EFFECTS OF SPLITTING UNTEMPERED AND PARTIALLY TEMPERED WHEAT AS A POSSIBLE METHOD TO SHORTEN TEMPERING TIME OF HARD RED WINTER WHEAT

by

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INTRODUCTION

Wheat conditioning is the adjustment of moisture content of wheat with time and with or without the use of added heat. The purpose of wheat conditioning is to assist the milling process by toughening the bran to resist attrition and abrasion, to facilitate extraction of the endosperm from the bran and to ease reduction of middlings to flour sizes.

The addition of moisture to grain and holding for a period of time without the addition of heat is cold conditioning or tempering (3). Warm conditioning is the addition of moisture to wheat with added heat to raise grain temperatures to a maximum of 46° C. (115° F.). Hot conditioning is the addition of moisture to wheat with added heat to raise grain temperatures to 46° C. or higher.

The four variables encountered in conditioning are moisture, time, temperature and pressure. In this study moisture and pressure were constants, while time and temperature were variables.

As temperature increases, the rate of water penetration into the wheat kernel increases. A holding period prior to milling is necessary to allow the moisture to penetrate throughout the kernel and achieve the mellowing effect of conditioning.

The weather, restricted temper bin capacity and frequent changing of mill mixes sometimes forces the miller into a shorter than desired temper time. Lack of enough tempering bin capacity is a problem to the miller because wheat must be given sufficient time for moisture penetration and conditioning to occur.

This investigation involved samples of hard red winter wheat which were split on smooth rolls prior to conditioning. The split samples were conditioned at temperatures of 21.1° C. and 43.3° C. at 16 percent moisture. The samples were held for periods ranging from 2 to 16 hours prior to being milled. Each individual flour stream from the milled samples was analyzed for moisture, ash and color. A germ fraction from each milled sample was analyzed for moisture and protein.

Cumulative ash, cumulative color, germ extraction and germ protein were studied to determine the effects of splitting hard red winter wheat prior to conditioning at varying times and temperatures.

REVIEW OF LITERATURE

Kernel Structure. Moisture movement in wheat is primarily dependent on kernel structure. Moisture may be added to wheat by immersion, tempering or wetting the grain, or by exposure to air of high humidity. Moisture movement occurs within the wheat kernel by diffusion, with some degree of capillary action on or near the outside surface of the grain towards the crease (18) (31).

It was once thought that a major portion of the wheat kernel was surrounded by an impermeable membrane so that moisture was introduced by way of the beard and placenta, or by the small aperture, the micropyle. However, Pence and Swanson (28) showed that the kernel is not enclosed by a nonpermiable membrane, but absorbs water through the entire bran surface. The bran coat does have a greater affinity for water than the endosperm of the wheat (28).

Investigations have shown that maximum water absorption occurs at the germ end of whole, sound grain (14) (27) (28) (33). Penetration occurs more slowly through the back and brush end. Any indication of moisture entry through the crease could not be detected. Ugrimoff (37) stated that wheat kernels could have their brush ends immersed in water for long periods of time without germination taking place. The slow absorption into whole sound grain is probably due to a film of air held by the fine hairs or because of friction caused by the hairs (29). This does not hold true for scoured grain. Hinton (16) found that the effective barrier to ready entry of water is the testa layer, not the aleurone layer.

Bradbury, Cull and MacMasters (4) outlined the path of moisture entry into the wheat kernel. The attachment area at the base of the kernel is the only region that permits immediate and rapid entrance of water. This is the only portion not covered by a cuticle. The parenchyma tissue located in the attachment area contains numerous intercellular spaces. Rapid movement of water takes place upward from this spongy tissue, through the pericarp and into the area of thin-walled cells. This maze of intercellular spaces, among intermediate cross and tube cells along the dorsal surface of the kernel, forms another pathway for rapid movement of water. The spongy parenchyma on the crease side connects with the pericarp tissue in the "V" of the crease and, therefore, with relatively large air spaces which formed during maturation.

Hinton (16) reported the permeability of the endosperm by water is influenced primarily by the degree of mealiness it has developed. In both hard and soft wheats, fully mealy endosperm was found to be twice as permeable by water as fully vitreous endosperm. Once the water has penetrated the bran layers, it is transferred slowly and uniformily along the grain through the endosperm (31) (33).

Hinton (16) attributed the slow movement of water in the endosperm as the reason for the long period of time required for complete distribution throughout the grain. Although the rate of movement through the endosperm is three to six times faster than that through the testa, the distances involved in the endosperm are much greater (16) (32). Haltmeier (14) stated that in any case (with or without heat) the brush end always gets its moisture through the bran coat. This occurs because the penetration from the germ end is too great a distance and takes too long in spite of more rapid absorption.

Time and Temperature. Pence and Swanson (28) observed two stages of moisture absorption by an immersed kernel of wheat. First there is a rapid uptake of moisture followed by a gradual decrease in uptake as the length of time increases.

A small change in immersion time has greater affect with shorter immersion time than with longer immersion time.

Temperature has no appreciable affect during the initial rapid uptake of moisture. After the grain has been soaked two minutes, an increase in temperature results in an increased rate of absorption (28). Jones and Campbell (8) reported that a rise of 12° C. between 20° C. and 43.5° C., causes a threefold increase in speed of movement of moisture to the cheek center. The increase in speed of moisture movement to the cheek center ceases abruptly above 43.3° C. From 49° C. to 60° C. there is no increase in speed of moisture movement.

Jones and Campbell (7) developed a method for determining small changes in moisture content of small endosperm particles by utilizing the change in density. Complete saturation of the kernel has been reported in the literature as taking from 2-3 hours (12) up to 24 hours (28) at room temperatures. Jones and Campbell (7) reported that when a 5 percent increase in moisture was added to vitreous Manitoba wheat, the center of the cheek had received about ½ its final moisture increment in about 5 hours. After 24 hours it had received approximately 85 percent of its final moisture increment. The moisture movement in this part of the grain was not complete until 60 hours after tempering.

Kernel Size. Work done by Fraser and Haley (12) showed that smaller kernels of grain absorbed moisture faster than larger kernels. This increase was attributed to the larger absorbing surface area of the smaller kerneled grain in relation to its weight.

Internal Fissures. Fisher and Hines (11), Milner and Shellenberger (25) found that wheat which had been moistened and dried several times had fissures or cracks in the endosperm. Wheat that was treated in this manner absorbed water more quickly than untreated or unfissured wheat. The rapid moisture pick up was attributed to the fissures.

Scouring. Campbell (6), Fraser and Haley (12), showed that scouring resulted in an increase in rate of absorption when immersed for one minute in water. Campbell (6) reported that the rate of subsequent moisture penetration into the endosperm is increased only in the peripheral dorsal region of the endosperm. The beard end is responsible for the greater part of the increased rate of moisture penetration.

Texture. Herd (15) reported that soft wheats absorbed moisture more slowly than did hard wheats.

Wheat Conditioning

Wheat conditioning is the adjustment of moisture in the grain with time, with or without the use of heat. This study utilized both cold and warm conditioning.

Cold Conditioning. Cold conditioning or tempering is the adjustment of moisture with time without the use of heat. After the wheat has been cleaned, the necessary amount of water is added to raise the moisture content to an optimum level for milling. The grain is then held for 6 to 24 hours for moisture penetration and mellowing.

Water is usually metered by a flow meter which controls the moisture added to the wheat. After the water is added and thoroughly mixed using a mixing screw or some other suitable device, the dampened grain is held in tempering bins. The proper milling moisture for different classes of wheat and the holding time is determined by personal opinion and experience with the mill on which the wheat is to be milled. In the United States the milling moisture averages between 15 and 16 percent and length of bin lie runs anywhere from 6 to 24 hours. The two variables encountered in cold conditioning are moisture and time.

Anderson (1) tempered a Turkey variety wheat to different moisture contents ranging from 14 to 22 percent and held for varying periods of time ranging from 1 to 125 hours. The samples were passed through only the first break using a constant roll setting and feed rate. The scalp was made with a 20W cloth. The throughs of the 20W scalp were weighed and the percent extraction calculated. The temperature was held constant at 75° F.

Anderson (1) found that tempering the Turkey variety wheat to 18 percent moisture for 63 hours resulted in maximum break release through a 20W when compared to other moistures of 14, 16, 20 and 22 percent for holding periods ranging from 1 to 125 hours. He also reported that wheat tempered to 18 percent moisture for 24 hours gave the best mixograph curves as compared with other samples tempered to 16, 20 and 22 percent moisture for 24 hours.

Dedrick (9) in an investigation dealing with different tempering containers (glass jar, earthen crock, sheet iron can, wooden box) found that large moisture losses during the holding period resulted in a lower flour extraction having a poorer quality than tempered wheat in which the moisture content was maintained throughout the holding period.

Swanson (34, 35) investigated the effects of wetting and drying wheat repeatedly up to six times at moisture contents varying from 12 to 28 percent. The wheat was air dried back to 10 percent moisture after each wetting period. The wheat was milled at 16 percent moisture. He reported a slight trend toward greater break releases with higher moisture levels for each wetting and increased number of wettings. Flour yield and ash showed no relation to the number of times or degree of wetting of the samples. There was a decrease in hardness with added moisture up to 20-24 percent.

Pelshenke and Shafer (26) found that increased levels of moisture in Manitoba 5 wheat resulted in decreased power consumption, flour yield and amylose number. In addition, bran yield and the amount of starch in bran increased. A standing time of more than 24 hours at 16 percent moisture produced no further change than that brought about by 24 hours.

Seeborg and Barmore (30) investigated different tempering moistures on soft wheat and reported that as moisture content increased, the flour yield, ash and break release decreased.

Weber (39) found that individual treatment of different wheat varieties making up a mill mix prior to blending gave the best milling results.

Wichser and Shellenberger (40) tempered 2000 gram samples of hard red spring and hard red winter wheats to 16 percent moisture and held them for periods ranging from 4 to 48 hours. The samples were then milled on Allis experimental rolls. They found no differences in granulation, farinographs or baked products from the flour of the milled samples.

Stark (32) found slight differences in milling Kansas hard wheat of 10.5 percent moisture tempered to approximately 15 percent at holding periods varying from 12 to 54 hours.

Vermeylen (38) found that tempering brought about an improvement in gluten characteristics over dry milling. He stated that better farinographs were obtained by adding water in several steps rather than all at one time. Vermeylen concluded that 48 hours appeared to be the optimum holding period.

McCormick (24) tempered hard red winter wheat to 15 percent moisture and held for varying temper times ranging from 3 to 72 hours. McCormick reported that the length of temper time did not affect the ash content of the break flour, the amount of middlings released or the power consumption.

Warm Conditioning. Warm conditioning is the adjustment of moisture levels in wheat with time at temperatures up to 46° C. The principal advantage of using heat during the conditioning process is an increase in the rate of water penetration into the wheat kernel. This reduces the required holding time prior to milling.

Brabender and Abdon (5) found that warm conditioning does not eliminate the need for separate preliminary treatment of different types of wheat. In their investigation, a mixture of Manitoba, soft Plate and a soft Russian wheat was washed and held for eight hours. The wheat mix was then conditioned at 42^{o} C. for a period of 75 minutes. Farinographs of the flour streams showed that the later breaks and reductions exhibited more Manitoba-like strength than the head end streams.

Brabender and Abdon (5) then tempered separately the Manitoba wheat for 48 hours and the two soft wheats together for 8 hours. The wheats were mixed together and conditioned at 42^{o} C. for a period of 75 minutes. The higher grade flour streams were properly strengthened, indicating that best results were obtained by allowing the hard wheat a longer time to properly mellow. Thus the properly tempered hard Manitoba wheat could be reduced more easily into flour at the head of the reduction process rather than at the tail end.

Vermeylen (38) found that heating Manitoba II wheat to 40^{o} C. for one hour resulted in no improvement in baking quality over holding it for 24 hours without heating.

Losev (23) stated that wheat conditioned at 27^{o} C. at 16.5 percent moisture for 24 hours produced a flour that gave poorer loaves of bread than that from wheat conditioned at 18^{o} C., 16.5

percent moisture for 24 hours.

Remington (29) noted an increase in strength for warm conditioned wheat over unconditioned wheat using Manitoba, Australian and English wheats milled at 17 percent moisture.

Eustace (10) reported that warm conditioning of a hard red winter wheat mix consisting of Kaw and Ottawa varieties at 43° C. can result in lower ash in the flour. Conditioning at 43° C. for one hour at 15.5 percent moisture with an additional eleven hour holding period at room temperature gave a significantly higher yield without a significant change in ash as compared with conditioning at 43° C. at 15.5 percent moisture for 12 hours. This indicates that heating for long periods of time will tend to lower yield as compared to heating for moderate periods of time.

Hot Conditioning. Hot conditioning is conditioning at temperatures in excess of 46° C. with time. Like warm conditioning, hot conditioning increases the rate of water penetration into the wheat kernel. Heating wheat at higher temperatures can cause damage to the wheat proteins (10).

Swanson (36) conditioned hard wheat at three different temperatures (48, 70, and 98° C.) using 25, 50 and 100 cc. of water per kilogram. Four different treatment times were used at each temperature. As soon as each sample was treated it was dried as quickly as possible. Some were dried in the sun, and others in an artificial drier constructed for the purpose. The samples were then tempered to 13.5 percent and milled. A temperature of 45° C. did not improve the baking quality of the flour and 98° C. was harmful. The best loaves were from samples heated to 70° C. with 25 cc. of water for 12 to 24 hours and with 50 cc. of water for 3 hours.

Swanson (36) later conducted experiments at temperatures of 50, 60, 70 and 80° C. for different lengths of time on Kansas hard wheat moistened to 13.5 percent. Wheat heated to 80° C. for 3 to 12 minutes resulted in the best loaves of bread. Swanson concluded that heat, especially when applied to recently harvested wheat, can improve the milling quality of wheat and the baking qualities of the flour.

Kent-Jones (19, 20, 21) found that holding dampened grain at 17 to 18 percent moisture for a period of 24 hours at 110° F. produced no changes in chemical properties or baking quality of the flour. No changes occured after 6 hours, but slight chemical changes occured after 16 hours. After 24 hours at 135° F., the flour increased in strength, but it developed sour odors on standing for a few more hours.

√ Geddes (13), Becker and Sallans (2) investigated the affect of temperature, time and moisture as evaluated by baking quality. Geddes found that as moisture content of the wheat increased, the critical temperature where baking quality is improved, is lowered. Becker and Sallans found that when using a hard red spring wheat, the temperature which brought about a decrease in loaf volume was lower with higher moisture contents.

Wild (41) reported that hot conditioning of a soft German wheat at 16.5 percent moisture improved baking quality as compared with cold conditioning. The best conditions for improvement of baking quality were temperatures of 50° C. to 57° C. for $1\frac{1}{4}$ to $1\frac{1}{2}$ hours.

Vermeylen (38) reported that different lots of wheats vary in their response to heat. His studies of farinograph curves of flour from Manitoba II wheat indicated that wheat held for 24 hours with 5 percent increase in moisture added and then heated for $1\frac{1}{2}$ hours at 55° C. gave the most improvement. Kuhl (22) found that the gluten of German domestic wheat improved with heat treatment up to 62° C. to 65° C. for one to two hours.

Ziegler (42) found an increase in the extensibility of dough for Manitoba and Swiss domestic wheats after treatment in a hot air conditioner at temperatures of 48° C. and 47° C. respectively.

Eustace's (10) investigation dealing with hard red winter wheat showed heating can cause protein damage. Heating for 12 hours at 60° C. and milling at 15.5 percent moisture had a detrimental effect on the farinograph curves of the flour. Heating to 70° C. for fifteen minutes and 90° C. for five minutes also produced heat damage as shown by the farinogram.

Tempering Split Wheat. Hodler (18) investigated tempering split wheat by splitting 16 samples of hard wheat on smooth rolls operating at 1.5:1 differential. Each sample consisted of 1500 grams of wheat. Two sets of trials were run with eight samples of split wheat and eight samples of whole wheat in each set of trials. One set was tempered to 16 percent moisture and the other to 18 percent moisture. The samples were then milled after 3/4, 1-1/2, 2, 4, 8, 18, 30 and 48 hours of tempering time.

Hodler (18) concluded that splitting hard, vitreous wheats before tempering may be expected to speed up the tempering effect, particularly in the first few hours of tempering, as indicated by studying the dough-mixer curves of the flour. In addition, the percent ash of the straight grade flour was lower in all but two cases. Examination of both dry and wet Pekar slicks did not reveal any significant color variations.

MATERIALS AND METHODS

The wheat used in this experiment was a blend of hard red winter wheats. The wheat had 11.0 percent protein, 11.8 percent moisture and 1.7 percent ash.

Cleaning

The grain was cleaned by passing it through the Kansas State University cleaning house. The grain was conveyed pneumatically throughout. Equipment used included a permanent magnet, a pneumatic lift aspirator, milling separator, dry stoner separator and gravity table, disc separators, Entoleter scourer aspirator and duo-aspirator. The flow rate through the cleaning operation was sixty pounds per minute.

Splitting

Two thousand gram samples were first passed over a number 8 wire sieve to give two fractions of different sizes. This increased the control over splitting the kernels. Each fraction was passed through a pair of smooth Ross experimental rolls operating at a 1.5:1 differential. The rolls were set just close enough to split open each fraction of wheat along the kernel crease. After splitting, the two fractions were rejoined and immediately tempered to the desired milling moisture.

Addition of Moisture

The final moisture of the wheat for milling was 16 percent for each test. The moisture added to the wheat was calculated by the following formula:

$$\frac{(100-M_1)}{(100-M_2)} \times W_1 = W_1 + H$$

M_1 = percent moisture in the untempered wheat sample.

M_2 = percent moisture in the tempered wheat sample.

W_1 = weight of untempered wheat sample.

H_1 = weight of water to be added.

Water was added to the wheat in a rotating metal drum. The moistened wheat was removed from the rotating metal drum after fifteen minutes and placed in a sealed plastic bag.

Cold Conditioning

Control Cold. In this investigation cold conditioning involved two split treatments and a control. The control consisted of eight 2000 g. samples of unsplit wheat tempered to 16 percent moisture and held in sealed plastic bags for 6, 8, 10 and 16 hours before milling.

Partially-Tempered Split (P.T.S. Cold). The partially-tempered split treatment involved the addition of one percent moisture to each of twelve 2000 g. samples of wheat prior to splitting on smooth rolls. Five minutes were allowed for mixing. The samples were then passed over the number 8 wire sieve and split fifteen minutes after the one percent moisture increase was added. The samples were immediately tempered to 16 percent moisture and held in sealed plastic bags for 2, 4, 6, 8, 10 and 16 hours before being milled.

Dry Split (D.S. Cold). The dry split treatment involved splitting ten 2000 g. samples of wheat on smooth rolls at their original moisture content of 11.8 percent. The samples were then immediately tempered to 16 percent moisture and held in sealed plastic bags for 4, 6, 8, 10 and 16 hours before milling.

Warm Conditioning

Warm conditioning was accomplished by heating a sample of wheat, moistened to 16 percent, in a Miag laboratory wheat conditioner to a temperature of 43.3° C. in seven minutes. The wheat was then removed and placed in a sealed plastic bag. The wheat was allowed to cool to room temperature for the desired length of time before milling.

As in the cold conditioning, the warm conditioning consisted of an unsplit treatment (Control Warm), a partially-tempered split treatment (P.T.S. Warm) and a dry split treatment (D.S. Warm). The only difference between cold temper and warm conditioning being the warm conditioned samples were raised to a temperature of 43.3° C. immediately following their final moisture adjustment to 16 percent. The number of samples and holding periods were the same for both cold and warm conditioning.

Operation Of The Miag Laboratory Wheat Conditioner

The Miag laboratory conditioner has a heating chamber which is an insulated rotating drum. This drum contains electric heating elements in the sides and ends. The desired temperature is preset with a thermostatic regulator. A twenty minute period was allowed for pre-heating the conditioner prior to placing the sample inside. It was determined by trial and error that a setting of 60 on the thermostatic regulator would raise the temperature of the wheat to 43.3° C. in seven minutes. After a temperature of 43.3° C. was reached, the sample was removed and placed in a sealed plastic bag and allowed to cool to room temperature for the desired holding period before milling.

Experimental Milling

A batch system of milling was useu in this experiment.

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EXPERIMENTAL MILLING FLOW SHEET

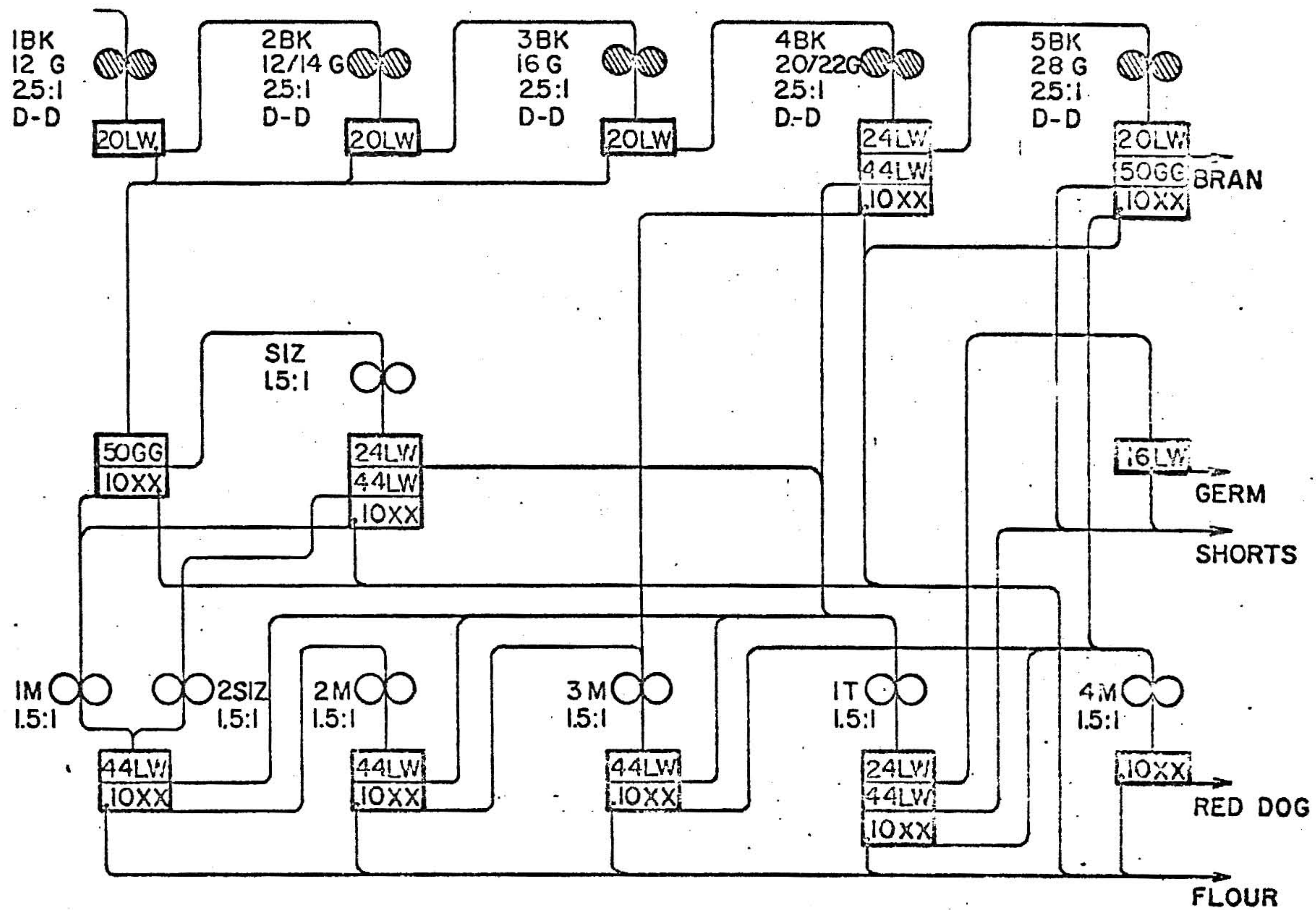

Fig. 1

Figure 1 shows the flowsheet that was followed. Ross experimental roller mills were used and the sifting of stock was accomplished by a Great Western laboratory sifter.

A pre-break was only used on the control samples. A pair of smooth 9" X 6" rolls was used, operating at a 1.5:1 differential. The rolls were set just close enough to split open the kernels along the crease. After the stock passed through the pre-break rolls, it was taken directly to first break without sifting.

All break rolls were 9" diameter X 6" long operating dull to dull at a 2.5:1 differential with Getchell corrugations. The break roll corrugations were as follows: first break, 12 corrugations per inch, $\frac{1}{4}$ inch spiral; second break, 12 corrugations per inch for the fast roll, 14 corrugations per inch for the slow roll, $\frac{1}{4}$ inch spiral; third break, 16 corrugations per inch, $\frac{1}{4}$ inch spiral; fourth break, 20 corrugations per inch for the fast roll, 22 corrugations per inch for the slow roll, $\frac{1}{2}$ inch spiral; fifth break, 28 corrugations per inch, $\frac{1}{2}$ inch spiral.

The degree of grinding action of the break rolls was set on the basis of break release. In this investigation, 100 g. of stock was passed between the rolls and sifted for 60 seconds to determine the quantity passing through the scalp sieve. The different break rolls were adjusted to obtain the following break releases; first break, 30 percent through a number 20 light wire (30%-20 L.W.); second break, 40%-20 L.W.; third break, 35%-20 L.W.; and fourth break, 25%-24 L.W. Fifth break was adjusted to clean up the bran as much as possible without cutting it into slivers.

With the exception of sizings and first tailings, the reduction rolls were all set to make as much flour as possible without flaking. Coarse sizings was set to reduce the sizings stock to a size comparable to that stock going to first middlings. First tailings was ground close enough to flatten the germ and reduce any coarse endosperm that might be present.

The sifting times were as follows: first, second and third breaks were sifted three minutes; fourth and fifth break were sifted two minutes; first middlings for three minutes; second sizings for thirty seconds; second, third and fourth middlings for two minutes and first tailings for one minute.

A germ fraction was taken off the overs of the 24 L.W. sieve of first tailings. This fraction was sifted for thirty seconds on a number 16 L.W. sieve. The overs of this separation was germ and the throughs went to shorts.

Extractions were reported on clean tempered wheat basis. Temperature in the mill averaged 74° F. Humidity was not controlled but was recorded and shown in Table 1.

This experiment was set up on a specific randomized complete block design. There were thirty tests and two replications. As previously mentioned, there were three kernel treatments: whole or control, a partially-tempered split and a dry split treatment. There were two temperatures, cold or room

Table 1. Relative Humidity During Milling

Temper Time	Replication	Cold Temper Control	Cold Temper P.T.S.	Cold Temper D.S.	Warm Conditioned Control	Warm Conditioned P.T.S.	Warm Conditioned D.S.
2 Hr.	1.		56			74	
	2.		44			29	
4 Hr.	1.		71	55		63	65
	2.		33	37		26	34
6 Hr.	1.	56	70	62	52	55	58
	2.	22	29	37	37	26	20
8 Hr.	1.	60	58	74	48	59	62
	2.	33	30	34	35	44	26
10 Hr.	1.	64	46	58	65	58	56
	2.	20	32	29	31	33	28
16 Hr.	1.	52	53	56	58	75	54
	2.	41	41	36	38	38	23

temperature and warm (43.3° C.). Hall's table of random numbers was used in determining the random order in which each test was run for each replication.

Analysis

The moisture and ash analysis were conducted on each individual flour stream according to procedures 44-15A and 08-01 in Approved Methods of the American Association of Cereal Chemists.

The moisture and protein analysis were performed on the germ fraction according to procedures 44-15A and 46-10 in the Approved Methods of the American Association of Cereal Chemists.

A dry Agtron color was run on each individual flour stream. A Model F2-61 with a green mode light source was used. Each flour stream sample was placed in the sample cup and then raised approximately ½ inch and dropped 30 to 40 times on a slightly resilient but solid surface. This procedure was done to eliminate all roughness and fissures from the viewing surface of the sample cup. This gave assurance against irregular results.

Cumulative ash curves were plotted for both replications of each treatment. Each treatment's individual flour stream ash percentages were converted to a 14 percent moisture basis and placed in an array from low to high. The percent of wheat for each flour stream was summed in the order of the increasing ash. Each stream's percent of wheat was then multiplied by its respective ash percentage (14% moisture basis) and then again summed in the order of increasing ash. To calculate the cumulative percent ash, the sum of the product of percent of total product times the percent ash was divided by the cumulative percent of total product. An example of the cumulative percent ash as calculated for the first replication of P.T.S. Cold, 2 hr. temper is shown in Table 2.

The total cumulative percent ash of "straight grade" flour (total flour extracted) and the percent extraction of 0.40% ash "patent" flour was obtained from each cumulative ash curve. These values, along with the total percent extraction of straight grade flour, were used to calculate a "processed materials value" for each treatment.

When calculating the materials value it was assumed that no product loss occurred during processing. From the cumulative ash curves, the percent of 0.40 ash patent flour, percent of "first clear" flour (percent total or straight grade flour minus percent patent flour), and percent feed (100 percent minus percent total flour) were calculated. Each product percentage was then multiplied by its respective market price per hundred pounds ($/cwt.) bulk Kansas City on June 18, 1976, as reported in Milling and Baking News. On that date, patent flour was selling for $8.85/cwt. bulk Kansas City; first clear for $7.60/cwt. bulk feed for $4.40/cwt. bulk. The products were then summed to obtain the materials value in dollars per hundred weight milled. An example of the processed materials value as calculated for the first replication of P.T.S. Cold, 2 hr.

Table 2. Cumulative Ash Calculation

1-P.T.S. Cold 2 Hrs.		Q	S of Q	A	Q X A	S of Q X A	S of Q X A / S of Q
Flour Stream	Stream Weight Grams	% of Total Wheat	Cumulative % Total Wheat	% Ash 14% M.B.	% Total Wheat X % Ash	Cumulative Q X A	Cumulative % of Ash
1 M	636.27	30.61	30.60	0.323	0.897	9.897	0.323
C Siz	112.67	5.42	30.61	0.364	1.974	11.871	0.330
2 M	161.43	7.77	.43.79	0.401	3.117	14.988	0.342
2 Bk	64.85	3.12	46.91	0.468	1.460	16.448	0.351
3 Bk	31.70	1.53	48.43	0.505	0.770	17.218	0.355
4 Bk	25.88	1.25	49.68	0.522	0.650	17.868	0.360
1 Bk	64.77	3.12	52.79	0.530	1.651	19.519	0.370
3 M	125.00	6.01	58.81	0.540	3.247	22.766	0.387
F Siz	16.04	0.77	59.58	0.619	0.477	23.243	0.390
1 T	18.08	0.87	60.45	0.737	0.641	23.884	0.395
4 M	114.00	5.48	65.93	1.000	5.483	29.367	0.445
5 Bk	27.84	1.34	67.27	2.012	2.694	32.061	0.477

temper is shown in Table 3.

Cumulative color curves were also plotted for both replications of each treatment. The cumulative color was calculated on the basis of increasing ash. All calculations were the same as that for cumulative percent ash, except that they were not adjusted for moisture. An example of the cumulative color calculation is shown in Table 4, for the P.T.S. Cold, 2 hr. temper time treatment.

From the cumulative color curves, the cumulative color of straight grade and patent flour was determined.

RESULTS AND DISCUSSION

A randomized complete block design with 30 treatment and two replications was run. Eight variables were measured: total percent extraction of straight grade flour ($\bar{Y}_1$, results shown in Table 5), percent cumulative ash of straight grade flour ($\bar{Y}_2$, results Table 6), percent extraction of 0.40% ash patent flour ($\bar{Y}_3$, results Table 7), processed materials value of products in dollars per hundred weight ($\bar{Y}_4$, results Table 8), cumulative Agtron color of straight grade flour ($\bar{Y}_5$, results Table 9), cumulative Agtron color of 0.40% ash patent flour ($\bar{Y}_6$. results Table 10), percent germ extraction ($\bar{Y}_7$, results Table 11) and percent protein in germ ($\bar{Y}_8$, results Table 12).

The cumulative ash and cumulative color curves for each replication of the 30 treatments can be seen in Figures 2 through 45. The results of the first six variables were calculated from

Table 3. Processed Materials Value Calculation

1-P.T.S. Cold, 2 Hr. Temper			
Product	$/cwt.	% of Wheat	$/cwt. X % of wheat
Patent Flour	8.85	60.45	5.35
First Clean Flour	7.60	6.82	.52
Feed	4.40	32.73	1.44
Materials Value			7.31

Table 4. Cumulative Color Calculation

1-P.T.S. Cold, 2 Hr. Temper

Flour Stream	Stream Weight Grams	Q % of Total Wheat	S of Q Cumulative % Total Wheat	A Color	Q X A % Total Wheat X Color	S of Q X A Cumulative Q X A	S of Q X A / S of Q Cumulative Color
1 M	643	30.68	30.68	80.0	2454.4	2454.4	80.00
C Siz	114	5.44	36.12	71.5	389.0	2843.4	78.72
2 M	162	7.73	43.85	71.5	552.7	3396.1	77.45
2 Bk	66	3.14	46.99	63.5	199.4	3595.5	76.50
3 Bk	32	1.53	48.52	63.0	96.4	3691.8	76.09
4 Bk	26	1.24	49.76	62.0	76.9	3768.7	75.74
1 Bk	66	3.15	52.91	60.0	189.0	3957.7	74.80
3 M	125	5.96	58.87	72.0	429.1	4386.8	74.51
F Siz	16	.76	59.63	65.0	49.4	4436.2	74.40
1 T	18	.86	60.49	53.0	45.6	4481.8	74.09
4 M	114	5.44	65.93	55.0	299.2	4781.0	72.51
5 Bk	28	1.34	67.27	55.5	74.4	4855.4	72.18

Table 5. Percent Total Flour Extraction

Temper Time		Cold Temper Control	Cold Temper P.T.S.	Cold Temper D.S.	Warm Temper Control	Warm Temper P.T.S.	Warm Temper D.S.
1 Hr.	1.		67.27			69.95	
	2.		70.19			71.12	
4 Hr.	1.		66.87	69.94		70.81	67.58
	2.		71.06	70.84		70.04	69.47
6 Hr.	1.	69.80	69.78	70.35	69.36	70.28	71.03
	2.	70.23	71.09	70.96	70.54	71.24	71.12
8 Hr.	1.	69.75	70.21	71.08	69.70	69.20	70.51
	2.	70.62	73.25	70.32	70.63	69.53	70.93
10 Hr.	1.	69.71	69.42	70.69	69.67	68.83	69.75
	2.	70.70	71.55	69.71	71.18	70.99	71.12
16 Hr.	1.	69.18	70.42	69.04	69.35	69.35	69.59
	2.	70.80	71.36	70.01	71.17	70.13	70.45

Table 6. Percent Cumulative Ash of Straight Grade Flour

Temper		Cold Temper Control	Cold Temper P.T.S.	Cold Temper D.S.	Warm Temper Control	Warm Temper P.T.S.	Warm Temper D.S.
2 Hr.	1.		.477			.440	
	2.		.457			.472	
4 Hr.	1.		.444	.425		.462	.428
	2.		.427	.424		.459	.433
6 Hr.	1.	.428	.445	.459	.452	.479	.449
	2.	.442	.459	.470	.428	.489	.477
8 Hr.	1.	.422	.438	.462	.456	.466	.462
	2.	.465	.443	.457	.461	.435	.483
10 Hr.	1.	.423	.444	.441	.431	.460	.458
	2.	.455	.483	.451	.415	.429	.476
16 Hr.	1.	.444	.468	.429	.445	.459	.425
	2.	.437	.444	.460	.403	.447	.472

Table 7. Percent Extraction of .40% Ash Flour

Temper Time		Cold Temper Control	Cold Temper P.T.S.	Cold Temper D.S.	Warm Temper Control	Warm Temper P.T.S.	Warm Temper D.S.
2 Hr.	1.		60.45			61.25	
	2.		66.30			62.10	
4 Hr.	1.		61.25	67.20		64.75	63.80
	2.		68.40	67.90		58.30	67.00
6 Hr.	1.	66.20	65.90	63.90	61.10	58.80	65.90
	2.	60.10	63.75	63.10	67.05	57.50	58.48
8 Hr.	1.	67.60	66.50	65.00	63.40	58.50	62.70
	2.	63.80	69.00	62.60	64.00	65.30	56.10
10 Hr.	1.	66.70	61.40	66.30	66.10	62.33	63.43
	2.	59.50	62.40	62.90	69.80	68.75	57.20
16 Hr.	1.	64.60	63.80	65.20	66.20	64.80	67.30
	2.	67.50	66.90	61.46	71.10	65.80	57.60

Table 8. Processed Materials Value of Products in Dollars Per Cwt. of Wheat

Temper Time		Cold Temper Control	Cold Temper P.T.S.	Cold Temper D.S.	Warm Temper Control	Warm Temper P.T.S.	Warm Temper D.S.
2 Hr.	1.		7.31			7.40	
	2.		7.48			7.45	
4 Hr.	1.		7.31	7.48		7.48	7.36
	2.		7.53	7.52		7.37	7.46
6 Hr.	1.	7.46	7.46	7.45	7.38	7.38	7.50
	2.	7.40	7.47	7.46	7.50	7.40	7.41
8 Hr.	1.	7.48	7.48	7.49	7.42	7.35	7.44
	2.	7.46	7.61	7.43	7.46	7.44	7.37
10 Hr.	1.	7.47	7.39	7.49	7.46	7.38	7.43
	2.	7.41	7.47	7.42	7.55	7.53	7.39
16 Hr.	1.	7.42	7.45	7.42	7.45	7.43	7.47
	2.	7.51	7.52	7.41	7.57	7.47	7.38

Table 9. Cumulative Color Straight Grade Flour

Temper Time		Cold Temper Control	Cold Temper P.T.S.	Cold Temper D.S.	Warm Temper Control	Warm Temper P.T.S.	Warm Temper D.S.
2 Hr.	1.		72.18			70.59	
	2.		65.88			68.67	
4 Hr.	1.		73.10	69.32		71.26	75.52
	2.		66.05	68.82		65.59	67.01
6 Hr.	1.	72.92	70.12	69.16	70.92	72.97	67.82
	2.	68.63	68.44	68.07	70.15	67.03	67.97
8 Hr.	1.	70.35	75.21	72.32	72.89	66.72	72.86
	2.	69.31	66.55	69.50	70.28	69.16	66.26
10 Hr.	1.	71.95	71.12	68.72	71.58	70.56	67.92
	2.	66.07	68.45	69.48	67.70	67.61	71.23
16 Hr.	1.	74.85	73.02	70.14	73.26	69.15	73.54
	2.	70.38	67.88	71.05	70.68	68.28	68.43

Table 10. Cumulative Color .40% Ash Patent Flour

Temper Time		Cold Temper Control	Cold Temper P.T.S.	Cold Temper D.S.	Warm Temper Control	Warm Temper P.T.S.	Warm Temper D.S.
2 Hr.	1.		74.1			68.3	
	2.		69.9			70.9	
4 Hr.	1.		74.3	70.0		76.2	76.4
	2.		66.8	69.4		67.9	67.8
6 Hr.	1.	73.9	71.1	71.0	72.8	75.1	69.1
	2.	70.8	70.1	69.8	71.2	69.6	70.2
8 Hr.	1.	70.9	76.1	74.0	75.2	68.9	74.5
	2.	71.1	67.7	71.1	72.0	70.2	68.7
10 Hr.	1.	72.7	72.7	70.0	72.8	72.2	69.1
	2.	68.3	70.5	71.1	68.1	68.3	73.8
16 Hr.	1.	75.9	74.5	71.1	74.5	70.1	73.4
	2.	71.4	69.0	73.1	70.7	69.4	71.2

Table 11. Percent Germ Extraction

Temper Time		Cold Temper Control	P.S.T.	D.S.	Warm Temper Control	P.S.T.	D.S.
2 Hr.	1.		1.13			.98	
	2.		.94			.80	
4 Hr.	1.		.98	1.07		.78	1.03
	2.		.90	1.00		.86	.80
6 Hr.	1.	.95	1.06	1.08	1.14	.78	1.06
	2.	1.00	1.05	1.05	.84	.81	1.10
8 Hr.	1.	.75	1.46	1.30	.94	.76	.98
	2.	.90	.85	1.29	1.09	1.21	.91
10 Hr.	1.	1.13	1.04	1.07	1.25	.97	1.24
	2.	.75	1.10	1.50	.80	1.25	1.10
16 Hr.	1.	.99	.98	1.17	.78	1.17	1.06
	2.	.74	.90	1.30	1.14	1.10	1.16

Table 12. Percent Protein in Germ

Temper Time		Cold Temper Control	Cold Temper P.T.S.	Cold Temper D.S.	Warm Temper Control	Warm Temper P.T.S.	Warm Temper D.S.
2 Hr.	1.		22.01			22.10	
	2.		19.81			20.91	
4 Hr.	1.		21.33	22.69		23.80	22.02
	2.		20.77	21.64		18.85	19.75
6 Hr.	1.	20.01	22.03	23.14	20.72	22.62	22.35
	2.	19.82	22.07	22.00	20.70	20.04	21.50
8 Hr.	1.	21.31	22.01	24.57	20.09	21.02	24.03
	2.	20.77	21.22	21.50	19.91	20.09	21.05
10 Hr.	1.	21.17	20.58	23.26	20.71	23.19	22.25
	2.	21.12	21.71	21.21	21.98	20.51	20.86
16 Hr.	1.	22.81	23.47	22.84	22.65	22.80	22.25
	2.	21.22	21.80	21.29	20.88	20.67	20.39

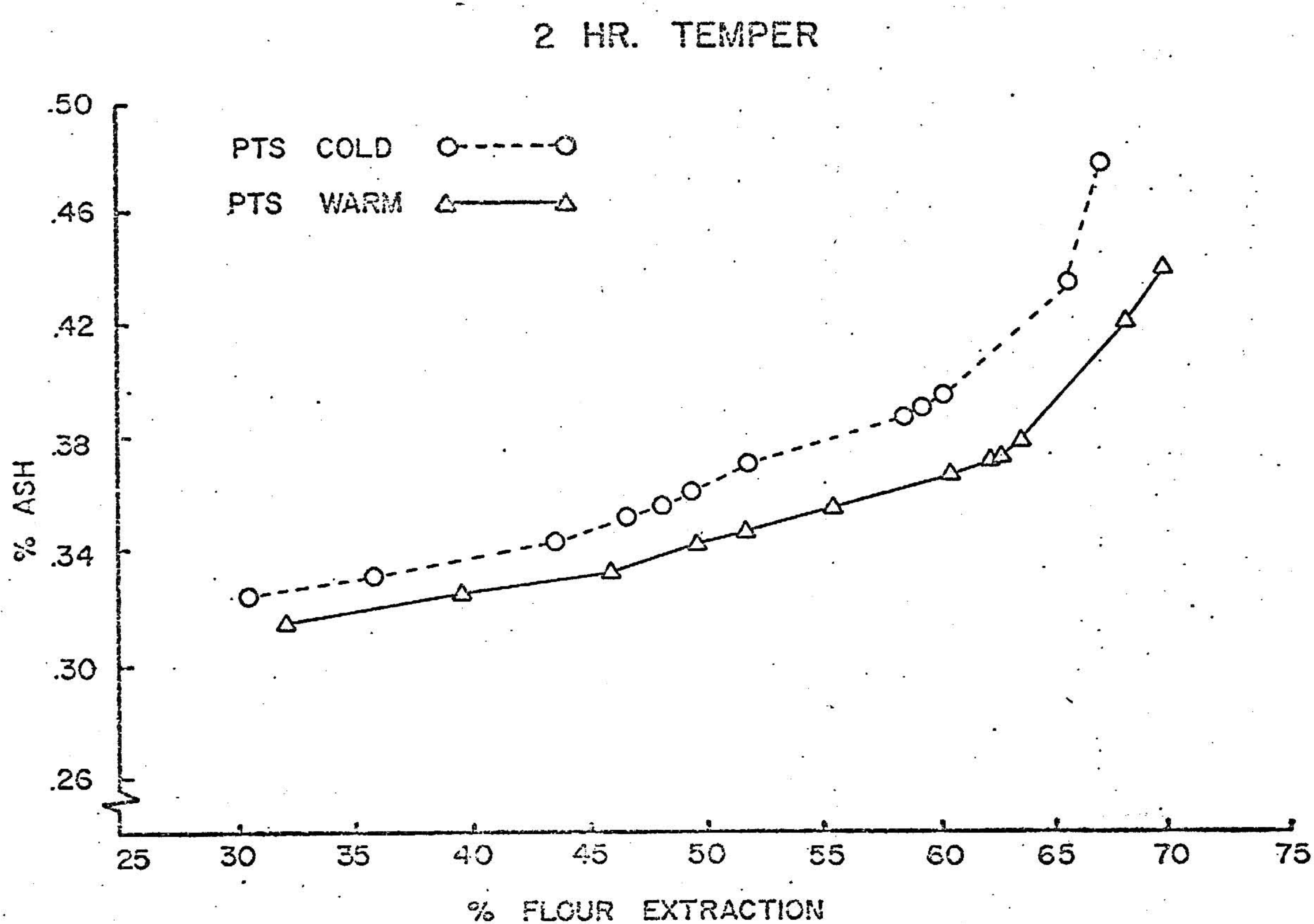

Fig. 2. Cumulative ash curves (14% moisture basis), two hours temper, first replication.

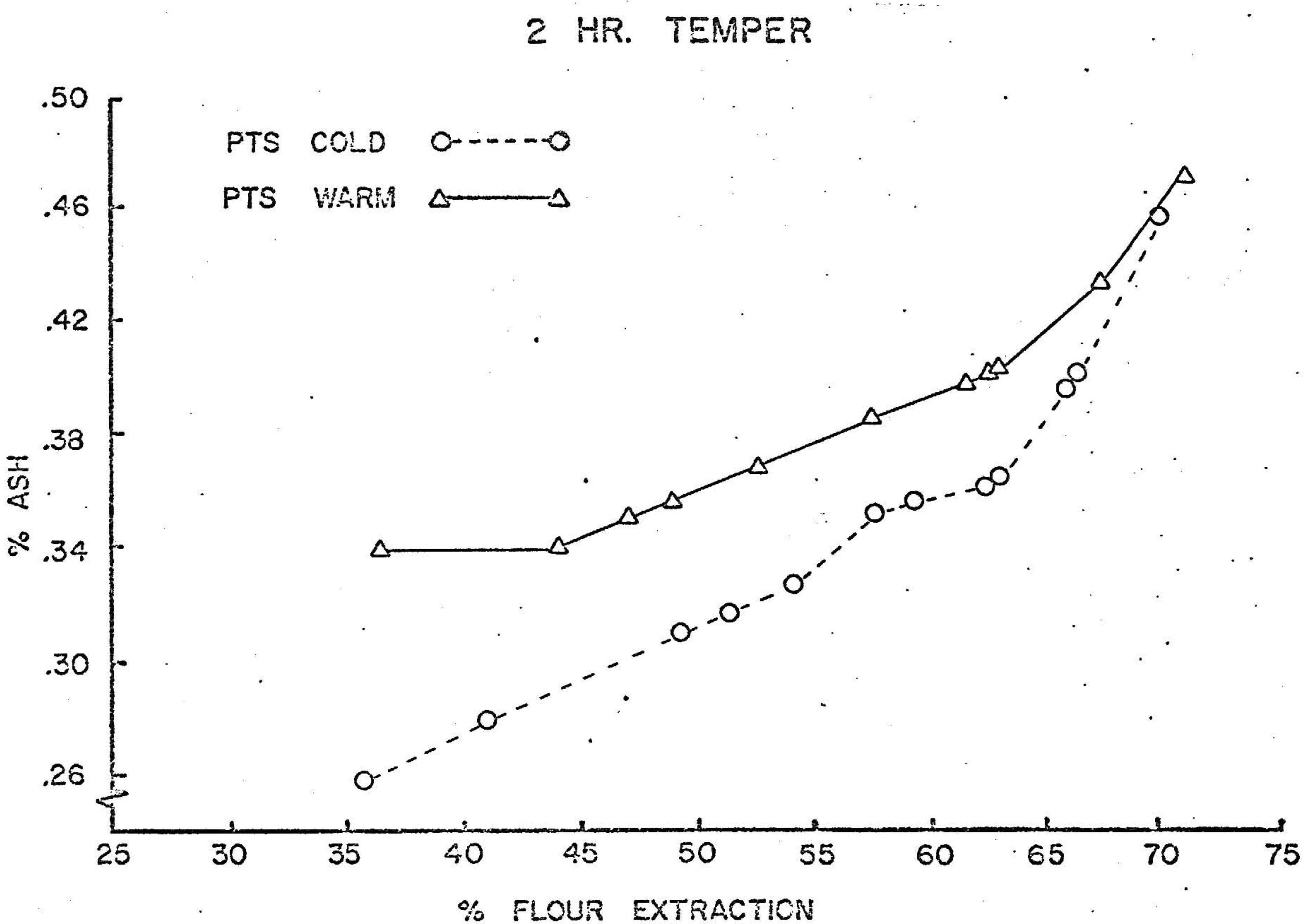

Fig. 3. Cumulative ash curves (14% moisture basis), two hours temper time, second replication.

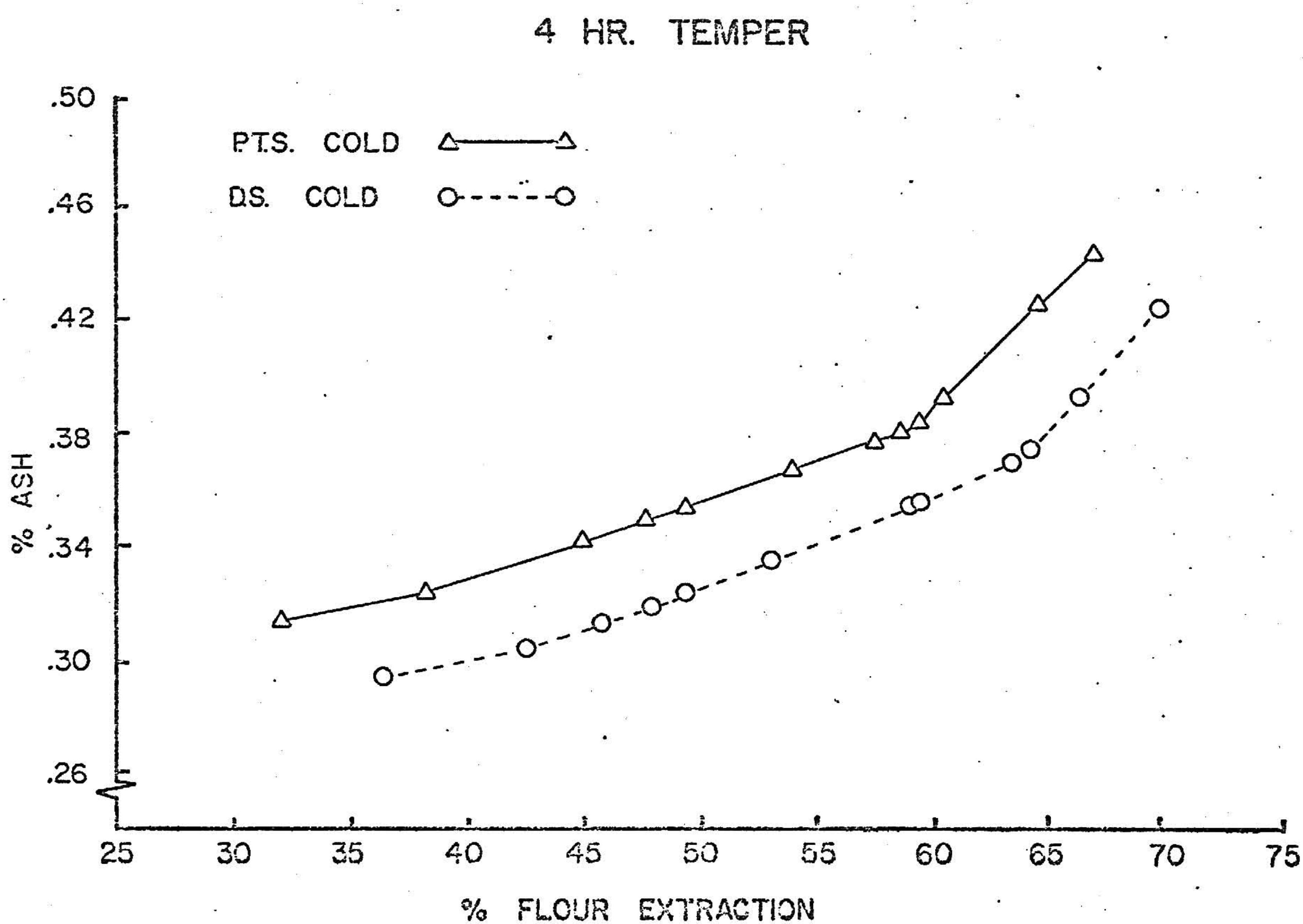

Fig. 4. Cumulative ash curves (14% moisture basis), cold four hour temper, first replication.

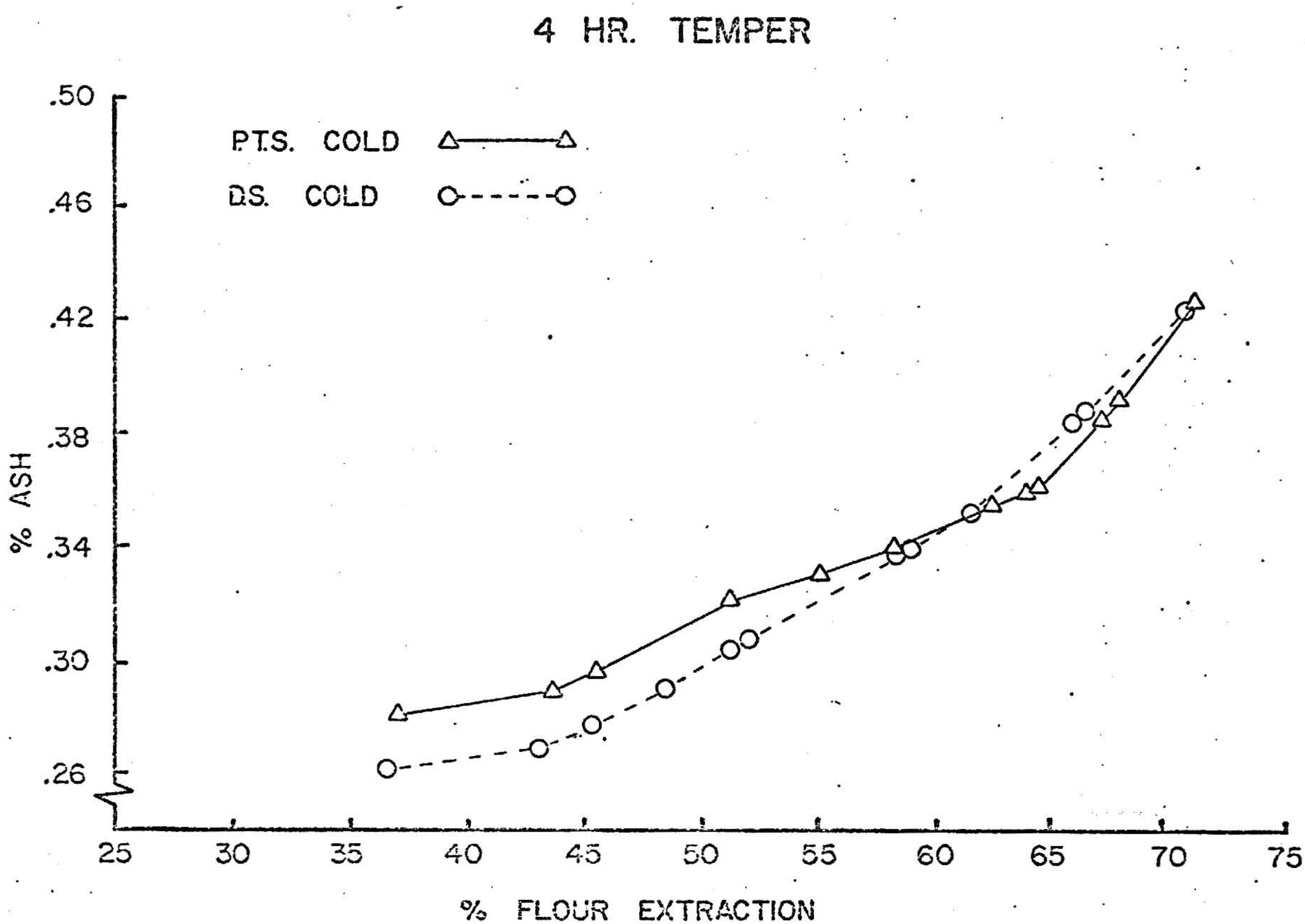

Fig. 5. Cumulative ash curves (14% moisture basis), cold four hour temper, second replication.

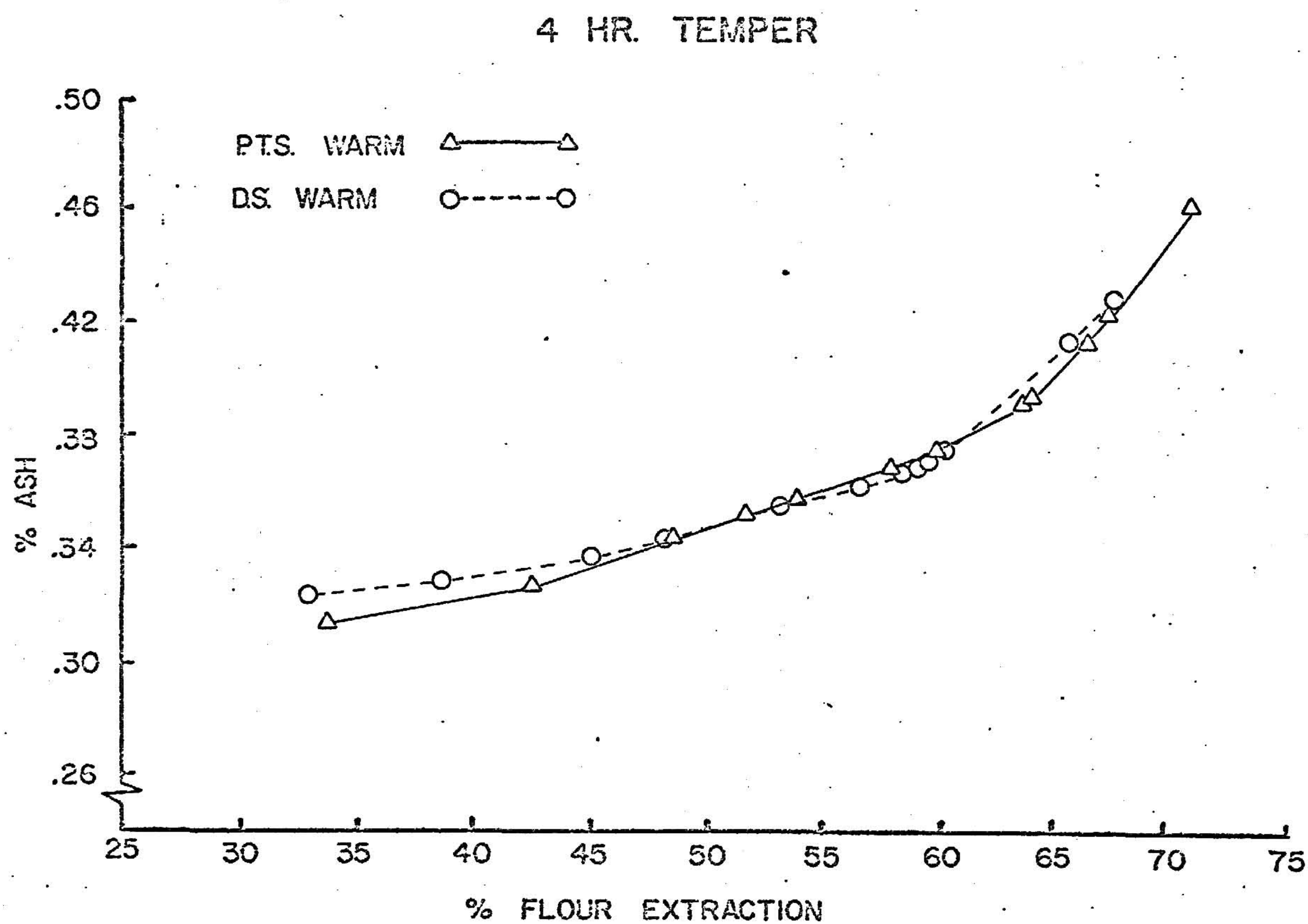

Fig. 6. Cumulative ash curves (14% moisture basis), warm four hour temper, first replication.

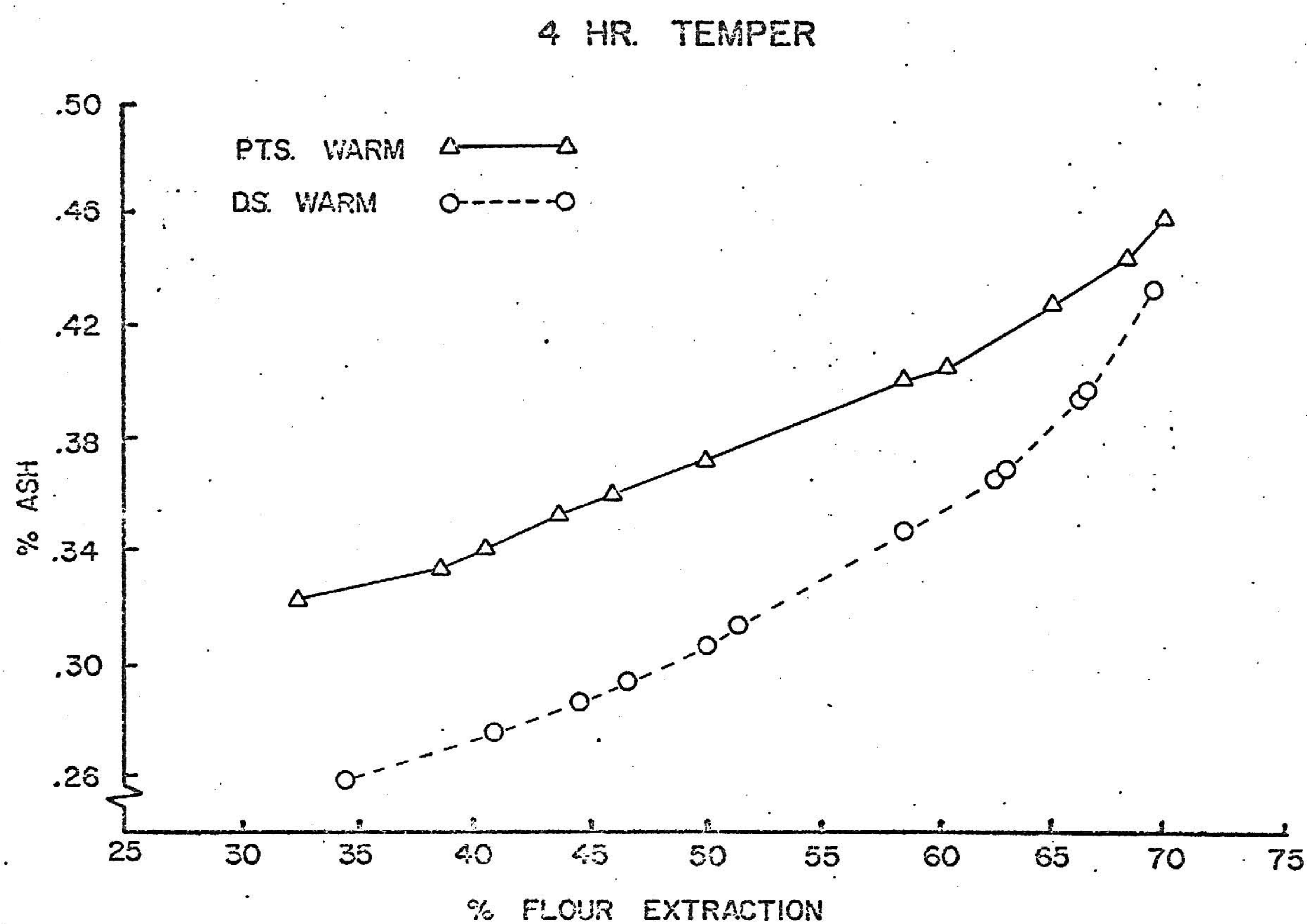

Fig. 7. Cumulative ash curves (14% moisture basis), warm four hour temper, second replication.

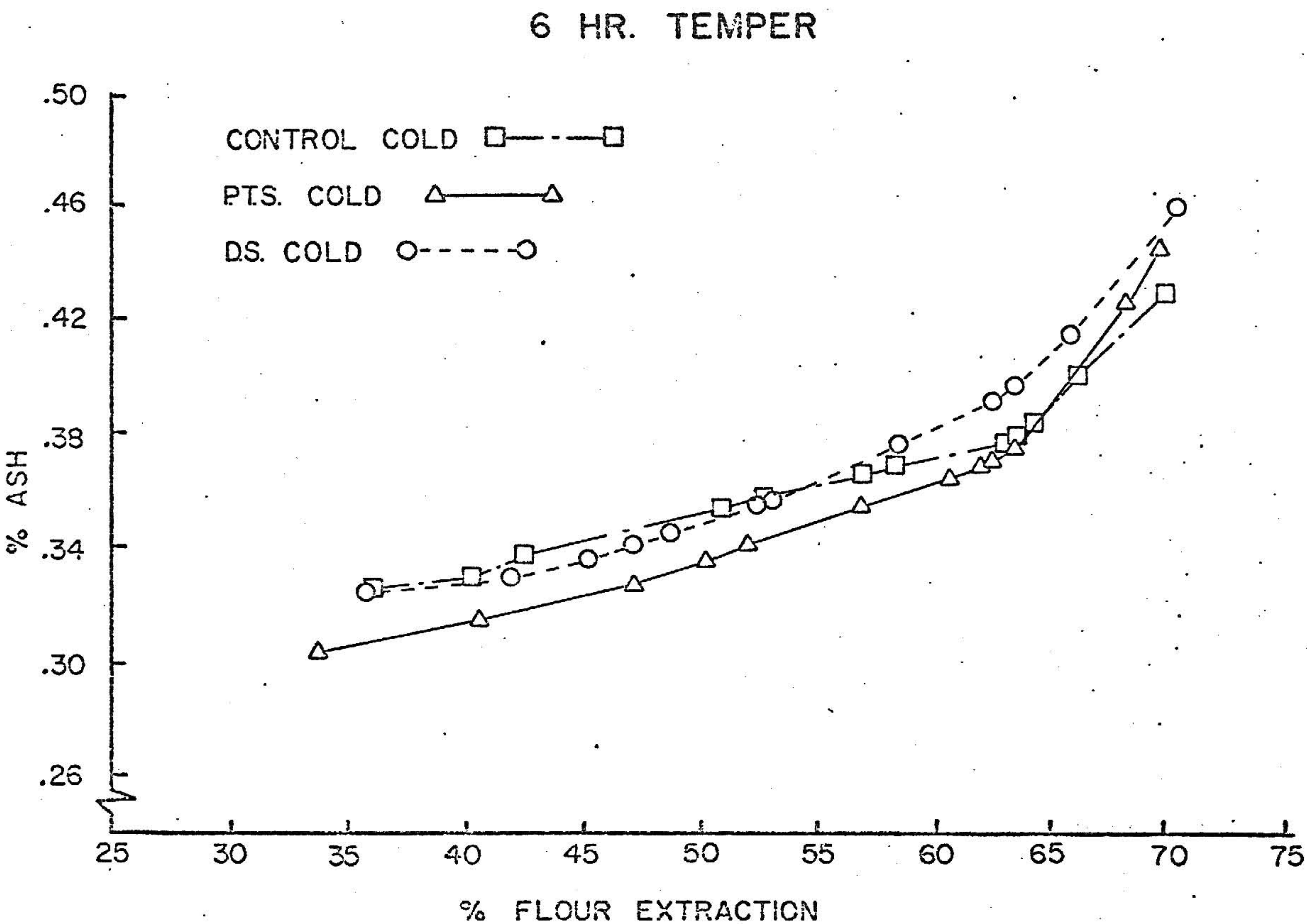

Fig. 8. Cumulative ash curves (14% moisture basis), cold six hour temper, first replication.

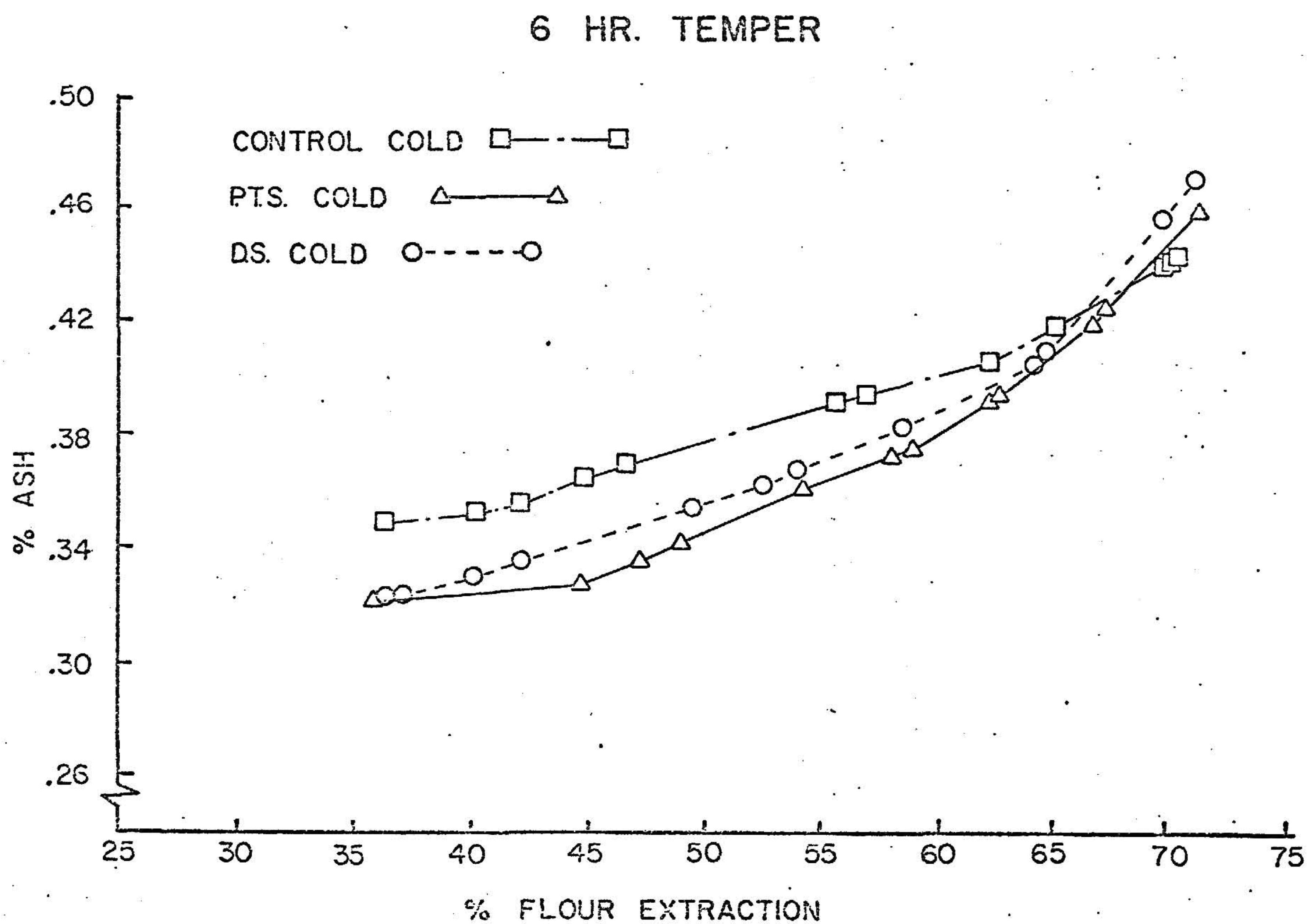

Fig. 9. Cumulative ash curves (14% moisture basis), cold six hour temper, second replication.

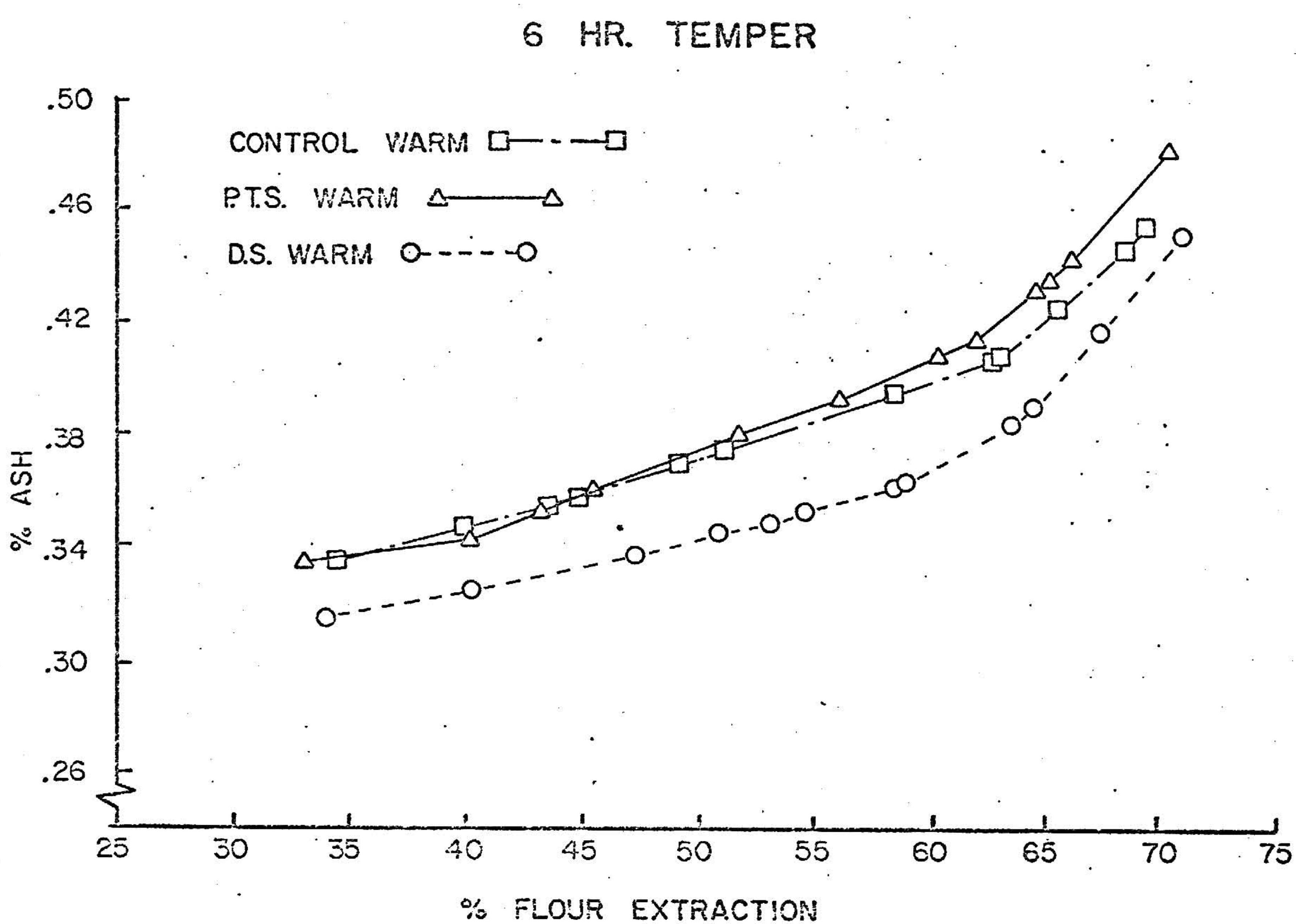

Fig. 10. Cumulative ash curves (14% moisture basis), warm six hour temper, first replication.

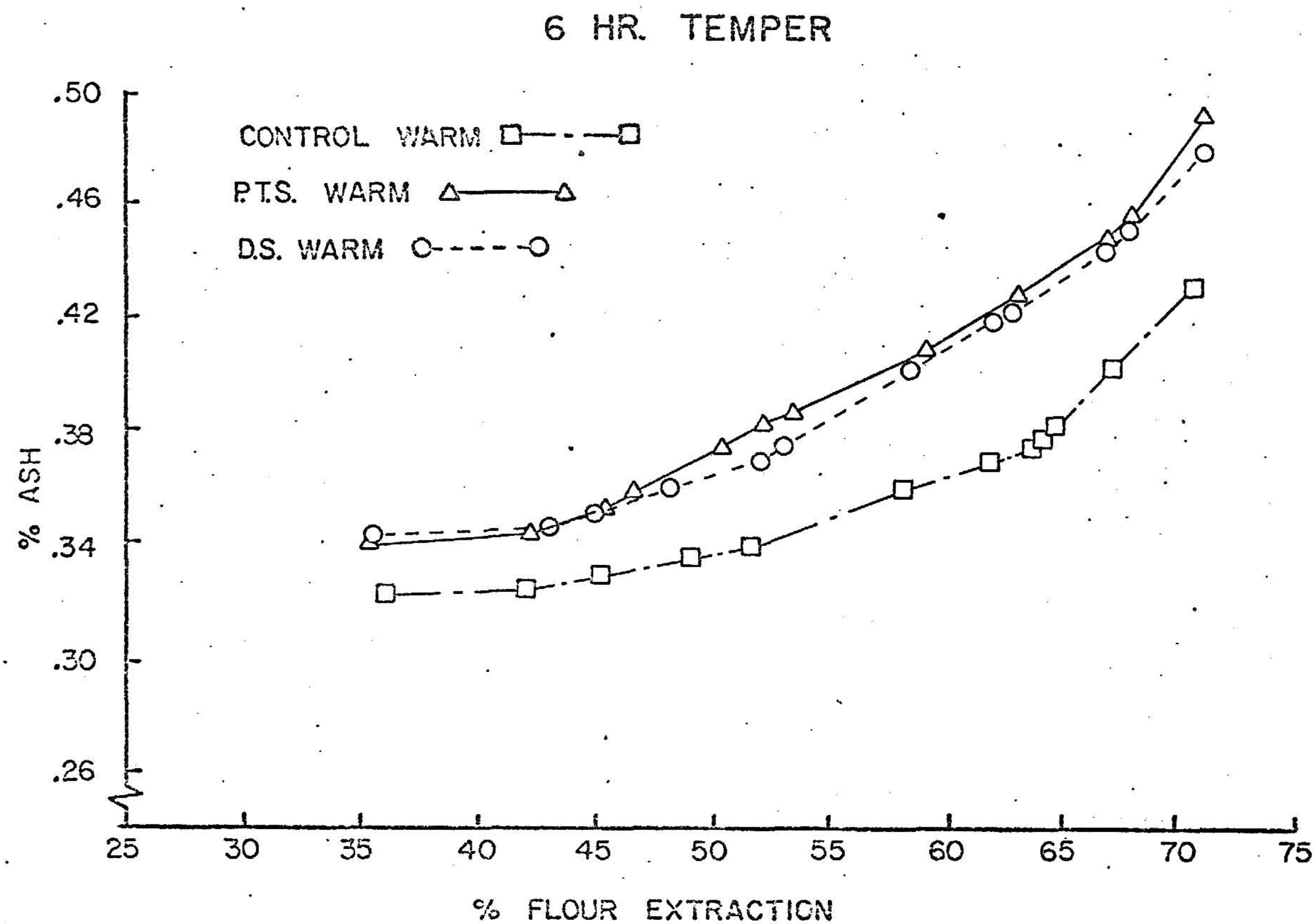

Fig. 11. Cumulative ash curves (14% moisture basis), warm six hour temper, second replication.

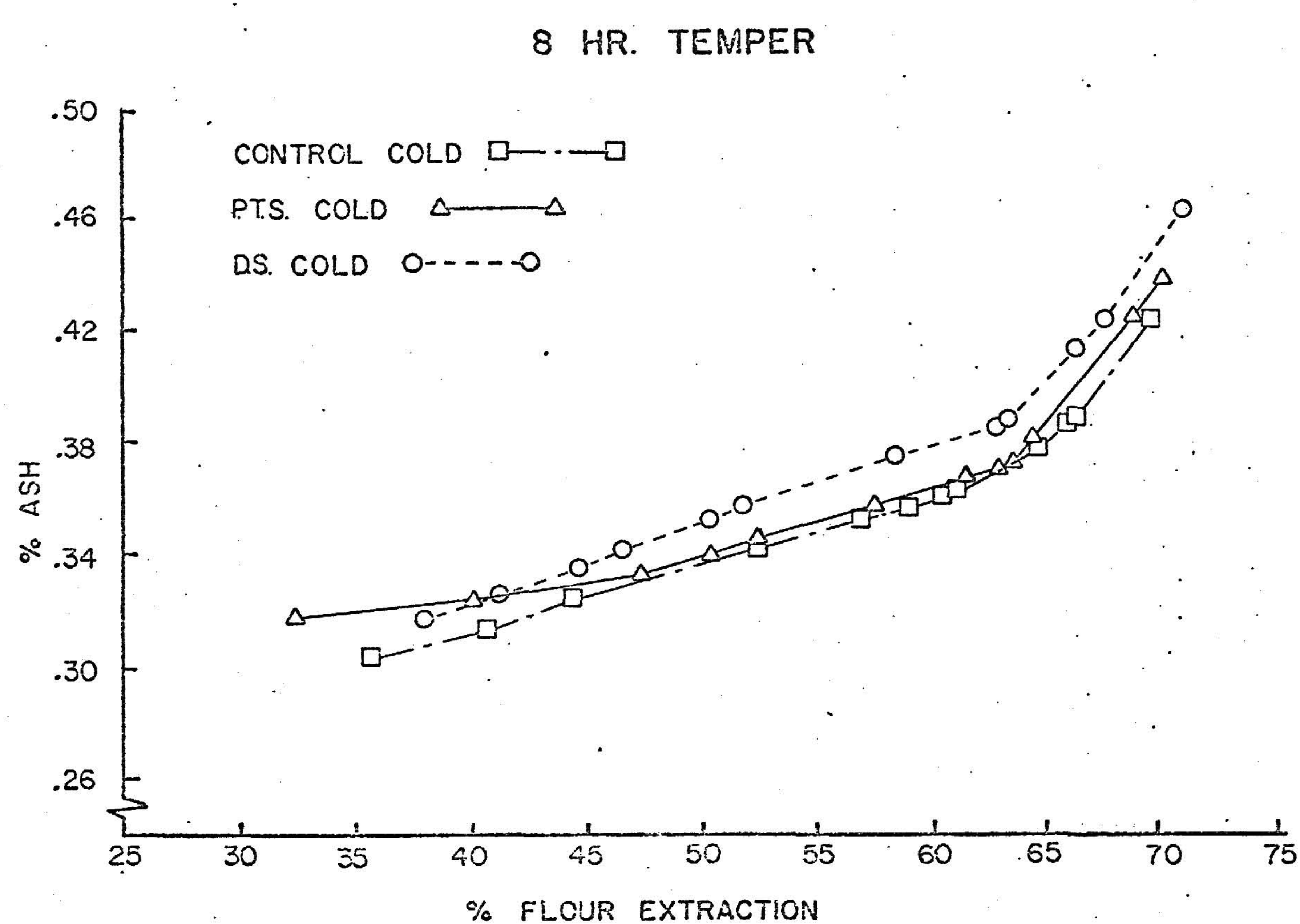

Fig. 12. Cumulative ash curves (14% moisture basis), cold eight hour temper, first replication.

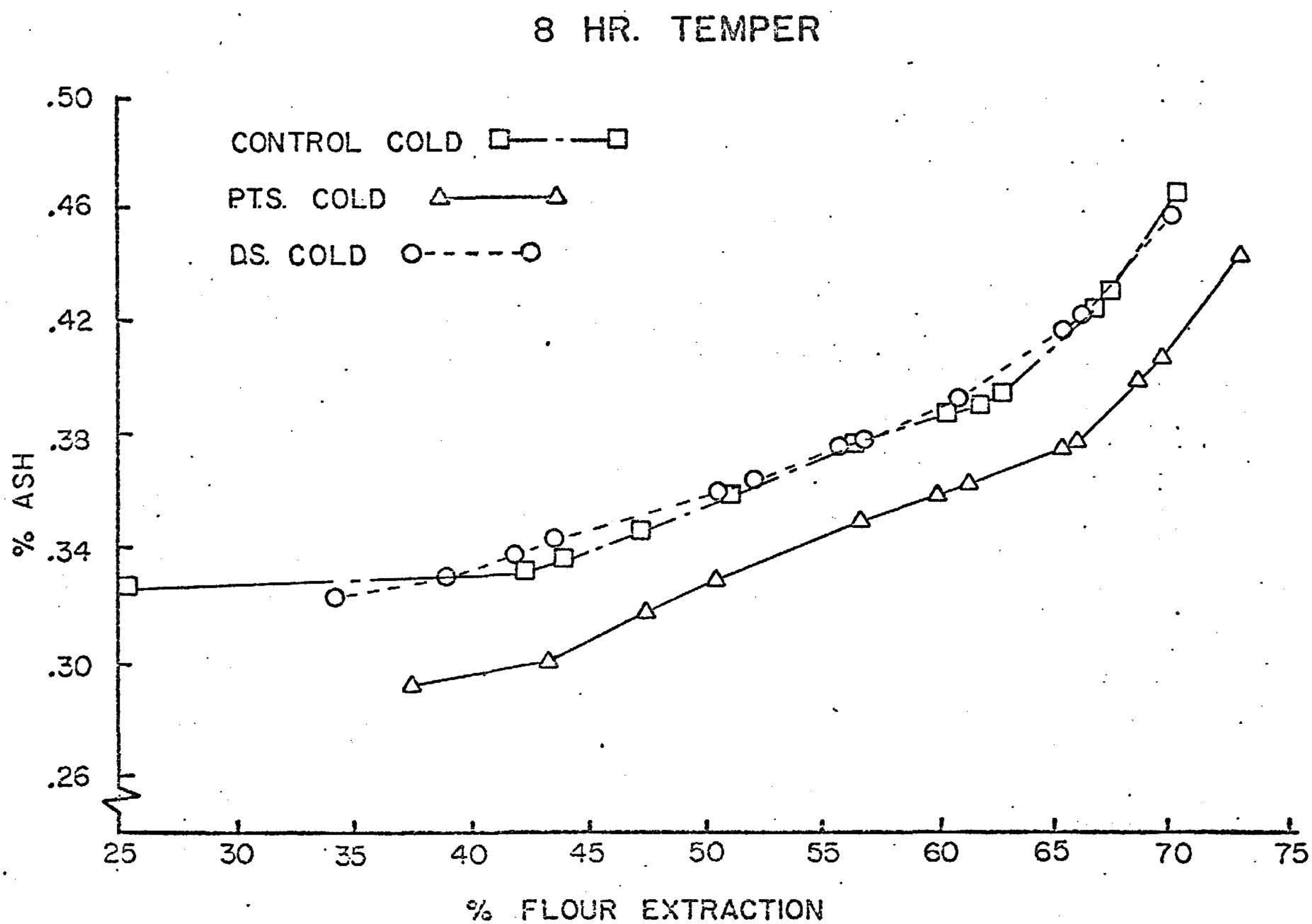

Fig. 13. Cumulative ash curves (14% moisture basis), cold eight hour temper, second replication.

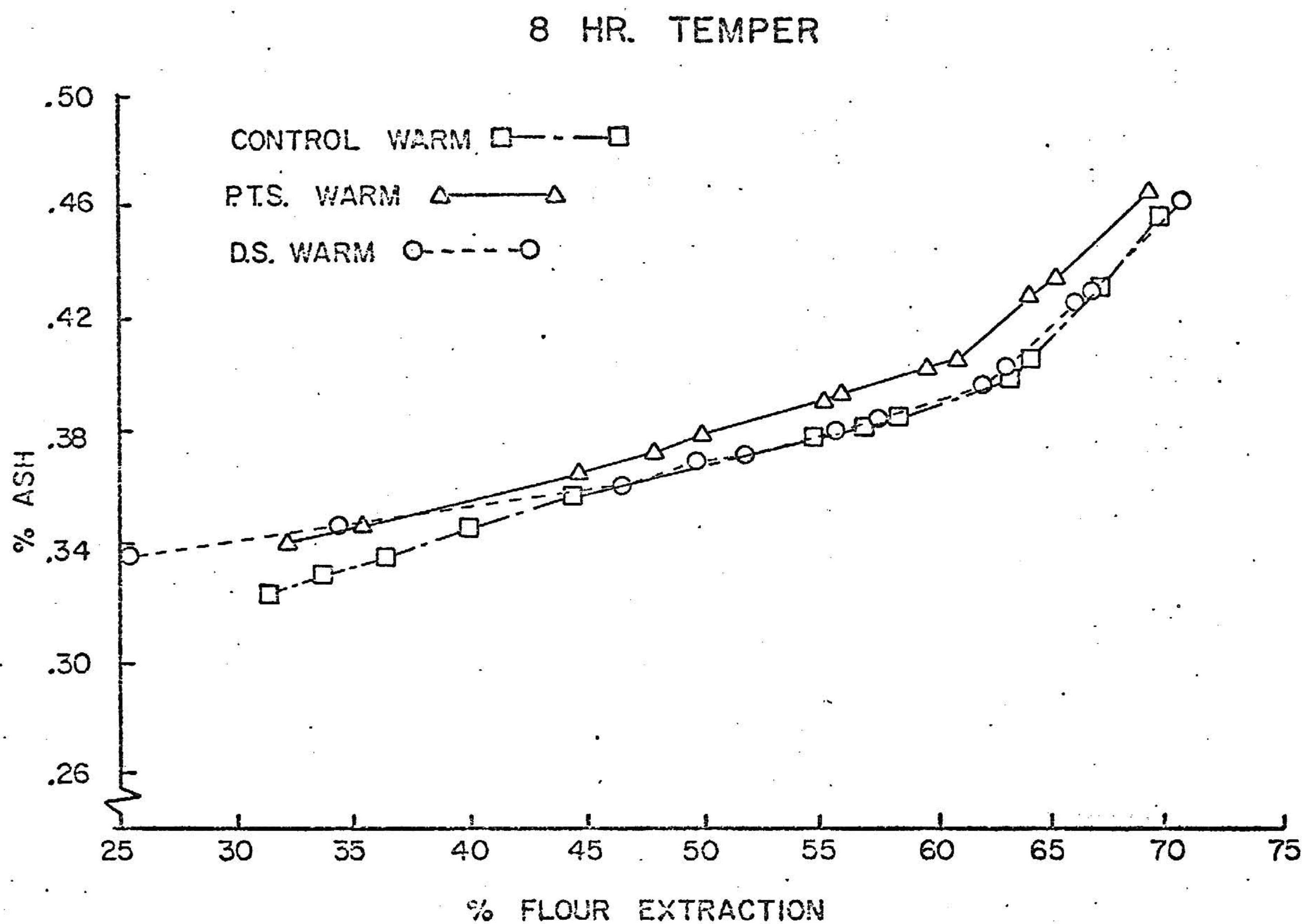

Fig. 14. Cumulative ash curves (14% moisture basis), warm eight hour temper, first replication.

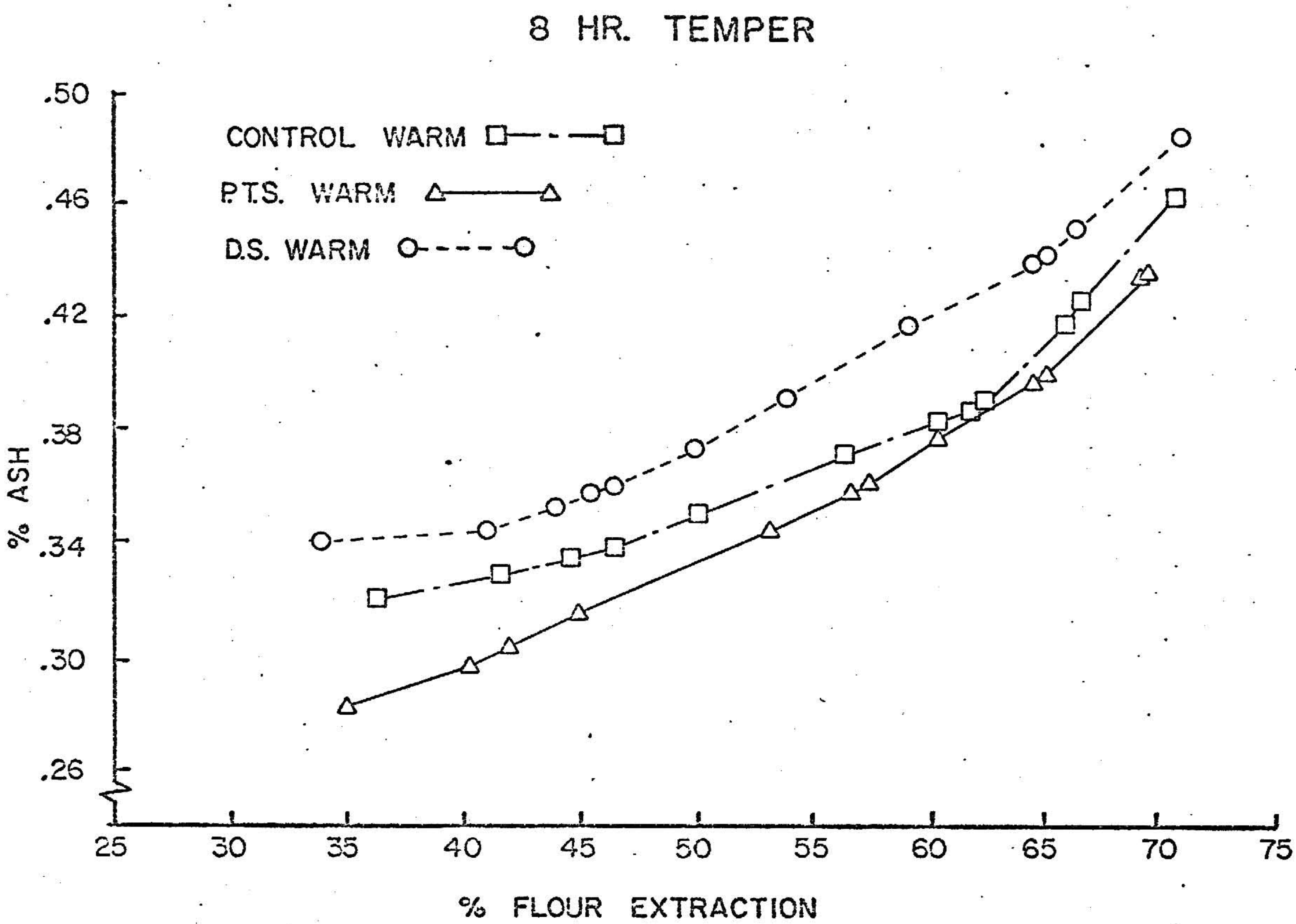

Fig. 15. Cumulative ash curves (14% moisture basis), warm eight hour temper, second replication.

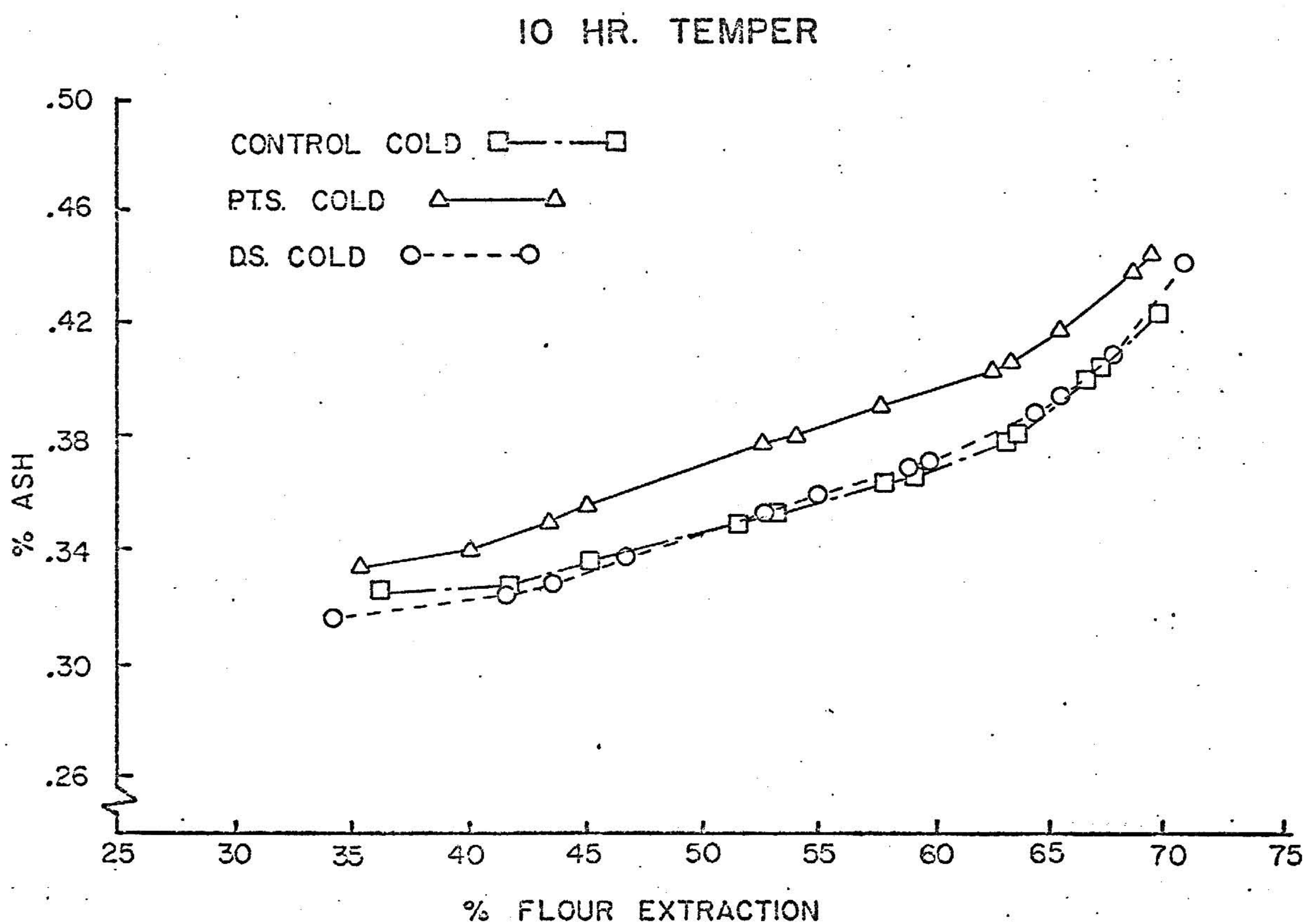

Fig. 16. Cumulative ash curves (14% moisture basis), cold ten hour temper, first replication.

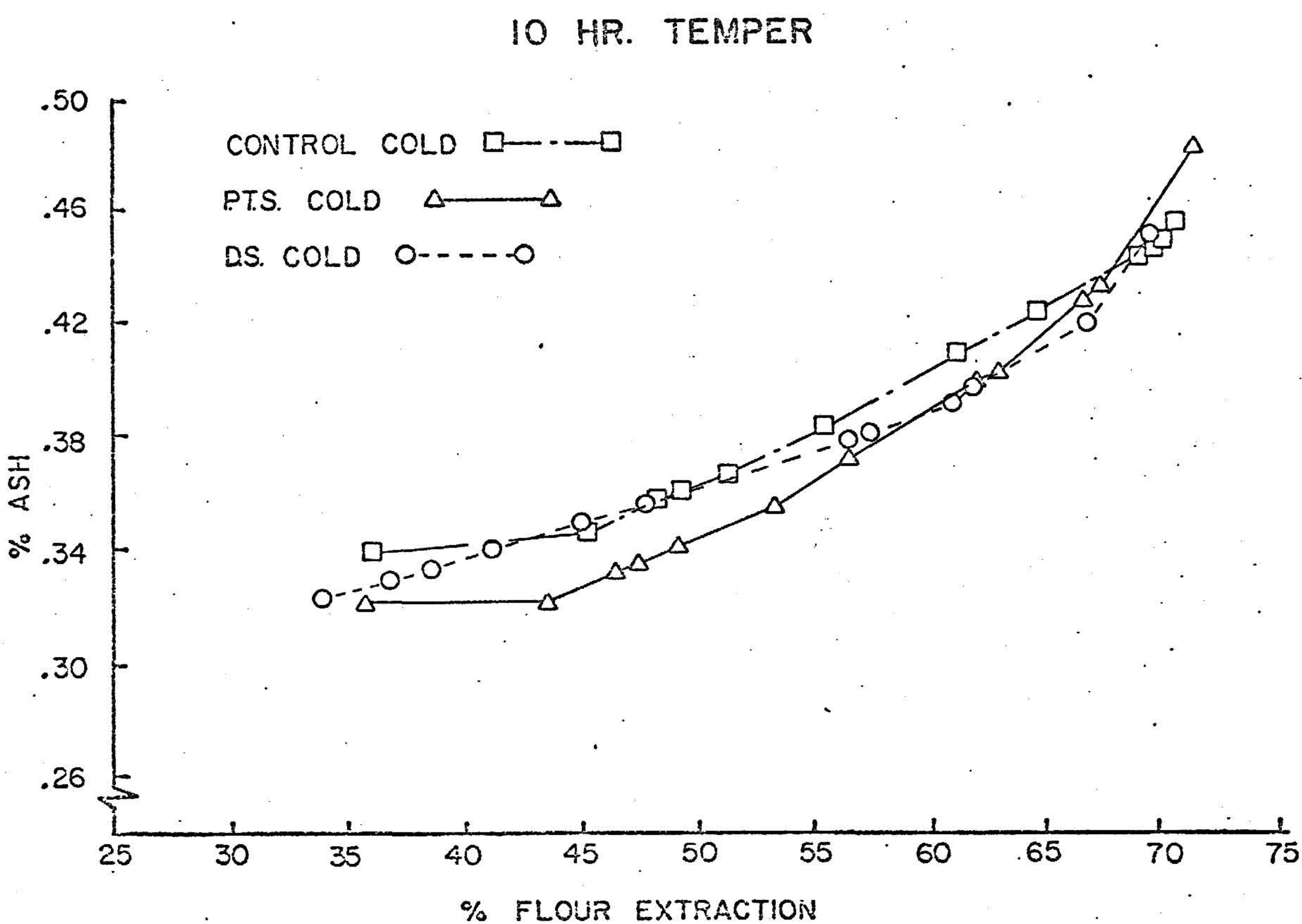

Fig. 17. Cumulative ash curves (14% moisture basis), cold ten hour temper, second replication.

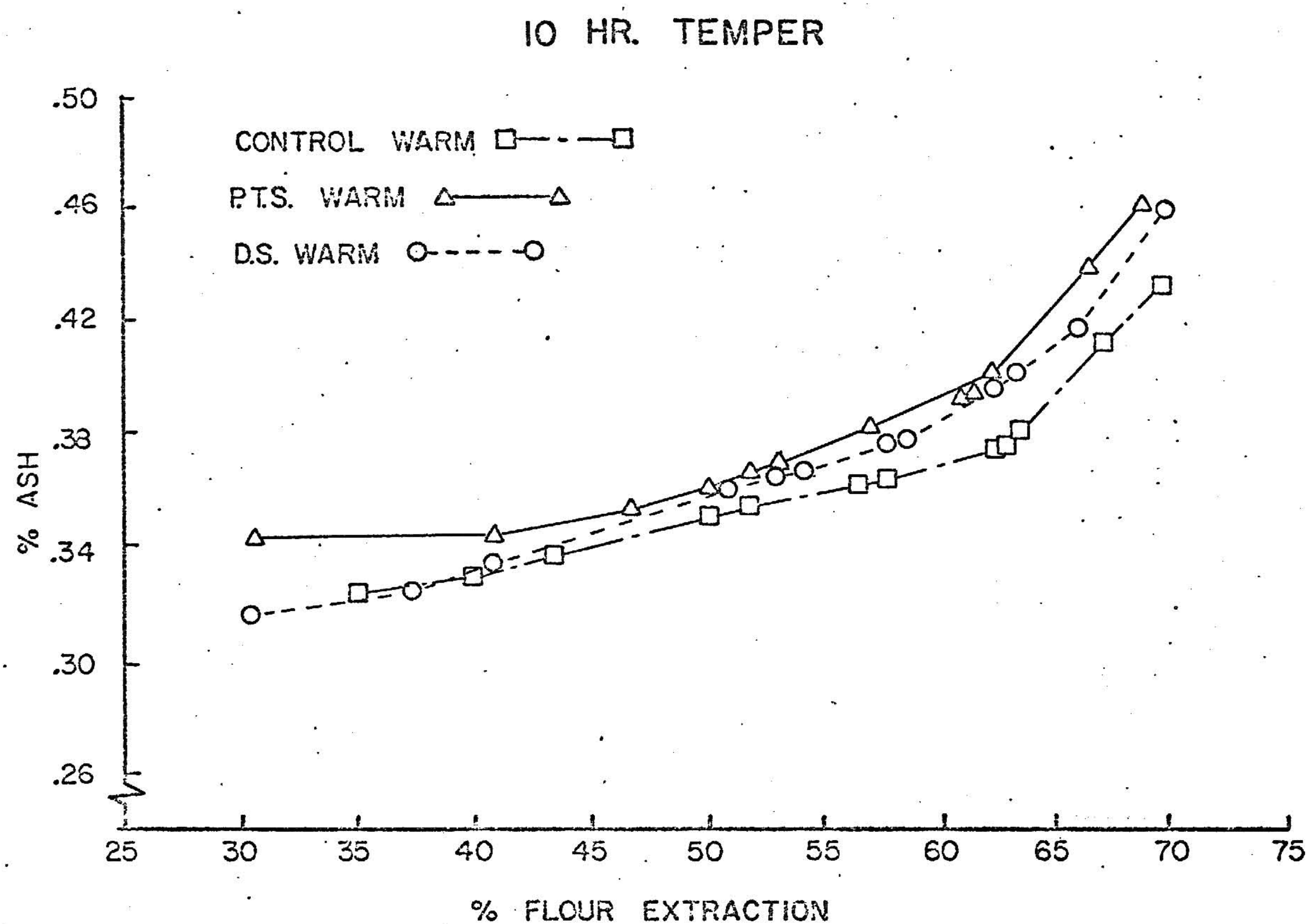

Fig. 18. Cumulative ash curves (14% moisture basis), warm ten hour temper, first replication.

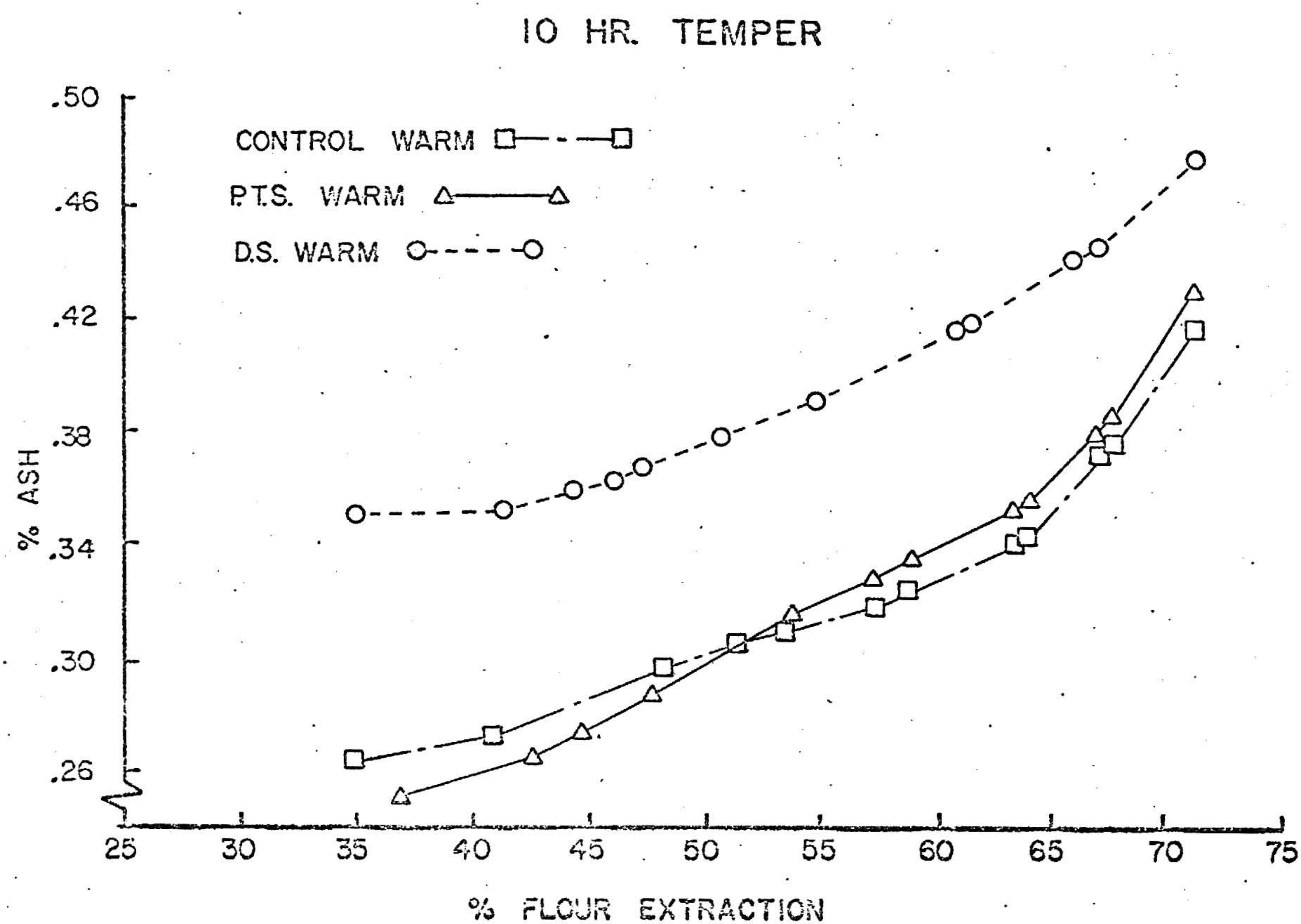

Fig. 19. Cumulative ash curves (14% moisture basis), warm ten hour temper, second replication.

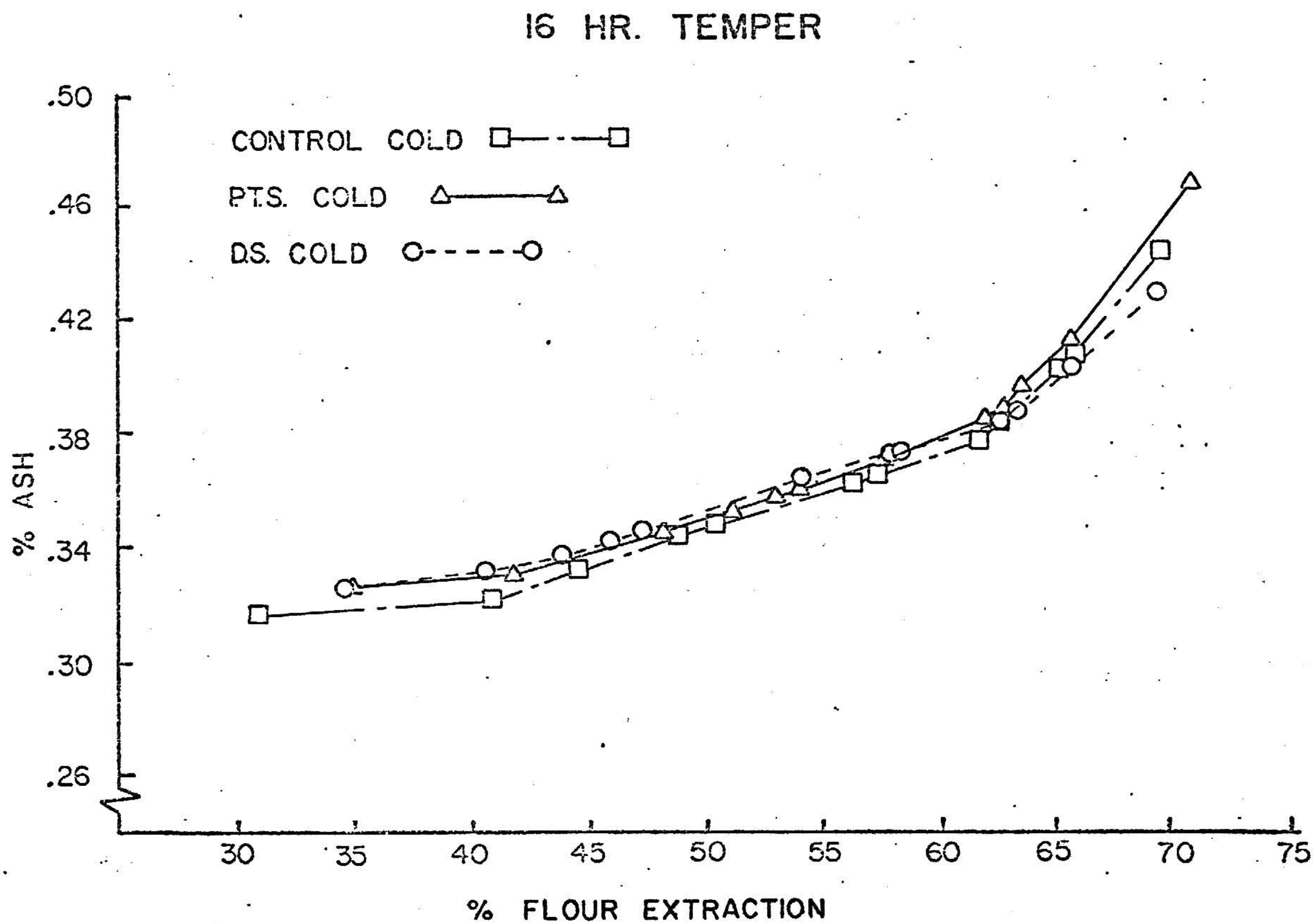

Fig. 20. Cumulative ash curves (14% moisture basis), cold sixteen hour temper, first replication.

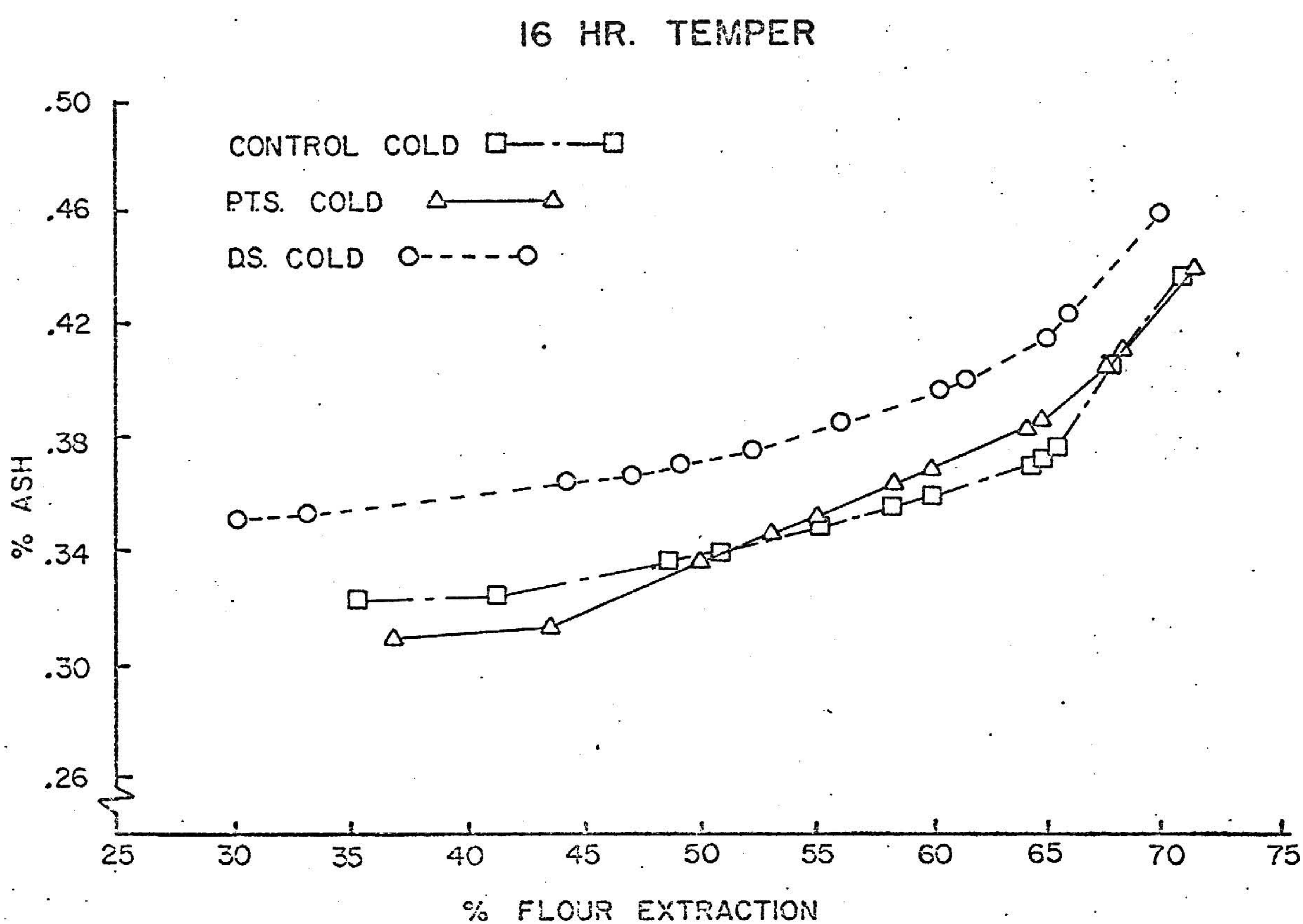

Fig. 21. Cumulative ash curves (14% moisture basis), cold sixteen hour temper, second replication.

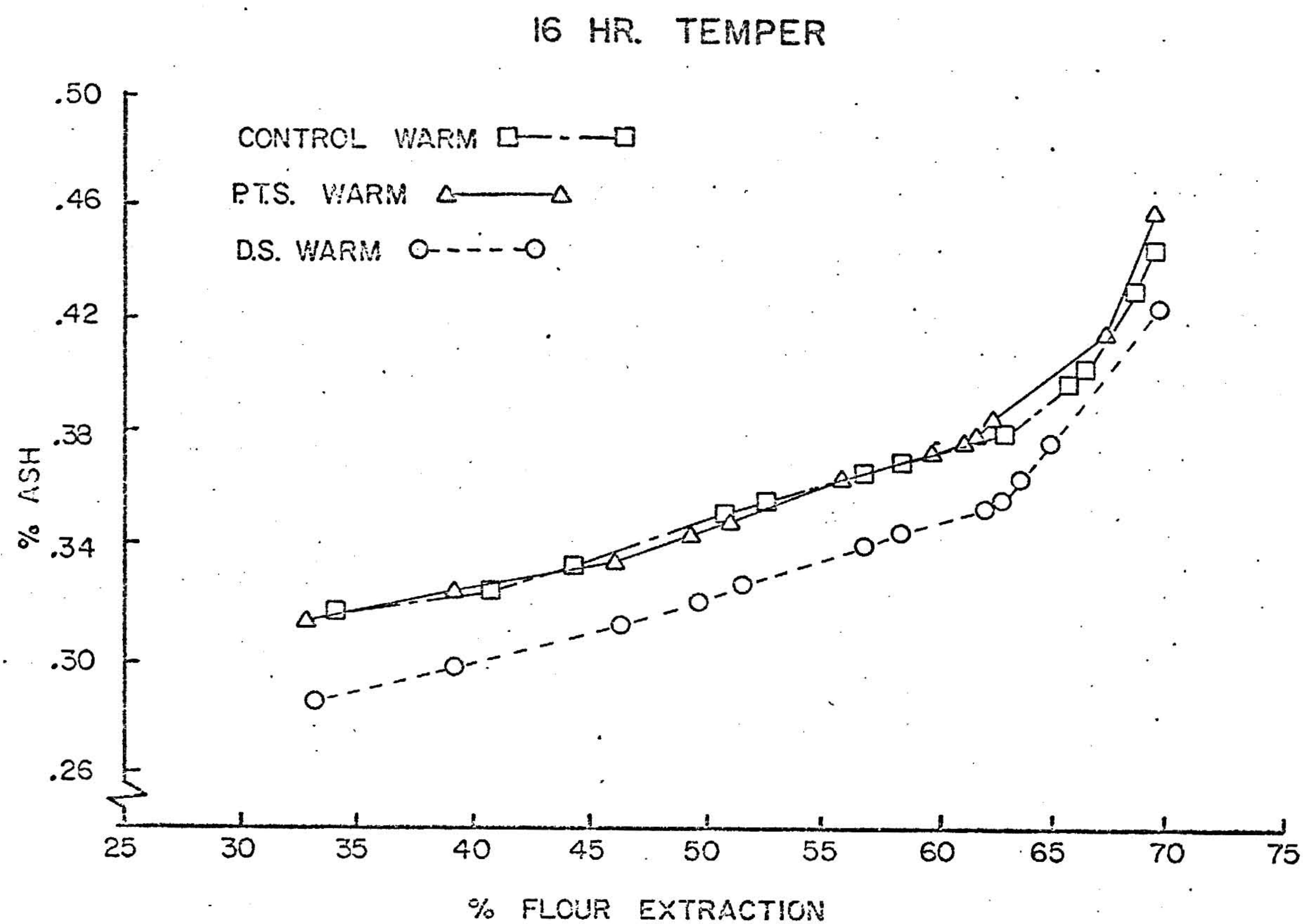

Fig. 22. Cumulative ash curves (14% moisture basis), warm sixteen hour temper, first replication.

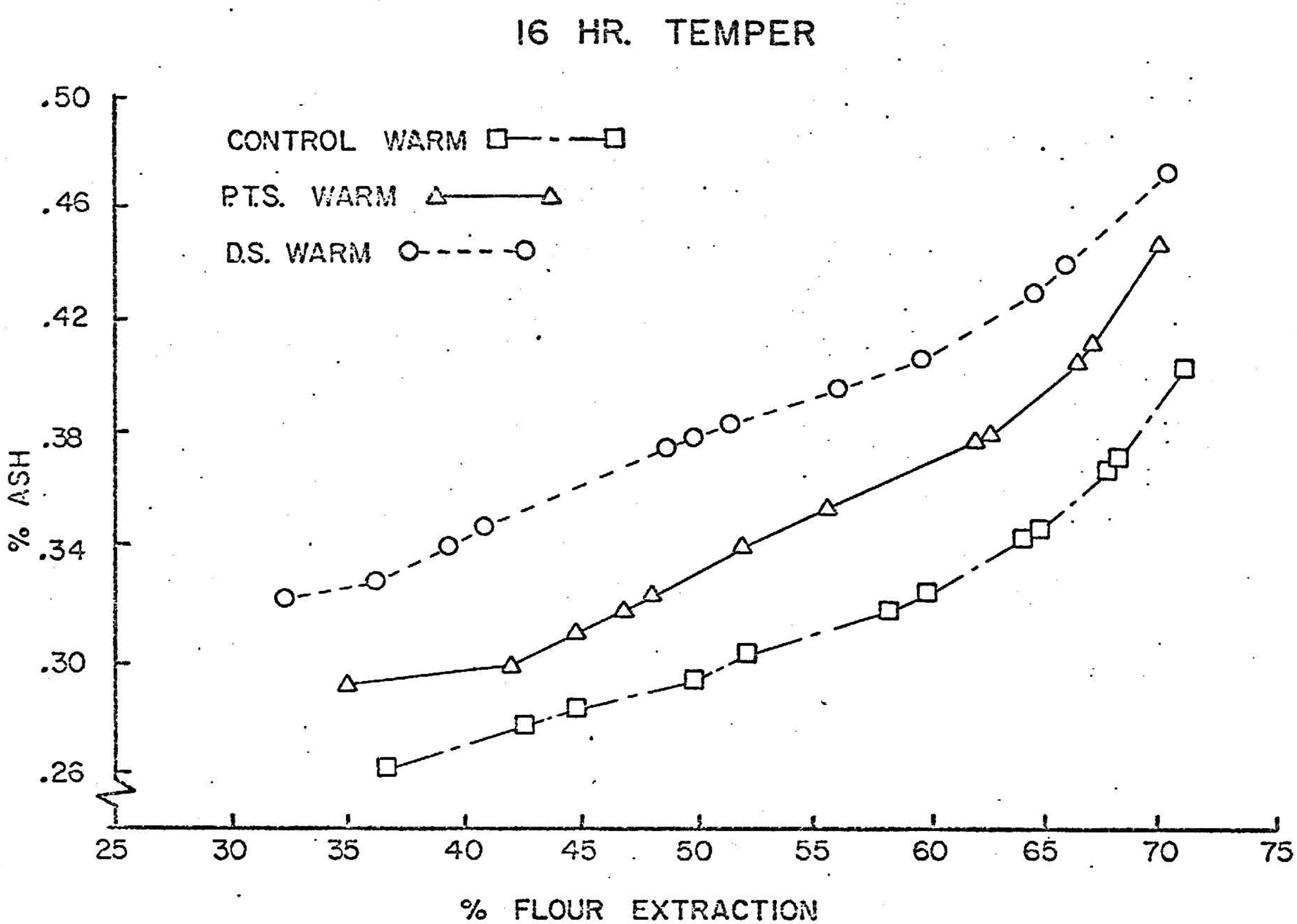

Fig. 23. Cumulative ash curves (14% moisture basis), warm sixteen hour temper, second replication.

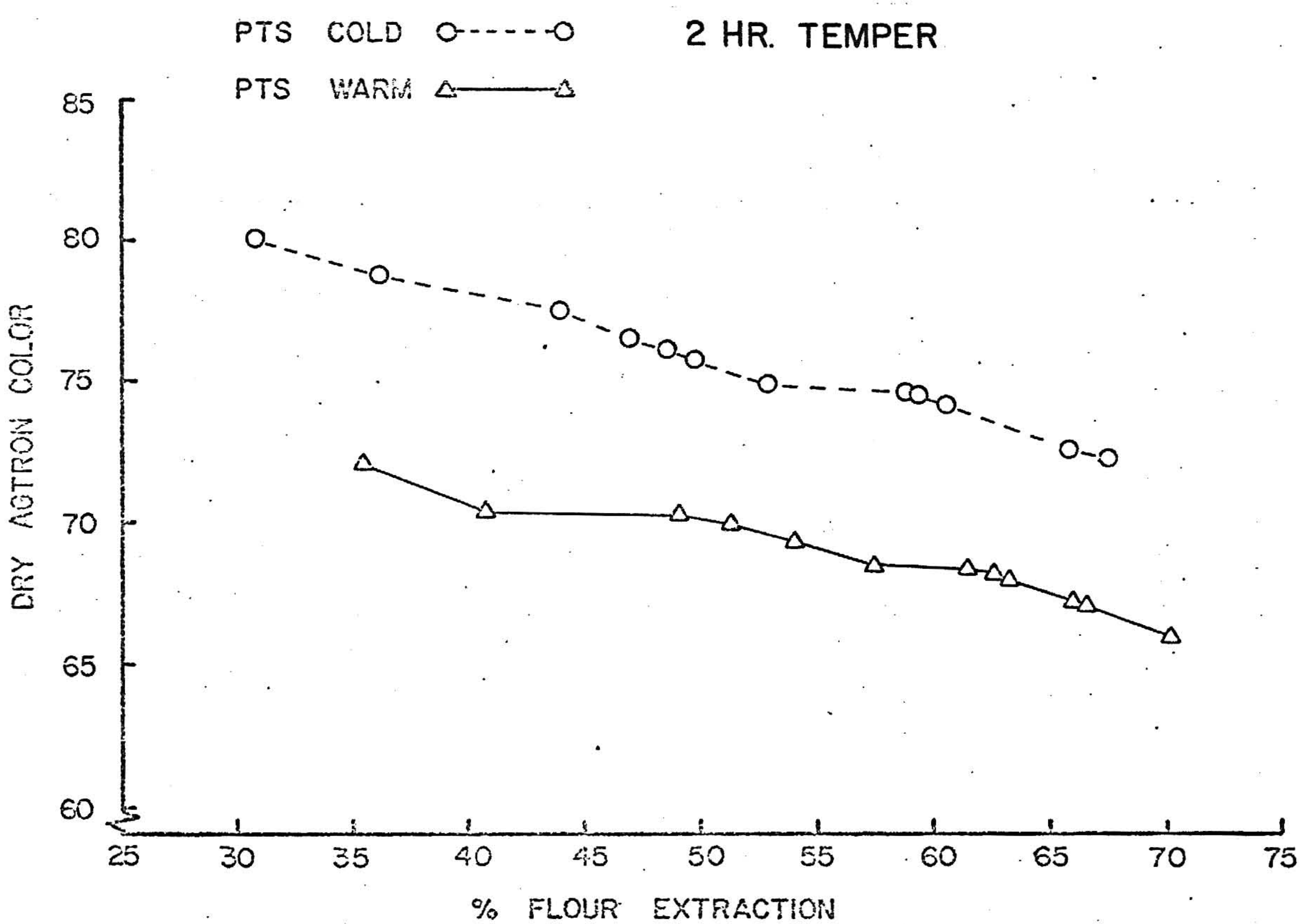

Fig. 24. Cumulative color curves, two hour temper, first replication.

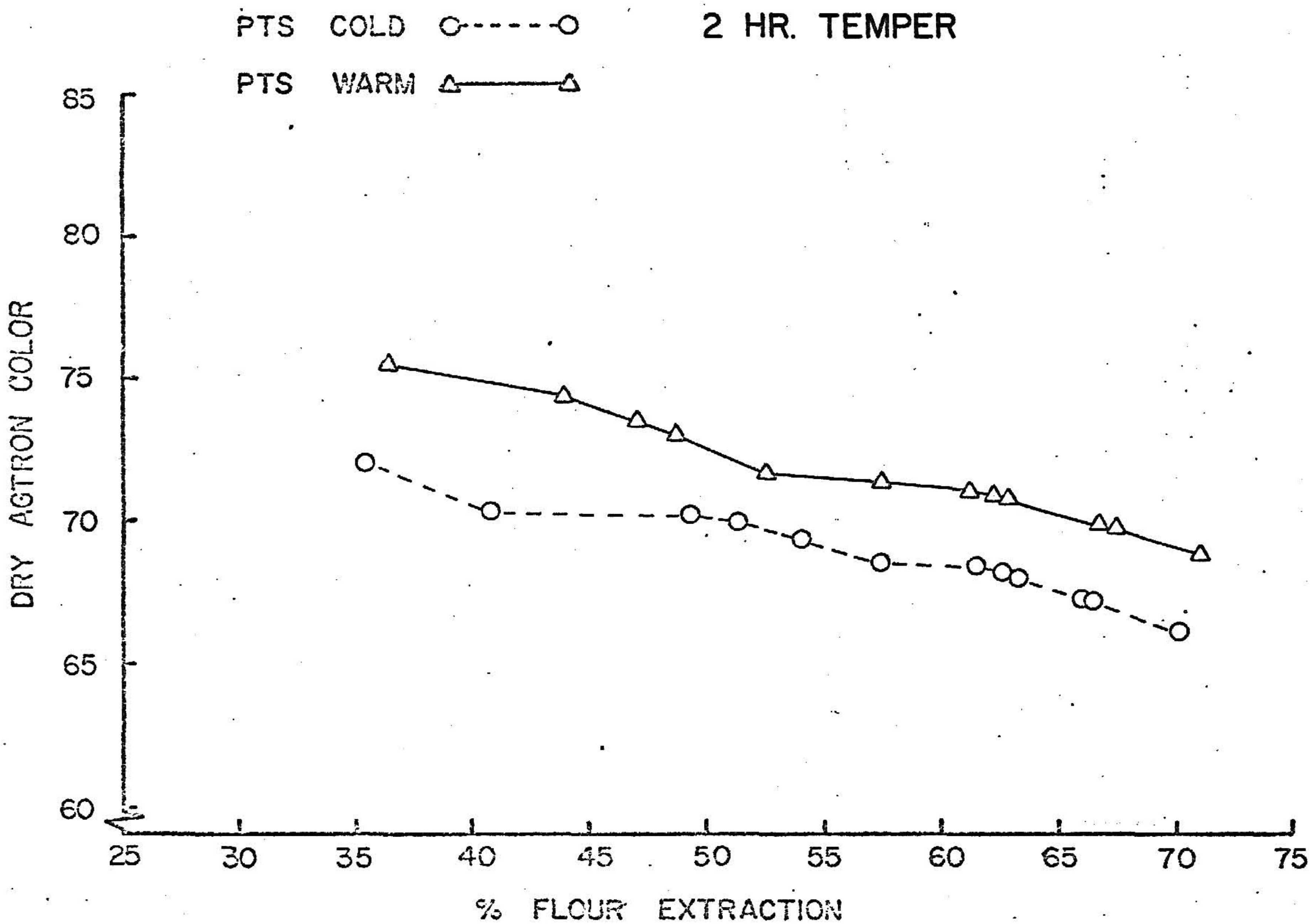

Fig. 25. Cumulative color curves, two hour temper, second replication.

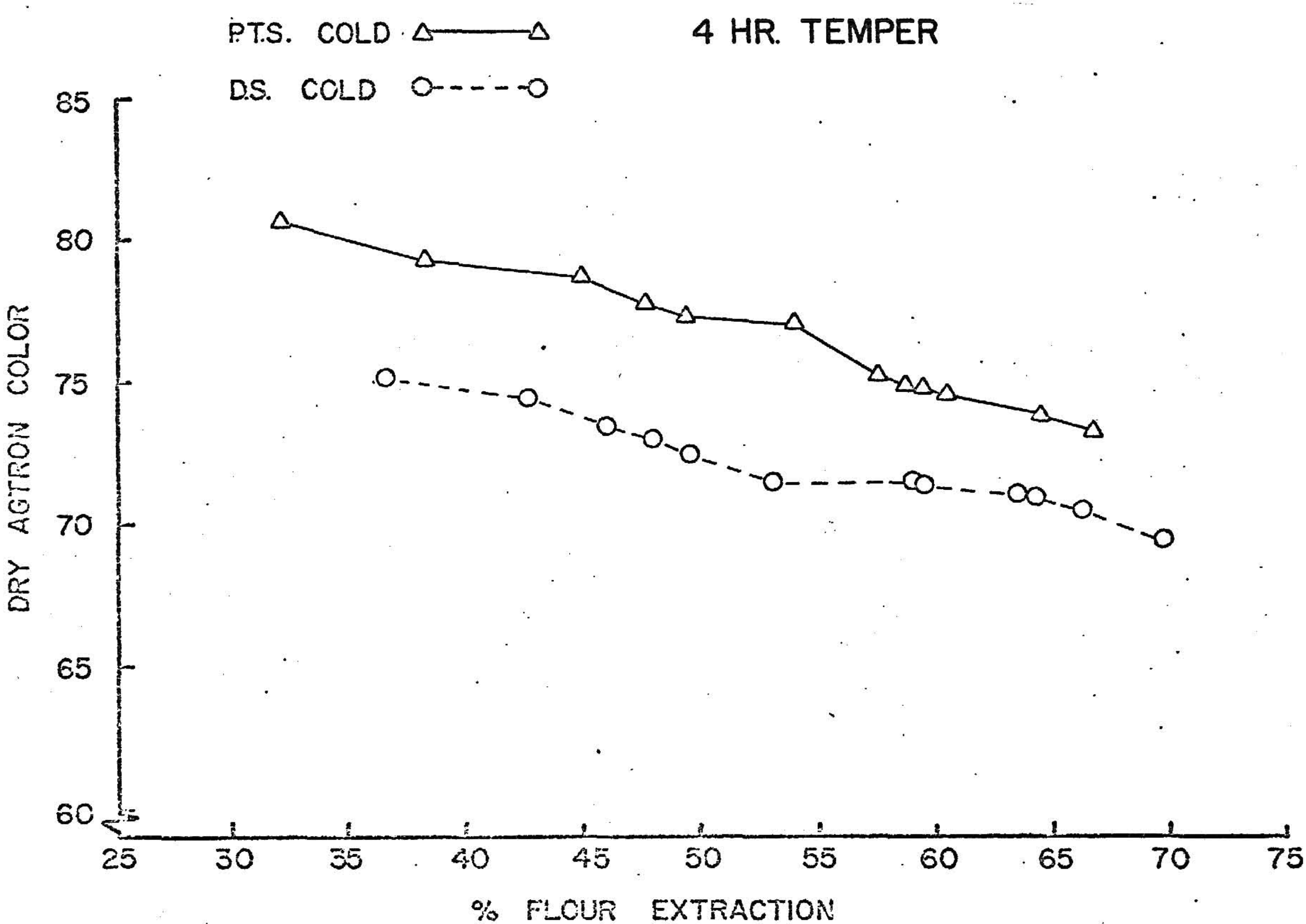

Fig. 26. Cumulative color curves, cold four hour temper, first replication.

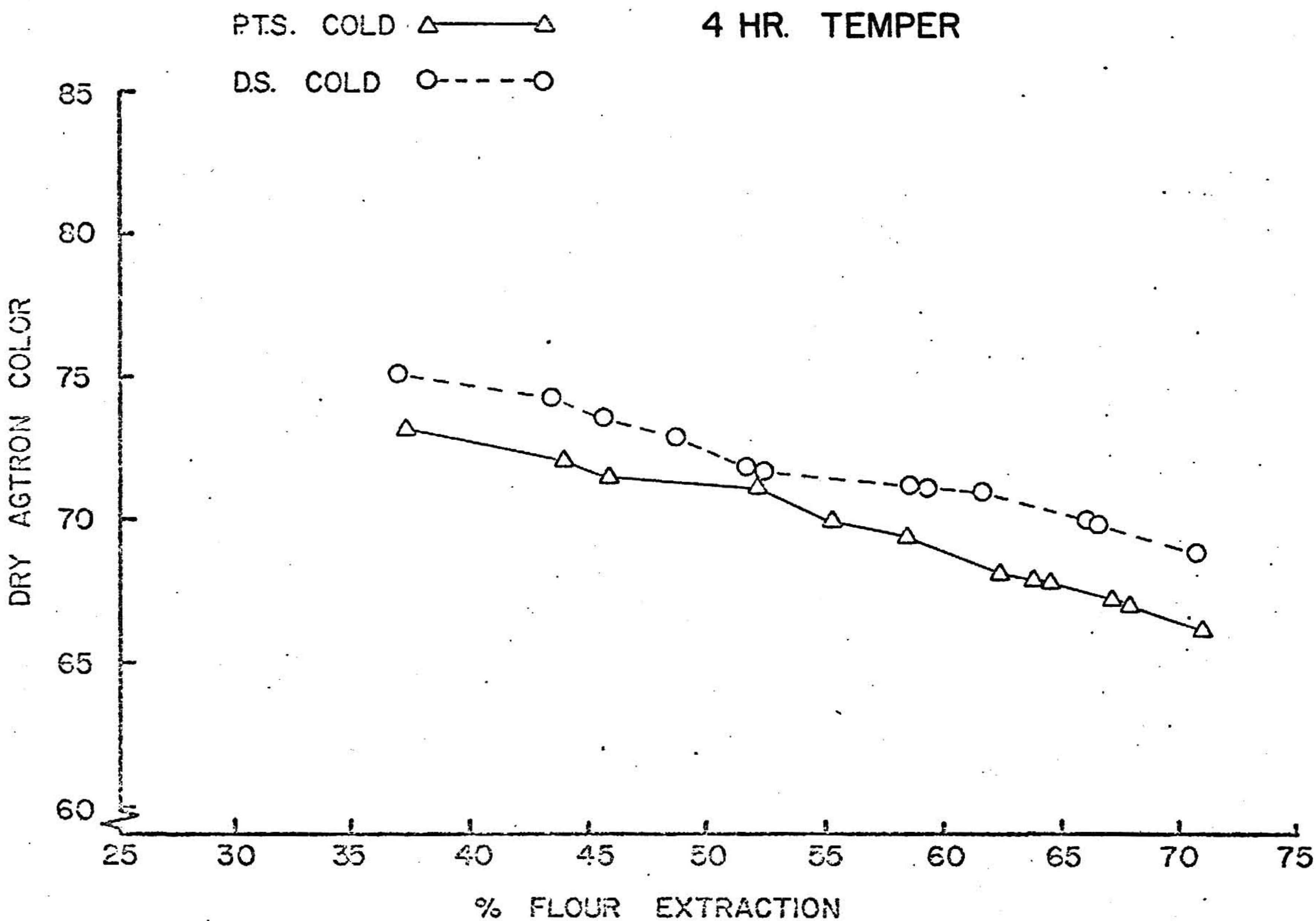

Fig. 27. Cumulative color curves, cold four hour temper, second replication.

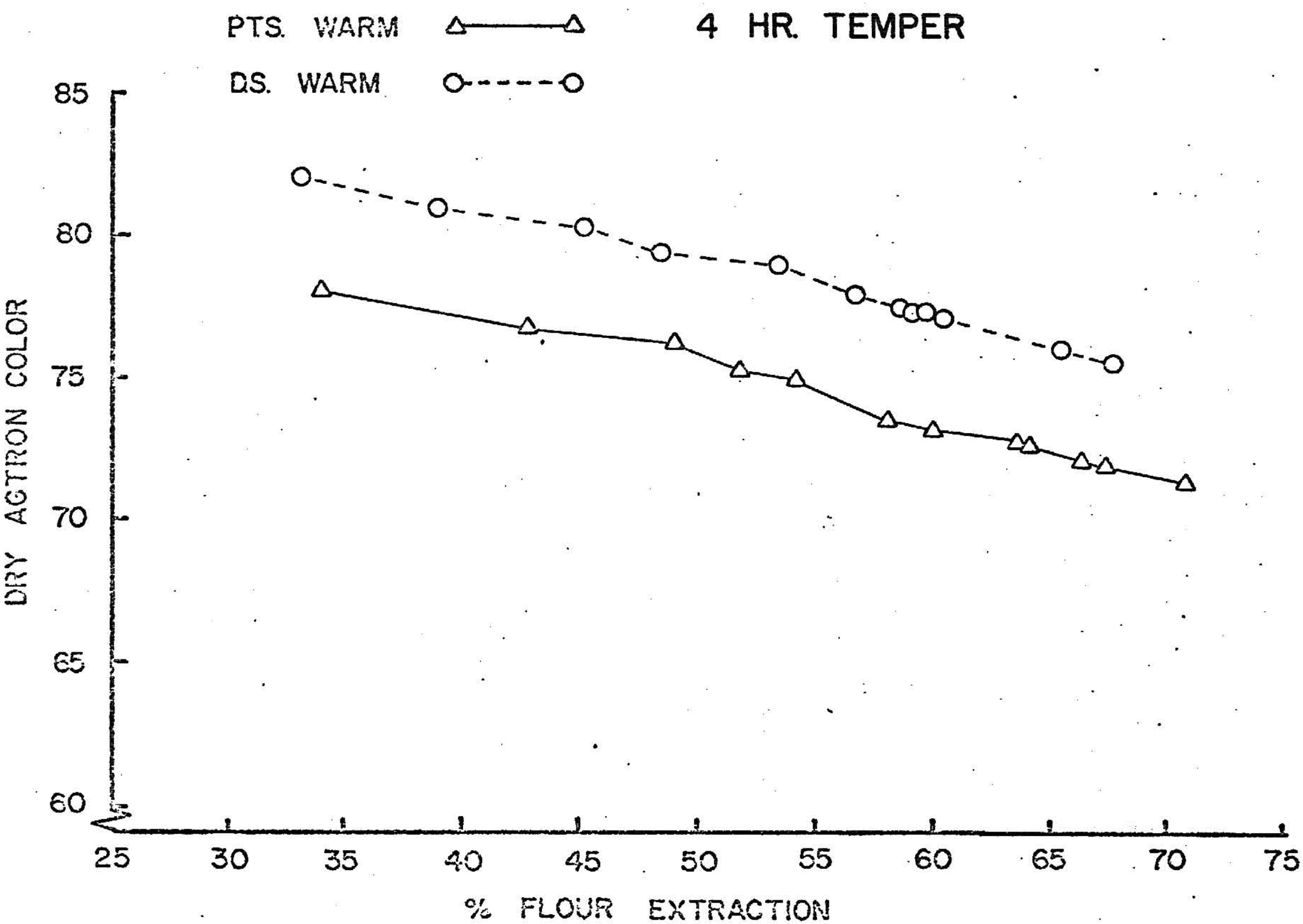

Fig. 28. Cumulative color curves, warm four hour temper, first replication.

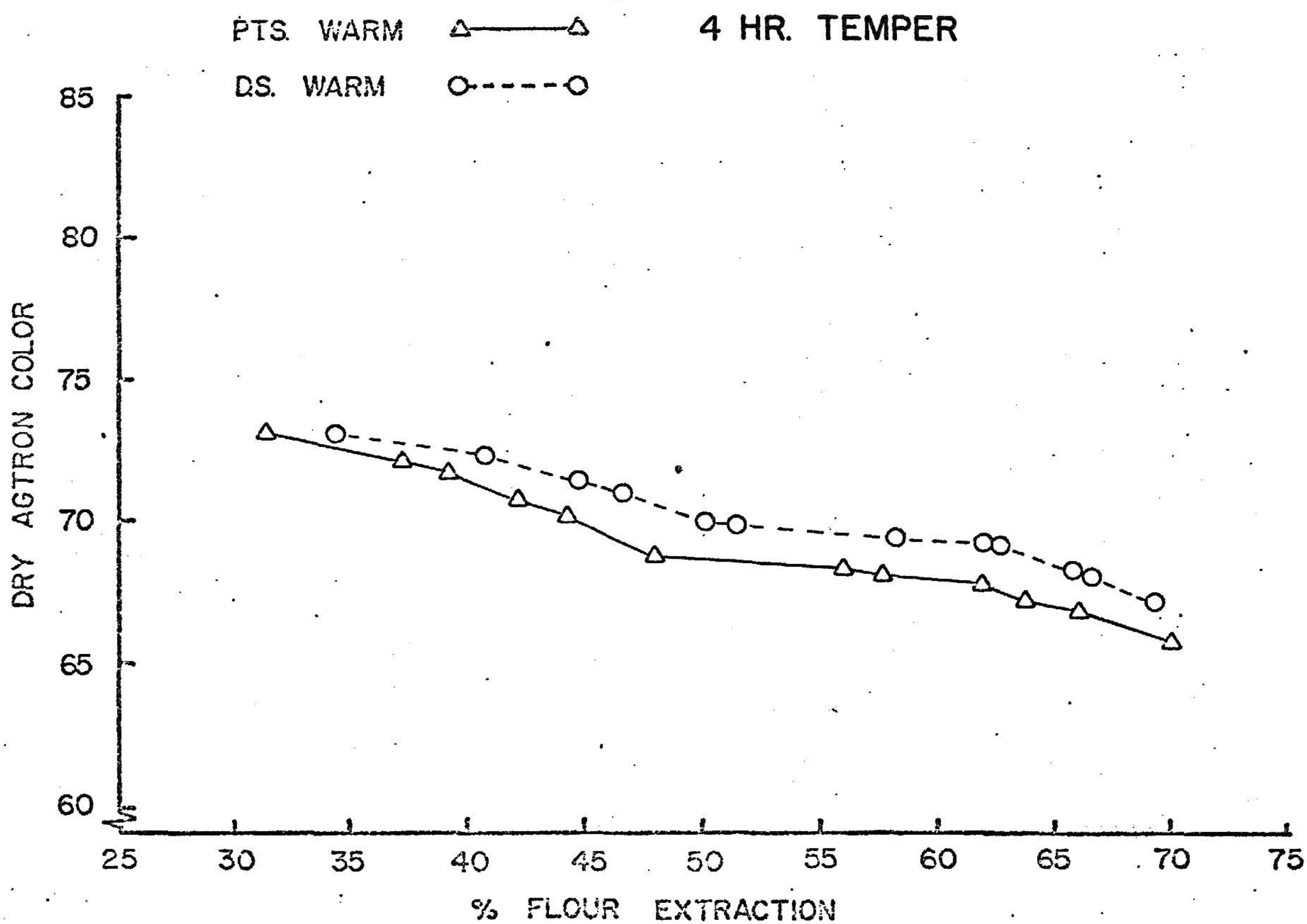

Fig. 29. Cumulative color curves, warm four hour temper, second replication.

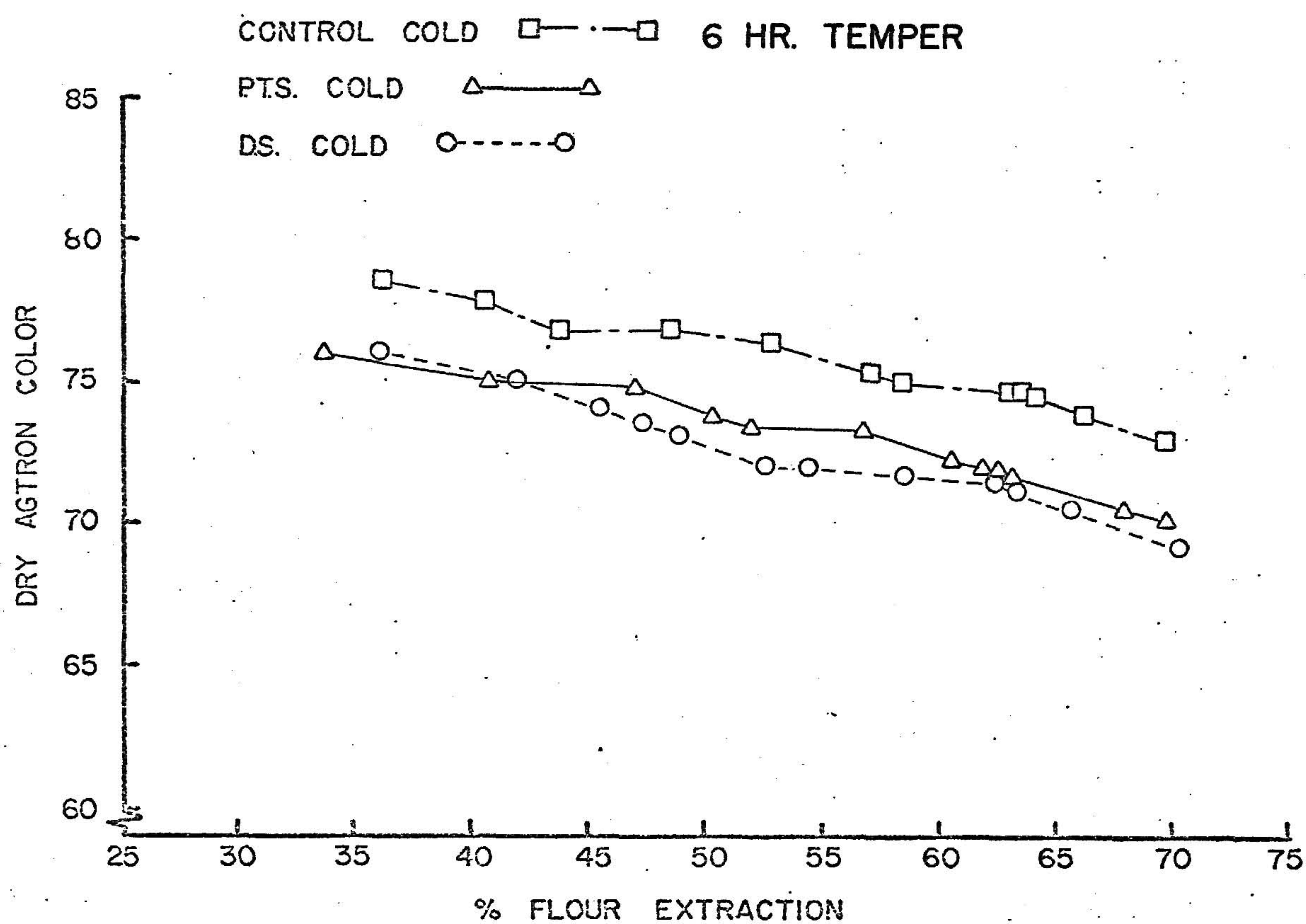

Fig. 30. Cumulative color curves, cold six hour temper, first replication.

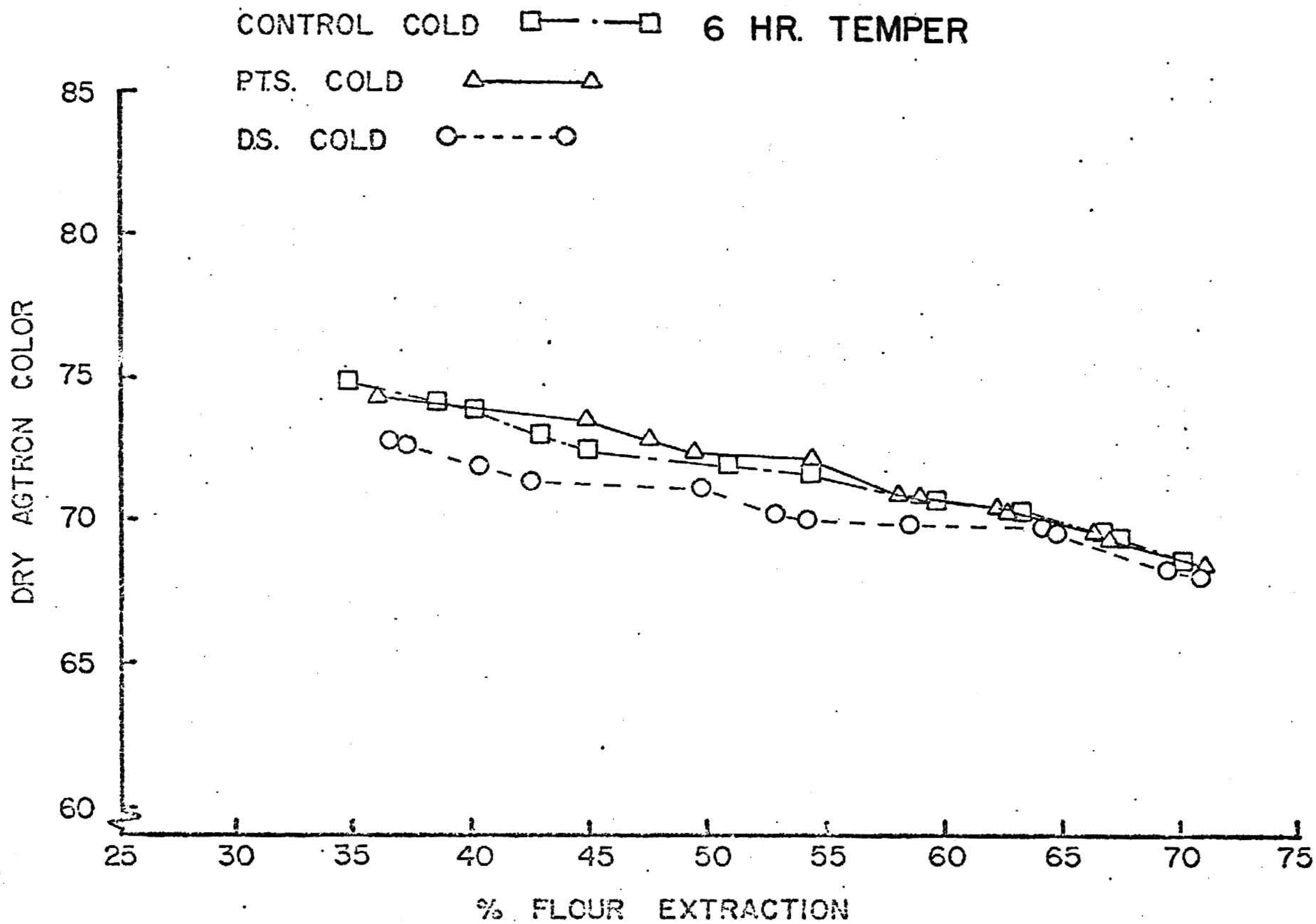

Fig. 31. Cumulative color curves, cold six hour temper, second replication.

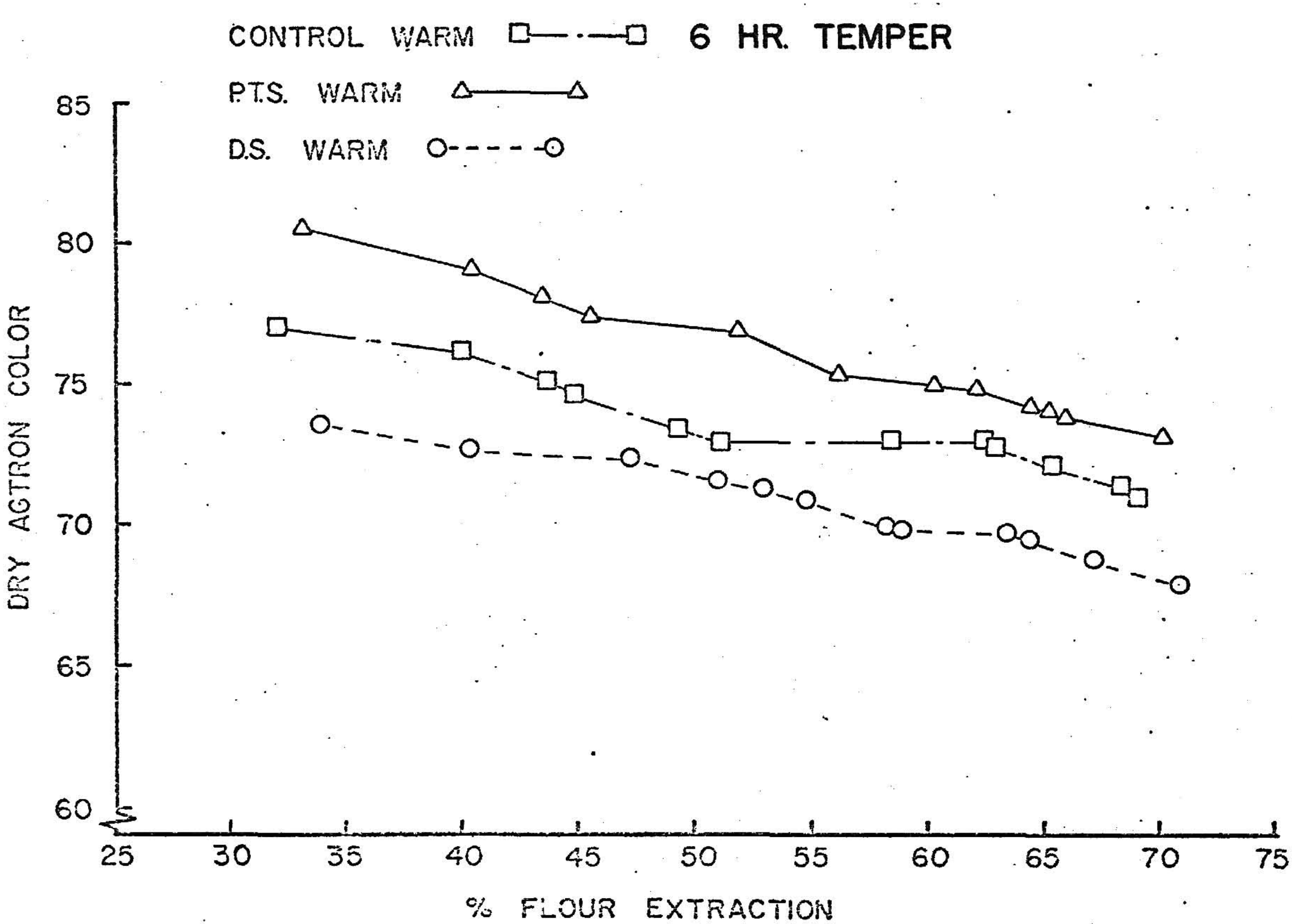

Fig. 32. Cumulative color curves, warm six hour temper, first replication.

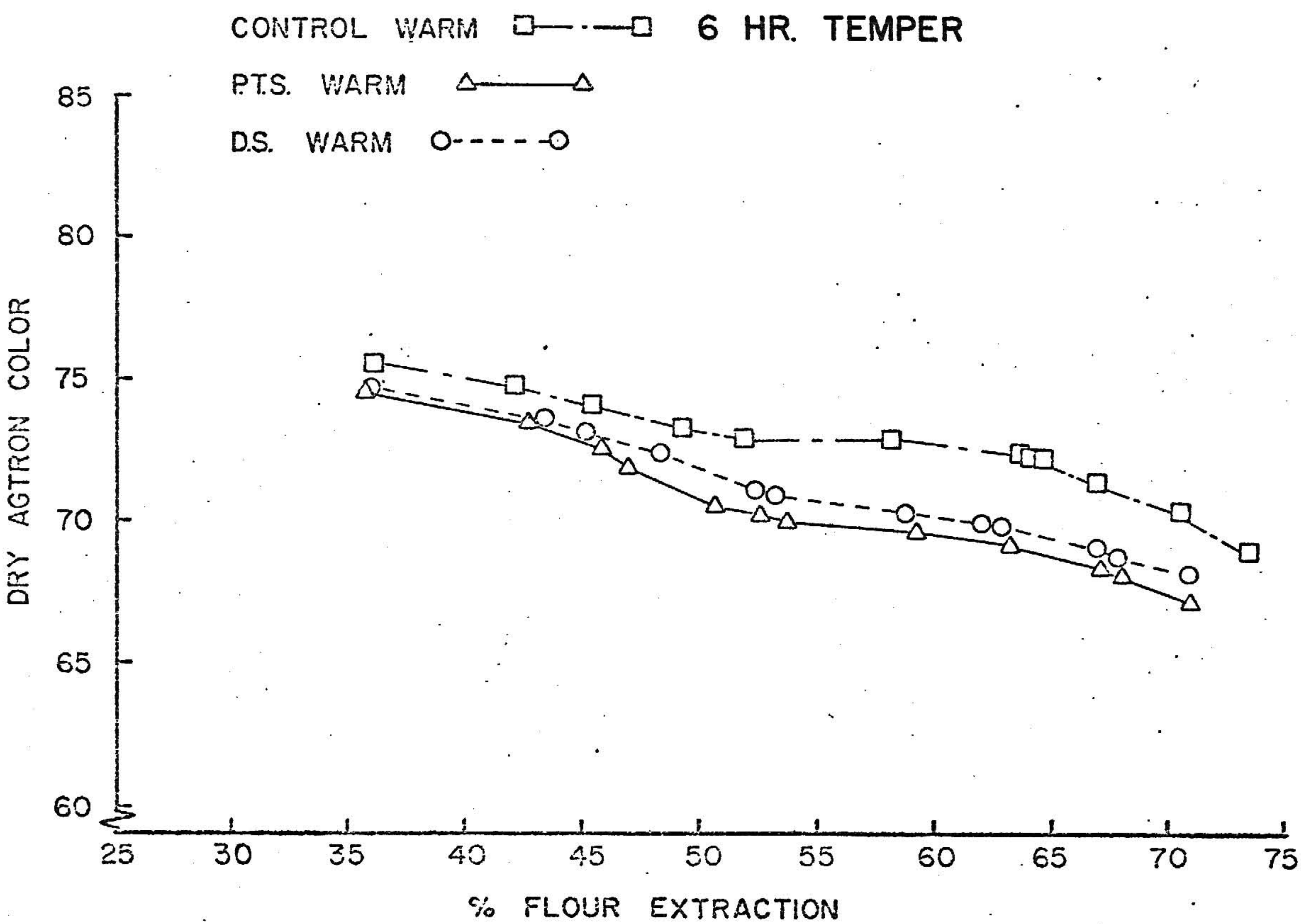

Fig. 33. Cumulative color curves, warm six hour temper, second replication.

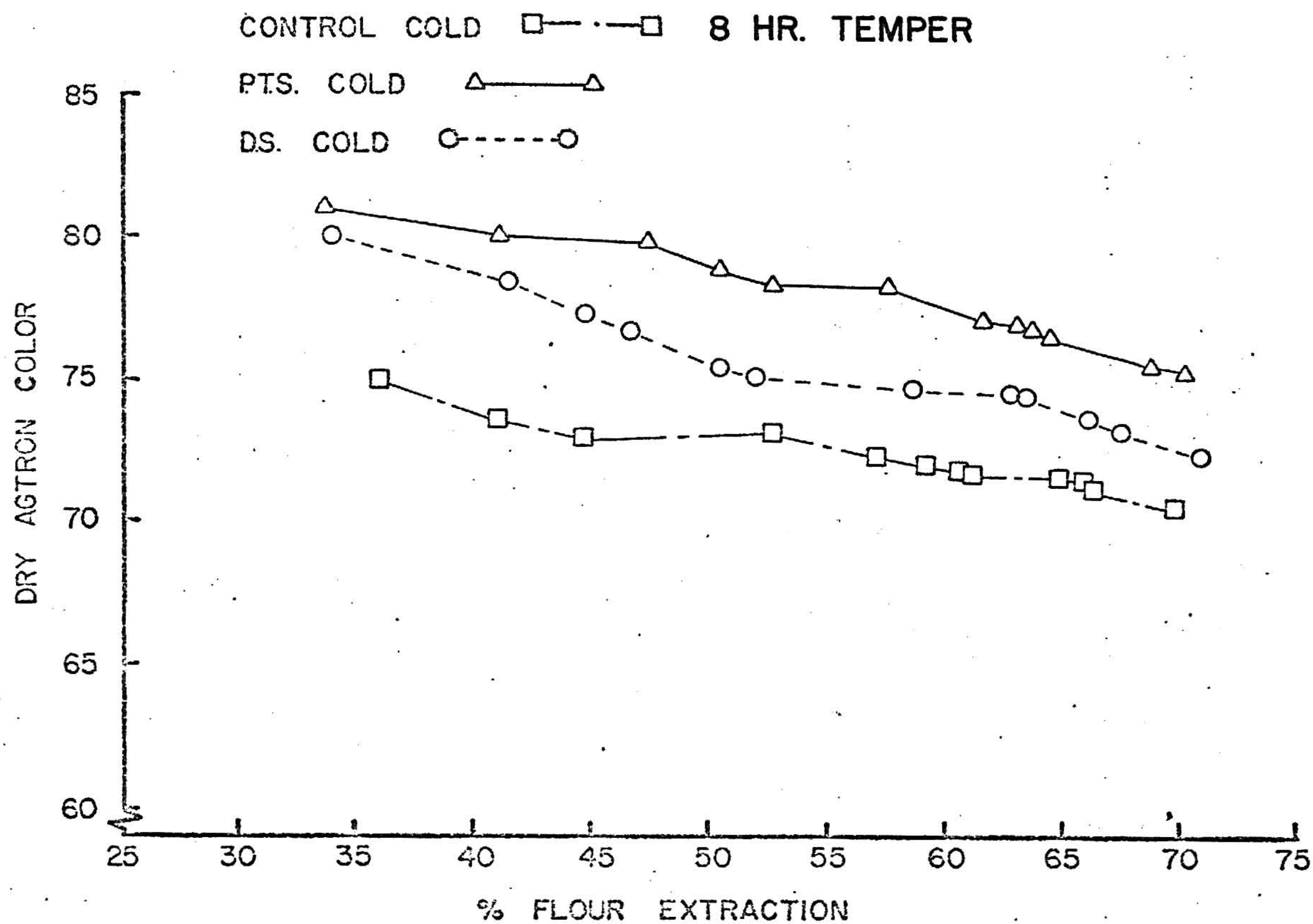

Fig. 34. Cumulative color curves, cold eight hour temper, first replication.

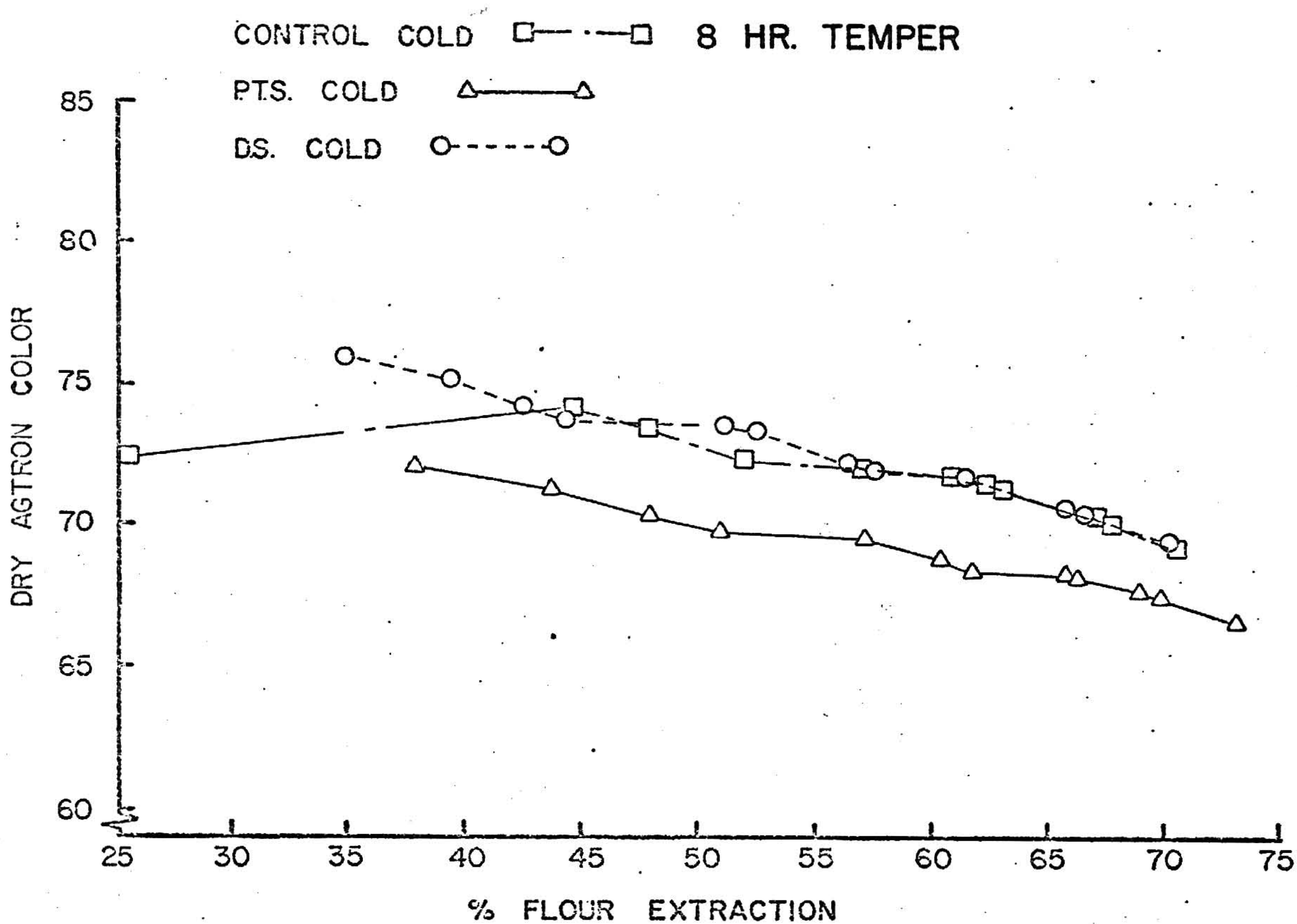

Fig. 35. Cumulative color curves, cold eight hour temper, second replication.

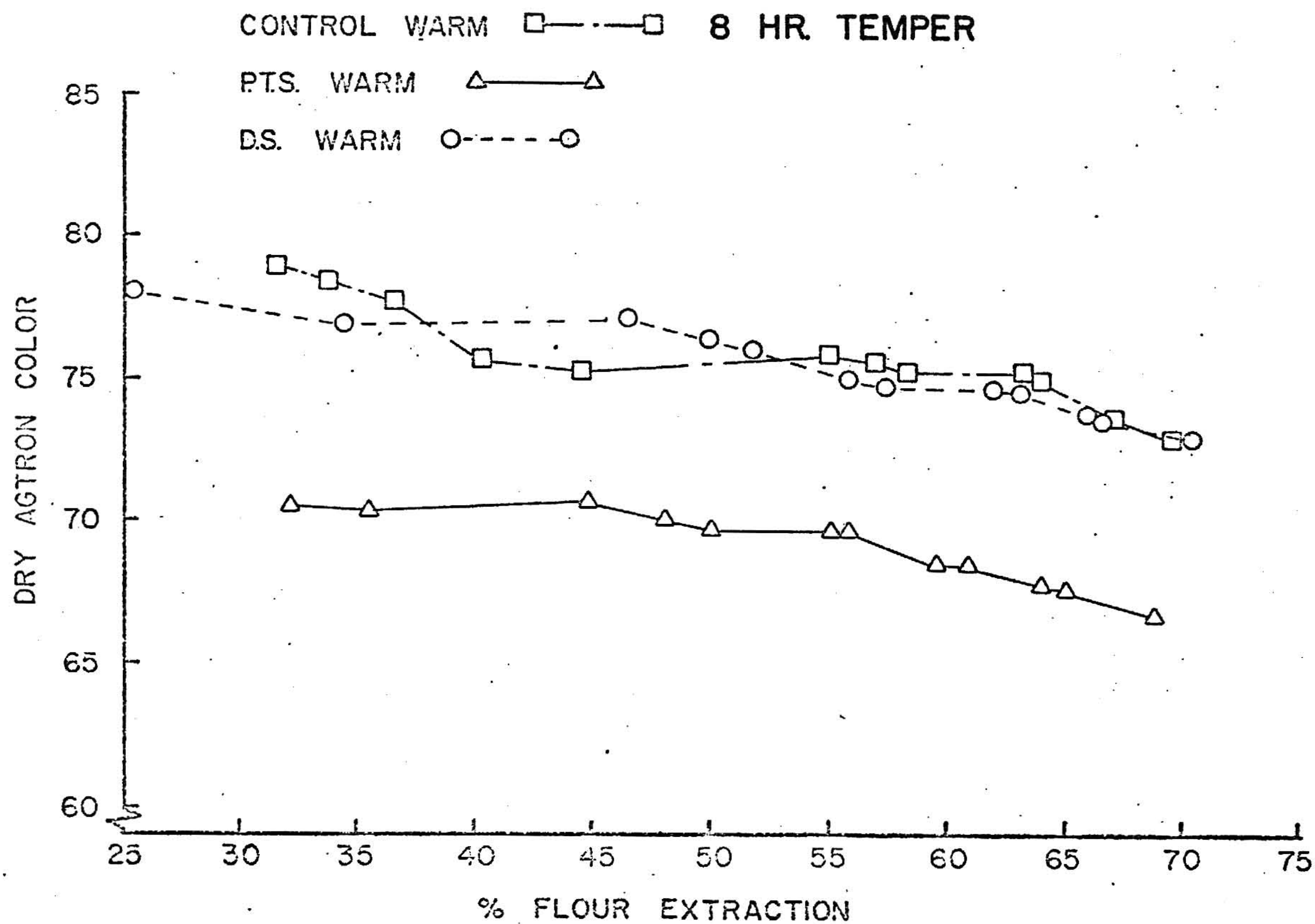

Fig. 36. Cumulative color curves, warm eight hour temper, first replication.

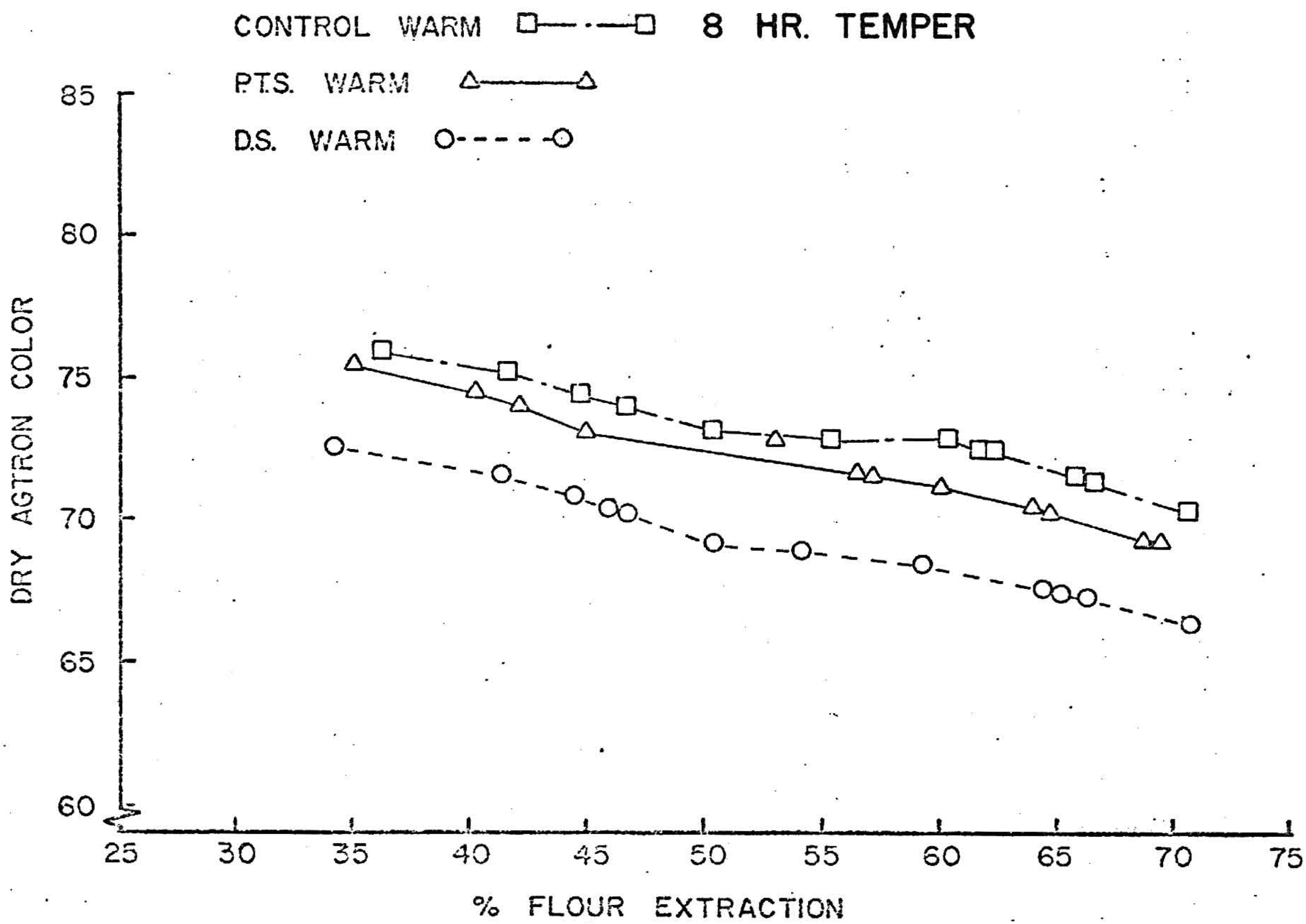

Fig. 37. Cumulative color curves, warm eight hour temper, second replication.

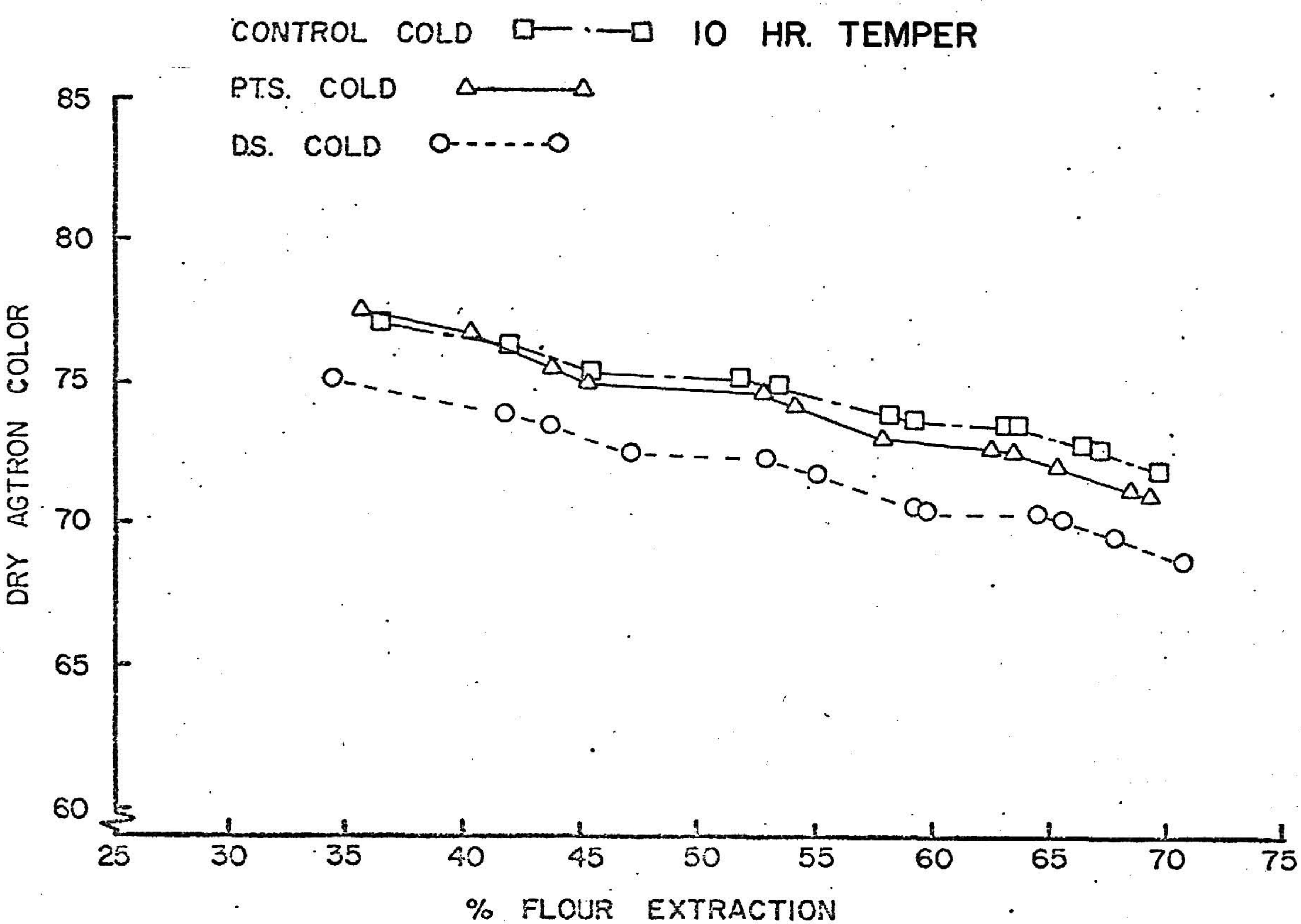

Fig. 38. Cumulative color curves, cold ten hour temper, first replication.

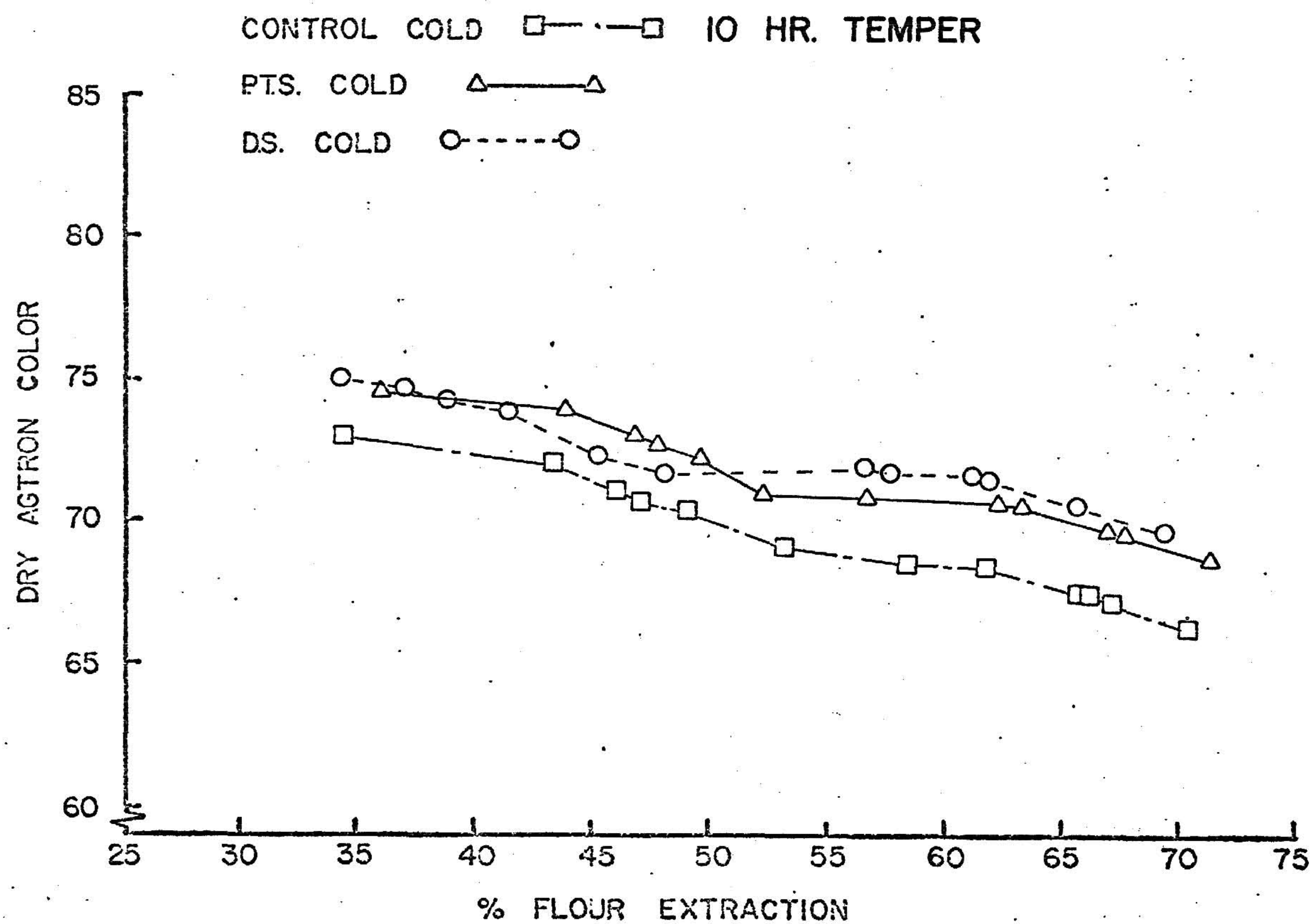

Fig. 39. Cumulative color curves, cold ten hour temper, second replication.

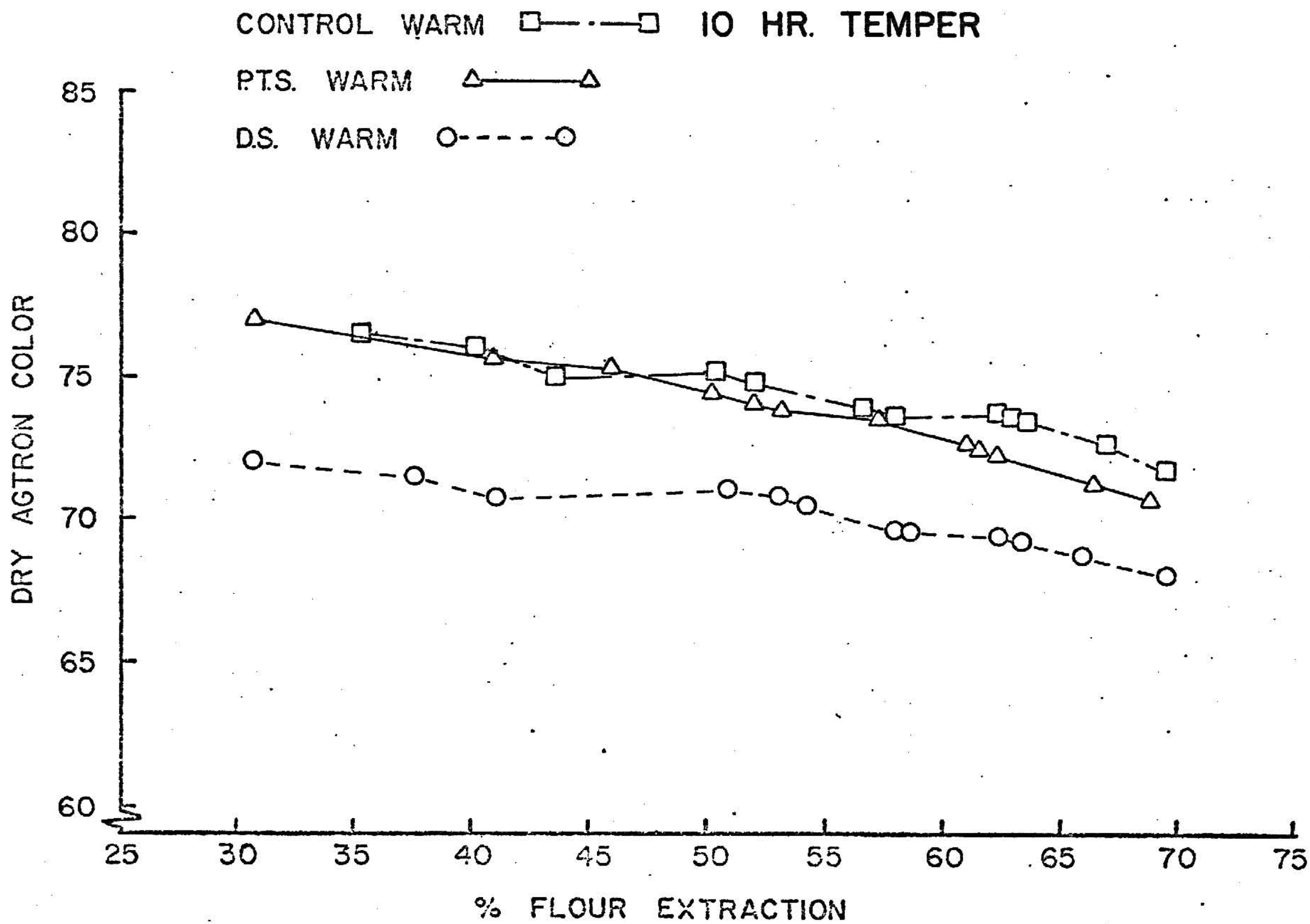

Fig. 40. Cumulative color curves, warm ten hour temper, first replication.

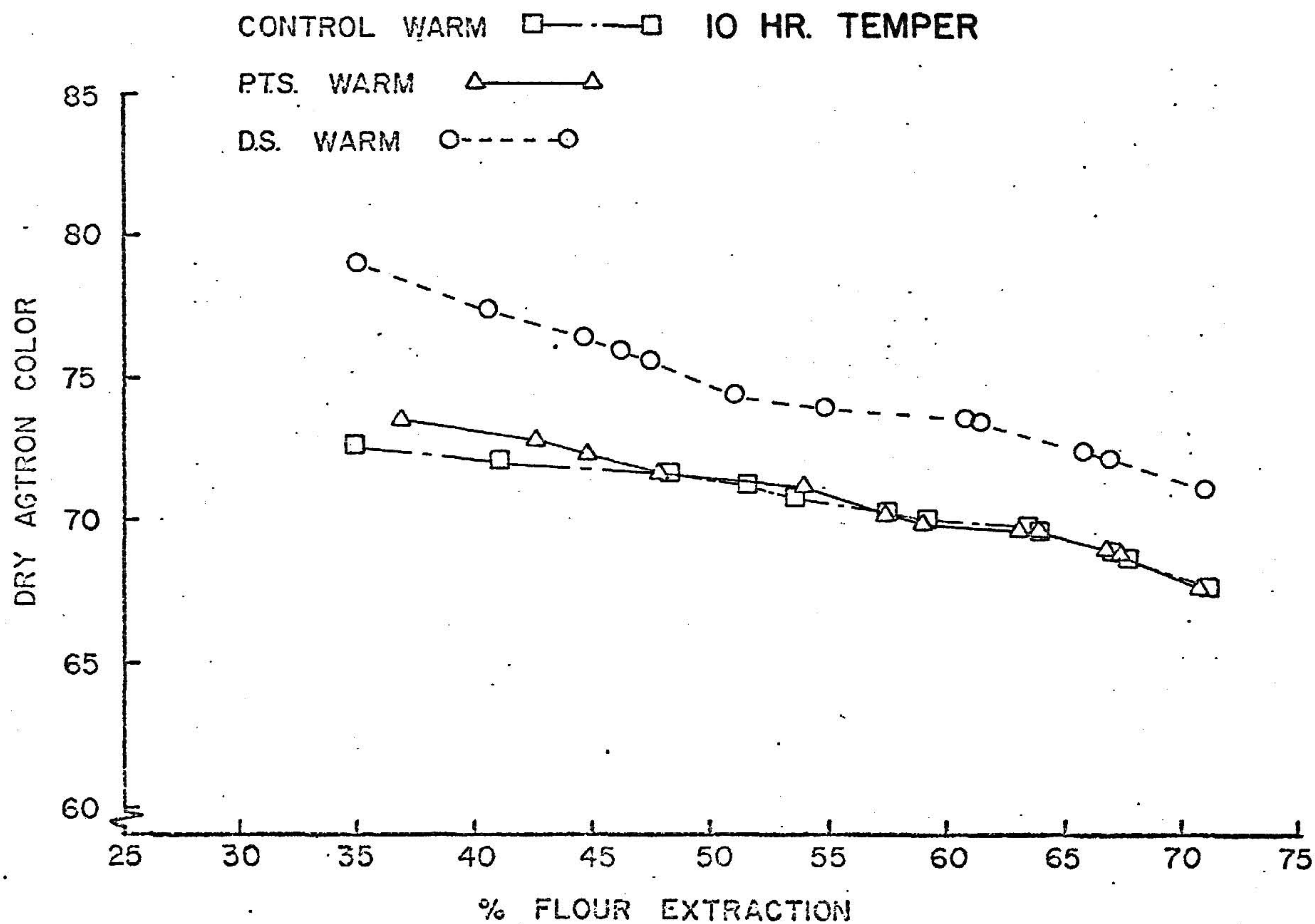

Fig. 41. Cumulative color curves, warm ten hour temper, second replication.

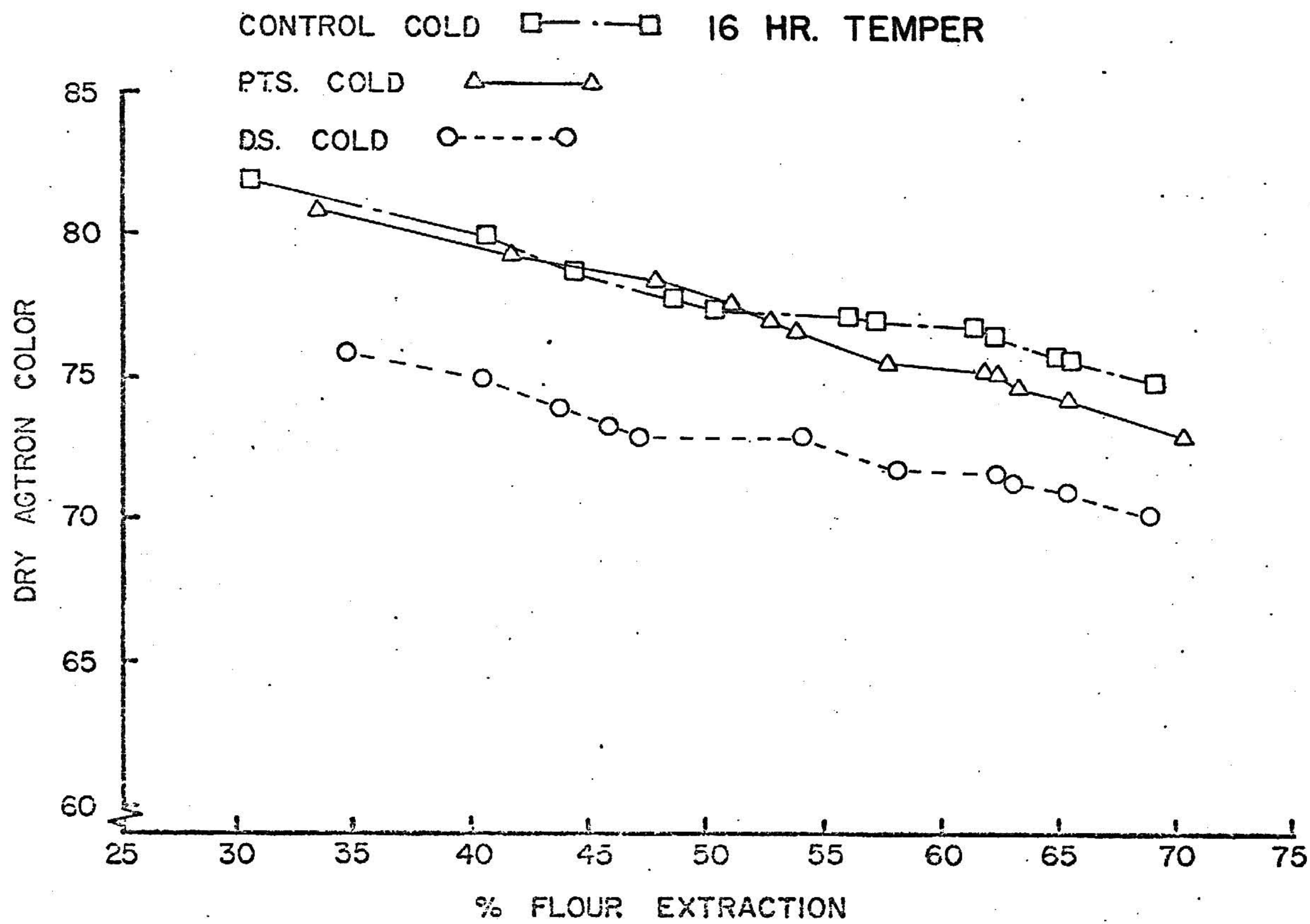

Fig. 42. Cumulative color curves, cold sixteen hour temper, first replication.

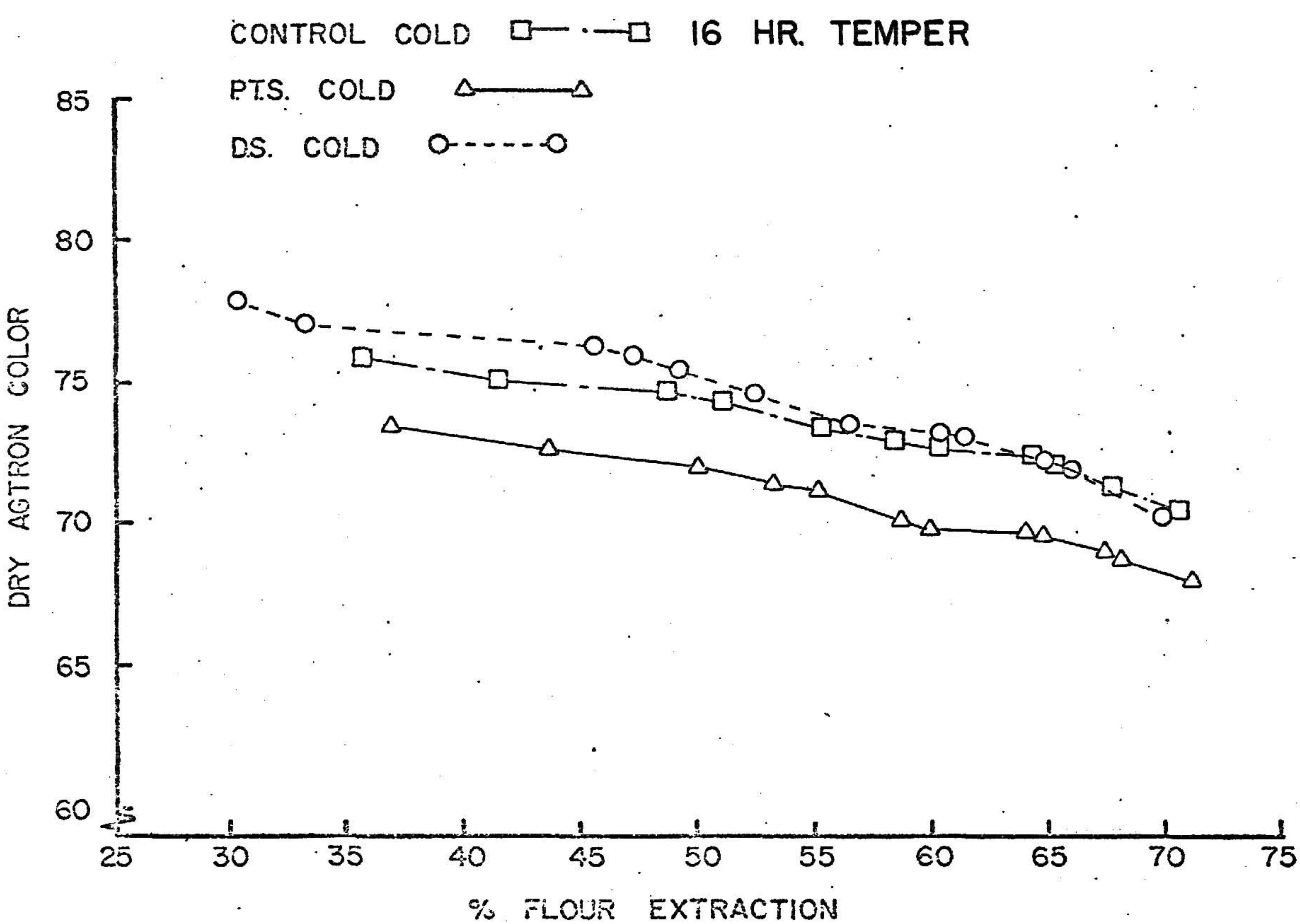

Fig. 43. Cumulative color curves, cold sixteen hour temper, second replication.

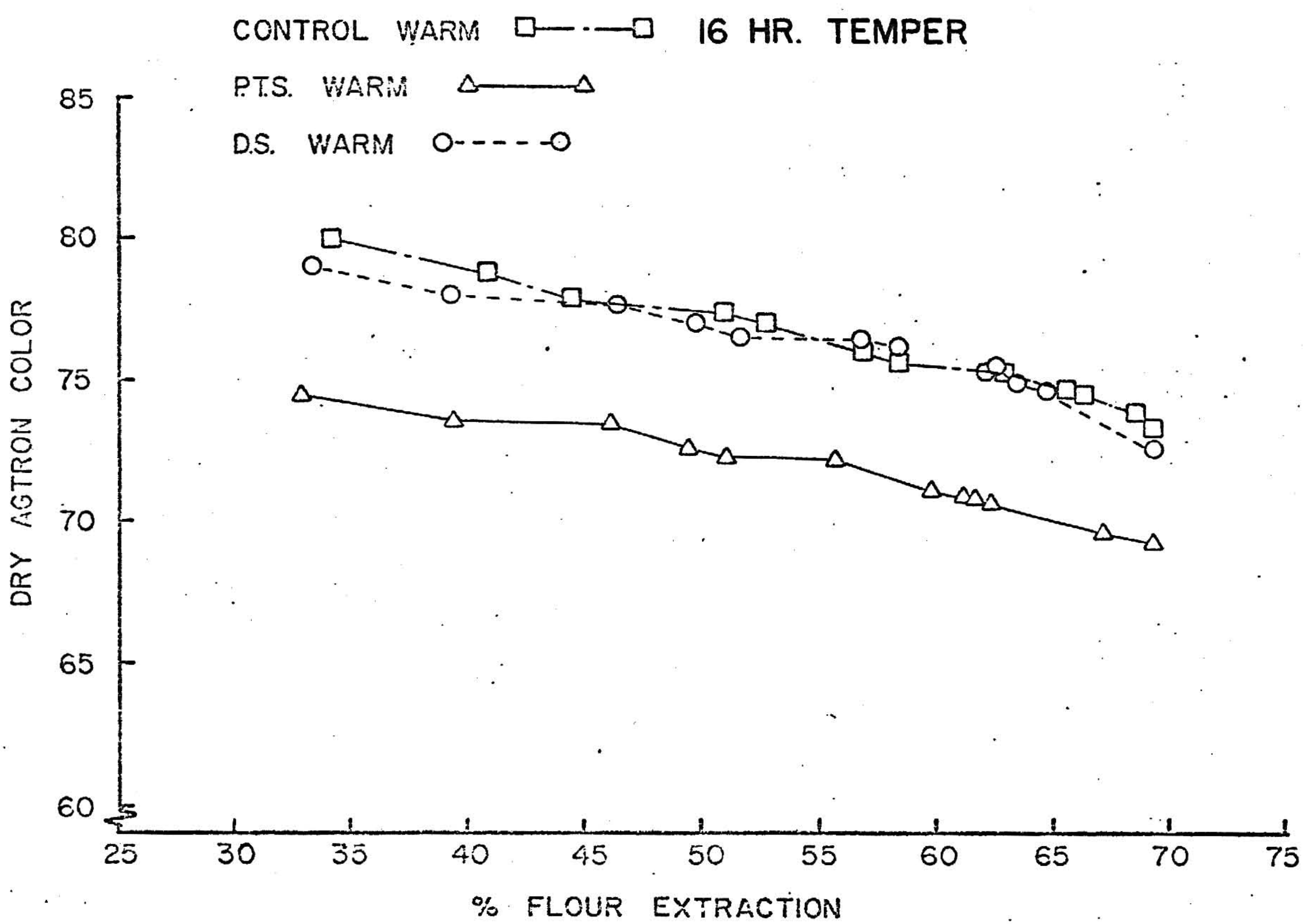

Fig. 44. Cumulative color curves, warm sixteen hour temper, first replication.

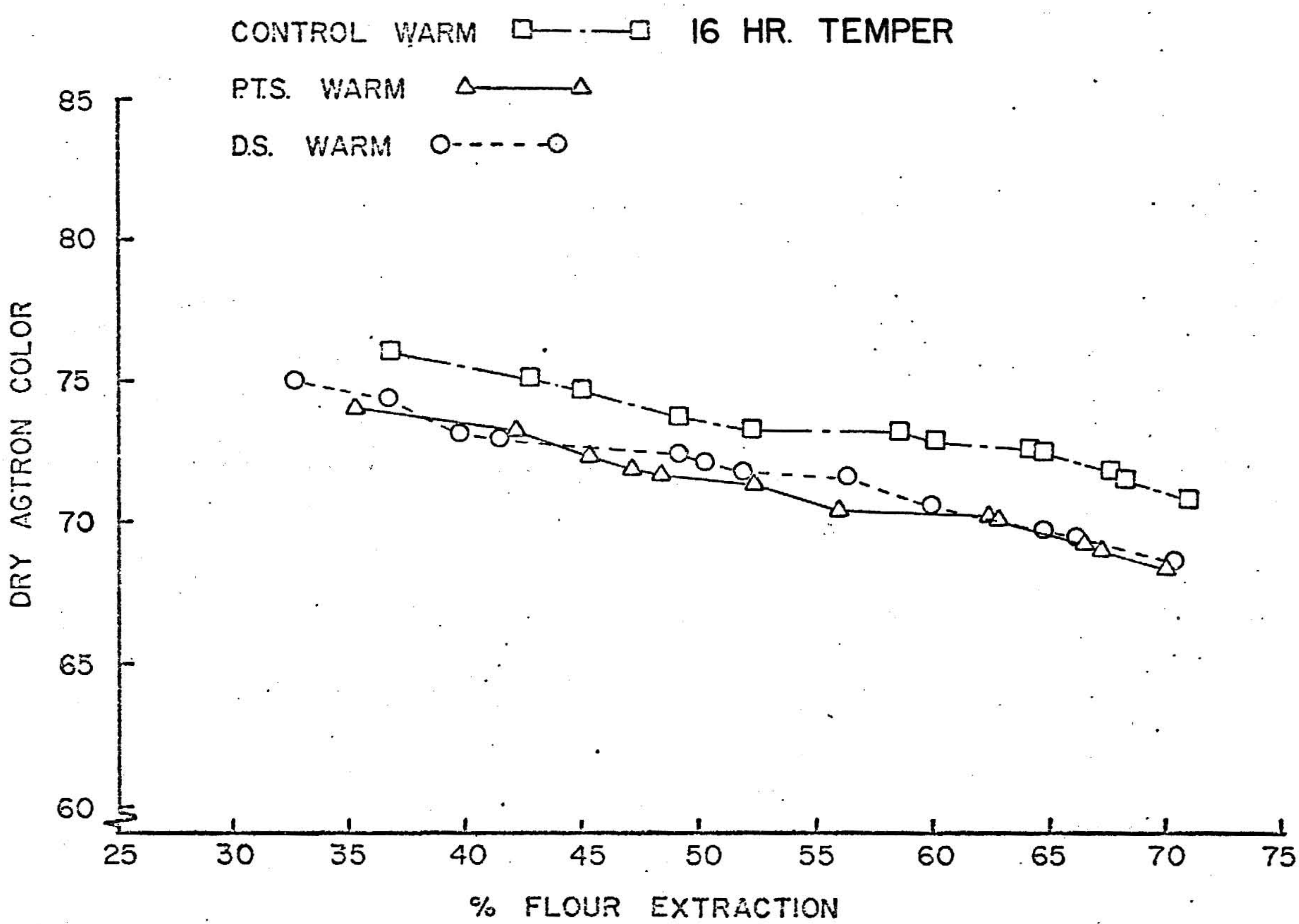

Fig. 45. Cumulative color curves, warm sixteen hour temper, second replication.

these cumulative ash and cumulative color curves.

An analysis of variance was run on the 60 measurements taken for each variable except relative humidity. It was shown that there was not justification for using the analysis of covariance with relative humidity as the independent variable.

Table 13 summarizes the results of those analyses of variance run to answer the question: are the 30 treatments equal, on the average, with regard to the eight variables studied when wheat is milled under the circumstances described for this study? A nonsignificant ($p > .10$) mean square for treatments indicates that the treatments are, in fact, equal aside from possible trivial differences.

The analysis summarized in Table 13 permit the following conclusions: (1) aside from variable $\bar{Y}_2$ (percent ash in the straight grade flour), the 30 treatment combinations studied produce equal effects on the variables investigated; (2) replication differences are of sufficient importance in such studies that, in the interest of good statistical design, they should not be allowed to become confounded with treatment effects; (3) the percent ash in the straight grade flour is affected by some of the different treatments used.

To pinpoint the treatment effects on percent ash in the straight grade flour, Fisher's least significant difference technique is employed. The significant mean square ($.05 < p < .10$) indicated in Table 13 assures that there are some significant (at 10% level) treatment effects and protects against

Table 13. Analysis of Variance on Eight Milling Variables

Source of Variation		Mean Square & Significance			
		Y_1	Y_2	Y_3	Y_4
Treatments	29	0.9084ns	.0004546+	12.28ns	.002747ns
Replication	1	19.13**	.0003037ns	1.897ns	.01536+
Error	29	0.6016	.0002799	11.98	.003781
Total	59				

Source of Variation	Y_5	Y_6	Y_7	Y_8
Treatments	2.688ns	2.717ns	.03346ns	1.100ns
Replication	139.32**	108.8**	.01176ns	26.39**
Error	4.753	5.792	.02931	0.8353

ns, +, and ** = nonsignificant, and significant at the 10 and 1 percent levels respectively.

noting "differences" which are merely sampling phenomena. This is especially true if only logical comparisons are made.

Figure 46, Tables 14 and 15 present the means of the 30 treatment combinations along with indications of the differences which one can consider to be beyond reasonable ($p > .10$) sampling error. Table 16 presents some other comparisons considered to be of interest, along with an assessment of their significance at the 10% level.

The following conclusions are supported by the least-significant-difference analysis of the ordered arrays of means in Tables 14, 15 and 16: (1) under control conditions the tempering time does not effect the mean percent ash of straight grade flour if cold tempering is used; (2) but long tempering times (10-16 hrs.) are associated with lower percent ash than the shorter times (6-8 hrs.) if warm tempering is employed.

Figure 47 shows the effects of time and temperature on percent ash under the P.T.S. treatment. There is no clear trend in percent ash with increasing time of tempering unless there are clear and independent reasons why the results for 2 hrs. cold and 6 hrs. warm are anomalous. Exclusive of those results, there would appear to be a downward trend in percent ash with time of tempering is used. However, no evidence is available to justify the exclusion of those two points.

Figure 47 shows there is a significant drop in percent ash in the straight grade flour when cold tempering time is increased from two to four hours, followed by a linear-appearing increase

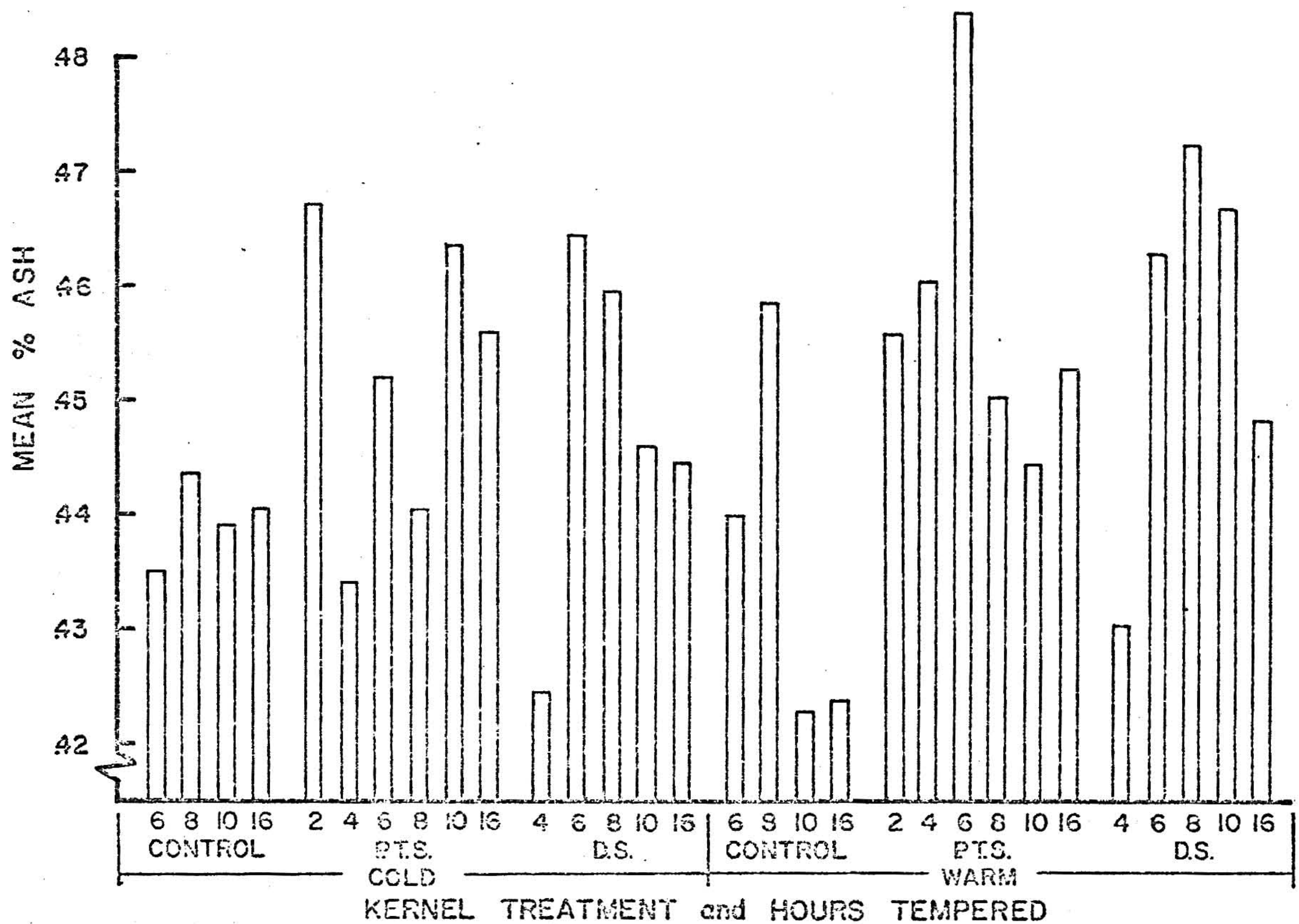

Fig. 46. Mean cumulative percent ash of straight grade flour for each kernel treatment and holding time. Least significant difference = 0.0280.

Table 14. Mean Straight Grade Ash Percentages, Cold Temper (r=2)

Control	P.T.S.	D.S.
6 hr. - .4350	4 hr. - .4340	4 hr. - .4245
10 hr. - .4390	8 hr. - .4405	16 hr. - .4445
16 hr. - .4405	6 hr. - .4520	10 hr. - .4460
8 hr. - .4435	16 hr. - .4560	8 hr. - .4595
	10 hr. - .4635	6 hr. - .4645
	2 hr. - .4670	

$LSD^{+}_{.10}$ = .0280

Table 15. Mean Straight Grade Ash Percentages, Warm Conditioning (r=2)

Control	P.T.S.	D.S.
10 hr. - .4230	10 hr. - .4445	4 hr. - .4305
16 hr. - .4240	8 hr. - .4505	16 hr. - .4485
6 hr. - .4400	16 hr. - .4530	6 hr. - .4630
8 hr. - .4585	2 hr. - .4560	10 hr. - .4670
	4 hr. - .4605	8 hr. - .4725
	6 hr. - .4840	

$LSD^{+}_{.10}$ = .0280

Table 16. Comparison of Control, P.T.S. & D.S. Treatments.

Differences in Mean Straight Grade Ash, L.S.D.$^{+}_{.10}$ = .0280%

(Control - P.T.S.)		(Control - D.S.)
6 Hr. Cold	.0010ns	-.0295+
8 Hr. Cold	.0030ns	-.0160ns
10 Hr. Cold	.0245ns	-.0070ns
16 Hr. Cold	.0155ns	-.0040ns
6 Hr. Warm	-.0440+	-.0230ns
3 Hr. Warm	-.0080ns	-.0240ns
10 Hr. Warm	-.0215ns	-.0440+
16 Hr. Warm	-.0290+	-.0245ns

in percent ash as time of cold tempering is increased under the partially-tempered split treatment. However, the correlation coefficient of +0.631 has only 3 degrees of freedom and is nonsignificant $(p > .10)$.

Only with 6 hours of tempering is there a significant $(p > .10)$ temperature effect as illustrated in Fig. 47.

Figure 48 shows the effects of time and temperature of tempering on percent ash in straight grade flour under the dry split treatment. Four hours of tempering is a practical optimum, as regards low ash content in the straight grade flour, among the times studied. Increasing time to six, eight or ten hours significantly increases the ash content with warm conditioning. With cold, the change to six and eight hours causes a significant change in percent ash. After that there appears to be a decreasing of ash content as tempering time is extended. Possibly the percent ash would drop as low as that found with four hours of tempering if time were extended beyond 16 hours. Under the dry split treatment there is no discernible difference in percent ash under the warm and cold treatments.

From tables 14 and 15, using the 10% least significant difference of 0.0280, the percent ash in the straight grade flour under control treatment is never significantly higher than under either the partially-tempered split or dry split treatments with the same time of tempering. Table 16 also shows this by having no positive significant differences.

The control is superior (lower ash) to the partially-tempered split treatment with either 6 or 16 hours of warm

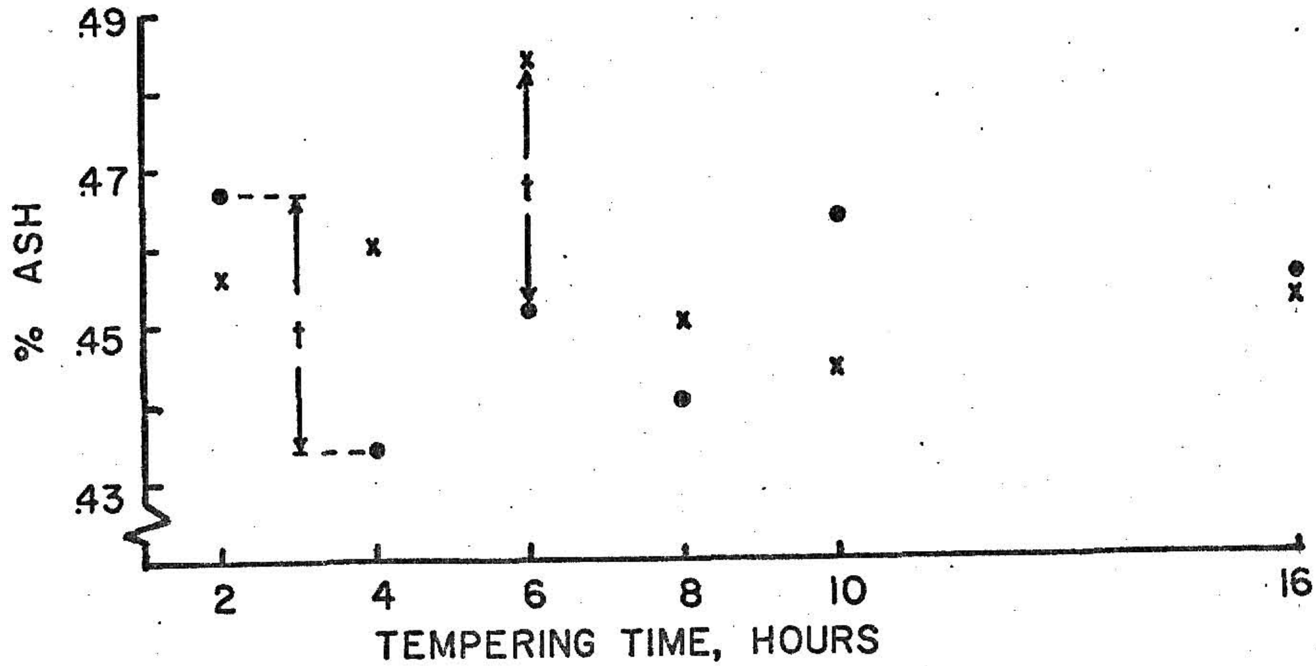

Fig. 47. Mean Cumulative Percent ash of straight grade flour for the P.T.S. Cold (•) and P.T.S. Warm (x) treatments (+ = significant @ 10% level).

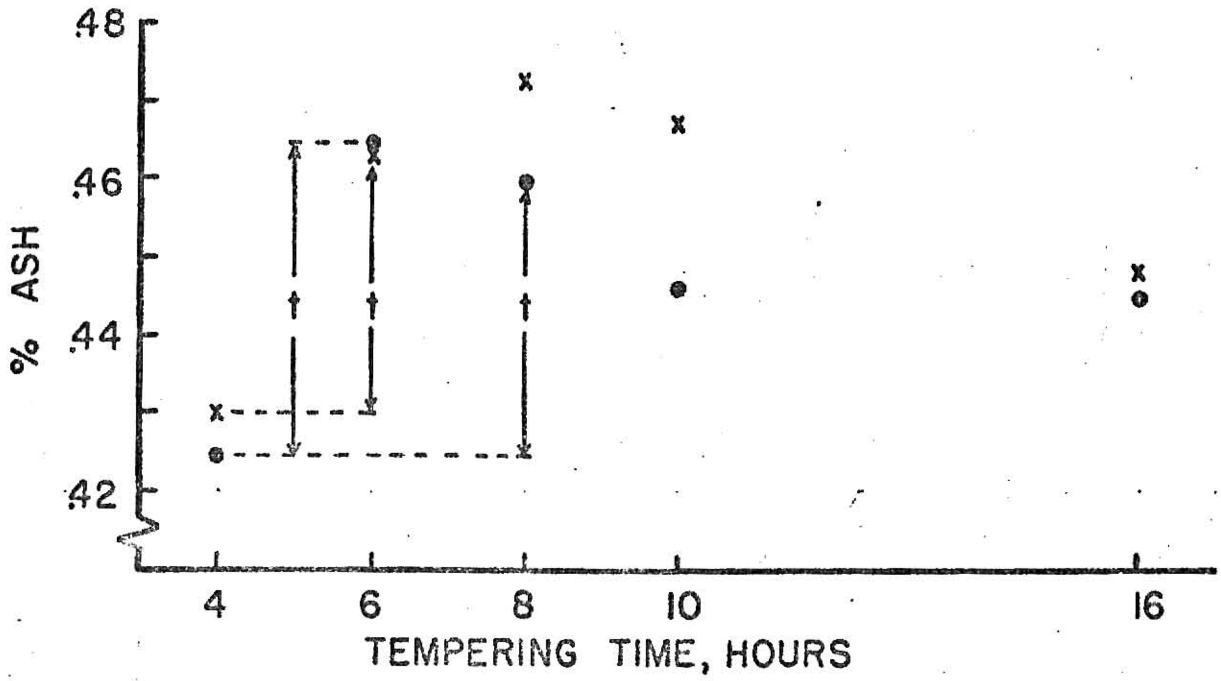

Fig. 48. Mean cumulative percent ash of straight grade flour for the D.S. Cold (·) and D.S. Warm (x) treatments (+ = significant @ 10% level).

conditioning. With either 6 hours cold or 10 hours warm tempering, control is superior to the dry split treatment. Table 16 supports these conclusions.

The partially-tempered split and dry split treatments are essentially equal as far as resulting percent ash in the straight grade flour is concerned except with 4 hours of warm conditioning, in which case the dry split is the better treatment.

Assuming that the shortest tempering time and cold tempering are preferable if they give at least as good a result as any other treatment, Table 17 leads to the following conclusions: a) 4 hours of cold tempering under the dry split treatment is the best combination for achieving a low ash content of straight grade flour; b) there appears to be no reason to choose one of the partially-tempered split treatments (Table 17) because of their high ash and more complicated conditioning process.

Correlation Analysis

On the assumption that the replications and treatments do not interact under the sampling conditions maintained, simple linear correlation coefficients were computed between all pairs of the treatments studied plus relative humidity in the milling area used for this study. The only significant ($p > .10$) correlations found are shown in Table 18. Cumulative dry Agtron color did not correlate with the cumulative percent ash of the straight grade flour.

Table 17. Treatment Giving Lowest Straight Grade Mean Ash Value for Each Temper Time (r=2)

10 hr.	Control	Warm	.4230
16 hr.	Control	Warm	.4240
4 hr.	D.S.	Cold	.4245
6 hr.	Control	Cold	.4350
8 hr.	P.T.S.	Cold	.4405
2 hr.	P.T.S.	Warm	.4560

ns: .4230–.4245; ns: .4230–.4350; ns: .4245–.4405; +: .4245–.4560

$LSD^{+}_{.10}$ - .0280%

Table 18. Significant Correlation Analysis

Variable Pair	r (58 D.F.)
Proposed materials value of products and percent protein in germ	+.218+
Cumulative dry Agtron color of patent flour and percent protein in germ	-.354**
Cumulative dry Agtron color of patent flour and relative humidity	+.258*
Percent extraction of straight grade flour and percent protein in germ	-.340**

+, *, and ** = statistically significant at the 10, 5 and 1% levels respectively.

SUMMARY AND CONCLUSIONS

The dry split and partially-tempered split treatments had no significant effects on percent extraction of straight grade flour, percent extraction of 0.40% ash patent flour, processed materials value of products, cumulative dry Agtron color of straight grade and 0.40% ash patent flour, percent germ extraction or percent protein in the germ.

The percent ash in the straight grade flour is affected by some of the different treatments used. The tempering times does not effect the ash in straight grade flour for the cold conditioned control treatments. Under the warm (43.3° C.) conditioned control treatments, long tempering times (10-16 hrs.) are associated with lower percent ash than the short holding periods (6-8 hrs.).

There is a significant drop in the mean percent ash of straight grade flour for the cold partially-tempered split treatments when tempering time is increased from 2 to 4 hours. Only at 6 hours tempering time was there a significant temperature difference for the partially-tempered split treatments.

Four hours of tempering time resulted in the lowest mean straight grade ash values for the dry split treatments. Increasing the holding period to 6, 8 or 10 hours significantly increases the ash content of the warm dry split treatments. For the cold dry split treatments, the change from 4 to 6 or 8 hours tempering time caused a significant increase in the ash content of straight grade flour. There is no dicernable difference due to temperature of conditioning used in this study on the percent ash in straight grade flour for the dry split treatments.

The control is superior (lower ash) to the partially-tempered split treatment under warm conditioning with holding periods of 6 to 16 hours in regard to straight grade flour. The control treatment is superior to the dry split treatment with 6 hours cold and 10 hours warm conditioning.

The mean percent ash of straight grade flour under the control treatments is never significantly higher than under either the partially-tempered split or dry split treatments for the same holding periods.

The split treatments are essentially equal as far as percent ash in straight grade flour is concerned except for the 4 hour warm treatments. The dry split treatment is significantly lower in ash than the partially-tempered split treatment when using 4 hours of warm conditioning.

It can be concluded that:

1) There were no significant treatment effects other than on the percent ash in straight grade flour, on those variables studied in this investigation.
2) There were no significant differences between cold tempering and warm conditioning except for the partially-tempered split treatments with 6 hours holding time.
3) The split treatments were essentially equal in

regard to percent ash in the straight grade flour except for 4 hours of warm conditioning when the dry split treatment resulted in a significantly lower ash than the partially-tempered split treatment.

4) Assuming that the shortest and simplest tempering conditions are preferable, 4 hours of cold tempering using the dry split treatment is the best combination to achieve a low percent ash content in straight grade flour.

SUGGESTIONS FOR FUTURE WORK

The dry split cold treatment with four hours holding time resulted in the most favorable milling results with the shortest holding period. However, the shortest holding time for the control was six hours and the milling results were not significantly different from the dry split cold, four hour treatment. Further work should be done to establish a significant improvement in milling results using the split treatments as compared to the control treatments at holding periods under six hours.

More work should be done to study the possibility of sifting out the dust created during the splitting process of untempered and partially-tempered wheat. This fraction could be added back into the tail end of the milling system, keeping the head end free from contamination of high ash material created by the splitting process.

Further work should be done on splitting wheats of lower initial moisture content than the 11.8% moisture used in this investigation.

A two percent increase in moisture fifteen minutes prior to splitting should be studied. This should result in toughening the bran more than the one percent increase used in this study for the partially tempered split treatments.

ACKNOWLEDGMENTS

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Appreciation is also expressed to all the members of the department who willingly gave assistance and advice.

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EFFECTS OF SPLITTING UNTEMPERED AND PARTIALLY TEMPERED WHEAT AS A POSSIBLE METHOD TO SHORTEN TEMPERING TIME OF HARD RED WINTER WHEAT

by

JERRY DEAN KUHN

B.S., Kansas State University, 1973

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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KANSAS STATE UNIVERSITY

Manhattan, Kansas

1976

Wheat conditioning is the preparation of clean wheat for milling using moisture, time and possibly added heat. The purpose of wheat conditioning is to toughen the bran to resist attrition and abrasion, facilitate extraction of the endosperm from the bran and ease reduction of middlings to flour.

In industry, due to a shortage of tempering bins and the necessity for frequent changing from one blend of wheat to another, it is often difficult or impossible to allow sufficient tempering time.

This investigation was designed to see if tempering time could be reduced by tempering split, rather than whole, kernels of hard red winter wheat. Two thousand gram samples of hard red winter wheat were tempered under warm and cold conditions for different holding periods ranging from 2 to 16 hours. There were three kernel treatments prior to tempering the samples to 16 percent moisture and milling. Treatment one involved splitting the wheat kernels open along the crease at the original moisture content of 11.8 percent. A second treatment consisted of partially tempering the kernels (1% moisture increase) fifteen minutes prior to splitting. A third treatment, the control, was tempered in one step without splitting. All split samples were opened by passing the wheat through 9" diameter X 6" long pair of smooth experimental rolls at 1.5:1 differential.

All samples were milled by a batch system using 5 breaks and 7 reductions. The flow included pre-break splitting rolls for the control samples.

The dry split and the partially tempered split treatments had no significant effects on percent extraction of straight grade flour, percent extraction of 0.40% ash patent flour, processed materials value of products, cumulative dry Agtron color of straight grade or 0.40% ash patent flour, percent germ extraction or percent protein in the germ when compared with each other or with the control treatment.

There were no significant differences between cold tempering and warm conditioning in regard to percent ash in the straight grade flour except for the partially tempered split treatments with 6 hours holding time.

Assuming the shortest and simplest tempering conditions are preferable, 4 hours of cold tempering with the dry split treatment is the best combination to achieve a low percent ash content in the straight grade flour.