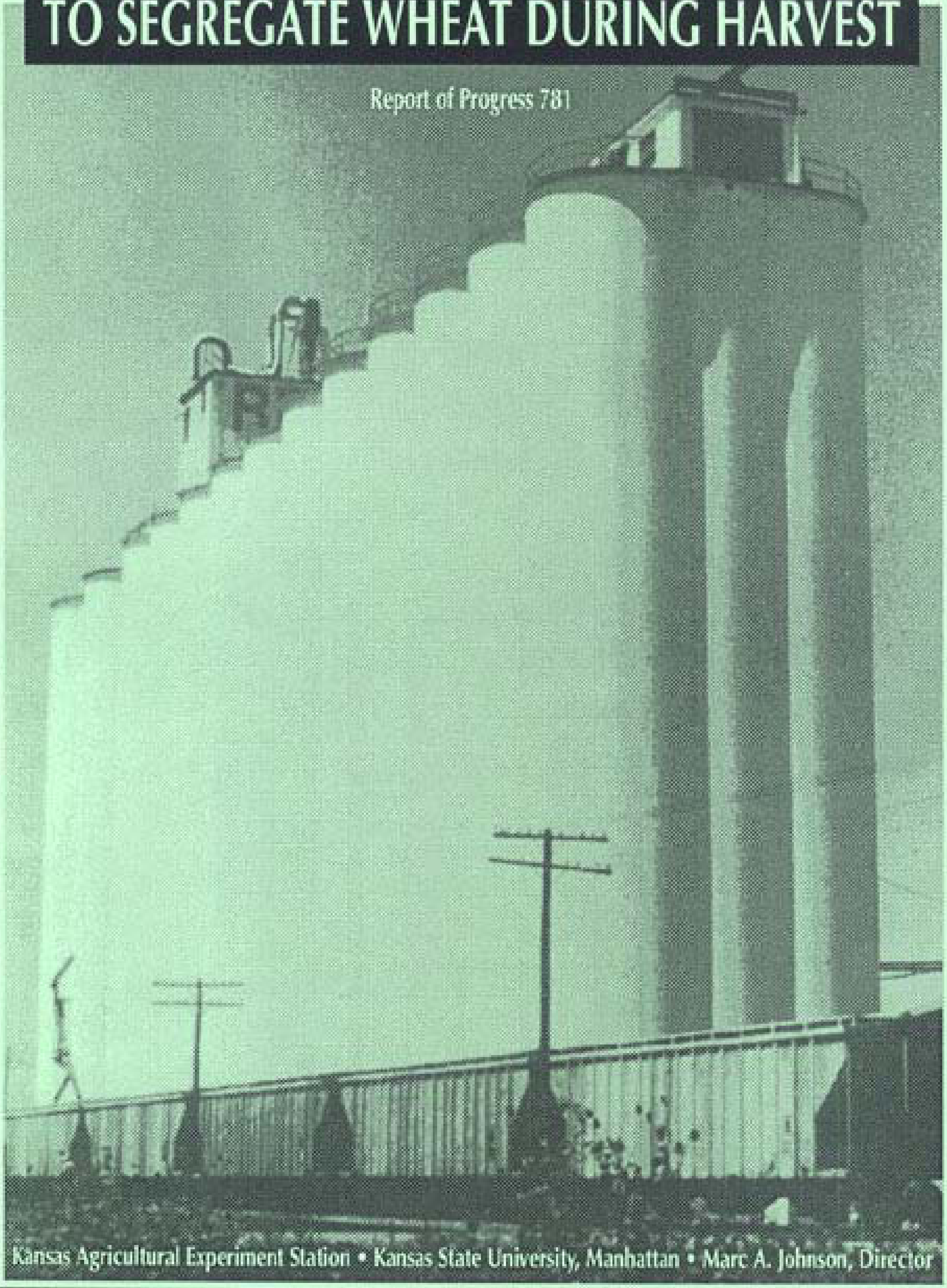
CAPABILITY OF KANSAS GRAIN ELEVATORS TO SEGREGATE WHEAT DURING HARVEST

Report of Progress 781



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CAPABILITY OF KANSAS GRAIN ELEVATORS TO SEGREGATE WHEAT DURING HARVEST[1]

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ABSTRACT

Several changes in U.S. farm policy and grain markets and advances in technology for the rapid assessment of wheat end-use quality have occurred during this decade. These changes increase the likelihood that a quality-oriented marketing system for hard winter wheat will be adopted in the Southern Plains. The ability of grain handlers to segregate wheat at the first collection point (country elevators) will be critical in the transition from a commodity-based to a quality-based marketing system. Information obtained from the Kansas Grain and Feed Association Directory showed that grain elevators in the North Central, Central, and South Central crop reporting districts of Kansas with a capacity of <1.0 million bushels account for 85% of the country elevators and 75% of the grain storage capacity, excluding inland terminals with capacities ≥ 2.0 million bushels. Our study characterized the potential of country elevators to segregate wheat during harvest rush based upon an analysis of the grain-receiving system of 20 country elevators in those three crop reporting districts. Results showed that 1) approximately 2 minutes were necessary to sample and evaluate wheat quality; 2) most country elevators had two receiving pits per bucket elevator; 3) less than 45% of the grain-receiving systems were operated at or above 70% of their capacity; 4) the distribution of the percentage of operating hours during harvest versus percent burden was skewed with the most frequent burden being 10%; 5) the distribution of the percentage of bushels received during harvest versus percent burden resembled a normal distribution centered around a burden of 40%. These observations led to the conclusions that an opportunity exists to improve the operating efficiency of receiving systems at country elevators and that segregation is possible.

[1]Contribution No. 97-269-S from the Kansas Agricultural Experiment Station. Trade names are used to identify products. No endorsement is intended, nor is any criticism implied of similar products not named.

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INTRODUCTION

The Grain Quality Acts of 1986 and 1990 contain congressional mandates for the Federal Grain Inspection Service and Agricultural Research Service to collaborate in the design and implementation of a quality-based marketing system. Much progress in the rapid identification and prediction of end-use quality has been made in recent years; however, the feasibility of first collection points (country elevators) segregating wheat has received little attention. Presently, more than 85% of the hard winter wheat grown in Kansas, Oklahoma, and Texas is delivered to commercial grain elevators during harvest. The ability to identify and segregate superior quality wheat during harvest is limited by the large volume of grain delivered in a short period of time. This "harvest rush" is believed to be the major hindrance in the identity-preserved marketing of wheat in the Southern Plains. Assessing the capability of country elevators to segregate grain under the present marketing structure is a necessary step in evaluating the feasibility of a quality-based marketing system.

The physical and time limitations as well as the burden on grain handling equipment during the harvest rush in the Southern Plains had not yet been quantified. Therefore, this study was designed to characterize the potential of country elevators to segregate wheat during harvest rush based upon an analysis of the grain receiving system of 20 country elevators in the North Central, Central, and South Central crop reporting districts of Kansas.

METHODOLOGY

The Kansas Grain and Feed Association Directory (1995) was used as the source from which a representative sample of commercial grain elevators was selected. This association represents approximately 98% of the elevators in Kansas. The elevators were stratified based upon crop reporting district (North Central (NC), Central (C), and South Central (SC) and vertical storage capacity (<0.5 million bushels, 0.5 - 1.0 million bushels, 1.0 - 2.0 million bushels, and >2.0 million bushels). Twenty elevators were included in the study (Table 1). At all locations, a stopwatch time-motion study was used to measure the time required to evaluate wheat quality. In addition, the capacity of the conveying equipment in the receiving system was estimated, and a second stopwatch time-motion study was used to measure the operating efficiency. Ticket scale data for 16 locations were used to estimate the burden on the receiving equipment.

Table 1. Distribution of Elevators

District	< 0.5 (Million Bu)	0.5 – 1.0 (Million Bu)	1.0 – 2.0 (Million Bu)	2.0 + (Million Bu)	Total
North	2	4	1	0	7
Central	2	1	1	0	4
South	4	2	2	1	9
Total	8	7	4	1	20

Time-Motion Study of Grain Sampling and Quality Evaluation

The stopwatch was started when the truck had stopped on the scale and the inbound weight of the truck had been printed on the ticket. The time required to probe the truck and evaluate the quality of the sample was recorded. Time measurement was stopped after all quality evaluations had been completed.

Characterization of Grain-Receiving Systems

In order to assess the potential for grain segregation at country elevators, the capacity of the conveying equipment in the grain-receiving system at each elevator was estimated. The capacity of the receiving system was determined by selecting the rate-limiting conveyor (i.e., lowest conveying capacity). In a majority of the elevators observed, the bucket elevator was the rate-limiting step. The following general equipment information was taken to estimate the grain-receiving capacity: number and holding capacity of receiving pits (capacity was estimated by elevator employees), conveyor manufacturer and model type (if available), motor Hp and RPM, sheave diameters of the motor and gear reducer, and gear reducer ratio. If the motor information was not available, a tachometer was used to measure shaft speed.

Estimating Bucket Elevator Capacity

Additional information that was required to estimate the bucket elevator capacity included: cup material, cup dimensions, cup spacing, and head pulley diameter. Cup carrying capacity was based upon a style CC bucket, because it was the most prevalent. Net carrying capacity was calculated as 75% of gross carrying capacity for both plastic and metal buckets based on manufacturer's literature. Cup spacing, measured as the distance between two consecutive cup projections, was used to determine the cup spacing multiplier (Appendix Table 1). Head pulley diameter was calculated by measuring the distance between the bucket elevator's two conveyor trunks and adding 2 inches. This was done based on the assumption that an inch clearance between the trunk casing and belt occurred on each side. This value then was compared to a list of standard head pulley diameters (Appendix Table 2) and the next largest diameter was selected as the pulley diameter. The estimated bucket elevator capacity was calculated using the following equations:

$$\text{Shaft RPM} = \frac{\text{Motor RPM} \times \text{Motor Sheave Dia (in)}}{\text{Reducer Sheave Dia (in)} \times \text{Gear Reducer Ratio}}$$

$$\text{Belt Speed (FPM)} = \frac{\text{Head Pulley Dia (in)} \times \text{Shaft RPM} \times 3.14}{12 \text{ (in/ft)}}$$

$$\text{Est. Capacity (Bu/Hr)} = \frac{\text{Belt Speed (FPM)} \times \text{Net Cup Capacity (in}^3\text{/cup)} \times \text{Cup Spacing Multiplier (cup/ft)} \times 60 \text{ (min/hr)}}{2160 \text{ (in}^3\text{/bu)}}$$

Estimating Belt Conveyor Capacity

Additional measurements that were required in order to estimate belt conveyor capacity included: pulley diameter, belt width, rise of the inclined idler (H), and run of the inclined idler (L). The idler angle then was calculated, and the nearest standard idler angle was chosen.

Appendix Table 3 shows the capacity of belt conveyors based upon belt width and standard idler angle. Estimated belt conveyor capacity was calculated using the following equations:

$$\text{Idler Angle} = \tan^{-1}(H/L)$$

$$\text{Shaft RPM} = \frac{\text{Motor RPM x Motor Sheave Dia (in)}}{\text{Reducer Sheave Dia (in) x Gear Reducer Ratio}}$$

$$\text{Belt Speed (FPM)} = \frac{\text{Pulley Dia (in) x Shaft RPM x 3.14}}{\text{12 (in / ft)}}$$

$$\text{Est. Capacity (Bu / Hr)} = \text{BPH / FPM Belt Speed x Belt Speed (FPM)}$$

Estimating Screw Conveyor Capacity

Trough screw conveyor capacity was estimated assuming 45% conveyor loading. This conveyor-loading percentage is used commonly in sizing motors for conveyors. Screw conveyor capacities can be found in Appendix Table 4. Screw conveyor capacity was calculated using the following equations:

$$\text{Shaft RPM} = \frac{\text{Motor RPM x Motor Sheave Dia (in)}}{\text{Reducer Sheave Dia (in) x Gear Reducer Ratio}}$$

$$\text{Est. Capacity (Bu / Hr)} = \text{BPH / RPM x Shaft RPM}$$

Estimating Drag Conveyor Capacity

Drag conveyor capacity was estimated by using information obtained from the manufacturer. Appendix Table 5 contains capacities of drag conveyors obtained from Essmueller and InterSystems. If the manufacturer's name and model type were not available, trough dimensions were measured, and the capacity was estimated using information obtained from Essmueller. Drag conveyor capacity was estimated using the following equations:

$$\text{Shaft RPM} = \frac{\text{Motor RPM x Motor Sheave Dia (in)}}{\text{Reducer Sheave Dia (in) x Gear Reducer Ratio}}$$

$$\text{Est. Capacity (Bu / Hr)} = \text{BPH / RPM x Shaft RPM}$$

Time-Motion Study of Operating Efficiency

Wheat was unloaded from the truck into a receiving pit whose slide gate remained closed. Time measurement began when the slide gate to the bucket elevator had been opened. Time measurement ended when the receiving pit was empty. This procedure was repeated for three trucks per bucket elevator. Operating efficiency was estimated by taking the average rate at which the bucket elevator removed grain from the receiving pit and dividing it by the estimated capacity. This value was multiplied by 100 to obtain percent operating efficiency.

Estimating Receiving-System Burden

The burden on the grain-receiving system was calculated on an hourly basis. Burden was calculated as the ratio of the total number of bushels received per hour to the estimated capacity of the receiving system. This value was multiplied by 100 to obtain the percent burden. The number of bushels received per hour was taken from ticket summaries from 16 locations at which the scale tickets had weigh-in and weigh-out times. The first truck that was weighed in after each full hour was taken as the starting point for calculating bushels received per hour. The percentage of bushels received at a specific burden was calculated by summing the number of bushels received at a specific burden and dividing by the total number of bushels received during harvest. This value was multiplied by 100 to obtain the percentage of bushels received. The percentage of operating hours at a specific burden was calculated in a similar manner. Operating hours were considered to be 7 am to 12 am. Hours in which no grain was received (i.e., zero percent burden) were not used in the calculation of total number of hours. Ticket summaries for the entire harvest were used.

RESULTS AND DISCUSSION

The numbers and total vertical storage capacities of the elevators in the NC, C, and SC Kansas crop reporting districts are illustrated in Figure 1. The numbers and total vertical storage capacities of grain elevators in the two smallest strata ($\leq$ 1.0 million bushels) show similar distributions for all three crop reporting districts. These elevators account for 85% of the country elevators in the NC, C, and SC Kansas crop reporting districts and 75% of the total storage capacity, excluding inland terminals with storage capacity of $\geq$2.0 million bushels. Grain elevators with a capacity between 1.0 - 2.0 million bushels are more prevalent in South Central Kansas. This crop reporting district is the largest wheat-producing region in the state, which may explain the greater proportion of large country elevators and inland terminals.

Figure 2 shows the characteristics of the grain-receiving systems across each stratum. Even though a majority of elevators with a capacity of $<$0.5 million bushels had one bucket elevator, only one was observed to have a single receiving pit. The presence of two pits per bucket elevator greatly enhances the ability to segregate wheat. Thus, grain elevators in NC, C, and SC Kansas crop reporting districts apparently were designed and constructed to segregate incoming grain. During the study, researchers observed wheat segregation based on quality criteria other than moisture content at two locations.

In addition to the number of receiving pits per bucket elevator, the design and construction of the receiving driveway are other physical limitations for wheat segregation. Many of the country elevators built before 1960 were designed to handle trucks with a capacity of approximately 200 bushels. Trucks with a capacity of $>$500 bushels are not able to fully elevate the truck bed if the receiving pit closest to the exit is used. This limitation is due to the presence of a low doorway or a truck hoist to elevate older trucks that are not equipped with a hydraulic hoist.

The results of the time-motion study of grain sampling and quality evaluation time are presented in Table 2. The sampling procedure indicates the number of probes taken and the orders and types of procedures used to evaluate wheat quality. All of the locations evaluated wheat for moisture and test weight, but only 12 locations evaluated the sample for dockage. Fifty percent of the locations that measured dockage content also measured test weight prior to the removal of dockage. Official grain inspection procedures require dockage to be removed before test weight measurement. As grain elevator companies attempt to make the transition from a commodity-based to a quality-based marketing system in which premiums and discounts better reflect true wheat quality, their grain sampling and evaluation procedures should conform to official grain inspection procedures. Furthermore, study results indicated that removing dockage before measuring test weight required only an additional 3 seconds. The results also indicated that approximately 2 minutes were required to sample and evaluate the grain quality.

Table 2. Time Required to Sample and Evaluate Wheat Quality

Sampling Procedure	No. of Elevators	Time (seconds)
1 Probe. T. Wt, Mst	8	55
1 Probe, T. Wt, Mst, Dockage	6	105
1 Probe, Mst, Dockage, T. Wt	2	108
2 Probes, Mst, Dockage T. Wt	3	149
3 Probes, Mst, Dockage T. Wt	1	150

Operating efficiencies determined from the time-motion study are shown in Figure 3. Results indicate that only 45% of the grain-receiving systems were operated at or above 70% of their estimated capacity. Reasons for the low operating efficiencies include inexperienced help, large amounts of dockage and foreign material in the wheat, and slow delivery rates. Regardless of the reason, receiving-system capacity does not appear to limit the feasibility of segregating wheat at most country elevators in our study.

Figures 4, 5, and 6 compare the percentage of operating hours and bushels received during harvest to the percent burden. At most facilities, the largest percentage of operating time during the harvest rush resulted in a 10% burden on the receiving system. These data support the common observation that country elevators are open for a long period of time when harvest activity is slow (e.g., from 8 a.m. to 1 p.m. and 8 p.m. to 11 p.m.). Peak receiving hours tend to occur between mid-afternoon and early evening. The distribution of the bushels received versus percent burden resembles a normal distribution, which is centered around a burden of 40%. A majority of the bushels were delivered at or below a burden of 60%. Country elevators with a capacity of < 0.5 million bushels experienced the highest percent burden on the grain-receiving system, whereas elevators with a capacity of > 1.0 million bushels had the lowest percent burden.

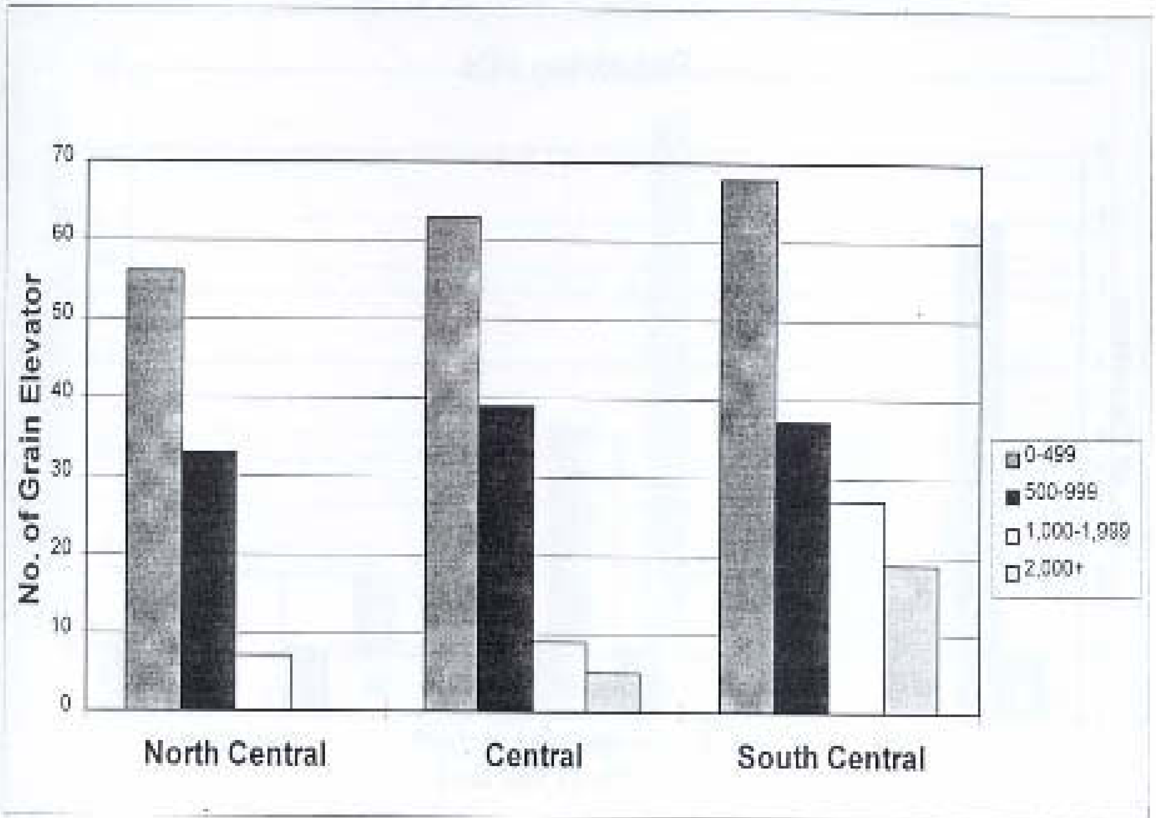
CONCLUSIONS

Study results indicate that, despite the presence of a harvest rush, segregating wheat at county elevators appears feasible. The limitations to segregation tend to be associated more with personnel issues and the configuration of the receiving driveway than receiving-system capacity. Raising the doorway or removing truck hoists from the driveway as well as the use of better qualified employees may be necessary in order to more efficiently segregate wheat.

A time-motion study showed that approximately 2 minutes were required to sample and evaluate grain quality, which suggests that ample time to utilize equipment for rapid evaluation of grain quality is available at the first collection point. This time-motion study also revealed that the evaluation procedures sometimes were done improperly, indicating the need for more education on proper procedures for wheat quality evaluation. A second time-motion study used to determine operating efficiencies as well as the analysis of the percent burden placed on the receiving system during harvest showed that grain-receiving systems often are not used to their full capacity.

The study should be extended for several more years to capture more variability between harvests. Because of the wide variability between elevators, approximately 50 more elevators should be included in future studies.

Figure 1. Grain Elevators in North Central, Central, and South Central Kansas



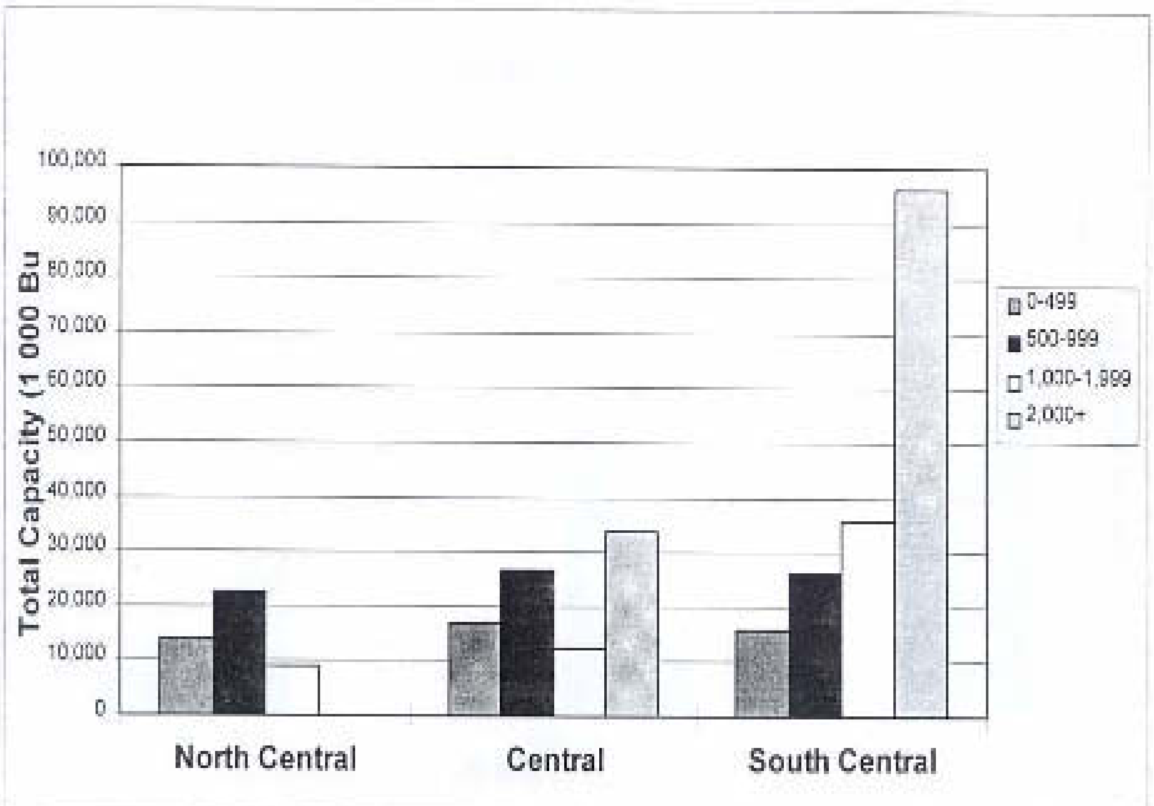
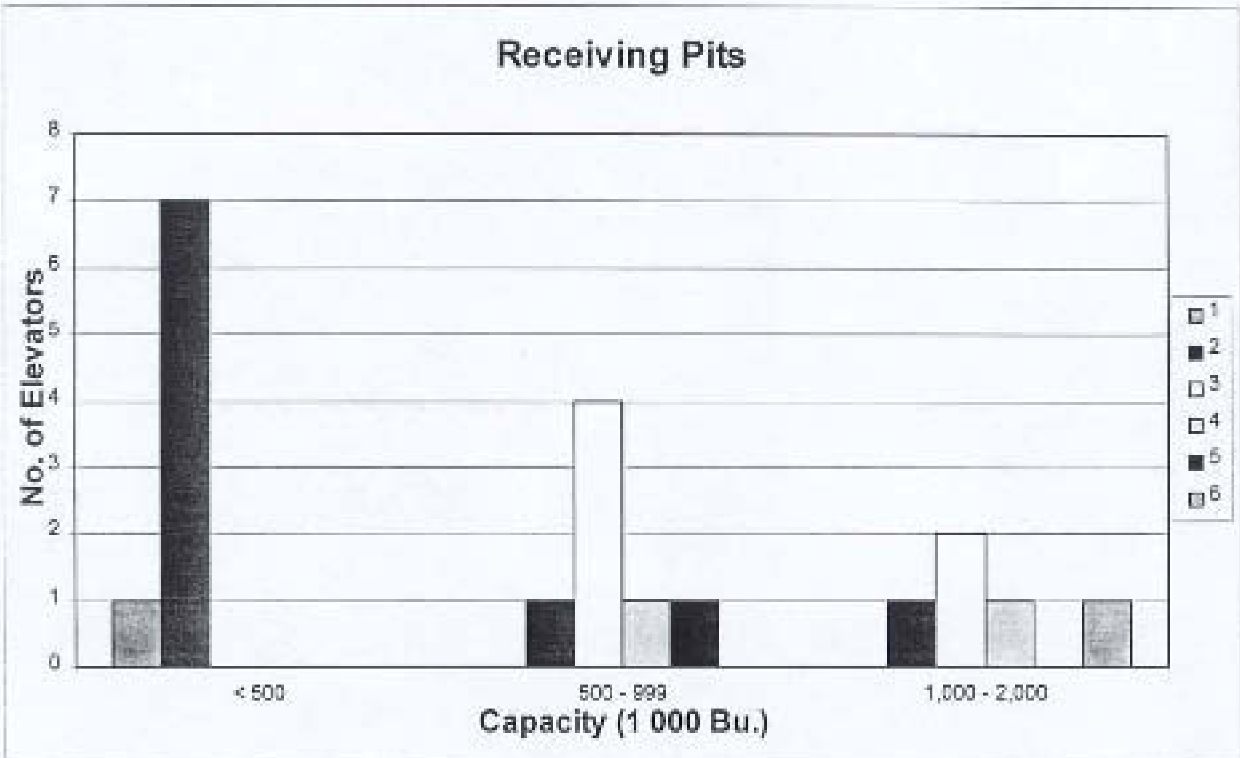


Figure 2. Characteristics of Grain Elevator Receiving Systems



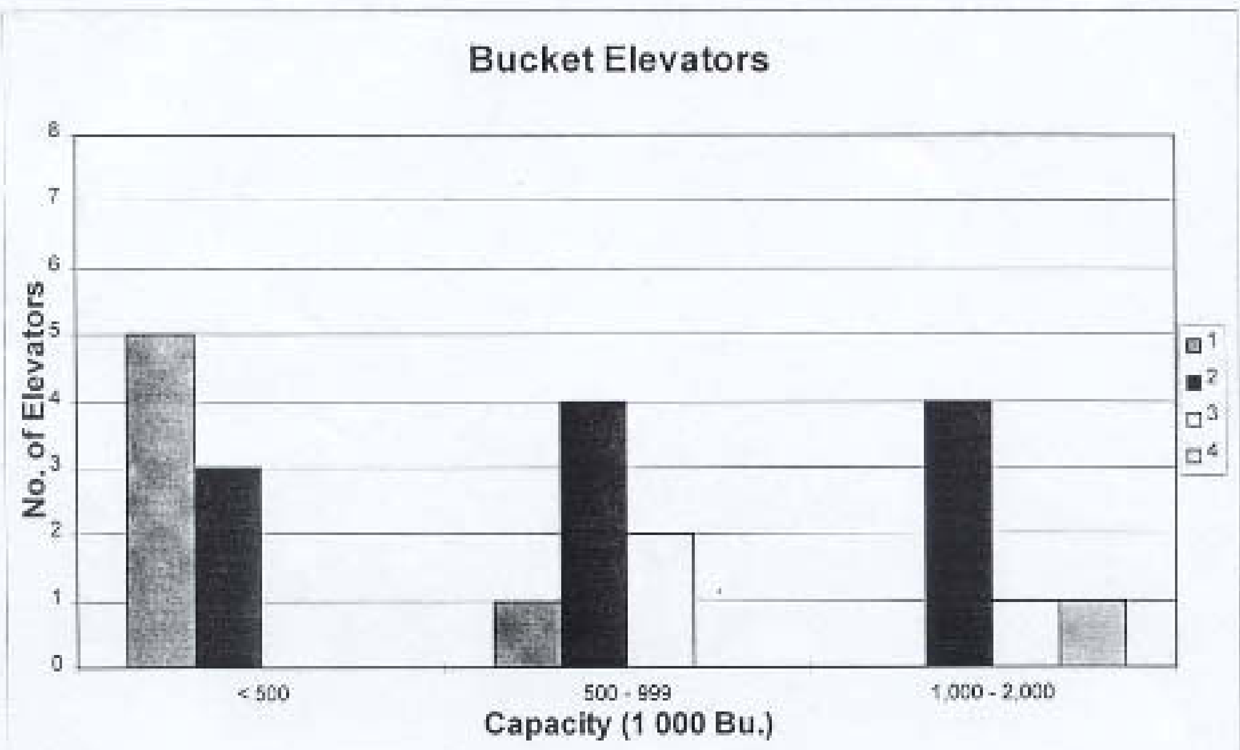


Figure 3. Operating Efficiency of Grain-Receiving Systems during the 1995 Harvest

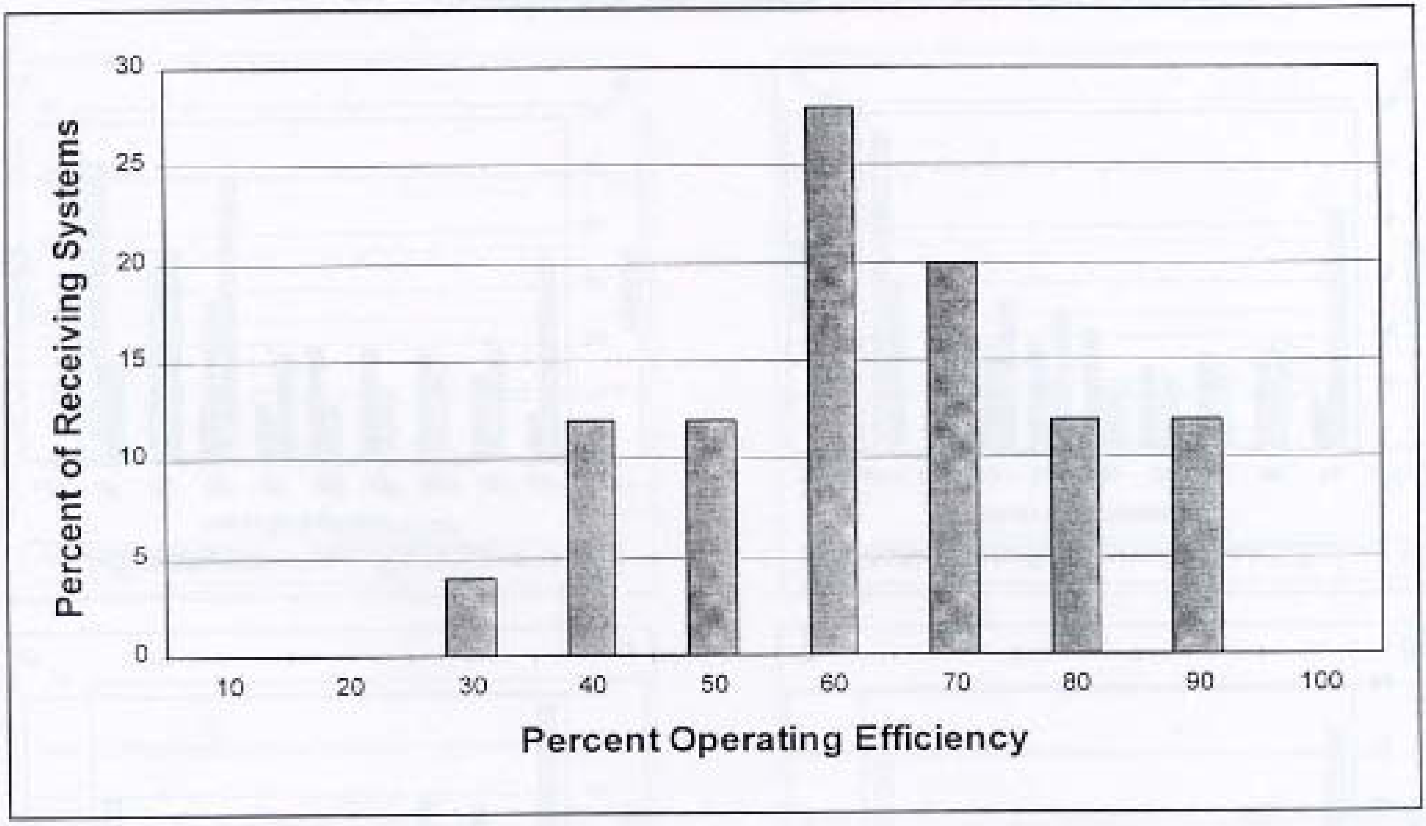


Figure 4. Burden on the Grain-Receiving System during the 1995 Harvest for Five Elevators with < 0.5 Million Bushels Storage Capacity

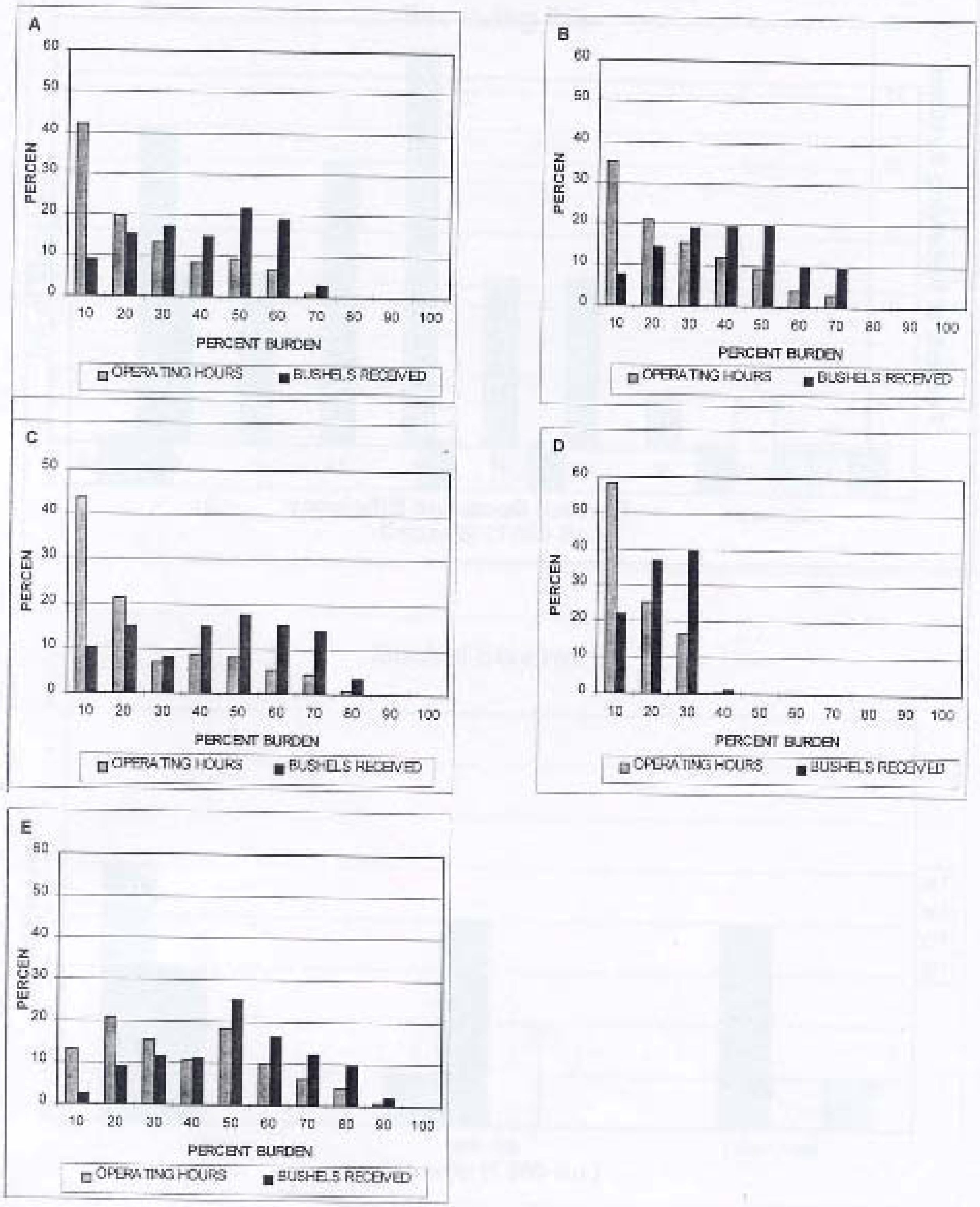


Figure 5. Burden on the Grain-Receiving System during the 1995 Harvest for Five Elevators with 0.5 - 1.0 Million Bushels Storage Capacity

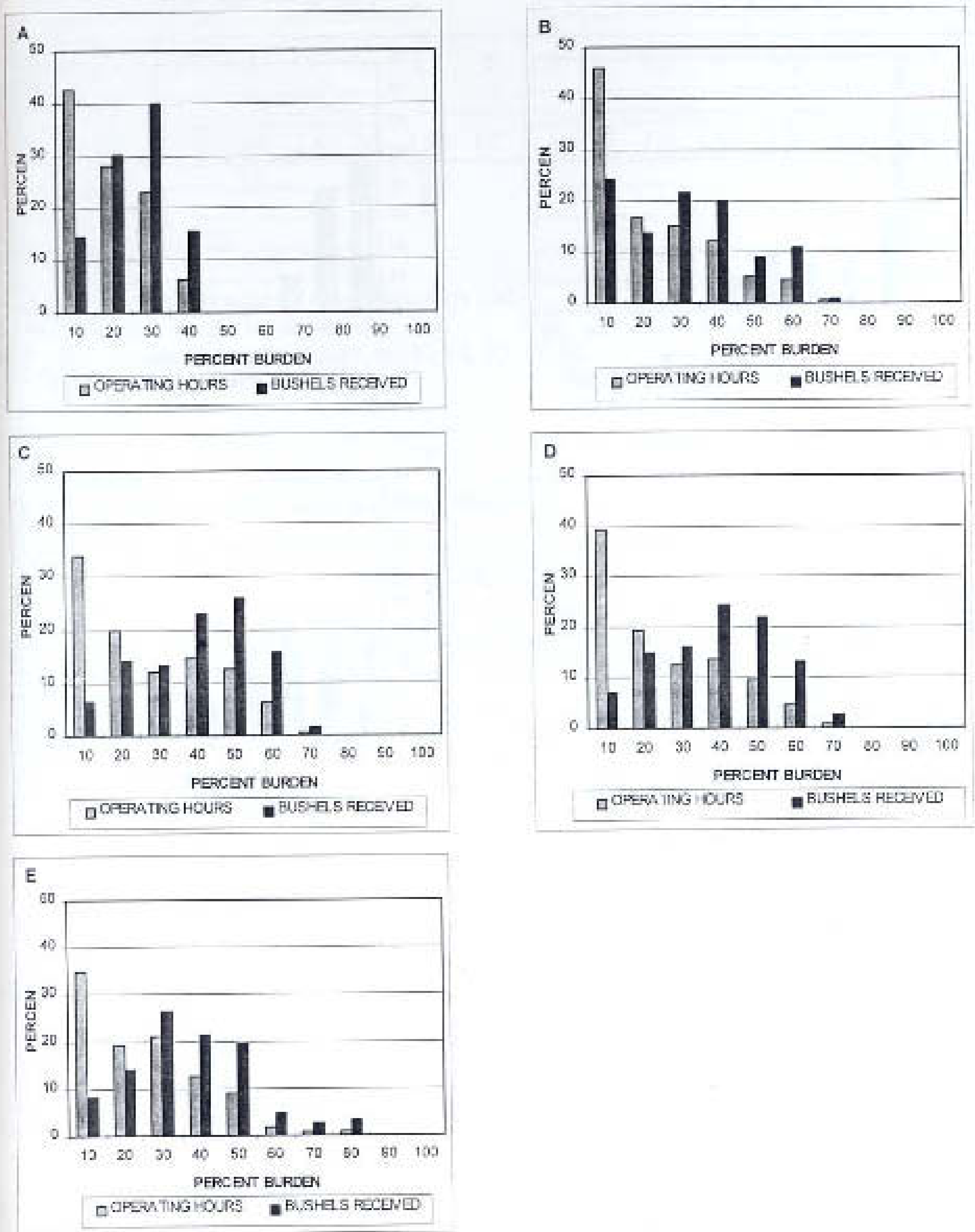
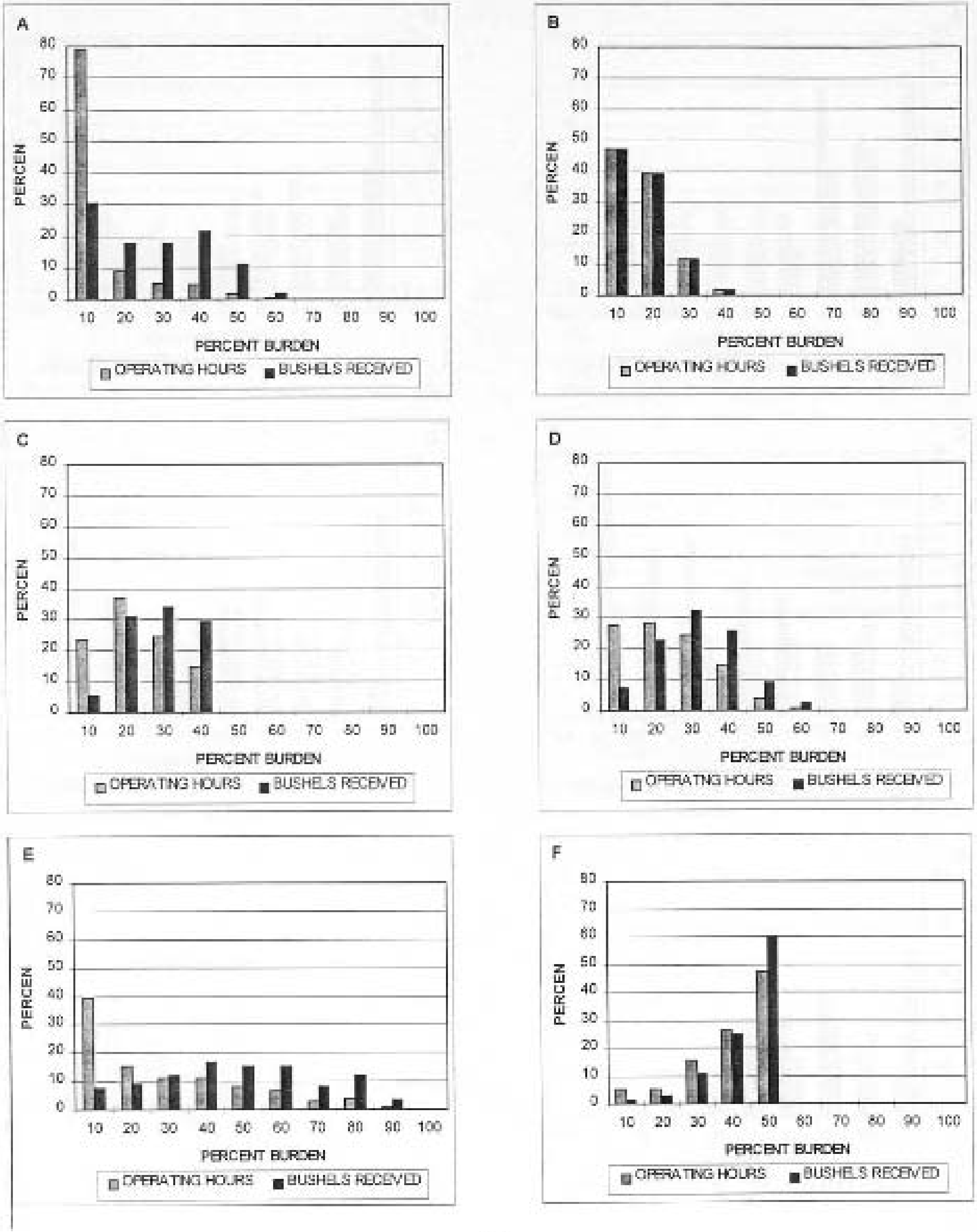


Figure 6. Burden on the Grain-Receiving System during the 1995 Harvest for Six Elevators with > 1.0 Million Bushels Storage Capacity



APPENDIX

Table 1. Cup Spacing Multipliers

Spacing (in)	3.5	4	5	6	6.5	7	7.5	8	8.5	9	9.5	10	11	12
Multiplier	3.43	3.0	2.4	2.0	1.85	1.7	1.6	1.5	1.4	1.33	1.26	1.2	1.09	1.0

Table 2. List of Standard Pulley Diameters (in)

8, 10, 12, 16, 20, 22, 24, 30, 36, 42, 48, 54, 60, 72, 84, 96

Table 3. Belt Conveyor Capacity (BPH / FPM)

		Belt Width (in)								
		14	16	18	20	24	30	36	42	48
Idler Angle	20	2.68	4.03	5.52	7.08	10.80	17.60	26.80	38.08	50.40
	35			7.20		15.20	25.60	37.60	52.00	68.80
	45					17.60	28.80	42.40	59.60	83.36

Table 4. Screw Conveyor Capacity (BPH / RPM)

	Screw Diameter (in)								
	6	9	10	12	14	16	18	20	24
45%	1.8	6.6	9.0	15.5	25.0	37.4	54.1	75.0	131.2

APPENDIX

Table 5. Drag Conveyor Capacity (BPH / RPM)

ESSMUELLER				**INTERSYSTEMS**			
ROUND BOTTOM		**FLAT BOTTOM**		**ROUND BOTTOM**		**FLAT BOTTOM**	
Housing (W X H)	Capacity	Housing (W X H)	Capacity	Housing (W X H)	Capacity	Housing (W X H)	Capacity
7x8	10.8	8xl0	32.0	9xl2	54.3	9xl2	45.7
10x11	20.5	12xl0	50.0	13xl2	83.7	13xl2	66.1
13xl4	50.2	12xl3	89.4	13xl7	117.8	9x17	114.4
15xl7	78.8	15xl3	113.1	17xI7	241.7	13xl7	165.9
17xl9	119.3	12xl8	207.6	17x26	581.7	17xl7	217.4
19x22	182.8	15xl8	261.5	25x260	864.8	2lxl7	269.2
2lx24	220.5	18xl8	315.3	30x26	1,078.3	25xl7	320.4
25x29	495.8	2lxl8	369.2			30xl7	384.8
		24xl8	423.0			17x26	540.6
		2lx24	640.0			2lx26	671.9
		24x24	730.0			25x26	796.4
		30x24	917.0			30x26	959.7

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

SRP 781 January 1997