STATIC PRESSURE DROP IN A FIXED BED OF GRAIN AS AFFECTED BY GRAIN MOISTURE CONTENT

by

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1974, USSR

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1981

Approved by:

Major Professor

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ACKNOWLEDGEMENTS

The author wishes to express his deep appreciation and many thanks to Dr. Ekramul Haque for his advice, valuable guidance and encouragement which led to the completion of this work. His untiring help, patience and friendship during the period of graduate study and preparation of this manuscript are very much appreciated.

Appreciation is extended to Dr. C. W. Deyoe, Professor and Head of the Department of Grain Science and Industry, serving as the major professor for his assistance and counsel. The author thanks the members of his committee: Dr. Do Sup Chung and Dr. Paul A. Seib for their assistance and review of this thesis.

The author wishes to recognize the Yemen Grain Storage and Processing Project, Government of Yemen and the World Bank for the financial assistance provided for this project.

The author wishes to acknowledge his deepest appreciation to his wife, Suad, for an immeasurable contribution of encouragement, patience and understanding without which this work could not have been fulfilled.

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I. INTRODUCTION

The practice of holding wet grain through the winter months with aeration is growing in the corn belt. Corn at 18 to 22% moisture has been held from harvest until warm weather the following spring (Foster, 1967). The use of aeration for holding wet grain for shorter periods of time until it can be dried, is even more widespread.

Aeration is used in some parts of the corn belt of the United States to permit storage of 18 to 20% moisture corn from the time it is harvested until early the following spring (Brooker et al., 1974). Frequently, large quantities of high moisture grain are stored in piles on the ground until the grain can be dried (Jindal and Thompson, 1972). Aeration with natural air has been used for temporary or extended storage of high moisture corn (Converse et al., 1973). Severe weather conditions and uncontrollable factors occasionally require the temporary storage of high moisture grain (Pierce and Thompson, 1975). Development of design criteria for high moisture grain aeration fan selection is definitely necessary.

Determination of grain resistance to airflow is fundamental in the design of drying and aeration systems. In order to select a fan capable of overcoming the resistance offered by drying or aeration systems, one has to know how much resistance will be developed in a particular bed of grain.

The most common approach in estimating pressure drop through grain is to use experimental curves relating airflow and pressure drop. Shedd (1953) developed such curves for common seeds and grains. Designers widely use Shedd's data on resistance of dry grains to airflow, for fan selection. They use the data even for storage of high moisture grain. But what effect grain moisture has on the static pressure drop has not yet been thoroughly investigated. The effect of grain moisture content on resistance to airflow (static pressure drop) is not clear (Brooker et al., 1974). There has been a controversy on the effect of grain moisture content; some workers claim moisture increases the pressure drop, others think it decreases it. So far no agreement has been reached.

The objectives of this study were to:

a) determine the resistance of grain as affected by their moisture content,

b) develop a relationship between grain moisture content and static pressure drop and

c) evaluate the possibility of expressing the static pressure drop in terms of void fraction rather than grain moisture content.

II. REVIEW OF LITERATURE

2.1 General

Extensive research findings have been reported on the resistance of grains to airflow. However, studies on the effect of grain moisture content on static pressure drop are extremely limited. The static pressure requirement of a fan providing aeration or drying air through a fixed bed of grain is a function of many variables including the specific resistance of the grain to airflow. Both empirical and theoretical data on dry grains are available.

2.2 Empirical

Since 1948 data on the airflow-static pressure relationship of a number of biological products have been published in graphical form in the American Society of Agricultural Engineers' Year Book. These curves, now known as "Shedd's curves" are widely used and were adopted in 1948 as ASAE Technical Data D 272 (American Society of Agricultural Engineer's Year Book, 1980.)

Many studies have involved development of similar experimental curves for various products. Stirniman et al. (1931) worked with rough rice; Henderson (1943) with corn; Henderson (1944) with oats and soybeans; Shedd (1945) with ear corn; Shedd (1951) with soybeans, corn, oats, rough rice, red cloves, and alsike clover; Day (1963) with crushed and noncrushed dry hay; Husain and Ojaha (1969) with rough rice; Calderwood (1973) with rough and milled rice; and Agrawal et al. (1974) with rough rice. The use of these experimental curves has a definite advantage in convenience, but the accuracy of the pressure drop prediction may be poor because of insufficient consideration of the effects of variations due to some important factors, such as void space and product moisture content. Shedd (1951) observed changes in pressure drop of over 60% at the same airflow rate when the filling method was changed. Shedd's curves are for loose fill condition which was obtained by pouring grain into a funnel, the outlet of which was held just above the surface of the grain in the bin. Shedd (1953) listed some arbitrary correction factors based on judgment to apply to values from Shedd's curves to account for variations in filling method, grain moisture content, and foreign material in the grain. Practicality and simplicity made the use of Shedd's data very widespread among grain drying and aeration system designers even though the data are empirical and arbitrary. Stephens and Foster (1976) reported increases in bulk density and airflow resistance for both dry and high moisture shelled corn in a bin filled by mechanical grain spreaders over the beds obtained without spreaders. The same conclusion was drawn by Stephens and Foster (1978) for wheat and grain sorghum. Lawton (1965) noted that the resistance to airflow, depends on the type of seed and largely on the degree of packing and the presence of contaminants. Thompson and Isaacs (1967) reported that a high grain test weight or bulk density denoted a low percentage of void space. The reduction in void space associated with the grain as it is dried probably accounts for the increased static pressure required to move a given quantity of air through the dry corn. Thompson and Isaacs found that the porosity (percent of voids or air space) of bulk lots of shelled corn was influenced by differences in variety, kernel moisture content, amount of fine material, method of harvesting, and method of drying. They found that the porosity of shelled corn increased with an increase in the kernel moisture content.

Several studies have involved attempts to fit equations to the experimental curves relating airflow and pressure drop. Henderson (1943) used the equation:

$$V = k\ (\Delta P)^{c} \tag{1}$$

where,

V = airflow rate, cfm/ft^2

ΔP = static pressure drop per ft. depth, in. of water,

k and c = constants.

Shedd (1953) also fitted equation (1) to his data. He stated that a particular set of constants k and c would give good prediction over only a narrow range of flow rates. The equation assumes a straight line relationship between ΔP and V on a log - log plot. Hukill and Ives (1955) proposed the following equation for Shedd's data:

$$\Delta P = \frac{a\ V^2}{\log_e\ (1+bV)} \tag{2}$$

where,

a and b = constants depending on the product.

This equation can be used to express the relationship between velocity, V, and pressure drop ΔP, with good accuracy throughout the range of velocities reported, by proper selection of the constants a and b.

Haque et al. (1978) modified equation (2) and made it applicable for corn containing fines. The equation presented by Haque is of the form:

$$\Delta P = C_1 V + C_2\ V^2 + C_3\ V\ (fm) \tag{3}$$

where,

fm = fine material percent expressed as decimal,

C_1, C_2 and C_3 = constants

and could be used for an airflow range of 15-75 cfm/ft^2. While Hukill and Ive's equation was based on a lower range of airflow (2-40 cfm/ft^2), equation

(3) can be applied for a higher airflow rate. Bern (1973) determined an equation to relate pressure drop to flow rate through a bed of corn. The equation is:

$$\Delta P = A_n V^2 + B_n V + C_n \tag{4}$$

where,

A_n, B_n, and C_n = grain characteristic coefficients.

Bern stated that the accuracy of equation (4) for pressure drop predictions is likely to be poor at the low flow rates.

2.3 Theoretical

Ergun (1952) developed an equation by theoretical analysis. The equation is:

$$\Delta P_o = \frac{150\ (1-\varepsilon)^2 \mu v}{\varepsilon^3 d^2 g} + 1.75\ \frac{(1-\varepsilon)}{\varepsilon^3} \frac{\rho v^2}{dg} \tag{5}$$

where,

ε = void fraction (dimensionless decimal) on volume basis

μ = fluid viscosity, $\frac{\text{lb-sec}}{\text{ft}^2}$

d = equivalent particle diameter (diameter of a sphere which has volume of the particle), ft

ρ = fluid density, lb/ft^3

g = acceleration due to gravity, ft/sec^2

ΔP_o = pressure drop

v = velocity, ft/sec.

The equation reflects all the independent variables on which the pressure drop depends. Bakker-Arkema et al. (1969) and Patterson et al. (1971) extended Ergen's equation to cover agricultural products such as cherry pits, shelled corn and navy beans. Matthies and Petersen (1974) developed a similar equation for different agricultural grains.

Application of these types of theoretical equations is extremely difficult and as such Matthies and Petersen suggested the use of a simpler equation given by:

$$\Delta P = C_0 V^{2-n} \tag{6}$$

where,

C_0 and n = product constants.

They found n to vary in the range 0.6 to 0.86. Equation (6) is similar to equation (1). Agrawal and Chand (1974) used the basic premise of Navier-Stokes' equation for airflow through rough rice. From a practical point of view, their equations are also difficult to apply.

2.4 Effect of Moisture Content on Static Pressure Drop

Shedd (1953) found that the resistance pressure for a given rate of airflow was less for corn at 20% or higher moisture than for the same corn after drying to lower moisture content by using same method of bin filling. Patterson (1969) reported that the pressure drop through corn increases with an increase in moisture content, by keeping porosity constant. Muchiri (1969) conducted tests with 8 to 28% moisture (w.b.) corn and found that at an airflow rate of 8.93 cfm/ft^2, pressure drop does not vary with grain moisture content if the fractional void volume is held constant. At a constant bed porosity and airflow, Patterson et al. (1971) found that static pressure drop for corn (15 to 25% w.b.) will increase with moisture, but will decrease for navy beans. This is not in agreement with the conclusion of Muchiri (1969). Nissing (1958) worked with cotton seed to establish a relationship between airflow and the airflow resistance of the seed. He reported that the amount of foreign matter and moisture content in the cotton seed, the bulk density and the bed depth affect the horsepower requirements to force air through the seed. Osborne (1961) studied the resistance to airflow with a bed depth of 2 ft. and air velocities below 17.5 ft/min, such as might be used when aerating stored grain. He noted that the results obtained can only be taken as a guide to the resistance to airflow, as the resistance will vary with change of bulk density which in turn is influenced by moisture content, degree of packing, and the amount and kind of impurities present. Calderwood (1973) mentioned that the moisture content causes a variation in resistance in seeds but he did not specify what kind of effect the moisture has. Jindal and Thompson (1972) reported that for grain sorghum the pressure gradients did not change for 16.5% moisture content but somewhat decreased with 8.0% grain. Chung and Converse (1971) studied the changes on physical properties of corn and wheat caused by changes in moisture content related to both adsorption and desorption of moisture. Their results were in agreement with the findings of Thompson and Isaacs (1967). They indicated that there was more void space in wheat than in corn at the same bulk density, due mainly to the higher true density of wheat. Brown (1962) studied the variation of bulk density of wheat, barley and oats with moisture content, and found that the bulk density decreases at higher moisture contents. Aas and Time (1960) found that the moisture content effect on the pressure drop is dependent on the grain and the moisture content range being tested. Brusewitz (1975) found that rewetted barley, corn, grain sorghum, oats, rye, soybeans, and wheat display a decrease in bulk density with increasing moisture content up to 30% and an increase in bulk density at moistures higher than 30%.

III. MATERIALS AND METHODS

3.1 Experimental Design

From a practical point of view, an empirical approach to the study is more desirable. As discussed in the literature review section, the theoretical equations need determination of many difficult-to-measure variables. We do not intend to isolate the effect of grain moisture on the void space. We will let the void space vary naturally with the grain moisture for a particular bin filling method, because that is the type of situation we encounter in grain storage. What the farmers control is the bin filling method not the void fraction; they might use a gravity filling spout, a spreader, a retarder, etc. If the filling method and air velocity remain the same for the same grain with different moisture content, the changes in static pressure drop caused by the changes in void fraction and surface characteristics due to variation in moisture content, may be attributed to a single variable, moisture.

We conducted experiments with clean yellow dent corn, grain sorghum and hard red winter wheat all harvested in 1980. Four levels of moisture contents such as moisture at harvest, moisture when dry and two moisture levels in between were studied. The lower level of moistures were obtained by natrual air drying. Each grain and each moisture were tested for seven different airflow rates. To minimize the experimental error, we obtained three replications for each moisture level. We prepared 36 different beds in all and tested each for 7 airflow rates.

3.2 Equipment and Procedure

The test column was constructed from 2.753 mm mild steel sheet rolled into 29.9 cm diameter x 30.5 cm long section. The sections were connected by flanges to increase or decrease the depth of bed as and when necessary. The total test bed was 51720 cm^3. The floor of the test bin was constructed of perforated sheet metal with 2 mm diameter holes, totaling 14% of the entire floor area. Three mm diameter 50 mm long copper tube pressure taps were welded to the test column wall at 30.5 cm intervals beginning approximately 7.6 cm above the bed floor by first drilling 4 mm diameter holes on wall. the taps protruded inside the column to make sure that air became static at the tap. The plenum chamber consisted of a 91.4 x 91.4 x 30.5 cm rectangular box made of 2.753 mm mild steel sheet.

Measurements of airflow to the test bed were made using a 25.4 mm throat diameter ASME nozzle and a hook gage manometer capable of measuring up to 305 mm of water with a smallest reading of 0.0254 mm. A 25.4 mm of water pressure differential across the nozzle corresponded to approximately 0.57 m^3/min air. The flow nozzle was placed between the blower and the plenum chamber with a 50 mm diameter plastic pipe.

The air was supplied by a fan equipped with a 1.119 KW (1½ HP.) variable speed motor. We regulated the air flow with a dial type controller. Temperature and relative humidity of supply air were controlled by using steam, electric heater and a cooler. The schematic diagram of the experimental setup is shown in Fig. 1.

Prior to each test, the air conditioning unit was started to allow for the temperature and relative humidity of the supply air to settle approximately at 26.6^{o}C and 65% R. H.

The test bed was filled by a loose fill method as described by Shedd (1953). We poured the grain into a funnel, the outlet of which was held just above the grain surface making sure to raise the funnel gradually as

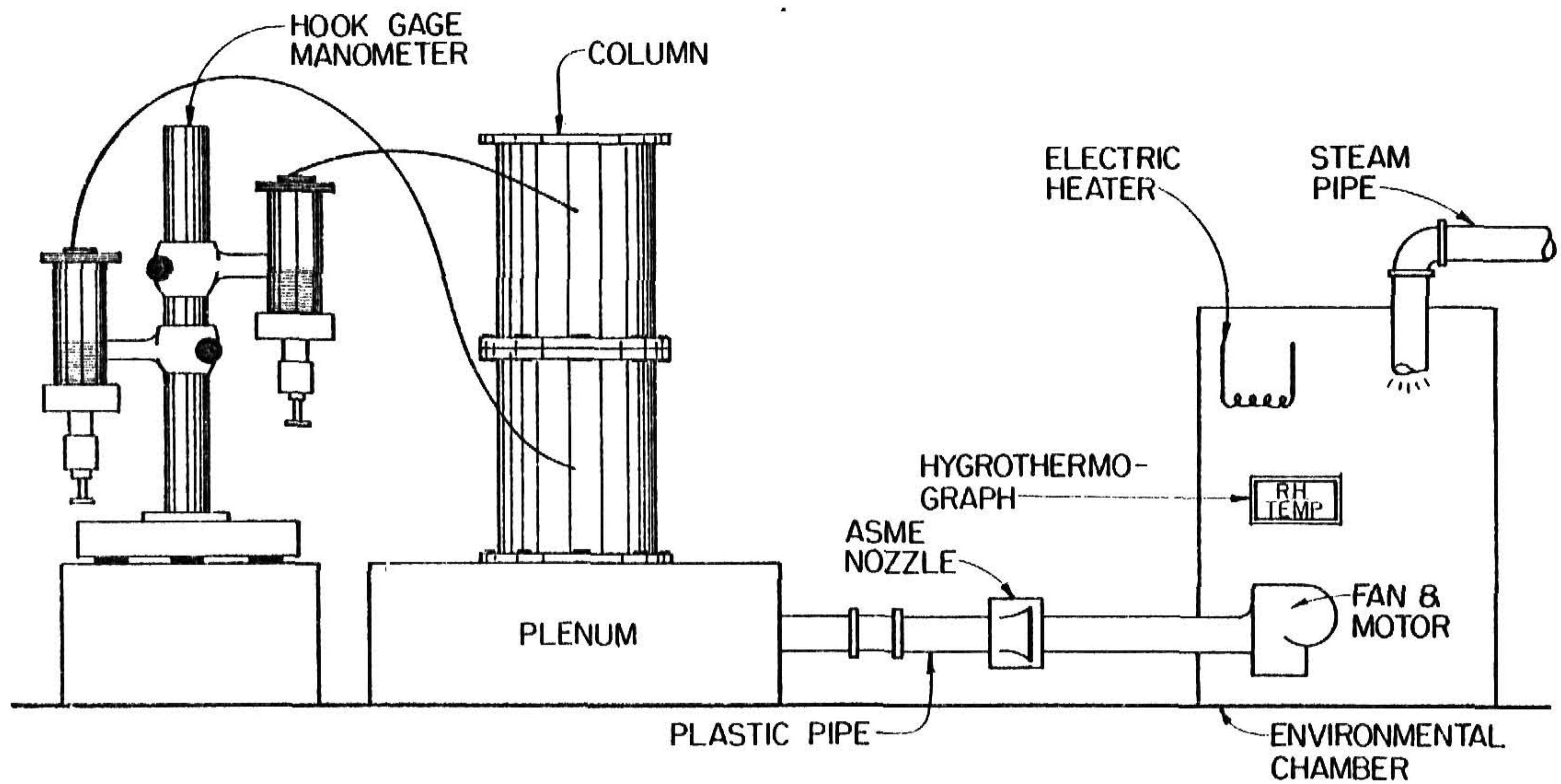

Fig. 1 **Schematic Diagram for Experimental Set-Up**

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the filling progressed. The depth of the test bed was 73.7 cm. The section fixed for measurement consisted of a 61 cm portion with the first measurement taken 7.6 cm above the bottom of the test unit.

The grain was cleaned before each test by using a cleaner. The average size calculated by using the fineness modulus (Henderson and Perry, 1976) was 6.5 mm, 3.3 mm and 3.2 mm for corn, sorghum and wheat, respectively. After filling the test bin with clean grain, the blower was turned on, and the desired dial reading to control the airflow was set. Pressure differential across the nozzle was read from the hook gage manometer for calculating the airflow volume rate. Then the static pressure drop across the 61 cm measuring section of grain bed was read by the same hook gage manometer after properly closing ASME nozzle taps. These procedures were repeated for all the 36 beds. Pressure data are presented in Tables 1-9, under the Results and Discussions section.

For the determination of the void fraction, the bulk and true densities of each grain were measured for all moisture levels. The moistures were obtained by rewetting and drying the grains. Standard test weight apparatus and the toluene displacement method, (using 50 cc toluene, 45 gm grain sample and 100 cc graduated cylinder) were used for the measurements of bulk and true density, respectively.

IV. RESULTS AND DISCUSSIONS

Static pressure drop data measured by the hook gage manometer for various moistures and airflow rates for shelled corn, grain sorghum, and wheat were tabulated in Table 1 through Table 6. We replicated the beds three times for each moisture level. However, it was not possible to keep the moisture exactly the same for all the three replications because we used the same lot of grain which lost a very small amount of moisture during test run and handling. The variations in moisture are so small that for all practical purposes, we can consider the three tests as three replications.

The static pressure drop data for each replication and four levels of moisture on each commodity were plotted on log- log graphs (Figs. 2 through 10). For the purpose of comparison, Shedd's data (1953) were also plotted and marked as Shedd's curve.

Fig. 2 shows that all the curves run almost parallel to Shedd's curve for corn at 12.4% moisture. The experimental curves for all moistures are to the left of Shedd's plot which means that high moisture corn displays less resistance than dry grains. This trend persisted consistently over the range of moisture tested. Our data for the lowest moisture level was somewhat less than Shedd's but were very close. This observation is expected because our lowest moisture was a little higher than Shedd's and confirms that our experimental procedure was accurate and reproducible. Figs. 3 and 4 display the same characteristics.

Figs. 5 through 7 for grain sorghum and Figs. 8 through 10 for wheat also show the same trend as corn.

For the purpose of minimizing experimental error, each of the seven air velocities and the corresponding static pressure drop and moisture readings of Table 1 through 6 were averaged over the three replications for each

Table 1. Static Pressure Drop Data for Shelled Corn at Various Moisture Contents-I

Replication	Air velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static pressure Drop ΔP (pa/m)	Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)
	0.023	23.6	11		0.018	20.1	13
	0.050	23.6	31		0.047	20.1	39
	0.082	23.6	61		0.081	20.1	82
1	0.115	23.6	99	1	0.111	20.1	130
	0.153	23.6	158		0.147	20.1	200
	0.199	23.6	236		0.189	20.1	295
	0.222	23.6	300		0.215	20.1	366
	0.023	23.3	12		0.022	19.9	16
	0.050	23.3	31		0.049	19.9	41
	0.082	23.3	63		0.080	19.9	83
2	0.117	23.3	107	2	0.110	19.9	134
	0.153	23.3	161		0.146	19.9	204
	0.196	23.3	240		0.189	19.9	304
	0.224	23.3	300		0.215	19.9	371
	0.023	23.1	12		0.021	19.5	16
	0.051	23.1	33		0.048	19.5	42
	0.083	23.1	65		0.079	19.5	84
3	0.117	23.1	109	3	0.110	19.5	135
	0.154	23.1	168		0.146	19.5	205
	0.199	23.1	253		0.188	19.5	304
	0.224	23.1	308		0.215	19.5	380

Table 2. Static Pressure Drop Data for Shelled Corn at Various Moisture Contents-II

Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)	Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)
	0.019	16.6	17		0.019	12.8	17
	0.047	16.6	43		0.043	12.8	44
	0.077	16.6	86		0.075	12.8	88
1	0.109	16.6	136	1	0.104	12.8	144
	0.145	16.6	209		0.140	12.8	218
	0.187	16.6	308		0.179	12.8	322
	0.213	16.6	384		0.206	12.8	396
	0.021	16.2	17		0.018	12.7	16
	0.046	16.2	43		0.043	12.7	44
	0.079	16.2	86		0.074	12.7	88
2	0.110	16.2	140	2	0.104	12.7	144
	0.145	16.2	210		0.137	12.7	220
	0.187	16.2	309		0.180	12.7	322
	0.213	16.2	386		0.206	12.7	397
	0.020	16.2	18		0.017	12.7	17
	0.048	16.2	45		0.044	12.7	44
	0.079	16.2	87		0.074	12.7	87
3	0.111	16.2	141	3	0.105	12.7	143
	0.145	16.2	214		0.140	12.7	219
	0.188	16.2	320		0.181	12.7	321
	0.213	16.2	395		0.206	12.7	397

Table 3. Static Pressure Drop Data for Grain Sorghum at Various Moisture Contents-I

Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)	Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)
	0.015	25.4	20		0.013	20.8	20
	0.031	25.4	56		0.033	20.8	60
	0.060	25.4	116		0.058	20.8	122
1	0.087	25.4	185	1	0.084	20.8	198
	0.120	25.4	287		0.117	20.8	298
	0.161	25.4	429		0.157	20.8	445
	0.185	25.4	529		0.181	20.8	541
	0.015	25.3	20		0.013	20.5	21
	0.032	25.3	58		0.030	20.5	61
	0.060	25.3	118		0.055	20.5	120
2	0.087	25.3	190	2	0.081	20.5	198
	0.120	25.3	290		0.115	20.5	305
	0.159	25.3	427		0.154	20.5	454
	0.184	25.3	528		0.178	20.5	551
	0.016	25.3	19		0.013	20.3	22
	0.031	25.3	58		0.031	20.3	62
	0.057	25.3	118		0.054	20.3	121
3	0.086	25.3	191	3	0.083	20.3	200
	0.120	25.3	295		0.116	20.3	307
	0.158	25.3	432		0.154	20.3	456
	0.183	25.3	529		0.177	20.3	553

Table 4. Static Pressure Drop Data for Grain Sorghum at Various Moisture Contents-II

Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)	Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)
	0.014	17.5	21		0.011	13.2	20
	0.030	17.5	59		0.028	13.2	59
	0.053	17.5	122		0.049	13.2	120
1	0.079	17.5	200	1	0.070	13.2	204
	0.113	17.5	308		0.099	13.2	310
	0.146	17.5	460		0.133	13.2	461
	0.171	17.5	555		0.156	13.2	572
	0.013	17.4	20		0.011	13.1	20
	0.029	17.4	60		0.028	13.1	60
	0.051	17.4	123		0.049	13.1	121
2	0.077	17.4	202	2	0.070	13.1	203
	0.115	17.4	309		0.099	13.1	315
	0.153	17.4	463		0.132	13.1	461
	0.176	17.4	560		0.157	13.1	573
	0.015	17.3	20		0.011	13.1	20
	0.028	17.3	60		0.027	13.1	60
	0.052	17.3	125		0.048	13.1	123
3	0.078	17.3	206	3	0.070	13.1	206
	0.113	17.3	316		0.099	13.1	316
	0.151	17.3	471		0.133	13.1	461
	0.174	17.3	561		0.156	13.1	574

Table 5. Static Pressure Drop Data for Wheat at Various Moisture Contents-I

Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B)	Static Pressure Drop ΔP (pa/m)
1	0.013	21.3	20
	0.033	21.3	61
	0.059	21.3	125
	0.085	21.3	201
	0.117	21.3	298
	0.158	21.3	442
	0.181	21.3	536
2	0.013	20.6	20
	0.032	20.6	64
	0.055	20.6	122
	0.082	20.6	199
	0.115	20.6	307
	0.155	20.6	456
	0.179	20.6	554
3	0.012	20.3	24
	0.032	20.3	63
	0.054	20.3	123
	0.084	20.3	205
	0.117	20.3	318
	0.154	20.3	459
	0.177	20.3	559

Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)
1	0.011	18.1	24
	0.031	18.1	71
	0.054	18.1	136
	0.080	18.1	223
	0.111	18.1	336
	0.148	18.1	489
	0.173	18.1	605
2	0.012	17.9	20
	0.030	17.9	65
	0.050	17.9	131
	0.074	17.9	220
	0.106	17.9	345
	0.146	17.9	514
	0.166	17.9	617
3	0.011	17.9	20
	0.029	17.9	68
	0.053	17.9	134
	0.080	17.9	222
	0.110	17.9	332
	0.147	17.9	487
	0.172	17.9	602

Table 6. Static Pressure Drop Data for Wheat at Various Moisture Contents-II

Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)	Replication	Air Velocity V (m/s)	Moisture Content M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)
	0.011	15.5	28		0.010	12.5	28
	0.028	15.5	78		0.024	12.5	73
	0.049	15.5	152		0.042	12.5	139
1	0.071	15.5	255	1	0.060	12.5	242
	0.099	15.5	396		0.093	12.5	374
	0.134	15.5	592		0.130	12.5	571
	0.159	15.5	716		0.150	12.5	694
	0.011	15.5	28		0.010	12.5	28
	0.027	15.5	73		0.024	12.5	74
	0.049	15.5	151		0.042	12.5	139
2	0.071	15.5	265	2	0.058	12.5	237
	0.100	15.5	384		0.091	12.5	366
	0.135	15.5	575		0.131	12.5	547
	0.162	15.5	696		0.150	12.5	681
	0.011	15.2	24		0.010	12.4	27
	0.026	15.2	71		0.024	12.4	70
	0.048	15.2	153		0.042	12.4	139
3	0.070	15.2	253	3	0.058	12.4	232
	0.100	15.2	392		0.091	12.4	369
	0.134	15.2	585		0.131	12.4	571
	0.158	15.2	704		0.149	12.4	686

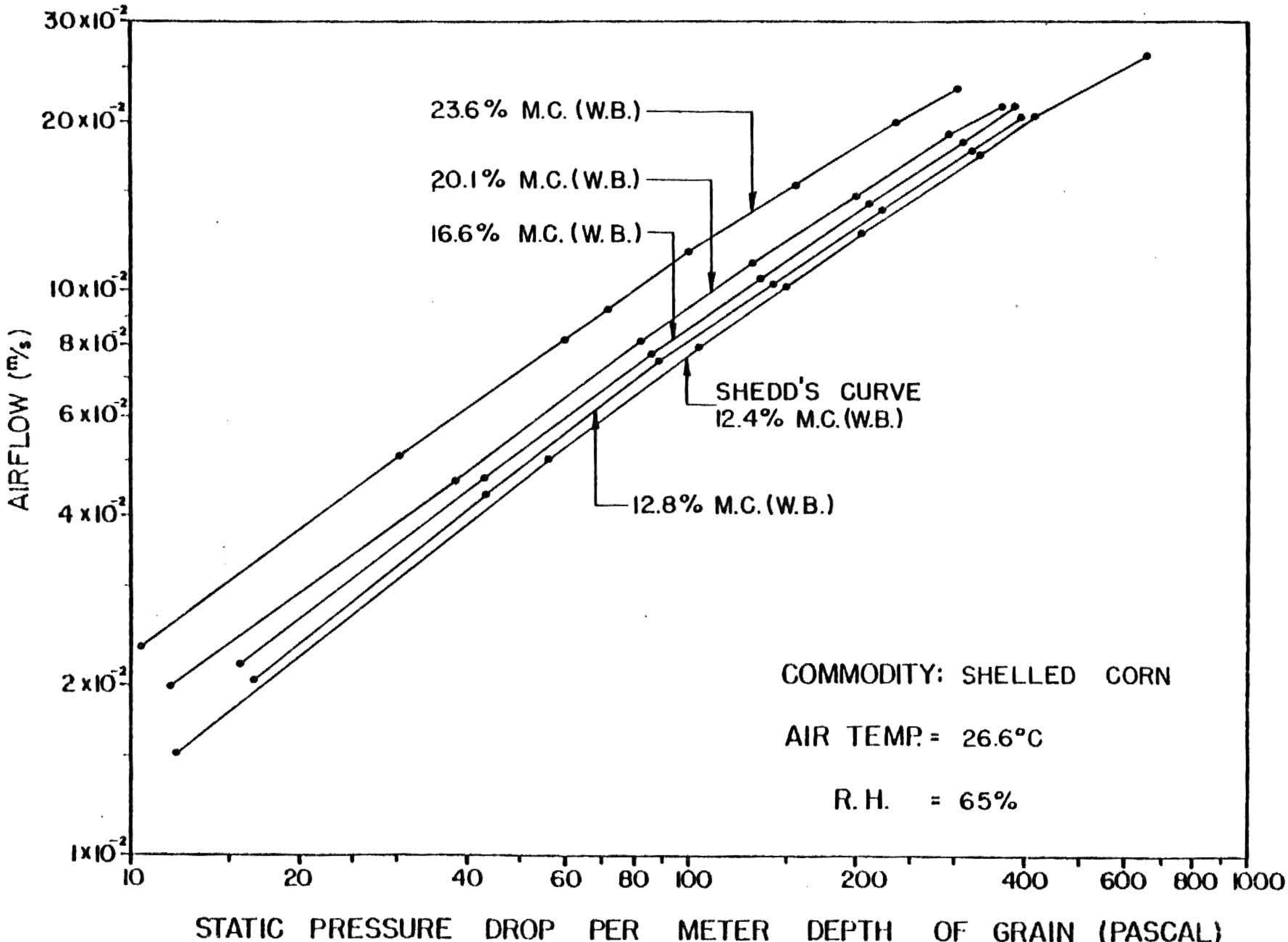


Fig. 2 Resistance of Shelled Corn with Various Moisture Contents on Airflow (Replication 1).

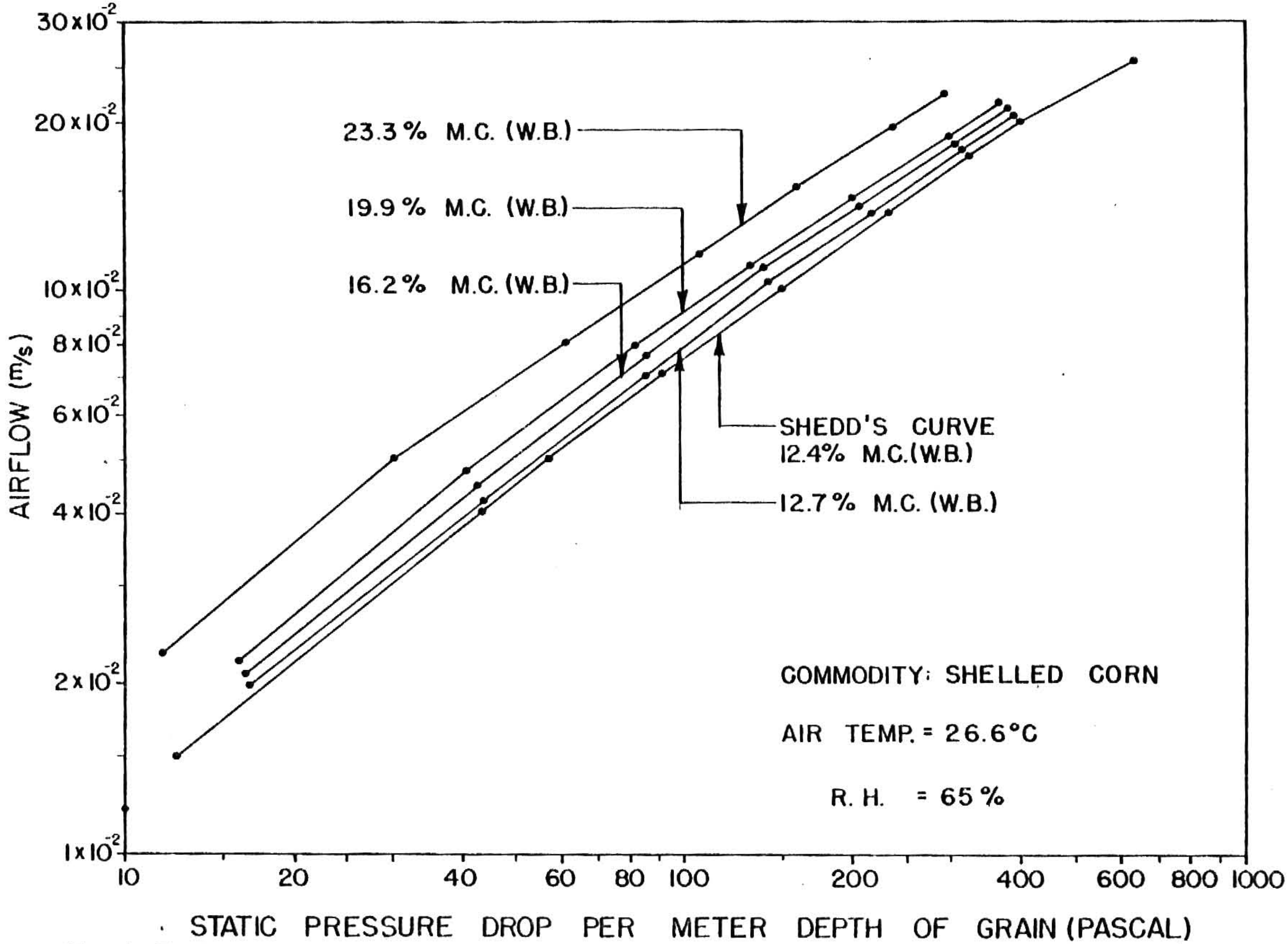


Fig. 3 Resistance of Shelled Corn with Various Moisture Contents on Airflow (Replication 2).

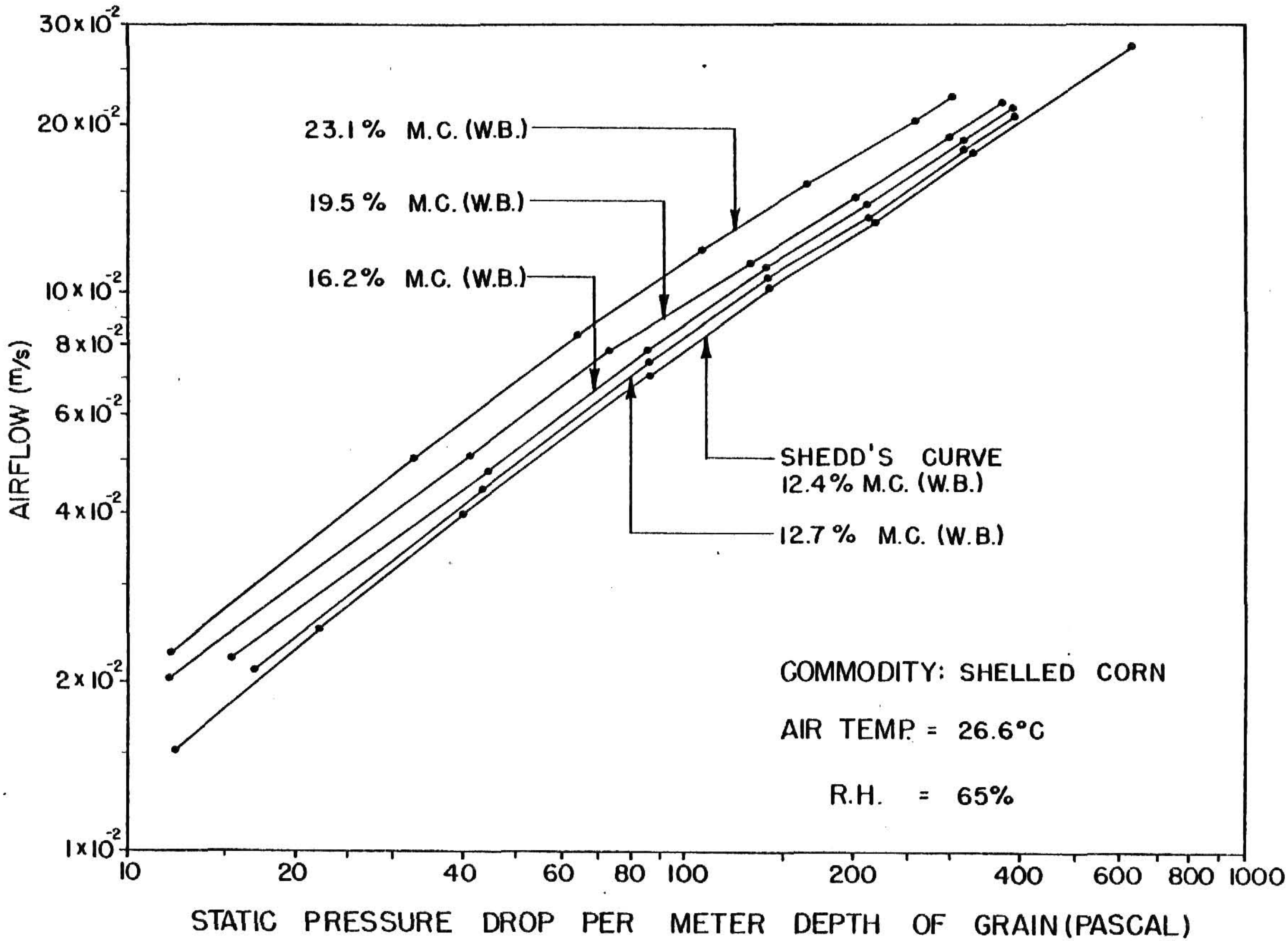


Fig. 4 Resistance of Shelled Corn with Various Moisture Contents on Airflow (Replication 3).

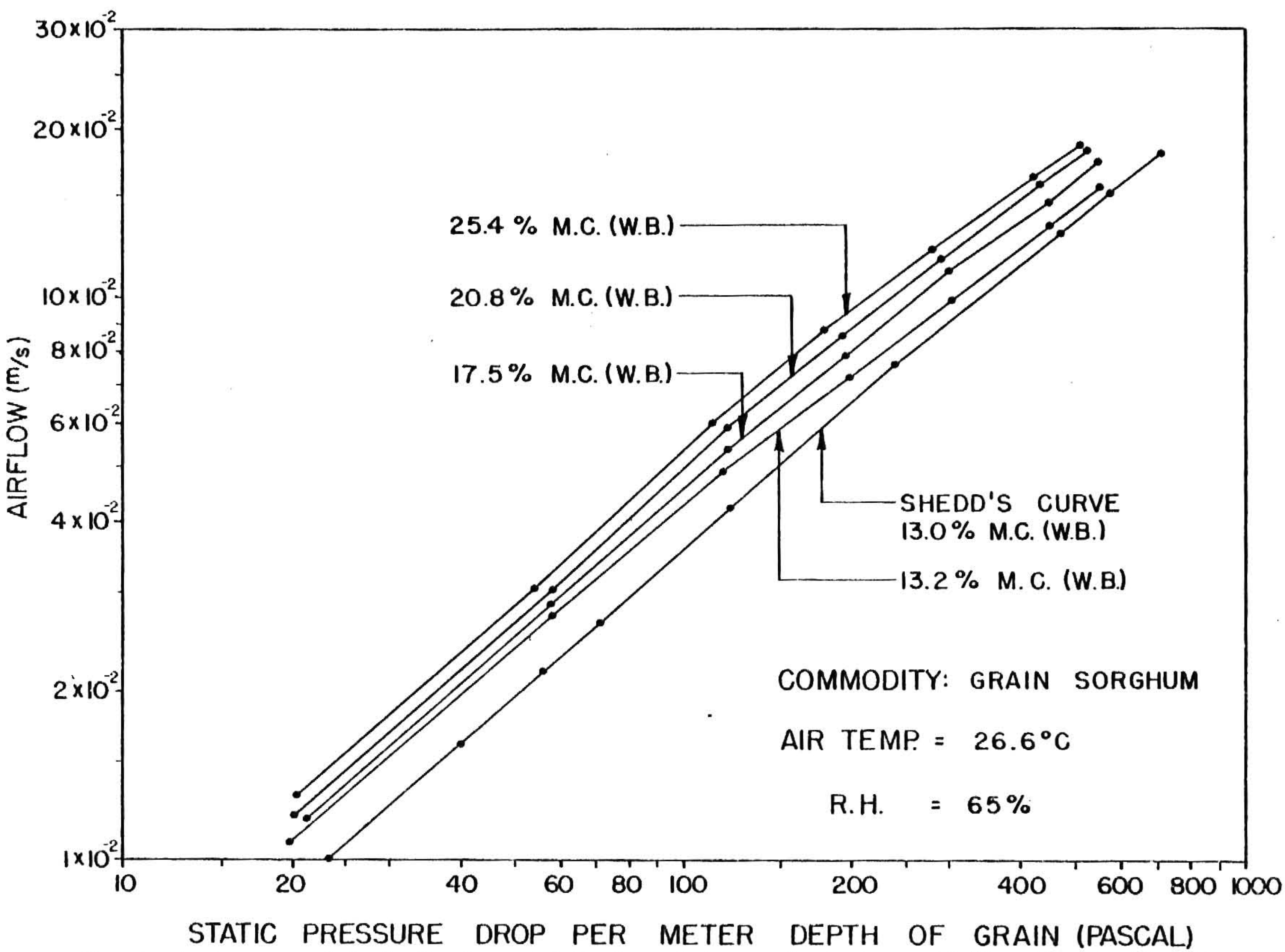


Fig. 5 Resistance of Grain Sorghum with Various Moisture Contents on Airflow (Replication 1).

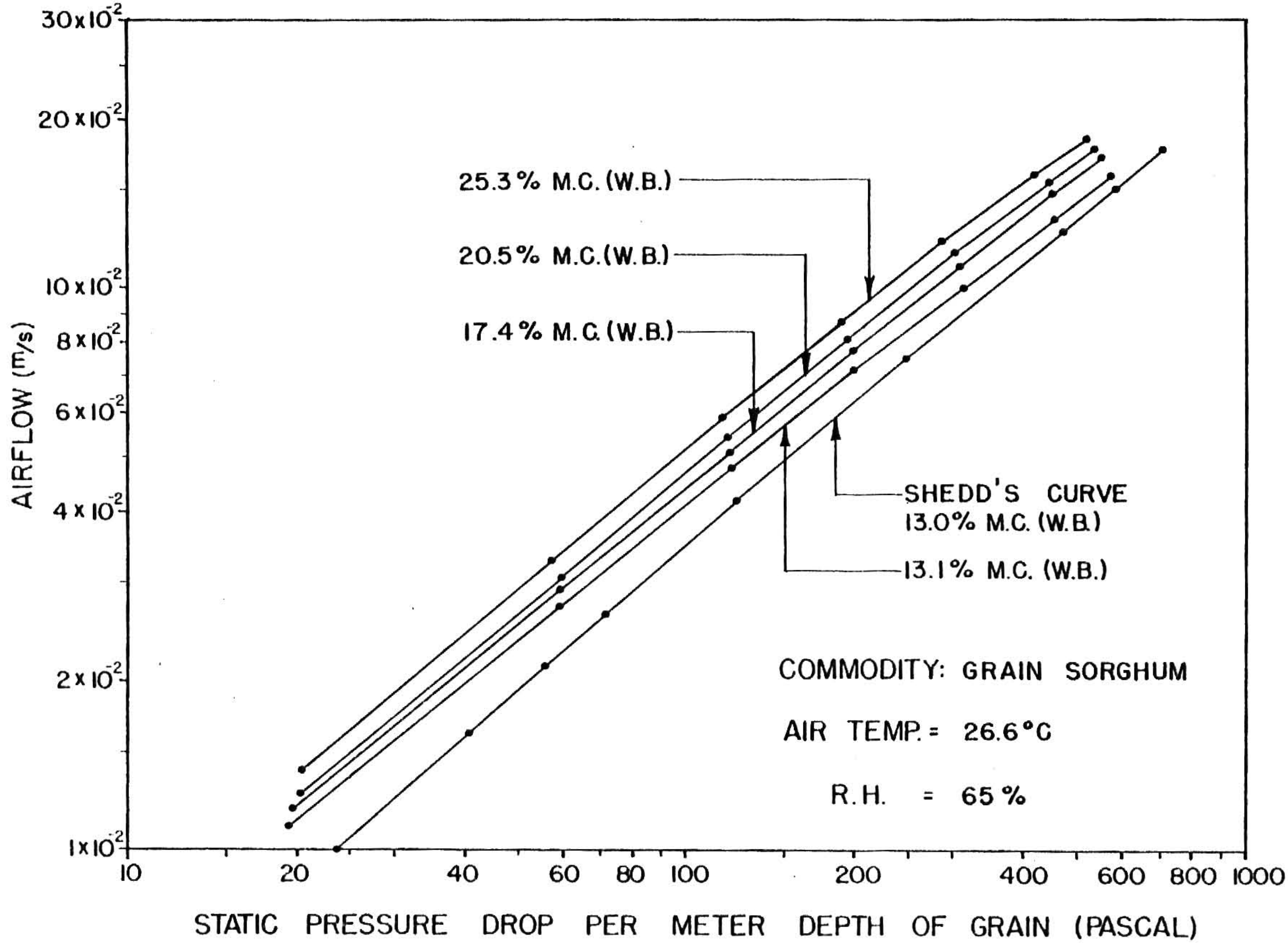


Fig. 6 Resistance of Grain Sorghum with Various Moisture Contents on Airflow (Replication 2).

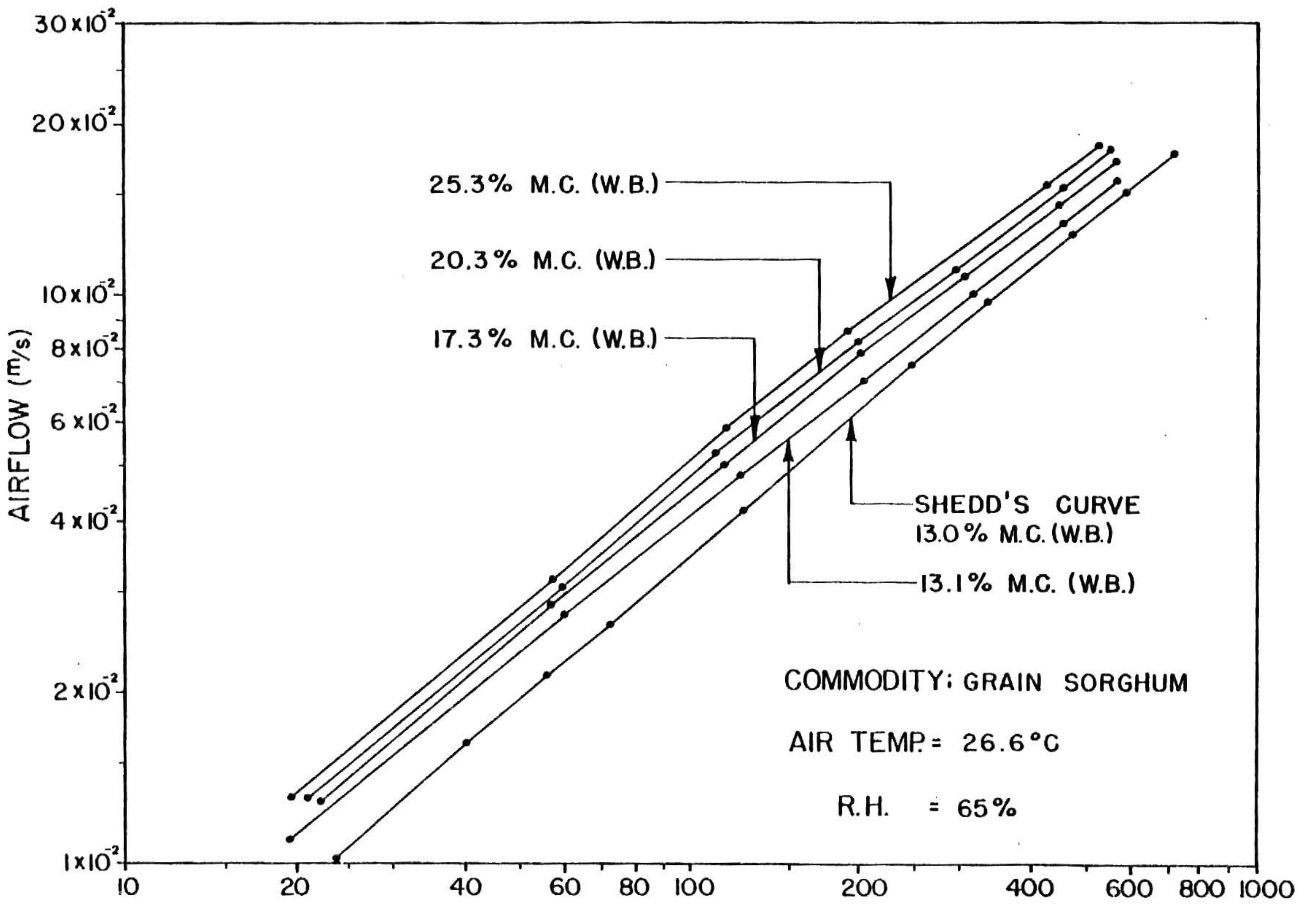
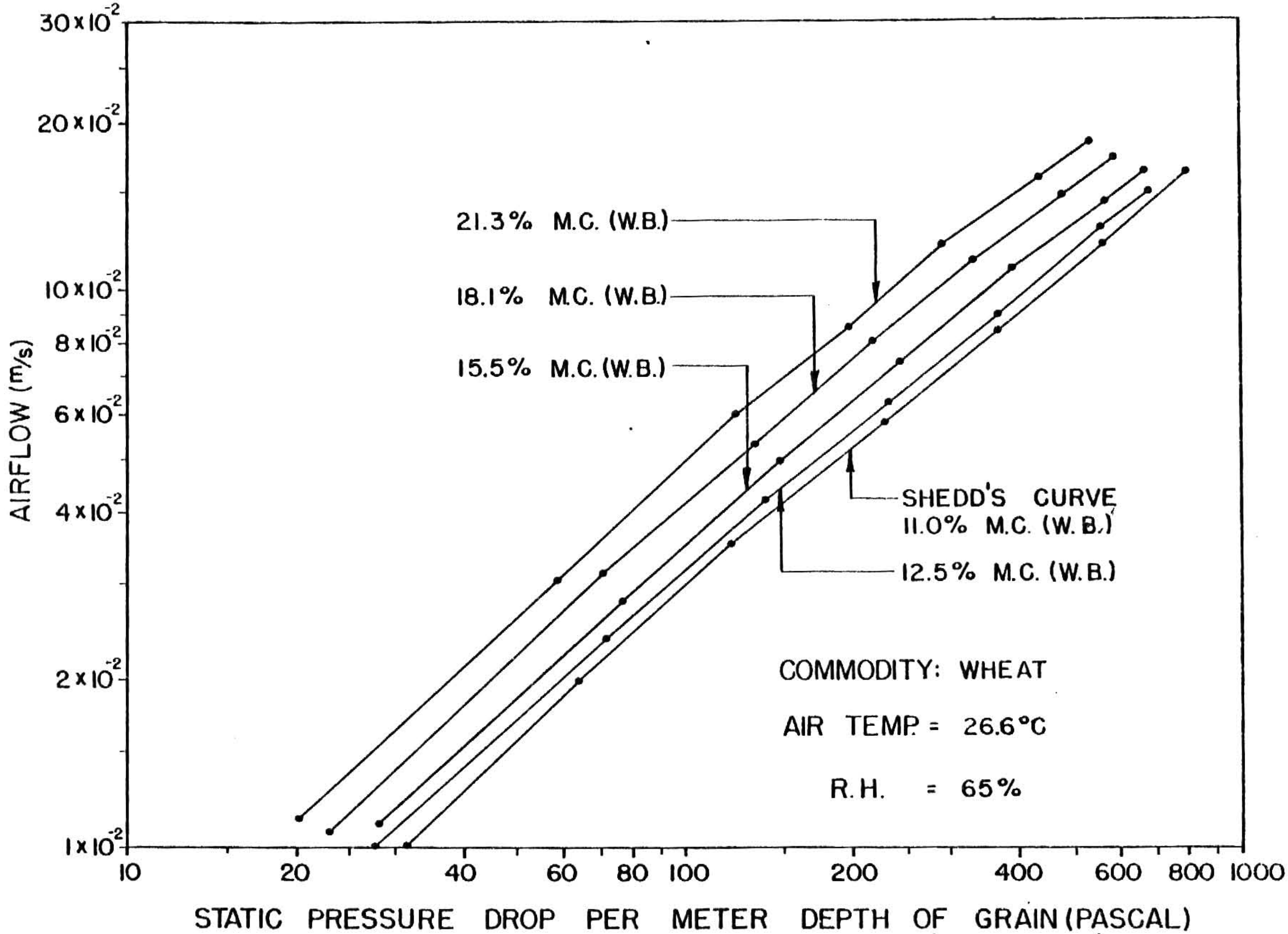


Fig. 7 Resistance of Grain Sorghum with Various Moisture Contents on Airflow (Replication 3).



AIRFLOW (m/s)
30x10^-2
20x10^-2
10x10^-2
8x10^-2
6x10^-2
4x10^-2
2x10^-2
1x10^-2
10
20
40
60
80
100
200
400
600
800
1000
STATIC PRESSURE DROP PER METER DEPTH OF GRAIN (PASCAL)
21.3% M.C. (W.B.)
18.1% M.C. (W.B.)
15.5% M.C. (W.B.)
SHEDD'S CURVE
11.0% M.C. (W.B.)
12.5% M.C. (W.B.)
COMMODITY: WHEAT
AIR TEMP. = 26.6°C
R.H. = 65%

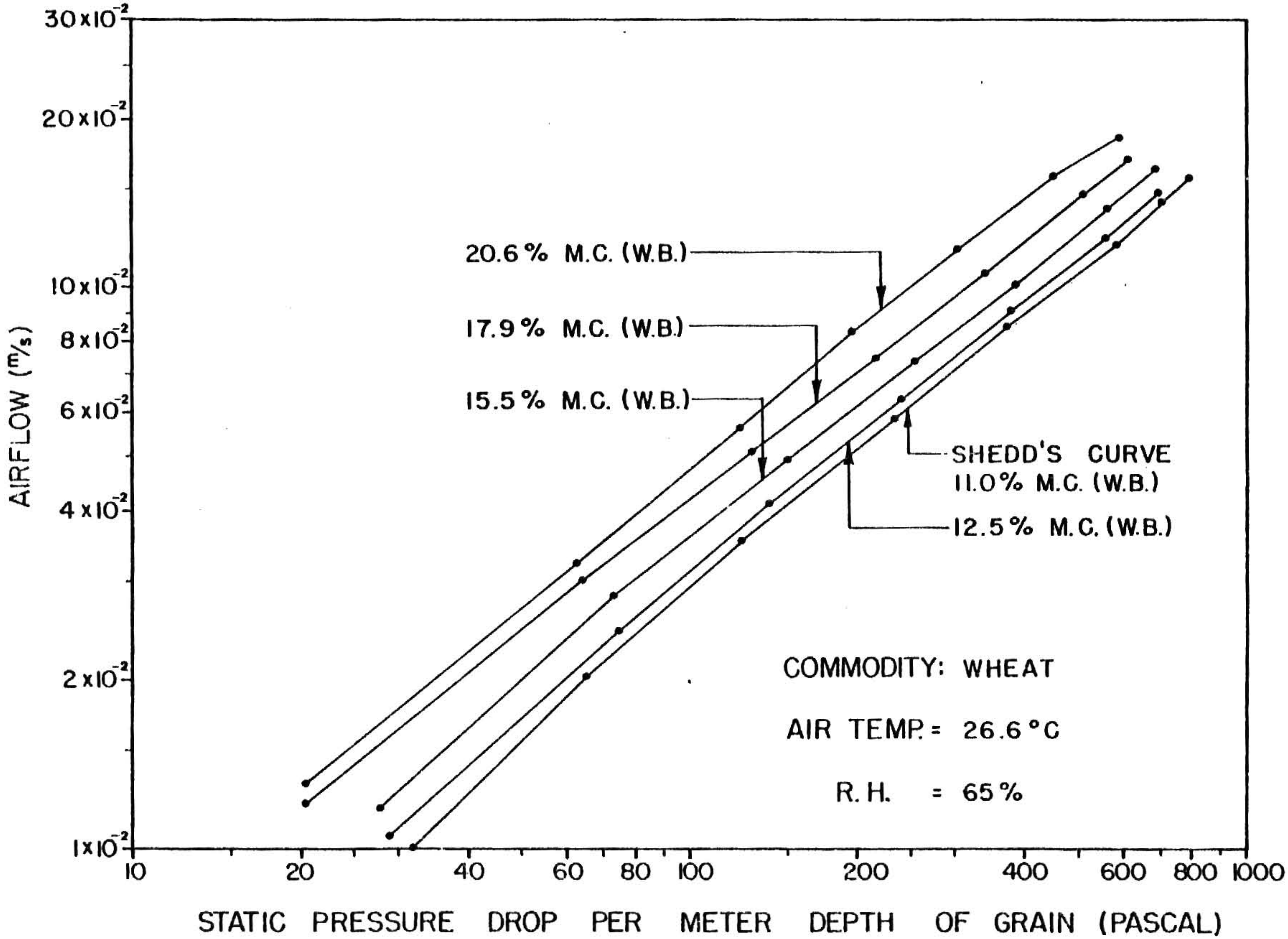


Fig. 9 Resistance of Wheat with Various Moisture Contents on Airflow (Replication 2).

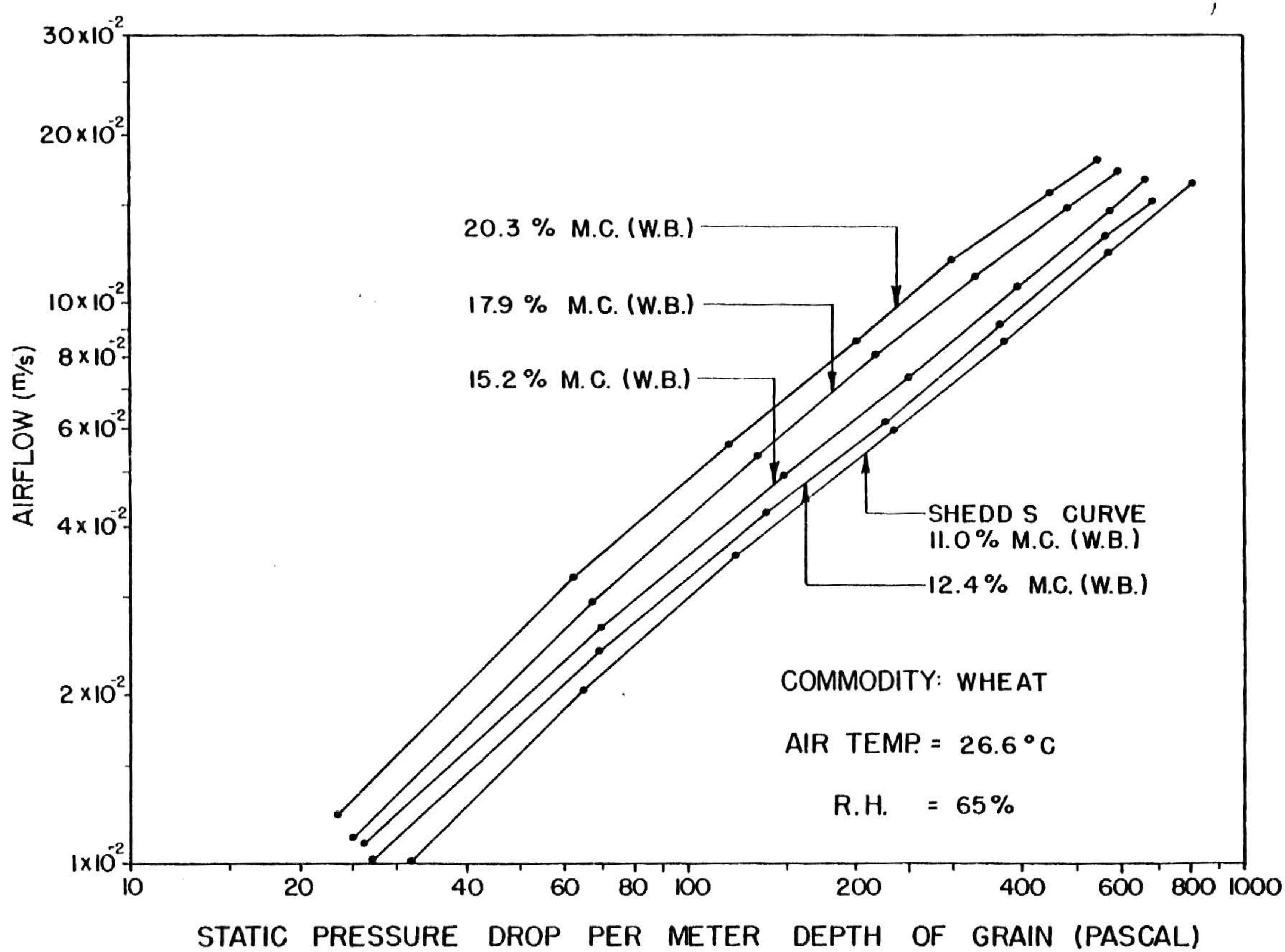


Fig. 10 Resistance of Wheat with Various Moisture Contents on Airflow (Replication 3).

commodity. These average data for corn, sorghum and wheat were plotted on log- log paper as shown in Figs. 11, 12 and 13, respectively. We can conclude from these plots also that the static pressure drop decreases with the increase in grain moisture. The reasons for this will be explained later.

Seven levels of air velocities were accomplished by seven different dial settings of the controller. It is seen from the data (Table 1 through 6) that even for the same dial setting under different grain moistures, we could not attain exactly the same air velocities. This made it difficult for us to analyze the data statistically. To overcome this difficulty, we read from graphs for corn (Figs. 2, 3 and 4) the static pressure drop data corresponding to a fixed set of air velocities such as 0.041, 0.061, 0.086, 0.107, 0.127, 0.152 and 0.203 m/s for three replications. These pressure drop data and the moistures were averaged and tabulated after truncating for simplicity (Table 7). Similar tables were created for grain sorghum (Table 8) and wheat (Table 9) for air velocities 0.015, 0.041, 0.061, 0.086, 0.107, 0.127 and 0.152 m/s.

The first two columns of Tables 7, 8 and 9 represent the values of the independent variables, air velocity and moisture content. The last column gives the values of the dependent variable, static pressure drop. These data were fitted into a nonlinear regression model arrived at by judicious selection. By analyzing the trend in data and plotting ΔP against moisture content for a few fixed velocities, we suspected that the relationship between ΔP and moisture could be linear. From our extensive literature review, it was obvious that the pressure drop equation involves a linear and a second order term in V (Ergun, 1952; Haque, 1978). So, the selected nonlinear regression model was of the form:

$$\Delta P = A \cdot V + B \cdot V^2 - C \cdot V \cdot (M.C) \tag{7}$$

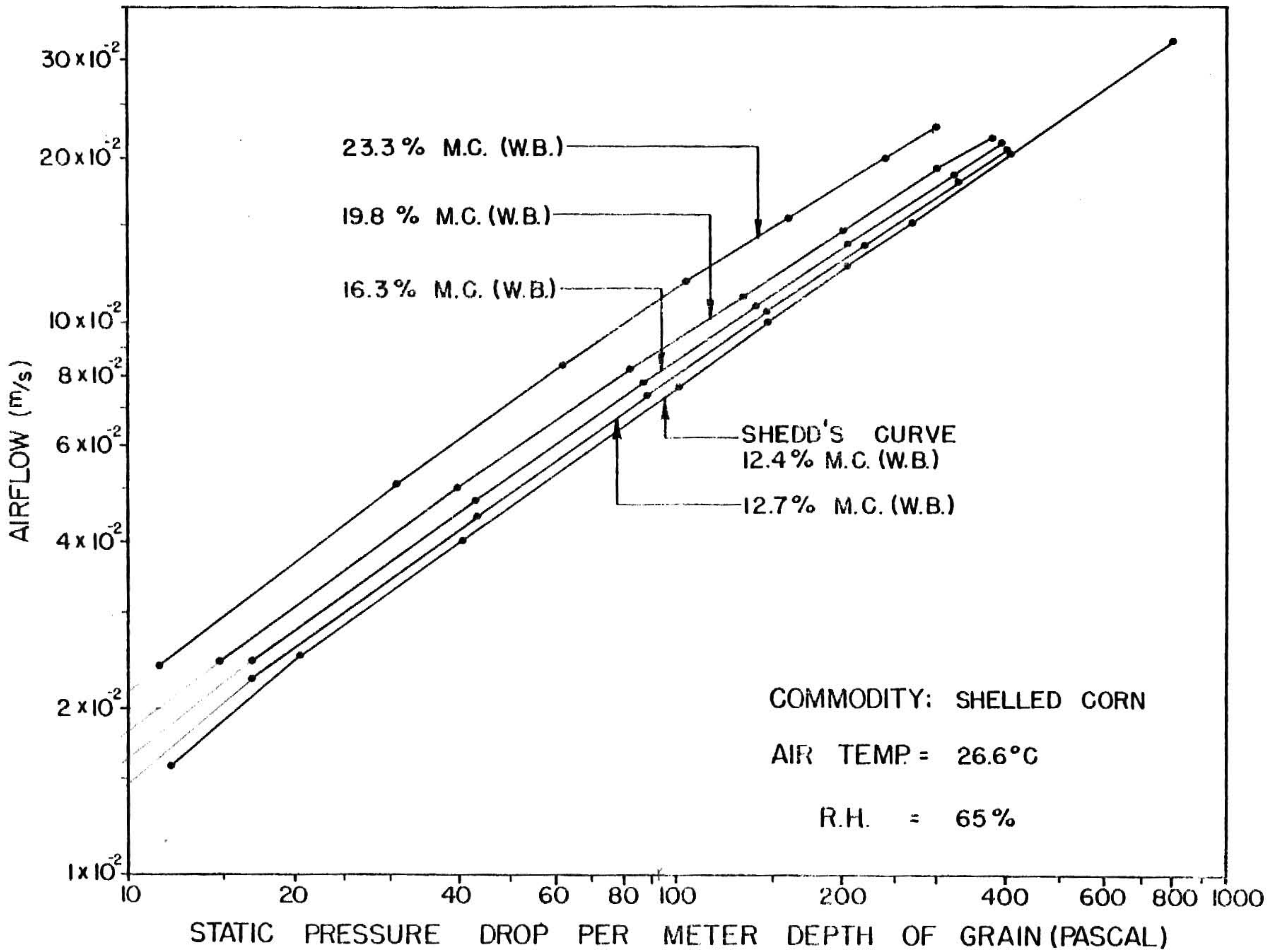


Fig. 11 Resistance of Shelled Corn with Various Moisture Contents on Airflow (Average of Replications).

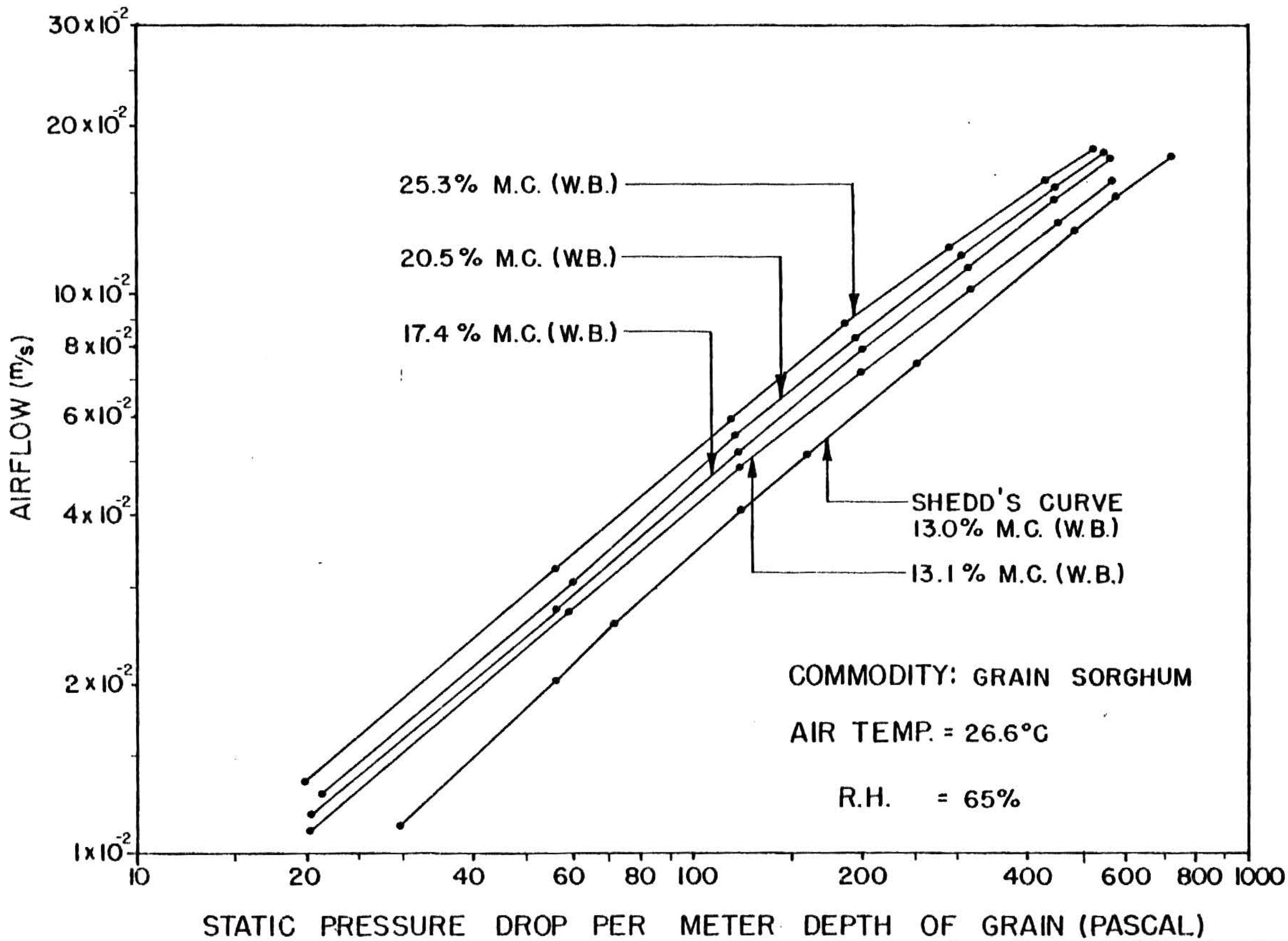


Fig. 12 Resistance of Grain Sorghum with Various Moisture Contents on Airflow (Average of Replications).

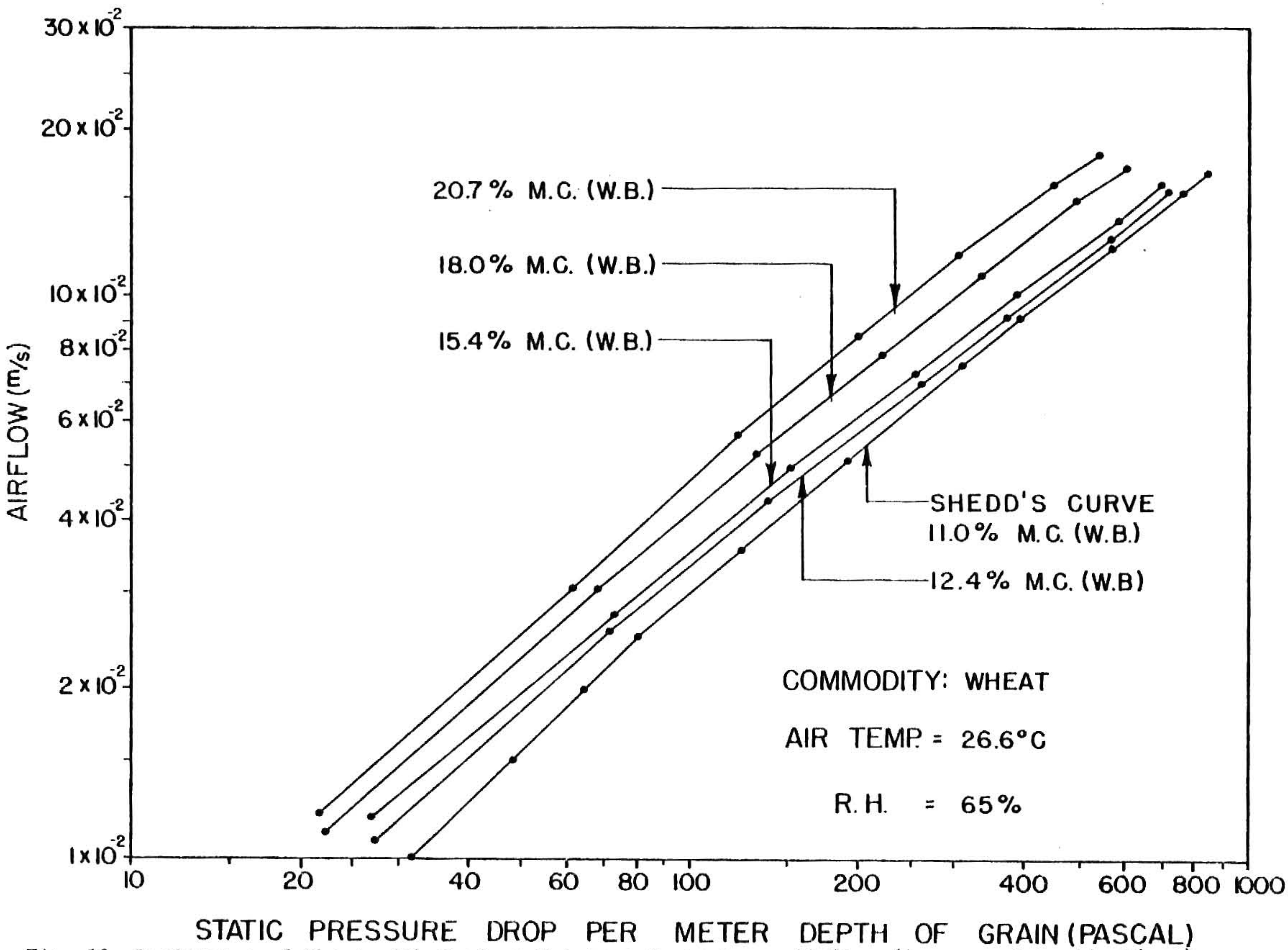


Fig. 13 Resistance of Wheat with Various Moisture Contents on Airflow (Average of Replications).

Table 7. Static Pressure Drop Data for Shelled Corn Read from Figs. 2, 3, 4 and Averaged.

Air Velocity V (m/s)	Moisture Content Average of All Rep. M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)
0.041	23.3	23
0.041	19.8	30
0.041	16.3	34
0.041	12.7	39
0.061	23.3	41
0.061	19.8	53
0.061	16.3	61
0.061	12.7	69
0.086	23.3	69
0.086	19.8	88
0.086	16.3	103
0.086	12.7	106
0.107	23.3	88
0.107	19.8	121
0.107	16.3	129
0.107	12.7	136
0.127	23.3	120
0.127	19.8	158
0.127	16.3	174
0.127	12.7	190
0.152	23.3	158
0.152	19.8	207
0.152	16.3	228
0.152	12.7	248
0.203	23.3	245
0.203	19.8	324
0.203	16.3	356
0.203	12.7	392

Table 8. Static Pressure Drop Data for Grain Sorghum Read from Figs. 5, 6, 7 and Averaged.

Air Velocity V (m/s)	Moisture Content Average of All Rep. M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)
0.015	25.3	21
0.015	20.5	25
0.015	17.4	27
0.015	13.1	29
0.041	25.3	75
0.041	20.5	83
0.041	17.4	101
0.041	13.1	105
0.061	25.3	120
0.061	20.5	137
0.061	17.4	152
0.061	13.1	170
0.086	25.3	190
0.086	20.5	211
0.086	17.4	233
0.086	13.1	264
0.107	25.3	248
0.107	20.5	258
0.107	17.4	283
0.107	13.1	340
0.127	25.3	318
0.127	20.5	343
0.127	17.4	375
0.127	13.1	430
0.152	25.3	408
0.152	20.5	441
0.152	17.4	479
0.152	13.1	535

Table 9. Static Pressure Drop Data for Wheat Read from Figs. 8, 9, 10 and Averaged.

Air Velocity V (m/s)	Moisture Content Average of All Rep. M.C. (% W.B.)	Static Pressure Drop ΔP (pa/m)
0.015	20.7	26
0.015	18.0	32
0.015	15.4	40
0.015	12.4	45
0.041	20.7	82
0.041	18.0	98
0.041	15.4	118
0.041	12.4	133
0.061	20.7	133
0.061	18.0	160
0.061	15.4	193
0.061	12.4	216
0.086	20.7	203
0.086	18.0	239
0.086	15.4	299
0.086	12.4	329
0.107	20.7	267
0.107	18.0	291
0.107	15.4	389
0.107	12.4	406
0.127	20.7	337
0.127	18.0	389
0.127	15.4	512
0.127	12.4	550
0.152	20.7	433
0.152	18.0	495
0.152	15.4	648
0.152	12.4	686

where,

ΔP = pressure drop per meter depth of grain, pascal

V = air velocity, m/s

M.C. = grain moisture, % w.b.

and A, B and C = product constants.

This model fitted very well with our data, the square of the correlation coefficient, R^2 was above 0.99 for all the three grains. The computer program for the statistical analysis and the printout are furnished in the Appendix I. The values of the constants A, B and C for corn, sorghum and wheat are given below:

Corn:

A = 1611.719

B = 4949.301

C = -55.116

Sorghum:

A = 3253.100

B = 7911.272

C = -72.521

and Wheat:

A = 5573.950

B = 9634.595

C = -200.283.

The computer output also compares the observed and predicted values and shows a very good agreement between them.

We also tested the validity of equation (7) by using velocities and moistures from Shedd's (1953) curves. Predicted values for both corn and wheat agree very well with Shedd's, however, for sorghum some small variations were observed. This variation can probably be attributed to differences in variety (Table 10).

We tried to develop an equation relating ΔP with void fraction rather than the moisture content with the hope of making the equation independent of the product. To accomplish this objective, we measured bulk and true densities of the commodity at different moisture levels. The void fraction ε was calculated by the equation:

$$\varepsilon = 1 - \frac{\rho_B}{\rho_T} \tag{8}$$

where ρ_B = bulk density, kg/m^3

and ρ_T = true density, kg/m^3.

Tables 10, 11 and 12 show the average of two readings of packing factors corresponding to different moistures for corn, sorghum and wheat, respectively. We used a similar equation as (7), replacing moisture content by void fraction:

$$\Delta p = a_o V + b_o V^2 - c_o V \varepsilon \tag{9}$$

where a_o, b_o, c_o = constants.

Void fraction very well replaces the moisture content (M.C.) provided different sets of a_o, b_o, and c_o are used for different grains. Our attempt to fit data of all the three commodities into equation (9) and similar other equations, failed to yield a single set of constants a_o, b_o, and c_o for all grains. So, we decided not to replace moisture content by void fraction because this will not serve any useful and practical purpose and the concept of void fraction is much more complicated than moisture. The attempted models and the computer printouts are shown in Appendix II.

However, from this analysis we can explain why the static pressure drop

Table 10. Pressure Drop Values Calculated by Equation (7) Compared With Those Read from Shedd's (1953) Curve.

Commodity	Moisture Content % (w.b.)	Velocity m/s	ΔP (Pāscal): Read from Shedd's (1953) curve	ΔP (Pāscal): Calculated by $\Delta P = AV + BV^2 - C(M.C.)V$	% Deviation from Shedd's Value
		.0508	57	60	+5
Corn	12.4	.1016	147	145	-1
		.1524	261	256	-2
		.0508	147	137	-7
Sorghum	13.0	.1016	351	316	-10
		.1524	588	535	-9
		.0508	196	196	0
Wheat	11.0	.1016	441	442	0
		.1524	735	737	0

Table 11. Bulk Density and Void Fraction of Shelled Corn as Affected by Moisture (Average of Two Readings).

Moisture Content Average of Two Readings M.C. (% W.B.)	Bulk Density ρ_B (kg/m^3)	True Density ρ_B (kg/m^3)	Void Fraction ε (expressed in decimal)
23.4	698.41	1208.08	0.42
19.5	774.01	1260.52	0.38
15.7	776.25	1256.10	0.38
12.0	784.26	1249.97	0.37

Table 12. Bulk Density and Void Fraction of Grain Sorghum as Affected by Moisture (Average of Two Readings).

Moisture Content Average of Two Readings M.C. (% W.B.)	Bulk Density ρ_B (kg/m^3)	True Density ρ_B (kg/m^3)	Void Fraction ε (expressed in decimal)
25.1	723.23	1251.71	0.42
20.5	732.84	1249.97	0.41
16.7	776.58	1272.98	0.39
13.3	784.90	1285.69	0.39

Table 13. Bulk Density and Void Fraction of Wheat as Affected by Moisture (Average of Two Readings).

Moisture Content Average of Two Readings M.C. (% W.B.)	Bulk Density ρ_B (kg/m^3)	True Density ρ_B (kg/m^3)	Void Fraction ε (expressed in decimal)
20.5	708.82	1287.53	0.45
17.5	745.82	1285.67	0.42
14.9	777.22	1311.97	0.41
12.3	804.13	1311.88	0.39

decreases with the increase in moisture content. From Tables 11, 12, and 13 it is apparent that void fraction, ε increases and bulk density, ρ_B decreases with grain moisture. So, we can expect a reduction in resistance to airflow at higher moistures. The second possible effect of the moisture is on the surface characteristics of the grain. We think that the change of surface characteristics due to higher moisture content tends to increase the resistance to airflow. But the effect of moisture on bulk density is more prominent than on surface characteristic and results in a net decrease in static pressure drop at higher levels of moisture.

The effect of particle size, shape and surface characteristics seems more pronounced than void fraction.

4.1 Energy Saving

Present practice of designing aeration system for high moisture grain storage on the basis of Shedd's data is arbitrary. If the design is based on dry grain, one will end up with a higher power requirement than what our study shows. To substantiate the point, let us consider a 7.315 m dia x 10.058 m high farm size grain bin with perforated floor. The bin is filled with 20% moisture (w.b.) corn and aerated by 0.4 m^3 of air per m^3 of grain volume.

Calculations:

Floor area = $(\frac{\pi}{4})\ (7{\cdot}315)^2 = 42{\cdot}026\ m^2$

Grain volume = $(42{\cdot}026)\ (10{\cdot}058) = 422.698\ m^3$

Airflow rate = $(0{\cdot}4)\ (422{\cdot}698) = 169{\cdot}079\ m^3/min$

Air velocity = $169{\cdot}079/(42{\cdot}026)\ (60) = 0{\cdot}067\ m/s$

From Shedd's data, ΔP = 90 Pa/m for 0.067 m/s air velocity. It is customary to increase Shedd's pressure drop data by 50% to account for packing in corn. So, total design pressure drop = (90) (1·5) (10·058) = 1358 Pa which means we have to have a 10·84 HP motor. This type of HP is not commercially available, so we have to select the next higher size which is 15 HP motor (11·19 KW).

On the contrary, if the design is based on our data:
total design pressure drop = (59) (1·5) (10·058) = 890 Pa.
A 6.9 HP motor will suffice but we are required to select the next available commercial size motor which is 7½ HP (5·595 KW).

Considering that grain is aerated round the clock from October 1 to March 31 with $0.05/KWH electricity, the expected saving will be $1,222.

As power requirement increases linearly with the static pressure drop, we can expect, in general, at least a 34% energy saving for this situation. However, the energy savings will vary at different airflow rates.

CONCLUSIONS

We can draw the following conclusions from this study.

1. Static pressure drop in grains decreases with the increase in moisture.

2. The statistical model: $\Delta P = AV + BV^2 - C\,(M.C.)\,V$ adequately describes the relationship between the static pressure drop ΔP and grain moisture content (M.C.) and air velocity, V.

3. $\Delta P = a_o V + b_o V^2 - C_o V \cdot \varepsilon$ also describes the relationship between ΔP and void fraction and air velocity.

4. The result of this study is expected to help designers in conserving energy for high moisture grain aeration systems.

5. This study will enhance our knowledge about the effects of moisture content on the static pressure drop in grain.

6. Effect of particle size, shape and surface characteristics seems more pronounced than void fraction. For this reason, wheat exhibits much more pressure drops than corn even though void fractions for both commodities remain almost the same.

We hope the result of this study for post harvest high moisture grain preservation will be very useful.

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APPENDIX I

AIRFLOW CALCULATIONS AND REGRESSION ANALYSIS

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

PROGRAM FOR AIRFLOW CALCULATION

```
1                    S T A T I S T I C A L   A N A L Y S I S   S Y S T E M       14:48 FRIDAY, NOVEMBER 14, 1980

NOTE: THE JOB A0001345 HAS BEEN RUN UNDER RELEASE 79.5A OF SAS AT KANSAS STATE UNIVERSITY.

NOTE: THIS IS THE MESSAGE BATCH USERS SEE
      WHEN OPTIONS NEWS IS SPECIFIED.
      THIS MESSAGE SHOULD BE REPLACED BY SOME
      MEANINGFULL TEXT.
      TO CHANGE THE MODULE RECOMPILE IT.
      IT IS: DSNAME=SAS.SOURCE(SASNEWS).
      SEE INSTALLATION INSTRUCTIONS PROGRAM LISTSPC.

       * THIS PROGRAM CALCULATES AIRFLOW RATE (LB/HR)
       * SP=STATIC PRESSURE (IN. OF WATER)
       * SPM=STATIC PRESSURE (PASCAL)
       *Q=CFM
       * PR=PRESSURE DEFLECTION (IN OF WATER)
       * PRM=PRESSURE DEFLECTION (MM OF WATER)
       * QF2=CFM/FT2
       * QH=CALCULATED CFM
       * QM=M/SEC
       * W=AIRFLOW RATE (LB/HR)
       * WH=CALCULATED AIRFLOW RATE (LB/HR)
       * V=FT/SEC
       * DEL=PERCENTAGE EXPRESSED AS DECIMAL
       * CD=COEFF. OF DISCHARGE
       * RO=RE NUMBER;
       DATA CORN;
       INPUT PR 1-6 SP 8-13 IRT REP;
       Q=1;
       REP = FLOOR((REP-1)/7); REP = REP+1;
       START: V=Q/1.374;
       W=Q*4.41;
       RO=V*.36107/.00016;
       CD=.19436+.152884*LOG(RD)-.0097785*LOG(RD)*LOG(RD)+.00020503*LOG(RD)*
       LOG(RD)*LOG(RD);
       WH=359*CD*1.0255*.3312*SQRT(PR*.0735);
       QH=WH/4.41;
       DEL=ABS((W-WH)/W);
       IF DEL <.001 THEN GO TO STOP;
       QF2=QH/.754;
       QM=QF2*.00508;
       SPM=SP*816.4;
       PUT QH=V= RD= CD= WH= DEL= PR= QF2= SP= QM= SPM=;
       Q=QH; GO TO START;
       STOP:LSP=LOG(SP);LQF2=LOG(QF2);LSPM=LOG(SPM);LQM=LOG(QM);OUTPUT;
       CARDS;

QH=3.247233 V=0.727802 RD=1642.103 CD=0.8750935 WH=14.3201 DEL=2.247233 PR=0.031 QF2=4.306675 SP=0.013 QM=0.02187791 SPM=10.6132
QH=3.40765 V=2.363341 RD=5332.292 CD=0.9183241 WH=15.02774 DEL=0.04940112 PR=0.031 QF2=4.51943 SP=0.013 QM=0.0229587 SPM=10.6132
QH=3.413201 V=2.480955 RD=5595.714 CD=0.9198201 WH=15.05222 DEL=0.001629017 PR=0.031 QF2=4.526792 SP=0.013 QM=0.0229961 SPM=10.6132
QH=6.959872 V=0.727802 RD=1642.103 CD=0.8750935 WH=30.69393 DEL=5.969972 PR=0.142 QF2=9.217337 SP=0.0375 QM=0.04682507 SPM=30.615
QH=7.462475 V=5.058131 RD=11412.41 CD=0.9296439 WH=32.90952 DEL=0.07215727 PR=0.142 QF2=9.897182 SP=0.0375 QM=0.05027767 SPM=30.615
QH=7.476395 V=5.431205 RD=12254.16 CD=0.9413907 WH=32.9709 DEL=0.001865292 PR=0.142 QF2=9.915643 SP=0.0375 QM=0.05037147 SPM=30.615
QH=11.15765 V=0.727802 RD=1642.103 CD=0.8750935 WH=49.20525 DEL=10.15766 PR=0.366 QF2=14.79776 SP=0.0745 QM=0.07517363 SPM=60.8218
QH=12.12004 V=8.120568 RD=18322.03 CD=0.9505727 WH=53.44938 DEL=0.08625274 PR=0.366 QF2=16.07432 SP=0.0745 QM=0.08165756 SPM=60.8218
QH=12.14223 V=8.82099 RD=19902.46 CD=0.9523133 WH=53.54725 DEL=0.001831036 PR=0.366 QF2=16.10376 SP=0.0745 QM=0.08180709 SPM=60.8218
QH=15.5841 V=0.727802 PD=1642.103 CD=0.8750935 WH=68.72584 DEL=14.5841 PR=0.714 QF2=20.66857 SP=0.1215 QM=0.1049963 SPM=99.1926
QH=17.05816 V=11.34214 RD=25590.7 CD=0.9574059 WH=75.13233 DEL=0.09394588 PR=0.714 QF2=22.61029 SP=0.1215 QM=0.1148603 SPM=99.1926
```

PROGRAM FOR REGRESSION ANALYSIS

```
1                                 S T A T I S T I C A L   A N A L Y S I S   S Y S T E M        14:53 FRIDAY, NOVEMBER 14, 1980

NOTE: THE JOB A0001351 HAS BEEN RUN UNDER RELEASE 79.3A OF SAS AT KANSAS STATE UNIVERSITY.

NOTE: THIS IS THE MESSAGE WHICH USERS SEE
      WHEN OPTIONS NEWS IS SPECIFIED.
      THIS MESSAGE SHOULD BE REPLACED BY SOME
      MEANINGFULL TEXT.
      TO CHANGE THE MODULE RECOMPILE IT.
      IT IS: DSNAME=SAS.SOURCE(SASNEWS).
      SEE INSTALLATION INSTRUCTIONS PROGRAM LISTSRC.

1          DATA GRAPH; INPUT  SP  MC  V;
2          SPM=SP*816.4;
3          VM=V*0.00508;
4          CARDS;

NOTE: DATA SET WORK.GRAPH HAS 28 OBSERVATIONS AND 5 VARIABLES. 433 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.48 SECONDS AND 120K.

33         PROC GLM;
34         MODEL SPM= VM  VM*VM  MC*VM /NOINT P CLM;
35         OUTPUT OUT=NEW PREDICTED=PSPM RESIDUAL=RSPM;

NOTE: DATA SET WORK.NEW HAS 28 OBSERVATIONS AND 7 VARIABLES. 317 OBS/TRK.
NOTE: THE PROCEDURE GLM USED 1.20 SECONDS AND 198K AND PRINTED PAGES 1 TO 2.

36         PROC PLOT;PLOT SPM*MC='.' PSPM*MC='*' /O;
37         PLOT RSPM*MC='.' RSPM*PSPM='.' RSPM*VM='.';

NOTE: THE PROCEDURE PLOT USED 1.42 SECONDS AND 160K AND PRINTED PAGES 3 TO 6.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      BOX 8000
      CARY, N.C. 27511
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AIRFLOW CALCULATIONS FOR CORN

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   14:48 FRIDAY, NOVEMBER 14, 1980   1

OBS	PR	SP	TRT	FLP	[illegible]	V	W	RE	CD	WH	QH
1	0.031	0.0130	1	1	3.4132	2.4841	15.052	5604.8	0.919870	15.053	3.4134
2	0.142	0.0375	1	1	7.4764	5.4413	32.971	12277.0	0.941436	32.972	7.4768
3	0.366	0.0745	1	1	12.1422	8.8371	53.547	19938.8	0.952351	53.549	12.1427
4	0.714	0.1215	1	1	17.0780	12.4294	75.314	29043.9	0.959014	75.317	17.0786
5	1.252	0.1935	1	1	22.7323	16.5446	100.250	37328.8	0.963997	100.252	22.7330
6	2.087	0.2895	1	1	29.4738	21.4511	129.979	48399.6	0.968071	129.983	29.4745
7	2.611	0.3670	1	1	33.0233	24.0344	145.633	54227.7	0.969725	145.636	33.0241
8	0.032	0.0145	1	2	3.4597	2.5253	15.301	5697.6	0.920375	15.302	3.4699
9	0.140	0.0375	1	2	7.4222	5.4019	32.732	12188.0	0.941259	32.733	7.4225
10	0.377	0.0770	1	2	12.2436	8.9109	53.994	20105.2	0.952523	53.996	12.2441
11	0.733	0.1305	1	2	17.3082	12.5969	76.329	28421.9	0.959260	76.332	17.3088
12	1.256	0.1975	1	2	22.7692	16.5715	100.412	37389.4	0.964024	100.415	22.7699
13	2.045	0.2940	1	2	29.1711	21.2308	128.644	47901.9	0.967917	128.649	29.1718
14	2.645	0.3670	1	2	33.2408	24.1927	146.592	54584.9	0.969819	146.595	33.2416
15	0.030	0.0145	1	3	3.3558	2.4423	14.799	5510.5	0.919346	14.800	3.3560
16	0.143	0.0405	1	3	7.5034	5.4610	33.090	12321.3	0.941524	33.091	7.5037
17	0.376	0.0795	1	3	12.3107	8.9597	54.290	20215.4	0.952636	54.292	12.3112
18	0.737	0.1340	1	3	17.3563	12.6319	76.541	28500.8	0.959310	76.544	17.3569
19	1.260	0.2055	1	3	22.8061	16.5983	100.575	37450.0	0.964051	100.578	22.8067
20	2.095	0.3095	1	3	29.5311	21.4928	130.232	48493.2	0.968100	130.235	29.5319
21	2.659	0.3770	1	3	33.2727	24.2159	146.733	54637.2	0.969832	146.736	33.2734
22	0.020	0.0155	2	1	2.7200	1.9797	11.995	4466.6	0.912651	11.996	2.7202
23	0.124	0.0480	2	1	6.9733	5.0755	30.754	11451.7	0.939723	30.756	6.9741
24	0.355	0.1010	2	1	11.9543	8.7004	52.718	19630.2	0.952027	52.721	11.9548
25	0.660	0.1595	2	1	16.4068	11.9409	72.354	26941.7	0.958273	72.357	16.4074
26	1.150	0.2345	2	1	21.7704	15.8445	96.007	35749.2	0.963278	96.010	21.7710

OBS	DFL	QF2	CM	SPM	LSP	LQF2	LSPM	LQM
1	0.0000545133	4.5268	0.022596	10.613	-4.3428	1.51001	2.36213	-3.7724
2	0.0000481927	9.9156	0.050371	30.615	-3.2834	2.29411	3.42149	-2.9883
3	0.0000398295	16.1038	0.081807	60.822	-2.5970	2.77905	4.10795	-2.5034
4	0.0000335357	22.6499	0.115062	99.193	-2.1078	3.12016	4.59706	-2.1623
5	0.0000284066	30.1490	0.153157	157.973	-1.6425	3.40615	5.06243	-1.8763
6	0.0000240285	39.0899	0.198577	236.348	-1.2396	3.66586	5.46530	-1.6166
7	0.0000222206	43.7975	0.222491	299.619	-1.0024	3.77958	5.70251	-1.5029
8	0.0000545564	4.6017	0.023377	11.838	-4.2336	1.52644	2.47130	-3.7569
9	0.0000493046	9.8437	0.050006	30.615	-3.2834	2.28683	3.42149	-2.9956
10	0.0000396772	16.2382	0.082490	62.863	-2.5639	2.78736	4.14095	-2.4951
11	0.0000332906	22.9552	0.116612	106.540	-2.0364	3.13354	4.66852	-2.1489
12	0.0000283783	30.1979	0.153405	161.239	-1.6220	3.40777	5.08299	-1.8747
13	0.0000241966	38.6884	0.196537	249.022	-1.2242	3.65554	5.48073	-1.6269
14	0.0000221184	44.0860	0.223957	299.619	-1.0024	3.78614	5.70251	-1.4963
15	0.0000544576	4.4536	0.022609	11.838	-4.2336	1.49305	2.47130	-3.7894
16	0.0000481372	9.9514	0.050553	33.064	-3.2065	2.29772	3.49845	-2.9847
17	0.0000395768	16.3272	0.082942	64.904	-2.5320	2.79283	4.17291	-2.4896
18	0.0000332399	23.0189	0.116936	109.398	-2.0099	3.13632	4.69499	-2.1461
19	0.0000283501	30.2468	0.153654	167.770	-1.5823	3.40939	5.12260	-1.8731
20	0.0000239974	39.1659	0.198963	252.676	-1.1728	3.66781	5.53211	-1.6146
21	0.0000221035	44.1283	0.224172	307.783	-0.9755	3.78710	5.72939	-1.4953
22	0.0000527265	3.6075	0.018326	12.654	-4.1669	1.28301	2.53799	-3.9994
23	0.0000492365	9.2490	0.046985	39.187	-3.0366	2.22452	3.66835	-3.0579
24	0.0000401161	15.8545	0.080541	82.456	-2.2976	2.76345	4.41227	-2.5190
25	0.0000342718	21.7597	0.110539	130.216	-1.1357	3.08006	4.86919	-2.2024
26	0.0000291646	28.8732	0.146676	199.610	-1.4095	3.36291	5.29636	-1.9195

OBS	PR	SP	TRT	REP	Q	V	W	RD	CD	WH	CP
27	1.895	0.3615	2	1	28.0639	20.4250	123.762	46083.9	0.967334	123.765	28.0646
28	2.442	0.4480	2	1	31.9207	23.2319	140.770	52417.1	0.969239	140.773	31.9214
29	0.029	0.0195	2	2	3.2974	2.3999	14.542	5414.7	0.918802	14.542	3.2976
30	0.133	0.0595	2	2	7.2293	5.2615	31.881	11871.2	0.940614	31.883	7.2296
31	0.350	0.1320	2	2	11.8679	8.6375	52.338	19488.4	0.951876	52.340	11.8684
32	0.655	0.1645	2	2	16.3433	11.8947	72.074	26837.4	0.958200	72.077	16.3439
33	1.145	0.2495	2	2	21.7222	15.8094	95.795	35670.0	0.963241	95.798	21.7228
34	1.898	0.3720	2	2	28.0865	20.4414	123.861	46120.5	0.967346	123.864	28.0872
35	2.433	0.4545	2	2	31.8609	23.1884	140.507	52318.9	0.969212	140.510	31.8616
36	0.026	0.0195	2	3	3.1162	2.2680	13.742	5117.1	0.917030	13.743	3.1164
37	0.129	0.0515	2	3	7.1168	5.1796	31.385	11686.5	0.940227	31.387	7.1171
38	0.343	0.1030	2	3	11.7460	8.5487	51.800	19288.1	0.951660	51.802	11.7465
39	0.657	0.1650	2	3	16.3687	11.9132	72.186	26879.2	0.958229	72.189	16.3693
40	1.136	0.2505	2	3	21.6351	15.7461	95.411	35527.1	0.963173	95.414	21.6357
41	1.870	0.3720	2	3	27.8752	20.2877	122.930	45774.0	0.967231	122.934	27.8759
42	2.450	0.4650	2	3	31.9737	23.2705	141.004	52504.1	0.969263	141.007	31.9744
43	0.021	0.0205	3	1	2.7897	2.0304	12.303	4581.0	0.913479	12.303	2.7899
44	0.122	0.0525	3	1	6.9158	5.0333	30.499	11356.4	0.939515	30.500	6.9161
45	0.324	0.1055	3	1	11.4086	8.3032	50.312	18734.2	0.951046	50.314	11.4091
46	0.643	0.1660	3	1	16.1899	11.7831	71.398	26585.5	0.958024	71.400	16.1905
47	1.126	0.2560	3	1	21.5380	15.6754	94.982	35367.6	0.963098	94.985	21.5386
48	1.856	0.3775	3	1	27.7690	20.2103	122.461	45599.6	0.967173	122.464	27.7697
49	2.405	0.4705	3	1	31.6743	23.0526	139.684	52012.4	0.969127	139.687	31.6750
50	0.025	0.0205	3	2	3.0535	2.2224	13.466	5014.2	0.916386	13.467	3.0537
51	0.117	0.0530	3	2	6.7687	4.9263	29.850	11114.9	0.938577	29.851	6.7690
52	0.341	0.1055	3	2	11.7109	8.5232	51.645	19230.5	0.951597	51.647	11.7114

OBS	DEL	QF2	QM	SPM	LSP	LQF2	LSPM	LQM
27	0.0000248300	37.2201	0.189078	295.129	-1.0175	3.61685	5.68741	-1.6656
28	0.0000227511	42.3351	0.215062	365.747	-0.8030	3.74562	5.90194	-1.5368
29	0.0000543878	4.3732	0.022216	15.920	-3.9373	1.47551	2.76756	-3.8069
30	0.0000487040	9.5879	0.048706	41.228	-2.9858	2.26050	3.71912	-3.0219
31	0.0000402489	15.7400	0.079959	83.273	-2.2828	2.75620	4.42217	-2.5262
32	0.0000343432	21.6755	0.110111	134.298	-1.8048	3.07618	4.90006	-2.2063
33	0.0000292036	28.9092	0.146851	203.692	-1.3883	3.36070	5.31661	-1.9217
34	0.0000248167	37.2500	0.189230	303.701	-0.9889	3.61765	5.71604	-1.6648
35	0.0000227827	42.2559	0.214660	371.054	-0.7886	3.74374	5.91635	-1.5387
36	0.0000540755	4.1329	0.020995	15.920	-3.9373	1.41898	2.76756	-3.8635
37	0.0000489380	9.4387	0.047949	42.045	-2.9662	2.24482	3.73873	-3.0376
38	0.0000404379	15.5782	0.079137	84.089	-2.2730	2.74587	4.43188	-2.5366
39	0.0000343146	21.7092	0.110283	134.706	-1.8018	3.07774	4.90339	-2.2047
40	0.0000292744	28.6938	0.145764	204.508	-1.3843	3.35669	5.32061	-1.9258
41	0.0000249412	35.9698	0.187807	303.701	-0.9899	3.61019	5.71604	-1.6723
42	0.0000227269	42.4055	0.215420	379.626	-0.7657	3.74778	5.93919	-1.5352
43	0.0000530469	3.6999	0.018796	16.736	-3.8873	1.30831	2.81757	-3.9741
44	0.0000493578	9.1721	0.046594	42.861	-2.9469	2.21617	3.75796	-3.0663
45	0.0000409697	15.1308	0.076865	86.130	-2.2490	2.71673	4.45586	-2.5657
46	0.0000345167	21.4721	0.109078	135.522	-1.7958	3.06675	4.90914	-2.2157
47	0.0000293538	28.5650	0.145110	208.998	-1.3626	3.35219	5.34233	-1.9303
48	0.0000250342	36.4289	0.187091	308.191	-0.5742	3.60628	5.73072	-1.6762
49	0.0000228755	42.0083	0.213402	384.116	-0.7540	3.73797	5.95095	-1.5446
50	0.0000539294	4.0498	0.020573	16.736	-3.8873	1.39866	2.81757	-3.8838
51	0.0000496658	8.9770	0.045603	43.269	-2.9375	2.19467	3.76744	-3.0878
52	0.0000404926	15.5317	0.078901	86.130	-2.2490	2.74288	4.45586	-2.5396

OBS	PR	SP	TRT	REP	Q	V	W	RD	CC	WH	CF
53	0.660	0.1715	3	2	16.4068	11.9409	72.354	26941.7	0.950273	72.357	16.4074
54	1.133	0.2575	3	2	21.6060	15.7249	95.283	35479.3	0.963151	95.285	21.6066
55	1.865	0.3790	3	2	27.8373	20.2601	122.763	45711.8	0.967211	122.766	27.8380
56	2.406	0.4725	3	2	31.6810	23.0575	139.713	52023.4	0.969171	139.716	31.6817
57	0.023	0.0215	3	3	2.9244	2.1284	12.897	4802.2	0.915005	12.897	2.9246
58	0.129	0.0550	3	3	7.1168	5.1796	31.385	11686.5	0.940227	31.387	7.1171
59	0.340	0.1065	3	3	11.6933	8.5104	51.568	19201.7	0.951565	51.570	11.6938
60	0.665	0.1725	3	3	16.4701	11.5870	72.631	27045.6	0.958344	72.636	16.4706
61	1.123	0.2625	3	3	21.5088	15.6541	94.854	35319.6	0.963075	94.856	21.5094
62	1.865	0.3915	3	3	27.8373	20.2601	122.763	45711.8	0.967211	122.766	27.8380
63	2.396	0.4835	3	3	31.6141	23.0088	139.418	51913.5	0.969100	139.421	31.6148
64	0.020	0.0210	4	1	2.7200	1.9797	11.995	4466.6	0.912651	11.996	2.7202
65	0.105	0.0540	4	1	6.4026	4.6558	28.235	10513.7	0.937569	28.237	6.4029
66	0.308	0.1075	4	1	11.1169	8.0909	49.026	18255.2	0.950495	49.028	11.1174
67	0.591	0.1760	4	1	15.5083	11.2870	68.392	25466.3	0.957212	68.394	15.5085
68	1.045	0.2670	4	1	20.7349	15.0909	91.441	34048.5	0.962453	91.444	20.7356
69	1.711	0.3940	4	1	26.6447	19.3921	117.503	43753.3	0.966538	117.506	26.6454
70	2.245	0.4855	4	1	30.5964	22.2609	134.886	50226.1	0.966619	134.889	30.5872
71	0.019	0.0190	4	2	2.6486	1.9277	11.680	4349.3	0.911775	11.681	2.6488
72	0.103	0.0540	4	2	6.3396	4.6140	27.958	10410.2	0.937316	27.959	6.3399
73	0.304	0.1080	4	2	11.0429	8.0370	48.699	18133.5	0.950352	48.701	11.0433
74	0.587	0.1765	4	2	15.4547	11.2480	68.155	25378.2	0.957146	68.158	15.4552
75	1.012	0.2690	4	2	20.3990	14.8464	89.959	33497.2	0.962173	89.962	20.3996
76	1.715	0.3945	4	2	26.6763	19.4151	117.643	43905.3	0.966556	117.646	26.6770
77	2.246	0.4865	4	2	30.5934	22.2659	134.917	50237.5	0.968622	134.920	30.5941
78	0.019	0.0210	4	3	2.5753	1.8743	11.357	4229.0	0.910844	11.358	2.5755

OBS	DEL	QF2	QM	SPM	LSP	LQF2	LSPM	LQM
53	0.0000342718	21.7597	0.110539	140.013	-1.7632	3.08006	4.94173	-2.2024
54	0.0000292982	28.6552	0.145568	210.223	-1.3567	3.35533	5.34817	-1.9271
55	0.0000249636	36.9196	0.187551	309.416	-0.9702	3.60874	5.73469	-1.6737
56	0.0000228722	42.0172	0.213447	385.749	-0.7497	3.73808	5.95519	-1.5444
57	0.0000535558	3.8786	0.019703	17.553	-3.8397	1.35547	2.86520	-3.9270
58	0.0000489340	9.4387	0.047949	44.902	-2.9004	2.24482	3.80448	-3.0376
59	0.0000405200	15.5084	0.078783	86.947	-2.2396	2.74138	4.46529	-2.5411
60	0.0000342011	21.8436	0.110966	140.829	-1.7574	3.08391	4.94755	-2.1985
61	0.0000293778	28.5262	0.144913	214.305	-1.3375	3.35082	5.36740	-1.9316
62	0.0000249636	36.9196	0.187551	319.621	-0.9378	3.60874	5.76713	-1.6737
63	0.0000229057	41.9285	0.212997	394.726	-0.7267	3.73596	5.97820	-1.5465
64	0.0000527265	3.6075	0.018326	17.144	-3.8632	1.28301	2.84167	-3.9994
65	0.0000504328	8.4915	0.043137	44.086	-2.9198	2.13906	3.78613	-3.1434
66	0.0000414493	14.7440	0.074899	87.763	-2.2303	2.69083	4.47464	-2.5916
67	0.0000353099	20.5681	0.104486	143.686	-1.7373	3.02374	4.96763	-2.2587
68	0.0000300273	27.4999	0.139700	217.979	-1.3205	3.31418	5.38450	-1.9683
69	0.0000256914	35.3178	0.179516	321.662	-0.9314	3.56495	5.77350	-1.7175
70	0.0000234318	40.5656	0.206073	396.362	-0.7226	3.70292	5.98233	-1.5795
71	0.0000523544	3.5128	0.017845	15.512	-3.9633	1.25640	2.74155	-4.0260
72	0.0000505644	8.4079	0.042712	44.086	-2.9138	2.12918	3.78613	-3.1533
73	0.0000415615	14.6457	0.074400	88.171	-2.2256	2.68415	4.47928	-2.5983
74	0.0000353738	20.4969	0.104124	144.095	-1.7344	3.02028	4.97047	-2.2622
75	0.0000303184	27.0543	0.137436	219.612	-1.3130	3.29785	5.39186	-1.9846
76	0.0000256716	35.3797	0.179729	322.070	-0.9301	3.56614	5.77477	-1.7163
77	0.0000234282	40.5747	0.206120	397.175	-0.7205	3.70315	5.58439	-1.5793
78	0.0000519207	3.4156	0.017351	17.144	-3.8632	1.22835	2.84167	-4.0541

OBS	PR	SP	TRT	REP	Q	V	W	RD	CD	WH	QP
79	0.107	0.0540	4	3	6.4650	4.7052	28.510	10616.1	0.937816	28.512	6.4653
80	0.305	0.1070	4	3	11.0616	8.0505	48.781	18164.0	0.950388	48.783	11.0619
81	0.597	0.1755	4	3	15.5884	11.3453	68.745	25597.8	0.957310	68.747	15.5890
82	1.045	0.2680	4	3	20.7349	15.0909	91.441	34048.9	0.962453	91.444	20.7356
83	1.735	0.3935	4	3	26.8340	19.5298	118.338	44064.1	0.966647	118.341	26.8346
84	2.245	0.4860	4	3	30.5864	22.2609	134.886	50226.1	0.968619	134.889	30.5872

OBS	DEL	QF2	CM	SPM	LSP	LQF2	LSPM	LQM
79	0.0000503022	8.5742	0.043557	44.086	-2.9188	2.14876	3.78613	-3.1337
80	0.0000415311	14.6703	0.074525	87.355	-2.2349	2.68583	4.46598	-2.5966
81	0.0000352147	20.6743	0.105026	143.270	-1.7401	3.02889	4.96479	-2.2536
82	0.0000300273	27.4999	0.139700	218.795	-1.3168	3.31418	5.38814	-1.9683
83	0.0000255731	35.5888	0.180791	321.253	-0.9327	3.57203	5.77223	-1.7104
84	0.0000234318	40.5656	0.206073	396.770	-0.7215	3.70292	5.98336	-1.5795

REGRESSION ANALYSIS FOR CORN

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   14:53 FRIDAY, NOVEMBER 14, 1980   1

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	840156.84404657	280052.28134886	3413.46	0.0001	0.997565	6.3487
ERROR	25	2051.08943638	82.04357746		STD DEV		SPM MEAN
UNCORRECTED TOTAL	28	842207.93348295			9.05779058		142.67173141

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
VM	1	798288.11301908	9730.05	0.0001	1	33116.44450441	403.64	0.0001
VM*VM	1	22022.61097498	268.43	0.0001	1	22022.61097498	268.43	0.0001
VM*MC	1	19846.12005251	241.90	0.0001	1	19846.12005251	241.90	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
VM	1611.71889989	20.09	0.0001	80.22130953
VM*VM	4949.30151092	16.38	0.0001	302.08683763
VM*MC	-55.11635904	-15.55	0.0001	3.54376576

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
1	23.43068000	21.48422821	1.94645179	18.01867518	24.94978125
2	30.45172000	29.32397912	1.12774088	26.18722578	32.46073247
3	34.28880000	37.16373003	-2.87493003	34.02943178	40.29802828
4	39.18720000	45.22747382	-6.04027382	41.75519997	48.69974768
5	41.39148000	38.35707773	3.03440227	33.77457022	42.93958524
6	53.06600000	50.11670410	2.94929590	46.10235566	54.13105254
7	61.23000000	61.87633046	-0.64633046	57.86629899	65.88636193
8	69.39400000	73.97194615	-4.57794615	69.37800581	78.56588649
9	69.39400000	65.19570409	4.19829591	59.68330002	70.70810815
10	88.41612000	81.85517477	6.56094523	77.31822470	86.39212484
11	103.43788000	98.51464545	4.92323455	93.98536368	103.04392722
12	106.13200000	115.65010101	-9.51810101	110.11863171	121.18157032
13	88.41612000	91.26465674	-2.84953674	85.25571989	97.27359358
14	121.07212000	111.84400287	9.22811713	107.24520921	116.44279655
15	129.23612000	132.42334901	-3.18722901	127.83610419	137.01059384
16	136.09388000	153.59067647	-17.49679647	147.55506404	159.62628889
17	119.76588000	121.42076633	-1.65488633	114.95658228	127.88495037
18	157.81012000	145.91998792	11.89013208	141.38279692	150.45717891
19	174.13812000	170.41920951	3.71891049	165.89861768	174.93980135
20	190.46612000	195.61840886	-5.15228886	189.11909922	202.11771851
21	157.81012000	164.86346777	-7.05334777	157.53440204	172.19253350
22	206.79412000	194.26253368	12.53158632	189.44716049	199.07790687
23	228.59200000	223.66155959	4.93044041	218.86875986	228.45443932
24	247.61412000	253.90063881	-6.28651881	246.52697560	261.27430203
25	244.92000000	270.90741883	-25.98741883	259.31406386	282.50077380
26	323.86588000	310.10617338	13.75970662	301.15435948	319.05798729
27	356.52188000	349.30492793	7.21695207	340.37463834	358.23521751

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPP

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
28	391.87200000	389.62364689	2.24835311	377.98012608	401.26716770

SUM OF RESIDUALS	-3.06007953
SUM OF SQUARED RESIDUALS	2051.08963630
SUM OF SQUARED RESIDUALS - ERROR SS	-0.00000000
PRESS STATISTIC	3563.57197336
FIRST ORDER AUTOCORRELATION	-0.01787508
DURBIN-WATSON D	2.03143843

AIRFLOW CALCULATIONS FOR SORGHUM

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   14:42 FRIDAY, NOVEMBER 14, 1980   1

OBS	PR	SP	TRT	REP	Q	V	H	RD	CD	WH	QH
1	0.013	0.0250	1	1	2.1748	1.5028	9.591	3571.2	0.905083	9.591	2.1749
2	0.056	0.0680	1	1	4.6324	3.3715	20.429	7606.5	0.928876	20.430	4.6327
3	0.199	0.1420	1	1	8.8897	6.4696	39.201	14597.0	0.945534	39.203	8.8896
4	0.410	0.2260	1	1	12.8675	9.3650	56.746	21129.7	0.953542	56.749	12.8680
5	0.776	0.3510	1	1	17.8185	12.9683	78.579	29259.7	0.959788	78.582	17.8190
6	1.376	0.5260	1	1	23.8509	17.3587	105.182	39165.6	0.964782	105.185	23.8516
7	1.814	0.6475	1	1	27.4490	19.9767	121.046	45072.4	0.966995	121.049	27.4487
8	0.014	0.0250	1	2	2.2602	1.6450	9.968	3711.5	0.906419	9.966	2.2603
9	0.060	0.0715	1	2	4.8001	3.4936	21.169	7882.3	0.929873	21.170	4.8004
10	0.194	0.1450	1	2	8.7740	6.3857	38.693	14407.8	0.945233	38.695	8.7744
11	0.415	0.2330	1	2	12.9474	9.4231	57.098	21261.0	0.953667	57.100	12.9479
12	0.779	0.3550	1	2	17.8535	12.9938	78.734	29317.3	0.959823	78.737	17.8541
13	1.352	0.5235	1	2	23.6384	17.2041	104.245	38816.7	0.964637	104.248	23.6391
14	1.797	0.6470	1	2	27.3170	19.8814	120.468	44857.3	0.966922	120.471	27.3177
15	0.015	0.0230	1	3	2.3427	1.7050	10.331	3847.0	0.907650	10.332	2.3428
16	0.057	0.0710	1	3	4.6749	3.4024	20.616	7676.6	0.929133	20.617	4.6751
17	0.191	0.1450	1	3	8.7042	6.3349	38.386	14293.2	0.945049	38.387	8.7046
18	0.403	0.2340	1	3	12.7547	9.2829	56.248	20944.6	0.953363	56.251	12.7552
19	0.775	0.3615	1	3	17.8067	12.9598	78.528	29240.5	0.959776	78.530	17.8073
20	1.334	0.5290	1	3	23.4778	17.0872	103.537	38553.0	0.964526	103.540	23.4785
21	1.780	0.6485	1	3	27.1854	19.7856	119.887	44641.2	0.966848	119.891	27.1861
22	0.011	0.0250	2	1	1.9937	1.4511	8.792	3273.9	0.902017	8.793	1.9938
23	0.061	0.0735	2	1	4.8412	3.5234	21.350	7949.8	0.930110	21.351	4.8415
24	0.188	0.1490	2	1	8.6338	6.2837	38.075	14177.7	0.944860	38.077	8.6342
25	0.382	0.2425	2	1	12.4107	9.0325	54.731	20379.6	0.952803	54.733	12.4112
26	0.738	0.3655	2	1	17.3683	12.6407	76.594	28520.5	0.959323	76.597	17.3689

OBS	DEL	CF2	CM	SPM	LSP	LQF2	LSPM	LQM
1	0.0000483253	2.8843	0.014652	20.410	-3.6889	1.05929	3.01602	-4.2231
2	0.0000539064	6.1438	0.031210	55.515	-2.6882	1.81544	4.01666	-3.4670
3	0.0000453917	11.7894	0.059890	115.929	-1.9519	2.46720	4.75298	-2.8152
4	0.0000387619	17.0656	0.086693	184.506	-1.4872	2.83706	5.21768	-2.4454
5	0.0000327595	23.6319	0.120050	286.556	-1.0470	3.16260	5.65794	-2.1198
6	0.0000275735	31.6325	0.160693	429.426	-0.6425	3.45418	6.06245	-1.8283
7	0.0000251967	36.4031	0.184928	528.619	-0.4346	3.59466	6.27027	-1.6878
8	0.0000493022	2.9976	0.015228	20.410	-3.6889	1.09782	3.01602	-4.1846
9	0.0000535455	6.3662	0.032340	58.373	-2.6381	1.85101	4.06685	-3.4314
10	0.0000456024	11.6366	0.059114	118.378	-1.9310	2.45416	4.77388	-2.8283
11	0.0000386476	17.1716	0.087232	190.221	-1.4567	2.84326	5.24819	-2.4392
12	0.0000327241	23.6784	0.120286	289.822	-1.0356	3.16456	5.66927	-2.1179
13	0.0000277279	31.3507	0.159261	427.385	-0.6472	3.44524	6.05769	-1.8372
14	0.0000252761	36.2294	0.184045	528.211	-0.4354	3.58987	6.26950	-1.6926
15	0.0000501248	3.1071	0.015784	18.777	-3.7723	1.13369	2.93264	-4.1488
16	0.0000537425	6.2901	0.031496	57.964	-2.6451	1.82457	4.05583	-3.4579
17	0.0000457369	11.5440	0.058644	118.378	-1.9310	2.44617	4.77388	-2.8363
18	0.0000389242	16.9161	0.085934	191.038	-1.4524	2.82827	5.25247	-2.4542
19	0.0000327719	23.6164	0.119971	295.129	-1.0175	3.16194	5.68741	-2.1205
20	0.0000278458	31.1377	0.158180	431.876	-0.6368	3.43842	6.06814	-1.9440
21	0.0000253563	36.0549	0.183159	529.435	-0.4331	3.58504	6.27181	-1.6974
22	0.0000457450	2.6442	0.013433	20.410	-3.6889	0.97238	3.01602	-4.3101
23	0.0000534784	6.4207	0.032617	60.005	-2.6105	1.85953	4.09443	-3.4229
24	0.0000458731	11.4507	0.058170	121.644	-1.9038	2.43805	4.80110	-2.8444
25	0.0000394279	16.4598	0.083616	177.977	-1.4168	2.80092	5.28915	-2.4815
26	0.0000332272	23.0349	0.117017	298.394	-1.0065	3.13701	5.69842	-2.1454

OBS	PR	SP	TRT	REP	Q	V	W	RD	CD	WH	QP
27	1.320	0.5450	2	1	23.3522	16.9958	102.983	38346.7	0.974439	102.996	23.3528
28	1.740	0.6625	2	1	26.8732	19.5584	118.511	44128.6	0.966670	118.514	26.8739
29	0.011	0.0255	2	2	1.9937	1.4511	8.792	3273.9	0.902017	8.793	1.9938
30	0.053	0.0745	2	2	4.5027	3.2771	19.857	7393.9	0.928072	19.858	4.5030
31	0.168	0.1475	2	2	8.1500	5.5316	35.941	13383.1	0.943507	35.943	8.1504
32	0.362	0.2420	2	2	12.0742	8.7876	53.247	19827.1	0.952235	53.249	12.0747
33	0.714	0.3740	2	2	17.0780	12.4294	75.314	28043.9	0.959014	75.317	17.0786
34	1.272	0.5560	2	2	22.9163	16.6785	101.061	37631.0	0.964130	101.064	22.9170
35	1.692	0.6745	2	2	26.4939	19.2823	116.838	43505.8	0.966450	116.841	26.4946
36	0.011	0.0270	2	3	1.9937	1.4511	8.792	3273.9	0.902017	8.793	1.9938
37	0.055	0.0755	2	3	4.5896	3.3403	20.240	7536.5	0.928613	20.241	4.5898
38	0.162	0.1485	2	3	7.9994	5.8220	35.277	13135.8	0.943064	35.279	7.9998
39	0.378	0.2450	2	3	12.3441	8.5841	54.437	20270.3	0.952652	54.440	12.3446
40	0.730	0.3755	2	3	17.2721	12.5706	76.170	28362.5	0.959221	76.172	17.2726
41	1.267	0.5585	2	3	22.8705	16.6452	100.859	37555.7	0.964097	100.862	22.8711
42	1.665	0.6770	2	3	26.2782	19.1253	115.887	43151.6	0.966322	115.890	26.2789
43	0.012	0.0260	3	1	2.0861	1.5183	9.200	3425.6	0.903623	9.200	2.0862
44	0.052	0.0720	3	1	4.4587	3.2450	19.663	7321.6	0.927792	19.664	4.4589
45	0.156	0.1500	3	1	7.8460	5.7103	34.601	12883.5	0.942601	34.602	7.8464
46	0.341	0.2450	3	1	11.7109	8.5232	51.645	19230.5	0.951597	51.647	11.7114
47	0.690	0.3770	3	1	16.7829	12.2146	74.013	27559.3	0.958793	74.015	16.7835
48	1.138	0.5640	3	1	21.6545	15.7602	95.496	35558.5	0.963188	95.499	21.6551
49	1.547	0.6795	3	1	25.3145	18.4240	111.637	41569.1	0.965736	111.640	25.3152
50	0.011	0.0240	3	2	1.9937	1.4511	8.792	3273.9	0.902017	8.793	1.9938
51	0.050	0.0730	3	2	4.3694	3.1800	19.269	7175.0	0.927213	19.270	4.3696
52	0.145	0.1505	3	2	7.5571	5.5000	33.327	12409.5	0.941697	33.328	7.5574

OBS	DEI	QF2	CM	SPM	LSP	LQF2	LSPM	LQM
27	0.0000279388	30.9711	0.157333	444.938	-0.6070	3.43305	6.09793	-1.8494
28	0.0000255487	35.6409	0.181056	540.865	-0.4117	3.57349	6.29317	-1.7090
29	0.0000457450	2.6442	0.013433	20.818	-3.6691	0.97238	3.03583	-4.3101
30	0.0000539913	5.9718	0.030337	60.822	-2.5970	1.78704	4.10795	-3.4954
31	0.0000468256	10.8090	0.054910	120.419	-1.9139	2.38038	4.79098	-2.9021
32	0.0000399330	16.0136	0.081349	197.565	-1.4188	2.77344	5.28609	-2.5090
33	0.0000335357	22.6499	0.115062	305.334	-0.9835	3.12016	5.72140	-2.1623
34	0.0000282661	30.3930	0.154396	453.918	-0.5870	3.41421	6.11792	-1.8682
35	0.0000257864	35.1378	0.178500	559.662	-0.3938	3.55928	6.31112	-1.7232
36	0.0000457450	2.6442	0.013433	22.043	-3.6119	0.97238	3.09239	-4.3101
37	0.0000538692	6.0869	0.030922	61.638	-2.5836	1.80615	4.12128	-3.4763
38	0.0000471274	10.6093	0.053895	121.235	-1.9072	2.36173	4.79773	-2.9207
39	0.0000395269	16.3715	0.083167	200.018	-1.4065	2.79554	5.29841	-2.4869
40	0.0000333289	22.9072	0.116369	306.558	-0.9795	3.13145	5.72541	-2.1510
41	0.0000283010	30.3322	0.154087	455.959	-0.5825	3.41221	6.12240	-1.8702
42	0.0000259236	34.8518	0.177047	552.703	-0.3901	3.55110	6.31482	-1.7313
43	0.0000471563	2.7667	0.014055	21.226	-3.6497	1.01766	3.05525	-4.2648
44	0.0000540504	5.9134	0.030040	58.781	-2.6311	1.77722	4.07382	-3.5052
45	0.0000474372	10.4058	0.052862	122.460	-1.8971	2.34237	4.80778	-2.9401
46	0.0000404926	15.5317	0.078901	200.018	-1.4065	2.74288	5.29841	-2.5396
47	0.0000338554	22.2585	0.113073	307.783	-0.5755	3.10272	5.72939	-2.1797
48	0.0000292586	28.7195	0.145895	460.450	-0.5727	3.35759	6.13229	-1.9249
49	0.0000265545	33.5737	0.170554	554.744	-0.3864	3.51374	6.31851	-1.7687
50	0.0000457450	2.6442	0.013433	19.594	-3.7297	0.97238	2.97520	-4.3101
51	0.0000541636	5.7049	0.029438	59.597	-2.6173	1.75698	4.08761	-3.5255
52	0.0000460268	10.0226	0.050915	122.868	-1.8938	2.30484	4.81111	-2.9776

OBS	PR	SP	TRT	REP	Q	V	W	RD	CC	WP
53	0.3250	0.2470	3	2	11.4266	8.3163	50.391	18763.7	0.951079	50.394
54	0.7100	0.3780	3	2	17.0292	12.3939	75.099	27963.7	0.958962	75.101
55	1.2560	0.5675	3	2	22.7692	16.5715	100.412	37389.4	0.964024	100.415
56	1.6520	0.6865	3	2	26.1738	19.0493	115.426	42980.0	0.966260	115.429
57	0.0140	0.0240	3	3	2.2602	1.6450	9.968	3711.5	0.906419	9.968
58	0.0470	0.0740	3	3	4.2321	3.0801	18.663	6949.5	0.926293	18.664
59	0.1530	0.1525	3	3	7.7682	5.6537	34.258	12756.2	0.942362	34.259
60	0.3310	0.2525	3	3	11.5340	8.3945	50.865	18940.1	0.951277	50.867
61	0.6900	0.3875	3	3	16.7829	12.2146	74.013	27559.3	0.958693	74.015
62	1.2200	0.5775	3	3	22.4349	16.3281	98.938	36840.3	0.963779	98.941
63	1.6200	0.6870	3	3	25.9148	18.8609	114.284	42554.8	0.966105	114.287
64	0.0130	0.0235	4	1	2.1748	1.5828	9.591	3571.2	0.905083	9.591
65	0.0470	0.0700	4	1	4.2321	3.0801	18.663	6949.5	0.926293	18.664
66	0.1740	0.1440	4	1	8.2980	6.0393	36.594	13626.2	0.943932	36.596
67	0.3690	0.2425	4	1	12.1930	8.8741	53.771	20022.2	0.952438	53.773
68	0.7080	0.3745	4	1	17.0047	12.3761	74.991	27923.5	0.958935	74.993
69	1.2350	0.5475	4	1	22.5748	16.4300	99.555	37070.1	0.963882	99.558
70	1.6050	0.6775	4	1	25.7926	18.7719	113.745	42354.1	0.966030	113.748
71	0.0120	0.0240	4	2	2.0861	1.5183	9.200	3425.6	0.903623	9.200
72	0.0440	0.0710	4	2	4.0904	2.9770	18.039	6716.8	0.925303	18.040
73	0.1490	0.1460	4	2	7.6633	5.5775	33.795	12584.0	0.942035	33.797
74	0.3600	0.2450	4	2	12.0401	8.7628	53.097	19771.0	0.952176	53.099
75	0.6600	0.3750	4	2	16.4068	11.9409	72.354	26941.7	0.958273	72.357
76	1.1200	0.5530	4	2	21.4795	15.6328	94.725	35271.5	0.963052	94.727
77	1.5350	0.6795	4	2	25.2145	18.3512	111.196	41404.9	0.965673	111.199
78	0.0120	0.0240	4	3	2.0861	1.5183	9.200	3425.6	0.903623	9.200

OBS	QH	DEL	QF2	QP	SPM	LSP	LQF2	LSPM	LQM
53	11.4271	0.000040941	15.1547	0.076586	201.651	-1.3984	2.71831	5.30654	-2.5641
54	17.0298	0.000031588	22.5851	0.114732	308.599	-0.9729	3.11729	5.73204	-2.1652
55	22.7699	0.000028378	30.1975	0.153405	463.307	-0.5665	3.40777	6.13839	-1.8747
56	26.1744	0.000025991	34.7132	0.176343	560.459	-0.3761	3.54712	6.32876	-1.7353
57	2.2603	0.000049302	2.9976	0.015228	19.594	-3.7297	1.09782	2.97520	-4.1846
58	4.2323	0.000054319	5.6128	0.028513	60.414	-2.6037	1.72505	4.10121	-3.5574
59	7.7686	0.000047595	10.3027	0.052338	124.501	-1.8806	2.33240	4.82431	-2.9500
60	11.5345	0.000040770	15.2971	0.077709	206.141	-1.3763	2.72767	5.32856	-2.5548
61	16.7835	0.000033855	22.2585	0.113073	316.355	-0.9480	3.10272	5.75687	-2.1797
62	22.4355	0.000028637	29.7544	0.151153	471.471	-0.5490	3.39298	6.15586	-1.8895
63	25.9155	0.000026158	34.3698	0.174599	560.867	-0.3754	3.53718	6.32948	-1.7453
64	2.1749	0.000048125	2.8843	0.014652	19.185	-3.7598	1.05929	2.95415	-4.2231
65	4.2323	0.000054319	5.6128	0.028513	57.148	-2.6593	1.72505	4.04564	-3.5574
66	8.2984	0.000046531	11.0053	0.055907	117.562	-1.9379	2.39839	4.76696	-2.8841
67	12.1935	0.000039753	16.1711	0.082149	197.977	-1.4168	2.78323	5.28815	-2.4992
68	17.0053	0.000033615	22.5527	0.114568	305.742	-0.9822	3.11585	5.72274	-2.1666
69	22.5754	0.000028528	29.9400	0.152095	446.979	-0.6024	3.39920	6.10251	-1.8832
70	25.7933	0.000026238	34.2077	0.173775	553.111	-0.3893	3.53245	6.31556	-1.7500
71	2.0862	0.000047156	2.7667	0.014055	19.594	-3.7297	1.01766	2.97520	-4.2648
72	4.0906	0.000054451	5.4249	0.027559	57.964	-2.6451	1.69100	4.05983	-3.5914
73	7.6637	0.000047809	10.1636	0.051631	119.194	-1.9241	2.31881	4.78076	-2.9636
74	12.0406	0.000039985	15.9683	0.081119	200.018	-1.4065	2.77060	5.29841	-2.5118
75	16.4074	0.000034272	21.7597	0.110539	306.150	-0.9808	3.08006	5.72408	-2.2024
76	21.4801	0.000029407	28.4874	0.144716	451.469	-0.5924	3.34946	6.11251	-1.9330
77	25.2152	0.000026622	33.4410	0.169880	554.744	-0.3864	3.50978	6.31851	-1.7727
78	2.0862	0.000047156	2.7667	0.014055	19.594	-3.7297	1.01766	2.97520	-4.2648

OBS	PR	SP	TRT	REP	Q	V	W	RD	CC	WH
79	0.0470	0.0700	4	3	4.2321	3.0801	18.663	6949.5	0.926293	18.664
80	0.1560	0.1450	4	3	7.8460	5.7135	34.601	12883.9	0.942601	34.602
81	0.3030	0.2470	4	3	12.0913	8.8000	53.322	19855.1	0.952264	53.325
82	0.6850	0.3755	4	3	16.7208	12.1695	73.739	27457.3	0.958625	73.741
83	1.2000	0.5545	4	3	22.2470	16.1914	98.109	36531.8	0.963640	98.112
84	1.6250	0.6855	4	3	25.9555	18.8904	114.464	42621.5	0.966129	114.467
85	0.0080	0.0240	5	1	1.6873	1.2280	7.441	2770.7	0.895931	7.448
86	0.0470	0.0720	5	1	4.2321	3.0801	18.663	6949.5	0.926293	18.664
87	0.1370	0.1475	5	1	7.3401	5.3421	32.370	12053.2	0.940987	32.371
88	0.2700	0.2495	5	1	10.3926	7.5638	45.832	17065.8	0.949039	45.833
89	0.5300	0.3800	5	1	14.6658	10.6767	64.694	24089.3	0.956145	64.696
90	0.9500	0.5650	5	1	19.7528	14.3761	87.110	32436.1	0.961616	87.112
91	1.3000	0.7010	5	1	23.1715	16.8643	102.187	38050.1	0.964312	102.189
92	0.0085	0.0240	5	2	1.7414	1.2674	7.680	2859.6	0.897103	7.687
93	0.0450	0.0735	5	2	4.1381	3.0117	18.249	6795.2	0.925641	18.250
94	0.1340	0.1460	5	2	7.2571	5.2817	32.004	11916.9	0.940708	32.005
95	0.2690	0.2490	5	2	10.3729	7.5494	45.745	17033.4	0.948997	45.747
96	0.5300	0.3860	5	2	14.6658	10.6767	64.694	24089.3	0.956145	64.656
97	0.9400	0.5650	5	2	19.6466	14.2989	86.642	32261.8	0.961522	86.644
98	1.3200	0.7015	5	2	23.3522	16.9958	102.983	38346.7	0.964439	102.986
99	0.0080	0.0240	5	3	1.6873	1.2280	7.441	2770.7	0.895931	7.448
100	0.0430	0.0740	5	3	4.0421	2.9419	17.826	6637.6	0.924955	17.827
101	0.1320	0.1505	5	3	7.2013	5.2411	31.758	11825.3	0.940518	31.759
102	0.2680	0.2520	5	3	10.3532	7.5351	45.657	17001.0	0.948956	45.659
103	0.5310	0.3870	5	3	14.6839	10.6870	64.756	24112.5	0.956163	64.758
104	0.9500	0.5655	5	3	19.7528	14.3761	87.110	32436.1	0.961616	87.112

OBS	QH	DCL	QF2	QM	SPM	LSP	LCF2	LSPM	LQM
79	4.2323	0.000054319	5.6128	0.028513	57.148	-2.6593	1.72505	4.04564	-3.5574
80	7.8464	0.000047437	10.4058	0.052862	118.378	-1.9310	2.34237	4.77388	-2.9401
81	12.0917	0.000039907	16.0362	0.081464	201.651	-1.3984	2.77485	5.30654	-2.5076
82	16.7214	0.000033923	22.1761	0.112655	306.558	-0.9795	3.09902	5.72541	-2.1834
83	22.2476	0.000028784	29.5053	0.149887	452.694	-0.5897	3.38457	6.11522	-1.8979
84	25.9561	0.000026132	34.4237	0.174872	559.642	-0.3776	3.53874	6.32730	-1.7437
85	1.6889	0.000943165	2.2378	0.011368	19.594	-3.7297	0.80548	2.97520	-4.4770
86	4.2323	0.000054119	5.6128	0.028513	58.781	-2.6311	1.72505	4.07382	-3.5574
87	7.3404	0.000048474	9.7349	0.049453	120.419	-1.9139	2.27571	4.79098	-3.0067
88	10.3931	0.000042653	13.7833	0.070019	203.692	-1.3083	2.62346	5.31661	-2.6590
89	14.6703	0.000036337	19.4560	0.098836	310.232	-0.9676	2.96815	5.73732	-2.3143
90	19.7534	0.000030895	26.1973	0.133082	461.266	-0.5709	3.26566	6.13397	-2.0168
91	23.1722	0.000028074	30.7315	0.156116	572.296	-0.3552	3.42529	6.34966	-1.8572
92	1.7431	0.000986744	2.3096	0.011733	19.594	-3.7297	0.83706	2.97520	-4.4454
93	4.1383	0.000054410	5.4882	0.027880	60.005	-2.6105	1.70261	4.09443	-3.5798
94	7.2575	0.000048646	9.6248	0.048854	120.827	-1.9105	2.26435	4.79436	-3.0181
95	10.3734	0.000042687	13.7572	0.069886	203.284	-1.3903	2.62156	5.31460	-2.6609
96	14.6703	0.000036337	19.4560	0.098836	315.130	-0.9519	2.96815	5.75299	-2.3143
97	19.6472	0.000030991	26.0565	0.132367	461.266	-0.5709	3.26027	6.13397	-2.0222
98	23.3528	0.000027939	30.9711	0.157333	572.705	-0.3545	3.43305	6.35037	-1.8494
99	1.6889	0.000943165	2.2378	0.011368	19.594	-3.7297	0.80548	2.97520	-4.4770
100	4.0423	0.000054489	5.3609	0.027233	60.414	-2.6037	1.67913	4.10121	-3.6033
101	7.2017	0.000048762	9.5508	0.048518	122.868	-1.8938	2.25663	4.81111	-3.0258
102	10.3536	0.000042721	13.7310	0.069753	205.733	-1.3783	2.61965	5.32658	-2.6628
103	14.6844	0.000036320	19.4747	0.098931	315.947	-0.9493	2.96912	5.75557	-2.3133
104	19.7534	0.000030895	26.1973	0.133082	461.674	-0.5700	3.26566	6.13486	-2.0168

STATISTICAL ANALYSIS SYSTEM 14:42 FRIDAY, NOVEMBER 14, 1980 5

OBS	PR	SP	TRT	REP	Q	V	W	RO	CD	WF	QH
105	1.3	0.704	5	3	23.1715	16.8641	102.187*	38050.1	0.964312	102.189	23.1722

OBS	OIL	CF2	CM	SPM	LSP	LQF2	LSPM	LCM
105	0.0000280735	30.7315	0.156114	573.925	-0.3524	3.42529	6.35251	-1.8572

REGRESSION ANALYSIS FOR SORGHUM

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   14:52 FRIDAY, NOVEMBER 14, 1980   1

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPP

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	2085689.42009611	695229.80669870	8788.49	0.0001	0.999053	3.8813
ERROR	25	1977.67118862	79.10684754		STD DEV		SPP MEAN
UNCORRECTED TOTAL	28	2087667.09128473			8.89420303		229.17514286

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
VP	1	2043712.46226567	25834.84	0.0001	1	77905.87917256	984.87	0.0001
VP*VM	1	15374.99017792	194.36	0.0001	1	15374.99017792	194.36	0.0001
VP*MC	1	26601.96764852	336.28	0.0001	1	26601.96764852	336.28	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
VP	3253.10018280	31.38	0.0001	103.65928565
VP*VM	7911.27203522	13.94	0.0001	567.47395503
VP*MC	-72.52146569	-18.34	0.0001	3.95472902

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
1	21.06312000	23.45245327	-2.38933327	21.33666661	25.56823993
2	25.06348000	28.75754353	-3.69406353	26.77997307	30.73511400
3	26.94120000	32.18374766	-5.24254766	30.20316041	34.16433491
4	28.81892000	36.93622435	-8.11730435	34.83157238	39.04087631
5	74.86388000	70.70633342	4.15754658	66.11018355	75.30248329
6	83.02788000	84.85324078	-1.82536078	80.71786259	88.98861896
7	100.66212000	93.98978515	6.67233485	89.84415296	98.13541726
8	104.74412000	106.66305628	-1.91893628	102.10340507	111.22270750
9	119.76588000	115.85924976	3.90663024	110.11727386	121.60123566
10	137.40012000	137.07961079	0.32050921	132.18895630	141.97022529
11	152.42188000	150.78442729	1.63745271	145.87431887	155.69453572
12	170.05612000	169.79433405	0.26178595	164.11019896	175.47046915
13	190.46612000	181.48766047	8.97845953	175.04765468	187.92766625
14	211.03940000	211.54983960	-0.51043960	206.72218622	216.37749098
15	232.67400000	230.96499531	1.70900469	226.03779246	235.83219815
16	263.94212000	257.89569655	6.04642345	251.57393507	264.21745802
17	247.61412000	241.34020126	6.27391874	234.45233538	248.23006714
18	258.55388000	278.47583306	-19.92195306	274.01961160	282.93205452
19	283.04588000	302.45926194	-19.41338194	297.93786674	306.98075714
20	340.19388000	335.72659876	4.46728124	328.99771453	342.45548300
21	318.39600000	307.72550846	10.67009154	299.76559559	315.68621734
22	342.89800000	351.93499395	-9.04699395	347.02815628	356.84183162
23	375.54400000	380.48669499	-4.94269499	375.49607518	385.47731480
24	429.95788000	420.09066740	9.90721260	412.11804880	427.84328601
25	408.20000000	399.89530776	8.30469224	388.90577671	410.88483880
26	440.85600000	452.94621034	-12.09021034	444.93415891	460.95826177
27	478.98188000	487.20825159	-8.22637159	479.12202505	495.29447812

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   14:52 FRIDAY, NOVEMBER 14, 1980   2

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPM

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
28	549.68212000	534.73301848	14.94910152	523.95941812	545.50661885

SUM OF RESIDUALS	-9.07714520
SUM OF SQUARED RESIDUALS	1977.67118862
SUM OF SQUARED RESIDUALS - ERROR SS	-0.00000000
PRESS STATISTIC	2747.16638550
FIRST ORDER AUTOCORRELATION	0.06299003
DURBIN-WATSON D	1.75813308

AIRFLOW CALCULATIONS FOR WHEAT

OBS	PP	SP	TRT	RIP	Q	V	W	RO	CD	WH
1	0.0100	0.0250	1	1	1.8972	1.3808	8.367	3115.4	0.900235	8.367
2	0.0620	0.0750	1	1	4.8920	3.5531	21.529	8016.7	0.930343	21.531
3	0.1930	0.1535	1	1	8.7508	6.3688	38.591	14369.7	0.945172	38.593
4	0.3920	0.2460	1	1	12.5757	9.1526	55.459	20650.5	0.953074	55.461
5	0.7450	0.3655	1	1	17.4521	12.7016	76.964	28658.1	0.959411	76.966
6	1.3270	0.5410	1	1	23.4151	17.0416	103.261	38450.0	0.964483	103.263
7	1.7490	0.6570	1	1	26.9438	19.6097	118.822	44244.5	0.966710	118.825
8	0.0100	0.0250	1	2	1.8972	1.3808	8.367	3115.4	0.900235	8.367
9	0.0600	0.0780	1	2	4.8001	3.4936	21.169	7882.3	0.929873	21.170
10	0.1720	0.1500	1	2	8.2489	6.0036	36.378	13545.6	0.943792	36.380
11	0.3700	0.2440	1	2	12.2099	8.8864	53.846	20049.9	0.952466	53.848
12	0.7170	0.3760	1	2	17.1146	12.4560	75.475	28103.9	0.959054	75.478
13	1.2760	0.5585	1	2	22.9530	16.7052	101.223	37691.1	0.964156	101.225
14	1.7010	0.6785	1	2	26.5654	19.3344	117.154	43623.2	0.966491	117.157
15	0.0090	0.0290	1	3	1.7959	1.3070	7.920	2949.0	0.898237	7.920
16	0.0580	0.0775	1	3	4.7170	3.4330	20.802	7745.8	0.929384	20.803
17	0.1660	0.1505	1	3	8.1001	5.8953	35.721	13301.2	0.943361	35.723
18	0.3820	0.2515	1	3	12.4107	9.0325	54.731	20379.6	0.952803	54.733
19	0.7370	0.3890	1	3	17.3563	12.6319	76.541	28500.8	0.959310	76.544
20	1.2730	0.5625	1	3	22.9255	16.6852	101.101	37646.0	0.964137	101.104
21	1.6690	0.6845	1	3	26.3103	19.1487	116.028	43204.2	0.966341	116.031
22	0.0080	0.0290	2	1	1.6873	1.2280	7.441	2770.7	0.895931	7.448
23	0.0570	0.0870	2	1	4.6749	3.4024	20.616	7676.6	0.929133	20.617
24	0.1600	0.1665	2	1	7.9486	5.7850	35.053	13052.4	0.942912	35.055
25	0.3520	0.2737	2	1	11.9026	8.6627	52.490	19545.2	0.951937	52.492
26	0.6690	0.4115	2	1	16.5205	12.0237	72.855	27128.4	0.958401	72.858

OBS	QH	DEL	CF2	CM	SPM	LSP	LCF2	LSPM	LCM
1	1.8973	0.000044022	2.5162	0.012782	20.410	-3.6889	0.92275	3.01602	-4.3597
2	4.8822	0.000053411	6.4747	0.032892	61.230	-2.5903	1.86791	4.11464	-3.4145
3	8.7512	0.000045647	11.6058	0.058958	125.317	-1.8741	2.45151	4.83085	-2.8309
4	12.5762	0.000039185	16.6786	0.084727	200.834	-1.4024	2.81413	5.30248	-2.4683
5	17.4526	0.000033139	23.1460	0.117581	298.374	-1.0065	3.14182	5.69842	-2.1406
6	23.4157	0.000027892	31.0545	0.157757	441.672	-0.6143	3.43574	6.09057	-1.8467
7	26.9445	0.000025505	35.7344	0.181531	536.375	-0.4201	3.57611	6.28483	-1.7063
8	1.8973	0.000044022	2.5162	0.012782	20.410	-3.6889	0.92275	3.01602	-4.3597
9	4.8004	0.000053545	6.3662	0.032340	63.679	-2.5510	1.85101	4.15386	-3.4314
10	8.2493	0.000046629	10.9402	0.055576	122.460	-1.8971	2.39245	4.80778	-2.8900
11	12.2104	0.000039728	16.1935	0.082263	199.202	-1.4106	2.78461	5.29432	-2.4978
12	17.1151	0.000033497	22.6984	0.115308	306.966	-0.9782	3.12229	5.72674	-2.1602
13	22.9536	0.000028238	30.4416	0.154643	455.959	-0.5825	3.41581	6.12240	-1.8666
14	26.5661	0.000025741	35.2327	0.178982	553.927	-0.3879	3.56197	6.31703	-1.7205
15	1.7959	0.000041889	2.3818	0.012099	23.676	-3.5405	0.86785	3.16444	-4.4146
16	4.7172	0.000053678	6.2555	0.031780	63.271	-2.5575	1.83353	4.14743	-3.4489
17	8.1005	0.000046925	10.7428	0.054574	122.868	-1.8938	2.37424	4.81111	-2.9082
18	12.4112	0.000039428	16.4598	0.083616	205.325	-1.3803	2.80092	5.32459	-2.4815
19	17.3569	0.000033240	23.0185	0.116936	317.580	-0.9442	3.13632	5.76073	-2.1461
20	22.9261	0.000028259	30.4052	0.154458	459.225	-0.5754	3.41461	6.12954	-1.8678
21	26.3110	0.000025903	34.8943	0.177263	558.826	-0.3791	3.55232	6.32584	-1.7301
22	1.6889	0.000043165	2.2378	0.011368	23.676	-3.5405	0.80548	3.16444	-4.4770
23	4.6751	0.000053742	6.2001	0.031496	71.027	-2.4418	1.82457	4.26306	-3.4579
24	7.9489	0.000057230	10.5419	0.053553	135.931	-1.7928	2.35535	4.91214	-2.9271
25	11.9030	0.000040196	15.7859	0.080192	223.449	-1.2957	2.75912	5.40918	-2.5233
26	16.5211	0.000034145	21.9105	0.111305	335.945	-0.8879	3.08697	5.81696	-2.1955

OBS	PR	SP	TRT	REP	Q	V	W	PO	CO	WH
27	1.1690	0.5999	2	1	21.9527	15.5772	96.811	36048.6	0.963418	96.814
28	1.5930	0.7405	2	1	25.6123	18.6407	112.950	42058.0	0.965920	112.953
29	0.0085	0.0250	2	2	1.7414	1.2674	7.680	2859.6	0.897103	7.687
30	0.0520	0.0800	2	2	4.4587	3.2450	19.663	7321.6	0.927792	19.664
31	0.1400	0.1610	2	2	7.4222	5.4019	32.732	12188.0	0.941259	32.733
32	0.3000	0.2700	2	2	10.9683	7.9827	48.370	18011.1	0.950206	48.372
33	0.6140	0.4220	2	2	15.8133	11.5090	69.737	25967.1	0.957581	69.739
34	1.1350	0.6300	2	2	21.6254	15.7390	95.368	35511.2	0.963166	95.371
35	1.4620	0.7555	2	2	24.5976	17.9022	108.475	40391.8	0.965278	108.478
36	0.0080	0.0250	2	3	1.6973	1.2280	7.441	2770.7	0.895931	7.448
37	0.0500	0.0835	2	3	4.3694	3.1800	19.269	7175.0	0.927213	19.270
38	0.1590	0.1640	2	3	7.9230	5.7664	34.941	13010.5	0.942835	34.942
39	0.3470	0.2720	2	3	11.8150	8.5996	52.108	19402.8	0.951784	52.110
40	0.6580	0.4070	2	3	16.3814	11.9224	72.242	26900.0	0.958244	72.245
41	1.1570	0.5960	2	3	21.8377	15.8935	96.304	35859.8	0.963330	96.307
42	1.5700	0.7375	2	3	25.5052	18.5627	112.478	41882.1	0.965854	112.481
43	0.0080	0.0350	3	1	1.6873	1.2280	7.441	2770.7	0.895931	7.448
44	0.0450	0.0955	3	1	4.1381	3.0117	18.249	6795.2	0.925641	18.250
45	0.1350	0.1865	3	1	7.2849	5.3019	32.126	11962.5	0.940802	32.128
46	0.2750	0.3125	3	1	10.4907	7.6351	46.264	17226.8	0.949244	46.266
47	0.5350	0.4850	3	1	14.7403	10.7280	65.005	24205.0	0.956237	65.007
48	0.9700	0.7260	3	1	19.9635	14.5294	88.039	32782.1	0.961800	88.042
49	1.3500	0.8770	3	1	23.6206	17.1911	104.167	38787.5	0.964625	104.170
50	0.0080	0.0350	3	2	1.6873	1.2280	7.441	2770.7	0.895931	7.448
51	0.0440	0.0900	3	2	4.0904	2.5770	18.039	6716.8	0.925303	18.040
52	0.1370	0.1845	3	2	7.3401	5.3421	32.370	12053.2	0.940987	32.371

OBS	QH	DEL	CF2	QM	SPM	LSP	LCF2	LSPM	LQM
27	21.9533	0.000029018	29.1149	0.147904	489.024	-0.5125	3.37125	6.19241	-1.9112
28	25.6130	0.000026356	33.9686	0.172560	604.544	-0.3004	3.52544	6.40447	-1.7570
29	1.7431	0.000986744	2.3096	0.011733	20.410	-3.6899	0.83706	3.01602	-4.4454
30	4.4589	0.000054050	5.9134	0.030040	65.312	-2.5257	1.77722	4.17918	-3.5052
31	7.4225	0.000048305	9.8437	0.050006	131.440	-1.8264	2.28683	4.87855	-2.9956
32	10.9687	0.000041684	14.5468	0.073898	220.428	-1.3093	2.67737	5.39557	-2.6051
33	15.9139	0.000034950	20.9726	0.106541	344.521	-0.8627	3.04322	5.84215	-2.2392
34	21.6260	0.000029282	28.6809	0.145699	514.332	-0.4620	3.35623	6.24287	-1.9262
35	24.5983	0.000027044	32.6228	0.165724	616.790	-0.2804	3.48501	6.42453	-1.7974
36	1.6809	0.000943165	2.2378	0.011368	20.410	-3.6889	0.80548	3.01602	-4.4770
37	4.3696	0.000054164	5.7949	0.029438	68.169	-2.4829	1.75698	4.22200	-3.5255
38	7.9234	0.000047281	10.5080	0.053381	133.890	-1.8079	2.35214	4.89702	-2.9303
39	11.9163	0.000040329	15.6708	0.079608	222.061	-1.3020	2.75180	5.40255	-2.5306
40	16.3820	0.000034300	21.7261	0.110368	332.275	-0.8989	3.07851	5.80596	-2.2039
41	21.8381	0.000029110	28.9625	0.147129	486.574	-0.5175	3.36600	6.18739	-1.9164
42	25.5058	0.000026427	33.8265	0.171838	602.095	-0.3045	3.52124	6.40042	-1.7612
43	1.6889	0.000943165	2.2378	0.011368	28.574	-3.3524	0.80548	3.35250	-4.4770
44	4.1383	0.000054410	5.4882	0.027880	77.966	-2.3496	1.70261	4.35628	-3.5798
45	7.2852	0.000048589	9.6616	0.049081	152.259	-1.6793	2.26816	5.02558	-3.0143
46	10.4911	0.000042485	13.9134	0.070680	255.125	-1.1632	2.63285	5.54175	-2.6496
47	14.7408	0.000036249	19.5494	0.099311	395.954	-0.7236	2.97295	5.98130	-2.3095
48	19.9641	0.000030704	26.4767	0.134502	592.706	-0.3202	3.27627	6.38470	-2.0062
49	23.6213	0.000027741	31.3271	0.159142	715.983	-0.1312	3.44448	6.57366	-1.8380
50	1.6889	0.000943165	2.2378	0.011368	28.574	-3.3524	0.80548	3.35250	-4.4770
51	4.0906	0.000054451	5.4249	0.027559	73.476	-2.4079	1.69100	4.29656	-3.5914
52	7.3404	0.000048474	9.7349	0.049453	150.626	-1.6991	2.27571	5.01480	-3.0067

OBS	PR	SP	TRT	REP	C	V	W	RD	CD	WH
53	0.2900	0.3250	3	2	10.5879	7.7055	46.692	17186.4	0.949444	46.694
54	0.5400	0.4709	3	2	14.8104	10.7790	65.314	24320.2	0.956329	65.316
55	0.9750	0.7050	3	2	20.0158	14.5675	88.270	32868.0	0.961846	88.272
56	1.4000	0.8525	3	2	24.0615	17.5120	106.111	39511.5	0.964924	106.114
57	0.0080	0.0300	3	3	1.6873	1.2280	7.441	2770.7	0.895931	7.448
58	0.0400	0.0870	3	3	3.8939	2.8340	17.172	6394.2	0.923853	17.173
59	0.1300	0.1870	3	3	7.1451	5.2002	31.510	11732.9	0.940325	31.511
60	0.2730	0.3100	3	3	10.4516	7.6067	46.091	17162.6	0.949162	46.093
61	0.5320	0.4800	3	3	14.6980	10.6972	64.818	24135.7	0.956182	64.821
62	0.5680	0.7170	3	3	19.9425	14.5142	87.946	32747.6	0.961782	87.949
63	1.3300	0.8620	3	3	23.4420	17.0611	103.379	38494.2	0.964501	103.382
64	0.0060	0.0340	4	1	1.4523	1.0570	6.404	2384.8	0.890234	6.409
65	0.0350	0.0900	4	1	3.6343	2.6450	16.027	5567.9	0.921786	16.028
66	0.1000	0.1700	4	1	6.2440	4.5444	27.536	10253.2	0.936925	27.537
67	0.2000	0.2970	4	1	8.9120	6.4862	39.302	14634.5	0.945593	39.304
68	0.4700	0.4580	4	1	13.7971	10.0416	60.845	22656.3	0.954942	60.847
69	0.9000	0.7000	4	1	19.2163	13.9857	84.744	31555.2	0.961135	84.747
70	1.2000	0.8500	4	1	22.2470	16.1914	98.109	36531.8	0.963640	98.112
71	0.0060	0.0350	4	2	1.4523	1.0570	6.404	2384.8	0.890234	6.409
72	0.0330	0.0910	4	2	3.5254	2.5658	15.547	5789.0	0.920862	15.548
73	0.1000	0.1700	4	2	6.2440	4.5444	27.536	10253.2	0.936925	27.537
74	0.1900	0.2900	4	2	8.6808	6.3179	38.282	14254.8	0.944986	38.284
75	0.4500	0.4490	4	2	13.4941	9.8210	59.509	22158.7	0.954500	59.511
76	0.9200	0.6700	4	2	19.4326	14.1431	85.698	31910.4	0.961331	85.701
77	1.2000	0.8340	4	2	22.2470	16.1914	98.109	36531.8	0.963640	98.112
78	0.0055	0.0330	4	3	1.3879	1.0100	6.120	2278.9	0.888465	6.124

OBS	QH	DEL	CF2	QM	SPM	LSP	LQF2	LSPM	LCM
53	10.5883	0.000042320	14.0423	0.071335	265.120	-1.1239	2.64207	5.58097	-2.6404
54	14.8109	0.000036161	19.6424	0.099784	383.708	-0.7550	2.97769	5.94988	-2.3048
55	20.0164	0.000030657	26.5461	0.134854	575.562	-0.3496	3.27888	6.35535	-2.0036
56	24.0622	0.000027422	31.9119	0.162112	695.981	-0.1596	3.46298	6.54532	-1.8195
57	1.6889	0.000943165	2.2378	0.011368	24.492	-3.5066	0.80548	3.19835	-4.4770
58	3.8941	0.000054579	5.1644	0.026235	71.027	-2.4418	1.64178	4.26306	-3.6407
59	7.1454	0.000048879	9.4762	0.048139	152.667	-1.6766	2.24879	5.02826	-3.0337
60	10.4520	0.000042552	13.8615	0.070416	253.084	-1.1712	2.62912	5.53372	-2.6533
61	14.6985	0.000036302	19.4934	0.099026	391.872	-0.7340	2.97008	5.97094	-2.3124
62	19.9431	0.000030723	26.4489	0.134360	585.359	-0.3327	3.27522	6.37222	-2.0072
63	23.4427	0.000027872	31.0902	0.157938	703.737	-0.1485	3.43689	6.55640	-1.8456
64	1.4533	0.000716857	1.9261	0.005785	27.758	-3.3914	0.65549	3.32351	-4.6270
65	3.6445	0.000054623	4.8200	0.024486	73.476	-2.4079	1.57277	4.29696	-3.7097
66	6.2443	0.000050764	8.2811	0.042068	138.788	-1.7720	2.11399	4.93255	-3.1685
67	8.9125	0.000045338	11.8197	0.060044	242.471	-1.2140	2.46977	5.49088	-2.8127
68	13.7976	0.000037473	18.2985	0.092957	373.911	-0.7809	2.90682	5.92402	-2.3756
69	19.2169	0.000031390	25.4858	0.129468	571.440	-0.3567	3.23812	6.34823	-2.0443
70	22.2476	0.000028784	29.5053	0.149887	693.940	-0.1625	3.38457	6.54239	-1.8979
71	1.4533	0.000716857	1.9261	0.005785	28.574	-3.3524	0.65549	3.35250	-4.6270
72	3.5256	0.000054588	4.6756	0.023752	74.292	-2.3969	1.54235	4.30801	-3.7401
73	6.2443	0.000050764	8.2811	0.042068	138.788	-1.7720	2.11398	4.93255	-3.1685
74	8.6812	0.000045782	11.5130	0.058486	236.756	-1.2379	2.44348	5.46703	-2.8390
75	13.4946	0.000037883	17.8977	0.090915	365.747	-0.8010	2.88462	5.90154	-2.3978
76	19.4332	0.000031188	25.7727	0.130925	546.988	-0.4005	3.24932	6.30443	-2.0331
77	22.2476	0.000028784	29.5053	0.149887	680.878	-0.1815	3.38457	6.52338	-1.8979
78	1.3887	0.000641764	1.8406	0.009350	26.941	-3.4112	0.61007	3.29366	-4.6724

OBS	PR	SP	TRT	REP	Q	V	W	RC	CE	WH	QF
79	0.034	0.0855	4	3	3.5802	2.6057	15.7888	5879.1	0.921332	15.7896	3.5804
80	0.100	0.1700	4	3	6.2440	4.5444	27.5357	10253.2	0.936925	27.5373	6.2443
81	0.190	0.2840	4	3	8.6808	6.3179	38.2824	14254.8	0.944586	38.2841	8.6812
82	0.450	0.4520	4	3	13.4941	9.8210	59.5090	22158.7	0.954500	59.5112	13.4946
83	0.520	0.7000	4	3	19.4326	14.1431	85.6979	31910.4	0.961331	85.7005	19.4332
84	1.190	0.8400	4	3	22.1525	16.1226	97.6923	36376.6	0.963565	97.6951	22.1531

OBS	DEL	QF2	QM	SPM	LSP	LQF2	LSPM	LQM
79	0.0000546101	4.7483	0.024121	69.802	-2.4592	1.55779	4.24567	-3.7247
80	0.0000507638	8.2811	0.042068	138.788	-1.7720	2.11398	4.93295	-3.1685
81	0.0000457822	11.5130	0.058486	231.658	-1.2588	2.44348	5.44612	-2.8390
82	0.0000378833	17.8967	0.090915	369.013	-0.7941	2.88462	5.91083	-2.3978
83	0.0000311884	25.7727	0.130925	571.480	-0.3567	3.24932	6.34823	-2.0331
84	0.0000288587	29.3799	0.149250	685.776	-0.1744	3.38031	6.53055	-1.9021

REGRESSION ANALYSIS FOR WHEAT

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   14:52 FRIDAY, NOVEMBER 14, 1980   1

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	3093279.07507008	1031093.02502336	3352.65	0.0001	0.997521	6.3349
ERROR	25	7688.63976745	307.54559070		STD DEV		SPM MEAN
UNCORRECTED TOTAL	28	3100967.71483753			17.53697781		276.82957714

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
VM	1	2973625.36507447	9668.89	0.0001	1	174181.81241078	566.36	0.0001
VM*VM	1	22802.85033412	74.14	0.0001	1	22802.85033412	74.14	0.0001
VM*MC	1	96850.85966149	314.92	0.0001	1	96850.85966145	314.92	0.0001

PARAMETER	ESTIMATE	T FOR HO: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
VM	5573.94963601	23.80	0.0001	234.21590855
VM*VM	9634.59499657	8.61	0.0001	1118.90611480
VM*MC	-200.28351082	-17.75	0.0001	11.29021211

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
1	26.36972000	24.00166177	2.36805823	19.85844956	28.14487398
2	32.41108000	32.24292768	0.16815232	28.32889322	36.15696214
3	39.75868000	40.17896151	-0.42028151	36.27118390	44.08673911
4	44.90200000	49.33592362	-4.43392362	45.17390022	53.49794702
5	81.88492000	73.94979989	7.93512011	64.98105185	82.91854792
6	97.96800000	95.92650896	2.04149104	87.72239547	104.13062246
7	118.37800000	117.08926585	1.28873415	108.90638577	125.27214193
8	133.31812000	141.50783149	-8.18971149	132.47735975	150.53830323
9	133.31812000	122.85914202	10.45897798	111.70649706	134.01178698
10	160.58588000	155.82420563	4.76167437	146.08571571	165.56262556
11	193.24188000	187.56834097	5.67353903	177.87020797	197.26647396
12	216.34600000	224.19618942	-7.85018942	212.93203427	235.46034458
13	202.71212000	195.18435925	7.52776075	182.79020117	207.57851732
14	239.45012000	241.88486603	-2.43474603	232.17298416	251.59674790
15	299.37388000	286.85572441	12.51815559	277.22508926	296.48635957
16	329.25412000	338.74517640	-9.49105640	326.15026009	351.34009271
17	266.71788000	261.99536467	4.72251533	248.82920871	275.16152063
18	291.20988000	319.68422595	-28.47434599	310.58108805	328.78736393
19	389.17788000	375.23646282	13.94141718	366.26600781	384.20691783
20	405.50588000	439.33519762	-33.82931762	425.88146211	452.78893313
21	337.41812000	336.76266488	0.65545512	321.60134220	351.92398757
22	389.17788000	405.43988074	-16.26200074	395.35852943	415.52123206
23	511.63788000	471.57349602	40.06438398	461.66211701	481.48485502
24	549.68212000	547.88151364	1.80060636	532.36651749	563.39650978
25	432.69200000	441.41032971	-8.71832971	420.29682611	462.52383330
26	495.30588000	523.82298874	-28.51310874	507.66359934	539.98237814
27	647.65012000	603.18332707	44.46675293	587.17608272	619.19057141

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPM

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
28	685.77600000	694.75294921	-8.97694821	673.27265097	716.23324545

SUM OF RESIDUALS	2.75887500
SUM OF SQUARED RESIDUALS	7688.63576745
SUM OF SQUARED RESIDUALS - ERROR SS	-0.00000000
PRESS STATISTIC	10444.42529494
FIRST ORDER AUTOCORRELATION	-0.44209277
DURBIN-WATSON D	2.87297506

APPENDIX II

VOID FRACTION ANALYSIS

REGRESSION ANALYSIS PROGRAM USING PACKING FACTOR

```
1                        S T A T I S T I C A L   A N A L Y S I S   S Y S T E M          14:54 FRIDAY, NOVEMBER 14, 1990

NOTE: THE JOB A0001352 HAS BEEN RUN UNDER RELEASE 79.3A OF SAS AT KANSAS STATE UNIVERSITY.

NOTE: THIS IS THE MESSAGE PATCH USERS SEE
      WHEN OPTIONS NEWS IS SPECIFIED.
      THIS MESSAGE SHOULD BE REPLACED BY SOME
      MEANINGFULL TEXT.
      TO CHANGE THE MODULE RECOMPILE IT.
      IT IS: DSNAME=SAS.SOURCE(SASNEWS).
      SEE INSTALLATION INSTRUCTIONS PROGRAM LISTSPC.

1          DATA PACKING; INPUT SP PF V;
2          SPM=SP*816.4;
3          VM=V*0.00508;
4          CARDS;

NOTE: DATA SET WORK.PACKING HAS 28 OBSERVATIONS AND 5 VARIABLES. 433 OBS/TRK.
NOTE: THE DATA STATEMENT USED 0.57 SECONDS AND 128K.

33         PROC GLM;
34         MODEL SPM=  VM  VM*VM  PF*VM /NOINT P CLM;
35         OUTPUT OUT=NEW PREDICTED=PSPM RESIDUAL=RSPM;

NOTE: DATA SET WORK.NEW HAS 28 OBSERVATIONS AND 7 VARIABLES. 317 OBS/TRK.
NOTE: THE PROCEDURE GLM USED 1.24 SECONDS AND 198K AND PRINTED PAGES 1 TO 2.

36         PROC PLOT;PLOT SPM*PF='.' PSPM*PF='*' /O;
37         PLOT RSPM*PF='.' RSPM*PSPM='.' RSPM*VM='.';

NOTE: THE PROCEDURE PLOT USED 1.56 SECONDS AND 160K AND PRINTED PAGES 3 TO 6.

NOTE: SAS INSTITUTE INC.
      SAS CIRCLE
      BOX 8000
      CARY, N.C. 27511
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NOMENCLATURE

VM = VELOCITY, m/s

PF = VOID FRACTION, ε

SPM = STATIC PRESSURE DROP, PASCAL

REGRESSION ANALYSIS FOR CORN

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   14:54 FRIDAY, NOVEMBER 14, 1980   1

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	840316.95462403	280105.65154134	3991.43	0.0001	0.997917	5.8725
ERROR	25	1754.41793811	70.17671352		STD DEV		SPM MEAN
UNCORRECTED TOTAL	28	842071.37246213			8.37715426		142.65132143

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
VM	1	798087.86407867	11372.55	0.0001	1	25165.18461594	358.60	0.0001
VM*VM	1	22041.89515849	314.09	0.0001	1	22041.89515849	314.09	0.0001
VM*PF	1	20187.19538686	287.66	0.0001	1	20187.19538686	287.66	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
VM	5334.97222518	18.94	0.0001	281.72709377
VM*VM	4951.46797416	17.72	0.0001	279.38688855
VM*PF	-12036.22152387	-16.96	0.0001	709.65732826

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
1	23.43068000	18.62725925	4.80342075	15.25887139	21.99564719
2	30.45172000	35.58146471	-5.12974471	32.70798536	38.45494406
3	34.28880000	36.17734973	-1.88854973	33.29594167	39.05875779
4	39.18720000	42.74534095	-3.55814095	39.66325757	45.82742433
5	41.39148000	34.07430790	7.31717210	29.56027012	38.58834569
6	53.06600000	59.50561609	-6.43961609	55.84147329	63.16975890
7	61.23000000	60.39944362	0.83055638	56.72131810	64.07756915
8	69.39400000	70.25143046	-0.85743046	66.22387042	74.27899049
9	69.39400000	59.13319906	10.26080094	53.58006631	64.68633181
10	88.41612000	95.16088567	-6.74476567	91.05140564	99.27036569
11	103.43788000	96.42714133	7.01073867	92.29266812	100.56161454
12	106.13200000	110.38412268	-4.25212268	105.64093467	115.12731069
13	88.41612000	83.78937626	4.62674374	77.59335527	89.96739725
14	121.07212000	128.28516560	-7.21304560	124.16290497	132.40742623
15	129.23612000	129.84936377	-0.61324377	125.68914216	134.00958538
16	136.09388000	147.09034073	-10.99646073	142.03528081	152.14540066
17	119.19440000	112.51649948	6.67790052	105.71786026	119.31513870
18	157.81012000	165.49839155	-7.68827155	161.49164525	169.50513385
19	174.13812000	167.36053223	6.77758777	163.29856499	171.42249947
20	190.46612000	187.88550480	2.58061520	182.57642288	193.19458672
21	157.81012000	154.18673384	3.62338616	146.37414070	161.99932698
22	206.79412000	217.76500433	-10.97088433	213.57031778	221.95969087
23	228.59200000	219.99957314	8.59242686	215.72908716	224.27005911
24	247.61412000	244.62954023	2.98457977	238.70788475	250.55119571
25	244.92000000	256.69413704	-11.77413704	244.78643290	268.60184119
26	323.86588000	341.46516435	-17.59928435	333.42995503	349.50037368
27	356.52188000	344.44458944	12.07729056	336.33870828	352.55947061

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPM

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
28	391.87200000	377.28454556	14.58745444	367.50562129	387.06326983

SUM OF RESIDUALS	-2.96602702
SUM OF SQUARED RESIDUALS	1754.41783810
SUM OF SQUARED RESIDUALS - ERROR SS	-0.00000001
PRESS STATISTIC	2822.24206141
FIRST ORDER AUTOCORRELATION	-0.23212651
DURBIN-WATSON D	2.32981145

REGRESSION ANALYSIS FOR SORGHUM

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   14:52 FRIDAY, NOVEMBER 14, 1980   1

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	2080857.51702482	693619.17234161	2546.49	0.0C01	0.996738	7.2015
ERROR	25	6809.57425992	272.38297040		STD DEV		SPM MEAN
UNCORRECTED TOTAL	28	2087667.09128473			16.50402E91		229.17514286

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
VP	1	2043712.46226561	7503.08	C.0001	1	32599.37300150	119.68	0.0001
VP*VM	1	15374.99017792	56.45	0.0001	1	15374.99017792	56.45	0.0001
VP*PI	1	21770.06457723	79.92	C.0001	1	21770.06457723	79.92	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
VP	9747.81820058	10.94	0.0001	891.03091632
VP*VM	7911.27203522	7.51	0.0001	1053.00121100
VP*PI	-19470.94928902	-8.94	0.0001	2177.95115226

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
1	21.06312000	25.11108510	-4.04796510	21.26337633	28.95879388
2	25.06348000	26.72504242	-1.66156242	22.97689075	30.47319408
3	26.94120000	34.68058489	-7.73938489	30.89094857	38.47022121
4	28.81892000	34.81325640	-5.99433640	31.01542717	38.61108562
5	74.86388000	75.12935164	-0.26547164	66.85852265	83.40918062
6	83.02788000	79.43323780	3.59464220	71.49415510	87.37232050
7	100.66212000	100.64801774	0.01410226	92.57010361	108.72593196
8	104.74412000	101.00180841	3.74231159	92.89657877	109.10703806
9	119.76588000	122.49377708	-2.72789708	112.30644693	132.68110724
10	137.40012000	128.94960633	8.45051367	119.37452695	138.52468571
11	152.42188000	160.77177623	-8.34989623	150.93890353	170.60464894
12	170.05612000	161.30246225	8.75365775	151.41914296	171.18578155
13	199.46612000	190.89657417	-0.42045417	179.78478116	201.98836719
14	211.03940000	200.03233227	11.00706773	190.08413231	209.98053224
15	232.67400000	245.11373964	12.43973564	234.67305440	255.55442488
16	263.94212000	245.86554483	18.07657517	235.32969913	256.40139053
17	247.61412000	252.95062407	-5.33650407	241.37509058	264.52615756
18	258.55188000	264.24332525	-5.69344525	254.40261033	274.09404017
19	283.04598000	319.93712258	-37.89124258	309.34181578	330.53242939
20	340.19388000	320.86582312	19.32805688	319.12773513	331.60351111
21	318.39600000	321.54784039	-3.15184039	308.28517297	334.81050780
22	342.88000000	334.99748465	7.89051535	323.88965745	346.10527186
23	375.54400000	401.29367195	-25.74967195	389.24799263	413.33935123
24	429.95788000	402.39926782	27.59861218	390.17571293	414.62282272
25	408.20000000	416.48162606	-8.28162606	397.64165142	435.32160070
26	440.85600000	432.62119918	8.23480082	415.90825647	449.33414188
27	478.98188000	512.17662394	-33.19474394	494.55298336	529.80026451

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPW

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
28	549.68212000	511.50333898	36.17878102	495.79420843	531.10246954

SUM OF RESIDUALS	-9.07714520
SUM OF SQUARED RESIDUALS	6809.57425591
SUM OF SQUARED RESIDUALS - ERROR SS	-0.00000001
PRESS STATISTIC	10125.92155891
FIRST ORDER AUTOCORRELATION	-0.56057683
DURBIN-WATSON D	2.92733206

REGRESSION ANALYSIS FOR WHEAT

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   14:50 FRIDAY, NOVEMBER 14, 1980   1

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPM

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	3087677.04105813	1029225.68035271	1935.99	0.0001	0.995714	8.3290
ERROR	25	13290.67377941	531.62695118		STD DEV		SPM MEAN
UNCORRECTED TOTAL	28	3100967.71483753			23.05703691		276.82957714

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
VM	1	2973625.36507447	5593.44	0.0001	1	126207.43593544	237.40	0.0001
VM*VM	1	22802.85033412	42.89	0.0001	1	22802.85033412	42.89	0.0001
VM*PF	1	91248.82564954	171.64	0.0001	1	91248.82564954	171.64	0.0001

PARAMETER	ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
VM	13241.44577008	15.41	0.0001	859.40213700
VM*VM	9634.59499657	6.55	0.0001	1471.10065773
VM*PI	-26436.28668978	-13.10	0.0001	2017.85658300

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
1	26.36972000	22.95126579	3.41845421	17.42244587	28.48008572
2	32.41108000	34.86473381	-2.45365381	29.75265344	39.97677418
3	39.75868000	39.82836658	-0.06968658	34.69461665	44.96211651
4	44.90200000	48.11510840	-3.21310840	42.68922591	53.54099089
5	81.88492000	71.14874394	10.73617606	59.09033719	83.20715068
6	97.96800000	102.51799199	-4.94999199	92.24708969	113.58889429
7	119.37800000	116.15434604	2.22365396	105.40958489	126.89910719
8	133.31812000	138.25232422	-4.93420422	126.53113248	149.97351597
9	133.31812000	118.65755810	14.66056190	103.51445537	133.80066083
10	160.58596000	166.31143017	-5.72555017	153.72750108	178.89535926
11	193.24188000	186.16596125	7.07591875	173.44141104	198.89051146
12	216.34600000	219.31292853	-2.96692853	204.77775820	233.84809885
13	202.71212000	189.23211535	13.48000465	172.07831657	206.38591414
14	239.45012000	256.74176746	-17.29164746	244.41928927	269.06424565
15	299.37398000	284.86901982	14.50496018	272.26005488	297.47798476
16	329.25412000	331.82722346	-2.57310346	315.76351435	347.89093257
17	266.71788000	254.64255280	12.07528720	236.10981924	273.17536635
18	291.20988000	338.03686893	-46.82698893	326.80504203	349.26865583
19	389.17788000	372.78229832	16.39558168	361.07533085	384.48926579
20	405.50588000	430.78947105	-25.28361105	413.81277480	447.76620730
21	337.41812000	328.00936504	9.40875496	306.57477489	349.44395519
22	389.17788000	427.28826520	-38.11038520	414.98123591	439.59529449
23	511.63788000	468.65187161	42.98600839	455.73252125	481.57122196
24	549.68212000	537.70805343	11.97406657	518.18543331	557.23067356
25	432.69200000	430.90636990	1.78563010	401.58070413	460.23203567
26	495.30588000	550.04105009	-54.73517009	529.63258699	570.44951320
27	647.65012000	599.67737778	47.97274222	578.73105272	620.62370283

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: SPP

OBSERVATION	OBSERVED VALUE	PREDICTED VALUE	RESIDUAL	LOWER 95% CL FOR MEAN	UPPER 95% CL FOR MEAN
28	685.77600000	682.54479597	3.23120403	655.20929208	709.88029985

SUM OF RESIDUALS	2.79887500
SUM OF SQUARED RESIDUALS	13290.67377540
SUM OF SQUARED RESIDUALS - ERROR SS	-0.00000001
PRESS STATISTIC	17495.40960783
FIRST ORDER AUTOCORRELATION	-0.52234611
DURBIN-WATSON D	3.04302741

STATIC PRESSURE DROP IN A FIXED BED OF

GRAIN AS AFFECTED BY GRAIN MOISTURE CONTENT

by

YOUSEF NAGI AHMED (ASSALIMY)

M.S. Engineering (Civil), Kiev Civil Engineering Institute
1974, USSR

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1981

Determination of grain resistance to airflow is fundamental in the design of drying and aeration systems. Designers widely use Shedd's data on resistance of dry grains to airflow for fan selection. But grains such as corn and grain sorghum that are harvested at higher moisture levels do not follow Shedd's data which does not consider grain moisture as a variable. Our study was intended to determine the effect of grain moisture on airflow resistance. We determined resistance of corn, sorghum and wheat as affected by the moisture content.

The result shows that resistance to the airflow decreases with the increase in grain moisture. We analyzed the data statistically and obtained a non-linear regression model describing the mathematical relationship between grain moisture and static pressure drop. The model is:

$$\Delta P = AV + BV^2 - C\,(M.C.)\,V$$

where,

ΔP = pressure drop per meter depth of grain, pascal

V = air velocity, m/s

M.C. = grain moisture, % w.b.

and A, B, and C = product constants.

The values of the constants A, B, and C for corn, sorghum and wheat are given below:

Corn:

A = 1611.719

B = 4949.301

C = -55.116

Sorghum:

A = 3253.100

B = 7911.272

C = -72.521

Wheat:

A = 5573.950

B = 9634.595

C = -200.283

The results of this study are expected to help designers in conserving energy for high moisture grain aeration systems and to give us a better understanding of the effect of moisture on the airflow resistance of grains.