 1954 harvest and, therefore, were not used in this study.

The remaining 13 farms were visited and detailed information was obtained from the operators concerning the drying installations and their operation. The farms were relatively large units. The average total acres per farm was 1,5552 acres of which an average of 762 acres were under cultivation. The average wheat acreage was 284 acres. Allotments were complied with on all 13 farms.

Principal reasons given for installing grain drying equipment were: (1) to prevent spoilage of the grain, (2) to be eligible for government wheat loans, and (3) to permit earlier harvest of the grain in order to prevent field losses and make possible more flexible cropping programs.

Total average storage capacity of the 13 units equipped for drying was 11,200 bushels. The average initial investment in the drying equipment, exclusive of grain bins, was $857. Total fixed costs averaged $245.52 per year assuming the units would be fully depreciated in five years. Depreciation was the largest fixed cost and amounted to 91.5 per cent of the total costs. Variable costs averaged $22.77 per year.

Fixed costs per bushel on the grain dried in 1954 averaged 3.4 cents. Under the above total fixed cost conditions these costs could have been reduced to an average of 2.3 cents per bushel if the available storage had been used to capacity. Variable costs averaged .32 cents per bushel.

On 6 survey farms equipped for drying and having storage capacities of 1,200 to 4,999.9 bushels, the average fixed and variable costs for drying amounted to 6.1 cents per bushel compared with 3.9 cents per bushel on 2 farms having storage capacities of 5,000 to 9,999.9 bushels and 3.7 cents on 5 farms with storage capacity of 10,000 bushels or more.

Operating costs of 4.6 cents per bushel dried on farms operating drying units in Eastern Oklahoma were double those of 2.3 cents on farms in Western Oklahoma despite favorable grain storage conditions in all sections of the state in 1954.

Shrinkage, an indirect cost of drying wheat, average 9.7 cents per bushel on the 13 farms studied. The average moisture content on these farms was 15.8 per cent. All farms attempted to dry their grain to 12.5 per cent moisture content or below. The difference between 15.8 per cent and 12.5 per cent moisture content was used as a conservative basis for arriving at shrinkage costs. This indirect cost represented almost 75 per cent of the total cost of 13.4 cents per bushel.

The difference between 13.4 cents per bushel when artificially dried on the farm with unheated air, as compared with 8 cents per bushel discount in price at the elevator for undried grain, raises serious doubt about the profitability of drying grain on the farm. However, in spite of these findings, it is difficult to conclude that drying is definitely not desirable on these survey farms. Considerations other than those evaluated in this study were recognized by the farmers operating these drying units. In some cases it is difficult to place monetary values on these items. These considerations, some of which have already been cited, were: (1) to protect the quality of the grain, (2) to be eligible for government price support loans, (3) to insure against the shortage of commercial storage, (4) to hold the grain for seasonal price rises, (5) to re duce field losses by earlier harvest,and (6) to permit a more flexible cropping program.

No comparison of shrinkage costs in Eastern Oklahoma and Western Oklahoma were made in this study. However, because rainfall and humidity are usually higher in Eastern than in Western Oklahoma, it may be assumed that these costs will normally be higher in Eastern Oklahoma.

There are five important factors to consider as conditions for safe grain storage. These are as follows: (1) moisture content of the grain, (2) temperature of the grain, (3) the presence of cracked grains and foreign materials or trash, (4) insects, and (5) age of the grain.

Under Oklahoma climatic conditions, wheat containing moisture in excess of 12.5 per cent is considered unsafe for storage. Temperatures in Oklahoma, during harvest and for several months thereafter, are usually high enough to be favorable for mold growth. This mold growth is generally the principal cause of grain spoilage. Cracked grain and foreign material are also favorable for mold growth and insect damage.

Insects are an added cause of grain spoilage and the age of the g grain becomes a factor in spoilage if the storage extends over a long period of time.

Research has been cited which provides the basis for recommendations of conditions desirable for the use of unheated air for drying and storing wheat on the farm. Basic operating procedures, before, during, and after drying, should be followed to operate unheated air dryers successfully. Records would be helpful to provide a progress report of the grain drying operation and condition of the grain in storage. A form suitable for keeping such records was developed in the course of this study.

This study should be continued and expanded for the next several years. As they operate their drying units, the experience of the survey farmers, and other farmers who may install on-farm drying equipment, will provide more accurate indications of the value of such equipment in meeting the problem of grain storage in Oklahoma. Limitations on the adequacy of this study were imposed by the fact that operating data were available only for the year 1954, that unusually favorable climatic conditions for storing grain on the farm prevailed, and that, as yet, only a few farms are equipped for grain drying.

BIBLIOGRAPHY

Anderson, J. A., and A. W. Alcock. Storage of Cereal Grains and Their Products. American Association of Cereal Chemists, Monograph Series, Vol. II, 1954.

Biological Abstracts, Vol. 26, No. 11470, Baltimore 2, Md., 1952.

Chaffin, Wesley, and Edward L. Grandstaff. Wheat Harvesting Losses. Circular 527, Extension Service, Oklahoma Agricultural and Mechanical College, undated.

Davis, W. K., and J. A. Shute. Artificial Corn Drying by 29 Selected Elevators in Indiana. General Report 5, Farmers Cooperative Service, United States Department of Agriculture, 1954.

Fifield, C. C., and D. W. Robertson. "Milling, Baking, and Chemical Properties of Marquis and Kanred Wheat Grown in Colorado and Stored 14 to 22 Years." Agronomy Journal, Vol. 37, No. 3, 233-239. 1945.

Hall, Thomas E., Adlowe L. Larson, Howard S. Whitney, and Charles H. Meyer. Where and How Much Cash Grain Storage for Oklahoma Farms. Farm Credit Administration Bulletin, No. 58. 1950.

Holman, Leo E. "Storage Problems in Country Elevators." Unpublished Public Address, National Grain Sanitation Conference, 1954.

Kelly, C. F., B. M. Stahl, S. C. Salmon, and R. H. Black. Wheat Storage in Experimental Farm Type Bins. Circular No. 637, United States Department of Agriculture. 1942.

Lane, C. H. "Seed Grains Are Tested for Longevity." Colorado A & M News, Agricultural Experiment Station, Fort Collins, Colorado.

McMasters, Majel. Correspondence and Private Communications, Chemist, Starch, Granule Section, Starch and Dextrose Division, Northern Regional Laboratory, United States Department of Agriculture. Peoria, Illinois. 1954.

Milner, Max. Private Communications and Lecture Notes. Department of Flour and Feed Milling Industries, Kansas State College, Manhattan, Kansas. 1954.

Sorenson, J. W., G. L. Kline, and L. M. Redlinger. Drying and Storing Sorghum Grain in Farm Storage Bins in South Texas. Progress Report 1685. Agricultural and Mechanical College of Texas, College Station Texas. 1954.

United States Department of Agriculture. Stocks of Wheat and Feed Grains. October 1, 1954. 318 Federal Building, Oklahoma City, Oklahoma.

United States Department of Agriculture. *Handbook of Official Grain Standards of the United States*. Production and Marketing Administration, Grain Branch. Revised 1951.

United States Department of Agriculture. *Drying Shelled Corn and Small Grains with Unheated Air*. Leaflet 332. 1952.

United States Department of Agriculture, Agricultural Stabilization and Conservation Service. *List of Commerical Warehouses in Oklahoma*. Stillwater, Oklahoma, January, 1955.

APPENDIX A

August 3, 1954

To All County Agents

Dear Agent:

Re: Grain Aeration or Drying Facilities

There has been for the past several years increased interest in grain aeration or grain drying, both on the farm and in country elevators. These facilities have been installed in a number of counties in Oklahoma.

In order that we may learn more about the operations and locations of the facilities in the state, please send us a report on the following questions.

1. There are ____________ (or are not) grain
number
aerating or drying facilities in ____________.
county

2. These facilities are on the farm ☐ or at a country grain elevator ☐. Check ✓ one or both.

It may be advisable to check these questions with the local ASC County Office Manager since they may have made loans on these facilities or on grain stored in facilities having aerating or drying equipment.

We will appreciate your report as soon as convenient.

APPROVED:

Shawnee Brown
Shawnee Brown
Director

Very truly yours,

James R. Enix
James R. Enix
Extension Wheat
Marketing Specialist

APPENDIX B

CONFIDENTIAL INFORMATION

ECONOMICS OF GRAIN AERATION AND GRAIN DRYING

1. Name of farmer ______________________________

2. Address ______________________ Location of farm ______________

3. Total acres operated ________ Acres Tillable ________ Tenure ________

4. What grain storage capacity do you have on the farm?

Bldg. type	Date Erected	Grain Stored	No. of Bins	Size Bins	Type of Bin Construction	Capacity Bushels

AERATION OR DRYER TYPE AND COST INFORMATION

1. Is your equipment used for aeration or drying grain? ____________

2. Type of aerator or dryer:

Portable	____________	Stationary	____________
Direct	____________	Indirect	____________
Oil	____________	Gas	____________
Batch	____________	Bin	____________
Heated Air	____________	Unheated Air	____________
Other	____________	Electric	____________

3. Make of aerator or dryer ______________________ Model ____________

4. What is the method you use to distribute the drying air?

False perforated floor ________ Duct system ______ Horizontal ___ Vertical __

5. Other ____

5. When did you install your aerator or dryer? 19__ How many of the years have you used the aerator or dryer? ______yrs. Have you operated it each year since it was installed? ______Yes ______No.

If no, explain ____

____

6. What was the cost of your aerator or dryer installed and ready for use?

Component part	New	Used	Cost if bought	Cost if homemade Labor (Hrs)	Cost if homemade Materials
Blower	___	___	$______	$______	$______
Motors	___	___	$______	______	$______
Burner Unit	___	___	$______	______	$______
Ducts	___	___	$______	______	$______
Fans	___	___	$______	______	$______
Container	___	___	$______	______	$______
Wiring	___	___	$______	______	$______
Installation	___	___	$______	______	$______
Contracted	___	___	$______	______	$______

7. Aerator or dryer depreciated at ____% per year. If broken down by component parts, what is depreciation rate?

Component Part	% Depreciation per year
Blower	______
Motor(s)	______
Burner Unit	______
Ducts	______
Fans	______
Container	______
Wiring	______
Other	______

8. What do you estimate the life of your aerator or dryer to be? ___years.

9. Does aerator or dryer have separate insurance coverage? ___yes. ___no.

a. If yes, what is the cost per year? $______

b. If no, how did the installation of your aerator or dryer affect your other insurance rates? ____no effect. $______increase. $____decrease.

c. If no, what is your insurance rate per $100? ______cents.

d. What is extent of insurance coverage $______fire, $______wind, and $______other?

AERATION AND DRYER OPERATION INFORMATION

1. Do you operate your aerator or dryer to reduce temperature ________ dry grain ________ or prevent moisture migration ________?

2. How many hours of fan operation is required to dry ______ bushels from ________% to ________% __________ hours.

3. What hours of the day or night do you prefer to operate aeration or drying equipment ________ a.m. to ______ p.m. Why? ____________

____

____

4. Do you consider humidity conditions in operation of aerator or dryer? Yes ____ No ____. If yes, at what humidity levels do you consider it satisfactory to start fans? __________%.

5. How are humidity conditions determined? Explain _______

____

6. Do you consider temperature conditions in operation of aeration or drying equipment? Yes______. No______.

   If yes, at what temperature levels do you consider satisfactory to start fans? _________ degrees F.

7. Is your temperature thermostatically controlled? ____ yes. _____ no.

   If yes, at what temperature? ______.

8. Are thermometers used to determine temperature? _____ yes. _____ no.

9. What kind of fuel does your aerator or dryer use? __________

   Is this satisfactory? ___ yes. ____ no. If no, explain __________

____

10. What was the amount of electricity used to operate aerator or dryer last year? ____ k. w. h. $______ rate per K. w. h. $____ total cost.

11. What are fuel costs to date this year? From ________________ to

________________, k. w. h. $________ rate per k. w. h. $__________
date
total cost.

12. What is horsepower of motor(s) and what use was made of them?

	No. of Hrs. Used		
	Drying	Other	Describe Other Use
________ H. P.	________	________	________________
________ H. P.	________	________	________________
________ H. P.	________	________	________________

13. What are the dimensions of your bins? (sketch)

Grain	Number	Size	Floor Area (sq.ft.) or Cross Section	Thickness of grain through which air passes
________	________	______	______________	________ inches
________	________	______	______________	________ inches
________	________	______	______________	________ inches

OPERATING COST INFORMATION

1. What was your cost for repairs during the last year? $____________

   Was this typical? _____yes. ______no. If no, explain______________

   ____

   a. Does the above total cost include labor? _____yes. _______no.

      If no, how many hours of labor was spent in repair work? _______hrs.

2. Please describe for the process through which you go in actual drier operation:

	Wheat	Other Grain
a. Man hours required per day to refuel dryer?	____	____
b. Man hours required per day on natural air dryer for		
(1)attention	____	____
(2)move fans	____	____
(3)change ducts	____	____
c. Man hours of labor required to prepare dryer for first batch?	____	____
d. Man hours of attention, supervision for first batch?	____	____
e. Average man hours required per batch after first batch?	____	____

f. Man hours per day(24 hr. period) required on continuous dryer? ____ ____

g. Extra man hours required, if any, to handle grain from field to storage through drier vs. direct? Per day ____ ____

GRAIN PRODUCTION AND QUANTITY DRIED

1.

Grain		Acres	Total Production	Harvested Start	Harvested Stop	% Moisture Start	% Moisture Stop	Bushels Dried
Wheat	(own)	____	____	____	____	____	____	____
	(bought)	____	____	____	____	____	____	____
	(custom)	____	____	____	____	____	____	____
Other Grains	(own)	____	____	____	____	____	____	____
	(bought)	____	____	____	____	____	____	____
	(custom)	____	____	____	____	____	____	____

2. What is your charge for custom drying grain?____________________

____

3. Disposition of grain. 19__.

Grain	Amount stored & fed	Fed in what form	Amount sold	Type market	Price received	% Moisture at sale	Discount (if known)
Wheat	____	____	____	____	____	____	____
Barley	____	____	____	____	____	____	____
Oats	____	____	____	____	____	____	____
Other grains	____	____	____	____	____	____	____

4. In 19__, you had ___acres of wheat. How many acres was your average per last five years? ___acres. Your 19__ yield was ____ bushels. What was your average yield over the last five years? ____bus. acre.

5. In 19__, you sold ___ bushels or ___% of your total wheat production. How many bushels did you sell on the average over the past five years? ____ bus.

6. In 19__, you purchased ___bushels of wheat and did custom work on ____ bushels. How many bushels did you purchase on the average over the last five years? ___ bushels. How many bushels of custom work did

you average over the last five years on wheat? ____ bushels.

7. In 19__, you had ____ acres of small grains other than wheat. How many acres was your average over the last five years? ____ acres. Your 19__ yield was ____ bushels. What was your average yield over the last five years? _____ bus. acre.

8. In 19__, you sold ____ bushels or ____% of your total small grain production. How many bushels did you sell on the average over the past five years? _____ bushels.

9. In 19__, you purchased ____ bushels of small grains and did custom work on ____ bushels. How many bushels did you purchase on the average over the last five years? ____ bus. Ave. custom work, past 5 years _____ bushels.

10. What is the custom drying rate at your local elevator? ___________

____

EFFECT OF DRYER ON FARM PROGRAM

1. Did the installation of your dryer change the acres of any crops you raise? __yes. __no. If yes, explain ___________________________

____

____

2. As compared to before you dried grain, do you harvest ____ earlier, ____ later, or the ____ same time? How much ___ wheat ____ small grains.

3. How was your method of harvesting changed by the installation of your drying equipment? ________________________________

____

4. Does your operation of grain drying compete with other farm work? ____yes. ____no. If yes, specify area. ____________________

____

5. Since the installation of your dryer, have you been able to cut down on your field losses? ____yes. ____no.

   a. What would you estimate your field losses to be in bushels per acre for

Grain	Best harvest Time	2 weeks later	3 weeks later	month later
Wheat	________	______	______	____
Other small grain	________	______	______	____.

   b. Do you use livestock to glean your grain fields? ____yes. _____no. What per cent of field losses do you estimate that your animals recover? _______%.

6. What other uses do you make of your grain drying equipment, if any?

____

____

SAMPLING METHODS AND MOISTURE CONTENT DETERMINATION

1. How do you determine moisture content of grain at harvest?

   For market____

   For storage____

2. What is your method of sampling grain for moisture content determination?

   At harvest____

   While drying____

   a. Is there any difference in sampling methods between grain to be stored or marketed? _____yes. _____no. If yes, explain______________

   ____

   ____

OTHER QUESTIONS

1. For what reasons did you decide to install your drier in 19__?

____

____

____

2. Have these objectives or goals been realized? ______________

____

3. If you had no drying equipment on the farm now, would you put any in?

_____yes. _____no. If yes, what type of installation would you

choose? ____

For what reasons? ____

____

4. Do you know of any other farmers in this community who dry grain?

Name________________________ Address ______________ Location____

Name________________________ Address ______________ Location____

Name________________________ Address ______________ Location____

Name________________________ Address ______________ Location____

APPENDIX C

Fan Requirements for Drying Wheat with Unheated Air from Different Percentages of Moisture Content and at Various Practical Depths[1]

Grain Moisture Content (percent)	Recommended Minimum air-flow rate per bushel	Practical Grain Depth	Static Pressure[2]	Maximum Quantity that can be dried per fan horse-power[3]
	Cubic feet per minute	Feet	Inches water gage	Bushels
20	3	4	(1.2	830
		6	(2.3	440
18	2	4	(.8	1880
		8	(2.5	600
16	1	8	(1.3	2300
		10	(2.0	1500

[1]United States Department of Agriculture, Leaflet No. 332, Drying Shelled Corn and Small Grains with Unheated Air, Table 1, Page 5.
[2]Static pressure includes 0.25 inch allowance for loss from duct friction.
[3]Air flow (cfm) per horsepower based on 3,000 cfm of air at 1 in.

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