# AIR STABILIZATION: THE EFFECT OF ATMOSPHERIC RELATIVE HUMIDITY ON FLOUR MILLING

by

KHALLID ABBASS AL-OBAIDY

B.S., Baghdad University, 1972

---

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science & Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

Approved by:

A. B. Ward

Major Professor

TABLE OF CONTENTS

# ACKNOWLEDGMENT

The author would like to express his grateful acknowledgment to his major professor, Prof. Arlin Ward, for his guidance and advise through the course of these studies. Appreciation is also extended to Professor Jospeh Ponte and Dr. Dale Eustace for serving on his graduate committee.

The author gratefully values the assistance of Prof. H. C. Fryer of the Statistics Department in the experiment design.

The author owes greatly to each and every member of the Grain Science and Industry Department for their understanding and accepting him as a part of this wonderful group and making his stay pleasant and rewarding.

Finally the author would like to thank his wife and his parents for their encouragement and confidence.

# INTRODUCTION AND REVIEW OF LITERATURE

Air stabilization is a very broad subject to discuss and can include almost anything we want to mention in connection with a flour mill.

It seems generally that not too much attention is given by the millers throughout the world to this extremely important factor on the milling operation. On the other hand, most of the experiments and investigations into this subject have been carried out largely by American investigators. This might be due to the wide variation in the atmospheric conditions all year around in the United States.

Recently, there has been an apparent lack of research on this subject, which makes it very necessary to achieve this research and let it be another step toward finding those facts behind the influence of relative humidity on milling operations and processes.

It is essential to know something about the history of "Air stabilization: and the meaning of this term. Kice (15) indicated that millers have long been aware of the influence of air on their milling processes. At first, they were mainly concerned with humidity. Accordingly, an installation using one of the early Carrier air washers as a central humidifier was found in the Wichita Flour Mills 50 years ago. The same humidity system during that period was carried out in many mills. Recently, air stabilization system has become more popular among the mills in U.S.A. and some mills around the world, like in Saudi Arabia (15).

The term air stabilization might lead to the misunderstanding that means cooling units to keep the millers comfortable in the summer. Kice (16) mentioned that actually the term originally meant "complete control of air temperature and humidity and purity and movement - all year around."

It has long been known the significance of relative humidity on milling operations. Guthrie and Norris (8) considered that flour moisture and total yields depend more on atmospheric conditions in the mill than upon the moisture content of the wheat. Miller (25) indicated that control of moisture in mill stocks is actually a problem of controlling the deficiency of moisture in the air in contact with these stocks. He found that high air temperatures produced high evaporation losses and made proper conditioning of the air difficult.

Ferguson (11) considered that the commercial mill worked best when the conditioned air was kept between $65^{o}$ and $70^{o}$F during the winter months and as cool during the summer as well water could make it. Conditioning the air increased the capacity during the summer months. Henkle (14) observed during a 10-month operating period that the temperature ranged from $72^{o}$ to $84^{o}$F, with an average relative humidity of 62%. He observed that evaporation from mill stocks during milling was twice as great during the summer as in the winter. Cooling by roll, purifer, and elevator suction was considered mainly due to evaporation. Pence (38) found that there may be a large loss in the moisture content of the wheat entering the first break rolls when the relative humidity is low. Moisture is absorbed by some stocks when relative humidities in the millrooms are maintained higher that 65%. Also, he indicated that little changes in bolting capacity resulted concerning the variation in size of openings in silk bolting cloth due to changes in humidity.

Arnold (6), regarding the air conditioning in the commercial mill, considered that the most important part was the removal of excessive heat. He maintained his roll floor at 78$^{o}$F and 55% RH. Melvin (22) considered the best winter temperatures in the mill building of 60$^{o}$ - 70$^{o}$F and found that higher temperature necessitated compensation through decreased rate of feed to the first break rolls.

Some millers prefer relatively low humidities in the millrooms. Thus, Arnold (6) quotes May as preferring 40% RH or lower. Robbins (39) also considered 40% a desirable relative humidity for mill rooms. Vilm (45) mentioned that controlling the temperature of mill stocks and relative humidity within the roll stands was equally as important as controlling the atmospheric conditions in the mill rooms.

Everybody who works in a flour mill might note the enormous influence caused by moisture on the milling operations, even if there is relatively small change. Concerning the effects of evaporation from wheat and mill stocks on the processes of milling, Kautz (17) concluded that the effect of the rate of evaporation from mill stocks on the maintenance of the stocks in the best condition for milling depends so much on humidity conditions that the length of temper, the temperature of tempering, and even the temperature due to grinding have little influence compared with that of humidity conditions. Anderson (2) believed that more heat must be removed from the rolls and stocks by evaporation than by radiation; otherwise, temperature far above practical limits would be attained by stock and rolls. During milling, the moisture content of various stocks tends toward equilibrium with the moisture of the surrounding environment, and variations in moisture content affect the yield of products materially. Shollenberger (40) showed that by using a small experimental mill in which the humidity of atmosphere was controlled, for each 10% increase in RH above 35%,there was an average increase of approximately 0.5% in the total weights of milling products. He found no apparent relationship between air temperature and yield of products, so he concluded that humidity was a minor factor of importance. Also,he indicated that there is no relationship between flour moisture and amount of added tempering water. Frank (12) opposed this, finding that moisture added to commercial mill mixes influenced the moisture content of the flour milled.

Considerable work has been reported upon the equilibrium relative humidities of wheat and flour; in one of the investigations (27) the following table has been published:

| Relative Humidity % | Equilibrium Moisture % |
|---|---|
| 30 | 9.5 |
| 40 | 11.0 |
| 50 | 12.0 |
| 60 | 13.5 |
| 70 | 14.0 |
| 80 | 16.0 |

Among others, Frank (13) indicated that if 5 lb packs exposed to a relative humidity near the equilibrium figure of 60% change in weight by about .1% during a period of eight week's storage but lost about 1.7% in weight in three days when RH of the environmental atmosphere was reduced to about 45%. Anderson (3) found a change of about 5% in equilibrium humidity for each 0.9% change in wheat moisture. Working with hard wheat he found the following relationship:

| Relative Humidity % | Moisture in Wheat % |
|---|---|
| 50 | 12.0 |
| 60 | 13.75 |
| 70 | 15.6 |

Anker, Geddes, and Bailey (5) found that if the flour was stored at a relative humidity much below the equilibrium level the moisture can be lost rapidly, but if the opposite happened, the flour will have reabsorbed the moisture but not in the same rate. Also, they showed that the flour moisture was affected by both relative humidity and temperature of air in the storage room.

One of the best studies upon the effect of temperature and relative humidity on experimental flour yields and flour properties had been accomplished by Bayfield, Anderson, Geddes, and Hildebrand (8). They found that relative humidity is reponsible for greater changes in flour characteristics during milling than air temperature. A series of milling tests were carried out on a Buhler laboratory mill (*) and Allis-Chalmers batch-type mill in which the stocks are handled manually. Two varieties of wheat were milled in duplicate on each of two mills at millroom temperature of 70$^{o}$, 80$^{o}$, and 90$^{o}$F and at 40, 50, 60, 70, 80 and 90% relative humidity at each temperature level. Flour yield values were computed as percentage of straight grade flour. Bayfield and _et al_. (8) indicated that higher relative humidity lowers milling loss and reduce the ash content of flour, while lower relative humidity makes sifting easier and

*It is continuous - flow, enclosed, automatic type of experimental mill but not pneumatic as the one used in this research.

improves extraction, although it increases milling loss.

Air conditioning is not in very great use in Britain (20). It has been stated earlier that 65$^{\circ}$F and 60% are the optimum temperature and humidity for milling in that country (20). Lockwood (20) pointed out the advantages of controlling the humidity and temperature in the mill as following: 1) Mill will run more regularly; 2) Less sweating and pasting up of silks; 3) Mill loss will be reduced; 4) The mill will be a more pleasant place in which to work; 5) Insect pests will be more easily controllable. Murray (35) accomplished another important investigation in Britain upon the influence of atmospheric humidity on mill operations. He reported (35) that controlled conditions of atmospheric conditions do not appear to be practiced in flour mills in Europe, except perhaps in one or two isolated cases. Several mills have installed modified plants largely for the purpose of air filtration and forced ventilation. Murray (36) pointed out that when the phenomenon of electrification in sifting becomes severe, processers are sometimes brought to a standstill and this can only be avoided by controlled atmospheric humidity level. Also,he concluded (37) that : a) to obtain the ideal conditions of clean air evenly distributed throughout the mill at constant and controlled temperature and humidity all year round, a complete air conditioning plant of the Central Station type with air distribution trunking is recommended,and this will give the most effective assistance in attaining regularity and improved quality of mill; b) When the extent of capital expenditure is limited or structural problems are existed, it can be used a simple system of filtering and forced ventilation of air to improve atmospheric conditions in the mill. They result in cooler stocks and consequent better dressing and provide dust free and more hygenic products.

In West Germany Kuhn (18) also pointed out the significance of relative humidity control and how we should pay more attention to it. He recommended using the impregnated cellulose-hydrate foils as the most suitable method for controlling relative humidity in each floor of the mill. Atmospheric humidity control is important, too, in offices and conference rooms. As Kuhn mention, it has been physically demonstrated that human beings are at their most comfortable in atmospheres with a relative humidity between 60% and 75% when they are doing manual work and of about 55% for mental work.

It seems that a relatively wide range of humidifiers has been used in various investigations which were carried out in the United States. Bayfield et al. (8) used 40, 50, 60, 70, 80, 90% relative humidity, Singh and Bailey (41) used 85%-90%, Bergsteinson, and Hadley (9) used 70%, and McCluggage (21) 50%. Less attention seems to have been given mill room temperatures (8).

Micka and Vrana (23) studied the influence of humidity and temperature upon sifting. The obtained the best results at $70^{o}F$ and 70% RH.

It is well known to millers that the moisture is one of the most important factors concerning wheat and flour, simply because it is playing an extremely important role during milling operations. First, there is the economic aspect (28). Obviously the lower the moisture level of the wheat when purchased, the greater will be the grain in bringing it up to normal milling moisture (28). Second, moisture is of prime importance in regard to the keeping qualities of the grain.

Moisture also has enormous effects in the actual milling. High moisture in the wheat and mill stocks causes more sluggishly flow down spouts and hoppers (29). Also it is noted that the flow of stock is greatly affected by atmospheric humidity. As mentioned (29), on sticky, humid days, especially during hot weather, the feeds to the coarse lower breaks, also the fourth break and certain other low grade flours, continually tend to back up, and if left untended for any length of time, are likely to cause a formidable choke. Wheat with higher moisture reduces the power because its potent effect on the way in which the wheat breaks down, but the power per sack of flour may rise if the moisture is increased (29).

When the moisture is increased (30) in wheat or atmosphere, there will be a tendency for flour extraction to drop. Flour regularity is one of the most important flour quality characteristics favored by the bakers (31). This characteristic (31) is affected by the moisture and extraction percent. Therefore, controlling those two factors will greatly help control the flour regularity.

The relationship between wheat and flour is not always only affected by the moisture percent in the wheat. Actually, many factors are causing these effects. The way in which the water is added and distributed in grain, what happens in milling, and the atmospheric conditions have all considerable influence on the moisture contents of the flour (32).

From the miller's viewpoint moisture has three main aspects: a) its operational effect b) its effect on flour quality, and c) its economical value (33). On the other hand, high moisture tends to make milling more difficult. Stocks will become more difficult to break down and flow, and also do not sift so freely. So, obviously, the moisture test is one of the most important tests in milling and should be given enough attention and done accurately (34).

It has been realized that the moisture content of a flour is not a fixed characteristic like its protein or its fiber content (27). So, it is not unusual to find some changes in the weight of flour in the pack after a period of time.

Another study has been carried out (42) to determine the relative humidity of the air over wheat which has been tempered to different moisture contents and, also, th determine what effect time after tempering has on the relative humidy over the wheat at the different moisture contents. The conculusions were that the relative humidity over the wheat has become practically constant after 16 hrs have elapsed, while not too much change has taken place between 8 and 16 hrs after tempering.

The use of air in milling increasing very fast happens mainly because of those advantages of using the pneumatic system over the conventional type. Abbott (1) reported those advantages as: 1) high efficiency, 2) improved bolting, 3) better infestation control, 4) less building costs. But, the main disadvantage he mentioned is the necessity to temperature and humidity control because the possibility of evaporation from mill stock occurs whenever the moisture content of the stock exceeds the equilibrium value which is determined mainly by the relative humidity of the surrounding air

Lanzrein (19) mentioned that today's higher specific loads on all the equipment do not allow for too many outside influences and the added heat results in condensation and unsanitary conditions in the plant.

Experimental milling (26) of small samples of wheat is accomplished with a wide variety of equipment and with a wide variety of purposes. Pneumatic experimental mills are used to get conditions and results approximately similar to those in the commercial mill. A milling in a non-pneumatic and non-continuous flour mills also was taken place for comparing the effects which were caused by relative humidity. Bayfield et al. (8) mentioned that it may be expected that the stocks within the milling machines are exposed to both warmer and more moist air than within the mill building for at least a major portion of the time during the milling operation, because moistened (tempered or conditioned) wheat is fed into the system continuously and heat is generated by the milling machine. Also, they reported that the principal purposes of experimental milling are to find how a wheat may be expected to mill commercially without carrying out a large-scale test on the commercial plant and to obtain a sample of flour which will be representative of flour which would be produced from the wheat if it were milled commercially.

Anderson (4), in making a comparison of experimental and commercial milling results, showed that commercial units used a greater number of grinding operations for reducing the endosperm to flour. With the experimental laboratory mills, i.e., Buhler, Allis-Chalmers, etc., with small number of grinding operations, the grain was subjected to more severe grinding than was practical in the commercial mills with 5 to 6 breaks. According to Miller (24) "the purpose of experimental milling is no more than the gathering of evidence concerning the characteristics of given small samples of wheats." It has been concluded by Bailey and Markley (7) that Buhler mill is useful for predetermining the commercial milling.

This study is a continuation of many studies which had been carried out in the department of grain science & industry at Kansas State University for several decades and about different subjects. The main purposes of this study are: 1) To find out whether variation in relative humidity affects flour extraction, ash, protein, moisture, and milling operations; 2) To find out if optimum RH% for milling can be recommended; 3) To conclude whether it is important to have air stabilization unit in the mill or not.

# MATERIALS AND METHODS

HRW wheat for the entire experiment was cleaned on laboratory separator and stored in large metal containers in form of 5 kgs bags. Analytical data for this wheat is given in Table 1.

Four different kinds of mills were used. Two of them were pneumatic (Multomat and Buhler mills) and two non-pneumatic (Quadrumat Jenior and Quadrumat Senior mills). The reasons for that were: 1) To see the effect of the relative humidity more clearly when the air was used in the mill; 2) Most of the mills today are pneumatic which can give a better idea about what is going on in the most of the commercial mills.

The wheat was milled in triplicate on each of four mills at relative humidity 40, 50, 60, 70%, also at RH 80 and 90% on Buhler and Quadrumat Senior mills.

The subsample was withdrawn for each milling and tempered to 16% by adding water and allowing the sample to stand for 24 hours at the room temperature.

Table 1. Analysis of Wheat

| Test Weight | 1000 Kernel Weight | Moisture % | Protein % | Ash % |
|---|---|---|---|---|
| 59.75 | 33.8 | 12.5 | 11.7 | 1.8 |

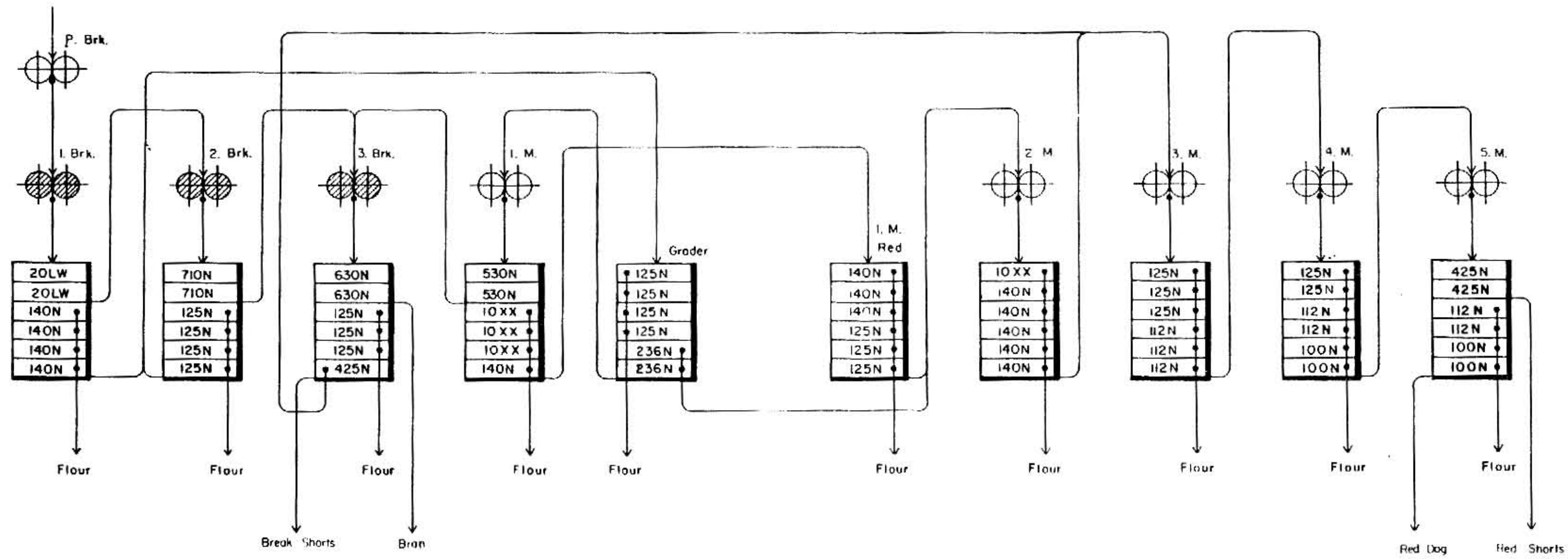
The samples were milled on a Multomat and Buhler mills (representative of the pneumatic, continuous-flow, automatic type of experimental mills) and also on Quadrumat Senior and Quadrumat Jenior (representative of the non-pneumatic. Specifications for these mills are shown in Figures: 1-1, 1-2, 2-1, 2-2, 3-1, 3-2, 4-1, 4-2.

Atmospheric conditions in the millroom were maintained within approximately $\pm 2^{0}$ RH by means of humidifier unit suspended near the ceiling and dehumidifier unit fixed on the bench. The readings for relative humidity were obtained by using the sling psychrometer. It gives the reading for wet and dry bulb thermometer, then by using psychrometric chart we can get that particular relative humidity.

About 12 hours before milling, the controls were brought into approximate adjustment for the conditions desired. A "warm-up" sample was milled on each mill before starting the actual milling so that final adjustment could be made up and the room conditions brought to equilibrium.

At the end of each day the flour samples were held in cold storage until they were taken to the laboratory for chemical analysis.

Protein, ash, and moisture determinations were made in triplicate. The results of protein and ash were corrected to 14% moisture basis.




| BOLTING CLOTH | |
|---|---|
| OPENING μ | NEAREST EQUIV. |
| 710 | 28 SS |
| 630 | 32 SS |
| 530 | 34 TT |
| 425 | 46 GG |
| 236 | 70 GG |
| 180 | 8 XX |
| 160 | 9 XX |
| 140 | 10 XX |
| 125 | 11 XX |
| 112 | 12 XX |
| 100 | 13 XX |

| ROLL CORRUGATION | | | |
|---|---|---|---|
| | SIZE (inch) | CORR. | ACTION |
| 1ST BREAK | 10" x 4" | 12 MD | D to D |
| 2ND BREAK | 10" x 4" | 16 MD | D to D |
| 3RD BREAK | 10" x 4" | 24 MD | D to D |

Fig. 1-1

K.S.U.

FLOW SHEET FOR MIAG MULTOMAT

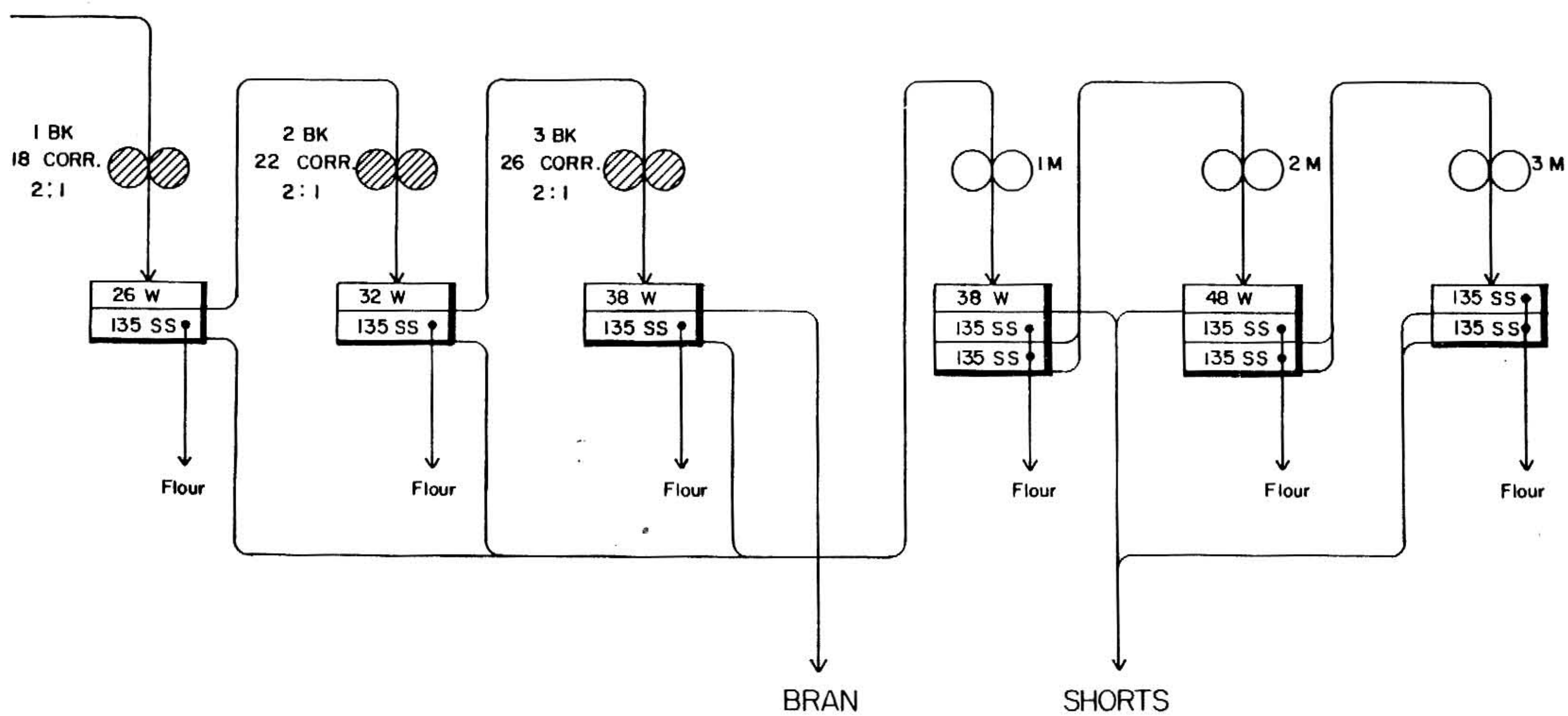
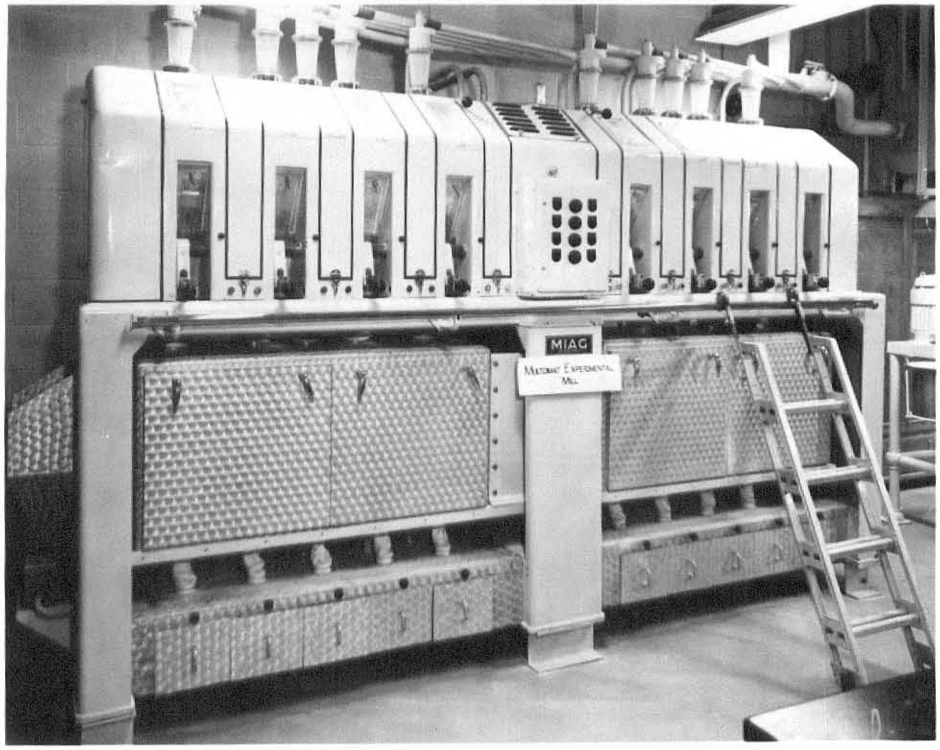


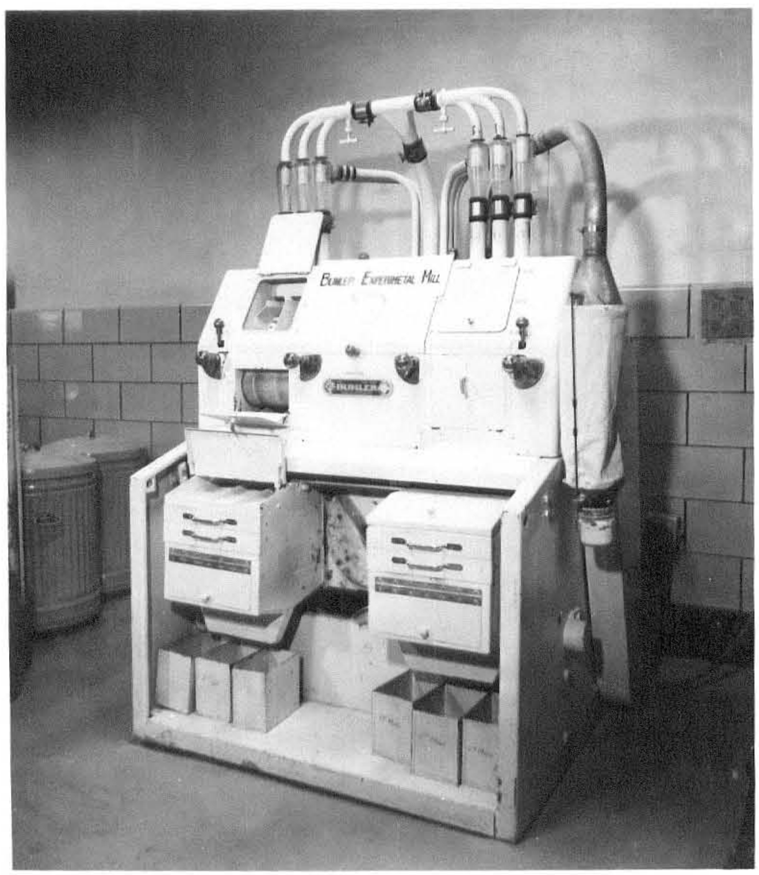

Fig. 2-1. BUHLER EXPERIMENTAL MILL

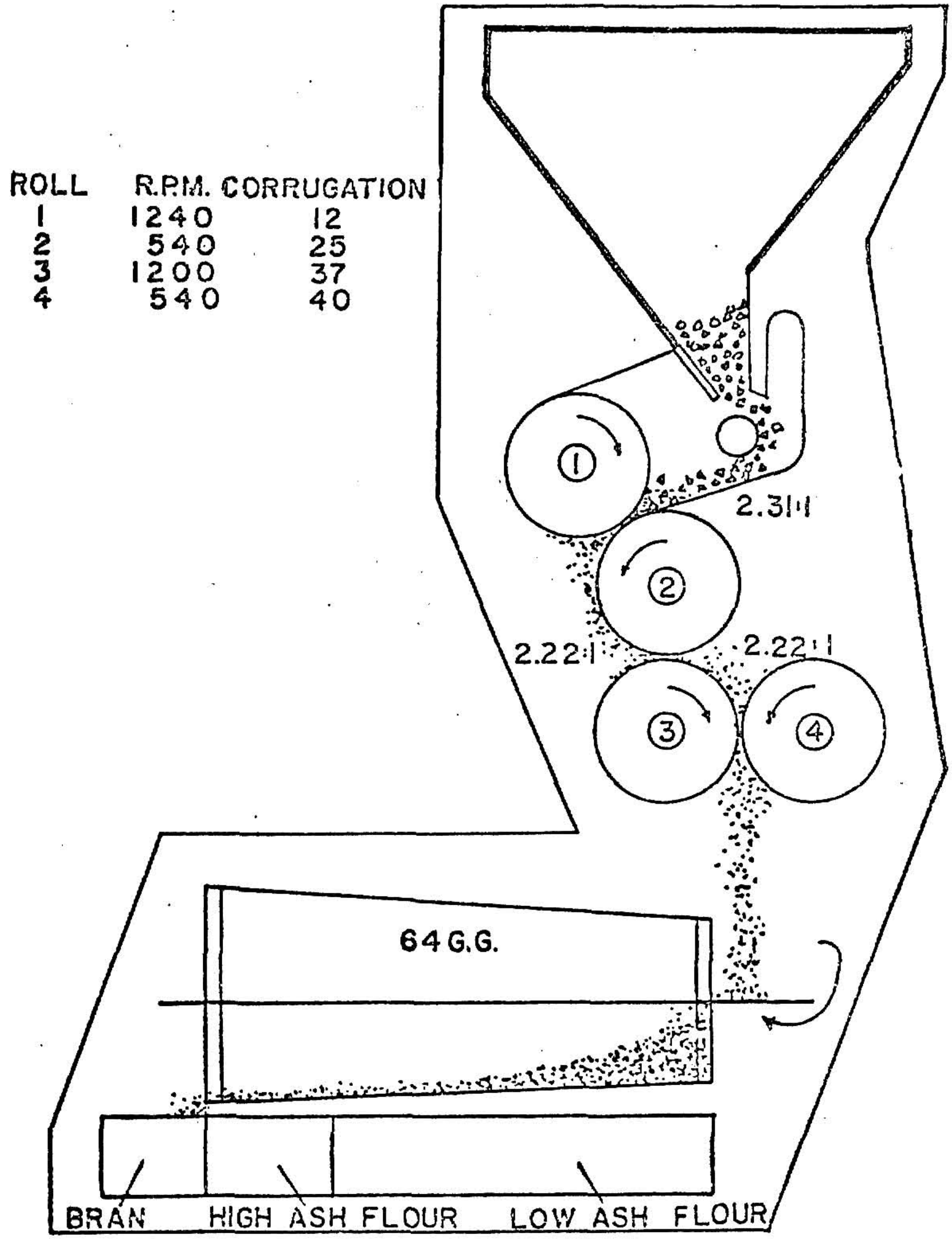
PNEUMATIC MILLS

Fig. 1-2. Miag-Multomat Mill

Fig. 2-2. Buhler Mill


MIAG






QUADRUMAT JUNIOR EXP. MILL

Fig. 3-1

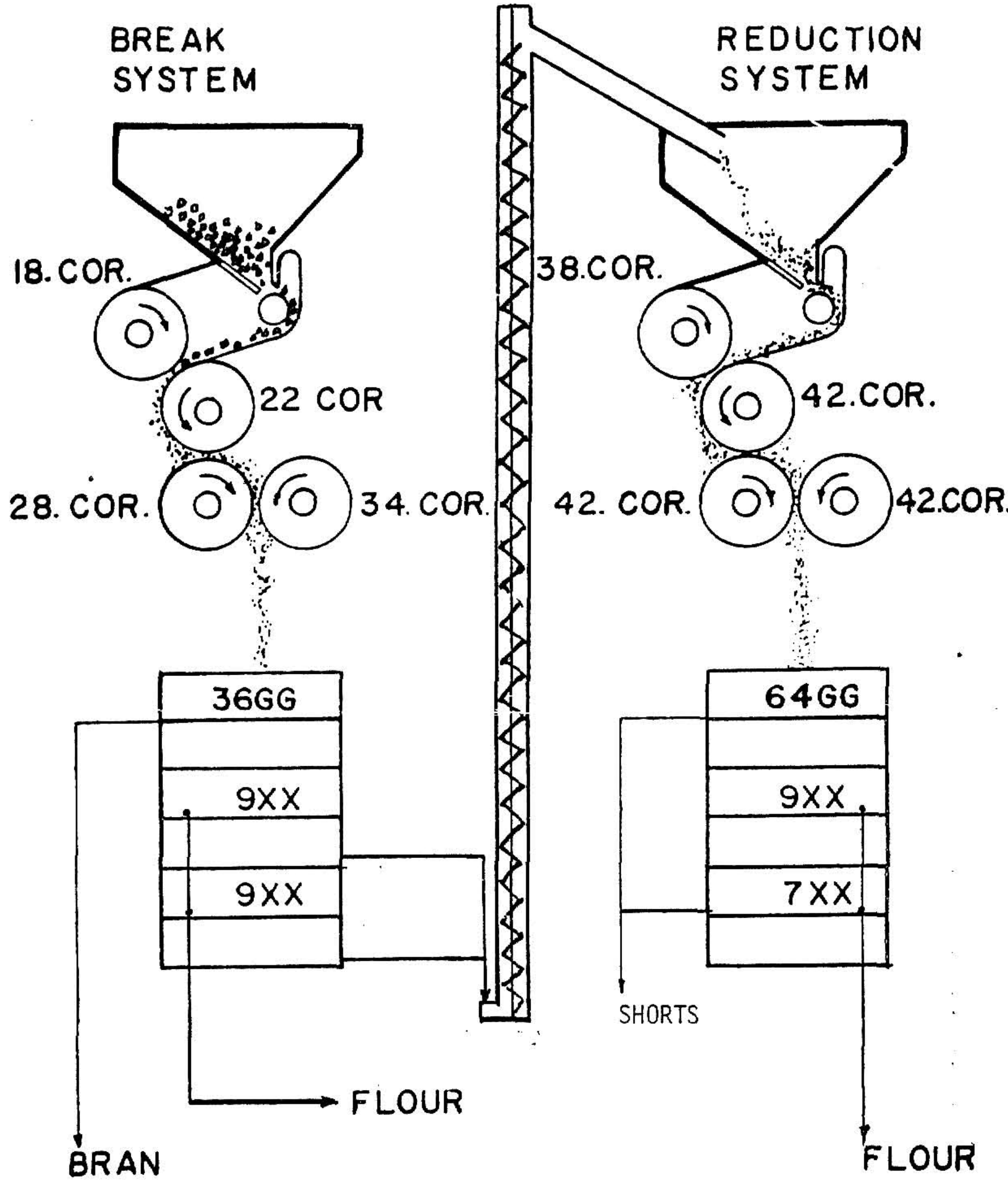
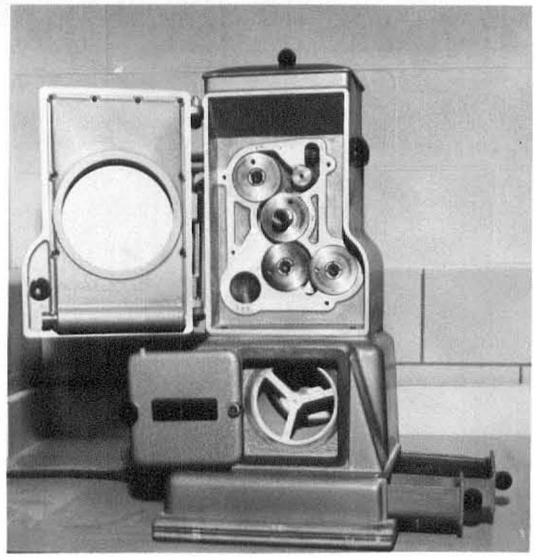


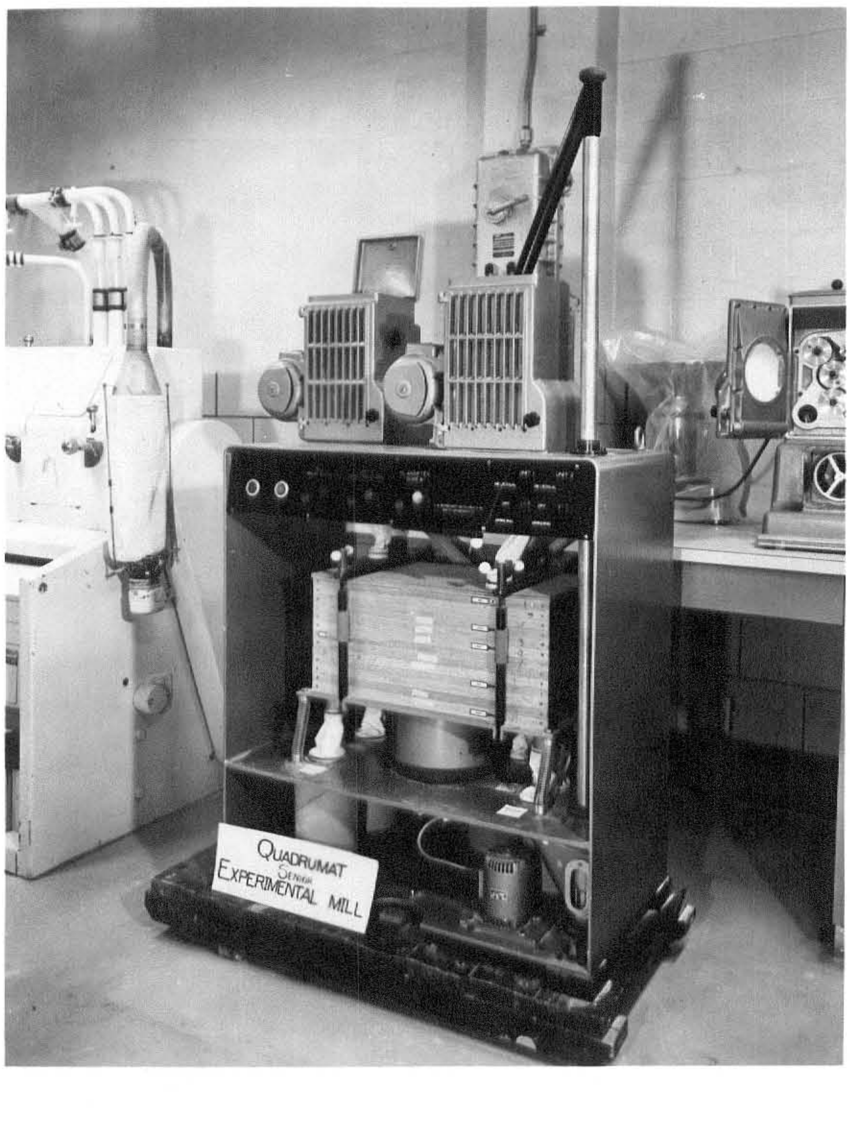

Fig. 4-1. QUADRUMAT SENIOR EXP. MILL

## NON-PNEUMATIC MILLS

Fig. 3-2. Quadrumat Jr. Mill

Fig. 4-2. Quadrumat Sr. Mill




QUADRUMAT
SENIOR
EXPERIMENTAL MILL

Results:

The data obtained have been submitted to statistical analyses. For these analyses, results obtained in triplicate for each mill, means, standard deviations are calculated and the correlation coefficients are computed. The mean values, standard deviations for flour extraction, milling loss, moisture, proteins and ash of all flour streams, are tabulated.

1) Flour Extraction: Results and statistical data are shown in Table II. The Buhler and Miag-Multomat mills gave a much higher yield than the Quadrumat Sr. and Quadrumat Jr. Mills. This is due to incomplete clean-up of bran and presence of unreduced middlings found during rebolting which were not included in the flour weight. With Buhler and Miag-Multomat mills the yield decreased markedly with increasing millroom humidity (See Fig. 5). The effect of humidity on the stocks was very clear with these mills because these are pneumatic type mills and use air for transporting stocks from one stage to the other. When the humidity conditions are changed in the room, it affects humidity of air in the room and, therefore, the stocks. But, when Quadrumat Sr. and Quadrumat Jr. were used, no significant effect was observed in the data of analyses. This is due to the reason that these mills do not use air to transport stocks within the system, and so variation in humidity of the room does not have any significant effect on the milling.

These mills which have a tendency for flour extraction to drop when humidity in the atmosphere is increased can have many causes.

Table II. Results of the Influence of RH% on Flour Extraction and the Statistical Data.

| Mill | RH% | Sample No. 1 | 2 | 3 | Average | Standard Deviation |
|---|---|---|---|---|---|---|
| Miag-Multomat | 40 | 71.91 | 71.86 | 72.36 | 72.04 | .27 |
| | 50 | 72.00 | 71.88 | 71.75 | 71.88 | .12 |
| | 60 | 71.36 | 71.20 | 71.87 | 71.48 | .35 |
| | 70 | 71.14 | 71.59 | 71.18 | 71.30 | .25 |
| | Mean | | | | 71.67 | |
| | Standard Deviation | | | | .34 | |
| | Correlation Coefficient | | | | - .98 | |
| Buhler | 40 | 72.64 | 72.29 | 72.77 | 72.55 | .25 |
| | 50 | 71.63 | 71.03 | 71.68 | 71.45 | .36 |
| | 60 | 70.61 | 70.35 | 70.09 | 70.35 | .26 |
| | 70 | 70.15 | 70.02 | 70.07 | 70.08 | .065 |
| | 80 | 67.89 | 67.37 | 67.50 | 67.59 | .27 |
| | 90 | 66.89 | 67.14 | 67.06 | 67.03 | .13 |
| | Mean | | | | 69.89 | |
| | Standard Deviation | | | | 2.16 | |
| | Correlation Coefficient | | | | - .98 | |
| Quadrumat Jr. | 40 | 61.04 | 61.04 | 60.64 | 60.90 | .08 |
| | 50 | 60.69 | 60.56 | 61.04 | 60.76 | .24 |
| | 60 | 61.04 | 60.60 | 60.84 | 60.83 | .22 |
| | 70 | 61.04 | 61.04 | 60.80 | 60.94 | .11 |
| | Mean | | | | 60.85 | |
| | Standard Deviation | | | | .09 | |
| | Correlation Coefficient | | | | + .40 | |
| Quadrumat Sr. | 40 | 65.92 | 65.99 | 65.58 | 65.83 | .22 |
| | 50 | 65.72 | 65.78 | 65.59 | 65.70 | .10 |
| | 60 | 65.88 | 66.12 | 65.65 | 65.88 | .23 |
| | 70 | 66.07 | 65.93 | 66.00 | 66.00 | .07 |
| | 80 | 65.92 | 65.86 | 65.93 | 65.90 | .04 |
| | 90 | 65.78 | 65.75 | 65.86 | 65.80 | .06 |
| | Mean | | | | 65.85 | |
| | Standard Deviation | | | | .10 | |
| | Correlation Coefficient | | | | + .27 | |

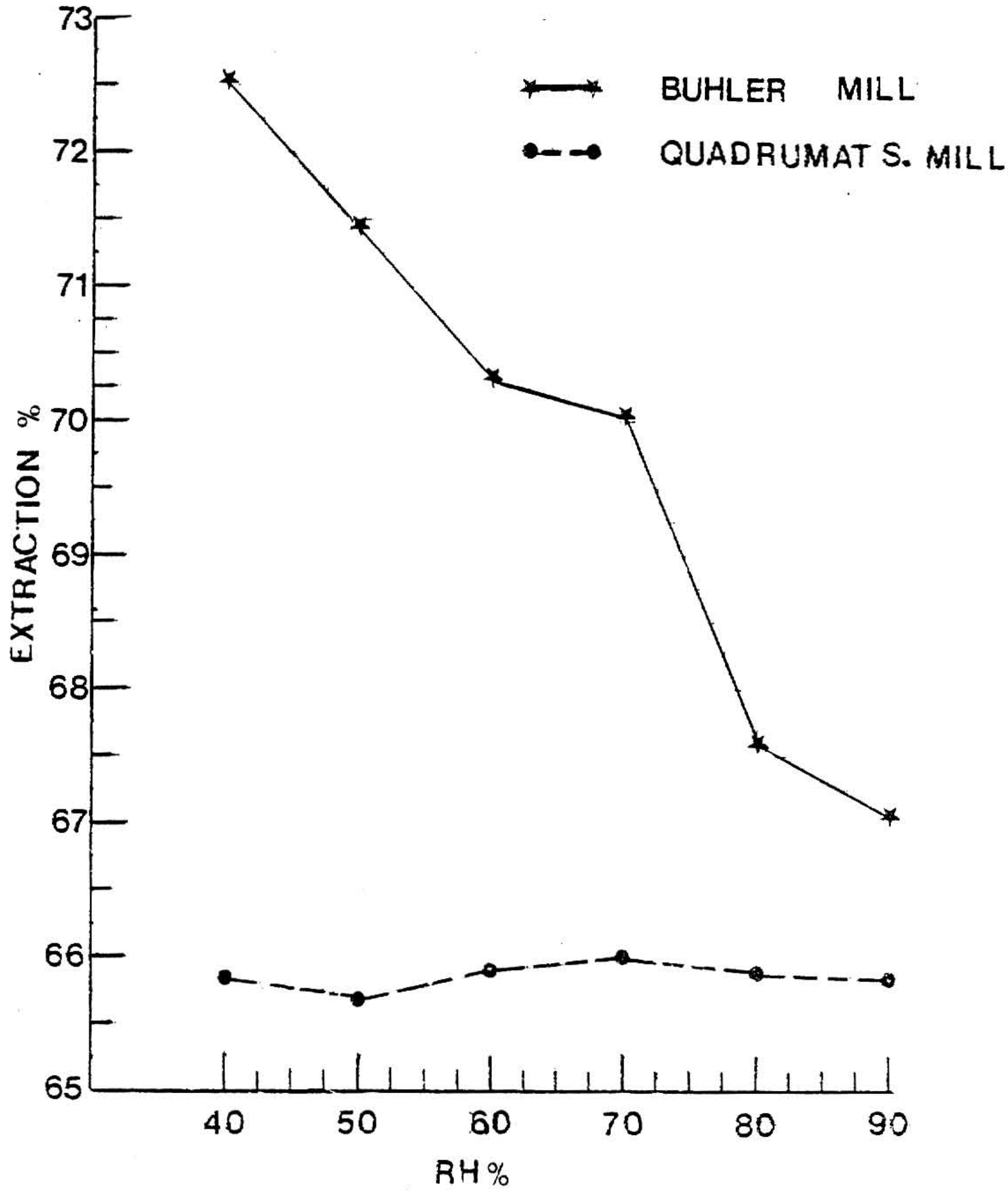



Fig. 5. THE EFFECT OF RELATIVE HUMIDITY ON MILLING EXTRACTION.

This is due (30) to the tendency for the wheat fragments to remain more whole and for generally reduced rates of sieving, the trend towards a lower percentage of throughs from nearly every sieving operation is natural. Another reason for reducing sieving rate is that flour particles tend to cohere and pass less readily the meshes of the sieves (30).

2) Moisture Content: Referring to Tables III-A, III-B, III-C, III-D it will be seen that the Buhler and Miag-Multomat milling stocks showed a clearer effect because of the variation in humidities than the Quadrumat Sr. and Quadrumat Jr. did. This difference may be accounted for by the relatively greater exposure of the stocks to the atmosphere where pneumatic system was used in the case of Buhler and Miag-Multomat mills.

Taking the results for those two mills, stocks moisture increased with increasing humidity in the millroom.

It is known that moisture not only leaves the air and enters the solid material. This exchange of moisture is continuous under all humidity conditions. As it was reported by Anderson (4) there are three possible conditions relative to the amounts of moisture which are exchanged:

1. When the amount of moisture leaving the mill stocks is greater than the amount which returns.

2. When the amount of moisture returning to the stocks is greater than that which is leaving.

3. When the amounts leaving and returning are equal.

Table III-A. The Effect of Relative Humidity on Moisture Content.

| MIAG MILL | Relative Humidity | | | |
|---|---|---|---|---|
| Stream | 40% | 50% | 60% | 70% |
| 1BK | 14.4 | 14.7 | 14.7 | 15.0 |
| 2BK | 13.8 | 13.8 | 14.8 | 15.3 |
| GR | 12.9 | 14.0 | 14.6 | 15.1 |
| 3BK | 12.5 | 12.9 | 14.0 | 14.5 |
| 1 M | 12.1 | 13.5 | 14.5 | 14.6 |
| 2 M | 13.4 | 13.5 | 14.1 | 14.4 |
| 3 M | 13.3 | 13.0 | 13.8 | 14.0 |
| 1 $M_{Red}$ | 13.1 | 13.5 | 14.0 | 14.2 |
| 4 M | 12.5 | 12.0 | 13.2 | 13.5 |
| 5 M | 11.6 | 11.0 | 12.5 | 12.6 |
| R.D. | 10.6 | 10.8 | 12.0 | 12.2 |
| Red. Sh. | 10.5 | 10.6 | 11.8 | 12.0 |
| Bk. Sh. | 13.3 | 13.0 | 14.1 | 14.3 |
| Bran | 13.7 | 13.9 | 15.1 | 15.7 |

Table III-B. The Effect of Relative Humidity on Moisture Content.

| BUHLER MILL STREAM | Relative Humidity | | | | | |
|---|---|---|---|---|---|---|
| | 40% | 50% | 60% | 70% | 80% | 90% |
| 1BK | 13.8 | 13.9 | 14.1 | 14.7 | 15.4 | 15.8 |
| 2BK | 12.7 | 13.8 | 13.8 | 14.2 | 15.5 | 15.5 |
| 3BK | 11.4 | 12.1 | 12.4 | 13.7 | 14.8 | 15.8 |
| 1M | 13.4 | 13.6 | 13.8 | 14.7 | 14.8 | 15.7 |
| 2M | 11.7 | 12.5 | 12.5 | 13.6 | 14.0 | 14.9 |
| 3M | 11.5 | 12.3 | 12.4 | 14.1 | 14.5 | 15.3 |
| Shorts | 10.4 | 11.9 | 12.4 | 12.6 | 14.1 | 16.0 |
| Bran | 13.1 | 13.9 | 14.1 | 14.6 | 17.0 | 17.3 |

Table III-C. The Effect of Relative Humidity on Moisture Content.

| QUADRUMAT JR. STREAM | 40% | Relative Humidity 50% | 60% | 70% |
|---|---|---|---|---|
| Flour | 15.7 | 15.8 | 15.6 | 15.7 |
| Bran | 16.0 | 16.2 | 16.1 | 16.0 |

Table III-D. The Effect of Relative Humidity on Moisture Content.

| QUADRUMAT SR. STREAM | 40% | 50% | Relative Humidity 60% | 70% | 80% | 90% |
|---|---|---|---|---|---|---|
| BK-FL | 15.4 | 15.4 | 15.3 | 15.3 | 16.0 | 15.8 |
| Red.-FL | 15.6 | 15.5 | 15.4 | 15.4 | 15.7 | 16.0 |
| Shorts | 14.1 | 14.0 | 14.2 | 14.2 | 15.4 | 15.7 |
| Bran | 15.9 | 16.2 | 16.1 | 16.0 | 16.8 | 17.0 |

The results of Buhler and Miag-Multomat Mills can be explained according to those three positions which are mentioned above. If more moisture leaves or evaporates from the stocks than the amount which returns to them, the stocks become dry because of the unequal rates of exchange (3). The second condition exists when moisture is returning to the mill stocks at a faster rate than moisture is escaping from the mill stocks into the air. This second condition exists when there is such an amount of moisture in the air surrounding the stock that the net result is absorption of moisture out of the air by the solid material or mill stocks (3). The third condition exists when equal amounts of moisture are exchanged between the mill stocks and the surrounding air. Moisture leaves the stock and enters the air. Moisture also leaves the air and enters the stock, particle for particle, so that no change occurs in the amount of moisture present in either the stock or the surrounding air.

The figures for relative humidity alone do not give the true picture. To see just what changes in moisture have taken place it will be necessary to consider the actual moisture content or the absolute humidities. From the psychrometric table and chart the actual grains of moisture present per 1 pound of dry air in saturated mixture foot under the temperature and humidity conditions can be known and are given in Table IV.

In Miag-Multomat, the calculated (44) amount of air which was used per 1 pound of milled wheat was 11.6 lb of air/1 lb of wheat, while in Buhler mill was 12.7 lb of air/1 lb of wheat. The grains of moisture for each mill found to be the same for all its streams. This may be due to having the same pipe diameter and velocity pressure in that particular mill.

Table IV. The Amount of Grains Moisture/1 lb air (Pneumatic Mills):

| | Relative Humidity | | | | | |
|---|---|---|---|---|---|---|
| | 40 % | 50 % | 60 % | 70 % | 80 % | 90 % |
| 1) Miag-Multomat | | | | | | |
| Temp. ($F^o$) | 68 | 75 | 75 | 74 | | |
| Density of air lb/CF | .0745 | .0734 | .0734 | .0736 | | |
| Grains of Moisture/ 1lb dry air | 46 | 66 | 75 | 82 | | |
| Grains of Moisture/ 1lb dry air for each stream | 55.7 | 79.2 | 90.75 | 99.2 | | |
| 2) Buhler Mill | | | | | | |
| Temp. ($F^o$) | 77 | 75 | 74 | 69 | 71 | 70 |
| Density of air lb/CF | .0730 | .0734 | .0736 | .0740 | .0738 | .0739 |
| Grains of Moisture/ 1lb dry air | 56 | 68 | 74 | 78 | 92 | 100 |
| Grains of Moisture/ 1lb dry air for each stream | 51 | 62.6 | 67.3 | 71.8 | 84.6 | 92 |

3) Ash Content: From the data in Table V, it will show that Buhler mill produced flours of significantly higher average ash content than the Miag-Multomat mill, which is in accord with mill specifications.

Flour ash with both mills, decreased with increasing relative humidity. No significant relationship was shown between the flour ash and relative humidity when Quadrumat Sr. and Quadrumat Jr. mills were used (see Fig. 6, 7, 8, 9).

The decreasing of flour ash with increasing of relative humidity in the pneumatic mills is due simply to decreasing of flour yield under the same atmospheric conditions that are used for evaluating the ash content.

Table V. Results of the influence of RH% on Ash content (on 14% moisture basis) and the Statistical Data.

| Mill | RH % | Sample No. 1 | 2 | 3 | Average | Standard Deviation |
|---|---|---|---|---|---|---|
| Miag-Multomat | 40 | .401 | .425 | .417 | .421 | .006 |
| | 50 | .406 | .412 | .407 | .408 | .003 |
| | 60 | .366 | .391 | .382 | .386 | .006 |
| | 70 | .352 | .357 | .361 | .357 | .004 |
| | Mean | | | | .393 | |
| | Standard Deviation | | | | .028 | |
| | Correlation Coefficient | | | | -.98 | |
| Buhler | 40 | .494 | .504 | .510 | .503 | .008 |
| | 50 | .459 | .452 | .463 | .458 | .005 |
| | 60 | .441 | .451 | .445 | .446 | .005 |
| | 70 | .426 | .431 | .421 | .426 | .005 |
| | 80 | .425 | .423 | .421 | .423 | .002 |
| | 90 | .402 | .400 | .398 | .400 | .002 |
| | Mean | | | | .443 | |
| | Standard Deviation | | | | .036 | |
| | Correlation Coefficient | | | | -.96 | |
| Quadrumat Jr. | 40 | .458 | .442 | .448 | .449 | .008 |
| | 50 | .449 | .447 | .450 | .448 | .002 |
| | 60 | .456 | .448 | .447 | .450 | .005 |
| | 70 | .446 | .447 | .449 | .447 | .002 |
| | Mean | | | | .448 | |
| | Standard Deviation | | | | .001 | |
| | Correlation Coefficient | | | | -.40 | |
| Quadrumat Sr. | 40 | .367 | .370 | .361 | .366 | .004 |
| | 50 | .364 | .365 | .362 | .364 | .007 |
| | 60 | .368 | .363 | .363 | .365 | .005 |
| | 70 | .359 | .371 | .364 | .365 | .006 |
| | 80 | .360 | .366 | .366 | .364 | .006 |
| | 90 | .360 | .365 | .364 | .363 | .003 |
| | Mean | | | | .364 | |
| | Standard Deviation | | | | .002 | |
| | Correlation Coefficient | | | | +.10 | |

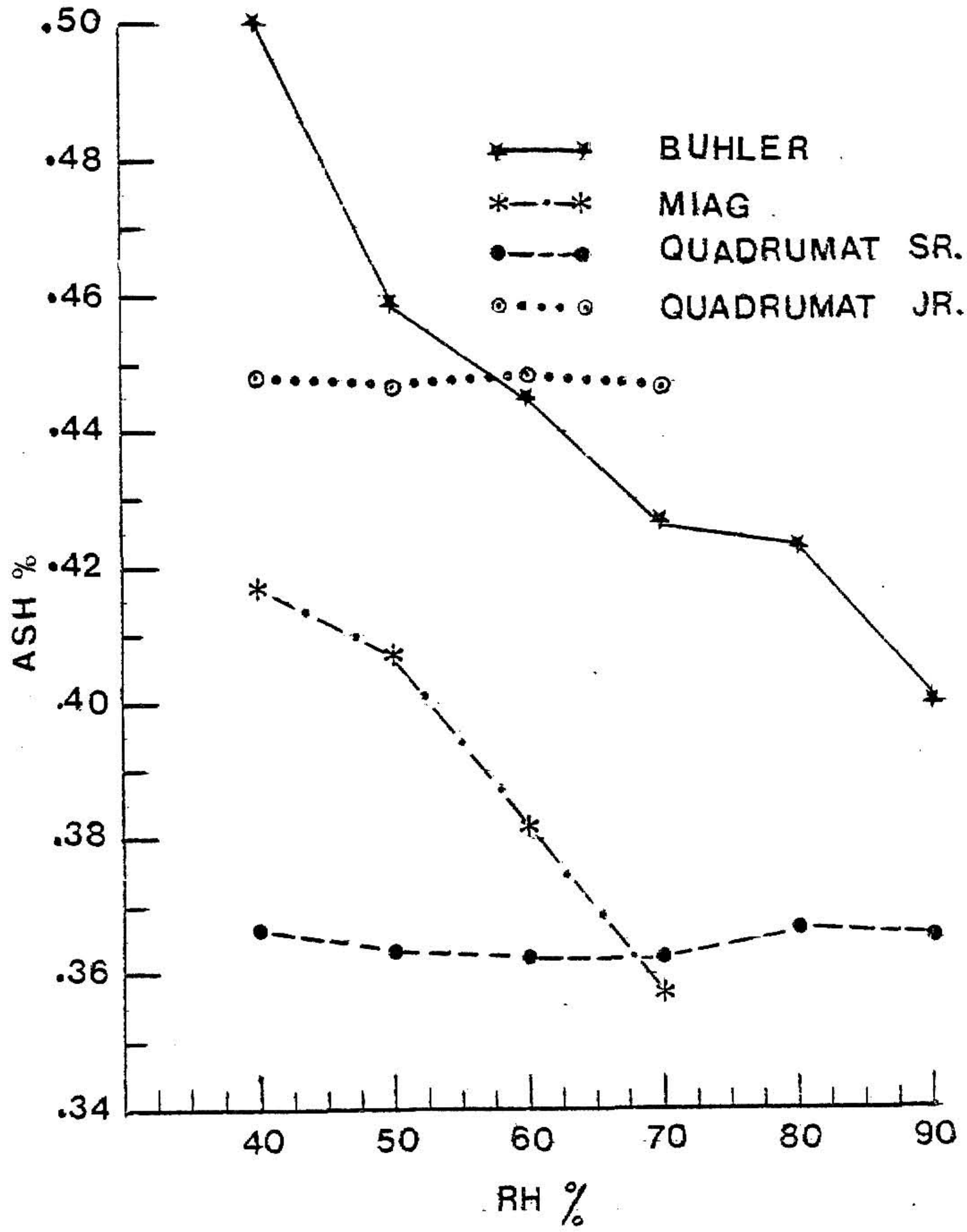



Fig. 6. THE EFFECT OF RELATIVE HUMIDITY ON ASH CONTENT

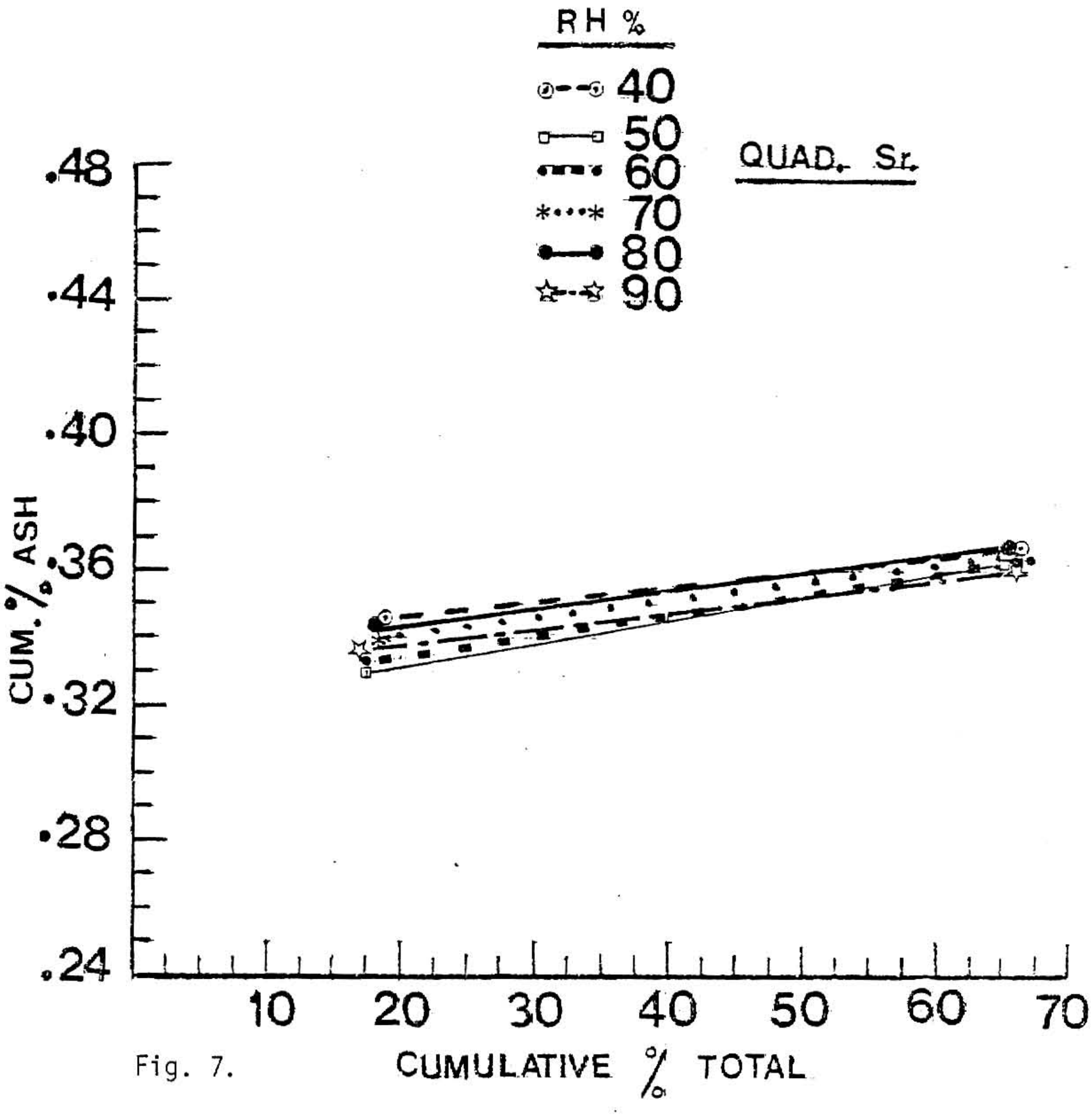
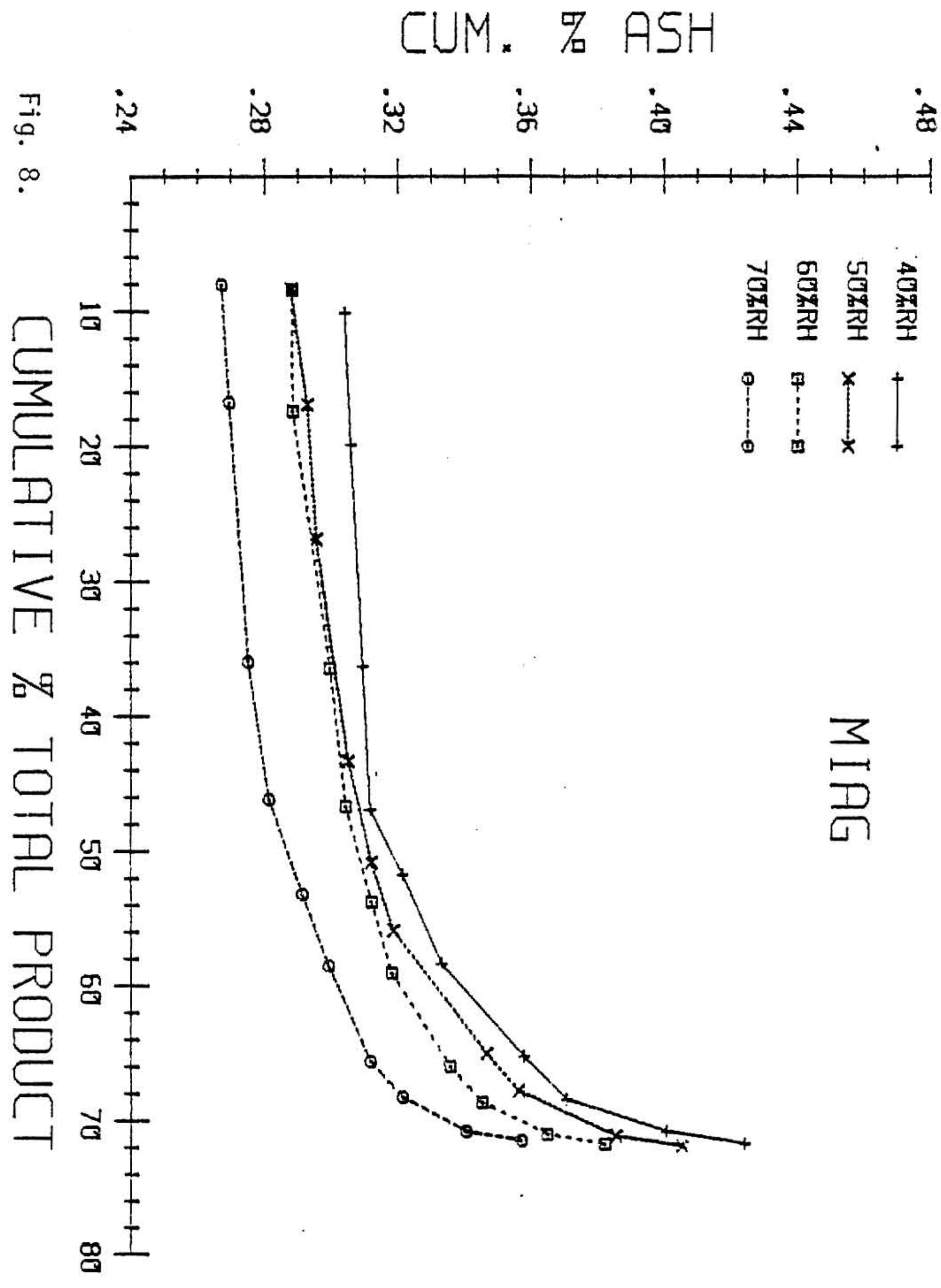

RH %
40
50
60
70
80
90
QUAD. Sr.
.48
.44
.40
.36
.32
.28
.24
CUM. % ASH
10
20
30
40
50
60
70
CUMULATIVE % TOTAL

Fig. 7.



CUM. % ASH
.24
.28
.32
.36
.40
.44
.48
40%RH
50%RH
60%RH
70%RH
MIAG
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT


Fig. 8.

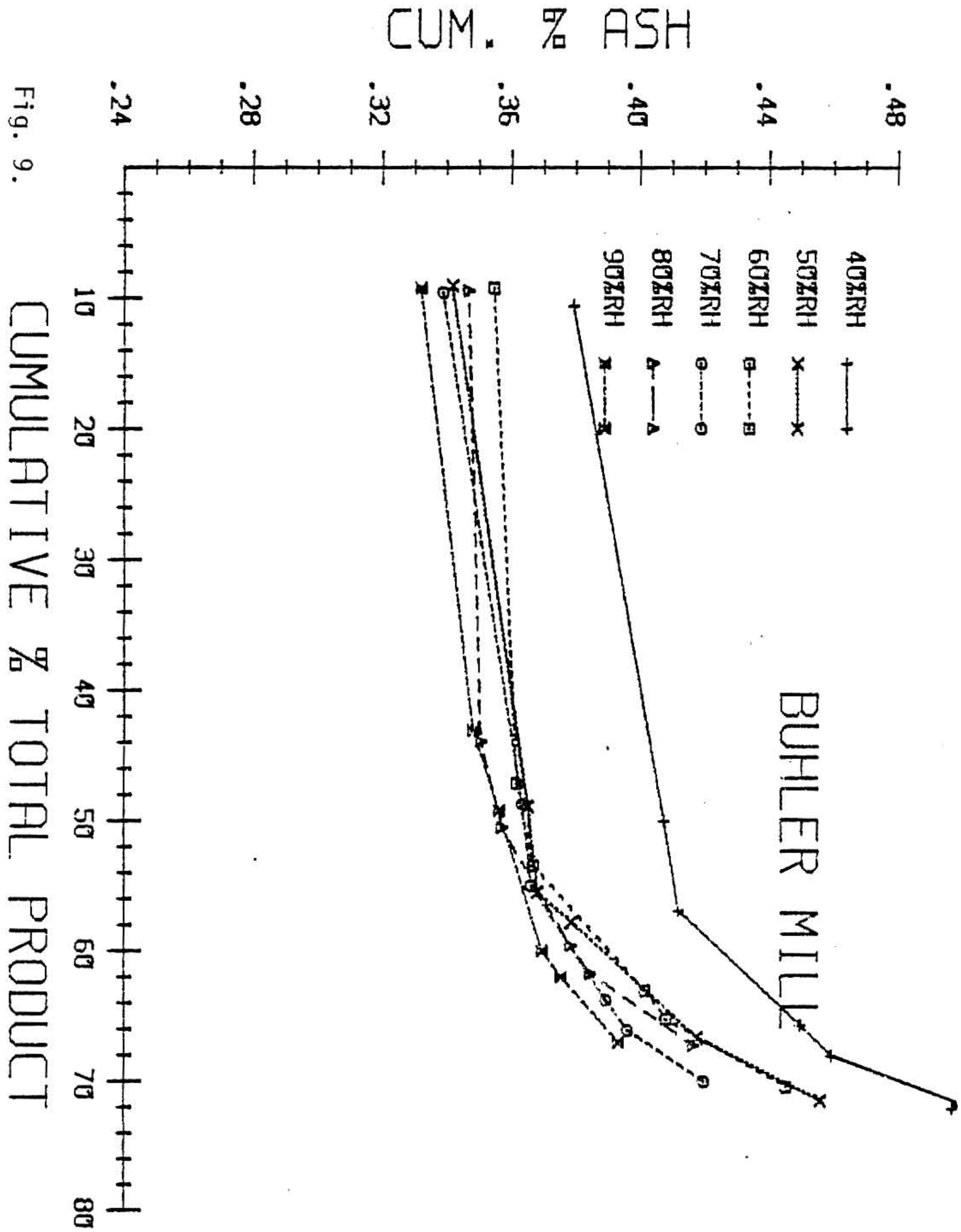

CUM. % ASH
.24
.28
.32
.36
.40
.44
.48
40%RH
50%RH
60%RH
70%RH
80%RH
90%RH
BUHLER MILL
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

Fig. 9.

4) Protein Content: Table VI gives the effects of relative humidity upon flour protein. Significantly higher protein values were obtained with pneumatic mills, with lower humidities (see Fig. 10, 11, 12).

The variation in values was not too much, but it gave an indicator about the influence of relative humidity on flour protein. The variations might be higher if large quantities of wheat were milled and wheats with high percent protein were used.

Table VI. Results of the Influence of RH% on Protein Content (on 14% moisture basis) with Statistical Data.*

| Mill | RH % | Sample No. 1 | 2 | 3 | Average | Standard Deviation |
|---|---|---|---|---|---|---|
| Miag-Multomat | 40 | 10.28 | 10.22 | 10.16 | 10.22 | |
| | 50 | 10.20 | 10.18 | 10.16 | 10.18 | |
| | 60 | 10.08 | 9.99 | 10.15 | 10.07 | |
| | 70 | 10.03 | 10.10 | 10.06 | 10.06 | |
| | Mean | | | | 10.13 | |
| | Standard Deviation | | | | .08 | |
| | Correlation Coefficient | | | | - .96 | |
| Buhler | 40 | 10.19 | 10.20 | 10.20 | 10.20 | |
| | 50 | 10.13 | 10.22 | 10.21 | 10.18 | |
| | 60 | 10.07 | 10.14 | 10.23 | 10.15 | |
| | 70 | 10.01 | 10.17 | 10.10 | 10.09 | |
| | 80 | 10.11 | 9.90 | 9.88 | 10.06 | |
| | 90 | 9.83 | 9.99 | 10.02 | 9.95 | |
| | Mean | | | | 10.11 | |
| | Standard Deviation | | | | .09 | |
| | Correlation Coefficient | | | | - .95 | |
| Quadrumat Jr. | 40 | 10.66 | 10.20 | 10.11 | 10.12 | .07 |
| | 50 | 10.11 | 10.15 | 10.24 | 10.17 | .07 |
| | 60 | 10.04 | 10.09 | 10.16 | 10.10 | .06 |
| | 70 | 10.14 | 10.06 | 10.12 | 10.11 | .04 |
| | Mean | | | | 10.12 | |
| | Standard Deviation | | | | .03 | |
| | Correlation Coefficient | | | | - .41 | |
| Quadrumat Sr. | 40 | 9.94 | 9.99 | 9.86 | 9.93 | .06 |
| | 50 | 9.97 | 10.00 | 9.87 | 9.95 | .07 |
| | 60 | 9.96 | 9.90 | 9.84 | 9.90 | .06 |
| | 70 | 9.97 | 9.86 | 9.93 | 9.92 | .06 |
| | 80 | 9.98 | 9.91 | 9.87 | 9.88 | .02 |
| | 90 | 9.93 | 9.84 | 9.91 | 9.91 | .02 |
| | Mean | | | | 9.92 | |
| | Standard Deviation | | | | .024 | |
| | Correlation Coefficient | | | | - .64 | |

*The figures are representing the accumulative protein.

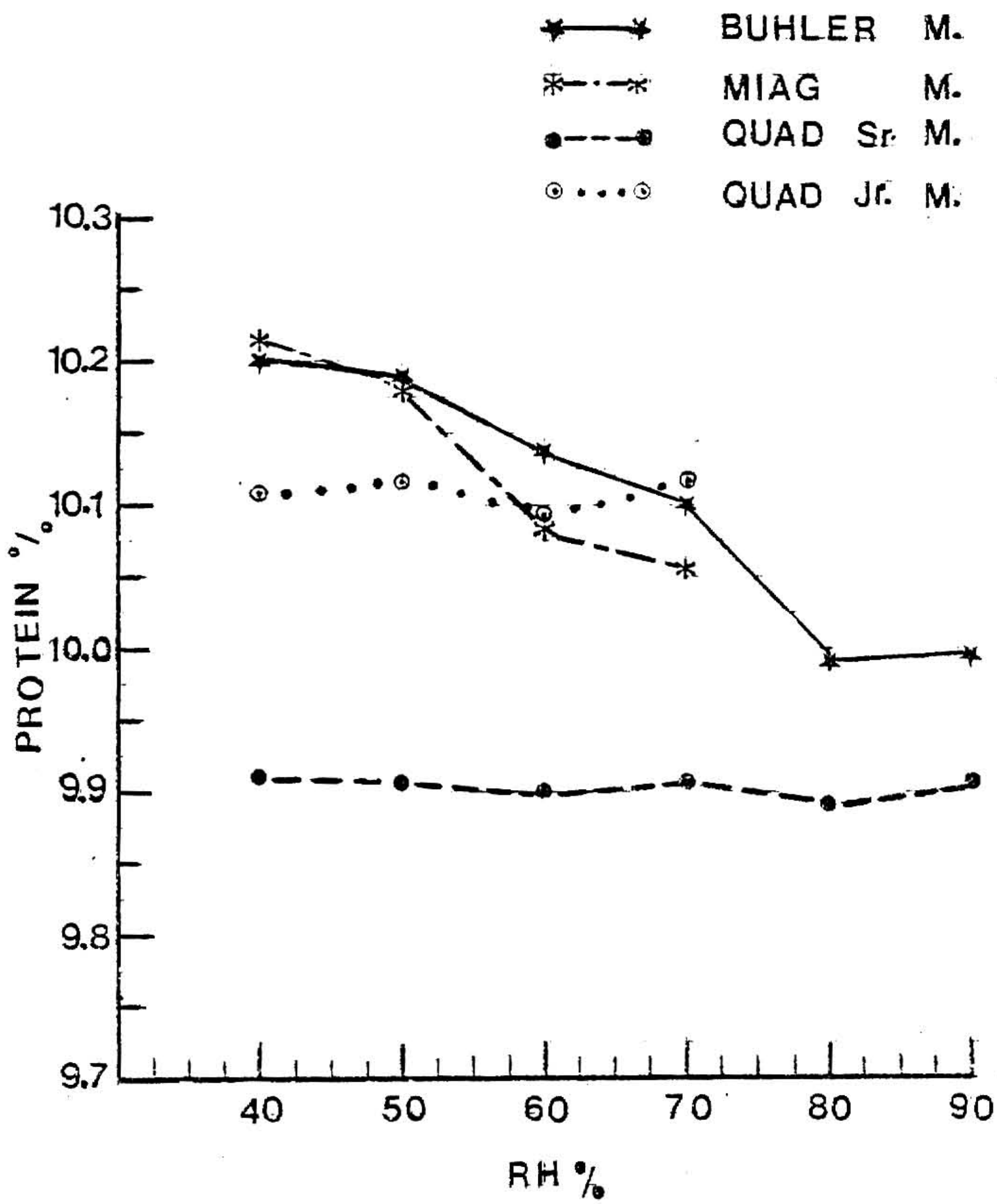



Fig. 10. THE EFFECT OF RELATIVE HUMIDITY ON PROTEIN CONTENT

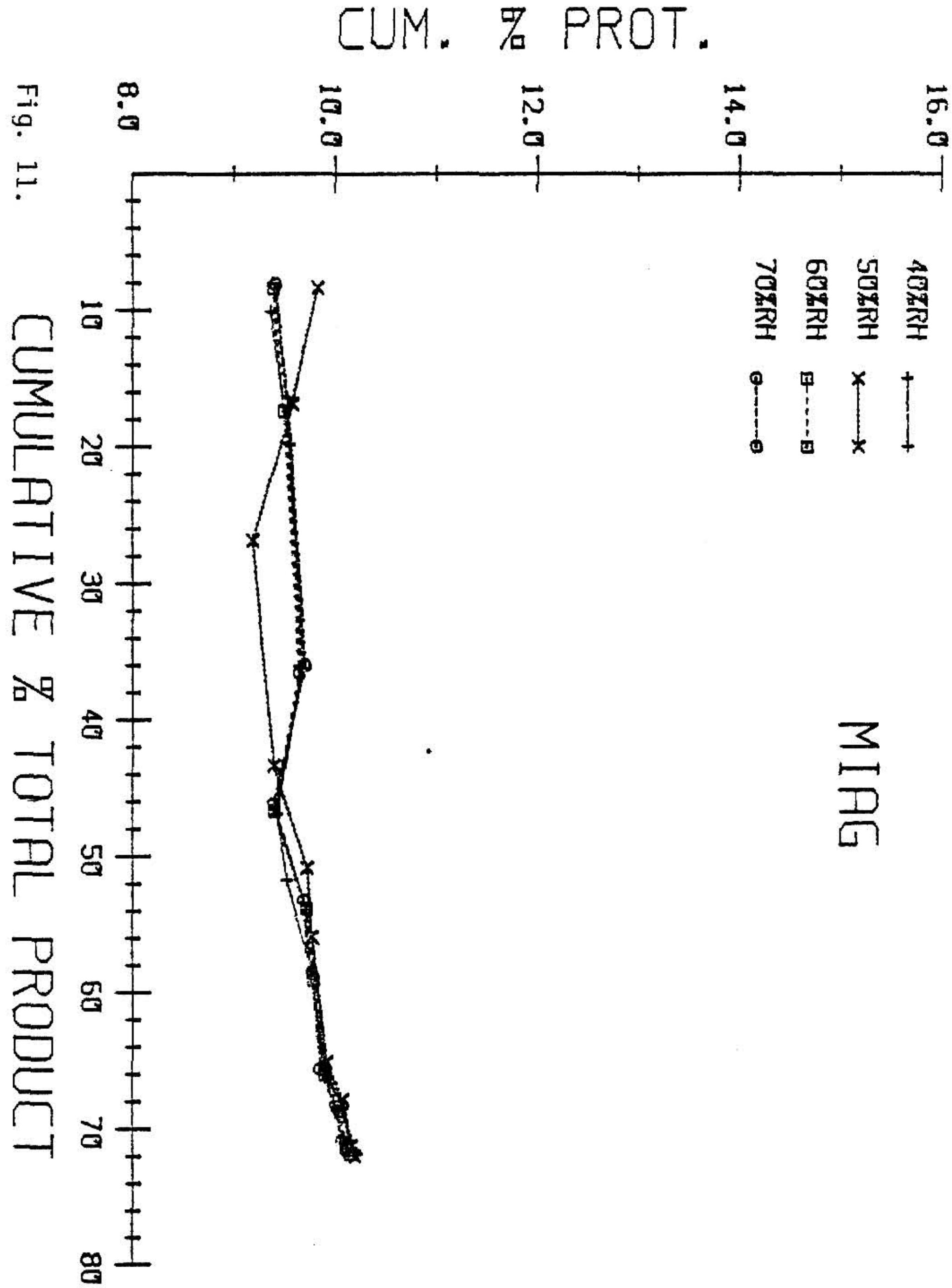

CUM. % PROT.
16.0
14.0
12.0
10.0
8.0
MIAG
40%RH
50%RH
60%RH
70%RH
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

Fig. 11.

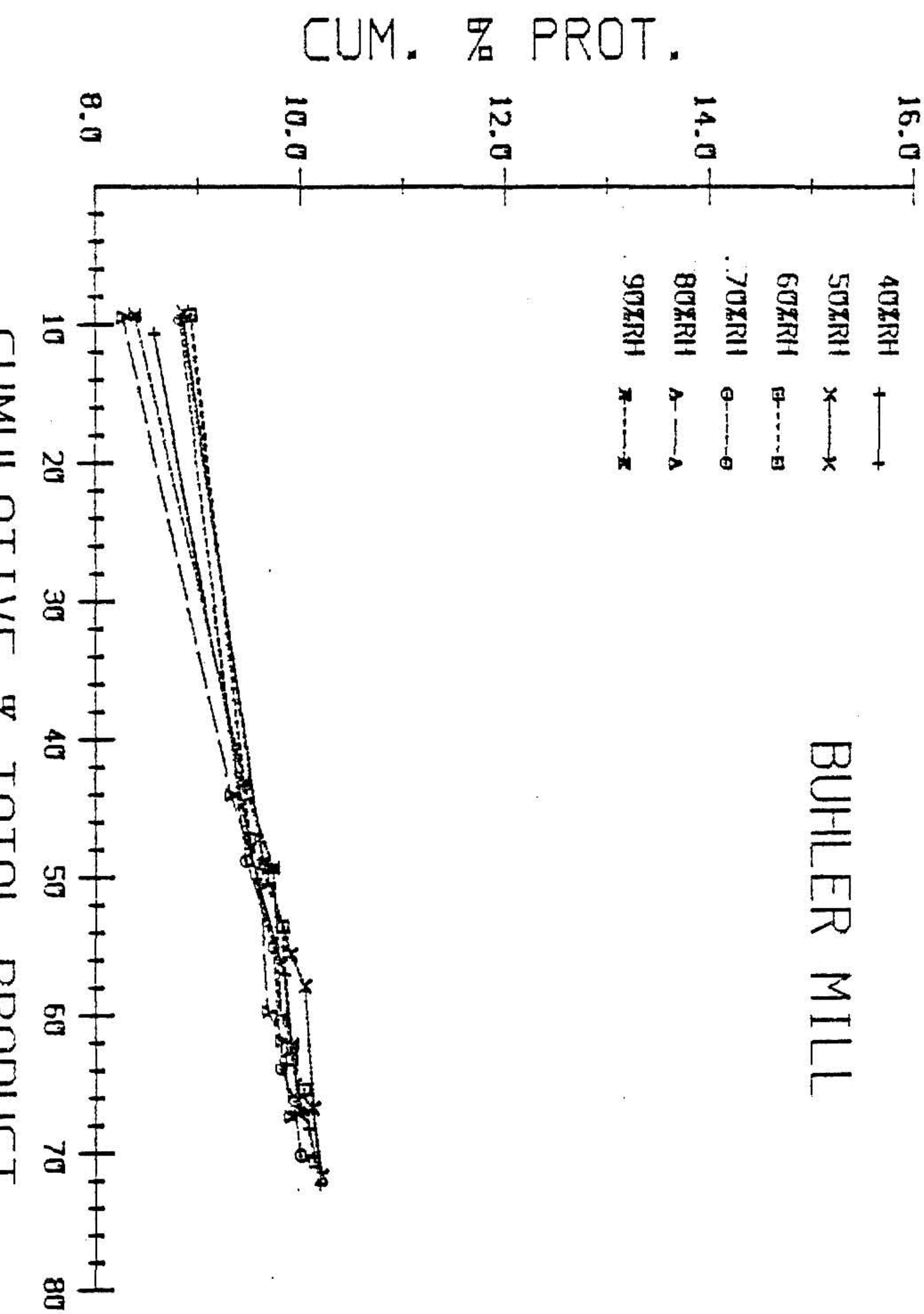

BUHLER MILL
CUM. % PROT.
CUMULATIVE % TOTAL PRODUCT
40%RH
50%RH
60%RH
70%RH
80%RH
90%RH
8.0
10.0
12.0
14.0
16.0
10
20
30
40
50
60
70
80

Fig. 12.

5) Milling Loss: Referring to Figure 13 it will be seen that milling loss responded to the variations in humidities and mills in the same manner as flour yield. Higher losses are due to the loss of moisture because of the dry atmosphere, dry atmosphere can be an important factor in creating the dust and increasing the milling loss. This can be result in an unsanitary and unsafe situation.

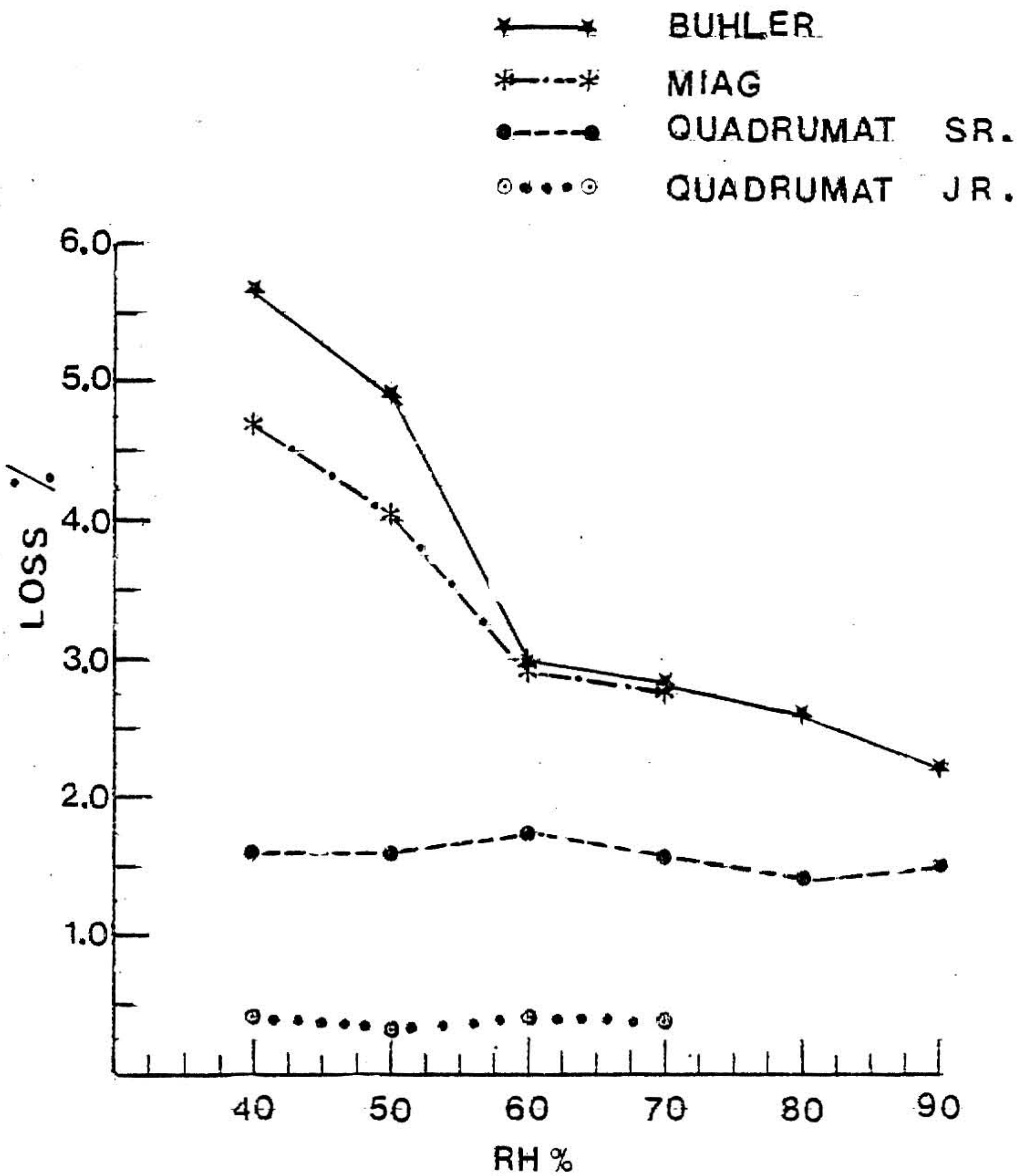



Fig. 13. THE EFFECT OF RELATIVE HUMIDITY ON MILLING LOSS

Discussion

This study clearly demonstrates that variations in millroom relative humidity influences flour extraction and all flour properties investigated when pneumatic mills were used. In this type of mills where the air is used to transfer the milling stock has more contact with atmospheric condition than the non-pneumatic mills. This can bring up the variations in millroom relative humidity inside the mill and affect the milling operations.

The standard deviation for the influence of variations in relative humidity on flour extract-on and flour properties was significant only when the pneumatic mills were used.

The correlation coefficient (=r) was calculated as a measure of how strongly related x (= RH %) and y (= flour extraction and flour properties, in a linear sense). There are three conditions for (r) (10):

1) If $r > o$ → large x-values tend to associate with large y-values or small x-values tend to associate with small y-values.

2) If $r < o$ → large x-values tend to associate with small y-values or small x-values tend to associate with large y-values.

3) If $r = o$ → x and y are linearly unrelated.

If $r = \pm 1$ (10) then a straight line fits the data perfectly and y can be perfectly predicted from x. The further r from ±1, the less related x and y.

In our data we can see clearly how strongly x and y were related to each other when pneumatic mills were used. While x and y were weakly related when non-pneumatic mills were used.

The response for using a wide variation in RH % and pneumatic mills was to get the tendency of producing flours as nearly as possible identical in properties with those which would be obtained by commercial-scale milling. The use of such conditions would minimize the need for translation of results.

60 - 70% RH might be recommended for milling operations. At lower level of RH % (40 - 50%) we got higher milling loss and higher ash content but not significantly higher protein. At higher level of RH % (80 - 90%) we got lower ash but lower extraction. Also,dry conditions resulted in more dry dust in the atmosphere which is not good when considering dust explosion. Humid conditions resulted in condensation because of heat inside the mill which can cause also choke-up. So,we then can conclude that there are many disadvantages with using dry or humid conditions including the producing of unsafe and unsanitary conditions in the mill. Using 60 - 70% RH can give us the reasonable results. If we could maintain this level by using any kind of air stabilization unit, then we can get the required specifications for our products almost all year-around with all advantages which are mentioned before.

## Conclusions

Flour extraction decreased with increasing humidity for those pneumatic mills. Nothing significant was there for those non-pneumatic experimental mills during all the observations.

Flour moisture increased with increasing humidity in the atmosphere. Miag-Multomat produced higher moisture flour than the Buhler mill for the same RH %.

Flour ash increased with decreasing relative humidity. Buhler mill gave higher ash than Miag-Multomat mill.

Flour protein responded to variations in RH % in the same manner as flour ash.

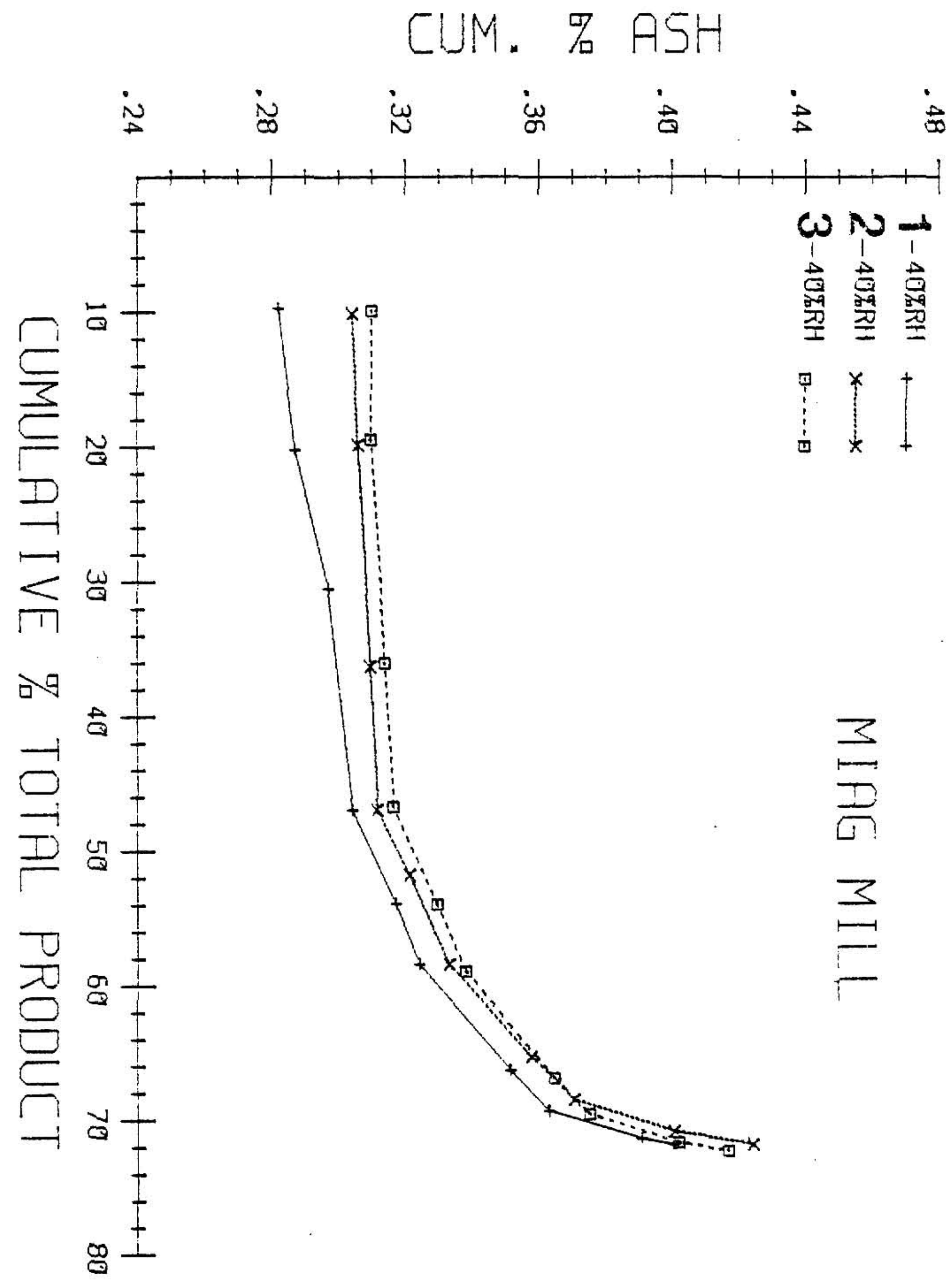
Milling loss decreased with increasing in RH %.

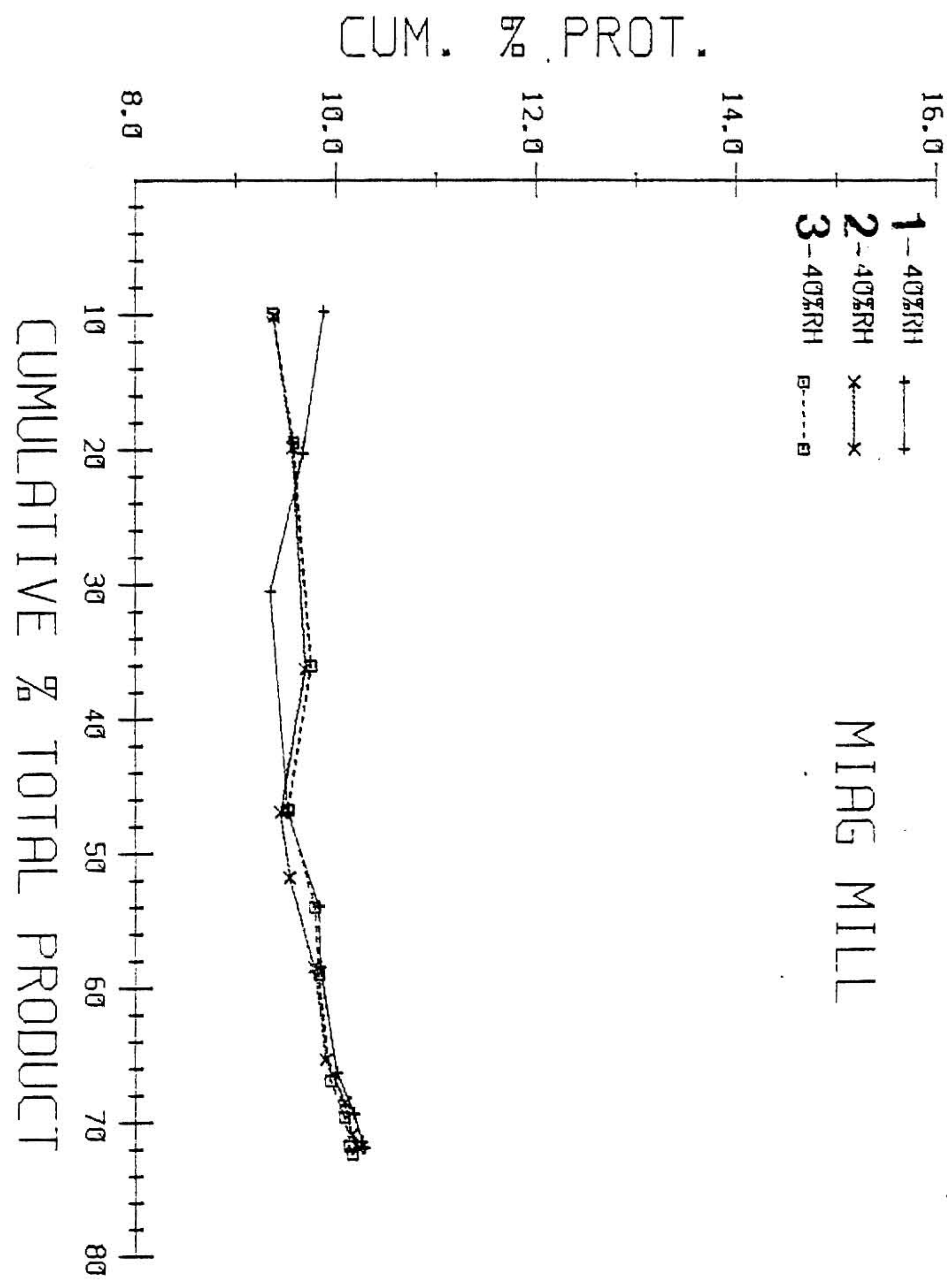
According to the most reasonable results we may recommend 60 - 70% relative humidity as the best for flour milling.

Also, our investigation showed the necessity of having an air stabilization unit in the plant, particulary those plants which are using pneumatic systems. Finally, this investigation can be improved by getting more controllable millroom atmospheric conditions.

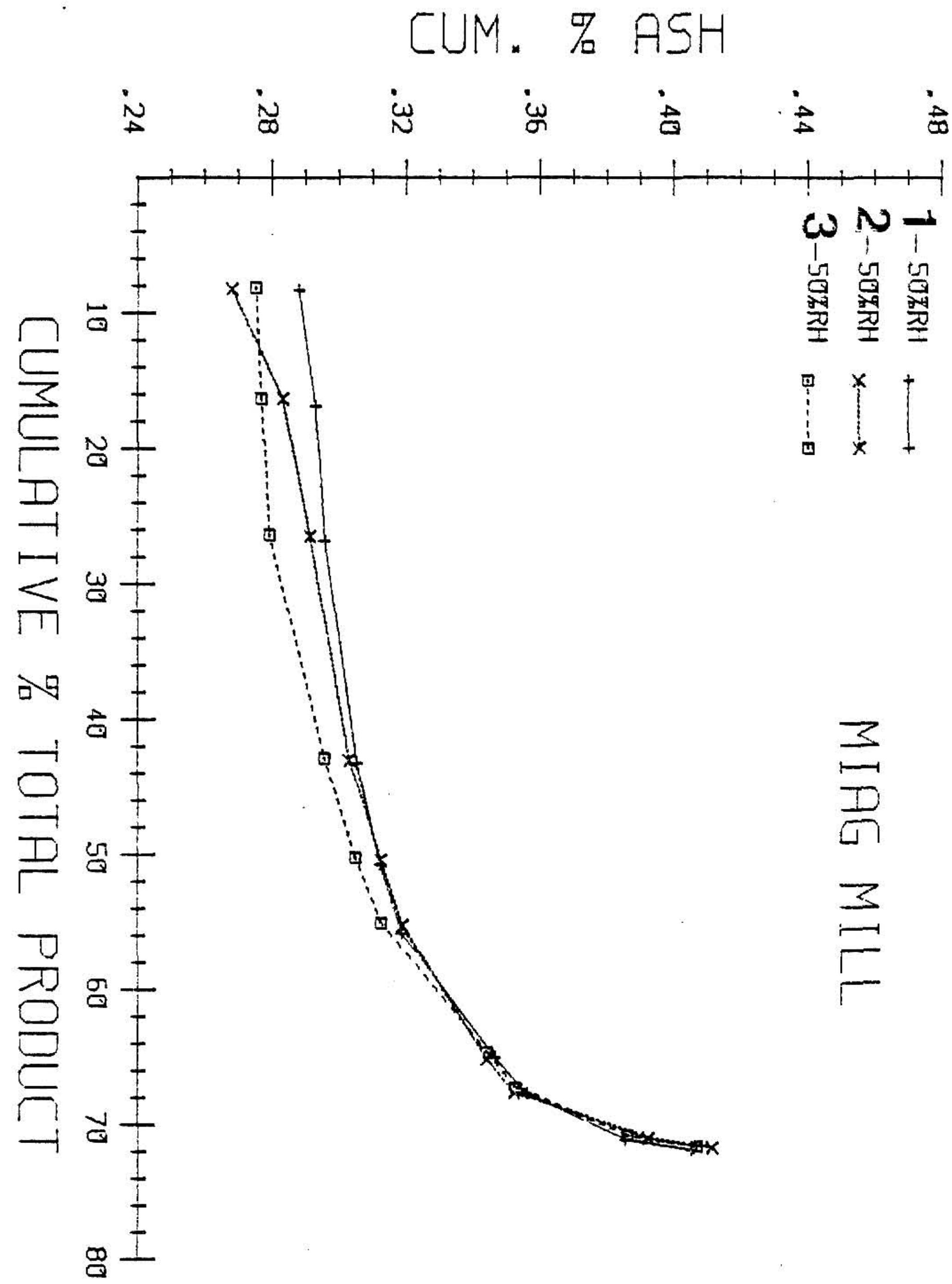
# APPENDIX

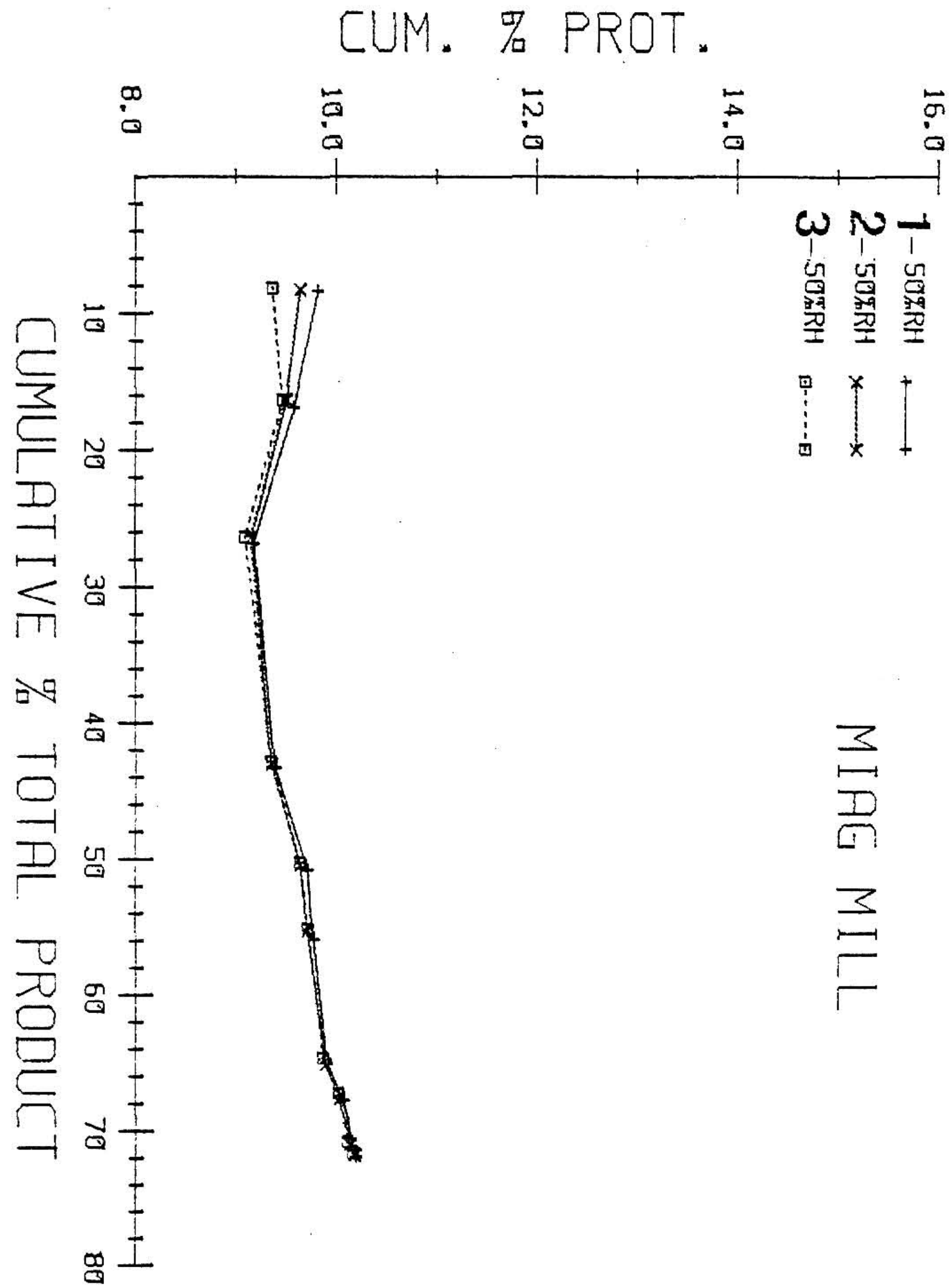
CUMULATIVE ASH & PROTEIN FOR
MIAG-MULTOMAT AND BUHLER MILLS
OF TRIPLICATE SAMPLES FOR EACH
PARTICULAR RH % USED.

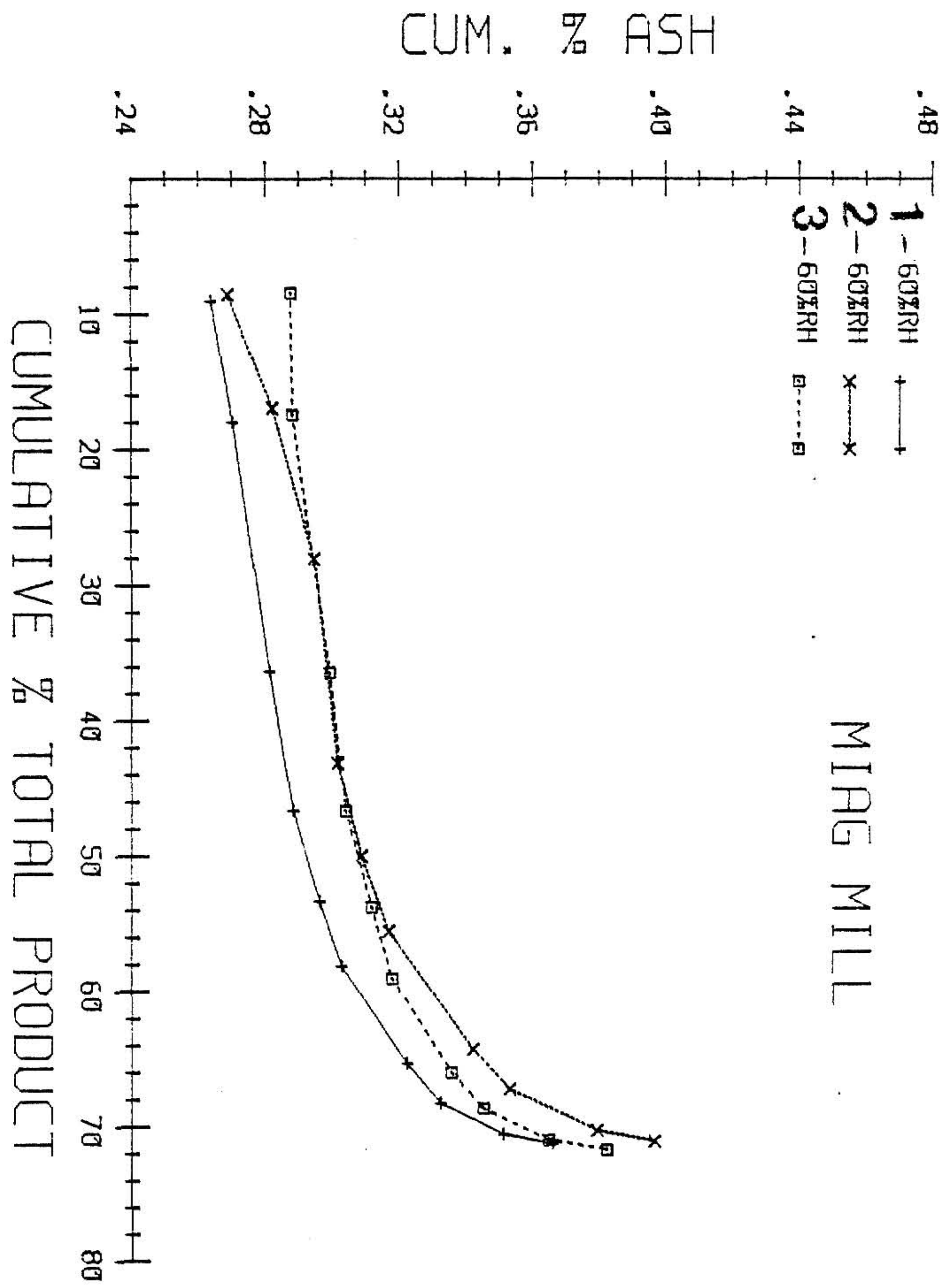

MIAG MILL
CUM. % ASH
.24
.28
.32
.36
.40
.44
.48
1-40%RH
2-40%RH
3-40%RH
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

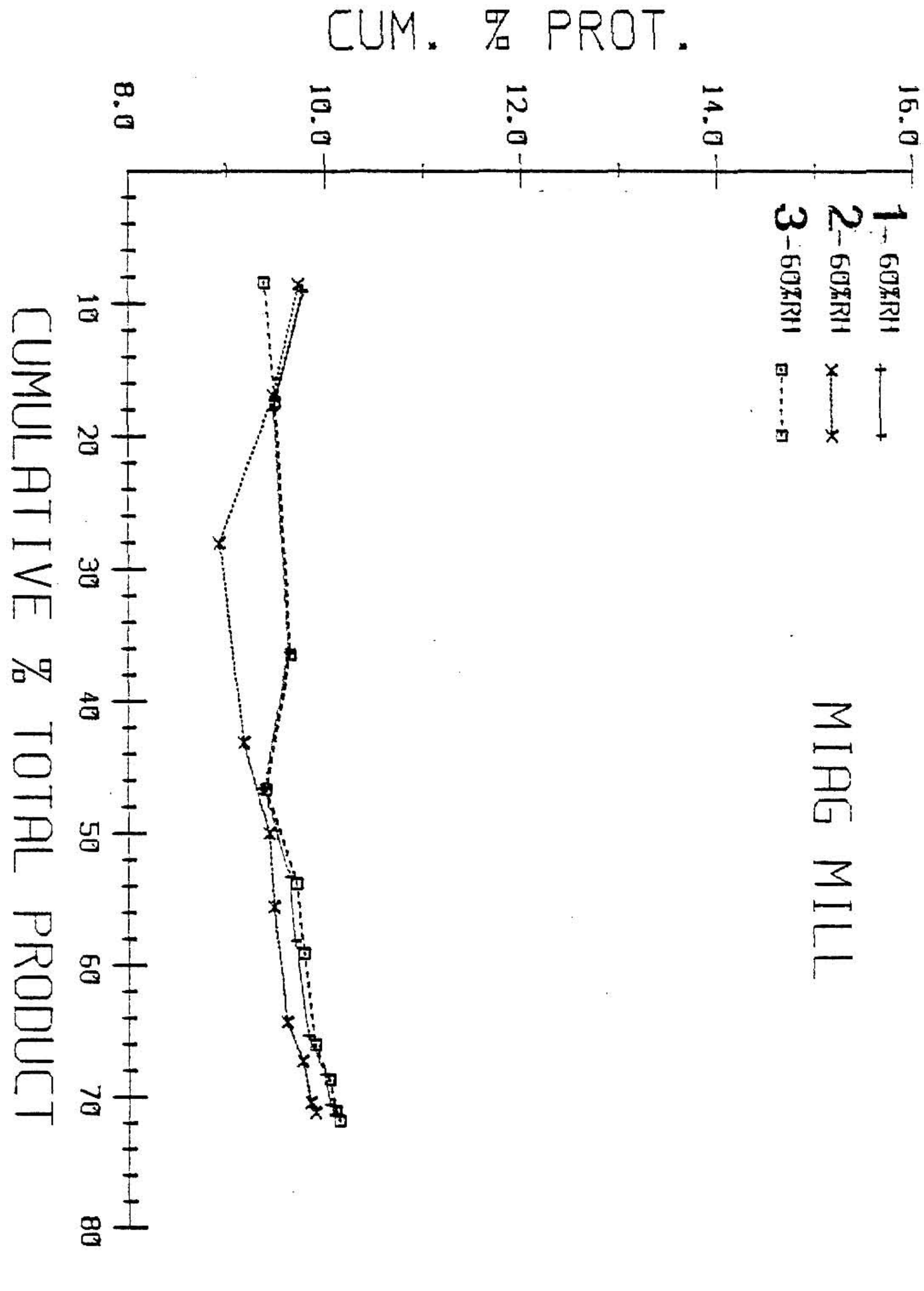


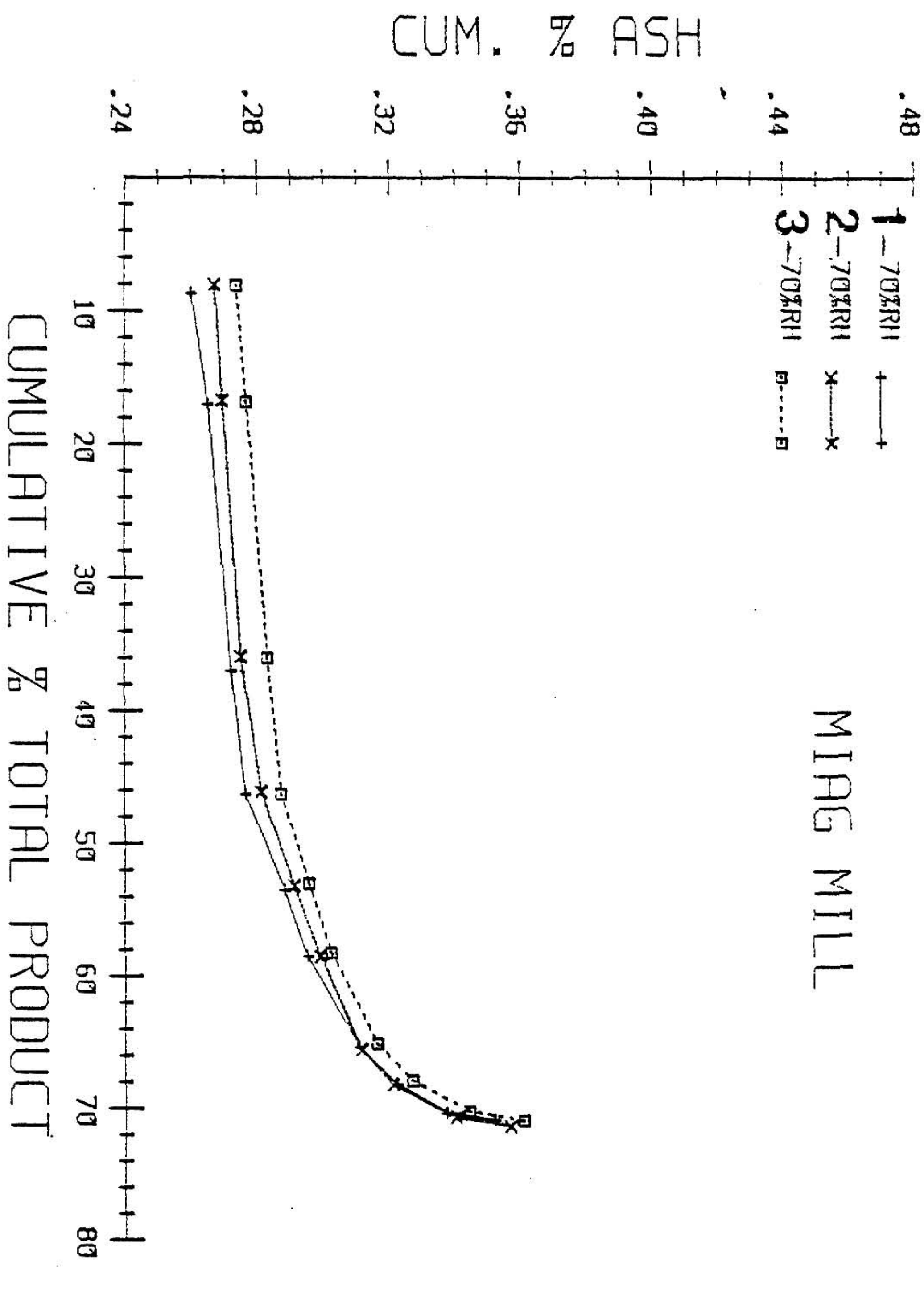
CUM. % PROT.
16.0
14.0
12.0
10.0
8.0
1-40%RH
2-40%RH
3-40%RH
MIAG MILL
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

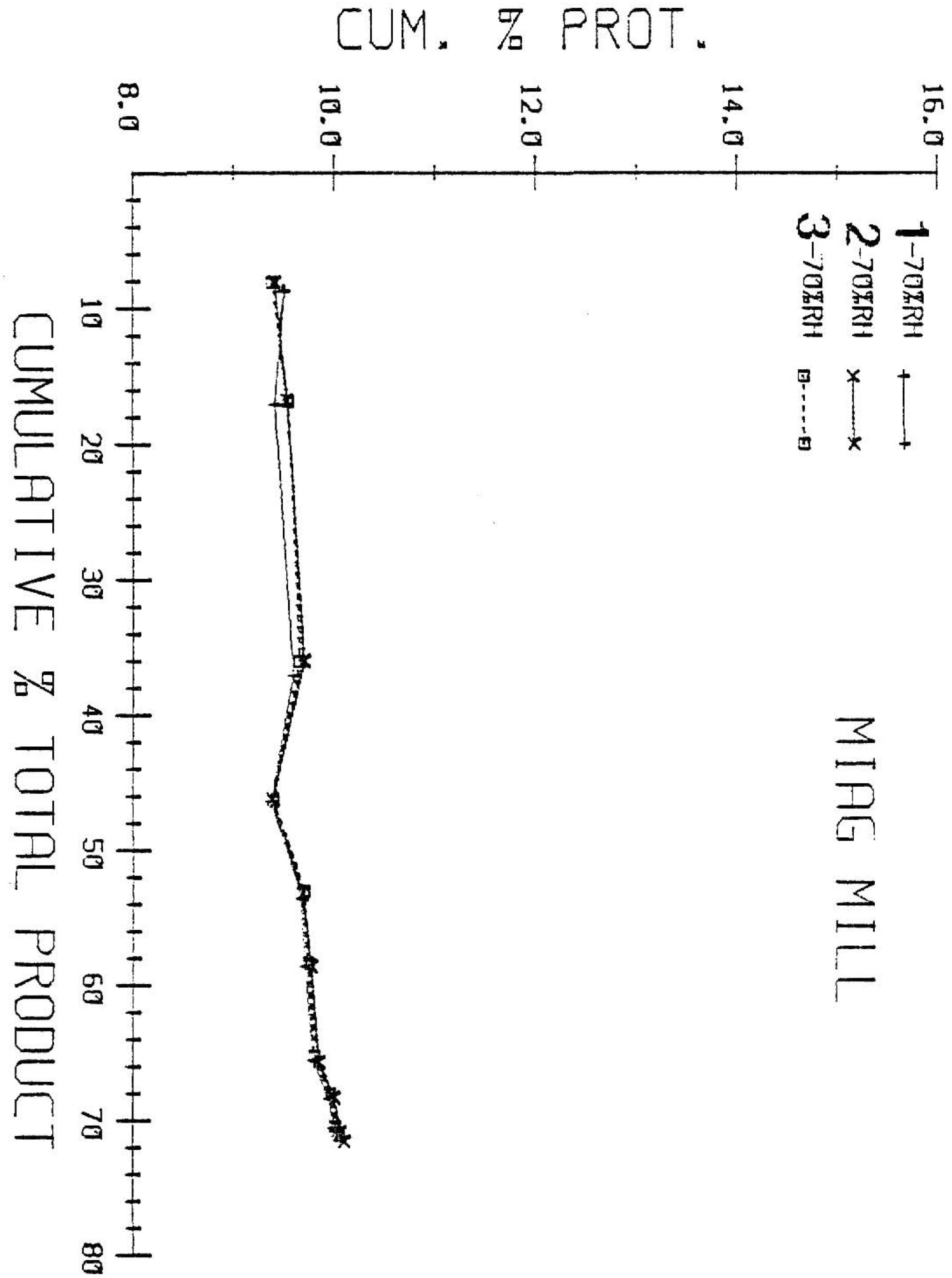

MIAG MILL
CUM. % ASH
CUMULATIVE % TOTAL PRODUCT
1-50%RH
2-50%RH
3-50%RH
.24
.28
.32
.36
.40
.44
.48
10
20
30
40
50
60
70
80

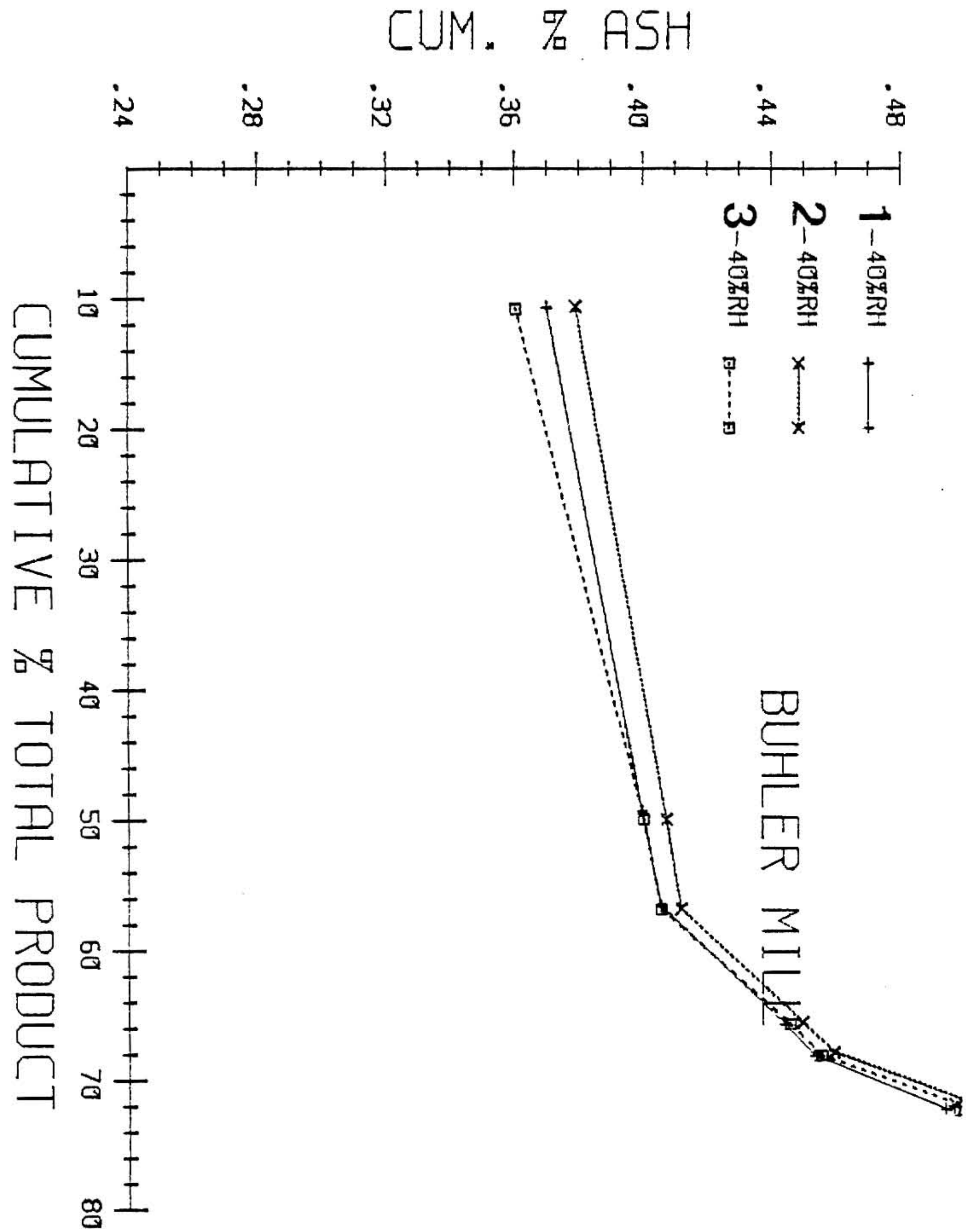

CUM. % PROT.
8.0
10.0
12.0
14.0
16.0
1-50%RH
2-50%RH
3-50%RH
MIAG MILL
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

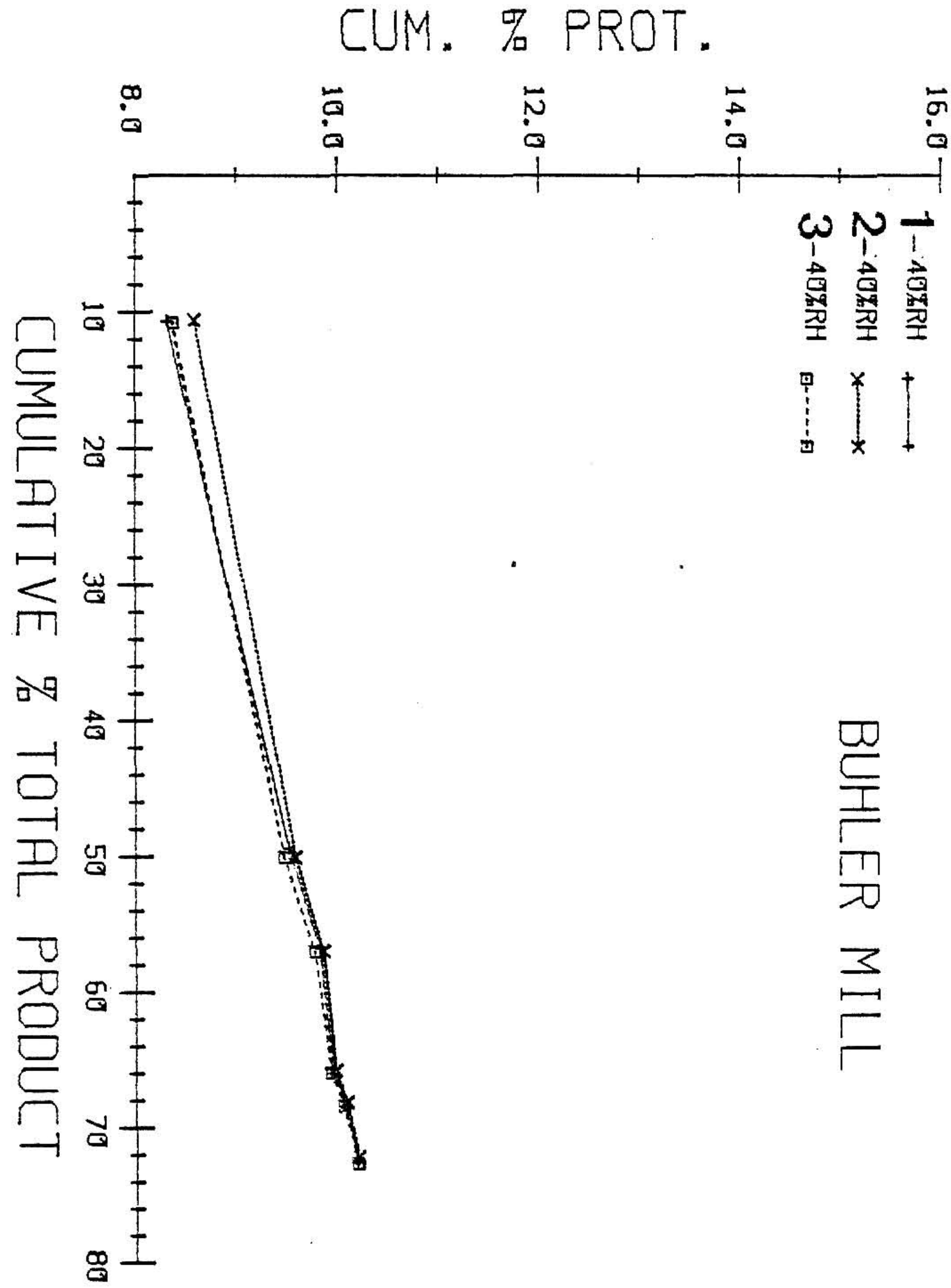

CUM. % ASH
.24
.28
.32
.36
.40
.44
.48
1 - 60%RH
2 - 60%RH
3 - 60%RH
MIAG MILL
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT


MIAG MILL
CUM. % PROT.
8.0
10.0
12.0
14.0
16.0
1-60%RH
2-60%RH
3-60%RH
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

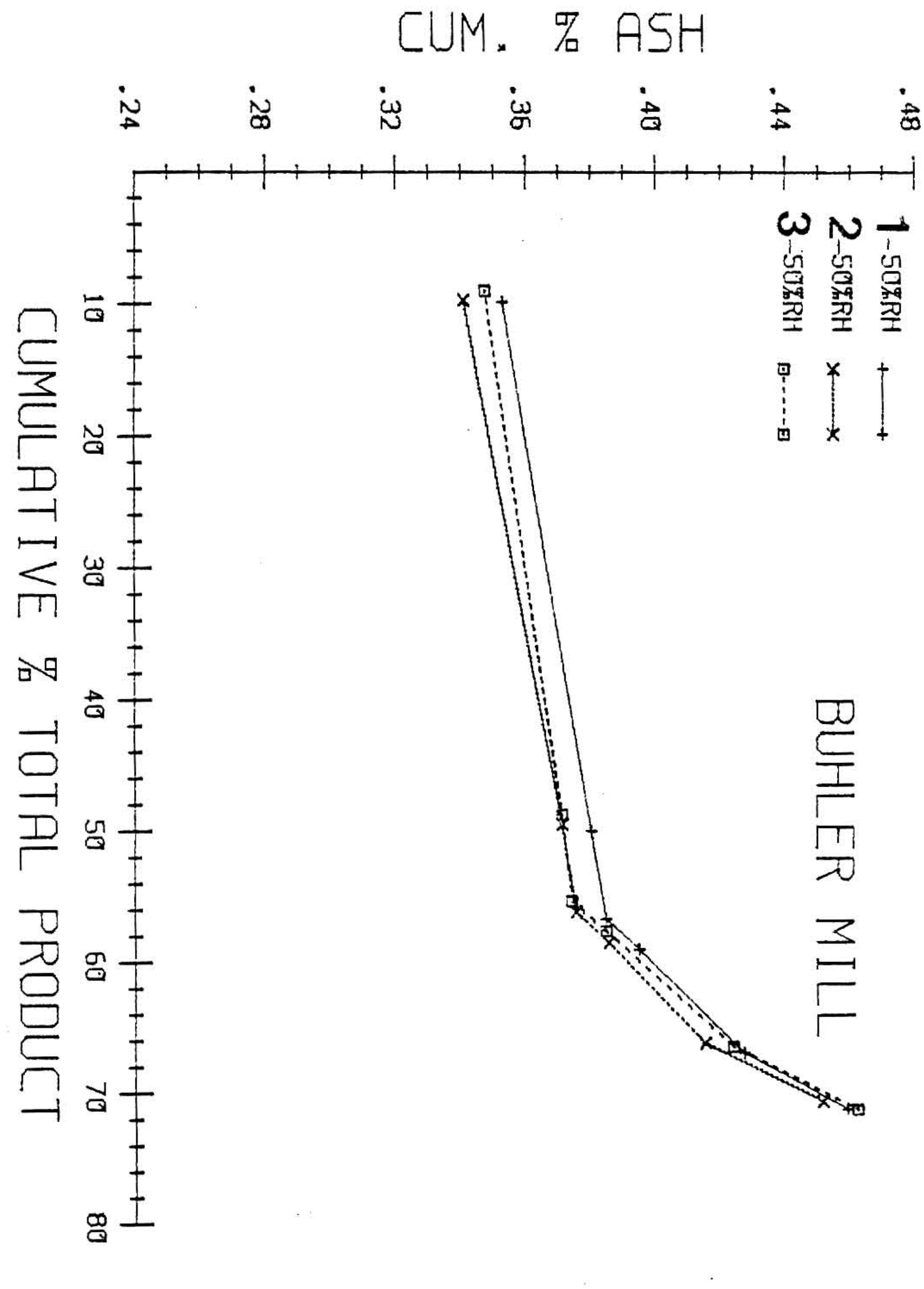

MIAG MILL
CUM. % ASH
CUMULATIVE % TOTAL PRODUCT
1–70%RH
2–70%RH
3–70%RH
.24
.28
.32
.36
.40
.44
.48
10
20
30
40
50
60
70
80

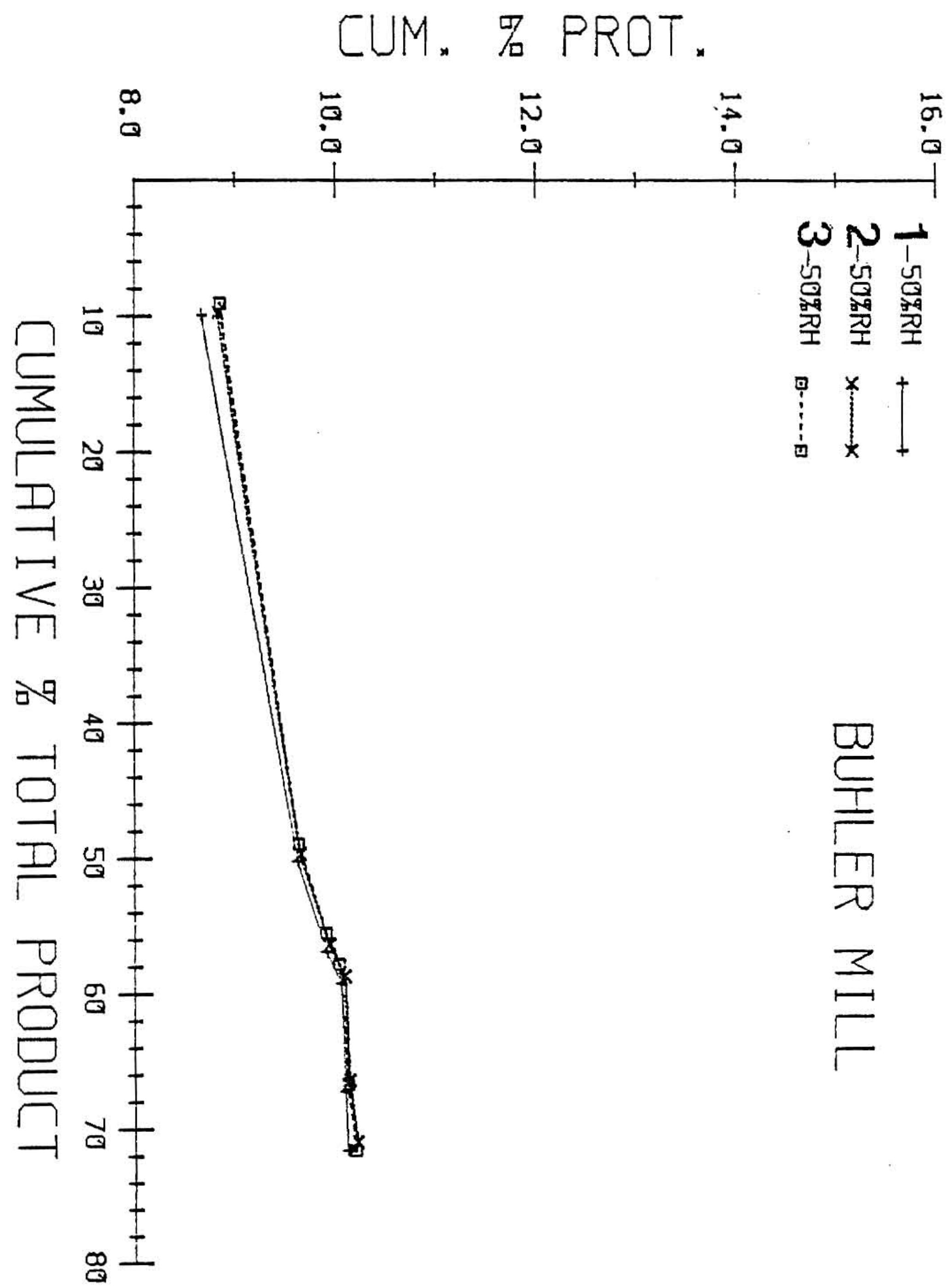

MIAG MILL
CUM. % PROT.
8.0
10.0
12.0
14.0
16.0
CUMULATIVE % TOTAL PRODUCT
10
20
30
40
50
60
70
80
1-70%RH
2-70%RH
3-70%RH

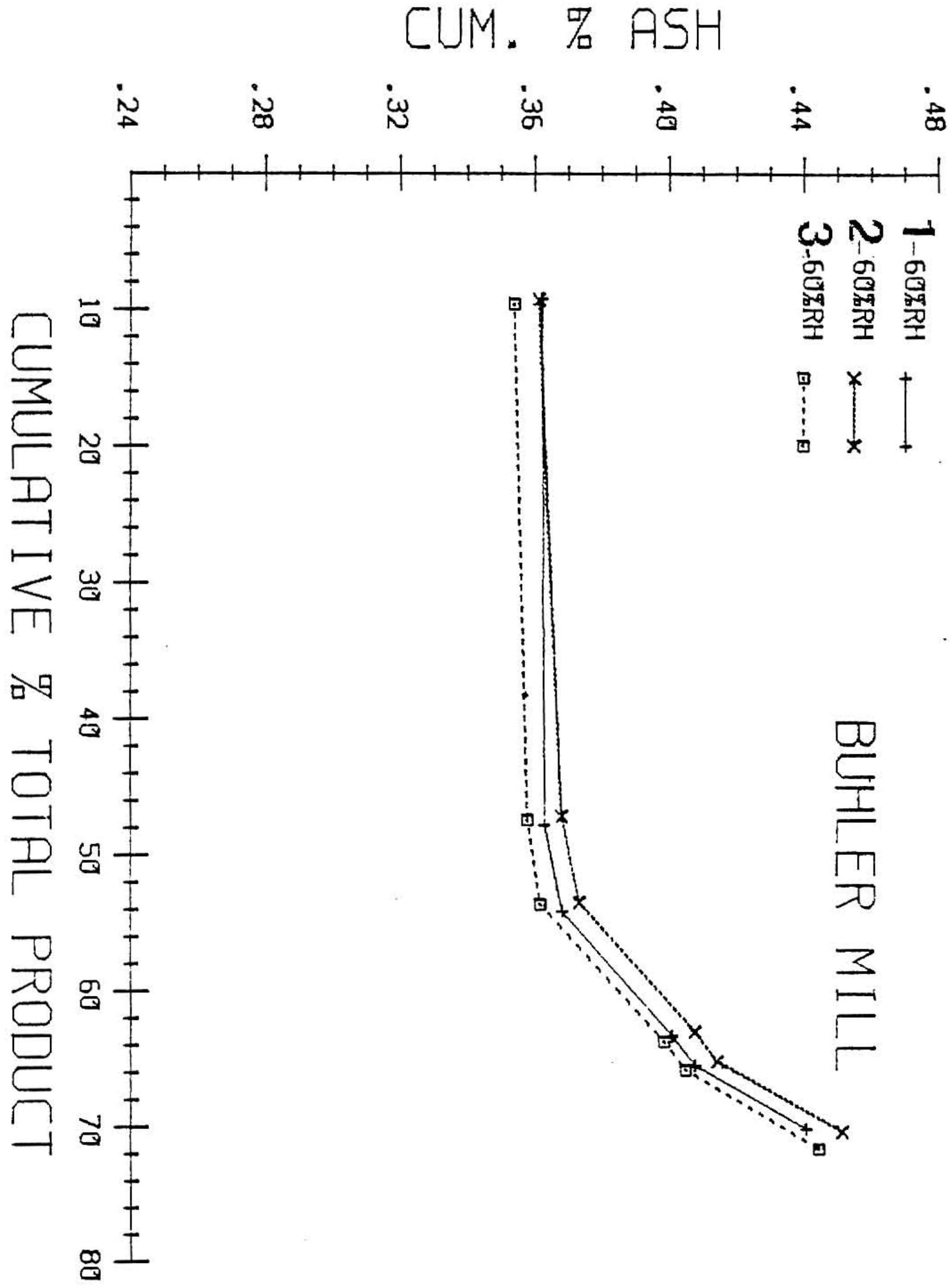

CUM. % ASH
.24
.28
.32
.36
.40
.44
.48
1-40%RH
2-40%RH
3-40%RH
BUHLER MILL
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

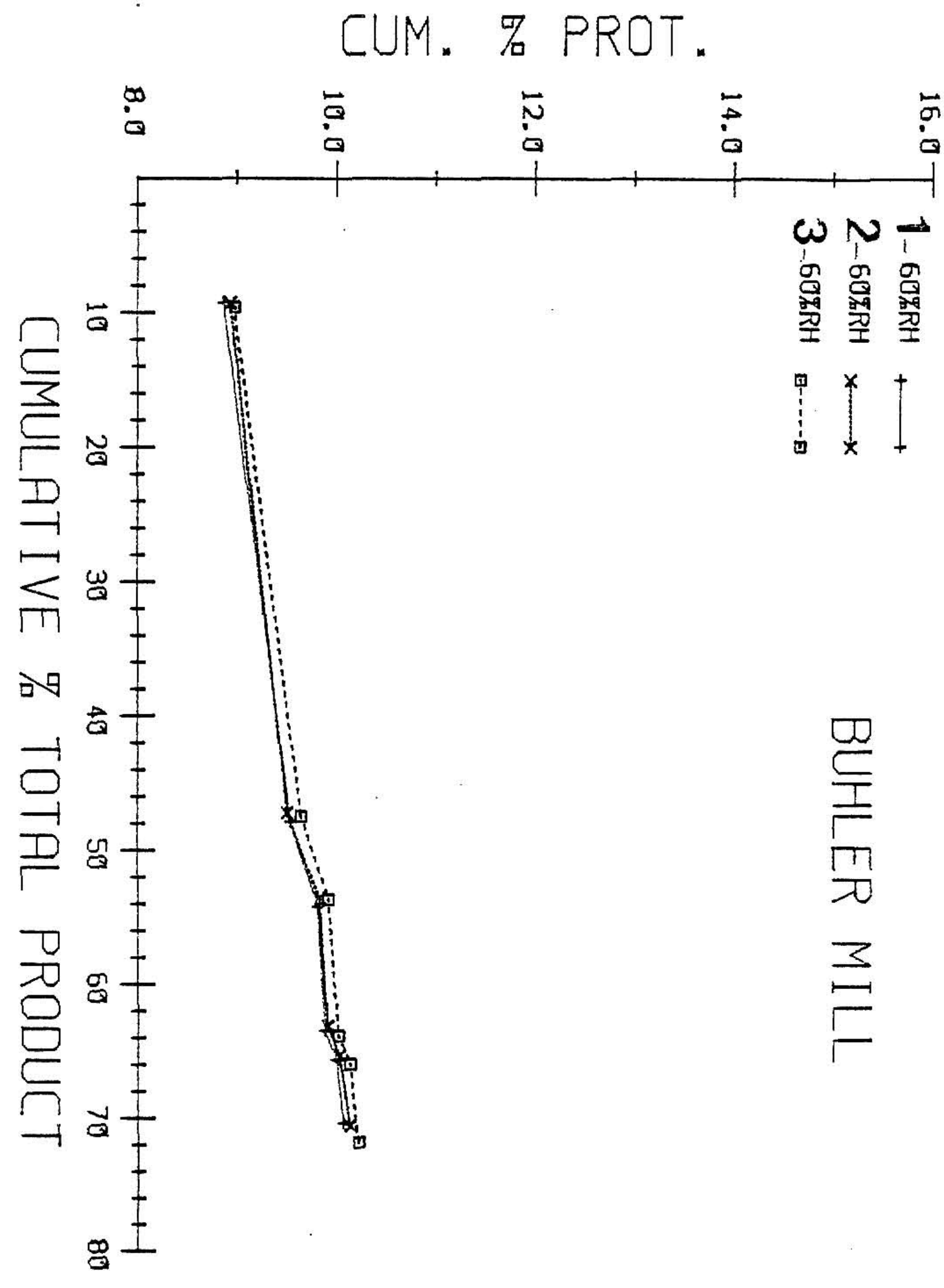


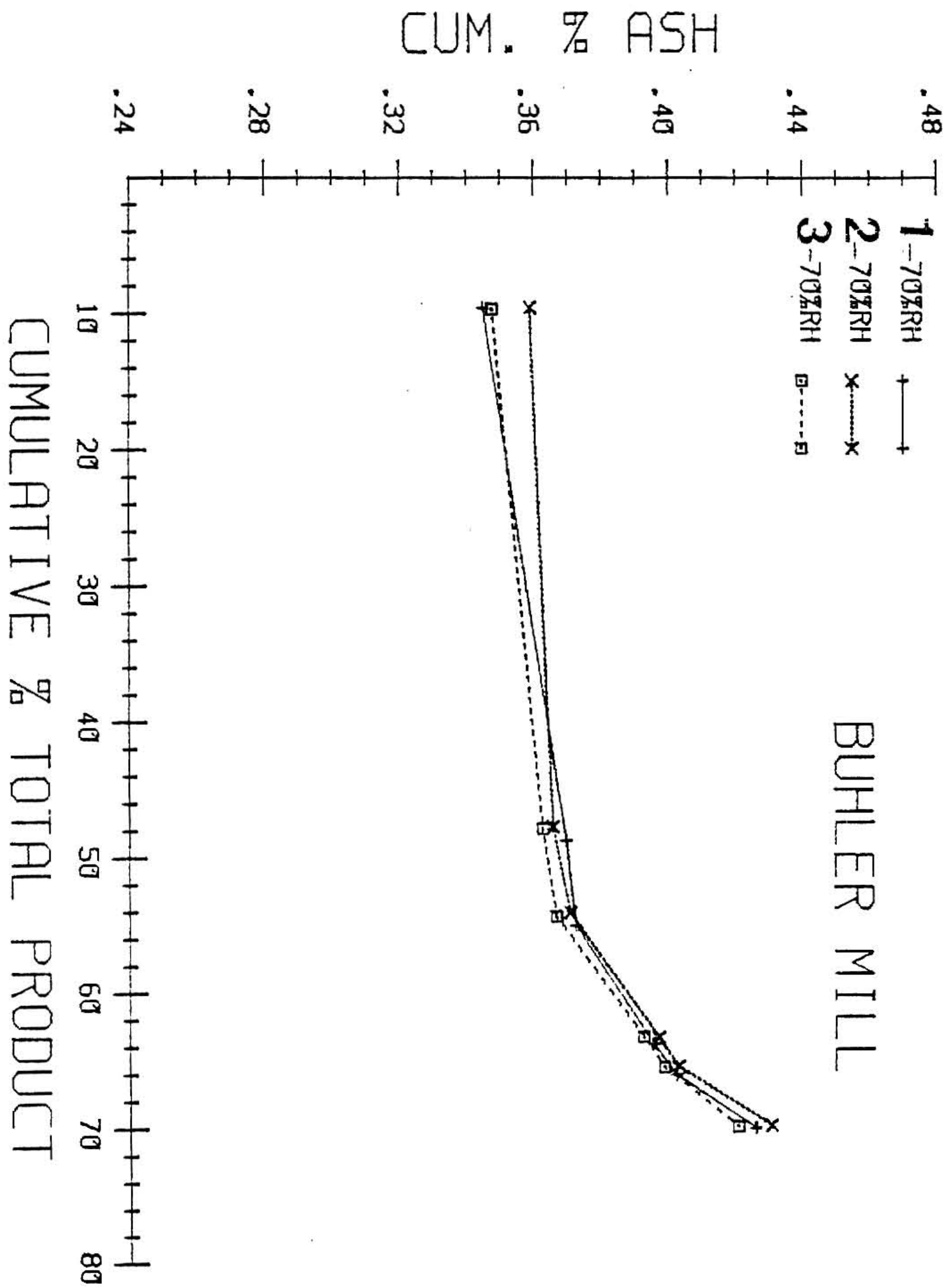
BUHLER MILL
CUM. % PROT.
8.0
10.0
12.0
14.0
16.0
1-40%RH
2-40%RH
3-40%RH
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT


BUHLER MILL
CUM. % ASH
.24
.28
.32
.36
.40
.44
.48
1-50%RH
2-50%RH
3-50%RH
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

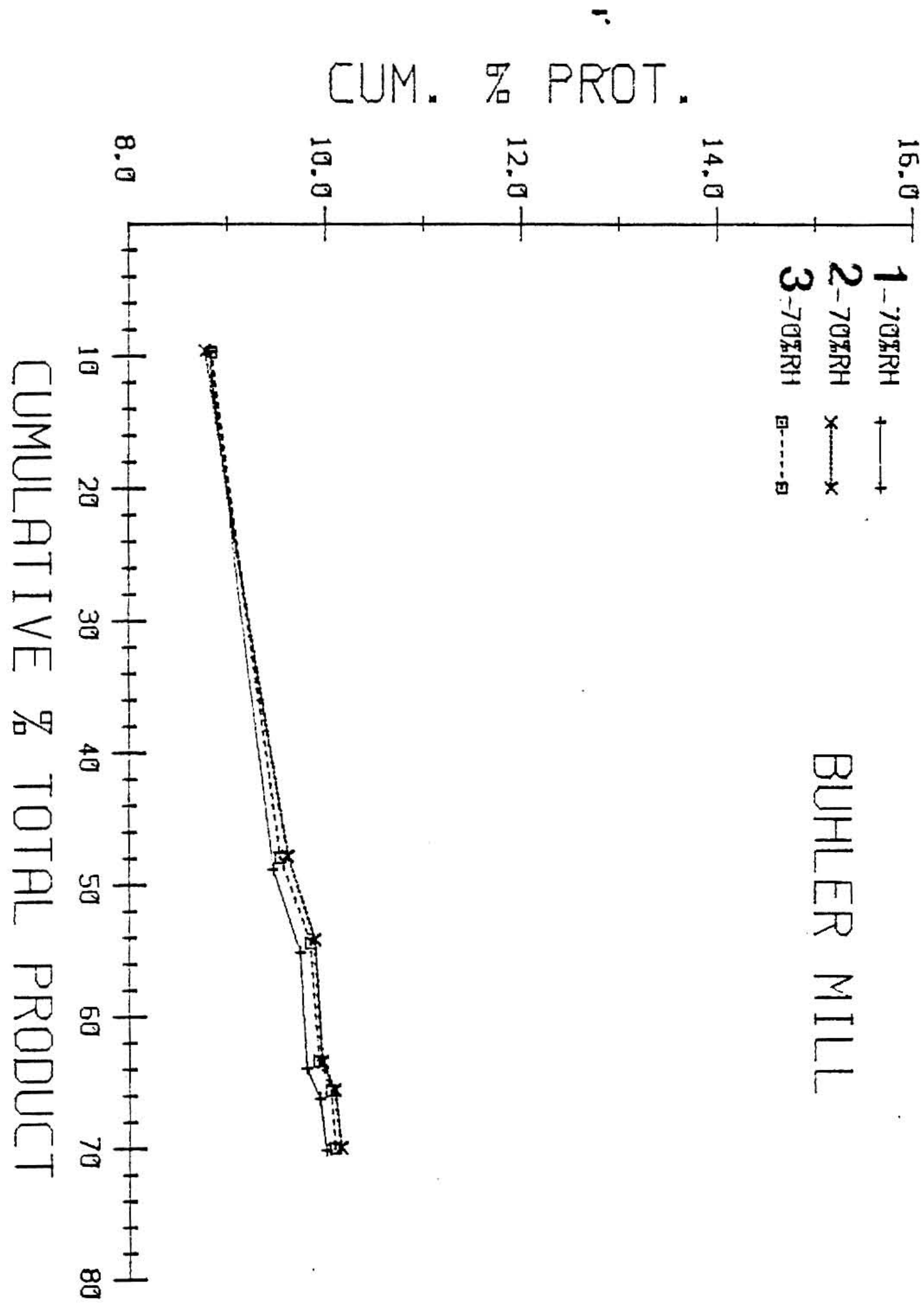

BUHLER MILL
CUM. % PROT.
CUMULATIVE % TOTAL PRODUCT
8.0
10.0
12.0
14.0
16.0
10
20
30
40
50
60
70
80
1-50%RH
2-50%RH
3-50%RH

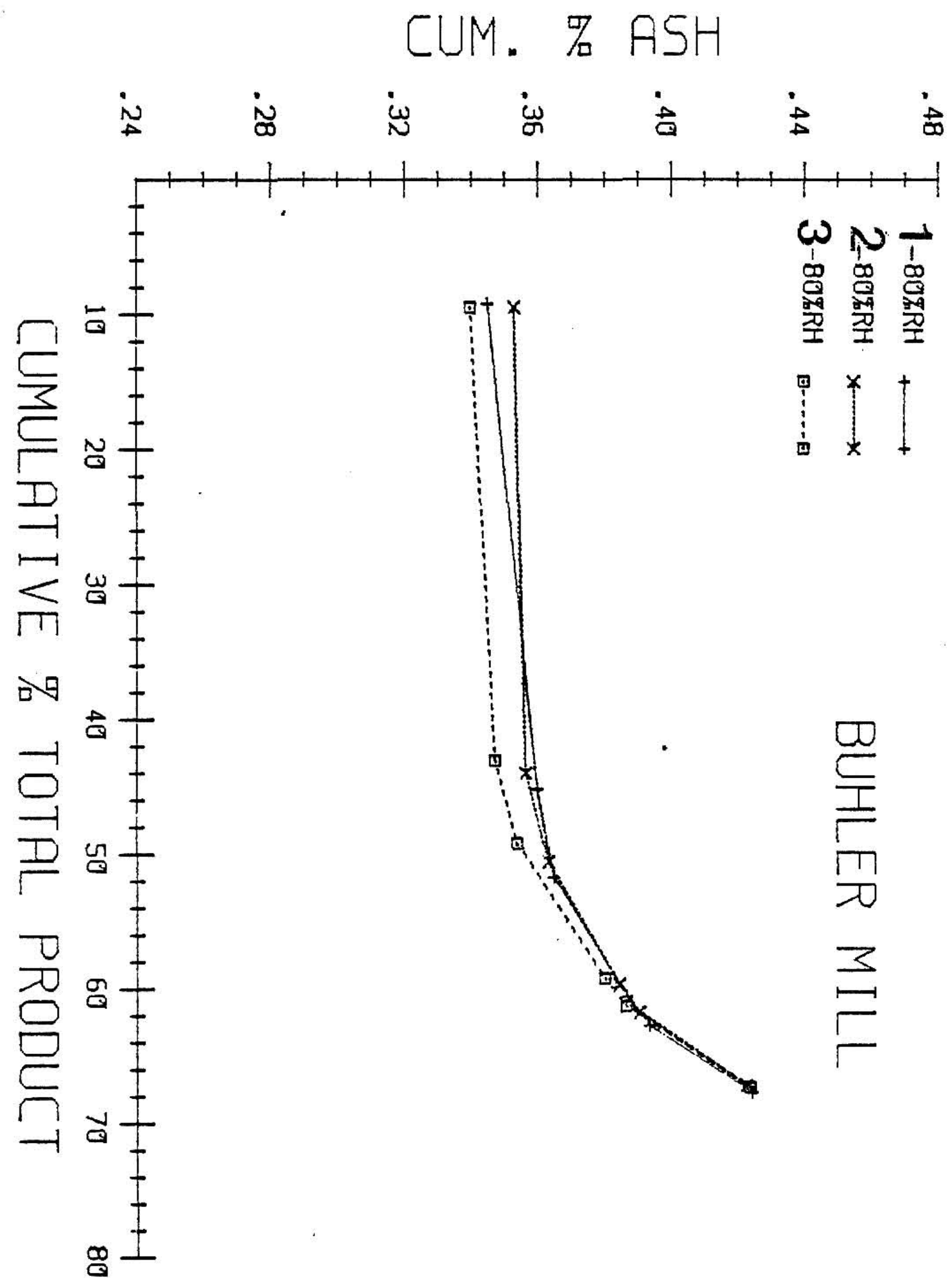

CUM. % ASH
.24
.28
.32
.36
.40
.44
.48
1-60%RH
2-60%RH
3-60%RH
BUHLER MILL
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT


CUM. % PROT.
8.0
10.0
12.0
14.0
16.0
1-60%RH
2-60%RH
3-60%RH
BUHLER MILL
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

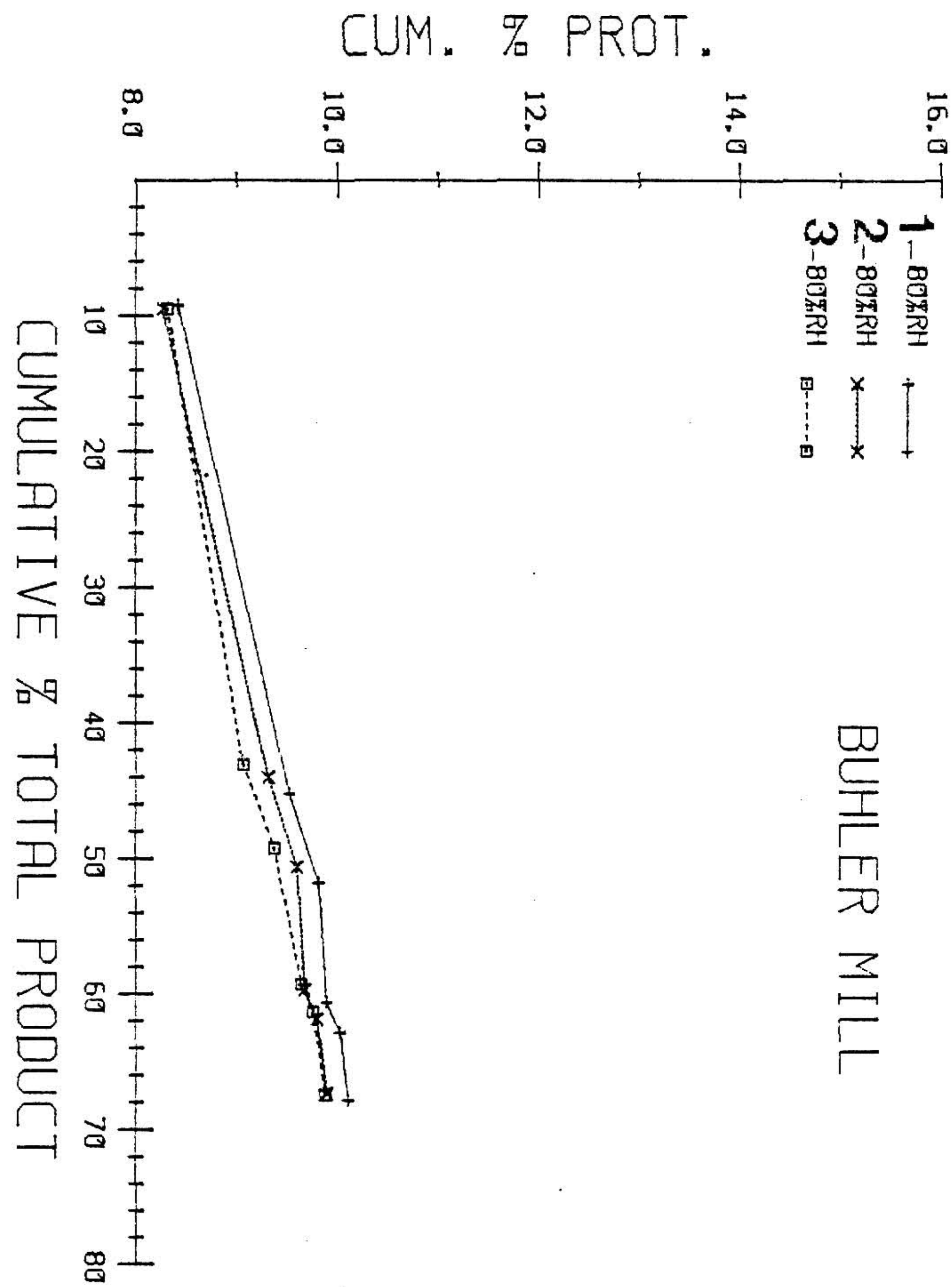


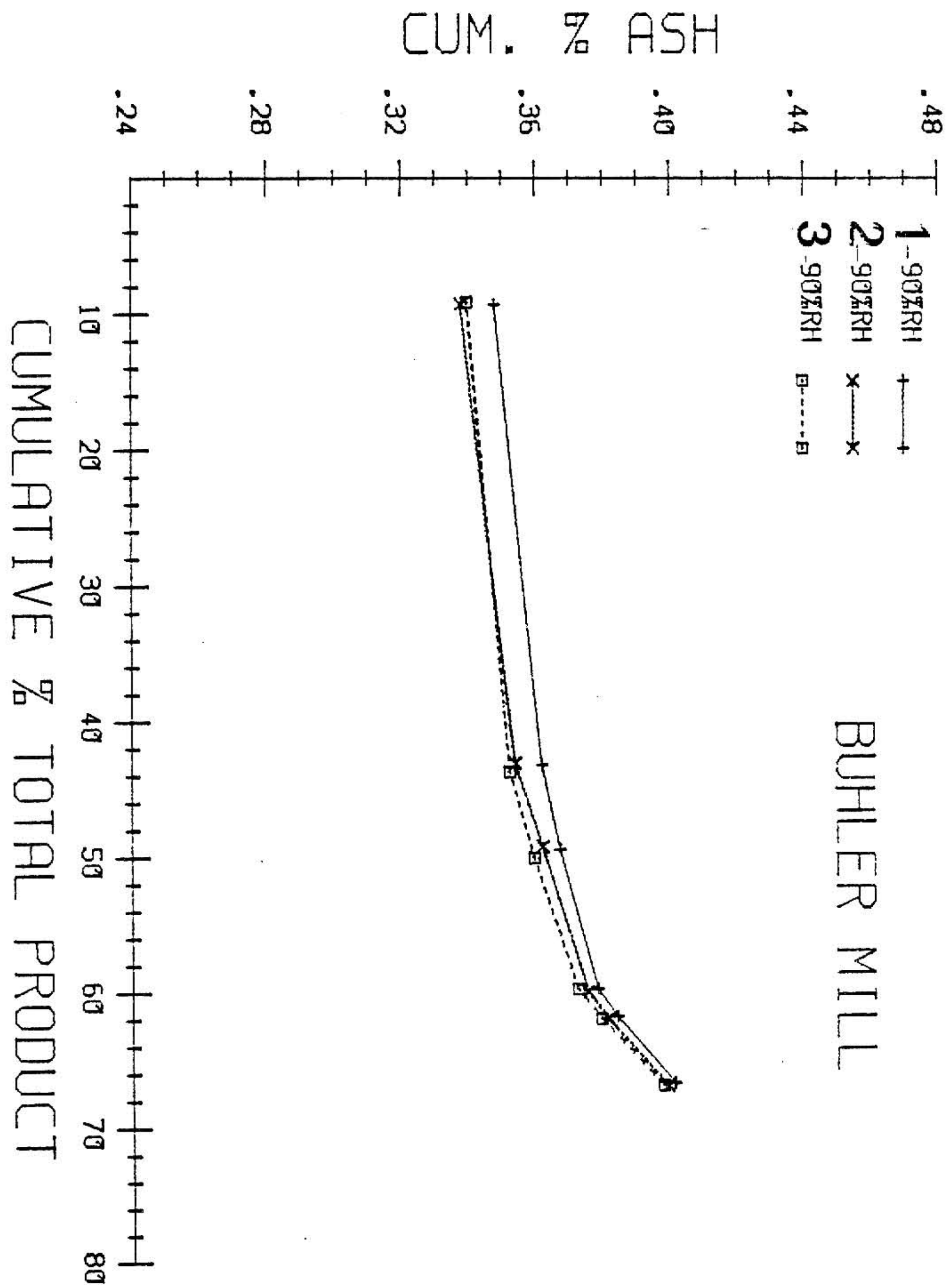
BUHLER MILL
CUM. % ASH
.24
.28
.32
.36
.40
.44
.48
1-70%RH
2-70%RH
3-70%RH
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT


BUHLER MILL
CUM. % PROT.
8.0
10.0
12.0
14.0
16.0
1-70%RH
2-70%RH
3-70%RH
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

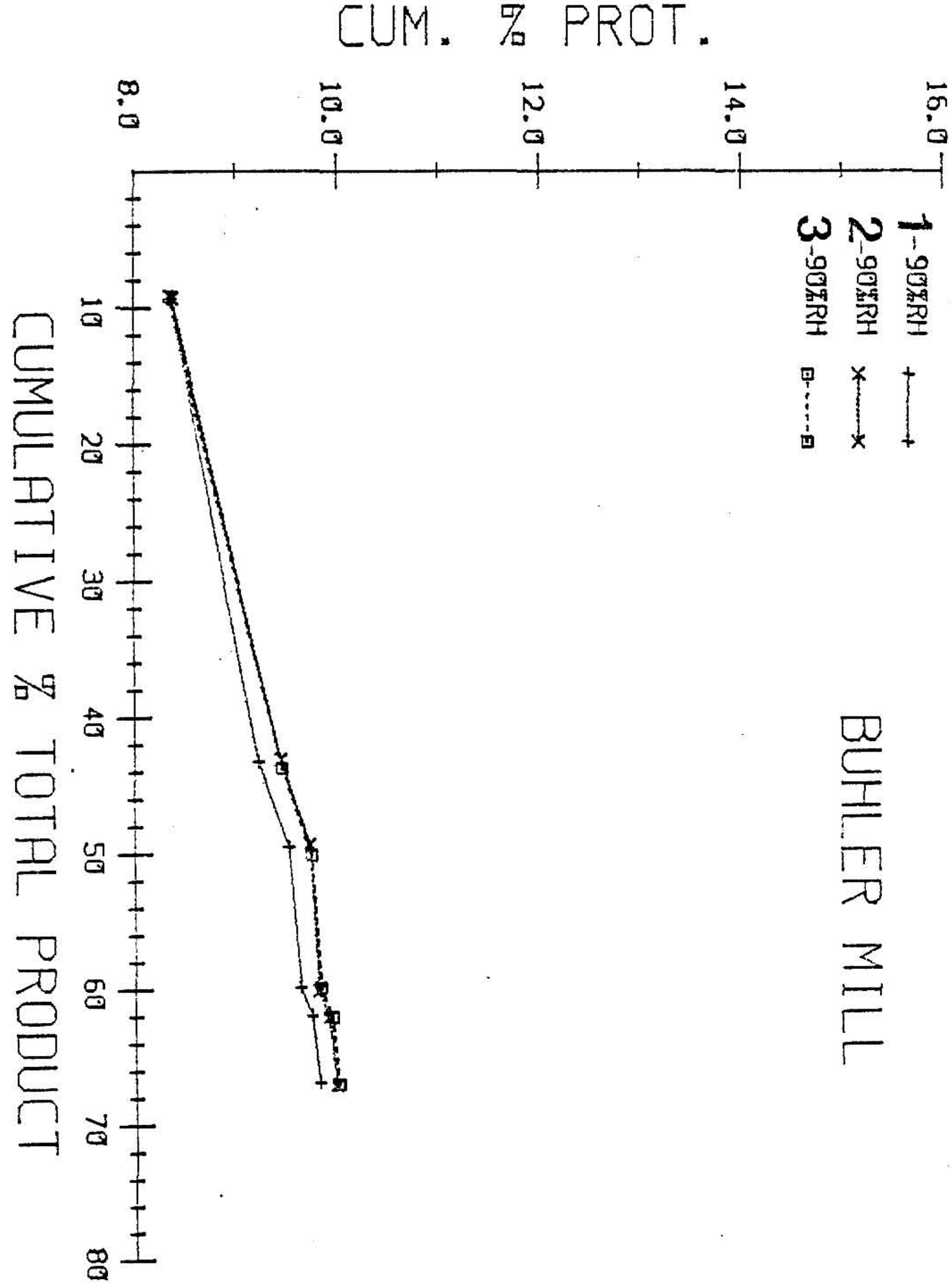


CUM. % ASH
.24
.28
.32
.36
.40
.44
.48
1-80%RH
2-80%RH
3-80%RH
BUHLER MILL
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT


BUHLER MILL
CUM. % PROT.
CUMULATIVE % TOTAL PRODUCT
1-80%RH
2-80%RH
3-80%RH
8.0
10.0
12.0
14.0
16.0
10
20
30
40
50
60
70
80



CUM. % ASH
.24
.28
.32
.36
.40
.44
.48
BUHLER MILL
1-90%RH
2-90%RH
3-90%RH
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT


BUHLER MILL
CUM. % PROT.
8.0
10.0
12.0
14.0
16.0
1-90%RH
2-90%RH
3-90%RH
10
20
30
40
50
60
70
80
CUMULATIVE % TOTAL PRODUCT

# LITERATURE CITED

1. Abbott, F. M. "Observation In Pneumatic Milling," Assoc. of Operative Millers Bul., vol. 4, pp. 501-503.

2. Anderson, J. E. "Principles of Humidification Applied To Flour Millin Process," Assoc. of Operative Millers Bul., vol. 1, pp. 374-384.

3. Anderson, J. E. "Equilibrium Relative Humidities for Hard Wheat and Mill Stocks," N. W. Miller, Prod. Ann. No., Section 2, 192: 20-22.

4. Anderson, J. E. "Comparison of Experimental and Commercial Milling Results," N. W. Miller, Aug, 1938, pp. 46-53.

5. Anker, C. A., Geddes, W. F., and Bailey, C. H. "A study of the Net weight Changes and Moisture Content of Wheat Flour At various Relative Humidities," Cereal Chem., 1942, 19:128-150.

6. Arnold, C. N. "Running An Air Conditioned Mill," Assoc of Operative Millers Bul., 1937, pp. 804-806.

7. Bailey, C. H. and Markley, M. C. "Correlations Between Commercial and Laboratory Milling Tests," Cereal Chem., 1933, 10:515-520.

8. Bayfield, E. G., Anderson, J. E., Geddes, W. F., and Hildebrand, F. C. "The Effect of Millroom Temperature and Relative Humidity on Experimental Flour Yields and Flour Properties," Cereal Chem., 1942, 20:149-171.

9. Bergsteinnson, H. N., and Hadley, S. T. "The Influence of Experimental Milling in Evaluating Wheat Strength," Cereal Chem., 1933, 10:555-559.

10. Cochran, W. G. "Statistical Methods," Chap. 10 (1980).

11. Ferguson, G. C. "What progress has Been Made in Controlling Humidity and Temperature in Flour Mills," Assoc. of Operative Millers, Bul., 1925, pp. 177-178.

12. Frank, W. L. "Short Weights of Flour and Feed," Cereal Che., 1923, 8:19-67.

13. -------- "Moisture Control of Wheat and the Flour Made Therefrom," Natl. Miller, 1925, 31(9):15 (Sep.).

14. Henkle, L. R. "Air Conditioning and Humidity Control For Flour Mills," Assoc. of Operative Millers Bul., 1928, pp. 256-256.

15. Kice, J. "History of Air Stabilization," Assoc. of Operative Millers Bul., 1979, pp. 3762-3764.

16. -------- "Air Stabilization and Make up System,", Assoc. of Operative Millers Bul., vol. 4, pp. 471-475.

17. Kautz, G. M. "The Effect of Evaporation From Wheat and Mill stocks on the process of Milling," Assoc. of Operative Millers Bul., 1937, vol. 2, pp. 155-159.

18. Kühn, I. K. "The Control of Atmospheric Humidity in Flour Mills," Milling, June 29, 1957, pp. 846-867.

19. Lanzrein, H. -R. "Climate and Temperature in Milling Process," Buhler Co., Uzwil, Switzerland.

20. Lockwood, J. F. "Flour Milling," Edited by J. F. Lockwood, (1949) chap. 34, pp. 476-480.

21. McCluggage, M. C. "A Method for the Determination of the Milling Properties of Hard Winter Wheat and Tests of it's Reliability," 1940, Master Thesis on file, Kansas State University, Manhattan, Kansas.

22. Melvin, G. E. "The Temperature of the Mill," Assoc. of Operative Millers Bul., 1922, pp. 77.

23. Micka, J. and Vrann, K. "Concerning the Possibilities of Standardizing the Granulation Test for Flour," Cereal Chem., 1930, 7:280-306.

24. Miller, E. S. "The purpose of Experimental Milling," Assoc. of Operative Millers Bul., vol. 2, pp. 75-78.

25. Miller, E. S. "Some Data on Evaporation and Humidity," Assoc. of Operative Millers Bul., 1924, pp. 135-140.

26. Miller Handbook - Assoc. of Operative Millers, pp. 402.

27. Milling Journal. "Relative Humidity and Moisture Content," Edited by the Science Editor, Milling Jr., June 3, 1960, pp.

28. Milling Journal. "The Role of Moisture in Milling - 1," Edited by the Science Editor, Milling Jr., May 9, 1959, pp. 482.

29. Milling Journal. "The Role of Moisture in Milling - 2," Edited by the Science Editor, Milling Jr., May 16, 1959, pp. 516.

30. Milling Journal. "The Role of Moisture in Milling - 3 and 4," Edited by the Science Editor, Milling Jr., June 6, 1959, pp. 569 and 592.

31. Milling Journal. "The Role of Moisture in Milling - 5," Edited by the Science Editor, Milling Jr., June 13, 1959, pp. 606.

32. Milling Journal. "The Role of Moisture in Milling - 6," Edited by the Science Editor, Milling Jr., July 18, 1959, pp. 4-5.

33. Milling Journal. "The Role of Moisture in Milling - 8," Edited by the Science Editor, Milling Jr., Aug. 29, 1959, pp. 128.

34. Milling Journal. "The Role of Moisture in Milling - 9," Edited by the Science Editor, Milling Jr., Sep. 11, 1959, pp. 176.

35. Murray, R. W. "Influence of atmospheric humidity on Mill Operations," Milling Jr., July 5, 1952, pp. 12-16.

36. Murray, R. W. "Influence of atmospheric humidity on Mill Operations," Milling Jr., July 19, 1952, pp. 68-70.

37. Murray, R. W. "Influence of atmospheric humidity on Mill Operations," Milling Jr., August 30, 1952, pp. 213-215.

38. Pence, R. O. "Some effects of RH on milling process," Assoc. of Operative Millers Bul., 1933, vol. 1, pp. 219-225.

39. Robbins, D. "The Principles of Conditioning in a Flour Mill," Assoc. of Operative Millers Bul., vol. 2, pp. 196-222.

40. Shellenberger, J. H. "Influence of Relative Humidity and Moisture Content of Wheat on Milling yields and Moisture Content of Flour," U.S.D.A. Bul. (1921) No. 1013.

41. Singh, R. and Bailey, C. H. "Biochemical and Technological Study of punjab wheat varieties," Cereal Chem., 1940, 17:169-203.

42. Staff: "Relative Humidity Over Wheat At Different Moisture Contents," made by staff in Grain Science Department, Kansas State University, Manhattan, Kansas.

45. Vilm, Henry. "Humidity and Heat Conservation," Assoc. of Operative Millers Bul., 1924, pp. 148-150.

---

46. A Manual of Recommended Practice. "Industrial Ventilation," Edited by the American Conference of Governmental Industrial Hygienists, 16th Edition, 1980, section 1, pp. 1-2.

AIR STABILIZATION: THE EFFECT OF
ATMOSPHERIC RELATIVE HUMIDITY ON FLOUR MILLING

by

KHALLID ABBASS AL-OBAIDY

B.S., Baghdad University, 1972

---

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Grain Science & Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

ABSTRACT

Hard Red Winter Wheat for the entire experiment was cleaned on laboratory separator and stored in large metal containers in form of 5 kgs. bags.

Four different kinds of mills were used. Two of them were pneumatic (Multomat and Buhler mills) and two non-pneumatic (Quadrumat Jr. and Quardrumat Sr. mills).

The wheat after tempering to 16% moisture was milled in triplicate on each of four mills at relative humidity 40, 50, 60 and 70% and also at 80 and 90% on Buhler and Quadrumat Sr. mills.

Atmospheric conditions in the millroom were maintained within approximately ±2$^{O}$ RH by means of humidifier unit suspended near the ceiling and dehumdifier unit fixed on the bench. The readings for RH % were obtained by using the sling psychrometer.

Protein, ash, and moisture determinations were made in triplicate. The results of protein and ash were corrected to 14% moisture basis.

According to the results, nothing significant was there for those non-pneumatic experimental mills during all the observations. The results of the pneumatic experimental mills showed that with increasing humidity in the atmosphere the following effects can be noticed:

1) Flour moisture increased

2) Flour ash content decreased

3) Flour protein content decreased

4) Flour extraction decreased

5) Milling loss decreased

6) Grinding and sifting were difficult.

Final conclusions showed the necessity of having an air stabilization unit in the plant, particularly those mills which are using pneumatic systems.