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THEORETICAL AND PRACTICAL CONSIDERATIONS IN THE SEGREGATION OF CANADIAN WHEAT BY PROTEIN CONTENT

by

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TABLE OF CONTENTS

ABSTRACT

DUNNE WILLIAM, Ph.D. The University of Manitoba, March 1973.

THEORETICAL AND PRACTICAL CONSIDERATIONS IN THE SEGREGATION OF CANADIAN WHEAT BY PROTEIN CONTENT

MAJOR PROFESSOR: Dr. J. A. Anderson

The objective of this research was to aid in the development of a system for introducing protein content as a factor in grading Canadian wheat. In preliminary studies, historical data on carlots of wheat unloaded at mill and terminal elevators were examined. It was found that the average protein content of Thunder Bay Unloads was about 0.3% higher than West Coast Unloads. Reasonably consistent differences were also observed between terminals within each port.

Grouping of carlots according to fixed protein ranges indicated that the amount of wheat going into each sub-grade and the mean protein content of each sub-grade varied considerably from year to year. Nevertheless, division into three suitable sub-grades would result in sub-grade means differing by 1% protein.

About this time there was a developing consensus that Canadian wheat should be offered at guaranteed protein levels of 15.0%, 14.0%, and 13.0% or possibly at 14.5%, 13.5% and 12.5%. It was found that sub-grade means of the above protein levels could be achieved if the

protein ranges for each sub-grade was allowed to vary over time.

Current protein testing technology does not permit the testing of each carlot at Unload time. It was therefore necessary to know in advance the protein content of each carlot and the protein range for each sub-grade so that carlots can be objectively segregated by protein content.

It was found that a protein test made on a "Primary" sample taken by the country elevator agent at the time of loading provided a fairly accurate advance estimate of the protein content of each carlot. About 80% of the Primary proteins differed by less than 1% protein from results of tests made on the Unload sample taken by the Canadian Grain Commission. It was also found that the mean protein content for each shipping point, though not as accurate as the Primary protein, could be used to segregate the carlots by protein content.

It was established that the protein range for each sub-grade depended on the mean and the variance of the protein distribution of the carlots and the correlation between the Primary and Unload proteins. It was found that the Canadian Wheat Board by controlling grain movements could affect both the mean and the variance of the carlots arriving at unload position. Also the Canadian Grain Commission, in providing the protein testing and grading services, could influence the correlation between Primary and Unload proteins. It was therefore concluded that protein segregation can only operate effectively if there is a close co-operation between these two organizations.

I. INTRODUCTION

The research recorded in this thesis was begun early in 1969, in co-operation with the Board of Grain Commissioners for Canada, to assist in developing a system for introducing protein content as a factor in grading Canadian wheat. Since that time, the Canada Grain Act, which controls grading, has been completely re-written, passed by Parliament, and proclaimed on Dec. 18, 1970. The new Act permitted step-by-step introduction of new grades, and protein content as a grading factor, without further recourse to Parliament. The first new grade, No. 1 Canada Western wheat, essentially a combination of the old grades of No. 1 and 2 Manitoba Northern, was introduced August 1, 1971, and this grade was divided into sub-grades of guaranteed protein content, at Thunder Bay on that date, and at Pacific ports on January 1, 1972. The remaining new grades were implemented on August 1, 1972, and No. 2 Canada Western, which consists of No. 3 Manitoba Northern and the "best" of No. 4 Manitoba Northern, was segregated into protein sub-grades at Thunder Bay on that date. Thus, as the thesis is being written, the objectives of the research have been substantially achieved.

It should be noted that the new Act changed the Board's name to The Canadian Grain Commission, and it is referred to by that name, or by the abbreviation C.G.C., throughout this thesis.

Interest in the possible introduction of protein content as a factor in grading Canadian wheat dates back to the nineteen twenties. On February 16, 1928 Parliament resolved that "the National Council of

Industrial and Scientific Research in conjunction with the Board of Grain Commissioners be asked to investigate and report on the feasibility of utilizing the protein content of wheat as a basic factor in grading that product" (1). The minutes of proceedings and evidence and the report of the select standing Committee on Agriculture and Colonization of 1928 shows that the problems and prospects of introducing protein as a factor in the grading of Canadian wheat were extensively discussed by this committee. In 1929, R. Newton (2), then Professor of Field Crops and Plant Biochemistry at the University of Alberta, prepared "an interim report on protein content as a factor in grading wheat" for the National Research Council. This report covered an investigation of protein testing procedures and related problems in the United States, and also discussed the possible application of protein testing under Canadian conditions. This report also recommended that the inquiry should be extended to the countries to which the Canadian wheat crop was mainly exported. In 1930 Newton (3) reported on an "inquiry in Europe regarding the feasibility of using protein content as a factor in grading and marketing Canadian wheat". On the basis of these reports it was concluded that since it was probable that protein segregation would not result in a higher price for Canadian wheats to compensate for the difficulties and costs incurred in segregation.

In 1938 (4) the Turgeon Report of the Royal Grain Inquiry Commission in discussing protein selection of wheat by Canadian and American millers concluded that, while some protein selection probably occurs each year it saw no reason for suggesting a change in the existing attitude towards selection, provided the producer was made aware of possible premiums for high protein.

The next reference to protein grading was made by Anderson in 1953 (5). His recommendations were based on technological demands for closer control of protein content to meet the needs of an industry rapidly developing towards complete automation. Anderson proposed combining wheat of 1 and 2 Northern of over 60 lbs bushel weight and dividing this into three protein sub-grades. This proposal was not implemented, as it was again assumed that protein segregation would not result in higher price being paid to the producer.

It was not until the late 1960's that further interest developed in this problem. In 1969 the Board of Grain Commissioners made public proposals to introduce protein content as a grading factor. The system proposed was similar to Anderson's, with the emphasis placed on a middle grade maintained close to the long-term average protein content of 13.6% with constant upper and lower bounds. It was at this stage that the current research started.

The renewed interest in protein content as a grading factor in wheat was activated in response to the world wheat surplus supply situation and the ability of other exporting countries, such as the United States, Russia, and Australia to offer wheat of guaranteed protein content for which there appeared to be a market demand.

The increase in the market demand for guaranteed protein content resulted from a number of interrelated developments. In many importing countries the shortage of foreign exchange has resulted in policies aimed at self-sufficiency in wheat production. However, in most countries growing conditions are not conducive to the production of high quality, high protein wheat. This results in the need to import certain types of wheat which compensate for the quality deficiencies of indigenous supplies. Since these selective imports are usually expensive there is an increased demand for maximum uniformity and guaranteed quality.

Furthermore, past grain policies of importing countries not only attempted to increase domestic wheat production but also economically encouraged the milling and baking industry to make maximum use of available indigenous supplies. This in turn encouraged technological developments which would circumvent the quality deficiencies of the indigenous supplies. Moreover, the economic conditions in the milling and baking industries were such that not only were technological developments encouraged but they were applied almost immediately in an attempt to curtail increasing costs. An example of such a technological advance is the development and application of the Chorleywood Bread Process in Europe in the 1960's (6). Such technological advances are self-energizing and lead to more and more automation of the industry. Automation in turn increases the demand for uniformity and the need for guaranteed quality in raw materials.

This increased demand for uniformity is further reinforced by a recent structural change that has occurred in the milling and baking industry. In some countries bakeries have come under the direct control of the milling industry (6). This structural change will likely increase in intensity in the future since it offers the concentration of purchasing power and easier introduction of technological innovations which in turn increase the demand for uniformity in quality of raw materials. By the late 1960's the market demand for guaranteed quality, particularly protein content, had increased to such an extent that it became necessary to offer a protein guarantee to remain competitive in world wheat markets.

Historically, the quality and uniformity of Canadian wheat has been controlled by an official grading system which operated under the provisions of the Canada Grain Act. With the use of Government grades and standards the quality of wheat exported from the various export positions was extremely uniform for the quality parameters controlled by the Canadian grading system.

Under the Canadian wheat grading system, the grade to which a particular parcel of wheat was assigned depended on its bushel weight; variety; vitreousness; moisture; and the degree of visual or apparent soundness and cleanliness. The Canada Grain Act specifices minimum or maximum levels of each of these grading factors for each of the top grades of wheat. Uniformity with respect to protein quality has been achieved through a control over the licensing of new varieties under the Canada Seeds Act, and through varietal specification for the top grades of wheat under the Canada Grain Act. These specifications have also affected the protein quality of the lower grades of wheat because the vast majority of the farmers grew varieties "equal to Marquis".

The world-wide reputation enjoyed by the Canadian "Certificate final" offers a good indication of the success of the Canadian grading system in establishing and maintaining the quality and uniformity of export shipments. However, the Canadian wheat grading system has not in the past explicitly controlled an extremely important quality factor, namely, protein content. Since the high price that Canadian wheat commands on the world market is largely due to the quality and quantity of protein it contains, its uniformity with respect to these parameters is of prime importance.

The introduction of protein as a grading factor has presented a number of problems because of the geographic spread of the wheat growing area, the complexity of the collection, transportation, and storage systems, the roles played by country and terminal elevator operators and the C.G.C. in grading, and the interlocking responsibilities of the C.G.C. and the Canadian Wheat Board (C.W.B.).

The grain producing area of Western Canada is spread over about 84 million acres of the Provinces of Manitoba, Saskatchewan and Alberta.

This region produces annually about 600 million bushels of wheat of which domestic consumption for food, feed and seed utilizes about 180 million bushels. The remainder, which is about 70% of the wheat produced, must be exported as wheat and flour.

It is hardly surprising that wheat produced over such a vast geographic area would exhibit considerable variability in average quality from year to year and location to location. This is particularly true with quality parameters such as protein content which is significantly influenced by climatic conditions during the growing season. The geographic distribution of the protein content of Canadian wheat was first recorded by Alcock in 1925 (7). Anderson and Eva (8) in 1943 presented a considerable volume of data supporting Alcock's conclusion. These workers also discussed the relationship between the protein distribution and climatic and edaphic factors. In 1969 Martens and Hlynka (9) presented data on the geographic distribution of the protein content of the Western Canadian wheat crop for each year for the period 1927 to 1968. The above studies showed that the average protein content of the Western Canadian wheat crop varied from a low of 12.4% to a high of 15.2%; in most years the average was in the 13 to 14% range. Within each crop it was demonstrated that the average protein content varied from one region to another by over 3.0 protein percentage units. Generally speaking, protein levels were highest in the South-central part of the wheat producing area, and tended to decrease towards the North, West and East. This geographic variability with respect to protein content and the logistics of the existing grain handling and transportation system can seriously affect the uniformity of export shipments.

The following brief outline illustrates the complexity of the grain handling and transportation structures within which protein segregation must be achieved. Large quantities of bulk grain are collected from some 190,000 producers into almost 5,000 country elevators located at approximately 1,800 railway stations. These country elevators, which are both company and co-operatively owned, have combined storage capacity of about 400 million bushels. The function of the country elevator is to receive grain from the producer, weigh, grade, and bin it under the provisions of the Canada Grain Act, ship it out in boxcars when its forward movement is requested by the C.W.B. It will be demonstrated later that the accessibility and protein content of country elevator stocks are of considerable significance in the co-ordination of grain movements.

The transportation of Western Canadian grain from country elevators to terminal elevators is inescapably tied to rail transportation for two reasons. First, the distance of 500 to 1,000 miles over which the grain must be moved is in the range where rail transportation has a competitive advantage over trucking, (10). Secondly, since grain transportation rates in Western Canada are controlled by the "Crows Nest Pass" agreement the rates are low and hence trucking cannot economically compete. The structure of transportation rates affects the direction of flow of the grain. This flow is further complicated by the fact that there are two railway companies involved each serving approximately 900 stations.

In recent years the "Block Shipping System" was established to facilitate the co-ordination of grain movements. Under this system the grain producing area of Western Canada is divided into 48 "Railway Shipping Blocks". Although these shipping blocks are divided amongst the two railways on an almost 50/50 basis, one railway serves a more Northerly area than the other. This geographic unbalance in the areas served by each railway combined with the fact that some terminals receive grain from only one railway causes quality control problems, particularly with respect to protein content which itself is geographically distributed. Hence, transportation logistics can significantly affect the quality and uniformity of the wheat marketed at the different export positions.

All Canadian grain exported must move through terminal elevators located at Thunder Bay, Pacific Coast ports of Vancouver, Victoria, and Prince Rupert, or via the Northern route through Churchill. The function of these terminal elevators is to receive grain in carlots, weigh, grade, clean, dry and store when necessary, and ship out when requested.

At Thunder Bay there are 22 elevators with a total capacity of 102 million bushels (11). The shipping season from this port is limited to about eight months because of ice. The bulk of the grain from Thunder Bay is moved forward by lake vessel to transfer elevators in Eastern Canada and from there to overseas markets. The remainder, apart from small quantities moved forward to Eastern elevators by rail, is loaded directly into ocean going vessels at the Head of the Lakes.

At the Pacific Coast there are 7 elevators with a combined storage capacity of 28 million bushels. This export route is free from ice all year round and consequently this is the major export route in winter. The volume of grain exported through the West Coast has increased substantially in recent years. This has accentuated the quality control problems on export shipments for two reasons. Firstly, some terminal elevators, because of their country elevator affiliations and their rail supply areas, receive grain which differs in average quality from that received by other elevators. This is particularly true with respect to protein content. Secondly, West Coast elevators have a high handling to capacity ratio and this results in the wheat going almost directly from the railroad cars, through the terminals, into ocean going vessels. Therefore, the grain receives very little "blending" which contrasts sharply with export shipments via the Eastern route.

At Churchill there is only one terminal elevator with a storage capacity of 5 million bushels. Since this port is free of ice for only 8 to 10 weeks a year the volume of grain exported via Churchill is rather small. The transportation rate structure for the one railway which serves the Churchill elevator dictates that the grain exported via this route originates in the Northern portion of the wheat producing areas of Saskatchewan and Manitoba.

Besides the above terminals there are five public interior terminal elevators situated on the prairies at Moose Jaw, Saskatoon, Calgary, Edmonton and Lethbridge. These elevators provide facilities where grain can be cleaned, graded, and stored to serve as a reserve to meet unexpected surges in demand.

The C.W.B. is a semi-Governmental trading organization. The present Board was established under the Canadian Wheat Board Act to effect orderly marketing of Western Canadian grain entering interprovincial and export markets on behalf of Western producers. Currently, the C.W.B. is the sole purchasing agency for wheat, barley, and oats; it also exercises control over the movement of other grains. Since the C.W.B. has no grain handling facilities of its own it negotiates an annual agreement with the owners of country, terminal and port facilities which enables it to use existing facilities.

The C.W.B., within limits, controls the movement of grain from producer to export position with the dual objective of meeting market commitments with respect to time, location and grade and also of equalizing, as far as possible, the delivery opportunities for producers. Through the use of "permit books" and a "delivery quota" system the C.W.B. selectively controls the volume, type and grade of grain that a producer may deliver to country elevators. Within the framework of the "Block Shipping System" the C.W.B. controls the forward movement of the grain from country elevator to the terminal elevators. On the basis of sales commitments and stocks in transit and in store at various positions the C.W.B. establishes a weekly shipping programme for each grade and type of grain. These shipping orders are allocated among the shipping blocks, and between the grain companies within each block on the basis of the companies volume of business within the block. Within each block the grain companies assign the orders to the stations of their choice and notify the C.W.B. accordingly. The C.W.B. then transmits the shipping instructions to the railway companies who in turn relay them, and the necessary boxcars, to the country elevators.

While protein grading must operate within the above handling and transportation structure it is clear that the system allows the C.W.B. only limited control over grain movements. The C.W.B.'s ability to effectively market wheat by protein content is further confounded by the following factors. First, the protein content of wheat entering a country elevator can vary by about three protein percentage units. Secondly, the current lack of a quick, accurate and reliable method of determining protein content complicates the task of classifying wheat by protein content as it enters the country elevator. Thirdly, most of the existing country elevators lack adequate storage facilities to separately "bin" wheat of different protein levels. Therefore, since country elevator stocks cannot be accurately identified and classified with respect to protein content the task of controlling the forward movement of grain to meet well defined sales commitments is a complex operation.

The C.G.C., was set up by, and is responsible for the administration of, the Canada Grain Act. This Government body regulates and supervises all aspects of weighing, grading, and handling of grain from the producer to the consumer. The C.G.C. is responsible for the interpretation and maintenance of the quality and homogeneity of all grain exported from Canada. Theoretically, the C.W.B. can market and move any grain it considers desirable provided that its quality and uniformity conforms to the standards set and maintained by the C.G.C. In practice, there is much cooperation and transfer of information between the C.G.C. and the C.W.B. Protein grading has served to intensify this level of cooperation between these two bodies. To effectively operate protein segregation the C.G.C. requires detailed data on the protein content of wheat. To this end the C.G.C.'s protein testing facilities have been expanded considerably and also extensive protein data acquisition procedures have been developed in conjuction with country and terminal elevator operators. While such data is a prerequisite to C.G.C.'s effective operation of protein segregation, it is also of considerable value to the C.W.B. in co-ordinating grain movements. In fact, the interlocking responsibilities of the C.W.B. and the C.G.C. will become more and more obvious as the system is discussed in detail throughout the thesis.

II. LITERATURE REVIEW

A. Wheat Quality Criteria

Quality of a product may be thought of as those properties observed when that product is subjected to a specific test. Quality evaluations are usually in relation to the end use of the product. Wheat quality has many meanings, since there is virtually no limit to the number and variety of conditions and treatments to which wheat is subjected during processing. Different types of wheat are needed for various end-uses. The value of a particular lot of wheat for each of these end-uses is controlled by its genetic composition and the environmental conditions under which it is grown.

Traditionally, Canadian Red Spring wheat has been used for the production of bakery bread. Importers use Canadian wheat to serve two main purposes: first, to provide enough wheat to fill their domestic food and feed requirements and, second, to provide stronger wheat to permit the manufacture of the types of flours desired by bakeries. Bakery practices and flour quality demands vary over time, and from one country to another, and even from one region to another within the same country (12). Thus, wheat quality requirements vary from time to time and from country to country.

Even within a particular class of wheat, quality depends on numerous kernel, flour and dough properties, and several milling and baking characteristics each important in the production of bread. Finney and

Yamazaki (13) conclude that hard wheats of good milling quality should have normal sifting properties and also give a normal yield of flour of good colour and low ash content. A flour of good quality for breadmaking should have a high water absorption, a medium to long mixing requirement, a small to medium oxidation requirement, satisfactory mixing tolerance and dough handling properties, good loaf volume potentials, and yield a loaf of good internal crumb, grain, and colour.

Shellenberger et al. (14) note "there are many differences of opinion regarding the measurement of flour quality. Some consider baking results, particularly loaf volume, the major criterion of quality, with absorption values also highly important. ... Others contend that the ultimate in quality is a soft pliable dough that can be moulded easily and that gives a satisfactory loaf volume. Often, satisfactory physical dough properties are given paramount consideration, regardless of other factors."

B. Protein Content and Wheat Quality

The importance of protein content as an index of baking strength of bread wheats, particularly within one class of wheat, has been established by numerous researchers and is now widely recognized. The most commonly used method of determining protein content of wheat is to determine its nitrogen content by the standard Kjeldahl procedure. The nitrogen value obtained from this test is expressed as protein content by using a conversion factor. The conversion factors commonly used are 5.7

or 6.25. The 6.25 factor is used mainly for feed materials; the custom apparently originated from early research on proteins of animal origin which were found to contain about 16% nitrogen. For wheat and wheat flour the 5.7 conversion factor is commonly used. According to Tkachuk (15) the use of this factor is apparently derived from work done by Osborne in 1907 (16) on the nitrogen content of gliadin and glutenin in wheat. Recent work, using quantitative amino acid analysis data to calculate the nitrogen to protein ratio for wheat gave results close to the generally accepted value of 5.7 (15, 17, 18, 19). Tkachuk (18) reported a value of 5.61 while Eward (19) obtained a value of 5.68. Clearly, the conversion factor of 6.25, commonly used in estimating the protein content of animal feedstuffs, is erroneous for wheat and wheat products.

In Canada, a nitrogen to protein ratio of 5.7 and a moisture content of 13.5 is used when reporting the protein content of wheat. By contrast, in the United States, protein is usually reported on an "as is" moisture basis.

The Kjeldahl method of determining the protein content of wheat is quite accurate and subject to very good reproducibility when careful attention is paid to all the details of the procedure (20-26). Over time several simpler and more rapid methods of determining protein content have been developed. For wheat and similar products the more applicable of these methods include; Udy dye binding method (27, 28, 29), biuret method (30, 31); and more recently the light reflectance method, the

"Neotec Grain Quality Analyser" (32). All these methods are empirical and are calibrated against the Kjeldahl. Although many of them yield results that correlate very highly (.90 or greater) with those of the Kjeldahl they cannot be recommended as an alternative to the Kjeldahl under circumstances where a few tenths of a percent protein are significant.

Research has shown that the error associated with the Kjeldahl protein test is quite small; for ground wheat or flour the standard deviation varies from about .08% to .15% protein (20-26). However, Hildebrand and Koehn (33) conclude that, although the Kjeldahl test is quite precise, the determination of the protein content of bulk wheat is influenced by numerous actual and potential sources of error. These workers found that for bulk wheat, the errors associated with sampling, cleaning and grinding were greater that the errors associated with the actual protein test. For the protein determination of bulk wheat a standard deviation of .307% was obtained. This is a sizable error which assumes considerable significance in the segregation of wheat by protein content.

While accuracy and precision are extremely important in operations such as the segregation of wheat by protein content other factors must also be considered. An important aspect of any testing procedure, under practical grading conditions, is the rapidity with which the test can be performed because testing cannot interrupt the flow of grain.

For the production of yeast leavened bread, flour with a protein content of at least 11% is usually preferred. To produce such a flour the wheat must have a protein content of at least 12% (34). Flour protein content is an extremely important flour property because most other properties are in one way or another a function of protein quality (13). Pomeranz (35) notes "short of the baking test itself, determination of protein content of wheat or flour is considered one of the best single tests of breadmaking potentialities."

Larmour (36) in 1931 obtained a correlation of .9 between loaf volume and protein content of Canadian Red Spring wheat grown in one season. Using composite samples representing the normal protein range, he concluded that the regression of loaf volume on protein content was linear within the range of 7% to 15.9% protein. Aitken and Geddes (37) in 1934 using Canadian flour, rather than wheat, found the relation between loaf volume and protein content was approximately linear over the range of 11.4% to 15.7% protein. McCalla (38) also investigated the relationship between loaf volume and protein content. His data were obtained over four years, 1935 to 1938, from: field sample surveys; fertilizer experiments; and replicated yield trials throughout Alberta. McCalla reported that loaf volume was highly correlated ($r = .9$) with wheat protein content, but the increase in loaf volume per unit increase in protein content varied significantly from variety to variety. Finney in 1943 (39) developed a fractionation and re-constituting technique whereby factors of soil and climate were eliminated. He studied the relationship between loaf volume and protein content over the range of 0 to 20% protein, using varieties of wheat which differed in protein quality. This work showed that the relationship between loaf volume and protein content was linear between the limits of 7% and 20% protein. Below 7% the relation was curvi-linear, all curves meeting at 0% protein and 275 cc. loaf volume. This work also demonstrated that the slope of the regression line was a varietal characteristic. Finney and Barmore, in 1948 (40) suggested that regression analysis could be used for correcting the loaf volume of a given sample to a constant protein basis. Thus, making the comparison of the loaf volume potential of different varieties simpler. More recent studies by Bushuk _et al._ (41) showed that the relationship between protein content and loaf volume was essentially linear for two varieties grown in a crop nursery in 1967. Baker _et al._ (42) investigated the relationship among quality traits in wheat using over 20 cultivars grown at 15 locations in Western Canada over the five years 1965 to 1969. These workers concluded that protein content was an important parameter in predicting loaf volume.

Since bread is normally sold on a weight basis, water absorption is of considerable importance in determining bread yield. Finney (43) defines commercial baking absorption as the maximum amount of water that can be added to flour and yet yield a dough of a consistency that can be conveniently and efficiently handled by bakery equipment. It has long been established that baking absorption of flour depends to a large extent on its protein content. Finney (43) using flour from 10 pure varieties of hard red winter wheat, grown in widely different environments over the five years 1938 to 1942, found absorption to be essentially a linear function of protein content within a variety. However, other factors such as starch damage and soundness also influence water absorption (44, 45).

In most modern cereal chemistry laboratories the wheat quality is evaluated largely by subjecting wheat flour to several physical testing devices which measure various rheological properties of dough. The significance of rheological properties of dough at each particular step in the breadmaking process has been described in detail by Hlynka (46). Instruments developed to study the rheological properties of dough also provide information on such properties as water absorption, optimum mixing time, and mixing tolerance. These instruments have become almost a necessity for the efficient operation of a modern mechanized bakery.

In many countries dough testing equipment such as the farinograph, alveograph and extensimeter are used extensively to test Canadian wheat imported for blending with domestic supplies. Aitken et al. (47) in 1944 studied the effect of protein content of Western Canadian wheat on farinograms, extensograms, and alveograms and found that all curve dimensions were directly correlated with flour protein content, except alveogram height with which there was an inverse correlation. More recent studies (41, 42) also showed that most of the parameters measured by dough testing equipment are significantly correlated with protein content.

Many countries import large quantities of wheat to fulfill both quantity and quality demands. Traditionally, Canadian red spring wheat has been imported by many countries for blending with low quality domestic supplies. Aitken et al. (48) in 1946 studied the suitability of Canadian wheat for blending with European and other soft wheats. This research showed that Canadian wheat of highest protein content was most effective in increasing the loaf volume of the blend, and that a straight line relationship exists between loaf volume and the percentage of Canadian wheat in the blend. It was also demonstrated that there was a steady increase in water absorption, and an improvement in crumb colour, with increasing additions of Canadian wheat, and the higher the wheat protein content, the better the crumb score. Crumb texture and the handling properties of the dough were greatly improved in blends containing Canadian wheat of over 12% protein content. Shellenberger et al. (14) in 1969 investigated the value of North American wheats for blending with a number of European wheats. This study reported that North American wheats improved the performance of almost all soft wheat flours. However, with hard-wheat European flour, a protein content of at least 12% in the supplementing wheat was required for systematic improvement. In general, an increase in loaf volume and other improvements were correlated with the protein content of the blend.

C. Protein Variation in Canadian Wheat

It has long been recognized that the protein content of wheat varies considerably and depends mainly on the climatic and soil conditions under which it is produced. The first recorded reference of the variability in the protein content of Canadian wheat appears to be that of Alcock in 1925 (7). Alcock, over the 5 years 1920 to 1924, obtained data on the protein content of just over 1,000 carlots of wheat which originated at various points in the provinces of Manitoba and Saskatchewan. This data clearly demonstrated that in almost any crop samples may be found which contain anywhere from 9% to 17% protein. Alcock observed that the highest protein wheat was grown in the central and southern portions of Western Saskatchewan and the adjoining areas of Alberta, while Manitoba wheat was quite low in protein content. He also demonstrated that the protein content of a district varied significantly from year to year; and noted that it was not uncommon to find carlots of wheat shipped in the same season from the same country elevator differing in protein content by as much as 4%.

These findings were expounded in a comprehensive study covering the 12 year period 1927 to 1938 by Anderson and Eva (8). This report contained maps, based on 3,000 to 10,000 samples, showing the distribution of protein content for the Western Canadian wheat for each of the 12 years studied. In these twelve years, the annual mean protein content varied from a low of 11.4 in 1927 to a high of 14.9 in 1936. This study emphasized the similarity between maps for protein content, soil and natural vegetation; thus the higher protein levels occurred in the south-central region on brown soils developed under true prairie, and protein levels decreased as one moved towards the periphery of the crop-growing area, through bush country to forested areas, through the black to the grey, and grey wooded soils.

A more recent report by Martens and Hlynka (9) in 1969 examined the protein content of Canadian wheat for the 42 year period of 1927 to 1968. This report shows that the average protein content of individual crops varied from a low of 11.4% in 1927 to a high of 15.1% in 1941. The long term average protein content for Western Canadian wheat including all years was 13.6%. This study also shows that despite the fairly wide variation in protein content, and the shifting of protein zones, from year to year the general protein distribution pattern observed in the earlier studies does exist.

Paul and Anderson (49) investigated the relationship between protein content and rainfall distribution. This study was limited to a relatively small area on the brown soils in South Western Saskatchewan for which climatic data for six stations were available for the years 1927 to 1940. For each of these weather stations there was an average of 19 protein samples available for each of the 14 years studied. This work showed that when the effects of years and stations were removed that 34% of the variability in protein content could be explained by the rainfall data. Above average rainfall during the growing season generally tended to reduce protein content, but this tendency was much more pronounced during April and early May and during the latter part of July.

A number of studies show that factors other than rainfall influence the protein content of wheat. Newton and Malloch (50) in 1930 showed that considerable variation existed in the protein content of wheat grown in a level and apparently uniform field of a few acres. These workers observed that the average spread between high and low protein plots within a variety was 3.2% protein; the spread varied from a low of 2.2% to a high of 4.9% protein. They also found that the average difference between the highest and lowest variety was 2.3% protein which was significantly lower than the variability from plot to plot within a variety. Levi and Anderson (51) in 1950 outlined four sources of variation in the protein content of wheat: 1) The variation that occurs among the protein contents of individual kernels within each plant. 2) The variation that occurs among the mean protein contents of closely adjacent plants of a single variety grown in essentially the same environment. 3) Variation that occurs in the mean protein contents of the same variety grown under widely different environmental conditions. 4) The variation that occurs among the mean protein contents of lots of different varieties grown under essentially identical conditions. These workers concluded that a range of at least 6% in protein content can be expected for individual kernels of a single head. This source of variation is obviously of major significance with respect to sampling bulk wheat. Within a single plant, the average protein content of individual heads had a range of 1.7% or greater. The protein content of one variety had a range of 2.7% units. McKercher (52) in 1964, reporting on a 6-year field study, showed that differences in protein content of wheat of over 7% can be found within any one field. This within field variation was attributed to changes in soil profile and associated microclimate. Briggs et al. (53) reported a range of protein from 10.3% to 16.5% for a single crop of a single variety grown in a wheat breeding nursery. While it is generally recognized that environment exerts a strong influence on the protein content of wheat, a recent report shows that a genetic source of high protein wheat is available (54).

The above studies clearly demonstrate that there is considerable variability in the protein content of wheat even within a small area. Variability of this magnitude obviously affect the efficiency with which bulk wheat may be sampled for protein testing purposes. The accuracy with which the protein content of a particular lot of wheat can be determined is of considerable significance in the selective control of wheat movement and in the protein segregation of carlots at terminal elevators.

Despite the wide variation in the protein content of wheat produced in Canada there has been no direct effort made to control it. Indirectly, some control is exercised through the wheat grading system which provides minimum levels for kernel vitreousness in the top grades.

Shollenberger and Kyle (55) studied the relationship between kernel texture and the protein content of 1,290 samples of hard red spring wheat crops from 1915 to 1923. These samples covered 29 varieties and were collected over 4 crop years in North Western United States and Canada. A correlation coefficient of .54 and a standard error of estimate of ± 1.7 was found. It was concluded that although the highest percentage of dark kernels tended to be distributed about a high mean protein content there was wide variation in the protein content of samples having a given percentage of dark kernels. Mengels and Sanderson (56) reported similar results on data collected in annual protein surveys made in North Dakota for the four years 1922-25. The correlations obtained in this study range from .07 to .66. It was concluded that the low correlation of .07 reported for the 1923 crop was due to the fact that many of the samples were weather damaged. Coleman et al. (57) studied the relationship between kernel texture and protein content for about 100 samples from both the 1923 and 1924 hard red spring wheat crops. The correlation between protein content and the percentage of hard vitreous kernels was .641 in 1923 and .398 in 1924. These workers concluded that the percentage of dark and hard kernels was associated with high protein content but it was not a reliable measure of the protein content of wheat. Moreover, the correlation between kernel texture and baking strength, as measured by loaf volume, was not significant. Newton and Malloch (50) in 1930 examined the relationship between the protein content of individual varieties and the percentage of vitreous kernels, and concluded that there was a lack of a clear-cut relationship between these two quality factors.

Aamodt and Torrie (58) in 1935 examined the relation between kernel texture and protein content within populations from certain crosses. A strong positive relation between vitreous kernel texture and high protein content was found for several series of crosses.

The correlation between the percentage of hard vitreous kernels and protein content may be relatively high for pure varieties grown at one location. However, it can be appreciated that when wheat of different varieties and from different fields is mixed in country elevators that the kernel vitreousness of a sample taken from a carlot of grain shipped from these elevators will be a relatively poor index of its protein content. Therefore, the grade specification requiring a minimum percentage of vitreous kernels in the top grades of Canadian wheat is probably only effective in keeping very low protein samples out of these grades. Moreover, Anderson and Eva (59) have suggested that the relative importance of vitreousness and other grading factors vary from region to region of the producing area.

D. Protein Quality and Wheat Quality

It is generally recognized, that wheat flours that contain the same amount of protein may perform differently in baking. This difference in baking performance is usually attributed to protein quality. Wheat protein quality is involved with the physical rather than the nutritional characteristics of the end product produced from it. These protein quality criteria are related primarily to the gluten portion of the flour protein (60).

McCalla (38) in 1940 found that the regression of loaf volume on protein content varied enormously from one variety to another. He attributed this difference to the protein quality of the variety which was an inherited varietal characteristic. Finney and Barmore (40) suggested a method of comparing the relative protein quality of different varieties of wheat by adjusting the loaf volumes to a constant protein level by means of regression lines. These workers found that loaf volume level for different varieties at 13.5% protein varied from 823 cc. to 1015 cc. This represents a difference several times that required for statistical significance. Fifield et al. (61) examined a large number of samples of 10 varieties of wheat grown in four crop years under a wide range of climate and soil. They concluded that the relationship between loaf volume and protein content for each variety was linear and that the regression lines were essentially the same for the four years. However, the level of the regression lines differed significantly indicating differences between varieties in protein quality.

Historically, many attempts have been made to determine the fundamental nature of quality in wheat proteins. In 1907 Osborne (16) fractionated and classified the proteins of wheat on the basis of their solubility. He classified the proteins into four major groups: 1) water soluble proteins or albumins; 2) salt soluble proteins or globulins; 3) alcohol soluble proteins or gliadins; 4) proteins soluble in dilute acid or base, the glutenins. Osborne reported the two main groups, gliadins and glutenins, were present in about equal amounts and together constituted about 80% of the total protein of wheat flour.

Since 1907 numerous researchers have attempted to establish a relationship between individual components of wheat protein and breadmaking potential. Today it is generally recognized that breadmaking quality is related primarily to the water-insoluble proteins of flour which are collectively known as gluten (60).

In recent years many attempts have been made to correlate baking quality with individual components separated by chromatography and electrophoresis. Although marked differences in patterns have been observed by these techniques no direct relationship between particular protein bands and breadmaking quality have been established (60, 62, 63, 64).

Although there is a considerable difference in the protein quality of different varieties of wheat, wheat is seldom marketed on the basis of an individual variety. It is common practice to use class or grade specifications which accept a group of varieties of similar quality characteristics. This means that until a simple, instant, and accurate quality test is developed, desirable varieties must have readily distinguishable kernel characteristics to enable the grain inspector to make the proper classification. In the Canadian wheat grading system protein quality of the top grades is controlled by the varietal specification of "Marquis or any variety equal to Marquis." Furthermore, new wheat varieties are subjected to a rigorous testing programme, to ensure the breadmaking quality and kernel characteristics are of a desirable type, before they are licensed for sale as seed.

Differences in the protein quality of wheats that trade in volume on world markets appear to have decreased. This can probably be explained by the increasing efforts being made by most countries to replace inferior varieties with better quality ones and more rigid testing of new varieties before they are released. Finney and Bramore (40) concluded that the better hard red winter varieties are equal to hard red spring. These workers attributed observed differences in the flours from these classes to the normally higher protein contents of hard red spring wheat.

A recent study investigated the relative value of U.S. hard red spring and hard red winter wheats and Canadian red spring wheats as supplements for Western European wheats using four different baking procedures. It was concluded that hard red winter wheats and hard red spring wheats were equally effective on a per unit protein basis (14).

E. Weight Per Unit Volume and Wheat Quality

Any attempt to segregate wheat on a protein basis must take into consideration the possible effect of this segregation on weight per unit volume, which is one of the most widely used and simplest criteria of wheat quality. In Canada, the weight per unit volume determination is made with an imperial pint and a Cox funnel to give uniform packing. The grain in the measure is leveled with a round striker. The weight of the grain is multiplied by 64 and the results are reported in pounds per Imperial bushel (65). In the United States test weight per bushel is expressed in terms of the Winchester bushel which is only .969 of the Imperial bushel. In countries using the metric system the weight per unit volume is in terms of kilograms per hectoliter, which is 1.247

times the value of the weight per imperial bushel (34).

Weight per bushel is important chiefly because it has long been regarded as a general index of the flour yielding capacity of wheat. Very low test weights generally indicate shrivelled kernels which result from adverse conditions during kernel maturation. Shrivelled kernels produce less flour when milled, because the ratio of endosperm to bran is lower. The Canadian wheat grading system specifies a minimum bushel weight for each grade.

Mengels and Saunderson (56) found a correlation coefficient of $\mp$ 0.762 between test weight of wheat and flour yield. Similar values have been reported by other workers using laboratory mills (66, 67). Shuey (68) in 1960 found a significant correlation between test weight and flour yield using several commercial mills, but concluded that test weight was an inadequate measure of flour yield.

Finney and Yamazaki (13) maintain "... neither flour ash nor flour yield can be properly assessed or evaluated without a knowledge of kernel plumpness, usually indicated by weight per bushel." However, Zeleny (34) concludes "There seems to be considerable evidence that above 57 pounds per bushel test weight has relatively little influence on flour milling yield. At lower weights milling yield usually falls off rather rapidly with decreasing test weight."

Swanson (69) in 1938 observed that plumpness and shape of kernels were the principal factors influencing test weight. This author concluded that any factor which influences the flow of wheat into the test kettle would affect the packing density and hence test weight. Swanson and Pence (70) found that the amount of moisture in the grain influences test weight. A progressive decrease in test weight was observed with each increase in moisture content. It was concluded that part of the decrease in test weight was due to the lower specific-gravity of water compared with wheat and part was due to swelling after absorption. Furthermore, it was observed that after dry wheat was wetted and then re-dried it did not regain its original test weight. The apparent reason for this decrease in test weight is the inability of the kernel to contract after swelling and a decrease in kernel density through internal fissuring and roughening of the bran coat (71, 72).

Hlynka and Bushuk (73) concluded that the two main factors determining weight per bushel are packing density and the density of the grain itself. Packing density depends on kernel shape and uniformity of kernel size and shape. The condition of the kernel surface and the presence or absence of a brush and exposure to wetting and drying after maturation also influence packing density (69). Moving grain polishes the kernels and allows them to pack tighter in the test kettle and hence tends to increase bushel weight (68, 69). However, these changes do not alter flour yielding capacity. Anderson (74) reported that kernel density remained essentially constant for hard red spring wheat of constant moisture and ranging in bushel weight from 53-66 lbs. It was concluded that for such samples bushel weight is essentially a direct measure of packing efficiency but that kernel density becomes a significant factor in the bushel weight for different classes of wheat.

A number of investigators have studied the relationship between protein content of wheat and test weight per bushel. Davidson and Le Clerc (75), reporting on a 1917 nitrogen fertilizer field experiment, found no relationship between the protein content of wheat and test weight per bushel. Bailey and Hendel (76) collected over 300 samples of wheat from the red spring wheat area of the United States in each of the two years 1923 and 1924. A small negative correlation between protein content and test weight was found for the 1923 samples, and a small positive correlation was found for the 1924 data. However, when the data for the two years were combined a significant positive correlation of .51 was obtained. The significant correlation between these two parameters for the entire data was attributed to the effect of combining low protein low bushel weight data for one year with high protein high bushel weight data for the next year. Mengels and Saunderson (56, 77) reported both small negative and small positive correlations between protein content and bushel weight for samples from individual crops between 1916 and 1924. Shollenberger and Kyle (55) examined the relationship between test weight and protein content for 1,290 samples of hard red spring wheat collected from a large area of the United States between 1915 and 1923. For the entire data a correlation of -.215 was obtained between these two parameters. These workers concluded that the relationship between protein content and bushel weight was curvilinear. For wheats weighing more than 54 pounds the relationship was negative, and for those weighing less than 54 pounds the relationship was positive. These workers also noted that wheat below 54 pounds seldom occurs unless injured by rust which depresses both the protein content and bushel weight. Bushuk _et al_. (41) examined the relationship between protein content and other wheat quality parameters for one variety grown in an experimental field at the University of Manitoba for the two years 1966 and 1967. In 1966 a significant positive correlation of .27 was obtained between protein content and bushel weight, while in 1967 a non-significant correlation was found between these two quality parameters. Baker _et al_. (42) studied over 20 cultivars grown at about 15 locations in Western Canada over the five years 1965 to 1969 and found a non-significant relationship between protein content and bushel weight.

Published data on the relationship between the protein content and bushel weight of commercial Canadian wheat appears to be lacking. Data published in the Grain Research Laboratory annual reports (78) indicate that wheat from the low protein areas of Western Canada tend to have a higher than average bushel weight, while wheat from the higher protein areas tend to have a lower than average bushel weight. Shollenberger and Kyle (55) found that a negative relationship exists between protein content and bushel weight for wheat of over 54 pounds. If these findings are applicable under Canadian conditions, then it is realistic to expect that a negative relationship exists between these quality parameters for commercial Canadian wheat because all wheat entering the top grades must exceed 54 lbs. bushel weight. The effect of such a relationship will certainly have to be considered in the segregation of Canadian wheat by protein content.

F. Moisture Content and Wheat Quality

Moisture content is an important factor affecting the quality of wheat since the moisture itself has no commercial value. Moisture content is also of great significance in that it affects the keeping quality of wheat. Under practical storage conditions moisture content is usually the principal factor governing the keeping quality of wheat (79). It is difficult to set precise moisture limits for safe storage of wheat or to predict accurately how rapidly the quality will deteriorate at any given moisture level. However, near the critical moisture level of about 15%, small differences in moisture content make relatively large differences in keeping quality (34).

When grain contains excessive moisture its respiration rate increases. When respiration proceeds rapidly enough to produce heat faster than it can be dissipated, the temperature of the grain rises and heat damage may occur. It is now known that the heat produced in stored, damp grain is due both to the respiration of the grain itself and to the growth of fungi and insects (80). Furthermore, moulds and insects that develop under such conditions often produce odours, which if strong enough may be carried over into the flour (81).

Excessive moisture can be removed by artificial drying, but this must be carefully controlled as heat damage can easily occur. Excessive heat, resulting from either artificial drying or from spontaneous heating may injure the gluten quality of wheat (81, 82). Damage from excessive heat is usually recognized by discolouration of the kernels but this is not always so (82).

Wheat that is too dry also has some disadvantages. Very dry wheat tends to be brittle and to break easily in the handling operation. This is particularly true when wheat is artificially dried (34). Broken kernels are removed in cleaning operations and thereby result in an economic loss. Another disadvantage of very dry wheat is that it is difficult to temper it to the optimum moisture level required for milling (81).

The Canadian wheat grading system considers moisture content in establishing the grade of a particular lot of wheat. Within each grade there are three sub-grades for moisture content: straight, tough, and damp. Samples of 14.5 percent moisture, or less, are classified as a "straight grade." If the sample exceeds 14.5 but is not above 17.0% it is graded as it would have been otherwise except that the suffix "tough" is attached. If above 17% it must be described as "damp" (83). Damp grain is almost invariably dried before sale. Tough grain may be sold "as is". It may be blended with dry grain to reduce the average moisture content of the blend to a safe level for storage and shipment; or it may also be subjected to artificial drying. From a commercial viewpoint, grain must be dry enough to ship and store safely.

G. Soundness and Wheat Quality

Wheat may be damaged from many different causes occurring in the field before harvest, during harvest, or during subsequent processing and handling. Two types of damage often encountered in Canadian wheat are frost damage and immature kernels. The affect of frost damage is difficult to access because the attack may occur at various stages during growth, and to varying extents.

Newton and McCalla (84) studied the effect of frost on wheat at progressive stages of maturity and found that frost exposure reduced flour yield at all stages of maturity, the reduction in yield being roughly proportional to the immaturity of the sample and the severity of the exposure. Flour yield from mature frosted samples was slightly but definitely lower than from comparable unfrozen checks. The baking quality of unfrozen checks was relatively high, even when the wheat was cut while immature. Frost exposure reduced the quality of immature samples in proportion to the immaturity of the grain and the severity of the exposure, but had little effect on mature samples. Furthermore, flour from immature, frozen samples deteriorated in storage more rapidly than did flour from unfrozen checks. These workers concluded that, in grading frosted and immature wheat, the reduction in flour yield was proportional to the reduction in wheat grade, but the reduction in baking quality was, on average, less than anticipated from the grading results. Malloch _et al_. (85) in 1937 examined the quality and grading of frosted wheat. Samples from annual surveys of the 1950 to 1935 Western Canadian wheat crops were segregated into three main categories; immature, heavily frosted, and bran frosted. These researchers found that the greatest decrease in flour yield for a unit increase in damage was obtained with immature kernels, followed by heavily frosted, while the effect of bran frost was negligible. They concluded that for bulk lots, grade is a fairly good index of milling quality but a relatively poor index of baking quality. However, 60 to 98% of the variance in loaf volume could be predicted from a knowledge of the protein content and the percentage of bran frosted, heavily frosted, and immature kernels in the sample.

The milling of frosted wheat presents many difficulties. The bran is brittle and powders up on the break rolls causing the flour to become dark and specky. The middlings possess a fibrous texture and do not reduce easily; ash content of the flour tends to increase and yield decrease (7, 86).

Anderson (86) in 1950 concluded that frost damage and immaturity lower the quality of the protein of wheat entering the lower grades of Canadian wheat, and consequently decreased the relationship between loaf volume and protein content. Furthermore, frosted wheat showed higher water absorption than normal but this water was lost during fermentation resulting in a slack dough that was difficult to handle. There is some evidence that severe frost exposure while the grain is immature damages the protein of wheat by interrupting the synthesis of the protein (34). This may explain, in part, the decrease in the correlation between loaf volume and Kjeldahl protein content with decreasing grade.

Irvine (87) in 1964 examined the effect of dark immature kernels on milling and baking quality and found that heavily frosted, immature wheat markedly degraded flour colour, and crumb colour in the bread.

Another type of damage occasionally encountered in Canadian wheat is sprouting. Wet weather at maturity may lead to sprouting, which reduces flour yield and results in a flour of high alpha-amylase activity. A small amount of alpha-amylase activity may be desirable but excessive activity severely damages breadmaking quality (34). When the activity of this enzyme is too high, more starch is broken down into dextrins and sugars during the proving of the dough than is necessary for fermentation; this reduces the effective water absorption and results in a loaf of poor texture (45, 81). Sound flour does contain some alpha-amylase activity but this is much less than that observed in unsound flour or flour made from partly sprouted wheat (45, 80). Even if visible sprouting does not occur the alpha-amylase level may be considerably elevated as a result of wet harvest conditions. Thus the activity of this enzyme cannot be readily estimated by determining the percentage of sprouted kernels (34). Excessive alpha-amylase activity is a quality complaint greatly feared by millers in Europe, especially Britain (12).

On occasion Canadian wheat contains large or small amounts of shrivelled kernels. The principal factors invariably involved in this type of damage are drought and rust. Kent-Jones considers (81) drought wheat to be essentially sound but of low bushel weight with high protein content and baking strength. Low flour yield and yellowness of the flour and crumb are the only undesirable features of this kind of wheat. Greaney et al. (88) investigated the effects of stem rust on the milling and baking properties of Marquis wheat. This investigation showed that stem rust had its greatest effect in reducing the plumpness of the kernel, which in turn decreased the milling value of the wheat. The lowered milling value was reflected in reductions in flour yield and flour colour grade. Baking strength as judged by loaf volume and crumb texture was not seriously affected by rust.

Damage that can be recognized by inspection and simple physical tests is considered in assessing the quality of the wheat during grading. In most instances the estimation of the effects of damage is entirely subjective. In the Canadian wheat grading system the type, or types, and the extent of damage influence the grade (83). Anderson (89) has appropriately called this balancing of deficiencies in one factor against superiority in others in determining grade as the "Compromise" method of grading. He concludes that this method can be operated only by skilled grain inspectors aided by carefully prepared standard samples.

H. Impurities

The quality and character of impurities are of considerable importance in wheat quality evaluation. Since impurities must be removed before milling they cause an economic loss on two accounts. Firstly, there is the cost of separating them from the wheat, and this depends on the types and amounts present. Secondly, impurities are of considerably less value than wheat on a weight basis. In the Canadian grading system impurities which can be readily removed from wheat by prescribed mechanical means are classified as 'dockage'. It is established practice to determine dockage before grading and to deduct the weight of the dockage from the total weight of the product (83). Impurities which cannot be removed by standard dockage testing equipment is classified as "Foreign material other than dockage". Also, a particular lot of wheat may contain undesirable types or varieties of wheat. The Canadian grading system classifies this material as "wheat of other classes". Each grade has a maximum tolerance for the amount of foreign material other than dockage and for wheat of other classes.

I. Ultimate Criteria

It is evident from the above discussion that there are many factors which influence wheat quality. The market place provides the ultimate means of interpreting quality. The interpretation, however, rests on a value-in-use basis combined with the relative availability of wheat for a given use.

On world markets, top grades of Canadian wheat have consistently commanded higher prices than the best wheats of other countries, except when the protein levels have been extremely low. The principal reasons have been the high standards established for Canadian grades, and the expertise of Canadian grain inspectors. Control of the varieties eligible for top grades, and hence of protein quality and general baking behaviour, has been outstanding. There has also been excellent control of bushel weight, soundness, and moisture content, and of admixtures of other types of wheat or grains, and of weed seeds and other extraneous matter. In all these respects, cargoes of any given grade, and especially of the top three grades, have been uniform in quality and guaranteed to meet established standards exemplified each year by widely distributed "Export Standard Samples." Canadian wheat has been the only wheat that trades on "Certificate Final", that is, on the sellers guarantee of the properties listed above and covered by grade specifications and standard samples.

Protein content, as distinguished from protein quality, has been the only primary factor affecting the quality of the wheat that has not been covered by the grading system. It has varied widely in a given grade, not only from year to year and from coast to coast, but often to a significant extent among stowages in the same ship. Accordingly, it is not surprising that means of controlling protein content within the grading system are now being developed for Canadian wheat.

III. PRELIMINARY STUDIES

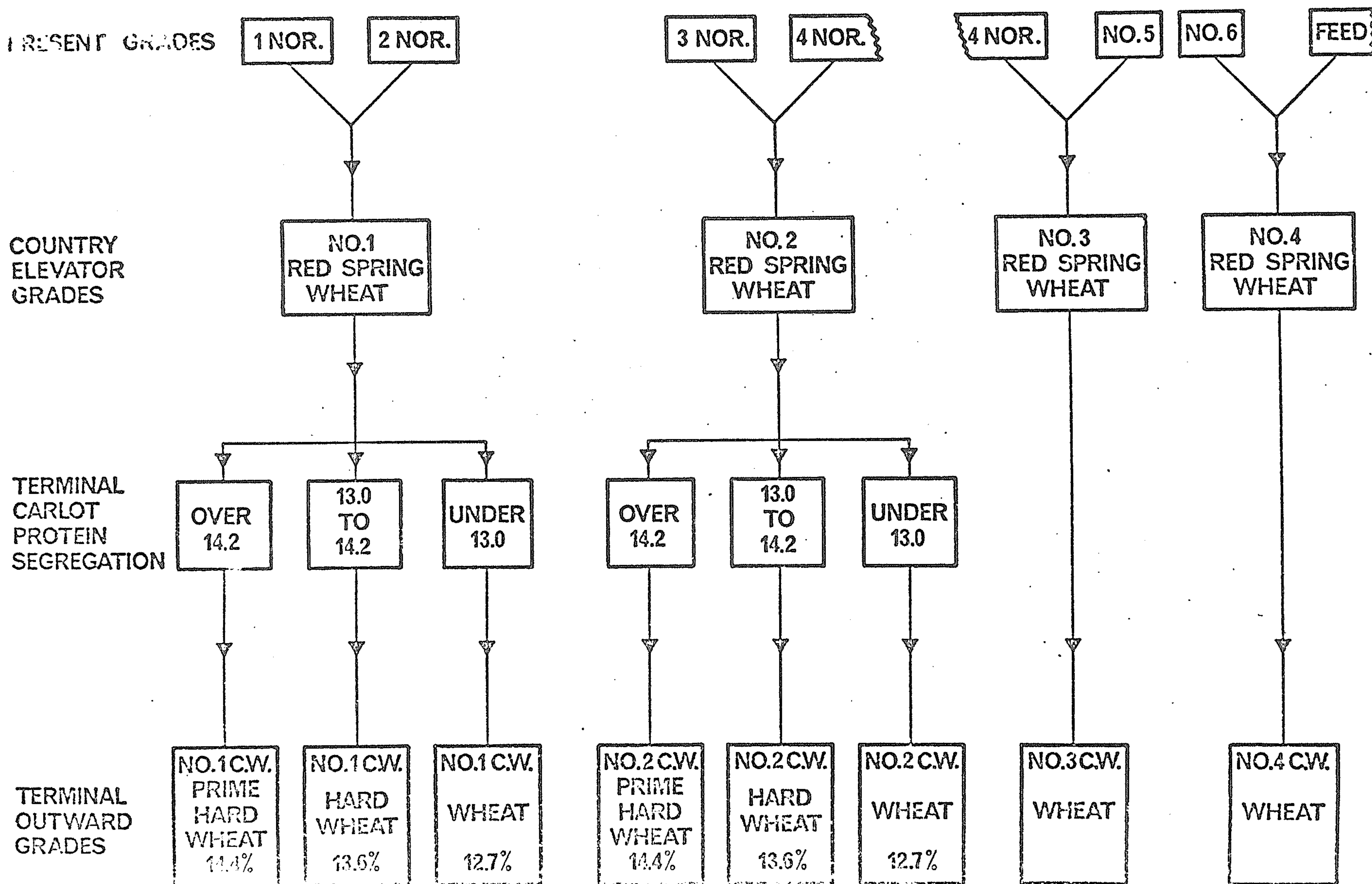
A. Introduction

In 1969 the Canadian Grain Commission made a proposal for introducing protein as a grading factor. The diagram illustrating this proposal is shown in Figure 1. The seven existing grades are consolidated into four new grades at the country level, and the first two are segregated by protein content at the time that the carlots are binned at terminal elevators. The proposed segregation levels are: over 14.2%; 13.0 to 14.2%; and under 13.0%. It was expected that, in most years, about 60% of the top grade wheat would enter the middle sub-grade which would have an average protein level of about 13.6%, corresponding to the long term average for Canadian wheat. In most years there would also be available smaller amounts of sub-grades of both higher and lower protein level.

Preliminary studies reported in this section were designed to determine the amounts and average protein levels of the wheat entering each sub-grade. It was obvious that both parameters would vary with variations in the average protein level that occur from year to year, and that data for a number of years would therefore have to be examined to provide a reasonable assessment of the proposal. The intention was to examine, in addition, various modifications of the C.G.C. proposal, and to include studies of bushel weight and moisture content.

The technique involved imposing the selected grading system, in retrospect, on data for past years. As a first step it was therefore

Fig. 1. Canadian Grain Commission's Proposal for Regrouping of Existing grades, and protein segregation.



necessary to assess the variability in annual protein levels shown by previous studies, and to select suitable years and data for the present investigation.

A great deal is known about the variations that occur in the protein content of Canadian wheat from year to year, from district to district, from grade to grade and, in export wheat, from coast to coast and from cargo to cargo. This information has been collected for many years by the Grain Research Laboratory of the C.G.C. in three systematic annual surveys.

The first of these involved surveys of the protein levels in each crop as it was harvested. These were started in 1927 and results were published each year in Bulletins (90); moreover, as noted earlier, comprehensive reports dealing with the first 12 years, and with the 42 years up to 1968, were published by Anderson and Eva (8) and by Martens and Hlynka (9). For purposes of the present research, these data were useful primarily for establishing the inter-annual variations in protein content.

The cargo surveys may be considered next. These provided data on grade, protein content, and other quality parameters of every cargo exported from Canadian ports since 1955-56 crop year. These data were summarized and published each quarter in a second series of bulletins (91). These data clearly showed that it would be necessary to make separate studies of protein segregation for each coast and probably for each individual elevator at each port. They also served to emphasize the need for improved control of protein content in export shipments.

The last survey, and the one without which the present study could hardly have been undertaken, involves carlots of wheat unloaded in the Western Division. Annual surveys were made of a systematic 5% sampling of all carlots of wheat unloaded at all ports and at interior and mill elevators. These were started in the 1939-40 crop year. Summary tables were published each year in the Annual Reports of the Grain Research Laboratory (78). However these summaries dealt mainly with the origin of the samples by province and crop district rather than with their distribution at unload points. Moreover, these and all other summaries published by the Laboratory gave frequency distributions only in 0.5% increments of protein content, and this was too coarse an analysis for studies of protein segregation.

It was therefore necessary to go back to the original data for the carlot surveys. Fortunately these were available on punch cards, and provided extremely detailed and comprehensive data. The only additional data that would have been useful in the research would have been the loading dates for individual carlots. Identification of shipping points by railway blocks and train runs was eventually required, but as these were introduced only in 1969 they could not have appeared in the original data. The information provided by the Carlot Surveys is described in more detail in a later section.

B. Selection of Data

Time series curves showing the mean protein content for both the crop and the carlot survey since their inception are presented in Figure 2. Only data for the milling grades of wheat, namely No. 1 to No. 4 Manitoba Northern are considered for both surveys. Figure 2 shows that the annual mean protein content for the crop survey exhibits greater year to year variation than the carlot survey and that the carlot survey mean tends to lag the crop survey mean by one, or more, years. The main factor responsible for the difference between these two surveys is the carry-over of stocks on farms and in country elevators from year to year. Carry-over stocks dampen the year to year fluctuations in the protein content of individual crops. In general, carlot levels do not reach as high as survey levels in high protein years such as 1941 and 1964, nor as low in low protein years such as in 1942, 1956, and 1966.

Table 1 shows a frequency distribution of the annual mean protein content for both the carlot and crop surveys. The significantly greater variability of the crop survey mean is readily apparent. However, despite the decrease in the protein variability from the crop to the carlot survey, the carlot survey mean varies from a low of 12.6 to a high of 14.4.

Variability of the above magnitude in the annual mean protein content of carlot shipments illustrates the difficulty of devising a protein grading system that will operate efficiently in all years.

The carlot survey data were obviously preferred for the current

Fig. 2. Annual Mean Protein Content for Both the Crop Survey and the Carlot Survey Since their Inception.

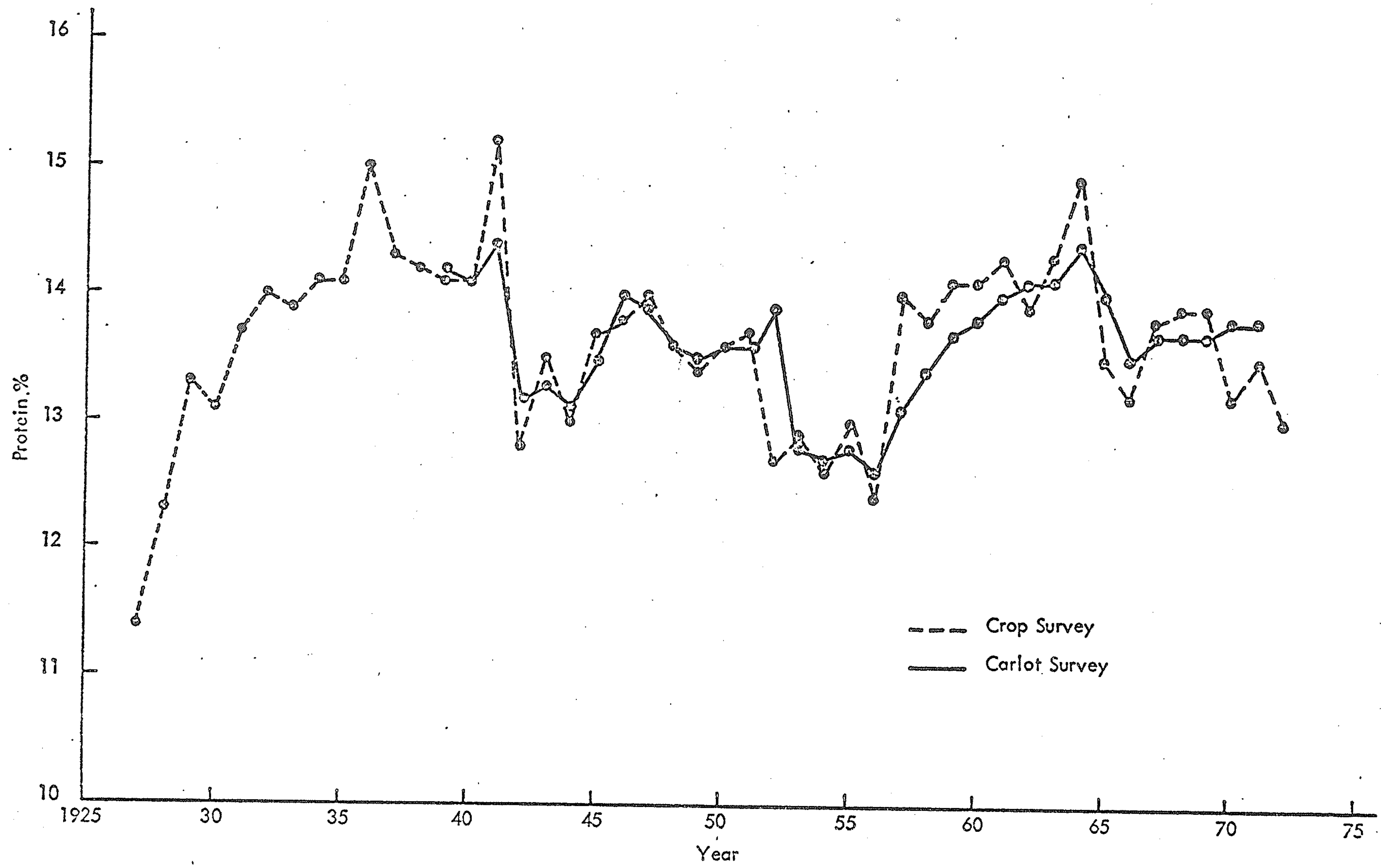


Table 1. Annual Protein Levels of Carlot Surveys and Crop Surveys of Grades 1 to 4 Northern.

Protein, %	Carlot Survey	Frequency	Crop Survey	Frequency
15.2			1941	1
15.1				
15.0			1936	1
14.9			1964	1
14.8				
14.7				
14.6				
14.5				
14.4	1941-42, 1964-65	2		
14.3			1937, 1961, 1963	3
14.2	1939-40	1		
14.1	1940-41, 1962-63, 1963-64	3	1934, 1935, 1938, 1939, 1940, 1959, 1960	7
14.0	1946-47, 1961-62	2	1932, 1947, 1957	3
13.9	1947-48, 1952-53, 1965-66	3	1933, 1962, 1968, 1969	4
13.8	1960-61, 1970-71, 1971-72	3	1946, 1958, 1967	3
13.7	1959-60, 1967-68, 1968-69, 1969-70	4	1931, 1945, 1951	3
13.6	1948-49, 1950-51, 1951-52	3	1948, 1950	2
13.5	1945-46, 1949-50, 1966-67	3	1943, 1965, 1971	3
13.4	1958-59	1	1949	1
13.3	1943-44	1	1939	1
13.2	1942-43	1	1966, 1970	2
13.1	1944-45, 1957-58	2	1930	1
13.0			1944, 1955, 1972	3
12.9			1953	1
12.8	1953-54, 1955-56	2	1942	1
12.7	1954-55	1	1952	1
12.6	1956-57	1	1954	1
12.5				
12.4			1956	1
.			1928	1
.				
.				
11.4			1927	1
		33		46
	Mean 13.61		Mean 13.63	

research. The data represent the wheat that actually moved to ports and other unload points, the sampling was more systematic and representative, and the available data were more complete. Nine of the available 31 years were selected, and these are underlined in Table 1. The last three year data, 1966-67, 1967-68, 1968-69, were most readily available, and were studied first both because they were the most recent, and because they represented years of average protein content. These data were used, sometimes as a single group for developing and experimenting with various computer programs. Two more years in the middle of the range, 1951-52 and 1958-59 were added later to obtain greater representation. The range of protein levels was then extended to include years of fairly high and low protein levels, 1963-64 and 1957-58, and two years representing the extremes 1964-65 and 1956-57.

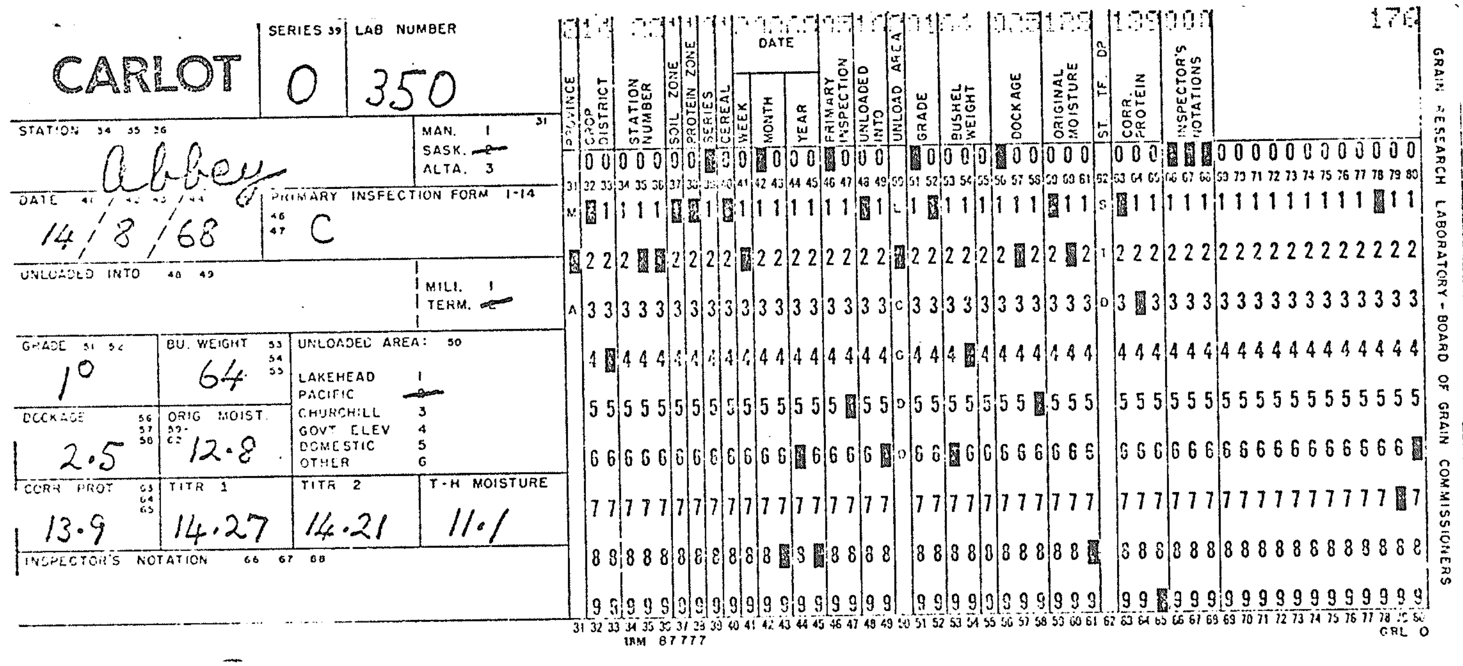
Twenty-four of the thirty-one years had protein levels in the range from 13.1 to 14.1%. It appeared that any standardized system of introducing protein as a grading factor, such as that proposed by the C.G.C., with its segregation levels set at 13.0 and 14.2%, would have to deal satisfactorily with years in that range. But modifications would also have to be devised to deal with levels appreciably above and below that range.

The data for the selected years were obtained from the Grain Research Laboratory (G.R.L.) of the C.G.C. The data represents a systematic stratified sampling to select five percent of the carlots for each year. Within each grade, on each working day, at each terminal elevator, carlots were counted, and each twentieth car was selected for sampling. Each selected carlot was represented by a specially designed punch card, a sample of which is shown in Figure 3. The entire data for the nine selected crop years totaled 94,894 cards. Each card shows data for quality, origin and unload destination. The quality data include: grade, protein content, bushel weight, moisture content, and dockage. Origin data include: station, crop district and province. Destination data include: unload area (i.e. Pacific Coast, Lakehead, Churchill, Interior government elevators, mill elevators) and elevator, week, month, and year in which the carlot was unloaded.

C. Treatment of the Data

The punch cards were obtained on loan from the G.R.L. and read *in toto* onto magnetic tape using the University IBM 360/65 computer. Since the card format had changed over time it was necessary to convert the data for the earlier years to the format currently in use. A special Fortran routine was prepared to achieve this. Another Fortran program was written to check the data for errors. Each card was checked column by column for invalid punches. The fields for bushel weight, protein content, moisture, dockage, week and month of unload, were verified by means of upper and lower bound values. The data on station, crop district, province of origin, unload area, unload elevator, and grade, all of which were coded, were similarly checked. Specific value checks were made on the fields for cereal (1), series (0), and year. The year-month combination required to give a specific crop year was also tested by

Fig. 3. Reproduction of Hollerith punch card used for the carlot survey in the Grain Research Laboratory.



means of an algorithm. Errors detected by the above methods were corrected by means of a specially written Fortran program and the data were then further checked to verify the corrections.

A number of Fortran programs were designed and written to summarize the data. Line printer tables from these programs, while classified as summary tables, still contain much detailed information. These tables later proved to be useful "Utility Tables" and are presented in a supplementary appendix. The data contained in these utility tables have been excerpted and condensed for presentation in the manuscript itself. The supplementary appendix will be referred to periodically in the text but its main function is to provide a permanent and detailed record which any investigator can examine for himself and apply to his particular need. The tables have been carefully documented and are reasonably self explanatory and are on file at the C.G.C.

The data for the nine selected crop years were initially summarized by existing grade, province, unload area, and terminal elevators within unload area. The objective of this investigation was to identify and quantify quality variations, particularly with respect to protein content, that arise under the existing grading system.

Sample copies of the summary tables produced on the computer are shown in Appendix A. Factors considered were the carlot distribution, protein content, and bushel weight. Table A-1 summarizes the data by existing grade and unload area. Table A-2 shows similar data by grade and province within unload area. Table A-3 shows monthly and quarterly data for a specific grade by elevator within unload area.

To facilitate the examination of a series of grading proposals computer tabulations showing the cumulative and reverse cumulative protein distributions were prepared. These summarized the data for the number of samples, the percentage distribution, mean protein content, and mean bushel weight. Sample copies of these tables are shown in Appendix A.

Tabulations of the type shown in Tables A-4 and A-5 proved extremely useful in examining alternate grading systems. Consider for example a three sub-grade system; data on grade distribution, protein content and bushel weight for the upper sub-grade can be read directly from the cumulative table; similar data for the lower sub-grade can also be obtained directly from the reverse cumulative table; data for the middle sub-grade can be secured from the difference of two products divided by the result of a subtraction.

An additional analysis involved a study of the effect on protein sub-grade of raising the minimum bushel weight of the new top grade from 58 lbs. to a level of 60 lbs.

In a small study of moisture content, data were examined for the three-year period 1966-67, 1967-68, and 1968-69. Moisture contents were recorded for 97.6% of the samples collected in the carlot surveys for these years. A separate computer analysis was therefore necessary.

D. A Descriptive Analysis of Quality Variations Under the Existing Wheat Grading System

To provide background information on quality variations under the existing wheat grading system the data for the selected years were first summarized by grade, province, unload area, and terminal within unload area.

1. Annual Distribution, Protein Content, and Bushel Weight by Existing Grade

Table 2 summarized the data for each of the nine selected years, on the amount of wheat entering each of the existing grades. Data for total carlots, actually a 5% sampling, are given in the last column and show wide differences between years. Hence, the annual variation in the grade distribution of the carlots can best be examined by comparing data. Percentage distribution of carlots among grades within years is shown in the remaining columns of Table 2. The grade headings are self-explanatory with the exception of "Others" which include the Garnet grades and a few samples for special grades. The third column, headed "1+2", was introduced since it was proposed to combine these two grades into a new top grade prior to protein segregation.

The data illustrate the relatively large variation in grade distribution that exists from year to year. Carlot movements in 1967-68 were of relatively high grade; 78% representing grades 1 and 2 Northern combined. This percentage dropped to an extremely low figure of 6% in 1951-52. For the other seven selected years the percentage is between these two extremes, usually in 40 to 50% range. The generally low grade distribution in 1951-52 was caused by the 1951 fall being the wettest on record, and large quantities of Western grain crops were not harvested until spring. Quality suffered severely as a result of weathering, sprouting, and other forms of damage associated with wet weather.

Table 2. Number of Carlots and Percent Distribution of Red Spring Wheat by Grade and Year for the Nine Selected Years.

	Grades									
Crop year	1	2	1+2	3	4	5	6	Feed	Others	All Grades
					Distribution %					Total Carlots
1964-65	2.9	40.5	43.4	31.4	14.5	9.3	1.3	.1	.1	10612
1963-64	5.1	53.7	58.9	28.3	7.8	3.9	.6	-	.5	14286
1968-69	13.6	34.8	48.4	18.4	21.0	10.0	1.7	.4	.1	8928
1967-68	30.4	47.2	77.6	17.0	4.2	.7	.2	-	.3	9137
1951-52	.4	5.7	6.1	37.1	29.1	17.5	8.5	1.2	.7	12082
1966-67	7.5	39.7	47.2	34.3	12.7	4.5	.9	.1	.2	14385
1958-59	2.1	34.9	36.9	32.6	21.1	8.5	.9	-	-	8283
1957-58	.4	23.8	24.3	36.3	23.5	12.1	3.8	.1	-	8329
1956-57	1.5	31.5	33.0	31.1	13.5	17.7	4.4	.2	.1	8852

The percentage of shipments in grade 3 Northern is more constant; varying from a low of 17% in 1967-68 to a high of 37% in 1951-52. In most of the other years the percentage in this grade is close to 30%. Grade 4 Northern usually encompasses 15-20% of the movements, with a somewhat smaller amount entering the lower grades.

The data for the crop years recorded in Table 2 are arranged in order of decreasing mean protein content. The percentage in the top grades tends to decrease as the mean protein content decreases indicating that factors which affect the grade distribution may also affect protein content. However, exceptions to the generalization can easily be observed.

The mean protein contents for each grade for the nine selected years are shown in Table 3. The data show the vagaries of this quality parameter under the present grading system. The annual mean for any grade can vary by almost two percentage units. Within years the mean protein contents of grades 1 and 2 Northern tend to be slightly higher than those of 3 and 4 Northern, but there are often exceptions. For example, the protein level of 1 Northern is below that of 3 Northern in four of nine crop years.

Table 4 shows that the distribution of individual carlots about the annual mean varies considerably as indicated by the variation in the overall standard deviations (all grades) from year to year. Moreover, there does not appear to be any association between the within year variability and the overall annual protein level. Within each crop year,

Table 3. Mean Protein Content (%), for Carlots of Red Spring Wheat by Grade and Year for Nine Selected Years.

Crop Year	Grade							
	1	2	1+2	3	4	5	6	All
1964-65	14.69	14.53	14.54	14.32	14.38	13.50	12.54	14.32
1963-64	14.52	14.24	14.26	13.93	14.05	13.40	12.95	14.10
1968-69	13.70	13.59	13.62	13.84	13.80	13.56	14.14	13.70
1967-68	13.79	13.70	13.73	13.56	13.31	13.05	12.60	13.67
1951-52	13.29	14.04	13.99	13.67	13.46	13.16	13.28	13.50
1966-67	13.38	13.64	13.60	13.42	13.20	13.00	12.37	13.44
1958-59	13.70	13.60	13.61	13.41	12.97	12.71	12.67	13.32
1957-58	12.85	13.01	13.01	13.24	13.02	12.65	12.55	13.03
1956-57	12.73	12.62	12.63	12.51	12.47	12.41	12.36	12.52

Table 4. Standard Deviation of Protein Content (%), for Carlots of Red Spring Wheat by Grade and Year for Nine Selected Years.

Crop Year	Grade							
	1	2	1+2	3	4	5	6	All
1964-65	.82	.91	.90	.94	.82	1.15	1.33	1.00
1963-64	.74	.77	.77	.88	.89	1.11	.96	.87
1968-69	.81	.85	.84	.96	1.18	1.35	.93	1.01
1967-68	.74	.82	.79	.89	.85	.97	.74	.83
1951-52	.89	1.13	1.13	1.07	1.14	1.13	.86	1.13
1966-67	.65	.78	.77	.87	.85	.93	.79	.85
1958-59	.76	.93	.92	.97	.92	.81	.82	.98
1957-58	.93	.78	.79	.98	.96	.80	.83	.93
1956-57	.67	.65	.65	.76	.77	.80	.77	.74

the standard deviation for each grade shows some tendency to increase with each decrease in grade. This indicates that, although the mean protein content of the top grades may be no higher than that of the lower grades, individual carlots in the upper grade deviate less from their mean than those of the lower grades. In other words, the distribution of the carlots about the mean is more peaked in the upper grades than in the lower grades.

Within a single grade the shape of the frequency distribution curve varies considerably from year to year as indicated by the magnitude of the standard deviations of a particular grade over a series of years. For example, the within-grade variation in the protein content of individual carlots of any grade in the 1951-52 crop year is 50 to 70 percent greater than that for the corresponding grade in the 1956-57 crop year. The within-grade variability in protein content in any one year is caused, in part, by the relative quantities of crops of different protein levels contributing to the movements in that grade in that year. The greater variability in the protein content of the lower grades can also be attributed to the fact that carlots of wheat entering these grades have been degraded for different reasons.

Data for the mean bushel weight for each grade for each of the nine selected years is shown in Table 5. The mean bushel weight drops consistently with grade in each year with the exception of 1963-64 when 3 Northern was lower than grades 4 and 5. A consistent decrease in the mean would be expected since bushel weight is a primary grading factor.

Table 5. Mean Bushel Weight (lb.) for Carlots of Red Spring Wheat by Grade and Year for Nine Selected Years.

Crop Year	Grade							
	1	2	1+2	3	4	5	6	All
1964-65	62.5	60.7	60.8	59.9	59.9	58.9	57.2	60.2
1963-64	62.4	60.8	60.9	59.8	60.9	60.4	59.9	60.6
1968-69	63.6	62.6	62.9	61.1	59.1	57.0	53.2	61.0
1967-68	63.6	62.5	62.9	62.0	61.2	59.8	58.5	62.7
1951-52	63.6	61.8	62.0	60.1	59.0	57.9	55.8	59.0
1966-67	63.7	61.8	62.1	60.6	59.4	58.5	56.5	61.0
1958-59	62.9	62.0	62.1	61.1	60.8	59.9	57.8	61.3
1957-58	64.1	62.7	62.7	61.1	60.8	60.1	57.8	61.2
1956-57	64.0	63.1	63.1	61.9	60.8	59.7	57.8	61.6

Because of a low inverse correlation between protein content and bushel weight, the mean bushel weight for all grades in the high protein years tends to be lower than the corresponding value in the low protein years. However, 1967-68 has a mean for all grades of 62.7 lbs. and 1951-52 has a mean of 59.0 for the same grades although the mean protein for these years differs by only .2 percentage units.

Table 6 shows that the distribution of individual carlots about the annual mean bushel weight varies considerably from year to year. The standard deviation for each grade shows a fairly consistent increase with each decrease in grade. Thus indicating the greater variability with respect to bushel weight of the lower grades of wheat. Lower bushel weight minima for the lower grades, and degrading of carlots from higher grades, for reasons other than bushel weight, account for this increase in variation.

Tables 4 and 6 show that the greatest within-grade variation with respect to both protein content and bushel weight occur in 1951-52 and 1968-69. It is of interest to note that 49% and 34% of these respective crop year movements were classified as tough or damp. Substantial degrading associated with wet harvest conditions doubtless explains the wide variability observed in these years.

2. Annual Distribution, Protein Content, and Bushel Weight by Province and Unload Area

Since protein grading will likely be introduced only for wheat grading 4 Northern or higher, further discussion will be restricted to these grades.

Table 6. Standard Deviations of Bushel Weight (lb.) for Carlots of Red Spring Wheat by Grade and Year for Nine Selected Years.

	Grade							
Crop Year	1	2	1+2	3	4	5	6	All
1964-65	1.20	1.42	1.48	1.60	1.48	1.69	2.25	1.72
1963-64	1.20	1.37	1.43	1.87	1.97	1.98	1.15	1.71
1968-69	1.16	1.52	1.49	1.63	1.81	2.18	2.38	3.0
1967-68	1.13	1.46	1.43	1.48	1.81	2.04	1.55	1.58
1951-52	.86	1.57	1.60	1.83	2.11	2.31	2.32	2.69
1966-67	1.02	1.57	1.65	1.78	1.94	1.87	1.73	2.13
1958-59	1.04	1.27	1.28	1.37	1.53	1.46	2.08	1.58
1957-58	.87	1.18	1.19	1.60	1.62	1.35	1.95	1.87
1956-57	.73	1.01	1.02	1.44	1.59	1.68	2.05	2.08

Although the volume of grain produced in each province varies considerably from year to year it is informative to examine the relative contribution of the individual provinces to the total grain movement in each of the nine selected years. The provincial distributions for carlots of grades 1 to 4 Northern combined, and grades 1 and 2 combined, are presented in Table 7. The mean protein contents and number of carlots, for grades 1 to 4 combined, for each year, are shown in columns 1 and 2 respectively. Percentage distribution for Manitoba, Saskatchewan and Alberta are shown in the next three columns. Over the nine years approximately 13% of the carlots of grades 1 to 4 Northern originated in Manitoba, 65% in Saskatchewan, and 23% in Alberta. The Manitoba figure varies from a low of 10% to a high of 16%; Saskatchewan varies from a low of 62% to a high of 72%; for Alberta the percentage varies from a low of 18% to a high of 24%. The years are arranged in order of decreasing annual protein mean. However, there does not appear to be any relationship between the overall annual mean and the provincial distribution of the carlots.

Similar data for grades 1 and 2 Northern combined are shown in the right hand section of Table 7. Only relatively minor differences exist between the annual protein means for the different grade combinations. However, the relative percentage distribution of the carlots among the provinces for the two grade combinations is most interesting. For each of the years studied Manitoba makes a significantly smaller contribution to the upper grades than it does to the lower grades. A similar situation

Table 7. Number of Samples and Percentage Distribution for Grades 1 to 4 Combined and Grades 1 to 2 Combined for each Province for the Nine Selected Years.

Crop Year	Grades 1 to 4 Combined					Grades 1 to 2 Combined				
	Protein Mean	No. of Carlots	Distribution %			Protein Mean	No. of Carlots	Distribution %		
			Man.	Sask.	Alta.			Man.	Sask.	Alta.
1964-65	14.44	9465	13.7	65.8	20.5	14.54	4602	4.6	76.3	19.2
1963-64	14.15	13567	9.8	72.5	17.7	14.26	8410	3.8	81.3	15.1
1968-69	13.71	7841	16.1	61.5	22.4	13.62	4317	12.0	62.9	25.1
1967-68	13.68	9026	11.3	62.6	26.1	13.73	7092	10.3	63.3	25.4
1951-52	13.61	8724	13.4	67.8	18.8	13.93	734	11.0	66.9	22.1
1966-67	13.48	13552	11.3	68.2	20.5	13.60	6787	5.6	79.4	15.0
1958-59	13.39	7506	14.2	61.6	24.2	13.61	3057	13.5	66.5	20.0
1957-58	13.11	7001	11.2	65.7	23.1	13.01	2021	2.0	77.4	20.6
1956-57	12.55	6867	12.3	65.2	22.5	12.63	2919	5.5	75.4	19.1

generally exists in Alberta while the reverse is true for Saskatchewan. The generally lower grade distribution of Manitoba and Alberta wheat, compared to Saskatchewan wheat, must result from provincial differences in environmental conditions during the growing and harvesting seasons.

Wheat from the three prairie provinces must be exported by two main routes, and one minor one. It either moves east via the Lakehead to the Atlantic Coast, or it moves west across the Rocky Mountains to the Pacific Coast. A relatively small amount, about 25 million bushels, is exported through Churchill on Hudsons Bay.

In the past, 70 to 80% of the wheat exports moved eastward but in recent years the percentage moving westward has increased considerably. For a number of reasons westward movements will probably increase even further. Western shipments consist almost entirely of carlots originating in Alberta and the Western portion of Saskatchewan. Similarly, Lakehead shipments originate in Manitoba and Eastern Saskatchewan. The transportation rate structure prohibits, except under exceptional circumstances, Manitoba wheat from moving westward and Alberta wheat from moving eastward.

The proportion of the total wheat shipments, grades 1 to 4 Northern combined, that moved east and west and the relative contribution of each of the provinces to each movement in each of the nine selected crop years is shown in Table 8. Columns 2 and 3 show that Pacific and Lakehead shipments combined account for approximately 80% of all unloads. The remaining 20% were unloaded at Churchill, interior terminals, and mill

Table 8. Number of Carlots, and Percentage Distribution for Grades 1 to 4 Combined for Each Unload Area and for Each Province Within Unload Area for Each of the Nine Selected Years.

	Unload Area			Pacific Unloads From			Lakehead Unloads From		
Crop Year	All Carlots	Pacific %	Lakehead %	Alta. %	Sask. %	W. Can. Carlots	W. Can. Carlots	Sask. %	Man. %
1964-65	9465	31.1	55.6	60.7	39.3	2939	5263	75.6	24.2
1963-64	13567	28.9	57.3	52.6	47.4	3926	7769	83.6	16.3
1968-69	7841	40.5	42.8	49.8	50.2	3179	3352	63.3	36.6
1967-68	9026	40.2	46.6	59.5	40.5	3631	4210	76.4	23.3
1951-52	8724	29.8	53.5	51.5	48.4	2598	4671	74.5	24.3
1966-67	13552	29.3	59.4	62.5	37.5	3966	8049	80.5	19.0
1958-59	7506	31.3	49.3	68.2	31.8	2352	3697	72.1	27.7
1957-58	7001	40.8	39.3	48.4	51.5	2858	2749	72.8	27.0
1956-57	6867	29.3	48.6	62.0	38.0	2007	3337	77.8	21.8

elevators. The percentage of total unloads that move to either the Pacific or Lakehead ports exhibits considerable year to year variation. The data probably reflect the relative demand and facilities available for wheat at these export positions in the different years. Pacific unloads vary from a low of 29% to a high of 41%. For the Lakehead the percentage varies from a low of 39% to a high of 59%. The next three columns of Table 8 show that, generally speaking, 55 to 60% of Pacific shipments originate in the province of Alberta and the remaining 40 to 45% in Saskatchewan. The final three columns show that approximately 75% of the Lakehead shipments originate in Saskatchewan and 25% in Manitoba.

Protein data for the same grades, years, unload areas, and provinces, using a similar format are shown in Table 9. The upper section of the table shows that the Lakehead mean protein content exceeded the Pacific mean, sometimes by almost 0.5%, in all years except 1964-65. The lower section of Table 9 shows that the standard deviations for Pacific shipments exceeded those of the Lakehead shipments in six of the nine crop years. Both unload areas showed equal variability in 1957-58 and in 1951-52, while in 1958-59 the Lakehead showed the largest variation. Thus it appears that the protein content of Pacific unloads is both lower and more variable than Lakehead unloads.

Protein data for Pacific unloads by province of origin show that the mean for Saskatchewan exceeds that of Alberta in all years. The within-year difference between the provincial means varies from .5 to

Table 9. Means and Standard Deviations for Protein Content for Grades 1 to 4 Northern Combined for Each Unload Area and for Each Province Within Unload Areas for Each of the Nine Selected Years.

	Grades	1-4 Northern					
	All	Pacific Unloads From			Lakehead Unloads From		
Crop Year	Unloads	Alta.	Sask.	W. Can.	W. Can.	Sask.	Man.
			Mean Protein Content, %				
1964-65	14.44	14.09	15.16	14.51	14.38	14.55	13.83
1963-64	14.15	13.74	14.43	14.07	14.12	14.17	13.88
1968-69	13.71	12.95	13.99	13.47	13.83	14.19	13.20
1967-68	13.68	13.34	13.90	13.57	13.74	13.93	13.10
1951-52	13.61	12.96	14.08	13.50	13.55	13.73	13.03
1966-67	13.48	13.03	13.49	13.20	13.54	13.64	13.10
1958-59	13.39	12.88	13.37	13.04	13.40	13.55	13.01
1957-58	13.11	12.65	13.03	12.85	13.06	13.08	13.03
1956-57	12.55	12.28	12.42	12.33	12.44	12.38	12.62
			Standard Deviation of Protein Content, %				
1964-65	0.91	0.94	0.86	1.05	0.83	0.82	0.57
1963-64	.83	.99	.87	.99	.72	.74	.57
1968-69	.96	1.05	.72	1.04	.90	.77	.76
1967-68	.82	.87	.68	.85	.77	.63	.84
1951-52	1.11	.98	.88	1.09	1.13	1.13	.92
1966-67	.83	1.01	.69	.93	.73	.71	.66
1958-59	.97	.83	.89	.88	.95	.96	.80
1957-58	.93	.84	.82	.85	.85	.89	.75
1956-57	0.72	0.70	0.61	0.67	0.65	0.61	0.77

1.0 percentage units in all but the two lowest protein years when the Saskatchewan mean was exceptionally low. The standard deviations reveal that the protein content of individual carlots of Alberta wheat deviate more from provincial mean than those of Saskatchewan. This occurred in all years, except 1958-59.

For the Lakehead unloads, the range in the annual mean protein content for Manitoba shipments is considerably smaller than for Saskatchewan shipments. However, the Saskatchewan mean exceeds the Manitoba mean, by .5 to 1.0 percentage units, in all but the two lowest protein years. The standard deviations indicate that in all but two years, 1956-57 and 1967-68, Saskatchewan wheat is more variable in protein content than Manitoba wheat.

In summary, the mean protein content of Saskatchewan wheat is considerably higher than that for Alberta or Manitoba; only minor differences exist between the latter two provinces. The variation about the mean is greatest in Alberta and least in Manitoba, with Saskatchewan intermediate. Lakehead means are higher and standard deviations lower than Pacific data. These differences will have significant effects on the application of protein grading at the two coasts.

Bushel weight data, by year, unload area, and province, using the same format as for protein content are shown in Table 10. The years are arranged in order of decreasing overall annual mean protein content; a low inverse correlation between protein content and bushel weight is apparent. The range in annual means is of the order of

Table 10. Means and Standard Deviations for Bushel Weight for Grades 1 to 4 Northern Combined for Each Unload Area and for Each Province Within Unload Areas for Each of the Nine Selected Years.

Grades	1-4 Northern						
	All	Pacific Unloads From			Lakehead Unloads From		
Crop Year	Unloads	Alta.	Sask.	W. Can.	W. Can.	Sask.	Man.
				Mean Bushel Weight, lb.			
1964-65	60.3	61.6	59.8	60.9	59.9	60.2	59.0
1963-64	60.6	61.9	60.7	61.3	60.1	60.3	48.8
1968-69	61.6	62.4	61.3	61.9	61.2	61.0	61.5
1967-68	62.7	63.5	63.2	63.3	62.2	62.1	62.6
1951-52	59.8	61.1	60.1	60.6	59.3	59.0	60.0
1966-67	61.2	62.2	62.0	62.1	60.7	60.9	60.0
1958-59	61.5	62.3	61.5	62.1	61.0	61.2	60.6
1957-58	61.5	62.4	61.8	62.1	60.9	61.4	59.5
1956-57	62.2	62.9	62.4	62.7	61.7	62.1	60.5
				Standard Deviation of Bushel Weight, lb.			
1964-65	1.59	1.44	1.44	1.68	1.46	1.31	1.55
1963-64	1.70	1.23	1.49	1.49	1.62	1.49	1.70
1968-69	2.25	2.04	2.37	2.28	2.18	2.09	2.26
1967-68	1.53	1.22	1.35	1.28	1.50	1.51	1.39
1951-52	2.10	1.94	1.75	1.91	2.07	2.12	1.69
1966-67	1.99	1.75	1.99	1.85	1.87	1.87	1.66
1958-59	1.47	1.14	1.37	1.27	1.46	1.43	1.42
1957-58	1.70	1.18	1.37	1.32	1.80	1.61	1.53
1956-57	1.56	1.10	1.41	1.25	1.62	1.51	1.43

2 lbs. The within year standard deviation is approximately 1.5 lbs.; it is noteworthy that a higher than average deviation was obtained in 1951-52 and 1968-69 when large quantities of the shipments graded tough and damp. A comparison of the fifth and sixth columns reveals that the annual mean for Pacific shipments tends to exceed the mean for the Lakehead shipments by .5 to 1 lb. Provincial data show that Alberta means are always the largest, with the Sastachewan mean generally exceeding the Manitoba mean by a slight margin. The higher mean for Pacific shipments probably reflects the relatively high Alberta mean. A study of the standard deviations shows that the within year variability of Lakehead shipments is somewhat greater than that for Pacific shipments but consistent differences between the provinces do not appear to exist.

Similar data for each individual grade, for each year, for each unload area, and province within unload area are available in the supplementary appendix. In general the above observations hold for this detailed data also.

3. Annual Distribution, Protein Content, and Bushel Weight by Elevator Within Unload Area

In the end, application of any system of protein grading will have to occur at individual terminal elevators. It is therefore important to examine data for wheat unloaded at individual elevators.

This study was restricted to the top two grades of wheat for three years data for West Coast carlot unloads. Data on the carlot distribution and protein content for Pacific unloads for the three years 1957-58, 1963-64, and 1968-69 are presented in Table 11. As expected the number of carlots unloaded varies from year to year and from elevator to elevator. However, in each of the three years, the bulk of the carlots were unloaded at four of the ten elevators.

For protein content; within elevator year to year variation is expected since the overall protein level moving to the port varies. However, within a year, differences of up to 1.0% protein can occur between the average of individual elevators. It is also apparent that in each of the three years the average protein content of wheat entering Saskatchewan Pool terminal is higher than that entering other Pacific terminals. The higher mean for Saskatchewan Pool results from the geographic distribution of this terminal's affiliated country elevators. The Saskatchewan Pool terminal draws its wheat almost entirely from the drier areas of Saskatchewan which are known to produce high protein wheat. Although the Alberta Pool elevator operates on a similar localized drawing area, the quality of wheat it receives is closer to the port average. Observed differences in the average protein content of terminal inward shipments must obviously be reflected in outward shipments.

The standard deviations presented in Table 11 indicate that the distribution of individual carlots about the mean protein content varies substantially from year to year, and from elevator to elevator within a year. Normal blending within an elevator would significantly reduce the protein variability of terminal outward shipments. However, with

Table 11. Number of Samples, and Protein Content of Carlots of Red Spring Wheat, Grades 1 and 2 Northern Combined, Unloaded at Individual Pacific Elevators in Selected Years.

Elevator	Number of Carlots			Protein Content % Mean			Protein Content % Standard Deviation		
	1957-58	1968-69	1963-64	1957-58	1968-69	1963-64	1957-58	1968-69	1963-64
AWP*	209	491	518	12.82	13.11	14.14	.71	.88	1.02
SWP	172	446	505	12.94	13.81	14.58	.70	.70	.80
PACI	228	453	403	12.70	13.36	14.21	.64	.87	.88
UGG	125	232	342	12.57	13.33	14.21	.58	.91	.98
PAC3	34	80	131	12.60	13.56	14.23	.60	.74	.79
BUR	17	61	115	12.80	13.72	13.99	.53	.71	.80
VIT	15	75	57	12.89	13.67	14.06	.59	.77	.92
PAC4	11	13	80	12.79	14.32	14.03	.56	.67	.86
PAC2	27	3	17	12.74	12.83	14.47	.48	.74	.93
CGE6	-	29	9	-	13.13	13.56	-	1.15	.65
TOTAL	838	1883	2167	12.77	13.43	14.26	.66	.87	.93

* Alberta Wheat Pool
Saskatchewan Wheat Pool
Pacific Elevators No. 1
United Grain Growers
Pacific Elevators No. 3
Burrard Terminals
Victoria Elevators
Pacific Elevators No. 4
Pacific Elevators No. 2
Canadian Government Elevator

variation of the above magnitude in terminal inward shipments, good control of the protein variability of outward shipments cannot be achieved by normal blending.

Bushel weight data for the same three crop years for the Pacific elevators are shown in Table 12. While the mean bushel weight may vary, by about 2 pounds, from year to year, within a year good control of the mean bushel weight for individual elevators is obtained under the existing grading system. However, the mean for Alberta Pool tends to exceed the mean for Saskatchewan Pool, reflecting the provincial differences in this quality parameter. The standard deviations of bushel weight indicate that there are only minor differences in the bushel weight variability from year to year and from elevator to elevator within a year.

Similar quality differences have been observed for wheat entering individual elevators at the Lakehead. Generally speaking, the mean protein content for Saskatchewan Pool elevators exceeds the port mean whereas the mean for Manitoba Pool elevators is less than the port average. Here again, the differences reflect the drawing areas of these elevators. Unlike at the Pacific Coast, the between house variability at Lakehead has only a relatively minor effect on cargo variability because most of the Lakehead grain receives further blending as it moves through the Eastern elevators.

Table 12. Bushel Weight, Mean and Standard Deviations, for Carlots of Red Spring Wheat, Grades 1 and 2 Northern Combined, Unloaded at Individual Pacific Elevators in Selected Years.

	Bushel Weight, lb.					
	Mean			Standard Deviation		
	1957-58	1968-69	1963-64	1957-58	1968-69	1963-64
AWP	63.1	63.1	61.9	1.05	1.35	1.27
SWP	62.6	63.2	60.7	.94	1.43	1.49
PACI	62.9	63.0	61.5	1.02	1.53	1.48
UGG	63.3	63.1	61.5	.80	1.18	1.40
PAC3	62.8	63.9	61.3	1.07	1.6	1.25
BUR	63.4	63.3	61.9	1.00	1.00	1.53
VIT	62.8	63.6	61.9	1.08	1.15	1.30
PAC4	63.5	64.0	61.4	.82	.91	1.53
PAC2	63.2	63.7	61.9	1.00	1.16	1.48
GGE6	-	63.1	61.9	-	.69	1.27
TOTAL	63.0	63.2	61.4	1.01	1.43	1.48

4. General Discussion

In the above analyses the protein distribution for each grade, province, unload area, and unload elevator was defined by using the mean as a measure of location and the standard deviation as a measure of dispersion. In the next section it will be demonstrated that both the mean and standard deviation are important statistics influencing the carlot distribution among protein sub-grades. It is therefore pertinent to review the results of the above analysis.

Under the existing grading system, the mean protein content of carlot shipments decreases, and the variability about the mean increases, with each decrease in grade. Moreover, the data for two years with poor harvest conditions (1951-52 and 1968-69) indicate that severe degrading of wheat tends to increase the protein variability of the lower grades.

Saskatchewan wheat has a considerably higher mean protein content than either Alberta or Manitoba wheat. The variability about the mean is greatest in Alberta and least in Manitoba, with Saskatchewan intermediate.

Provincial differences give rise to differences at unload areas. In general, Lakehead wheat has a slightly higher average protein content, and is less variable, than Pacific wheat. The protein data examined for Pacific elevators show considerable within-year heterogeneity between elevators. The between house variability in average protein content and its implications in relation to transportation logistics and protein grading are discussed further in a later section. Moreover, data presented later show that within an elevator the protein level varies from period to period within a year, reflecting the protein level of the areas from which carlots were drawn.

Since bushel weight is a primary grading factor, the mean bushel weight decreases, and the variability about the mean increases, with each decrease in grade. Provincial data show that the mean bushel weight of Alberta wheat is the highest, with the Saskatchewan mean generally exceeding the Manitoba mean by a slight margin. For unload areas; Pacific unloads tend to be less variable and to have a higher mean bushel weight than Lakehead unloads. Bushel weight differences between individual elevators at the Pacific Coast are small.

Throughout these studies there was considerable evidence of a negative correlation between bushel weight and protein content. This relationship, and its implications under protein grading, is considered in a later section.

E. Alternate Grading Systems

This section reports studies of the C.G.C.'s initial proposal for introducing protein as a grading factor. Several variants of the proposed system were also examined. The initial proposal was outlined earlier (p. 43, and Figure 1). In brief, it was suggested that Nos. 1 and 2 Northern be combined to give a new grade, No. 1 Canada Western Red Spring Wheat (1 CW), that No. 3 Northern and the best part of No. 4 Northern be combined to form a second new grade, No. 2 CW, and that each of the new grades be divided into three sub-grades on the basis of protein content. For purposes of the present study, it seemed necessary to examine only the first of the new grades. Considerably more data were available for this grade, which was obviously advantageous. Moreover, it appeared that conclusions drawn from a study of No. 1 CW would also apply in principle to No. 2 CW.

1. Canadian Grain Commission's Three Sub-Grade Proposal

In this report, the three sub-grades will be referred to as Nos. 1A, 1B and 1C. No. 1A represents that part of 1 CW of 14.3% protein and over; No. 1B, that part of 13.0 to 14.2% protein; No. 1C, that part of less than 13.0% protein.

Data for percentage grade distribution, protein content, and bushel weight for the main grade and each of the three sub-grades, for each of nine selected years are shown in Table 13. The data represent all unload areas combined. Crop years are arranged in order of decreasing annual mean protein content for grade 1 CW. The upper section of the table demonstrates that the percentage of 1 CW entering each of the three sub-grades 1A, 1B, 1C varies considerably from year to year. It is also evident that the mean protein content of 1 CW is a significant factor in determining how this grade divides among the sub-grades. In the four years when the 1 CW protein mean is close to the long term mean of 13.6% about 50 to 60% of the wheat enters the middle sub-grade,

Table 13. A Three Sub-Grade System: Sub-Grade Distribution, Mean Protein Content and Bushel Weight, for all Unload Areas Combined, for Nine Selected Years.

Crop Year	Grade	Protein Range, %		
	1 CW	A, over 14.2	B, 13.0-14.2	C, under 13.0
			Distribution %	
1964-65	100	59.7	37.8	2.6
1963-64	100	48.8	41.6	3.7
1951-52	100	40.5	40.7	18.8
1967-68	100	25.1	60.2	14.7
1968-69	100	23.1	56.9	20.0
1958-59	100	25.9	49.8	24.2
1966-67	100	18.4	63.8	17.8
1957-58	100	7.6	41.5	50.9
1956-57	100	0.9	29.3	69.8
			Protein Content, %	
1964-65	14.54	15.12	13.75	12.55
1963-64	14.26	14.89	13.70	12.55
1951-52	13.99	15.06	13.66	12.39
1967-68	13.73	14.68	13.66	12.40
1968-69	13.62	14.65	13.65	12.36
1958-59	13.61	14.78	13.56	12.43
1966-67	13.60	14.72	13.58	12.50
1957-58	13.01	14.70	13.43	12.40
1956-57	12.63	14.54	13.35	12.30
			Bushel Weight, lb.	
1964-65	60.8	60.4	61.3	62.2
1963-64	60.9	60.7	61.0	61.9
1951-52	62.0	61.6	62.5	62.6
1967-68	62.9	62.3	63.1	63.5
1968-69	62.9	62.2	63.0	63.4
1958-59	62.1	61.6	62.1	62.5
1966-67	62.1	61.0	62.2	62.9
1957-58	62.7	61.3	62.6	63.0
1956-57	63.1	62.4	63.0	63.1

and the remainder tends to be divided about equally between the other two sub-grades. When the mean protein content of 1 CW rises to 14.0%, more than 40% of it enters 1A, approximately 40% enters 1B, and less than 20% enters 1C. When the 1 CW mean protein content drops to 13.0% less than 10% enters 1A, 40% enters 1B, and in excess of 50% enters 1C.

The data for protein content show that the mean for 1A varies from a high of 15.1% to a low of 14.5%, 1C varies from a high of 12.6% to a low of 12.3%. It is significant that the middle sub-grade, with boundaries on either side, only varies in protein content from 13.35 to 13.75 and approaches the Commission's expectation that the sub-grade would always have a protein content close to the long-term average for Canadian wheat. But the second expectation, that the sub-grade would contain 60% of the wheat grading No. 1 CW, is approached only when the mean for that grade is close to 13.6%.

Bushel weight data for each of the sub-grades are shown in the lower section of the table. Because of a low inverse corrlelation between protein content and bushel weight the within-year mean bushel weight increases with decreasing protein separation level. The mean bushel weight for 1A is 0.5 to 1.0 lbs. lighter than 1B; 1B is about 0.5 lbs. lighter than 1C. These differences are small and probably are only of minor importance.

Since both the qualities and amounts of grain unloaded at the Pacific and Lakehead terminals differ, separate analyses were made for both these unload areas. Data for Pacific and Lakehead unloads are shown in Tables 14 and 15.

In Table 14, a comparison of the distribution of the carlots among the sub-grades for each unload area reveals that the Lakehead generally shows a higher percentage of sub-grades 1A, and 1B than the Pacific. The reverse occurs with grade 1C.

In protein content, Lakehead unloads of 1 CW are about 0.2% units higher than Pacific unloads. When the division is made into sub-grades 1A, 1B and 1C, the differences in the protein level between Lakehead and Pacific unloads become negligible.

In Table 15, because of a low inverse correlation between protein content and bushel weight, the bushel weight data tend to be the reverse of those for protein content. Thus, for both the main grade and the three sub-grades, bushel weights are higher for Pacific than for Lakehead unloads, and within unload area the means decrease with increasing protein separation level.

The data presented in Tables 13 and 14, as would be expected, demonstrate that the mean protein content of 1 CW is the major factor in determining how carlots of this grade will split among the proposed protein sub-grades. However, the distribution of the carlots about the annual protein mean is also a significant factor in this regard. Table 16 shows the standard deviation of protein content, for grade 1 CW for the major unload areas, for the nine selected years. The annual standard deviations clearly indicate that the shape of the protein frequency distribution for 1 CW varies considerably from year to year and from

Table 14. A Three Sub-Grade System: Sub-Grade Distribution, Mean Protein Content, for Pacific and Lakehead Unloads, for Nine Selected Years.

Crop Year	PACIFIC UNLOADS				LAKEHEAD UNLOADS			
	Grade	Protein Range, %			Grade	Protein Range, %		
	1 CW	1A over 14.2	1B 13.0-14.2	1C under 13.0	1 CW	1A over 14.2	1B 13.0-14.2	1C under 13.0
				Distribution %				
1964-65	100	60.8	34.7	4.5	100	59.4	39.0	1.7
1963-64	100	53.6	39.4	7.0	100	52.1	45.5	2.4
1951-52	100	31.2	46.3	22.5	100	36.8	38.4	24.8
1967-68	100	20.7	61.3	18.0	100	26.7	60.4	13.0
1968-69	100	17.4	53.7	28.9	100	26.1	57.9	16.0
1958-	100	12.0	50.1	37.9	100	28.1	51.2	20.7
1966-67	100	9.0	62.3	28.7	100	19.7	66.0	14.3
1957-58	100	2.0	35.6	62.4	100	5.1	39.8	55.1
1956-57	100	0.1	16.6	83.3	100	0.4	20.0	78.6
				Protein Content, %				
1964-65	14.60	15.28	13.68	12.48	14.51	15.03	13.79	12.61
1963-64	14.26	14.95	13.63	12.56	14.21	14.72	13.73	12.52
1951-52	13.76	14.88	13.64	12.45	13.96	15.39	13.63	12.34
1967-68	13.63	14.66	13.65	12.42	13.77	14.63	13.69	12.36
1968-69	13.43	14.62	13.64	12.34	13.70	14.63	13.65	12.35
1958-59	13.23	14.70	13.50	12.41	13.67	14.72	13.61	12.41
1966-67	13.30	14.62	13.51	12.41	13.67	14.71	13.60	12.57
1957-58	12.77	14.54	13.37	12.37	12.94	14.68	13.41	12.44
1956-57	12.39	14.30	13.23	12.22	12.52	14.54	14.01	12.29

Table 15. A Three Sub-Grade System: Mean Bushel Weight for Pacific and Lakehead Unloads for Nine Selected Years.

Crop Year	Grade	Mean Bushel Weight, lb.		
		Protein Range %		
		1A	1B	1C
	1 CW	over 14.2	13.0-14.2	under 13.0
			PACIFIC UNLOADS	
1964-65	61.3	60.5	62.3	62.9
1963-64	61.4	61.0	61.8	62.3
1951-52	62.4	61.6	62.5	63.3
1967-68	63.6	63.2	63.7	63.8
1968-69	63.2	62.7	63.2	63.3
1958-59	62.7	62.0	62.7	63.0
1966-67	63.2	62.3	63.2	63.6
1957-58	63.0	61.8	62.8	63.1
1956-57	63.4	61.0	63.3	63.4
			LAKEHEAD UNLOADS	
1964-65	60.5	60.2	60.8	61.2
1963-64	60.5	60.4	60.7	61.2
1951-52	61.7	61.3	61.7	62.0
1967-68	62.4	61.8	62.5	63.1
1968-69	62.6	61.8	62.7	63.5
1958-59	61.7	61.5	61.7	62.0
1966-67	61.7	61.5	61.7	62.2
1957-58	62.5	61.0	62.4	62.8
1956-57	62.9	61.8	65.5	63.0

Table 16. Standard Deviation of Protein Content for Grade 1 CW for the Major Unload Areas for Nine Selected Years.

	Unload Area		
Crop Year	ALL	PACIFIC	LAKEHEAD
	Standard deviation of protein content, %		
1964-65	.90	1.06	.82
1963-64	.77	.93	.68
1951-52	1.13	.97	1.37
1967-68	.79	.79	.77
1968-69	.84	.87	.83
1958-59	.92	.83	.88
1966-67	.77	.76	.72
1957-58	.79	.66	.71
1956-57	.65	.57	.60

unload area to unload area. The standard deviation for 1951-52 crop year, for example, was about twice that for the 1956-57 crop year. Moreover, within a year the standard deviation for Pacific unloads tends to exceed that for Lakehead unloads.

An appreciation of how differences in the annual protein mean and standard deviations affect the sub-grade distribution of the carlots can be obtained by studying Figures 4 through 6. The curves shown in these figures are photographic reproductions of line printer plots (see Table 27) of the protein frequency distribution for 1 CW carlots (all unload areas), for each of the nine crop years used in this study. Horizontal bar-graphs were used in place of the more traditional vertical histograms to simplify programming and permit direct photography of the computer output.

Curves for three years with essentially the same mean protein content but significantly different standard deviations, and shape, are presented in Figure 4. The dotted lines show the barrier between sub-grades at 13.0 and 14.2 on the protein scale. Assuming a constant mean, it is clear that, as the standard deviation for protein content for 1 CW increases, the percentage of the carlots entering 1A and 1C increase, while the percentage entering 1B decreases accordingly. Moreover, it is apparent that the distributions are not symmetrical. Of course, this skewness of the protein distribution also affects the percentage distribution of the carlots among the sub-grades.

Figure 4. Frequency Distribution, No. 1 C.W.

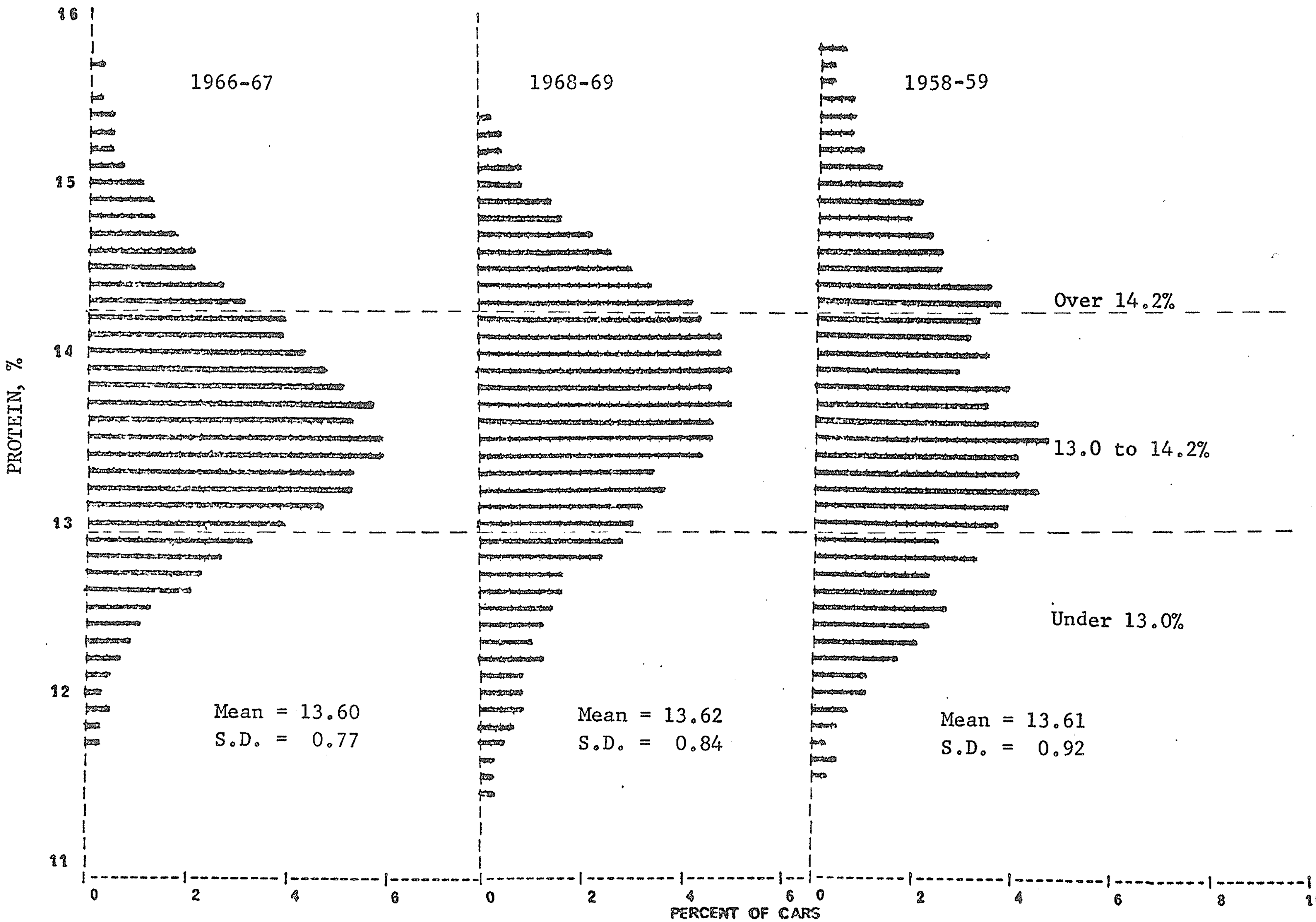


Figure 5 shows protein frequency distributions for three crop years with similar standard deviations but considerably different means. It is apparent that the three curves have essentially the same shape but the difference in mean protein content causes the complete distribution to shift along the protein scale. A substantial increase in the mean places both sub-grade minima below the peak of the distribution, as occurred in the 1963-64 crop year. A substantial decrease in the mean protein positions both sub-grade minima above the peak of the curve, as occurred in 1957-58. Conceivably, a very large increase or decrease in the mean would result in either one or both of the fixed sub-grade minima not cutting the distribution at all.

The three curves presented in Figure 6 differ significantly in both mean protein content and standard deviation. These three curves serve to illustrate the combined effects of differences in the means and standard deviations. Clearly, the three distributions have little in common. The curves in Figure 6 are unusual in many respects; the average protein content for the 1956-57 crop year is the lowest on record, while the average for the 1964-65 crop year is the highest on record. Moreover, the 1951 harvest was the wettest on record. This wet harvest resulted in severe degrading of the 1951-52 crop year shipments; only about 6%, compared with the normal of over 30%, of the carlots in this year graded 1 CW.

The above data demonstrate that both the mean and standard deviation

Figure 5. Frequency Distribution, No. 1 C.W.

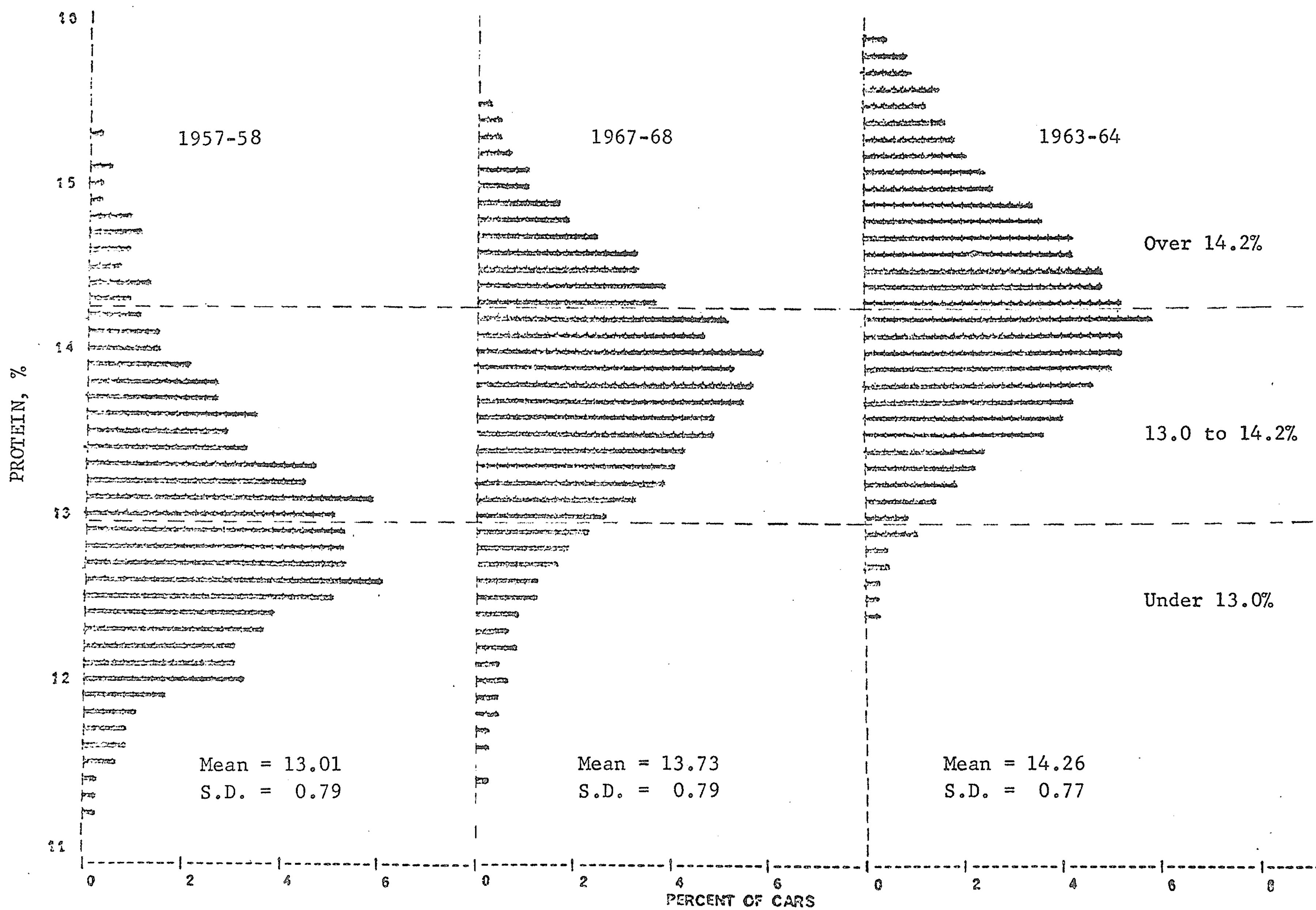
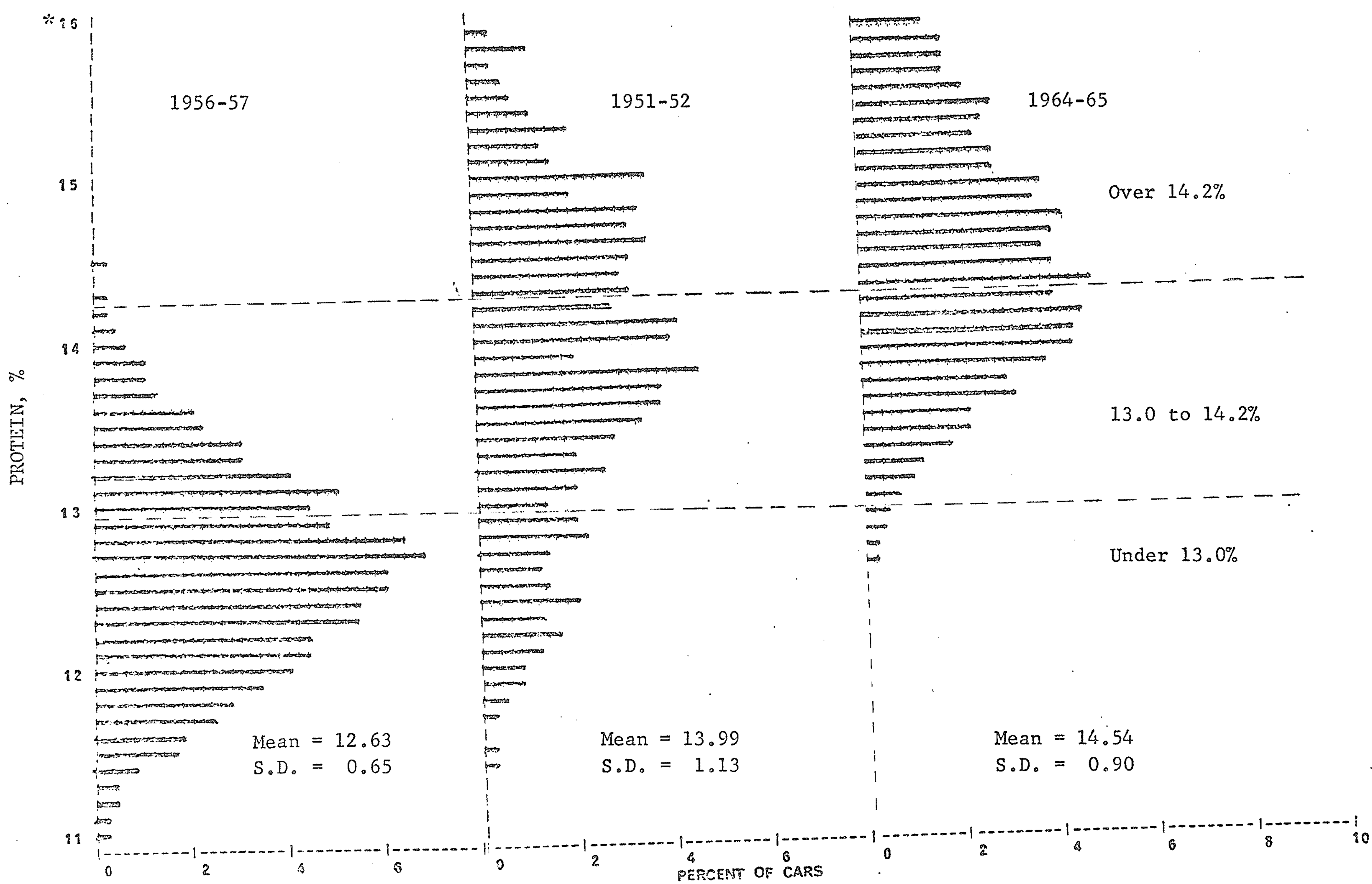


Figure 6. Frequency Distribution, No. 1 C.W.



* Protein contents greater than 16.0 are omitted.

independently influence the relative volume of grain entering each of the sub-grades. When both parameters vary simultaneously a more complex situation occurs. Generally, speaking, since the curve is broader and less peaked when the standard deviation is large, an increase or decrease, in the mean has a significantly smaller effect on the distribution among the sub-grades than when the standard deviation is small. It has been observed in an earlier section that the standard deviation for protein content increases with increasing existing grade number and that for the same grade the value for Pacific shipments tends to be larger than for the Lakehead shipments. Thus, it appears that extrapolation from grade to grade and unload area to unload area should be done with caution.

2. General Discussion

The middle sub-grade in the Commission's proposal seems reasonably satisfactory. Year to year variations in protein content are not large, and the amount of No. 1 CW entering the sub-grade would seldom drop below 40%. A reasonably uniform product could thus be consistently offered for export.

The high and low-protein sub-grades, with boundaries only on one side are less satisfactory. They can vary widely in protein content from year to year, and the amount of the main grade entering each sub-grade can vary from essentially zero to as much as 60%.

Despite these limitations, introduction of the system would effect a substantial improvement in the uniformity of protein content in export shipments of top grades of Canadian wheat. However, it appeared that improvements could be introduced. In particular, thinking developed at this stage of the research on the advisability of guaranteeing protein content as other countries were doing. Moreover, the guaranteed levels should be at traditional levels, e.g., 13.5 or 14.0%, and these could not be met by the Commission's proposed system. It therefore seemed advisable to examine additional alternative systems that might provide for rational levels for guaranteeing protein content.

3. Other Constant-Boundary Systems

At this stage of the research it was the concensus that boundaries between protein sub-grades should remain constant from year to year, and that other systems would be too complex to be practicable. Accordingly, in this section, variations in boundaries are examined to determine at what levels these should be placed to enable protein levels to be guaranteed at levels of 13.5, 14.0%, etc.

These options are examined with carlot data (5% sampling) for crop years having the following protein levels: 12.6, 13.0, 13.7 (three years combined), 14.3 and 14.5%. The first and last years represent the lowest and highest protein levels during the thirty-one crop years for which carlot data were available. The three crop years 1966-67, 1967-68, and 1968-69 are considered as a single entity representing a period of average protein level.

a. Option 1. A Three Sub-Grade System: This option differs from the Canadian Grain Commission's proposal, in that the lower and upper bounds of the middle sub-grade are raised by 0.1 percentage units to

13.1 and 14.3, respectively. The objective of the change is to provide better protection for the guarantee especially in the low protein years. The three sub-grades are given the following names: 1A, 1B and 1C. Data for this system are shown in the bottom three lines of each section of Table 17. Distribution data in the top section show that the middle sub-grade No. 1B contains 61% of the 1 CW in the medium protein year; but this decreases to 25% in the lowest year and to 42% in the highest year. The annual mean protein content of No. 1B ranges from 13.4 to 13.8%.

The low sub-grade, No. 1C ranges from 74% of 1 CW in the low year down to 3.3% in the high year, and the protein content ranges from 12.34 to 12.65%.

The high sub-grade, No. 1A, is most interesting. There is practically none in the low year, some 18.5% in the medium year, and as much as 55% in the high year. The protein content for No. 1A ranges from 14.6 to 15.2%.

Bushel weights in the bottom section of the table naturally show differences between years. But within each year bushel weight increases with each decrease in protein content. This result, the effect of a low inverse correlation between protein content and bushel weight, is repeated in each of the systems examined in this report.

b. Option 2. Additonal Optional Splitting of Top Sub-Grade: Data for No. 1A suggest that in years when the protein level is above average this top sub-grade should be split to give a sub-grade of

Table 17. A 3 Sub-Grade System with Optional Splitting of the Top Sub-Grade (All unload areas).

Sub-Grade	Protein range	1956-7	1957-8	1966-7 to 1968-9	1963-4	1964-5
				Distribution, %		
1A1	15.0 & over	0.1	1.5	4.4	18.0	30.8
1A2	14.4 - 14.9	0.6	5.1	14.1	25.6	23.9
1A	14.4 & over	0.7	6.6	18.5	43.6	54.7
1B	13.1 - 14.3	25.1	37.4	61.2	51.7	42.0
1C	under 13.1	74.2	56.0	20.3	4.7	3.3
				Protein content, %		
1A1	15.0 & over	15.05	15.24	15.26	15.43	15.62
1A2	14.4 - 14.9	14.57	14.62	14.60	14.63	14.65
1A	14.4 & over	14.62	14.76	14.76	14.96	15.19
1B	13.1 - 14.3	13.42	13.52	13.70	13.83	13.84
1C	under 13.1	12.34	12.45	12.52	12.64	12.65
				Bushel weight, lb.		
1A1	15.0 & over	61.0	61.0	61.3	60.6	60.0
1A2	14.4 - 14.9	62.1	61.2	62.0	60.8	60.7
1A	14.4 & over	62.0	61.2	61.8	60.7	60.4
1B	13.1 - 14.3	63.0	62.6	62.7	61.0	61.3
1C	under 13.1	63.1	63.0	63.2	61.8	62.1

guaranteed 15.0% protein as well as one of guaranteed 14.5%. It is assumed that Canada should sell wheat of 15.0% protein when such wheat is available.

The two top lines in each section of Table 17 show the effects of this split. The two sub-grades of No. 1A are called Nos. 1A1 and 1A2. In the high protein year, 30% of 1 CW enters No. 1A1 and averages 15.6% protein. In the year of medium high protein level, 1963-64, the percentage is 18.0 and the protein level is 15.43%. Even in the medium year there is 4.4% of 1 CW in No. 1A1, say 7.5 million bushels, with a protein content of 15.26%. No. 1A1 would be of no significance in years of below average protein level.

c. Option 3. A Revision of Option 2: Option 3 is similar to Option 2 except that the lower limit of No. 1B is raised to 13.3% protein so that No. 1B can be guaranteed at 13.5% protein. The data are shown in Table 18.

The middle sub-grade, No. 1B now represents 53% rather than 61% of 1 CW in the medium protein year; it falls to 39% in the high protein year and to 16% in the low protein year. Its mean annual protein content ranges from 13.58 to 13.88%. The top sub-grades, Nos. 1A1 and 1A2, are identical with those in Option 2 which has been discussed.

The low sub-grade becomes larger, 28% in the medium protein year and 66% and 83% in the low protein years. It is still 5.9% in the high year. Protein levels range from 12.4 to 12.9%.

Table 18. Revised 3 Sub-Grade System Guaranteeing 14.5 & 13.5% Protein with Optional Splitting of the Top Sub-Grade (All unload areas).

Sub-Grade	Protein range	1956-7	1957-8	1966-7 to 1968-9	1963-4	1964-5
				Distribution, %		
1A1	15.0 & over	0.1	1.5	4.4	18.0	30.8
1A2	14.4 - 14.9	0.6	5.1	14.1	25.6	23.9
1A	14.4 & over	0.7	6.6	18.5	43.6	54.7
1B	13.3 - 14.3	15.9	27.1	53.0	48.5	39.4
1C	under 13.3	83.4	66.3	28.5	7.9	5.9
				Protein content, %		
1A1	15.0 & over	15.05	15.24	15.26	15.43	15.62
1A2	14.4 - 14.9	14.57	14.62	14.60	14.63	14.65
1A	14.4 & over	14.62	14.76	14.76	14.96	15.19
1B	13.3 - 14.3	13.58	13.66	13.78	13.87	13.88
1C	under 13.3	12.43	12.56	12.70	12.85	12.87
				Bushel weight, lb.		
1A1	15.0 & over	61.0	61.0	61.3	60.6	60.6
1A2	14.4 - 14.9	62.1	61.2	62.0	60.8	60.7
1A	14.4 & over	62.0	61.2	61.8	60.7	60.4
1B	13.3 - 14.3	63.0	62.4	62.6	61.0	61.2
1C	under 13.3	63.1	63.0	63.1	61.7	62.0

Table 19 gives data for Lakehead and Pacific unloads for the sub-grades of Option 3 together with a few additional protein ranges. In all years the bushel weight is higher at the Pacific Coast; and in the two low-protein years and in the medium protein year the protein levels are lower at the Pacific Coast. Protein grading reduces the difference in protein levels between Pacific and Lakehead unloads to negligible amounts; but the proportion of lower sub-grades (under 13.3%) is appreciably higher in Pacific than in Lakehead unloads. Of course, differences in bushel weight persist between the two unload areas.

d. Option 4. A System Guaranteeing 15%, 14% and 13% Protein: At this stage of the investigation, Mr. A. W. Alcock,[1/] of the Canadian Wheat Board, suggested that a system with sub-grades that could be guaranteed at 15% (when available), 14% and 13% was more rational in itself and more consistent with marketing practices throughout the world.

Data for this proposal are given in Table 20. The top four lines in each section of the Table (Option 4A) represent splits at 14.9, 13.8 and 12.7%; the next set of four lines (Option 4B) raises these levels to 15.0, 13.9 and 12.8% and the last two lines (Option 4C) raise the lowest level from 12.8 to 12.9%. The sub-grades are given the following names: 1A, 1B, 1C and 1D.

The protein data in Table 20 suggest that Option 4A (top four lines in each section), is barely adequate to protect the protein

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[1/] Private Communication.

Table 19. Comparison of Lakehead and Pacific Unloads for all Revised Options.

Sub-Grade	Protein range	1956-7 Lake.	1956-7 Pac.	1957-8 Lake.	1957-8 Pac.	1966 - 1969 Lake.	1966 - 1969 Pac.	1963-4 Lake.	1963-4 Pac.	1964-5 Lake.	1964-5 Pac.
						Distribution, %					
1A1	15.0 & over	-	-	0.9	0.2	4.1	2.7	13.4	22.7	27.2	37.2
1A2	14.4 - 14.9	0.4	-	3.7	1.3	15.1	11.0	25.8	22.9	26.5	19.7
1A	14.4 & over	0.4	-	4.5	1.6	19.2	13.6	39.2	45.6	53.6	57.0
1B	13.3 - 14.3	10.5	6.4	24.9	19.2	55.7	49.8	54.8	40.8	42.4	33.1
1C	under 13.3	89.1	93.6	70.6	79.2	25.1	36.6	6.0	13.7	3.9	9.9
1C1	12.5 - 13.2	43.0	41.0	47.0	47.8	19.9	25.8	5.4	11.4	3.6	8.3
1C2	under 12.5	46.2	52.7	23.6	31.4	5.2	10.8	0.6	2.3	0.4	1.6
1B1	13.9 - 14.3	2.1	0.4	5.7	4.3	24.0	20.7	31.2	19.1	25.8	16.3
1B2	13.3 - 13.8	8.3	6.0	19.2	14.9	31.7	29.1	23.6	21.6	16.6	16.8
						Protein content, %					
1A1	15.0 & over	-	-	15.23	15.00	15.26	15.23	15.36	15.52	15.56	15.71
1A2	14.4 - 14.9	14.54	-	14.60	14.54	14.60	14.59	14.62	14.64	14.63	14.67
1A	14.4 & over	14.54	-	14.73	14.61	14.74	14.72	14.87	15.08	15.10	15.35
1B	13.3 - 14.3	13.59	13.50	13.63	13.63	13.79	13.77	13.89	13.82	13.91	13.84
1C	under 13.3	12.39	12.31	12.58	12.52	12.74	12.63	12.88	12.83	12.91	12.83
1C1	12.5 - 13.2	12.79	12.78	12.82	12.84	12.95	12.91	13.00	12.97	13.00	12.98
1C2	under 12.5	12.01	11.95	12.10	12.03	11.96	11.98	11.75	12.15	12.03	12.06
1B1	13.9 - 14.3	13.98	14.17	14.07	14.04	14.09	14.08	14.10	14.11	14.11	14.11
1B2	13.3 - 13.8	13.48	13.46	13.50	13.51	13.56	13.55	13.60	13.57	13.59	13.57
						Bushel weight, lb.					
1A1	15.0 & over	-	-	60.7	63.0	61.1	62.3	60.1	60.7	60.0	60.0
1A2	14.4 - 14.9	61.8	-	61.0	61.7	61.4	62.9	60.4	61.2	60.4	61.2
1A	14.4 & over	61.8	-	60.9	61.9	61.3	62.8	60.3	61.0	60.2	60.5
1B	13.3 - 14.3	62.3	63.3	62.2	62.5	62.0	63.4	60.6	61.7	60.7	62.2
1C	under 13.3	62.9	63.4	62.8	63.1	62.6	63.6	61.1	62.2	61.0	62.8
1C1	12.5 - 13.2	62.9	63.3	62.7	63.1	62.5	63.6	61.2	62.2	60.9	62.8
1C2	under 12.5	63.0	63.4	62.9	63.2	63.0	63.6	60.7	62.4	61.9	62.8
1B1	13.9 - 14.3	61.6	62.7	61.7	62.1	61.8	63.3	60.6	61.4	60.7	62.0
1B2	13.3 - 13.8	62.5	63.3	62.3	62.6	62.2	63.4	60.7	61.9	60.8	62.4

Table 20. 4 Sub-Grade Systems Guaranteeing 15, 14, 13 & 12% Protein (All unload areas).

Sub-Grade	Protein range	1956-7	1957-8	1966-7 to 1968-9	1963-4	1964-5
				Distribution, %		
1A	14.9 & over	0.2	1.9	5.9	21.4	34.6
1B	13.8 - 14.8	4.4	14.5	40.6	53.7	46.7
1C	12.7 - 13.7	43.9	48.5	43.5	23.2	17.5
1D	under 12.7	51.5	35.0	10.0	1.7	1.2
1A	15.0 & over	0.1	1.5	4.4	18.0	30.8
1B	13.9 - 14.9	3.4	12.3	36.8	52.3	46.6
1C	12.8 - 13.8	38.2	45.9	46.8	27.6	21.0
1D	under 12.8	59.4	40.3	11.9	2.1	1.6
1C	12.9 - 13.8	31.7	40.6	44.5	27.0	20.6
1D	under 12.9	64.8	45.6	14.3	2.7	2.0
				Protein content, %		
1A	14.9 & over	14.96	15.17	15.17	15.34	15.54
1B	13.8 - 14.8	14.02	14.19	14.20	14.28	14.29
1C	12.7 - 13.7	13.07	13.14	13.29	13.40	13.39
1D	under 12.7	12.12	12.22	12.16	12.22	12.26
1A	15.0 & over	15.05	15.24	15.26	15.42	15.62
1B	13.9 - 14.9	14.13	14.29	14.28	14.36	14.38
1C	12.8 - 13.8	13.16	13.22	13.37	13.48	13.48
1D	under 12.8	12.19	12.28	12.24	12.31	12.36
1C	12.9 - 13.8	13.23	13.28	13.40	13.49	13.49
1D	under 12.9	12.25	12.34	12.34	12.41	12.46
				Bushel weight, lb.		
1A	14.9 & over	62.4	60.8	61.4	60.6	60.1
1B	13.8 - 14.8	62.6	61.8	62.3	60.8	61.0
1C	12.7 - 13.7	63.1	62.8	62.9	61.3	60.6
1D	under 12.7	63.1	63.1	63.3	61.9	62.4
1A	15.0 & over	61.0	61.0	61.3	60.6	60.0
1B	13.9 - 14.9	62.5	61.7	62.2	60.8	60.9
1C	12.8 - 13.8	63.0	62.8	62.8	61.2	61.6
1D	under 12.8	63.2	63.0	63.3	61.9	62.3
1A	12.9 - 13.8	63.1	62.7	62.8	61.2	61.5
1B	under 12.9	63.1	63.0	63.3	61.9	62.2

guarantee (13%) for No. 1C in low protein years. Option 4B may be more satisfactory but seems too conservative for No. 1A (15%) in high protein years. Option 4C provides added protection for No. 1C in low years but whether this is required seems debatable. The following comments are restricted to Option 4B, the middle four lines of each section.

The amounts of 1 CW entering No. 1C remain the most consistent of the various sub-grades; the amounts range between 21 and 47%. No. 1B, though only 3% in the lowest year, rises to 37% in the medium year and to 52 and 47% in the higher protein years. No. 1A is essentially non-esistent in the two lower protein years but ranges from 4.4 up to 31% in the three higher years. The lowest grade, No. 1D, ranges from 58% in the low year down to less than 2% in the high year.

Omitting 1956-57 for 1A because the amount is too small, mean protein levels range from 15.24 to 15.62% in 1A; from 14.13 to 14.38 in No. 1B; from 13.16 to 13.48 in No. 1C; and from 12.19 to 12.36 in No. 1D.

Within each year, bushel weight increases as protein content decreases. The difference in bushel weights between the high and low protein sub-grades ranges from about 1 lb. in the highest protein year to about 2 lbs. in the medium and low protein years.

It seemed apparent that the possibility of guaranteeing 14.5% in the top sub-grade for years when 15% protein is not available (or possibly in accordance with market demands) should also be examined. Results, again with two different sets of separation levels, are shown in Table 21.

The separation at 14.4% (top two lines in each section) fails to

Table 21. Alternate Top Sub-Grade Guaranteeing 14.5% Protein.

Sub-Grade	Protein range	1956-7	1957-8	1966-7 to 1968-9	1963-4	1964-5
				Distribution, %		
1A1	14.4 & over	0.7	6.6	18.5	43.6	54.7
1B	13.8 - 14.3	3.9	9.8	28.0	31.5	26.6
1A1	14.5 & over	0.5	5.4	15.2	38.6	50.5
1B	13.9 - 14.4	2.9	8.4	26.1	31.6	26.9
				Protein content, %		
1A1	14.4 & over	14.62	14.76	14.76	14.96	15.19
1B	13.8 - 14.3	13.96	13.99	14.03	14.06	14.06
1A1	14.5 & over	14.69	14.84	14.84	15.03	15.26
1B	13.9 - 14.4	14.05	14.11	14.12	14.15	14.15
				Bushel weight, lb.		
1A1	14.4 & over	62.0	61.2	61.8	60.7	60.4
1B	13.8 - 14.3	62.7	62.1	62.5	60.8	61.1
1A1	14.5 & over	62.3	61.1	61.7	60.7	60.3
1B	13.9 - 14.4	62.5	61.9	62.4	60.8	61.0

protect the guaranteed level of 14% for No. 1B adequately.

Accordingly the split at 14.5% is preferred. It will be noted that No. 1B becomes much more uniform in protein level from year to year when the upper part of that grade is removed at a level of 14.5% and over. In years of medium protein level, for which this option (4D) would be most used, 15% of 1 CW enters No. 1A1; this amount drops to 5.4% in the year of next lower protein level - say 9 million bushels at an average protein content of 14.8%. In the medium protein years there is also 26% of 1 CW in 1B and this amount drops to 8.4% in the next lower protein year. Since No. 1A1 would not be used in a very low protein year it may be said that the annual protein level of No. 1B remains extremely uniform.

e. Option 5. Two Sub-Grade Systems: Two sub-grade systems are considered briefly to elucidate the principles involved and because of their possible use for No. 2 CW (No. 3 Northern and part of No. 4 Northern). Nevertheless, this option was applied to No. 1 CW for purposes of this report.

Table 22 shows divisions at each of two levels, namely 14.4 and 13.9%. The former would provide a top sub-grade with a mean protein content of 14.5% or higher in all years; the latter level provides a top sub-grade with a mean of 14.0% or higher.

With the split at 14.4% No. 1A ranges from 0.7 to 55% of 1 CW; it amounts to 18.5% in the medium years. With the split at 13.9% No. 1A ranges from 3.4 to 77%, with a level of 41% in the medium years.

The most interesting aspect of the two sub-grade option is the

Table 22. Two Sub-Grade System (All Unload Areas).

Sub-Grade	Protein range	1956-7	1957-8	1966-7 to 1968-9	1963-4	1964-5
				Distribution, %		
1A	14.4 & over	0.7	6.6	18.5	43.6	54.7
1B	under 14.4	99.3	93.4	81.5	56.4	45.3
1A	13.9 & over	3.4	13.8	41.2	70.2	77.4
1B	under 13.9	96.6	86.2	58.8	29.8	22.6
				Protein content, %		
1A	14.4 & over	14.62	14.76	14.76	14.96	15.19
1B	under 14.4	12.61	12.88	13.41	13.73	13.75
	Difference	-2.01	-1.88	-1.35	-1.23	-1.44
1A	13.9 & over	14.14	14.40	14.39	14.63	14.87
1B	under 13.9	12.57	12.78	13.14	13.40	13.40
	Difference	-1.57	-1.62	-1.25	-1.23	-1.47
				Bushel weight, lb.		
1A	14.4 & over	62.0	61.2	61.8	60.7	60.4
1B	under 14.4	63.1	62.8	62.8	61.1	61.4
	Difference	-1.1	-1.6	-1.0	-0.4	-1.0
1A	13.9 & over	62.5	61.6	62.2	60.7	60.6
1B	under 13.9	63.1	62.9	62.9	61.3	61.6
	Difference	-0.6	-1.3	-0.7	-0.6	-1.0

relatively wide difference in protein content that occurs between the top and bottom portions, no matter where the split is made in relation to the mean. These differences are shown in Table 22 and range from a low of 1.23 up to a high of 1.88 percentage units (2.01% for 1956-57 is disregarded because the amount of No. 1A is insignificant). Thus a single division of a grade into two parts on a protein basis provides sub-grades of substantially different protein contents. The effect of the inverse correlation between protein content and bushel weight is also illustrated; the differences in bushel weight between the top and bottom portions range from a low of 0.4 lbs. to a high of 1.6 lbs.

If the two sub-grade system is applied to 2 CW, a somewhat larger difference in the average protein levels of the two sub-grades would be expected since the protein distribution for 2 CW is less peaked than for 1 CW.

It should also be noted that under a two sub-grade system there is no upper protein bound on the upper sub-grade, and no lower protein bound on the lower sub-grade. The absence of either upper or lower bounds and the potentially broad range of protein contents eligible for the two sub-grades would result in considerable variability within the sub-grades.

4. A System Involving Promotion from Lower to Higher Sub-Grades

A rigid system of non-mixing sub-grades presents difficulties. If minimum protein levels are set high enough in each sub-grade to protect the guarantee in low-protein years, mean protein levels are well above the guarantee in high-protein years, and excessive amounts of high-protein wheat are essentially given away. Moreover, some terminals will have difficulty at times in providing shipments that meet the guarantee, while others may be forced to make shipments with protein levels that are far too high. These difficulties are substantial but should not be exaggerated; any rigid system will represent a marked advance over current practice.

A possible alternative is a system involving promotion of carlots at terminals from one protein grade to another. In retrospect it is clear that this is equivalent to permitting moveable barriers between sub-grades that change in accordance with the mean protein content of the main grade. Thus the study reported in this section represents the first step from the initial proposal towards the system finally adopted when protein grading was introduced.

Assuming that one wishes to guarantee 15% (when available), 14% and 13%, the sub-grades become:

1A 15.0% and over

1B 14.0% to 14.9%

1C 13.0% to 13.9%

1D under 13.0%

Investigation of this system takes a different tack. It is essential to determine, not only how much of each sub-grade enters terminals, but also how much of each leaves terminals. The difference represents the amount of each sub-grade that is promoted.

The following criteria were tentatively adopted: (1) promotion is permitted only from one protein sub-grade to the next higher protein sub-grade; and (2) the mean of all outgoing shipments must be of the order of 0.15 percentage units above the guaranteed levels of 15%, 14% and 13%.

By "cut and try" methods, the protein ranges that would meet the second criterion were established for each year. These revised protein ranges are shown in the top half of Table 23. The resulting mean protein levels are given in the lower half; and these seem reasonably satisfactory.

A comparison of what moves "In" with what moves "Out" is shown in Table 24. Mean protein levels for each grade behave as expected. The differences between the "In" and "Out" protein means seem reasonably small; of the order of 0.1 to 0.4 percentage units. Yet relatively large percentages of the sub-grades are promoted. The bottom sub-grade disappears entirely in the two high protein years. Bushel weights tend to fall by 0.1 to 0.2 lbs., which seems negligible.

Promotions are recorded in Table 25. Percentage of No. 1 CW promoted are shown in the top section. The most interesting data are those in the bottom line, which represent the total percentage of No. 1 CW promoted by one sub-grade. Neglecting the low protein year (12.6%), from 20 to 30% of all carlots of No. 1 CW entering terminals are promoted by one sub-grade. The lower half of Table 25 shows the percentage of "In" cars promoted in each sub-grade. These percentages are also

Table 23. Revised Protein Ranges for Each Year to Provide for Promotions to Guarantee 15.0%, 14.0% and 13.0%.

Sub-Grade	1956-7	1957-8	1966-7 to 1968-9	1963-4	1964-5
			Revised Protein Range		
1A	-	14.9 & over	14.9 & over	14.7 & over	14.4 & over
1B	13.9 & over	13.8 - 14.8	13.7 - 14.8	13.7 - 14.6	13.9 - 14.3
1C	12.8 -	12.7 - 13.7	12.3 - 13.6	under 13.7	under 13.9
1D	under 12.8	uner 12.7	under 12.3	-	-
			Protein content, %		
1A	-	15.17	15.17	15.18	15.19
1B	14.14	14.19	14.14	14.15	14.10
1C	13.16	13.14	13.14	13.24	13.40
1D	12.19	12.22	11.80	-	-

Table 24. Comparison of Sub-Grades "in" (15.0 & over, 14.0-14.9, 13.0-13.9, under 13.0%) with Sub-Grades "Out" after Promotion.

Sub-Grade	Graded	Protein range	1956-7	1957-8	1966-7 to 1968-9	1963-4	1964-5
					Protein content, %		
1A	In	15.0 & over	-	15.24	15.26	15.43	15.62
1A	Out	Revised	-	15.17	15.17	15.18	15.19
1B	In	14.0 - 14.9	14.24	14.38	14.34	14.41	14.43
1B	Out	Revised	14.14	14.19	14.14	14.15	14.10
1C	In	13.0 - 13.9	13.31	13.37	13.49	13.58	13.58
1C	Out	Revised	13.16	13.14	13.14	13.24	13.40
1D	In	Under 13.0	12.30	12.40	12.43	12.55	12.55
1D	Out	Revised	12.19	12.22	11.80	-	-
					Distribution, %		
1A	In	15.0 & over	-	1.5	4.4	18.0	30.8
1A	Out	Revised	-	1.9	5.9	29.4	54.7
1B	In	14.0 - 14.9	2.3	10.1	31.8	47.2	42.1
1B	Out	Revised	3.4	14.5	46.1	50.0	22.7
1C	In	13.0 - 13.9	27.8	37.5	46.7	31.1	24.6
1C	Out	Revised	38.2	48.5	43.3	20.6	22.6
1D	In	Under 13.0	69.8	50.9	17.1	3.7	2.5
1D	Out	Revised	58.4	35.0	4.7	-	-
					Bushel weight, lb.		
1A	In	15.0 & over	-	61.0	61.3	61.6	60.0
1A	Out	Revised	-	60.8	61.4	60.6	60.4
1B	In	14.0 - 14.9	62.4	61.6	62.2	60.8	60.9
1B	Out	Revised	62.5	61.8	62.4	60.9	61.1
1C	In	13.0 - 13.9	63.1	62.7	62.8	61.2	61.5
1C	Out	Revised	63.0	62.8	63.0	61.4	61.6
1D	In	Under 13.0	63.1	63.0	63.2	61.9	62.2
1D	Out	Revised	63.2	63.1	63.4	-	-

Table 25. Percentage Promoted with Wheat Graded "In" at 15.0% & over, 14.0-14.9%, 13.0-13.9%, under 13.0%.

Promotion	1956-7	1957-8	1966-7 to 1968-9	1963-4	1964-5
			Percentage of 1 CW		
1B to 1A	-	0.4	1.5	11.4	23.9
1C to 1B	1.1	4.8	15.8	14.2	4.5
1D to 1C	11.5	15.8	12.4	3.7	2.5
Total, by one sub-grade	12.6	21.0	29.7	28.9	30.9
			Percentage of Sub-grade		
1B to 1A	-	4.0	4.7	23.3	56.8
1C to 1B	3.9	12.8	33.8	45.7	18.3
1D to 1C	16.5	31.0	72.5	100.	100.

substantial; neglecting the low-protein year, from 31 to 100% of No. 1D is promoted to No. 1C; from 13 to 45% of No. 1C to No. 1B; and from 4 to 57% of No. 1B to No. 1A.

It should be emphasized that the criterion of 0.15 percentage points above the guaranteed level may not provide adequate protection. If this protection is increased, the percentage of promotions will be reduced.

The promotion system must also be compared with a corresponding rigid non-mixing system. Accordingly a comparison was made with Option 4B (middle four lines of data in each section of Table 20). The results of this comparison are shown in Table 26, which corresponds to Table 25.

As would be expected, the promotion system is identical with Option 4 in the lowest protein year; and promotion is progressively more advantageous as the mean annual protein level increases. The percentages of carlots of No. 1 CW gaining one sub-grade, if promotion is used rather than Option 4, remains substantial: 8% in the medium-low years, and well over 20% in the higher protein years.

The promotion system can be considered from a different viewpoint. Instead of the promotion taking place within the terminals it could be achieved as the grain moves into the terminals. In such a situation the sub-grade boundaries would be allowed to vary to produce a specified protein mean for the sub-grade

A computer program which simulated this variable sub-grade boundary technique was developed. A sample copy of the output from the program is shown in Table 27. The program first establishes a protein frequency

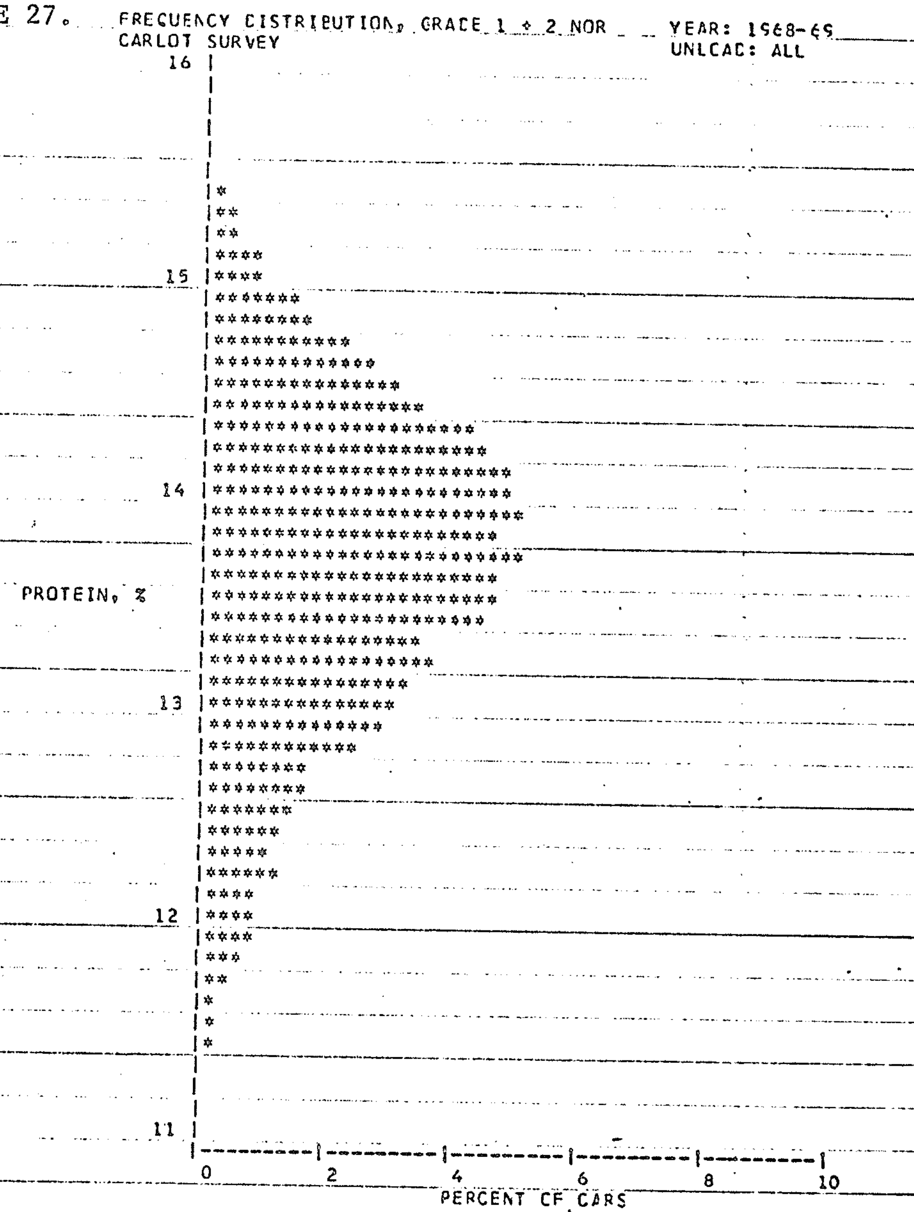
Table 26. Percentages Promoted with Wheat Graded "In" at 15% & over, 13.9-14.9%, 12.8-13.8%, under 12.8%.

Promotion	1956-7	1957-8	1966-7 to 1968-9	1963-4	1964-5
			Percentage of 1 CW		
1B to 1A	-	0.4	1.5	11.4	23.9
1C to 1B	0	2.6	10.8	9.1	0
1D to 1C	0	5.2	7.3	2.1	1.6
Total, by one sub-grade	0	8.2	19.6	22.6	25.5
			Percentage of Sub-grade		
from 1B	-	3.2	4.1	21.8	51.3
from 1C	0	5.7	23.1	33.0	0
from 1D	0	12.9	61.3	100.	100.

TABLE 27.

FREQUENCY DISTRIBUTION, GRADE 1 + 2 NOR CARLOT SURVEY — YEAR: 1968-69 UNLOAD: ALL

PROT-EIN, %	CAR COUNT	CARS %	CUMULATIVE CARS, %	CUMULATIVE PRCT, %	SEGREGATION CARS, %	SEGREGATION PROT, %
OVER	4	0.1	0.1	16.10		
15.9	0	0.0	0.1	16.10		
15.8	1	0.0	0.1	16.04		
15.7	1	0.0	0.1	15.98		
15.6	8	0.2	0.3	15.76		
15.5	8	0.2	0.5	15.67		
15.4	12	0.3	0.8	15.57		
15.3	23	0.5	1.3	15.46		
15.2	24	0.6	1.9	15.39		
15.1	38	0.9	2.8	15.29		
15.0	43	1.0	3.8	15.22		
14.9	68	1.6	5.3	15.12		
14.8	76	1.8	7.1	15.04	7.1	15.04
14.7	99	2.3	9.4	14.96		
14.6	120	2.8	12.2	14.88		
14.5	130	3.0	15.2	14.80		
14.4	152	3.5	18.7	14.73		
14.3	188	4.4	23.0	14.65		
14.2	193	4.5	27.5	14.57		
14.1	212	4.9	32.4	14.50		
14.0	214	5.0	37.4	14.44		
13.9	217	5.0	42.4	14.37		
13.8	204	4.7	47.1	14.31		
13.7	222	5.1	52.3	14.25		
13.6	204	4.7	57.0	14.20		
13.5	205	4.7	61.8	14.15	54.7	14.03
13.4	198	4.6	66.3	14.09		
13.3	155	3.6	69.9	14.05		
13.2	157	3.6	73.6	14.01		
13.1	144	3.3	76.9	13.97		
13.0	133	3.1	80.0	13.93		
12.9	125	2.9	82.9	13.90		
12.8	104	2.4	85.3	13.87		
12.7	77	1.8	87.1	13.84		
12.6	75	1.7	88.8	13.82		
12.5	68	1.6	90.4	13.80		
12.4	59	1.4	91.8	13.78	30.0	13.01
12.3	51	1.2	92.9	13.76		
12.2	56	1.3	94.2	13.74		
12.1	43	1.0	95.2	13.72		
12.0	39	0.9	96.1	13.70		
11.9	36	0.8	97.0	13.69		
11.8	31	0.7	97.7	13.67		
11.7	21	0.5	98.2	13.66		
11.6	17	0.4	98.6	13.65		
11.5	16	0.4	98.9	13.65		
11.4	13	0.3	99.2	13.64		
11.3	4	0.1	99.3	13.64		
11.2	4	0.1	99.4	13.64		
11.1	6	0.1	99.6	13.63		
11.0	4	0.1	99.7	13.63		
REMAINDER	15	0.3	0.3	10.73	8.2	11.88
ALL	4317	100.0	100.0	13.62	(S.C. = 0.84)	



distribution and then sequentially "cuts", from the top end of the distribution, a series of sub-grades of a predefined mean protein content. In the example presented in Table 27, protein means of 15.0, 14.0 and 13.0% were required; columns 6 and 7 show the percentage of carlots and the mean protein content of each of the sub-grades, with the sub-grade minima at 14.8, 13.5, and 12.4% protein. The program also produces a line printer plot of the protein frequency distribution. In fact, the protein curves presented in Figures 4, 5 and 6 of Section II are reproductions of the printer plots from this program.

In practice, the setting of the variable boundaries would presumably be the responsibility of the Canadian Grain Commission. The overall result should be the same irrespective of whether promotion is permitted or the boundaries are adjusted.

5. General Discussion

The above presentation shows that there are two main factors to consider in the selection of a protein grading system for wheat:

(1) The protein level of the guarantee; sub-grades should be designed to guarantee:

 (a) 13.0%, 14.0% (and 15.0% when available), or

 (b) 13.5%, 14.5% (and 15.0% when available).

(2) Methodology of protein grading; the system should be:

 (a) a rigid non-mixing system, or

 (b) a system involving promotion of carlots within terminals, or

(c) a system involving promotion of carlots as they enter the terminals.

Option 1a is preferable to 1b since it follows current world marketing practices.

With respect to methodology, the rigid system (2a) appears the least desirable of the three sub-options for two reasons. First, since the segregation levels must be set high enough to protect the guarantee in the low protein years, excessive amounts of high-protein wheat will be given away in high protein years. Second, within each protein subgrade variability would be greater under rigid method than with the promotion method.

It appears that either promotion system, 2b or 2c, is advantageous to producers because substantial quantities of the wheat are promoted one sub-grade. Moreover, cargoes of wheat leaving the country will be more homogeneous both within and between years. The increase in homogeneity should definitely benefit the producer in the long run.

With option 2b it is assumed that the promotion would be undertaken by terminal operators on a fee per carlot basis; and that for each carlot promoted, the price spread between sub-grades, less a fee, would be added to the pooled payments to producers for the lower two sub-grades involved. This system is advantageous to terminals, provided that the promotion fee represents adequate compensation for the valuable service the terminals will render producers. The system also makes full use of the experience and skill of terminal management and staff.

Option 2c retains many of the advantages associated with promotion, but, with decision-making and control more centralized, the system may be easier to administer. However, it does not take full advantage of the skill and experience of terminal operators.

The system eventually adopted by the Canadian Grain Commission was option 1a for Eastern shipments and option 1b for Western shipments; option 2c was selected as the method of achieving the desired protein level.

It should be noted that all the above protein data represent single determinations on single samples. It was assumed that experimental errors would cancel out and would not introduce any systematic bias. However, it was demonstrated later that, under practical conditions, the experimental error does introduce a systematic bias. This topic will be discussed in a later section (pp. 138 to 141).

F. Subsidiary Studies

Two subsidiary studies were undertaken and are discussed in this section. The first related to the proposal that the new top grade should have a minimum bushel weight of 60 rather than 58 pounds per bushel. The second concerned the possible relation between protein content and moisture content, and the question of whether sub-grades of different protein levels would also have different moisture levels.

1. Effect of Excluding Wheat of Less Than 60 Pounds Per Bushel

The minimum bushel weight for wheat entering grade 1 Northern is 60 lbs.; for 2 Northern 58 lbs. When these two grades are combined to form 1 CW the minimum bushel weight might be raised to 60 lbs., thus eliminating a portion of the current 2 Northern carlots. The effect of such a decision on the protein sub-grades was examined using historical data. A report on this matter was submitted to the Canadian Grain Commission in May, 1970. This study was made with data on carlot shipments of No. 2 Northern, unloaded at the Lakehead and the Pacific coast, in the five crop years 1956-57, 1957-58, 1959-60, 1963-64 and 1966-67. The grade is divided into wheat of 60 lb. per bushel or over, and wheat of under 60 lb.; it is further subdivided into three protein categories: under 13.0%; 13.0 - 14.4%; and over 14.4%.

Table 28 shows the distribution of the grade between unload areas and between bushel weight categories. Unloads at the Lakehead represented 68% compared with 32% at Pacific terminals. Wheat of under 60 lb. per bushel represented 10.9% of the grade, and the proportion of low weight wheat was far higher at the Lakehead than at Pacific terminals.

Table 29 shows the distribution among protein ranges for total unloads in both unload areas. Wheat of low bushel weight is divided almost equally between the high and medium protein ranges and is negligible in the low protein range. In the high protein range, the removal of lower weight wheat reduces the total amount in the range from 20.6 to 15.2%, a reduction of 26% in the amount of high protein 2 Northern that might

Table 28. Grade Distribution Among Bushel Weight Ranges for Lakehead and Pacific Unloads.

No. 2 Northern	Lakehead	Pacific	Both Areas
		Number of Carlots	
Total grade	11,524	5,425	16,949
60 lb. and over	9,951	5,144	15,095
under 60 lb.	1,573	281	1,854
		Percentages	
Total grade	68.0	32.0	100
60 lb. and over	58.7	30.4	89.1
under 60 lb.	9.3	1.6	10.9

Table 29. Grade Distribution Among Bushel Weight and Protein Ranges for Lakehead and Pacific Unloads Combined.

No. 2 Northern	Protein range in %			
	Under 13.0	13.0-14.4	over 14.4	Total
		Number of carlots		
Total grade	3,873	9,586	3,490	16,949
60 lb. and over	3,846	8,681	2,568	15,095
under 60 lb.	27	905	922	1,854
		Percentage		
Total grade	22.8	56.6	20.6	100
60 lb. and over	22.7	51.2	15.2	89.1
under 60 lb.	0.1	5.4	5.4	10.9

be made available for export.

The percentage distribution among protein ranges for 2 Northern and on that part of it weighing 60 lb., or more, is also interesting:

	Under 13.0%	13.0 - 14.4%	over 14.4%	Total
Total grade	22.8	56.6	20.6	100
60 lb. & over	25.5	57.5	17.0	100

These data emphasize that removal of wheat of under 60 lb. has the effect of decreasing the percentage of high protein wheat and increasing the percentage of low protein wheat. The same effect would be apparent if the high protein range were established at over 14.2%.

The data are presented in more detail for Lakehead unloads in Table 30. Trends noted above are even more apparent for Lakehead unloads. The amount of high protein wheat is reduced from 21.6% to 15.2% when the low weight wheat is removed. Data for mean protein content and mean bushel weight are also shown. Removal of low weight wheat reduces the mean protein content by 0.04% in the high range and by less in the other two ranges. Mean bushel weight is increased by 0.65 lb. in the high protein range, by 0.3 lb. in the medium range, and by 0.04 lb. in the low range.

Corresponding data for Pacific unloads are shown in Table 31. The same comments apply, but the effects are less pronounced.

It is not easy to decide whether it would be advantageous to exclude 2 Northern of less than 60 lb. per bushel from the proposed grade of No. 1 CW wheat. The reduction in the amount of wheat entering the high protein sub-grade would be partially offset by the gain in average

Table 30. Grade Distribution Among Bushel Weight and Protein Ranges for Lakehead Unloads.

No. 2 Northern	Protein range in %			
	Under 13.0	13.0-14.4	over 14.4	Total
		Number of Carlots		
Total grade	2,049	6,989	2,486	11,524
60 lb. and over	2,026	6,179	1,746	9,951
under 60 lb.	23	810	740	1,573
		Percentages		
Total grade	17.8	60.6	21.6	100
60 lb. and over	17.6	53.6	15.2	86.4
under 60 lb.	0.2	7.0	6.4	13.6
		Mean Protein Content, %		
Total grade	12.42	13.77	14.94	
60 lb. and over	12.41	13.74	14.90	
under 60 lb.	12.60	13.94	15.02	
		Mean Bushel Weight, lb.		
Total grade	62.47	61.01	60.20	
60 lb. and over	62.51	61.31	60.85	
under 60 lb.	58.74	58.75	58.68	

Table 31. Grade Distribution Among Bushel Weight and Protein Ranges for Pacific Unloads.

No. 2 Northern	Protein range in %			
	Under 13.0	13.0-14.4	over 14.4	Total
	Number of Carlots			
Total grade	1,824	2,597	1,004	5,424
60 lb. and over	1,820	2,502	822	5,144
under 60 lb.	4	95	182	281
	Percentages			
Total grade	33.6	47.9	18.5	100
60 lb. and over	33.5	46.1	15.2	94.8
under 60 lb.	0.1	1.8	3.3	5.2
	Mean Protein, %			
Total grade	12.33	13.62	15.08	
60 lb. and over	12.33	13.60	15.04	
under 60 lb.	12.75	13.95	15.29	
	Mean Bushel Weight, lb.			
Total grade	63.18	62.27	60.88	
60 lb. and over	63.19	62.40	61.37	
under 60 lb.	58.75	58.65	58.66	

bushel weight of that sub-grade, and a similar situation would occur in medium protein sub-grade.

It is interesting to note that the decision finally made by the Canadian Grain Commission was to compromise by excluding wheat of less than 59 pounds per bushel from the new grade of No. 1 Canada Western Red Spring Wheat.

2. Relations Between Moisture and Protein Content

Moisture data for the three year period 1966-67 to 1968-69 are presented in Table 32. Mean data are given for Nos. 1, 2, 3 and 4 Northern (and for 1 and 2 Northern combined, i.e. No. 1 CW) for all unloads and separately for Lakehead and Pacific unloads, for each year, and for the weighted mean.

The characteristic increase in moisture content with increase in grade number is clearly apparent. On average, No. 1 Northern is 0.6 percentage units lower in moisture content than No. 2 Northern. When the two grades are combined to form No. 1 CW, this grade will be about 0.5 percentage units higher in moisture than No. 1 Northern and about 0.1 percentage units lower than No. 2 Northern.

Differences between Lakehead and Pacific unloads are small and neither area has any consistent advantage in moisture level.

Table 33 presents mean data for 1 and 2 Northern combined (No. 1 CW), for No. 3 Northern, and for No. 4 Northern divided into 0.5 percentage increments of protein content. There is a definite tendency

Table 32. Moisture Data for Present Grades.

Grade	Unload	Moisture Content, % 1966-7	1967-8	1968-9	Wt'd Mean
1 Northern	Lakehead	12.5	12.3	12.6	12.4
	Pacific	12.8	12.2	12.4	12.4
	All	12.6	12.2	12.5	12.4
2 Northern	Lakehead	13.2	12.8	13.2	13.1
	Pacific	13.1	12.8	13.3	13.1
	All	13.1	12.8	13.2	13.0
1 + 2 Northern	Lakehead	13.1	12.6	13.0	12.9
	Pacific	13.0	12.5	13.0	12.8
	All	13.0	12.6	13.0	12.9
3 Northern	Lakehead	13.9	13.3	14.8	14.0
	Pacific	14.4	13.7	14.7	14.3
	All	14.0	13.4	14.7	14.0
4 Northern	Lakehead	14.8	14.2	15.8	15.6
	Pacific	14.5	14.4	16.3	15.3
	All	14.6	14.3	16.5	15.5

Table 33. Moisture Data for Protein Ranges of 0.5% Within Grades (All unload areas).

Grade	Protein range %	Moisture Content, %			
		1966-7	1967-8	1968-9	Wt'd Mean
1 + 2 Northern	15.0 & over	12.8	12.3	12.8	12.58
	14.5 - 14.9	12.9	12.4	12.8	12.66
	14.0 - 14.4	13.0	12.6	12.9	12.79
	13.5 - 13.9	13.0	12.6	13.0	12.84
	13.0 - 13.4	13.0	12.6	13.0	12.91
	12.5 - 12.9	13.1	12.7	13.1	12.94
	under 12.5	13.4	12.9	13.4	13.21
3 Northern	15.0 & over	13.7	13.4	14.9	14.28
	14.5 - 14.9	13.7	13.2	14.7	13.92
	14.0 - 14.4	13.8	13.3	14.5	13.85
	13.5 - 13.9	13.9	13.3	14.4	13.88
	13.0 - 13.4	14.0	13.4	14.9	14.02
	12.5 - 12.9	14.0	13.5	15.0	14.05
	under 12.5	14.7	14.0	15.4	14.63
4 Northern	15.0 & over	14.4	14.0	16.5	16.15
	14.5 - 14.9	14.4	13.9	16.7	16.34
	14.0 - 14.4	14.5	14.2	16.6	15.77
	13.5 - 13.9	14.6	14.3	16.4	15.21
	13.0 - 13.4	14.6	14.0	16.4	14.95
	12.5 - 12.9	14.5	14.0	16.4	14.95
	under 12.5	15.2	15.2	16.6	15.77

for moisture level to decrease with increasing protein content, especially in 1 CW. For 1 CW, the difference in moisture is small; about 0.3 percentage units between wheat of 15.0% protein and over and wheat of 12.5% to 12.9% protein. For No. 1 CW and for No. 3 Northern, wheat of under 12.5% protein is always highest in moisture content. Results for No. 4 Northern are less consistent.

The wet year, 1968-69, introduces variations in the data for 3 Northern and 4 Northern and these also affect the weighted means. For the two years, 1966-67 and 1967-68, the trends in the data for these two grades (Nos. 3 and 4) are similar to those for No. 1 CW.

The inverse relationship between protein content and moisture content probably reflects a greater probability of poorer harvest conditions in the more Northern low protein areas of the provinces. However, it may be concluded that no major problems associated with moisture content will arise when protein grading is implemented.

IV. IMPLEMENTATION STUDIES

A. Introduction

In the preliminary studies historical data on the protein content of Canadian wheat were analyzed in an attempt to develop alternative methods by which protein segregation might be achieved. The research described in the following sections was undertaken on data collected by the C.G.C. under conditions similar to those expected to occur when protein segregation actually becomes a reality.

At this time, early in 1971, there had been a tentative decision to develop a system that would permit guaranteeing protein content in export shipments at 15, 14 and 13%, or at 14.5, 13.5 and 12.5%. It eventually turned out that the first set of levels was introduced for Atlantic shipments and the second for Pacific shipments.

Obtaining data for the research was no simple matter. The C.G.C. was heavily engaged in developing new techniques for accumulation and transmission of data and the design of control procedures for protein segregation. Its laboratories were being expanded, and new staff were being trained. Furthermore, methods of integrating the data accumulation and flow procedures of the protein laboratories with those of the Inspection Division and the Economics and Statistics Division were being developed. Under these conditions, research had to be undertaken with such data as became available rather than with sets of data designed for research purposes.

The research reported in the following sections dealt mainly with Pacific shipments, though some data were also investigated for Thunder Bay. The problems presented for both westward and eastward movements are similar, and it appeared that the principles developed in studying one movement would apply equally to the other.

B. Brief Outline of the Protein Segregating Procedures

The design of the system to segregate wheat by protein content is heavily dependent on the accuracy of the method used to measure protein content. At this point in time, the Kjeldahl procedure for measuring protein content is the most accurate and widely accepted method available. However, it is time consuming and it is not practicable to take a sample as a carlot of wheat is being unloaded and delay binning until the Kjeldahl protein test can be completed. The following is a brief outline of the methods developed by the C.G.C. to secure advance data on the protein content of each carlot of wheat to enable it to be binned by protein content at the terminal elevators.

The procedure for acquiring the advance information starts at the country elevators. The elevator operator is required to forward by mail a representative sample of the contents of each carlot directly to the C.G.C. grain inspection offices at Winnipeg or Calgary. The sample should consist of a sub-sample of each scale load or "draft" of about 100 bushels which goes to make up a carlot of about 2,000 bushels. However, if the agent is busy, one supposes that he may take a single "grab sample" during or after loading the carlot.

On arrival at the C.G.C.'s inspection office the above sample, called the "Primary sample", is cleaned, graded, moisture content is determined and a sub-sample is sent to the laboratory, with the relevant documentation, for protein determination. The protein values, corrected to a 13.5% moisture basis, are recorded on the documents which are then returned to the communications centre of the inspection division. Here, the information is transferred to paper tape and sent via telex to the central control office at Thunder Bay or Vancouver. At the unload area central office the information is filed by boxcar number. When the carlots arrive on track at a terminal, an employee of the C.G.C. records the car numbers for each shunt and telephones the C.G.C.'s central office for the Primary sample grade and protein sub-grade. With this information available, the carlot can be binned by grade and protein sub-grade.

During unload, the stream of wheat is continuously sampled; from this "Unload sample" a sub-sample is drawn and sent to the protein laboratories for eventual comparison with the Primary sample. All the information available at unload time is consolidated, coded, and transferred to paper tape, and subsequently transmitted via teletype - card punch to Winnipeg. Finally, when the Unload sample protein becomes available, probably two weeks later, the Unload protein value for each carlot is merged with the original data.

C. Description and Treatment of Available Data

Prior to the introduction of protein grading, a substantial quantity of protein data on both Primary and Unload samples was collected by the C.G.C. to test the above data acquisition procedures. Part of this data was obtained from the C.G.C. on punch-cards. Each carlot was represented by a punch-card which contained information on: boxcar number; consignor; station of origin; railway company; unload area; unload terminal; grade; together with Primary and Unload protein contents. Carlots for which the Primary protein was not available at unload time were also identified.

The cards were obtained periodically from the C.G.C. and read *in toto* onto magnetic tape using the University IBM 360/65 computer. A sequence number was added to each record for identification purposes. The data on each record was verified, using a specially prepared Fortran program, against a master file containing station names, consignors, and unload terminal names; range checks were also made to detect, and subsequently correct, errors in the data. At about this time, the C.W.B. reorganized the ordering of grain shipments. The shipping area was divided into 48 "Railway Blocks", each of these had from 5 to 10 "Train Runs". The geographic origin of the carlots, by Block and Train Run, also contained in the master file, was added to each record.

To analyze the data, a number of Fortran programs were developed to simulate various aspects of the proposed protein segregating system. Sample copies of what are considered to be the most useful outputs obtained from some of these programs are presented in a later section.

The data examined were collected over a considerable period during the 1970-71 crop year and were analyzed by weeks. Such a time period would probably approach what would be practical when the system becomes operational. For convenience, the week was defined by the date of unload of the carlots. Table 34 shows the time periods studied, with weeks numbered from 1 to 12.

Table 34. Time Periods Over Which the Selected Data Were Collected.

Week No.	Time Period
1	Dec. 31 - Jan. 6
2	Jan. 7 - Jan. 13
3	Jan. 14 - Jan. 20
4	Feb. 11 - Feb. 17
5	Feb. 18 - Feb. 24
6	Feb. 25 - Mar. 3
7	Mar. 4 - Mar. 10
8	Mar. 11 - Mar. 17
9	June 6 - June 12
10	June 13 - June 19
11	July 4 - July 10
12	July 11 - July 17

It should be noted that the data were collected over four separate time periods. Weeks 1, 2 and 3 are consecutive, followed by a break; weeks 4 though 8 are also consecutive, followed by about a two month break; the third period consists of weeks 9 and 10; weeks 11 and 12 comprise the fourth and final period studied.

Between weeks 8 and 9 a significant development occurred in the transportation logistics of Canadian grain. Data collected prior to and including week 8 were obtained under a transportation system which had been in effect for many years. Under this system carlots were allocated among terminals on the basis of the company of origin. As mentioned earlier, this system results in certain terminals obtaining carlots from a limited geographic area, which may be of high or low protein level.

In Summer 1971, in the interest of increasing handling capacity to meet record sales commitments, the various interests involved in grain movement agreed that carlots of grain would be allocated among terminals irrespective of the company of origin. Data collected from week nine onwards were obtained under the "new" transportation structure. For the purpose of this dissertation data collected under the new system are referred to as "Pooled Carlots" while the earlier data referred to as "non-Pooled Carlots". Since different quality control procedures may be necessary under the different transportation structures it seemed desirable to maintain the transportation identity.

D. Comparison of Primary and Unload Samples

Since both a Primary and an Unload sample were taken from each carlot a paired comparison between the primary and unload proteins can be made. It is pertinent to note, however, that the paired samples were obtained by different sampling procedures at different times and went through the protein laboratory on different dates. Hence, observed differences between the treatments reflect sampling errors, accuracy of the protein test, and the stability of the laboratory results over time.

Data for weekly paired comparisons are presented in Table 35. Column one shows that week in which the boxcars were unloaded. Column two shows the number of carlots unloaded in each week; as expected the number varies from week to week. Weekly Primary and Unload means are shown in columns three and four, respectively. As expected the means for both sample sets vary from week to week. However, within a week it was anticipated that the means for both sample sets would be essentially equal. The within-week difference between Unload and Primary means is shown in column five. It is noteworthy that in eleven of the twelve weeks studied that the Unload mean exceeds the Primary mean. Although the differences are small such an occurrence would indicate a systematic bias of some kind. It is doubtful if this bias could be attributed to laboratory stability. Since there is a time lag between protein testing of the Primary and its Unload pair, continuous positive differences between Unload and Primary means could only be attributed to the laboratory if the laboratory results were continuously increasing over time. There was no evidence of such an increase, and no explanation of the consistent difference between the Primary and Unload means has been developed.

The standard deviation of the difference between the Primary and the Unload samples for each week is shown in column six. The standard deviations indicate that the variance of the difference between Primary

Table 35. Weekly Paired Comparisons Between Primary and Unload Samples for Protein Content.

Week No.	Carlots	Primary Mean	Unload Mean	Difference U-P	S.D. of D	t Value
1	298	13.34	13.45	.11	.46	4.13**
2	539	13.22	13.35	.13	.41	7.36**
3	621	13.40	13.43	.03	.36	2.08*
4	675	13.57	13.63	.06	.28	5.56**
5	791	13.72	13.83	.11	.33	9.37**
6	937	13.65	13.70	.05	.28	5.46**
7	882	13.73	13.78	.05	.28	5.30**
8	677	13.95	14.02	.07	.28	6.51**
9	1012	13.91	14.08	.17	.44	12.29**
10	1107	13.85	13.93	.08	.40	6.65**
11	879	13.81	13.72	-.09	.41	6.51**
12	1373	13.79	13.84	.05	.40	4.63**

* Significant at 5% level.

** Significant at 1% level.

and Unload was considerably smaller in weeks 4 through 8 than in the remaining weeks. This is examined in more detail in a later section.

The last column of Table 35 shows weekly paired t values. The t values indicate that in 11 of the 12 weeks studied there were highly significant differences between the sample sets. Moreover, the t-value for the remaining week (week 3) was significant at the 5% level. However, each t-value is based on a very large number of degrees of freedom and hence small differences between the two means tend to result in significant t-values. Therefore, the significance of these differences under operational conditions should not be exaggerated.

E. The Performance of the Primary Sample in the Segregation of Carlots of Wheat by Protein Content

As previously mentioned, protein tests on the Primary samples offer a practical method of segregating carlots by protein content. A simulated segregation was therefore made on the carlot data for the 12 individual weeks. The protein content of the sub-grades was monitored by means of Unload sample proteins. The object was to divide the main grade (1 CW) into three sub-grades: the first guaranteeing 14.5% protein (1 CW 145); the second guaranteeing 13.5% (1 CW 135); and the third representing the remainder (1 CW 125). For this purpose boundaries were set at 14.4% and over, 12.8 to 14.3%, and under 12.8%. The results of this study are shown in Table 36 for each of the 12 weeks (column one), and these are arranged in decreasing order of the protein mean for the main grade (column 6). As expected the percentage of the carlots

Table 36. The Weekly Distribution of Carlots Among Protein Sub-Grades and Sub-Grades Mean Protein Content Based on Primary and Unload Samples.

Week No.	CARLOTS				CARLOTS SEGREGATED BY PRIMARY: Primary Protein Mean, %				Unload Protein Mean, %			
	1CW	1CW145 %	1CW135 %	1CW125 %	1CW	1CW145	1CW135	1CW125	1CW	1CW145	1CW135	1CW125
8	677	27.8	66.9	5.2	13.95	14.68	13.78	12.27	14.02	14.69	13.86	12.42
9	1012	24.5	68.7	6.8	13.91	14.80	13.74	12.33	14.08	14.77	13.95	12.84
10	1107	26.6	64.8	8.6	13.85	14.76	13.67	12.37	13.93	14.60	13.81	12.73
11	879	24.1	65.9	10.0	13.81	14.76	13.68	12.34	13.72	14.47	13.62	12.52
12	1373	21.8	68.6	9.6	13.79	14.76	13.67	12.38	13.84	14.60	13.77	12.65
7	882	18.1	70.4	11.5	13.73	14.66	13.71	12.33	13.78	14.61	13.78	12.42
5	791	23.1	65.8	11.1	13.72	14.76	13.61	12.26	13.83	14.78	13.71	12.49
6	937	18.7	65.9	15.4	13.65	14.69	13.68	12.25	13.70	14.61	13.75	12.35
4	675	13.8	71.1	15.1	13.57	14.74	13.62	12.27	13.63	14.65	13.69	12.42
3	621	14.2	61.2	24.6	13.40	14.69	13.55	12.28	13.43	14.62	13.56	12.42
1	298	10.0	65.8	24.6	13.34	14.70	13.52	12.30	13.45	14.62	13.61	12.56
2	539	7.8	62.5	29.7	13.22	14.80	13.47	12.28	13.35	14.71	13.58	12.52

in the 1 CW 145 sub-grade (column 3) decreases, and the percentage in the 1 CW 125 (column 5) sub-grade increases, as the 1 CW mean protein content decreases. These changes are substantial for a relatively small change in the mean protein content for 1 CW, from 13.95 to 13.22%. The percentage in the middle sub-grade (1 CW 135) is much more stable.

Primary protein means for the sub-grades are quite stable from week to week; for 1 CW 135 weekly means have a range of 0.3 protein percentage units, for 1 CW 145 and 1 CW 125 the range is about 0.1 percentage units. Unload means for the sub-grades show a somewhat larger week to week variation than the Primary means. It is also apparent that sub-grade means are related to the 1 CW mean.

When weekly Primary and Unload means within the protein sub-grades are compared certain consistent features become evident. Weekly mean differences between Unload and Primary samples for 1 CW and the three protein sub-grades are shown in Table 37. Column 2 shows that the Unload mean for 1 CW exceeded the Primary mean in all weeks except week 11 when the reverse was true. However, when the samples were segregated into three protein sub-grades on the basis of the primary protein the relationship between Primary and Unload mean observed for 1 CW does not hold: for 1 CW 145 the mean of the Unload Samples is less than the mean for the Primary samples in 10 of the 12 weeks studied; for 1 CW 135 and 1 CW 125 the Unload mean exceeds the Primary means with only one exception; and for 1 CW 125 the differences are much larger than they are for 1 CW 135. It is also noteworthy that the within sub-grade differences

Table 37. Weekly Mean Differences Between Primary and Unload Proteins for 1 CW and the Three Protein Segregates.

Week No.	Mean Difference (U-P)				Primary		
	1CW	1CW145	1CW135	1CW125	S.D. of D.	S.D.	ρ
8	.07	.01	.08	.15	.28	.68	.92
9	.17	-.03	.21	.51	.44	.74	.82
10	.08	-.16	.14	.36	.40	.77	.87
11	-.09	-.29	-.06	.18	.41	.79	.87
12	.05	-.16	.10	.27	.40	.76	.86
7	.05	-.05	.07	.09	.28	.74	.93
5	.11	.01	.10	.23	.33	.83	.92
6	.05	-.06	.07	.10	.28	.83	.94
4	.06	-.09	.07	.15	.28	.80	.94
3	.03	-.07	.01	.14	.36	.86	.91
1	.11	-.08	.09	.26	.46	.81	.84
2	.13	-.09	.11	.24	.41	.82	.88

between corresponding Unload and Primary means tend to increase as the mean protein level of 1 CW decreases. Thus, it would appear that the segregation of carlots on the basis of Primary sample protein content introduces a systematic bias into the system. Regression theory provides a satisfactory explanation of this phenomenon.

F. Regression Theory as it Relates to the Segregation of Wheat by Protein Content

The linear relationship between Unload Protein contents of carlots, U, and Primary protein contents, P, of those same carlots is given by

$$(U-\bar{U}) = \beta\ (P-\bar{P}) \qquad (1)$$

where $\bar{U}$ and $\bar{P}$ are the mean Unload and Primary proteins of carlots being considered and β is the coefficient of linear regression of Unload protein contents on Primary protein contents. Application of this equation to protein segregation assumes only that errors in protein determination are independent of the true protein content.

If the standard deviations of Unload and Primary protein contents are equal, the regression coefficient β can be replaced by the correlation coefficient ρ by the following identity:

$$\beta = \frac{\sigma_{up}}{\sigma^2_p} = \frac{\sigma_{up}}{\sigma_u \sigma_p} = \rho \text{ , since } \sigma_u = \sigma_p$$

Thus, linear regression theory, as applied to the problem of protein segregation of Canadian wheat, takes the mathematical form

$$(U-\bar{U}) = \rho_{up}\ (P-\bar{P}) \qquad (2)$$

In words, the amount by which the Unload protein content of a given subgrade differs from the overall protein content is expected to equal the amount by which the Primary protein content differs from the overall protein content multiplied by the factor ρ_{up}. The factor ρ_{up} is the linear correlation between Unload and Primary protein contents of the carlots being considered.

This application of regression theory is equivalent to that discussed by Cochran (92) where phenotypic values (Primary proteins) provide the basis of selection for improvement of genotypic values (Unload proteins).

In Cochran's paper the purpose of selection was to maximize the mean value of the selected portion while maintaining a specific fraction of the original population. Birnbaum (93), in 1950 investigated the related problem of maximizing the fraction of the population that is retained, subject to the condition that the mean value of the selected universe has some preassigned value. Birnbaum showed that truncation by means of linear regression was optimum for this problem also. The segregation of carlots of wheat by protein content is essentially the same as the selection problem investigated by Birnbaum. The mathematical technique used by Birnbaum to determine the truncation point could be used to establish the protein sub-grade minima in the segregation of carlots of wheat.

The selection problems studied by Cochran (92) and by Birnbaum (93), as in most selection programmes, only involved selection from one end of the population whereas the segregation of carlots of wheat by protein content involves the simultaneous selection of all carlots to give two, or more, pre-defined sub-grades. Hence, the term "segregation" rather than selection appears to be more descriptive of this specific application of the selection process.

Using equation 2, and the Primary protein data from Table 36 and the weekly correlation between Primary and Unload samples shown in the last column of Table 37, it is possible to predict with reasonable precision the weekly Unload mean protein for each of the sub-grades in Table 36.

It is noteworthy that the difference in the Unload mean is always a fraction of the difference in the Primary mean. Consequently, if the segregation is made above the 1 CW mean, the Primary mean of the segregated portion of the distribution will always exceed the corresponding Unload mean. Conversely, if the segregation is made below the 1 CW mean, the Primary mean of the segregated portion will be lower than the Unload mean. Furthermore, as the sub-grade minimum moves further and further away from the 1 CW mean (i.e. as the selection intensity increases) the absolute difference between the sub-grade Unload and Primary means increase.

Table 36 shows the same result is obtained if the sub-grade minima are held constant while the 1 CW mean varies. The shape of the distribution is also a factor influencing the selection intensity; assuming a distribution of constant mean and sub-grade minima, the selection intensity increases as the distribution becomes more peaked. The standard deviations shown in column 7 of Table 37 indicate that the shape of the distribution does actually vary from week to week. Determining the optimum sub-grade minima will be the subject of a later section.

G. Factors Affecting the Relationship Between the Primary and Unload Means for the Protein Sub-Grades

In equation 2 above, the magnitude of the correlation coefficient determines the proportional change in the Unload mean relative to the Primary mean, it is obvious that the larger the correlation coefficient the more effective the segregation. The magnitude of the correlation coefficient is influenced by many factors. Sokol and Rohlf (94) demonstrate that the correlation between logically paired observations (e.g. Primary and Unload proteins) may be divided into the following components:

$$\rho_{u.p} = \frac{S_u^2 + S_p^2 - S_D^2}{2\, S_u . S_p}$$

In this specific case, S_p and S_u are the respective standard deviations of the Primary and Unload samples and S_D is the standard deviation of the difference between Primary and Unload. If it is assumed that $S_u^2 = S_p^2 = S^2$, then

$$\rho_{u.p} = 1 - \frac{S_D^2}{2S^2} \qquad (3)$$

Equation 3 shows that the magnitude of the correlation coefficient, and hence segregation efficiency, is influenced by the magnitude of both the variance of the difference between Primary and Unload, and the variance of the protein distribution (i.e. protein range). The stability of both these statistics over time also influences the reliability of the regression equation (equation 2) in predicting the mean value of the protein sub-grades.

The standard deviation of the difference between Primary and Unload proteins (column 6) and the standard deviation of the Primary (column 7) for each of the 12 weeks shown in Table 37 indicates that both these statistics vary from week to week.

The homogeneity of weekly variances of the primaries and of weekly variances of the difference between Primary and Unloads were tested by Bartlett's test for homogeneity of variances (95). Each set of variances was tested for all twelve weeks combined and a separation was also made for each transportation structure referred to in Section C above. The Chi-square values obtained are shown in Table 38.

Table 38 shows that the heterogeneity of variances of the primaries for all twelve week combined are significant at the 1% level. However, when the weekly variances are tested within each transportation structure it was found that they were heterogeneous for the non-pooled carlots but homogeneous for the pooled carlots.

Table 38. Chi-Squared Values Obtained when Testing the Homogeneity of the Variance of the Primaries and the Variance of the Difference Between Primary and Unload Sample Proteins.

Type	d.f.	s_P^2	s_D^2
Non-pooled Carlots	7	54.39 **	301.51 **
Pooled Carlots	3	4.24	13.41 **
All Weeks	11	66.75 **	594.02 **

** Significant at 1% level.

Table 38 also shows that the weekly variances of the difference between Primary and Unload proteins are heterogeneous for the total period and within each transportation structure.

The heterogeneity of both sets of variances obviously affects the stability of the correlation coefficient, this in turn influences the efficiency of the regression equation in predicting the sub-grades means. In practice, attaining a stable correlation may be a difficult task. The C.W.B. in controlling the forward movement of wheat can influence the geographic origin of the carlots. Since protein content is also geographically distributed, a limited geographic distribution of the carlots by the C.W.B. would impose a protein selection at the origin. This protein selection would influence the mean and the variance of the carlots arriving at terminal positions. The smaller and more stable standard deviations for the pooled carlot period (Table 37 weeks 9 through 12) would indicate that such a selection may occur under this transportation structure. If under the pooled transportation structure the country elevator affiliations with terminals can be ignored, a limited geographic dispersion of the shipping orders may result. Protein selection by origin will be discussed in a later sub-section in relation to the Block Shipping System.

The variance of the difference between the Primary and the Unload is the second factor influencing the correlation. The variance of the difference may be further divided into sampling error and analytical error. These have been discussed in an earlier sub-section (page 17) where it was concluded that their combined errors would be about 0.3% protein. The standard deviation of the difference between Primary and Unloads should be about $\sqrt{2}$ times the combined error of .3, which is equal to .43. Table 37 shows that this value was exceeded in only weeks No. 1 and No. 9. Moreover, it may be concluded that the variances for weeks No. 3 through No. 8 were unusually small, also note the effect of this on the magnitude of the correlation in these weeks.

Since the C.G.C. operates the protein laboratories they can exercise control over the magnitude of the analytical component of the variance of the difference between Primary and Unload samples. This control is achieved by means of a laboratory "check" sample system.

The laboratory check sample records were examined in an attempt to explain the relatively large week to week variability obtained for the standard deviation of the difference between Primary and Unload samples. The check sample data indicate that the laboratory results were more variable than usual about the period the data for weeks 1 and 2 were obtained. As for weeks nine through twelve the laboratory records show that the protein tests on the Primary samples were made in the Calgary laboratory while some of the Unload proteins were done in the Winnipeg laboratory and others were done in the Calgary laboratory. It is also noteworthy that during this period the Winnipeg laboratory was being expanded to three shifts per day and consequently new staff had to be trained. In Calgary the situation was even more complex; not only was a new laboratory being "debugged" but this was being done by "new" staff.

The laboratory records further suggest that during the periods when the variance of the difference between Primary and Unload proteins were small the laboratory was not working at full capacity. Thus it would appear that, the small variances observed in weeks three through eight are at least partly the result of using experienced laboratory staff under more or less research conditions. In weeks nine through twelve the data were obtained with inexperienced staff in a new laboratory which was likely working at full capacity. Even with experienced staff it would probably be difficult to achieve the same degree of precision when the laboratory is working at full capacity as compared with the relatively relaxed conditions expected in a research laboratory. It is likely that in periods of high through-put there is less attention to detail and consequently the magnitude of the differences increase. However, the significance of maintaining the error at its absolute minimum was already noted in discussing the regression equation above.

H. Determining the Reliability of the Primary Sampling System

An attempt was next made to assess the reliability of the Primary sampling undertaken by country elevator agents. For this purpose the Inspection Division of the C.G.C. arranged to take duplicate sub-samples independently from the main Unload sample, and these then passed through the whole procedure as separate sets of samples not known to be duplicates. Protein data for these paired Unload samples were then compared with the corresponding Primary samples.

Duplicate Unload samples, together with corresponding Primary samples, were obtained for 931 carlots. Data for mean protein content, standard deviation of difference and correlation coefficients for the various sample combinations are shown in Table 39.

Table 39. Comparison of the Protein Contents of Paired Unload Samples with the Corresponding Primary Sample.

	Mean	S.D. of D.		Correlation	
	%	U_1	U_2	U_1	U_2
Unload 1 (U_1)	13.93	-	-	-	-
Unload 2 (U_2)	13.89	.33	-	.85	-
Primary (P)	13.93	.38	.40	.81	.79

The data on mean protein content show that there are only minor differences between the means of the sample sets. It may be concluded that there is no bias in the Primary sampling at country elevators. The standard deviation of the difference is smallest when Unload pairs are compared and largest when Unload set 2 and the primaries are compared. Although each Unload set performs somewhat differently when compared with the Primary, there is little doubt that the Unload sets are more closely related in themselves than is either set with the Primary. Moreover, the standard deviations of the difference between Primary and Unload samples shown in Table 39 are comparable with those reported earlier. Since the data shown in Table 39 represent Eastern grain movements and the earlier data represents Western movements it is unlikely that there were any sampling operators common to both sets of data. Hence, it may be concluded that the standard deviation of the difference between Primary and Unload proteins will be about .40.

If variances rather than standard deviations are compared, the above data indicate that the variance of the difference between Unload pairs accounts for 50% to 60% of the variance of the difference between Primary and Unload proteins. Hence, it may be concluded that sampling error accounts for the remaining 40% to 50%.

Differences between the Primary and Unload samples may arise for two reasons. First, differences may exist between the means of each set of samples. Such differences would occur if one sample set is consistently high or low relative to the other. Second, individual sample differences may be large but variable in direction. Such errors cannot be detected by comparing means. The magnitude of sample differences can be detected by calculating the standard deviation of the difference. A Fortran program which calculates the mean difference and the standard deviation of the difference between Primary and Unload samples for each company at each station was prepared. Paired samples over a number of weeks were analyzed using this program. Typical results for a number of stations for one elevator company (Saskatchewan Pool) are presented in Table 40.

Table 40. Comparison of Primary and Unload Protein by Station of Origin of Carlots.

		Protein, %			
Station	Samples	Primary	Unload	P-U	S.D. of D
HENRIBOURG	6	12.18	12.38	-.20	.15
ABERDEEN	10	13.18	13.28	-.10	.23
RICHMOUND	7	14.46	14.70	-.24	.24
BIGGAR	17	13.72	13.56	.15	.26
BORDEN	14	13.31	13.35	-.04	.28
FIELDING	8	13.44	13.38	.06	.29
DIXON	5	13.24	13.10	.14	.46
COURVAL	9	14.03	14.21	-.18	.50
MENDHAM	7	13.33	13.46	-.13	.58
TUNSTALL	4	14.65	14.67	-.02	.64
MAPLE CREEK	5	13.72	14.52	-.80	.64
LINACRE	7	13.94	14.03	-.09	.79
HAZLET	8	14.21	14.16	-.05	.97

It is apparent that the differences between the means are generally quite small, and in both directions. However, the magnitude of the standard deviations of the difference varies substantially from station to station. For about the first six stations in Table 40 the accuracy of the Primary samples is beyond criticism. However, for the stations in the lower half of the table the magnitude of the standard deviation of the difference indicates that sampling errors are both large and variable in direction. The Maple Creek samples are obviously low as indicated by the difference between the means, and variable as indicated by the magnitude of the standard deviation of the difference.

It may be concluded that differences in the standard deviations reflect sampling consistency. If Primary and Unload samples are compared periodically by an analysis of this type, it should be possible to detect operators with poor sampling technique and any attempt to "salt" samples with high protein wheat.

I. Variability in Protein Content Between Elevators Within Unload Area

In the "preliminary studies" section it was demonstrated that differences exist between the mean protein content of carlots unloaded at individual elevators within an unload area. The between-elevator variability, and the influence of transportation logistics on this variability, are examined in this sub-section.

The weekly distribution of carlots among elevators, and elevator mean protein content are shown in Table 41. Carlot distribution data

Table 41. Numbers of Carlots and Unload Sample Mean Protein Content for Pacific Elevators for Each Week for Grade 1 CW.

GRADE 1 CW

Week No.	Number of Carlots							Protein Content, %						
								Port	Deviation from Port Mean+					
	SWP	BUR	PACI	VIT	UGG	AWP	TOTAL	Mean	SWP	BUR	PACI	VIT	UGG	AWP
							NON-POOLED CARLOTS							
8	262	58	156	21	97	83	677	14.02	.28	-.06	-.10	.12	.14	-.48
5	150	-	284	5	77	275	791	13.83	.33	-	.02	-.05 n	.12	-.21
7	245	42	278	28	167	122	882	13.78	.31	-.23	.02	-.54	0 n	-.47
6	218	66	295	2	122	234	937	13.70	.33	.12	.01 n	.45	-.08	-.33
4	172	13	226	11	100	153	675	13.63	.28	.35	.04	-.15	-.05	-.35
1	77	-	65	1	93	62	298	13.45	.22	-	-.15	-.35 *	0	-.09
3	127	-	155	12	106	221	621	13.43	.65	-	.04	.39	-.21	-.32
2	107	-	191	4	90	147	539	13.35	.36	-	.04	-.28	-.26	-.15
							POOLED CARLOTS							
9	201	45	249	38	172	307	1012	14.08	.01 n	-.02 n	-.04	.02 n	.06	-.02
10	187	38	335	54	205	288	1107	13.93	.30	-.02 n	-.06	-.04 *	0	-.12
12	245	32	501	40	264	291	1373	13.84	.11	.07	.01 *	-.01 n	.14	-.18
11	196	31	250	49	125	228	879	13.72	.07	-.20	.02 *	.02 n	-.01n	-.06

+ Deviations greater than 2 standard errors are unmarked, those between 1 and 2 standard errors are marked by *, and those less than the standard error are marked by n.

show that during the twelve weeks under investigation five of the elevators received carlots of wheat in all twelve weeks, while one elevator (i.e. Bur) received carlots in only 8 of the 12 weeks. Moreover, the number of carlots unloaded at the Port, and the distribution of them among the elevators, varied from week to week.

It should be noted that the division is maintained between the periods when carlots were pooled and non pooled (cf. page 131). Column 9 shows that, within each transportation structure the weekly data are arranged in order of decreasing mean protein content. The protein mean for each elevator is shown as its within week deviation from the port mean. A scan of these deviations reveals that considerable differences exist among elevator means. To test if these observed differences were greater than the analytical error of protein indication, the deviations were analyzed statistically by treating the data for each elevator as a sub-sample of the data for the port within a week.[a/] It was found that most of the deviations were greater than twice the standard deviation of protein measurement, which was considered to be 0.2% protein.

A closer study of the deviations shows that within each week under the non-pooling system the mean protein content for SWP was about .3 percentage units higher than the port average while the mean for AWP was about .2 percentage units lower than the port average. As mentioned in the preliminary studies section, these differences arise because of the geographic origin of the carlots unloaded at the individual elevators. However, the differences between the means for SWP and AWP, shown in

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a/ Deviation greater than $(M-N)(.2)^2/MN$ where M is the number of carlots for the port and N is the carlots at an individual elevator.

Table 41, are quite large despite the fact that during this period there existed a carlot exchange programme. Under this programme, carlots which would normally be shipped to AWP were exchanged for SWP carlots originating in high protein areas. The aim of the programme was to reduce the protein differences between these elevators. It is apparent that the programme had only limited success.

The exchange programme outlined above did not involve the remaining elevators. Table 41 shows that the mean protein content for UGG tends to be less than the port average, while PACI approximately equals the port mean. The remaining two elevators, Bur and Vit, often exhibit relatively large differences in both directions. The erratic behaviour of these two elevators may be partly attributed to the small number of carlots each elevator receives within a week. Moreover, each of these elevators receive carlots from only one of the two railway companies and therefore the deviations may reflect a protein imbalance between railways. The mean for VIT is probably further complicated by reason of its location on Vancouver Island. Since cars move to this elevator by ferry, there is a serial delay which would influence the deviation of the elevator mean from the overall port mean, particularly when the port protein level is changing.

It would be expected that when the carlots were pooled and allocated between terminal elevators without regard to the company of origin, that the difference in protein means between elevators would disappear. The data for weeks 9 through 12 show that while the pooling of the carlots reduced the deviations considerably it did not entirely eliminate them. At least part of the differential between SWP and AWP is retained. However, this imbalance may be the reflection of a protein imbalance between the railways, since SWP receives carlots from both railways while AWP receives only Canadian Pacific cars. Furthermore, it was demonstrated later that, even under the pooled transportation structure, the carlots do not arrive in a random fashion at the terminals. It may be appreciated that train loads of grain will tend to be composited from a number of carlots which originate in a limited geographic area. It is obvious that the sequence of carlots in the train will tend to follow the sequence of the stations along the railway line in the area of origin. Since the protein content of wheat varies substantially from station to station, the protein content of carlots unloaded at the terminals will obviously exhibit runs of high and low protein. It is hoped that by binning the carlots of a particular protein sub-grade in two or more bins alternately that the effect of these runs within an elevator will be reduced. Moreover, it is anticipated that the runs to the individual elevators will average out over time.

In order to examine the effect on protein segregation operations of the observed differences between elevators in mean protein content, the segregation simulation system used in sub-section E was imposed on the data. The results of the segregation exercise are shown in Tables 42, 43, and 44. The presentation format for each of the three sub-grades is the same as for 1 CW.

The data for 1 CW 135, the centre and largest sub-grade, is presented in Table 42. Table 42 shows, that within weeks, mean protein differentials exist between elevators, and the pattern observed for 1 CW is essentially retained. The data for the remaining two sub-grades, 1 CW 125 and 1 CW 145, are presented in Tables 43 and 44, respectively. These tables also demonstrate that between elevator differences exist within a sub-grade. However, it is apparent that the elevator to elevator differences are larger in the centre sub-grade (1 CW 135) than for the extreme sub-grades 1 CW 125 and 1 CW 145.

The between elevator differences observed, particularly for the extreme sub-grades, do not always reflect the relative magnitude of the differences in protein means between elevators found for the unsegregated carlots. This would indicate that both the mean protein, and the distribution of the individual carlots about the mean varies from elevator to elevator. If the level and shape of the protein distribution varies from elevator to elevator, it can be appreciated that, when a segregation system which is adequate for the port as a whole is imposed on individual elevators, the selection intensity will vary from elevator to elevator. It follows, that if the selection intensity varies, the sub-grade means for each elevator will vary accordingly.

Ideally, the selection intensity should be equal for all elevators. This could be achieved by using an independent segregation system for each elevator. This means that the minimum for each sub-grade would vary from elevator to elevator. Such a system could be operated if

Table 42. Number of Carlots and unload Sample Mean Protein Content for Pacific Elevators for Each Week for Grade 1 CW 135.

GRADE 1 CW 135

Week No.	Number of Carlots							Protein Content, %						
								Port Mean	Deviation from Port Mean +					
	SWP	BUR	PACI	VIT	UGG	AWP	TOTAL		SWP	BUR	PACI	VIT	UGG	AWP
							NON-POOLED CARLOTS							
8	161	42	109	17	58	16	453	13.86	.18	-.07	-.03	.14	-.16	-.23
5	106	-	180	5	43	196	520	13.71	.22	-	-.01 n	.07 n	.09	-.13
7	174	30	204	21	120	72	621	13.78	.15	-.23	.02	-.27	-.02 *	-.19
6	149	45	206	2	77	139	618	13.75	.18	.03 *	.03	.40	-.17	-.16
4	116	12	160	9	74	109	480	13.69	.12	.20	-.08	-.28	.07	-.28
1	53	-	33	1	68	41	196	13.61	.09	-	-.08	-.51	-.06	.03 *
3	91	-	89	4	58	138	380	13.56	.31	-	-.05	.36	-.03 *	-.17
2	79	-	119	2	51	86	337	13.58	.07	-	-.04	-.03 n	-.03 *	-.01 n
							POOLED CARLOTS							
9	151	38	164	27	119	196	695	13.95	.03	.07	-.07	.12	.10	-.04
10	117	27	218	43	139	173	717	13.81	.19	-.02 n	-.03	-.08	-.02 *	-.04
12	162	29	353	30	177	191	942	13.77	.04	-.04 *	.02	.03 n	.01 n	-.08
11	132	25	170	41	87	124	579	13.62	.05	-.06 *	.02 *	.02 n	.02 *	-.06

+ Deviations greater than 2 standard errors are unmarked, those between 1 and 2 standard errors are marked by *, and those less than the standard error are marked by n.

Table 43. Number of Carlots and Unload Sample Mean Protein Content for Pacific Elevators for Each Week for Grade 1 CW 125.

GRADE 1 CW 125

Week No.	Number of Carlots							Protein Content, %						
								Port	Deviation from Port Mean +					
	SWP	BUR	PACI	VIT	UGG	AWP	TOTAL	Mean	SWP	BUR	PACI	VIT	UGG	AWP
							NON-POOLED CARLOTS							
8	1	1	11	2	9	11	35	12.42	.12 n	.02 n	.10	-.37	.12	.08 *
5	2	-	36	-	7	43	88	12.49	.26 *	-	.04 *	-	-.13 *	-.03 *
7	4	7	28	6	17	39	101	12.42	.33	.18	-.01 n	-.35	0	0
6	14	7	38	-	21	64	144	12.35	.18	.28	-.12	-	.17	-.04
4	14	-	36	1	18	33	102	12.42	-.01 n	-	.05 *	.28 *	-.06 *	-.03 *
1	11	-	24	-	19	18	72	12.56	.01 n	-	-.05 *	-	.11	-.08
3	1	-	39	3	37	73	153	12.42	.78	-	.14	-.09 n	-.06	-.04
2	13	-	55	2	37	53	160	12.52	.14	-	.15	.08 n	-.16	-.10
							POOLED CARLOTS							
9	7	2	21	1	10	28	69	12.84	.47	.36	-.02 n	.06 n	-.16	-.08
10	6	2	33	1	14	39	95	12.73	-.08 *	.12 n	-.05 *	-.33 *	.02 n	-.15
12	13	1	48	4	18	48	132	12.65	.27	.45	.10	-.10 *	-.07 *	-.16
11	10	3	23	-	13	39	88	12.53	.02 n	-.16 *	-.01 n	-	.30	-.10

+ Deviations greater than 2 standard errors are unmarked, those between 1 and 2 standard errors are marked by *, and those less than the standard error are marked by n.

Table 44. Number of Carlots and Unload Sample Mean Protein Content for Pacific Elevators for Each Week for Grade 1 CW 145.

GRADE 1 CW 145

Week No.	Number of Carlots							Protein Content, %						
								Port Mean	Deviation from Port Mean +					
	SWP	BUR	PACI	VIT	UGG	AWP	TOTAL		SWP	BUR	PACI	VIT	UGG	AWP
NON-POOLED CARLOTS														
8	100	15	36	2	30	6	189	14.69	.04	-.14	.07	.21 *	.02 n	-.26
5	42	-	68	-	27	46	183	14.78	.02 n	-	.01 n	-	-.17	.08
7	67	5	46	1	30	11	160	14.61	-.04	.23	.02 n	-.01 n	.02 n	-.03 n
6	55	14	51	-	24	31	175	14.61	.05	-.07 *	.08	-	.11	-.02 n
4	42	1	30	1	8	11	93	14.65	.05	.45	-.06	.25	-.05 n	-.04 n
1	13	-	8	-	6	3	30	14.62	-.16	-	.04 n	-	.20	.15 *
3	35	-	27	5	11	10	88	14.62	.02 n	-	.01 n	.02 n	-.11 *	.01 n
2	15	-	17	-	2	8	42	14.71	.20	-	-.05 *	-	.09 n	-.30
POOLED CARLOTS														
9	43	5	64	10	43	83	248	14.77	-.17	-.01 n	.11	-.48	-.04 *	.08
10	64	9	84	10	52	76	295	14.60	.12	-.32	-.03 *	.14	.02 n	-.08
12	70	2	100	6	69	52	299	14.60	-.14	-.05 n	.02 *	.23	.08	.03 *
11	54	3	57	8	25	65	212	14.47	-.14	-.14 *	.04 *	-.21	-.03 n	.11

+ Deviations greater than 2 standard errors are unmarked, those between 1 and 2 standard errors are marked by *, and those less than the standard error are marked by n.

jurisdiction on the changing of the minima existed at the elevator level. However, it would be cumbersome to operate if control of the sub-grade minima were centralized and required manual intervention. Undoubtedly, variable elevator minima could be used in conjunction with centralized control if the control were aided by the necessary computer facilties, such as a computer terminal in each unload elevator monitored by the C.G.C.'s central computer at that unload area.

In order to establish the optimum minima for each elevator some advance knowledge would be required of the level and shape of the distribution. It was demonstrated earlier that under the non-pooled transportation system consistent differences in mean protein content exist between elevators. Moreover, under this system the final destination of the carlots is known in advance. Therefore, under the non-pooled system it should be possible to use variable sub-grade minima for each elevator. In fact, under such a transportation structure it is doubtful if effective protein segregation could be achieved without the use of variable minima. Under the pooled transportation system the final destination of the carlots is unknown and consequently little is known in advance about the protein mean for each elevator. Accordingly, it may be concluded that the use of variable minima under the pooled system would be of very little benefit.

J. The Use of Station Means in Protein Segregation

The carlots of grain unloaded at terminal elevators may be shipped from any one of some 1800 stations. As the protein content of wheat is geographically distributed, protein means calculated on the basis of station of origin could perform a number of functions in the protein segregation system outlined above.

Firstly, station means might provide a mechanism whereby the premiums obtained from the sale of high protein wheat might be reflected back to the areas producing high protein wheat. Such a use of station means is beyond the scope of the present study.

Secondly, station means might be used to aid the forwarding of wheat by protein content to terminal elevators. This function will be considered in a later section. Thirdly, station means might be used to replace the Primary sample as a method of segregating the carlots by protein content.

For this last purpose, the station mean has one great advantage over the Primary sample system in that it is independent of the mail service. Therefore, in the event of a disruption of mail service, the use of station means enables segregation to be achieved when it would be impossible to do it with the Primary sample system. Moreover, it was found in practice that the Primary sample was not always available when the carlot arrived at the terminal. This occurs for a number of reasons, such as; no samples forwarded; sample received too late; clerical errors, etc. However, when a carlot of grain arrives at a terminal elevator it must be binned irrespective of the availability of the Primary sample. If the number of carlots without a Primary sample is very small then it might be reasonable to bin them on the basis of the average protein content of the port. But, if the number of cars without Primary samples is large, then binning on the basis of the port average could jeopardize the entire protein segregation operation. It would appear more realistic to bin carlots, for which there is no Primary sample available, on the basis of the mean protein content of the station of origin of the carlots. Data collected on Western grain movement prior to July 31, 1971 showed that about 20% of the carlots unloaded did not have Primary proteins available at Unload time.

A study was initiated to evaluate the use of station means as a method of segregating carlots of wheat by protein content. However, before such a study could be undertaken it appeared desirable to establish the best type of station mean to use for this purpose. Since the protein contents of a series of carlots shipped from one station varies over time it was concluded that a floating mean would be more suitable than a cumulative mean. However, the question still remains as to the optimum number of carlots to include in the station mean, and the frequency with which the means should be updated.

In order to study these problems protein data for 40 stations, each of which unloaded 35 or more carlots at West Coast Ports in June and July 1971, were selected. The number of carlots, mean protein and standard deviations for each of the selected stations are shown in Table 45. The data show that the Unload protein means for the selected stations cover a range of 1.5 percentage units. Moreover, the standard deviations

Table 45. Number of Carlots and Mean Protein Content and Standard Deviation by Station of Origin for Stations which Unloaded in Excess of 34 Carlots at the Pacific Coast in the Period June 6 to July 31, 1971.

Station	Carlots	Protein %		Station	Carlots	Protein %	
		Mean	S.D.			Mean	S.D.
GOLDEN PR	38	14.52	.32	SWFT CURNT	38	13.92	.36
MANTARIO	48	14.50	.35	GALAHAD	45	13.88	.46
KERROBERT	68	14.45	.56	MOOSE JAW	35	13.88	.43
LAPORTE	38	14.42	.44	ALLIANCE	37	13.84	.45
CLIMAX	43	14.41	.56	MEDICNE HT	49	13.81	.55
EATONIA	48	14.36	.32	UNITY	71	13.80	.56
ACADIA VY	42	14.36	.45	GULL LAKE	35	13.79	.36
LANDIS	53	14.34	.41	SALVADOR	35	13.71	.40
MAJOR	44	14.30	.53	ORION	60	13.63	.57
DODSLAND	37	14.24	.34	DENZIL	40	13.54	.48
N BATTLEFORD	80	14.22	.41	SKIFF	41	13.39	.37
LUSELAND	129	14.21	.43	TABER	53	13.39	.57
MANKOTA	37	14.19	.48	BOW ISLAND	93	13.24	.46
SHAUNAVON	67	14.12	.39	WRENTHAM	53	13.23	.52
ROSETOWN	44	14.12	.34	ETZIKOM	55	13.23	.44
BATTLEFORD	42	14.04	.39	FOREMOST	46	13.10	.52
CORONATION	39	14.01	.51	GRANUM	44	13.04	.56
HILDA	39	14.00	.47	VULCAN	53	12.97	.49
BIGGAR	36	14.00	.36	NEMISKAM	45	12.95	.55
ABERDEEN	42	13.97	.37	MILK RIVER	86	12.94	.49

indicate that, despite the short period over which the data were collected, there was considerable protein variation within each station.

Since the data shown in Table 45 covers a fairly large range of protein levels it should be a reasonable base on which to evaluate the most desirable type of station mean to use in protein segregation. Two types of floating means, based on a variable number of carlots, were examined. A "straight" floating mean; this was calculated by dropping the "oldest" protein value and adding the "newest" protein value. Such a mean has the disadvantage that all individual protein values must be retained in the computer memory. If, for example, a 10 carlot floating mean was being computed for some 1,800 stations, it would be necessary to sort the data in advance or use a large amount of memory while computing the means. Using a "Damped" mean, these cumbersome procedures can be avoided. The damped mean is calculated by dropping an average value and accumulating the next protein value.

The efficiency of both of the above types of floating means were evaluated by calculating a standard deviation of the difference between the floating mean and the protein value for the carlot to be binned. The pooled standard deviation of the difference obtained for both types of floating means is shown in Table 46. Column one shows the number of carlots on which the mean was based. Column two shows the number of carlots by which the mean lagged the value it was used to predict. That is to say, when the mean is used to predict the next carlot, the lag is 1; a lag of 5 indicates that the prediction was made on the fifth car

Table 46. Pooled Standard Deviation of the Difference Values Obtained by Using Different Types of Station Means to Predict Protein Content of Carlots.

Carlots			Type of Floating Mean	
Mean	Lag	Samples	Straight	Damped
5	1	957	.50	.47
10	1	957	.48	.47
20	1	957	.48	.48
20	5	757	.50	.49
5	10	557	-	.50
10	10	557	.50	.49
20	10	557	.49	.48

shipped after the mean was calculated. The time lag must obviously be considered since it will occur under practical conditions.

The standard deviations of the difference indicate that the damped mean was at least as good as the straight floating mean. It must therefore be concluded that the damped mean, because of its computational advantages, is best suited for carlot segregation purposes. While the data in Table 46 are not too conclusive it would suggest that a 10 car damped mean is best. Moreover, it should be noted that all the standard deviations of the differences shown in Table 46 are larger than the standard deviation of the difference between Primary and Unload pairs shown in earlier tables. This indicates, as expected, that the station mean is not as efficient as the Primary sample system for segregating carlot by protein content.

A carlot segregation exercise using a 10-car damped station mean was examined using the data collected under the non-pooled transportation structure. Unload protein data collected during weeks one through five were used to establish a data file of station means. These station means, updated weekly, were used to segregate the carlots for weeks 6, 7 and 8. The results of the segregation exercise are shown in Table 47.

Since station means cover a narrower protein range than Primary samples, and since station means do not predict individual carlots as accurately as Primary samples, it was possible to segregate only two protein sub-grades. However, the data in Table 47 show that it is possible to use station means to segregate carlots into two protein

Table 47. Carlot Distribution and the Unload Sample Mean Protein Content Obtained Over a Number of Weeks for Pacific Elevators When Carlots were Segregated by Using the Mean Protein Content of the Station of Origin of the Carlots.

Elevator	1 CW Cars	1 CW Mean	Minima %	Sub, 1A Cars %	Sub, 1A Mean	Sub, 1B Cars %	Sub, 1B Mean
			WEEK NO. 6 (CONSTANT MINIMA)				
SWP	172	14.04	13.70	77.9	14.18	22.1	13.53
UGG	93	13.56	13.70	41.9	14.27	58.1	13.05
PAC1	249	13.65	13.70	57.8	14.11	42.2	13.02
BUR	46	13.94	13.70	65.3	14.11	34.7	13.62
VIT	2	14.15	13.70	50.0	14.70	50.0	13.60
AWP	209	13.37	13.70	31.1	13.98	68.9	13.09
TOTAL	771	13.67	-	53.6	14.13	46.4	13.14
			WEEK NO. 6				
SWP	172	14.04	13.00	96.5	14.07	3.5	13.13
UGG	93	13.56	13.60	42.0	14.27	58.0	13.05
PAC1	249	13.65	13.70	57.8	14.11	42.2	13.02
BUR	46	13.94	13.70	65.3	14.11	34.7	13.62
VIT	2	14.15	13.70	50.0	14.70	50.0	13.60
AWP	209	13.37	13.75	29.7	13.98	70.3	13.11
TOTAL	771	13.67	-	57.4	14.09	42.6	13.10
			WEEK NO. 7				
SWP	212	14.09	13.00	98.1	14.11	1.9	13.32
UGG	157	13.76	13.60	70.1	14.11	29.9	12.93
PAC1	263	13.78	13.70	62.4	14.10	37.6	13.25
BUR	42	13.55	13.70	54.8	14.03	45.2	12.96
VIT	23	13.50	13.70	30.5	14.33	69.5	13.14
AWP	112	13.35	13.75	35.7	14.05	64.3	12.96
TOTAL	809	13.77	-	68.0	14.10	32.0	13.08
			WEEK NO. 8				
SWP	247	14.30	13.00	99.6	14.31	0.4	13.10
UGG	96	13.88	13.60	62.5	14.29	37.4	13.19
PAC1	154	13.92	13.70	68.2	14.18	31.8	13.35
BUR	58	13.96	13.70	70.7	14.19	29.3	13.39
VIT	20	13.88	13.70	60.0	14.39	40.0	13.11
AWP	80	13.55	13.75	20.0	14.11	80.0	13.41
TOTAL	655	14.02	-	73.3	14.27	26.7	13.33

sub-grades which differ in mean protein content by 1.0 percentage units.

The protein minimum for sub-grade 1A is shown in column 4. The top section of the table shows that the minimum for 1A for all elevators in week 6 was 13.70. The remaining sections of the table demonstrate the use of variable elevator minima. The sub-grade mean protein data clearly demonstrate that it is possible for SWP elevator to achieve sub-grade means similar to the other elevators and yet use a sub-grade minimum that is significantly lower. The use of the variable elevator minima clearly affects the distribution of the carlots among the protein sub-grades.

The 1A sub-grade can be kept fairly uniform, and could presumably be guaranteed at 14.0% protein. No. 1B is more variable, but generally above a possible guarantee of 13.0%.

The station means used to segregate the carlot data presented in Table 47 were updated weekly. It was found that there was little advantage to be obtained by updating the means on a daily basis, because of the limited number of cars shipped from a station within a week.

While station means are obviously inferior to the Primary samples for controlling segregation, it seemed essential to know how the former behaved. Firstly, as previously noted, Primary protein data are not always available when a carlot is unloaded and station means must then be substituted. Secondly, in the event of a postal strike, which would make the use of the Primary system essentially impossible, a standby method of making at least a partial segregation would be badly needed.

In the above evaluation of station means for the segregation of carlots, Unload sample proteins were used because these were considered to be less subject to sampling error than the Primary sample proteins. It was subsequently observed that, because the Primary protein is more current than the Unload protein, the station means based on the Primary were superior to those based on the Unload, especially when a new crop of a higher, or lower, protein content is entering the system. Of course, in the event of a mail strike the Primary would not be available and consequently the station means based on the Unload protein would have to be used despite their limitations.

K. Determining the Protein Minima for the Sub-grades

In sub-section A above it was stated that the main objective of protein segregation was to obtain sub-grades of guaranteed 15, 14 and 13% protein, or of 14.5, 13.5, and 12.5% protein. For discussion purposes these alternate systems will be referred to as the "even" and "half" segregation systems.

The data presented thus far clearly indicate that the location and shape of the protein distribution of carlots arriving at terminal positions varies over time. Therefore, the sub-grade minima must also vary if the sub-grade means are to remain constant over time.

There are a number of possible methods by which the desired sub-grade minima might be determined. The preferred method seems to involve the following steps: First, find the "truncation" point A in Figure 7 that represents the minimum necessary to achieve a mean in the upper sub-grade of 14.5% protein. Second, find the point B, subject to point A, that will give the desired protein mean of the next lower sub-grade. Third, repeat step two subject to the last truncation point.

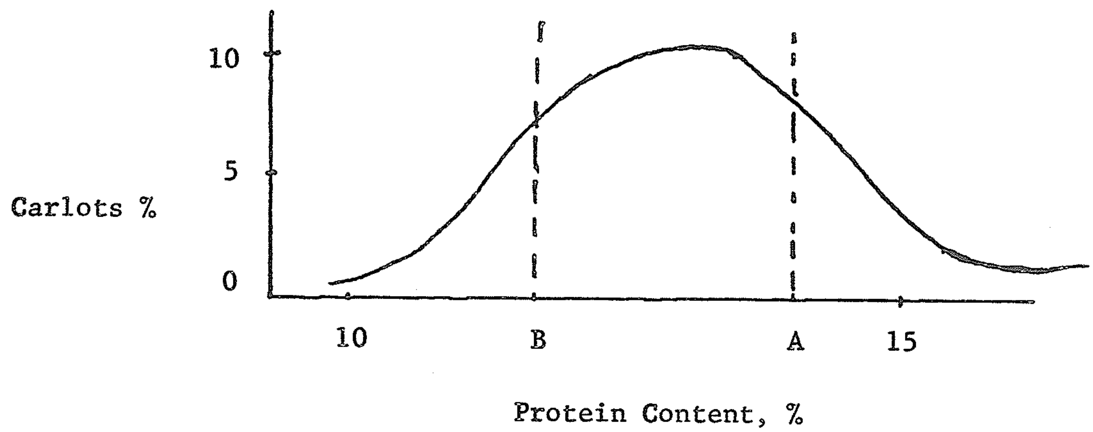


Figure 7. Theoretical Protein Frequency Distribution of Carlots of Wheat.

Having repeated step three as often as is necessary, it can be appreciated that all sub-grades above the last truncation point, will meet their required mean protein and also optimum use is made of the available protein. However, the lowest sub-grade, below the last truncation point, will always be a "residual sub-grade" of variable protein content over time. This sub-grade would be considered to be of the "filler type" and therefore, the consequences of its variability would not be too serious.

An obvious variation of the above segregation method is to sequentially segregate from the lower end, instead of the high end, of the protein distribution. This would result in the highest protein sub-grade being variable over time which is probably not as acceptable as a variable low protein sub-grade.

A third alternative might involve segregating one sub-grade from the top and another from the bottom of the distribution. But this would leave a large sub-grade of variable protein content in the middle. To control the mean protein content of this sub-grade it would be necessary to blend after segregation; if the mean for the middle sub-grade is too high it would be necessary to blend in some wheat from the low protein sub-grade, whereas if the mean for the middle sub-grade is too low wheat from the high protein sub-grade would have to be blended with the middle sub-grade. While such blending would achieve sub-grade means of the desired level and make maximum use of the available protein it may be cumbersome to operate and control on a daily basis.

The preferred method, sequential segregation from the high-protein end of the distribution was examined by imposing it on data for the 12 weeks examined in earlier sub-sections. A computer program that simulated the sequential technique was developed and this program will be discussed in detail in Part V.

Table 48 presents the results of the simulation exercise using the half-segregation system for each of the 12 weeks of available data. It is interesting to note that when the standard deviation of the Primary protein (3rd column) is under .80 a single truncation point produces two sub-grades of desirable mean protein, whereas when the standard deviation is larger three or more sub-grades are required. Moreover,

Table 48. The Distribution of Carlots, Mean Protein Content and Sub-Grade Minima Obtained by Using the Sequential Segregation Technique on Carlot Data for 12 Individual Weeks.

Week	Primary		S.D.	1 CW	Sub-Grade Distribution, %				Mean Protein Content, Unload					Sub-Grade Protein Minima, Primary			
No.	Mean	SD	of D	Carlots	1CW145	1CW135	1CW125	Residual	1CW	1CW145	1CW135	1CW125	Residual	1CW145	1CW135	1CW125	Residual
9	13.91	.74	.44	1012	41.1	58.9	-	-	14.08	14.57	13.73	-	-	14.1	Open		
8	13.95	.68	.28	677	33.4	66.6	-	-	14.02	14.63	13.71	-	-	14.3	Open		
10	13.85	.77	.40	1107	26.6	73.4	-	-	13.93	14.60	13.68	-	-	14.4	Open		
12	13.79	.76	.40	1373	21.8	78.2	-	-	13.84	14.60	13.63	-	-	14.4	Open		
7	13.73	.74	.28	882	18.1	81.9	-	-	13.78	14.61	13.59	-	-	14.4	Open		
11	13.81	.79	.41	879	13.0	87.0			13.72	14.61	13.58	-	-	14.7	Open		
5	13.72	.83	.33	791	37.4	48.7	13.9	-	13.83	14.58	13.60	12.57	-	14.1	12.9	Open	
6	13.65	.83	.28	937	18.7	76.1	-	5.2	13.70	14.61	13.59	-	12.06	14.4	12.2	-	Open
4	13.57	.80	.28	675	17.9	73.5	-	8.6	13.63	14.58	13.57	-	12.14	14.3	12.5	-	Open
1	13.34	.81	.46	298	12.8	57.4	29.9		13.45	14.58	13.63	12.63	-	14.3	12.9	Open	
2	13.22	.82	.41	539	10.2	55.8	34.0	-	13.35	14.63	13.59	12.58	-	14.3	12.9	Open	
3	13.40	.86	.36	621	14.2	58.8	21.7	5.3	13.43	14.62	13.59	12.59	11.97	14.4	12.9	12.1	Open

it is also apparent that as the means of the unsegregated carlots decrease, the truncation point moves up the protein scale with the consequent decrease in the percentage of carlots entering the high protein sub-grade. The apparently high truncation point obtained for week 11 is probably the result of the rather poor relationship that existed between Primary and Unload proteins in that week.

In 9 of the 12 weeks, the mean protein content of the carlots below the last truncation point were very close to the mean of the next sub-grade with the result that these carlots could be allocated to that sub-grade. However, the mean of the residual carlots in weeks 3, 4, 6 could not be allocated to an existing protein sub-grade but might well be guaranteed at 11.5% protein. Weeks 4 and 6 are also interesting in that there is a relatively high percentage of the carlots in sub-grade 1 CW 145, and particularly in 1 CW 135, despite a relatively low overall mean. Two factors probably contribute to this result; the broad protein distribution as indicated by the standard deviation, and a close relationship between the Primary and Unload samples as indicated by the small standard deviation of the difference. Week 3 differs from the remaining weeks in that it was the only week when four sub-grades were necessary. This probably results from the rather broad protein distribution obtained in week 3.

The above segregation technique was also examined for the even segregation system. Since the results for the even system are similar to those of the half system they are not presented.

The data presented in Table 48 clearly demonstrate that sequential segregation from the upper end of the protein distribution produces two or more sub-grades that are very uniform in protein content. However, the technique used in this simulation exercise to obtain the individual sub-grade minima requires that both the Primary and Unload protein contents be available prior to the calculation. In practice the sub-grade minima must be established prior to unloading the carlots. Accordingly, the utility of this technique depends on two factors, the rate at which the Primary distribution changes (mainly the overall mean), and the time lapse between Unload of the carlots and the availability of the Unload proteins. If the day to day changes in the mean are not too abrupt, and if prompt laboratory service is maintained for Unload samples so that the time lapse is minimized, the computer program might prove quite effective for controlling the sub-grade minima.

An alternative method of determining the sub-grade minima, independent of the Unload sample protein, might proceed as follows. In sub-section F above, it was shown that the Primary and Unload means for the protein sub-grades are related by the following equation:

$$(U-\bar{U}) = \rho_{u.p} (P-\bar{P}) \qquad (1)$$

where $(U-\bar{U})$ represents the differences between the main grade and the sub-grade Unload means and $(P-\bar{P})$ represents the difference between the main grade Primary mean and the sub-grade Primary mean. $\rho_{u.p}$ is the correlation between the individual Primary and Unload samples.

If we assume that the Primary and Unload mean for the main grade are equal, which subsequent data indicates is a valid assumption, and if we let OM equal the main grade mean, with P and U representing the respective Primary and Unload means of a sub-grade, equation (1) can be redefined as equation (2).

$$(U - OM) = \rho_{u.p} \cdot (P - OM) \tag{2}$$

Then, if equation (2) is re-arranged in the form of equation (3) it can be seen that the Primary sub-grade mean is a function of the main grade mean, the sub-grade Unload mean, and the correlation between the individual Primary and Unload samples.

$$P = \frac{U - OM}{\rho_{u.p}} + OM \tag{3}$$

In practice, the Unload sub-grade mean (U) is always known since it represents the export guarantee. Moreover, it may be assumed that the correlation ($\rho_{u.p}$) remains fairly constant over time. Therefore, the desired Primary sub-grade mean can be calculated once the mean for the main grade is known. Thus by using this regression equation the Primary sub-grade means required to achieve specified sub-grade Unload means can be estimated. Then, once the Primary protein distribution, or a good estimate of it, becomes available it is possible to determine the optimum sub-grade minima by sequentially segregating, from the top end of the distribution, sub-grades of the required Primary mean protein content. Later, when the Unload sample proteins become available the adequacy of the above sub-grade minima can be measured against the sub-grade minima obtained by using the computer program used to compute the data for Table 48.

L. Achieving the Protein Guarantee on Export Shipments

The above sub-section outlines methods by which sub-grade means of desired levels might be achieved. The ultimate objective of the entire segregation system is to be able to offer a protein guarantee on export shipments. While a cargo of wheat may be obtained from two or more terminal elevators the protein guarantee will only be applicable to the entire cargo. It is assumed, that for each protein sub-grade, within and between terminal variation can be controlled with reasonable precision.

Achieving the protein guarantee with a high degree of precision is not only important economically but also from the point of view of maintaining the integrity of the entire system of grain handling and grading. It was shown earlier (p. 17) that the standard deviation of a single protein measurement on a single sample of bulk wheat is of the order of .30% protein. With this in mind, it is clear that if the protein guarantee is to be achieved with a high degree of confidence, that the level of the sub-grade means will have to be somewhat higher than the guarantee. An estimate of the magnitude of the increment above the guarantee can be obtained with the following formula:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

The standard error of a cargo mean ($\sigma_{\bar{x}}$) can be estimated from the above equation, where σ is the standard deviation of protein measurement and n is the number of samples on which the mean is based. For the purpose at hand n is given a low value of 16. In practice, n will probably exceed this value. Thus, the standard error of the cargo mean should be less than .08% protein. If a failure rate of less than 1% is required for the protein guarantee; then, the sub-grade mean would need to exceed the guarantee by approximately three times the standard error, or by about .25 protein percentage units.

M. The Availability of the Protein Sub-Grades

If wheat is to be marketed by protein sub-grade advance estimates of the quantity available in each protein sub-grade will be required. Such estimates are also necessary for quality control purposes because it must be established in advance whether or not it is realistic to attempt to segregate a specific protein sub-grade. A significant factor in determining the availability of a specific sub-grade is the overall annual mean protein content. While methods of predicting the overall mean protein content are beyond the scope of this study the historical data presented in the Preliminary Studies Section (see Table 1) show that the mean protein content of individual crops is normally in the 12.0 to 15.0% range. While the variation in the annual mean protein content of carlot movements is considerably lower than the year to year variation in individual crops, the mean protein content of carlot movements has in the past been as low as 12.6% and as high as 14.4% protein. In about two-thirds of the years the mean was in the range of 13.0% to 14.0% protein. Accordingly it seemed appropriate to examine the effect of such a change in the annual mean protein content on the sub-grade distribution of carlots.

A mathematical procedure for estimating the sub-grade distribution of carlots might proceed somewhat as follows. In sub-section L it was established that the sub-grade mean protein content would need to exceed the guarantee by .25% protein; by adding this increment to the guarantee it is possible to establish a series of sub-grade target Unload means. In sub-section K it was established that the sub-grade Primary (segregating) sample mean is related to the sub-grade Unload mean (U) and the overall mean (OM) and the correlation between the Primary and Unload samples (ρ) by the following equation:

$$P = \frac{U - OM}{\rho} + OM \qquad (1)$$

To simplify the mathematics, we can choose a protein scale so that the overall mean protein content is zero (i.e. a linear transformation to zero). Now U represents the difference between the sub-grade Unload mean and the overall mean of the population which is zero. Therefore, equation (1) is reduced to equation (2).

$$P = \frac{U}{\rho} \qquad (2)$$

This facilitates the calculation because we are now dealing with standard units. Having established a series of sub-grade Primary means by using equation (2) it is then possible to establish the sub-grade minima by the linear truncation method outlined by Birnbaum (93), this is discussed briefly in sub-section F. Once the sub-grade minima (in standard units) are established the proportion of the carlots in each sub-grade can be calculated by integrating the normal curve between the sub-grade minima.

A somewhat different approach for examining the effect of the overall mean protein content on the sub-grade distribution of the carlots is outlined in the following paragraphs. Using protein data for Pacific carlot unloads for June and July of 1971, a symmetrical curve (a mirror image of the lower half of the curve) was generated. Also paired Primary and Unload proteins which differed by more than 1.0% protein were discarded. The resulting symmetrical curve had a standard deviation of .85; the standard deviation of the difference between Primary and Unload proteins was .36, these statistics should give a correlation between Primary and Unload protein of about .91 which is probably larger than the value expected in practice. The effect of the correlation on the sub-grade distribution will be discussed later.

The location of the above distribution was then altered by increments of 0.1% protein (i.e. increments of 0.1 were added to the individual Primary and Unload proteins) to cover the expected range in the overall annual mean of the carlot distribution. The distribution was then segregated into sub-grades by the sequential segregation technique.

It was found that for curves differing only in location, the pattern of sub-grade minima, mean protein content and carlot distribution repeats itself for each 1% change in the overall mean. Typical results for the even segregation system are shown in Table 49. Comparing the sub-grade data when the 1 CW mean is 13.5 with those when the 1 CW mean is 14.5 it is apparent that the sub-grade minima and means for the curve with an overall mean of 13.5 are exactly 1% lower (in a lower sub-grade) than the corresponding values when the overall mean is 14.5 and that the sub-grade distribution patterns are identical except that the sub-grades involved differ by 1% protein (i.e. there is a linear transformation by 1% protein).

Sub-grade data for both the half and the even segregation systems are shown in Table 50. If the two segregation systems are compared for a specific 1 CW mean, it is apparent that the half system is a linear transformation, by 0.5% protein, of the even system and vice versa.

In summary, for distributions differing only in location; a within segregation system change in location of the distribution by 1% protein results in a linear transformation by 1% protein or by one sub-grade, whereas for a distribution of specific location a change from one segregation system to the other amounts to a linear transformation by 0.5% protein or by half a sub-grade.

The effect of changes in location of less than 1% protein were also examined. Data showing the effect of a 0.1% protein change in the location of the distribution for the half segregation system are shown in

Table 49. Repetition of Minima, etc., for Each 1% Change in Location of the Protein Distribution.

1CW Mean, %	Sub-grade 1CW150	1CW140	1CW130	1CW120	1CW110
			Minima		
14.5	15.5	13.9			
13.5		14.5	12.9		
12.5			13.5	11.9	
			Mean Protein, %		
14.5	15.63	14.58	13.59		
13.5		14.63	13.58	12.59	
12.5			13.63	12.58	11.59
			Distribution, %		
14.5	10.9	70.3	18.8		
13.5		10.9	70.3	18.8	
12.5			10.9	70.3	18.8

Table 50. Comparison of Half and Even Segregation Systems for Distributions Differing only in Location.

1CW Mean, %	Half				Even			
	1CW155	1CW145	1CW135	1CW125	1CW150	1CW140	1CW130	1CW120
				Minima				
14.0	15.5	14.4			15.0	13.4		
13.5		14.5	12.9		15.0	13.9		
13.0		14.5	13.4			14.0	12.4	
				Protein, %				
14.0	15.46	14.60	13.70		15.13	14.08	13.09	
13.5		14.63	13.58	12.59	14.96	14.10	13.20	
13.0		14.46	13.60	12.70		14.13	13.08	12.09
				Distribution, %				
14.0	3.3	27.5	69.1		10.9	70.3	18.8	
13.5		10.9	70.3	18.8	3.3	27.5	69.1	
13.0		3.3	27.5	69.1		10.9	70.3	18.8

Table 51. The objective was to obtain sub-grade means of .25% protein above the guarantee. The data in Table 51 show that on all except one occasion (row 2) three sub-grades could be segregated. Since the sub-grade minima were obtained by sequential segregation from the high end of the protein distribution, the lowest protein sub-grade is a residual sub-grade. In all except the top two rows of Table 51 the residual could be allocated to the 1 CW 125 protein sub-grade.

The most interesting aspect of the data in Table 51 is the sub-grade distribution of the carlots. When the 1 CW mean protein content is in the upper half (i.e. 13.5 to 13.9) a reasonably good distribution of the carlots is obtained, whereas when the 1 CW mean is in the lower half of its 1% range only a small percentage of the carlots enter the high protein sub-grade and in excess of 50% enters the low protein sub-grade. Since the low protein sub-grade is essentially a residual sub-grade of uncontrolled protein content, it is highly undesirable that such a sub-grade contain a large proportion of the carlots. Even if the mean protein content of the residual sub-grade exceeds the guarantee by the required amount (.25%), the sub-grade as a whole would be very heterogeneous because of the wide range of protein eligible for the sub-grade.

Data in the lower section of Table 51 shows the sub-grade distribution that would result if the high protein sub-grade were eliminated when the 1 CW mean is between 13.0% and 13.4% protein. In such situations the elimination of the high sub-grade results in an approximately

Table 51. Comparison of Sub-Grade Minima, Means and Distribution for Curves Differing in Location by Increments of 0.1% Protein.

1CW	Sub-grade MINIMA, Primary				MEAN Protein Content, Unload				Distribution, %			
Mean, %	1CW145	1CW135	1CW125	Residual	1CW145	1CW135	1CW125	Residual	1CW145	1CW135	1CW125	Residual
13.9	14.6	12.5	-	OPEN	14.81	13.75	-	12.44	19	78	-	3
13.8	14.6	12.9	12.2	OPEN	14.78	13.77	12.77	12.08	16	73	9	2
13.7	14.6	13.1	OPEN		14.76	13.76	12.75		13	68	19	
13.6	14.7	13.2	OPEN		14.80	13.77	12.85		9	65	26	
13.5	14.7	13.3	OPEN		14.76	13.75	12.88		7	57	36	
13.4	14.8	13.4	OPEN		14.79	13.75	12.93		5	48	47	
13.3	14.8	13.5	OPEN		14.76	13.77	12.93		3	38	59	
13.2	14.9	13.5	OPEN		14.81	13.77	12.87		2	34	64	
13.1	14.9	13.5	OPEN		14.81	13.76	12.81		1	30	69	
13.0	14.9	13.6	OPEN		14.76	13.80	12.77		1	22	77	
13.4	13.2	OPEN				13.76	12.79			64	36	
13.3	13.4	OPEN				13.78	12.89			47	53	
13.2	13.4	OPEN				13.75	12.83			41	59	
13.1	13.5	OPEN				13.79	12.81			31	69	
13.0	13.5	OPEN				13.75	12.74			27	73	

50/50 split among the remaining two sub-grades. It should be noted that in going from three sub-grades to two sub-grades the increase in the percentage of carlots entering the middle sub-grade is more than double the amount that was originally in the high protein sub-grade. This is because the "best", rather than the average, of the low sub-grade was promoted.

As for the relative advantages of using two sub-grades instead of three sub-grades in the lower half of the 1.0% range; two sub-grades gives a somewhat better sub-grade distribution of the carlots and it may also increase handling and storage efficiency because it eliminates a sub-grade with small quantities. Moreover, the monetary returns from these sub-grade sets may differ depending on their relative efficiency in using the available protein and the price differentials between the protein sub-grades. However, it must be concluded that when the 1 CW mean is located in the lower half of the 1% range (i.e. 13.0 to 13.4) the half segregation system, using either two or three sub-grades, does not give good control of the within sub-grade variability.

The distribution of carlots among sub-grades for both the half and the even segregation systems, for each 0.1% increment of the 1 CW mean, for a protein range of 1.0% is presented in Table 52. It is apparent that when the even and the half systems are compared that the sub-grade distribution patterns are the same when the overall mean differs by 0.5% protein.

If it is assumed that a sub-grade distribution pattern which has

Table 52. Comparison of the Sub-Grade Distribution Patterns for the Half and the Even Segregation Systems.

1 CW	Half System				Even System				
Mean, %	1CW145	1CW135	1CW125	1CW115	1CW150	1CW140	1CW130	1CW120	1CW110
	Sub-grade as % of 1 CW								
13.9	19	78	-	3	5	48	47		
13.8	16	73	9	2	3	38	59		
13.7	13	68	19		2	34	64		
13.6	9	65	26		1	30	69		
13.5	7	57	36		1	22	77		
13.4	5	48	47			19	78	-	3
13.3	3	38	59			16	73	9	2
13.2	2	34	64			13	68	19	
13.1	1	30	69			9	65	26	
13.0	1	22	77			7	57	36	

three sub-grades with about equal amounts in both the high and low sub-grades gives best results. Such a sub-grade pattern can essentially always be obtained by using the even system when the overall mean is in the lower half of a 1% range and the half system when the overall mean is in the upper half of the 1% range.

Earlier in this sub-section it was stated that the standard deviation of the protein distribution used in this simulation exercise was .85, which is somewhat higher than the value obtained in practice. Moreover, it was also noted that when paired Primary and Unload proteins differed by greater than 1.0% they were eliminated. Both these factors would tend to bias upwards the correlation between Primary and Unload protein and therefore tend to increase the percentage of the carlots allocated to both the high and the low sub-grades of a three sub-grade system. However, it can be shown that even a moderate change in the values used would not substantially alter the sub-grade distribution pattern obtained.

It may therefore be concluded that three sub-grades, all containing in excess of 10% of the carlots, will tend to be available when the mean of the centre sub-grade is close to the overall mean, and that three such sub-grades could be made available at all times by alternating between the even and the half segregation systems when the overall mean indicates it is advantageous to do so. Such alternation would certainly appear to offer control of protein variability and make efficient use of handling facilities. Moreover, when wheat is sold on the basis of forward sales contracts, the protein supply position may change substantially between the time the sales contract is negotiated and the time the contract is filled. In such situations it may be easier to adjust contracts by a half sub-grade and change from one segregation system to the other than to adjust the contracts by a full sub-grade. However, the physical problems involved, and the magnitude and tenacity with which forward sales by protein sub-grade have to be adhered to, would certainly have to be considered before attempting to change from the even to the half segregation system or vice versa.

N. Possibilities of Controlling the Amounts of the Sub-Grades Available at Export Positions

In the above sub-section it was demonstrated that the overall mean protein content of the carlots arriving at the terminals is the main factor determining the volume of stocks available in each protein sub-grade. Therefore, if the C.W.B. is to make efficient use of terminal handling facilities at all times, they must attempt to make sales commitments in proportion to the volume of stocks available in each protein sub-grade. Such a supply oriented sales policy would undoubtedly be very restrictive.

Marketing flexibility would be increased if the volume of stocks available at each protein sub-grade could be varied over time by one of the following two methods. First, by blending sub-grades after segregation; 50/50 blends of two adjacent sub-grades under the even system would yield the intermediate protein level under the half system and vice versa (e.g. 15.0% and 14.0% blended 50/50 to give 14.5%). This would facilitate the transition from one system to the other as far as advance sales commitments are concerned. Of course, 50/50 blends of the two end sub-grades under either system would yield additional quantities of the middle sub-grades. Secondly, since the C.W.B. controls the forward movement of grain from country to terminal elevators, they could attempt to alter the location and shape of the protein distribution, which in turn should alter the relative volumes in the protein sub-grades. Such a system would amount to a protein selection at the country elevator or railway block level, and a protein segregation at the terminal elevator level.

A protein segregation system imposed on a protein selection programme results in some interesting operational problems. Since the C.G.C. must ensure that export shipments conform to the protein guarantee for that sub-grade they need to control the setting of the sub-grade minima. It was demonstrated earlier that the sub-grade minima are dependent on the location and shape of the protein distribution which, under the selection programme, could be varied over time by the C.W.B.

The C.W.B. could control the mean protein content of the main grade, at least in part, by directing shipments from specific Railway Blocks. Table 53 illustrates the sort of situation that the C.W.B. faces. It provides data on those Blocks that shipped more than 100 carlots to the Pacific Coast during June and July 1971. The Blocks are arranged in order of decreasing mean protein content of shipments (last column). While the overall mean protein content was 13.9, Block means varied from

Table 53. Distribution of Carlots and Unload Sample Mean Protein Content for the Protein Sub-Grades of Carlots Shipped from Individual Railway Blocks in June and July 1971.

Block	Number of Carlots	Distribution, %			Mean Protein Content, %			
		Sub A	Sub B	Sub C	Sub A	Sub B	Sub C	All
77	812	51	49	-	14.8	14.1	-	14.4
79	423	38	62	-	14.6	14.0	-	14.3
25	413	28	72	-	14.5	14.1	-	14.2
21	154	33	67	-	14.4	14.0	-	14.2
47	614	30	69	1	14.6	13.9	12.8	14.1
27	210	23	76	1	14.5	14.0	12.9	14.1
78	449	21	79	-	14.6	13.9	-	14.1
76	877	29	69	2	14.6	13.7	12.7	14.0
81	568	22	78	-	14.5	13.8	12.9	14.0
37	315	19	79	2	14.4	13.9	12.7	14.0
43	345	16	83	1	14.3	13.9	13.2	13.9
86	342	21	76	3	14.5	13.8	12.5	13.9
49	227	9	86	4	14.5	13.6	12.6	13.6
82	179	11	71	18	14.7	13.4	12.4	13.4
83	1017	2	84	14	14.3	13.3	12.5	13.2
84	549	1	68	31	13.6	13.1	12.4	12.9
Total	7494	23	72	5	14.6	13.7	12.5	13.9

12.9 to 14.4%. In this study the carlots for each Block were segregated, on the basis of the Primary sample protein content, into three sub-grades A, B and C using sub-grade minima of 14.4 and 12.5.

It is apparent that the sub-grade means for all carlots are close to those desired by the half segregation system. However, within a Block, the distribution of the carlots among the sub-grades, and the sub-grade means clearly reflect the protein level for the block as a whole. It is clear that while the sub-grade minima were satisfactory for the bulked carlots from all Blocks they were not satisfactory for the carlots from individual blocks. For Blocks with means in the range 13.4 to 13.9% the sub-grade minima yielded sub-grade means close to the desired level. For the Blocks with means higher than 14.0% the sub-grade means are too high, and for Blocks with means below 13.4, the sub-grade means are too low.

The data in Table 53 clearly indicate that the C.W.B. by selecting at the Block level can substantially alter the overall mean protein content of forward movements. Data for a number of Blocks shown in Table 53 were selected for further analysis by Train Run within Blocks. The results obtained for three of the selected Blocks are presented in Table 54 using a similar format to that used in Table 53. The data in Table 53 clearly demonstrate that the location and shape of the protein distributions also varies substantially within a Block. Block 77 segregates into essentially two sub-grades A and B; for the individual Train Runs the sub-grade split varies from a ratio of 97/3% to 25/73%. In

Table 54. Distribution of Carlots and Unload Sample Mean Protein Content for the Protein Sub-Grades of Carlots Shipped from Individual Train Runs, within Selected Railway Blocks, in June and July 1971.

Block	Train Run	Car-lots	Distribution, % A	B	C	Unload Mean Protein Content, % Sub A	Sub B	Sub C	All
77	2	34	97	3	-	15.2	15.0	-	15.2
	1	87	84	16	-	14.9	14.4	-	14.8
	6	127	72	28	-	14.9	14.2	-	14.7
	3	118	51	49	-	14.5	14.1	-	14.3
	4	332	32	68	-	14.5	14.0	-	14.2
	5	64	25	73	2	14.6	14.0	14.2	14.2
	ALL	812	51	49	-	14.8	14.1		14.4
76	4	80	71	29	-	14.8	14.2	-	14.7
	5	39	44	56	-	14.8	13.9	-	14.3
	8	38	42	58	-	14.6	14.1	-	14.3
	6	9	89	11		14.2	13.8	-	14.1
	3	300	32	67	1	14.6	13.8	13.2	14.0
	7	179	20	79	1	14.5	13.7	13.7	13.9
	9	5	-	100	-	-	13.7	-	13.7
	1	215	12	82	6	14.7	13.6	12.4	13.6
	2	12	-	75	25	-	13.5	12.8	13.3
	ALL	877	29	69	2	14.6	13.7	12.7	14.0
83	5	400	3	88	9	14.2	13.4	12.6	13.4
	4	17	6	65	29	16.5	13.5	12.4	13.4
	1	375	2	85	13	14.3	13.3	12.5	13.2
	2	158	2	78	20	13.8	13.2	12.5	13.1
	3	67	3	75	22	14.7	13.1	12.3	13.0
	ALL	1017	2	84	14	14.3	13.3	12.5	13.2

Block 76 a similar situation occurs but there is more of sub-grade B, whereas for Block 83 there is a fair percentage of sub-grade C.

The data presented in Table 54 indicate that the C.W.B. could increase amounts available in individual sub-grades by selecting at the Train Run level. An even further refinement of protein selection might involve selecting at the station, or even the country elevator level. However, boxcar allocation regulations would likely prohibit a selection of this intensity.

The above data clearly indicate that the C.W.B.'s protein selection potential should be quite high, assuming the accurate estimates of protein content by geographic location are available. It is also apparent that if the C.W.B.'s protein selection is too intense that the protein variability of carlots arriving at terminal positions will be too low to enable the C.G.C. to operate an efficient segregation of the carlots into two or more protein sub-grades differing in mean protein content by 1.0 protein percentage units. However, there may well be an economic optimum blend of the selection and segregation operations. But, even if this optimum were established, the practical realization of the optimum may not be possible because of the numerous operational constraints within the existing grain handling and transportation systems.

Although no quantitative estimates are given it may be concluded that the C.W.B., within limits, could successfully attempt to increase marketing flexibility by operating a protein selection programme for shipments from country points in conjunction with the C.G.C.'s segregation programme. Of course, it is imperative that there be very close co-operation between these two bodies if such an operation is attempted.

V. OPERATIONAL PROBLEMS AND MONITORING

The Canadian Wheat Board and the Canadian Grain Commission will be faced with a number of problems in operating and monitoring the new wheat grading system. These are described in this section, with particular reference to the responsibilities of the two organizations. In brief, the C.W.B. arranges the forward movement of grain so that its sales commitments can be met by date, port, grade and protein sub-grade, whereas the C.G.C. provides the protein testing facilities, grading, and protein segregation operations. Co-operation between these two organizations will have to be even closer in the future than it has been in the past to deal effectively with the new grading system.

The C.W.B., as in the past, faces problems associated with the need to make contracts for forward delivery, often these are made for the coming year before the crop for the current year has been harvested. Therefore, the C.W.B. needs to know, as early as possible, the estimated distribution of the new crop among the grades and the protein sub-grades. Similar estimates must also be available on carry-over stocks at the country elevator and farm level.

For many years the C.G.C. has made available, early in October of each year, its estimates of the grade distribution of the new crop, and a protein survey. With the aid of the protein survey data, estimates of the amounts in the protein sub-grades can be obtained. In addition, the protein survey data can be summarized by Railway Blocks, Train Runs, and if need by, by shipping station. The C.W.B. will thus have available estimates of the amounts and locations of the protein sub-grades of the new crop and these could be broken down as both Eastern and Western shipments.

Corresponding information on carry-over stocks at terminal positions will be accurately known. For carry-over stocks on farms and in country elevators, estimates of the amounts in each grade should be available from the data the C.W.B. normally collects. The amounts in each protein sub-grade can be estimated from data on past shipments in terms of protein means for Blocks and Train Runs. Combining these estimates with those of the new crop should provide a general assessment of the amount and location of potentially available stocks by grade and protein sub-grade.

Under normal conditions, the C.W.B.'s problem in dealing with forward contracts may be only slightly more complex than in the past. However, the occasional crop of low protein content (or even high protein content) may make it difficult or perhaps even impossible to meet contracts for specific sub-grades. Moreover, the problem will obviously be especially difficult if carry-over stocks are relatively small so that shipments will consist almost entirely of new crop. Compromise solutions will be inevitable since the C.W.B. cannot deliver sub-grades that are not available.

The C.W.B.'s second problem arises from the periodic need to meet short-term demands for large quantities of a specific protein sub-grade.

At Thunder Bay, with its large storage capacity, this may not prove too difficult. At the Pacific Coast, with a small number of terminals and these operating mainly as cleaning and transfer houses, the situation is quite different. It is also complicated by the difficulties the railways experience during winter months in transporting grain across the Rocky Mountains.

In the past the C.W.B. could order country elevators to ship only a specific grade of wheat at a given time, and since country elevator agents could estimate grade reasonably accurately, the required amounts of the grade could be delivered to the port. This is impossible for specific protein sub-grades since the agent cannot estimate the protein content of wheat. Moreover, experiments and experience with rapid protein testing methods, in both Canada and the United States, show that these are not yet suitable for use in country elevators.

The C.W.B. will thus have to resort to using available protein data for past shipments from Blocks, Train Runs, and even individual stations. By directing that shipments of a specified grade be made from selected areas, over a given period, the C.W.B. can increase the amount of a desired protein sub-grade delivered at export positions some two weeks later. The control will not be precise. It will merely produce a peaked protein distribution, with a lower than average standard deviation, and a mean close to the required Primary mean for the selected sub-grade. This interference with the normal flow of wheat to the port will have some disadvantages for both the C.W.B. and the C.G.C. The C.W.B., for example, will have additional problems in equalizing quotas. However, it does appear that the situation the C.W.B. faces will be similar, though somewhat more complex, than in the past. There have always been a number of grades of various grains and oilseeds to contend with both in making and in meeting contracts.

The control procedures used by the C.G.C. in segregating wheat by protein content will depend on the degree of centralization desired. A wholly centralized control system probably requires adherence to specified sub-grade minima, adjusted as required. Decentralization to the terminal elevator level might make it possible to dispense with formal sub-grade minima and use instead running Primary means for each grade and sub-grade for each terminal.

Such a decentralized system would probably require that there be a computer terminal in each elevator, or at least in the larger elevators, and that each computer terminal be monitored and controlled by the C.G.C.'s central computer at the port. Under such a system the running sub-grade means would have to be based on the Primary samples. Hence, the desired Primary mean for each sub-grade would have to be adjusted in relation to the port mean existing at that time and the expected correlation between the Primary and Unload samples. Since the Primary sub-grade means for carlot unloads at each individual elevator cannot be expected to remain constant over time, pre-defined tolerance limits will have to be established and corresponding adjustment procedures developed. Once the details of the procedures are worked out, and the necessary computer programs developed, the system should operate with little, if any, manual interference. However, the final decision on the adoption of this type of control system depends on the outcome of cost-benefit analysis studies.

In using the centralized control system, the C.G.C. must establish formal sub-grade minima in advance of carlot unload. Assuming that the relationship between the Primary and Unload samples remain stable over time, the main factor influencing the sub-grade minima is the mean protein content of the carlots moving to the port.

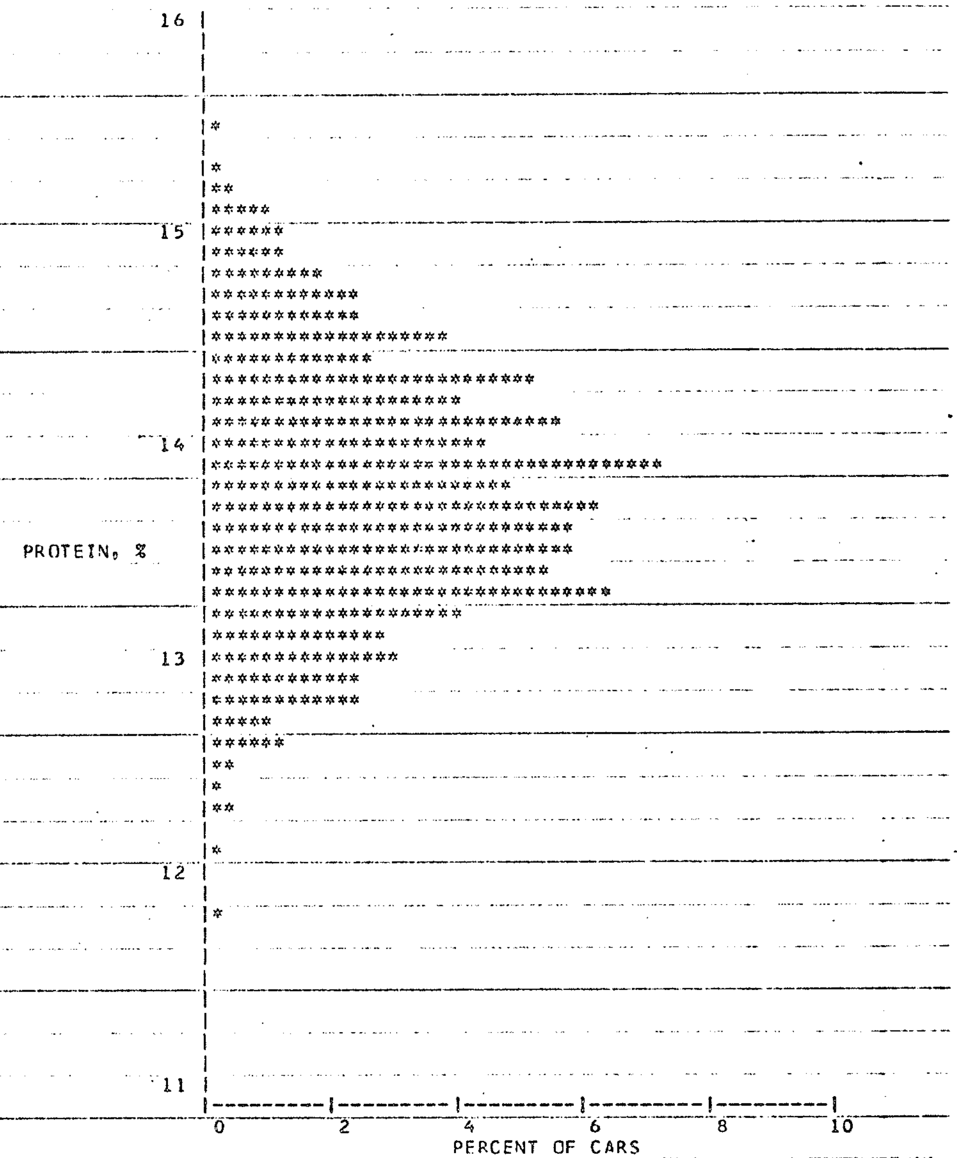
An initial estimate of the overall mean protein content can be obtained by calculating a weighted mean on the basis of the C.W.B.'s shipping orders to each Railway Block, Train Run and possibly station. If this mean remains fairly constant from week to week, or if it is changing slowly but steadily in one direction, it is probable that the shape of the distribution remains fairly constant. However, at times a better estimate of the distribution may be required. An estimate of the protein distribution of the carlots could be obtained by sorting the last available carlot data by reverse date and then accumulating the protein values for the appropriate number of carlots from each Block, Train Run, or even stations.

A second and more current set of estimates can be obtained by analyzing the Primary protein data telexed (Primary transmission data) from either Winnipeg or Calgary to the appropriate unload area each day. This protein data represents carlots that are actually in transit to the ports.

Table 55 shows the output obtained from a computer program developed

TABLE 55. FREQUENCY DISTRIBUTION, 1 CW PACIFIC PRIMARY DATA AT TRANSMISSION PERIOD ENDING FEB 3, 1973

PROTEIN, %	CAR COUNT	CARS %	CUMULATIVE CARS, %	CUMULATIVE PROT, %	SEGREGATION CARS, %	SEGREGATION PROT, %
OVER	0	0.0	0.0	0.0		
15.9	0	0.0	0.0	0.0		
15.8	0	0.0	0.0	0.0		
15.7	0	0.0	0.0	0.0		
15.6	1	0.1	0.1	15.60		
15.5	3	0.3	0.3	15.53		
15.4	1	0.1	0.4	15.50		
15.3	3	0.3	0.7	15.43		
15.2	7	0.6	1.3	15.32		
15.1	12	1.0	2.3	15.22		
15.0	15	1.3	3.5	15.14		
14.9	16	1.4	4.9	15.08		
14.8	22	1.9	6.8	15.00	6.8	15.00
14.7	30	2.5	9.3	14.92		
14.6	30	2.5	11.8	14.85		
14.5	45	3.8	15.6	14.76		
14.4	32	2.7	18.3	14.71		
14.3	63	5.3	23.6	14.62		
14.2	48	4.1	27.7	14.56		
14.1	67	5.7	33.4	14.48		
14.0	53	4.5	37.8	14.42		
13.9	86	7.3	45.1	14.34		
13.8	57	4.8	49.9	14.29		
13.7	75	6.3	56.3	14.22		
13.6	71	6.0	62.2	14.16		
13.5	71	6.0	68.2	14.10		
13.4	65	5.5	73.7	14.05		
13.3	76	6.4	80.2	13.99		
13.2	49	4.1	84.3	13.95		
13.1	35	3.0	87.2	13.92		
13.0	37	3.1	90.4	13.89		
12.9	29	2.4	92.8	13.86		
12.8	29	2.4	95.3	13.84	88.5	13.75
12.7	14	1.2	96.5	13.82		
12.6	15	1.3	97.7	13.81		
12.5	7	0.6	98.3	13.80		
12.4	4	0.3	98.6	13.79		
12.3	6	0.5	99.2	13.79		
12.2	1	0.1	99.2	13.79		
12.1	3	0.3	99.5	13.78		
12.0	0	0.0	99.5	13.78		
11.9	1	0.1	99.6	13.78	4.3	12.51
11.8	3	0.3	99.8	13.77		
11.7	0	0.0	99.8	13.77		
11.6	1	0.1	99.9	13.77		
11.5	0	0.0	99.9	13.77		
11.4	0	0.0	99.9	13.77		
11.3	1	0.1	100.0	13.77		
11.2	0	0.0	100.0	13.77		
11.1	0	0.0	100.0	13.77		
11.0	0	0.0	100.0	13.77		
REMAINDER	0	0.0	0.0	0.0	0.4	11.66
ALL	1184	100.0	100.0	13.77	(S.D. = 0.64)	



to estimate the sub-grade minima from the Primary transmission data. The program first establishes a protein frequency distribution, and a cumulative frequency, and a cumulative mean, over the entire protein range. Then, if the program is supplied with the Unload target mean for each sub-grade and an estimate of the correlation between the Primary and Unload samples, it proceeds to calculate the required sub-grade minima. The sub-grade minima are calculated by the following method: using the regression equation discussed in sub-section K (page 167), the program establishes the Primary sub-grade mean required to achieve each Unload sub-grade mean, it then proceeds to sequentially segregate from the top end of the protein distribution sub-grades of the required Primary mean.

On the computer output, shown in Table 55, columns 6 and 7 show the percentage of the carlots and the Primary mean protein for each sub-grade on the same row of the table as the sub-grade minimum. For this particular set of data the sub-grade minima, for the half segregation system, were at 14.8, 12.8, and 11.9% protein.

An assumption which influences the precision of the above advance estimates of the sub-grade minima, etc., is the expectation that the carlots will be unloaded in the sequence the C.W.B. ordered them out of the country or in the sequence in which the Primary protein values were transmitted to the unload area. Generally speaking, one would expect that the time elapsed between loading and unloading of the boxcars would be a function of the distance between origin and destination. However, as yet, no adequate data are available on the time in transit. In the absence of such data, it must be assumed that the sequence in which the carlots are unloaded is essentially the sequence in which the Primary protein values were transmitted to the unload area. In practice, this sequence might easily be broken by such events as snowslides, rail disruption, "break up" of the trains to negotiate the Rockies, and stock piling of carlots at various locations for a number of reasons. Of course, the consequence of a disruption in the sequence of carlots would depend on the protein variability from one period to the next.

When the carlots are unloaded at the terminals, calculating a daily Primary mean for each sub-grade for the actual carlots unloaded should give a good indication of the adequacy of the existing sub-grade minima. This data, plus the information on the carlots that are still in transit should provide a reasonable assessment of the need to adjust the sub-grade minima.

Later, when the Unload sample protein data become available it can be consolidated with the Primary sample data. A computer program was developed to provide a comprehensive analysis of this paired protein data. A sample copy of the output from this program is shown in Tables 56, 57, 58 and 59. While the data presented are for Pacific shipments the program can also be used for the Thunder Bay or Churchill shipments.

To compute the data for Table 56 the program establishes, on the basis of the protein content of the Primary sample, a carlot frequency, a percentage and a cumulative percentage frequency distribution; it

TABLE 56. FREQUENCY DISTRIBUTION, 1 CW — OCT 8--OCT 14, 1972
PACIFIC :SEGREGATED,PRIMARY; ACCUMULATED, UNLOAD — IF > 1%

PROT-EIN,%	PRIMARY SEGREGATION CARS	CARS,%	CUM.,%	ACCUM. PROT,%	SUBGRADES CARS,%	PROT,%
OVER	1	0.1	0.1	16.00		
15.9	0	0.0	0.1	16.00		
15.8	1	0.1	0.1	15.70		
15.7	1	0.1	0.2	15.67		
15.6	2	0.1	0.3	15.54		
15.5	1	0.1	0.4	15.43		
15.4	4	0.2	0.6	15.33		
15.3	4	0.2	0.8	15.23		
15.2	6	0.4	1.2	15.09		
15.1	5	0.3	1.5	15.00		
15.0	10	0.6	2.0	14.87		
14.9	17	1.0	3.0	14.77	3.0	14.77
14.8	14	0.8	3.9	14.70		
14.7	32	1.9	5.7	14.59		
14.6	30	1.8	7.5	14.53		
14.5	27	1.6	9.0	14.45		
14.4	47	2.7	11.8	14.38		
14.3	51	3.0	14.8	14.32		
14.2	63	3.7	18.4	14.25		
14.1	67	3.9	22.3	14.20		
14.0	64	3.7	26.1	14.14		
13.9	81	4.7	30.7	14.07		
13.8	85	5.0	35.7	14.03		
13.7	96	5.6	41.3	13.98		
13.6	92	5.4	46.7	13.94		
13.5	112	6.5	53.2	13.88		
13.4	93	5.4	58.6	13.84	55.6	13.79
13.3	102	6.0	64.6	13.79		
13.2	100	5.8	70.4	13.75		
13.1	76	4.4	74.9	13.72		
13.0	76	4.4	79.3	13.68		
12.9	69	4.0	83.3	13.66		
12.8	48	2.8	86.1	13.63		
12.7	51	3.0	89.1	13.60		
12.6	33	1.9	91.0	13.59		
12.5	34	2.0	93.0	13.57		
12.4	27	1.6	94.6	13.55		
12.3	21	1.2	95.8	13.54		
12.2	15	0.9	96.7	13.53		
12.1	11	0.6	97.3	13.53		
12.0	12	0.7	98.0	13.52		
11.9	10	0.6	98.6	13.51		
11.8	7	0.4	99.0	13.50		
11.7	4	0.2	99.2	13.50		
11.6	1	0.1	99.3	13.50		
11.5	4	0.2	99.5	13.50		
11.4	0	0.0	99.5	13.50		
11.3	0	0.0	99.5	13.50		
11.2	4	0.2	99.8	13.50		
11.1	1	0.1	99.8	13.50		
11.0	0	0.0	99.8	13.50		
REMAINDER	3	0.2	0.2	13.37	41.4	13.01
ALL	1714	100.0	100.0	13.50±0.69 (PRIMARY MEAN 13.50 ± 0.72)		

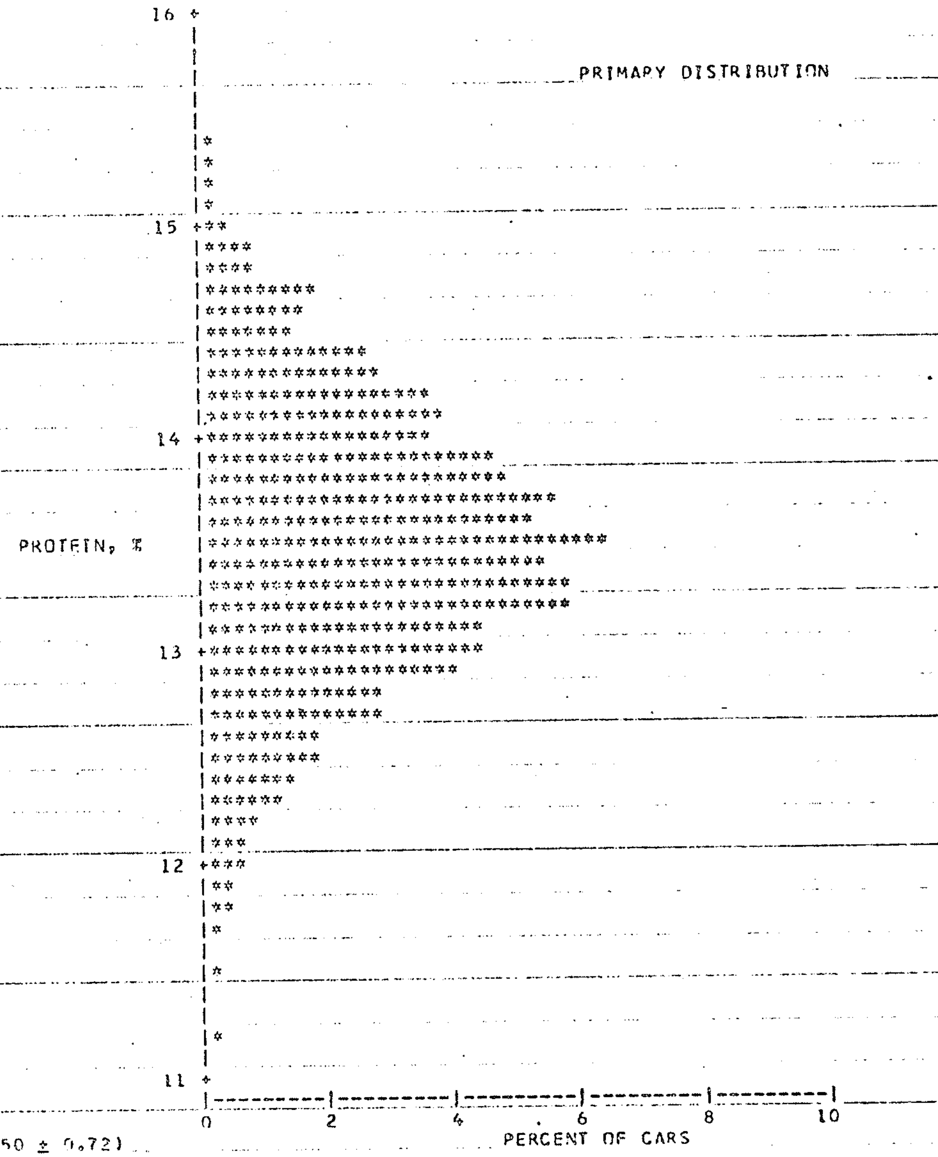


TABLE 57.

PACIFIC
SEGREGATED BY PRIMARY DATA, MINIMA UNIFORM
ACCUMULATED BY UNLOAD DATA

OCT 9--OCT 14, 1972
GRADE:1 CW
ORIGIN: ALL

NUMBER OF CARS AND PERCENT

ELEVATOR	MINIMA A	MINIMA B	MINIMA C	1CW NO.	1CW %	A NO.	A %	B NO.	B %	C NO.	C %	D NO.	D %	A + B NO.	A + B %	B+ C NO.	B+ C %	C + D NO.	C + D %
AWP	149	133	90	278	100.0	6	2.2	142	51.1	130	46.8	0	0.0	148	53.2	272	97.8	130	46.8
BUR	148	133	90	91	100.0	8	8.8	60	65.9	23	25.3	0	0.0	68	74.7	83	91.2	23	25.3
PAC1	149	133	90	390	100.0	20	5.1	218	55.9	152	39.0	0	0.0	238	61.0	370	94.9	152	39.0
SWP	148	133	90	415	100.0	16	3.9	284	68.4	115	27.7	0	0.0	300	72.3	399	96.1	115	27.7
UGG	149	133	90	271	100.0	15	5.5	158	58.3	98	36.2	0	0.0	173	63.8	256	94.5	98	36.2
VIT	148	133	90	109	100.0	1	0.9	81	74.3	27	24.8	0	0.0	82	75.2	108	99.1	27	24.8
CGES	148	133	90	160	100.0	0	0.0	98	61.3	62	38.8	0	0.0	98	61.3	160	100.0	62	38.8
OTHS	148	133	90	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
ALL				1714		66		1041		607		0		1107		1648		607	
ALL, %					100.0		3.9		60.7		35.4		0.0		64.6		96.1		35.4

MEAN PROTEIN, %

ELEVATOR	A	B	C	1CW %	A %	B %	C %	D %	A + B %	B+ C %	C + D %
AWP	149	133	90	13.22	14.55	13.58	12.78	0.0	13.62	13.19	12.78
BUR	148	133	90	13.65	14.35	13.80	13.03	0.0	13.86	13.59	13.03
PAC1	148	133	90	13.47	14.80	13.76	12.89	0.0	13.85	13.40	12.89
SWP	148	133	90	13.71	14.66	13.76	13.10	0.0	13.81	13.57	13.10
UGG	148	133	90	13.52	14.82	13.71	13.02	0.0	13.81	13.45	13.02
VIT	148	133	90	13.79	15.20	13.85	13.19	0.0	13.86	13.68	13.19
CGES	148	133	90	13.45	0.0	13.71	13.03	0.0	13.71	13.45	13.03
OTHS	148	133	90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL				13.50	14.70	13.73	12.96	0.0	13.79	13.45	12.96

COMPARISON WITH PRIMARY (INCLUDING STATION MEANS)

	1CW	A	B	C	D	A + B	B+ C	C + D
ALL ELEVATORS, MEAN PROTEIN,%	13.50	15.07	13.84	12.76	0.0	13.91	13.44	12.76
S.D. OF DIFFERENCES	0.50	0.53	0.43	0.54	0.0	0.44	0.50	0.54

CARS WITHOUT PRIMARY: 0.0 %

	CARS	MEAN
CN BLOCKS	936	13.62
CP BLOCKS	678	13.37

TABLE 58.

PACIFIC
FREQUENCY BY BLOCK AND TERMINAL

OCT 8--OCT 14, 1972
GRADE:1 CW
ORIGIN: ALL

NUMBER OF CARS AND PERCENT

BLOCK	AVP		3UR		PAC1		SWP		UGG		VIT		CGE6		OTHS		ALL	
1	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	0	0.0	0	0.0	0	0.0	0	0.0	2	0.7	0	0.0	0	0.0	0	0.0	2	0.1
5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
7	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
9	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
11	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
13	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
15	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
17	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
19	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
21	18	6.5	43	47.3	8	2.1	63	15.2	13	4.8	37	33.9	4	2.5	0	0.0	186	10.9
23	0	0.0	0	0.0	0	0.0	2	0.5	0	0.0	0	0.0	0	0.0	0	0.0	2	0.1
25	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
27	0	0.0	0	0.0	0	0.0	16	3.9	0	0.0	0	0.0	86	53.8	0	0.0	102	6.0
29	2	0.7	3	3.3	1	0.3	24	5.8	5	1.8	0	0.0	60	37.5	0	0.0	95	5.5
31	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
33	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
35	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
37	3	1.1	2	2.2	9	2.3	16	3.9	6	2.2	4	3.7	0	0.0	0	0.0	40	2.3
39	1	0.4	14	15.4	8	2.1	101	24.3	1	0.4	34	31.2	2	1.3	0	0.0	161	9.4
41	0	0.0	0	0.0	5	1.3	0	0.0	1	0.4	0	0.0	1	0.6	0	0.0	7	0.4
43	5	1.8	0	0.0	2	0.5	1	0.2	22	8.1	8	7.3	1	0.6	0	0.0	39	2.3
45	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
47	2	0.7	8	8.8	22	5.6	75	18.1	37	13.7	12	11.0	6	3.8	0	0.0	162	9.5
49	0	0.0	1	1.1	1	0.3	16	3.9	8	3.0	14	12.8	0	0.0	0	0.0	40	2.3
90	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
93	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
61	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
62	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
63	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
64	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
71	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
72	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
73	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
74	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
75	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
76	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
77	6	2.2	1	1.1	4	1.0	4	1.0	4	1.5	0	0.0	0	0.0	0	0.0	19	1.1
78	23	8.3	1	1.1	66	16.9	14	3.4	21	7.7	0	0.0	0	0.0	0	0.0	125	7.3
79	19	6.8	1	1.1	29	7.4	31	7.5	9	3.3	0	0.0	0	0.0	0	0.0	89	5.2
81	74	26.6	7	7.7	29	7.4	39	9.4	19	7.0	0	0.0	0	0.0	0	0.0	168	9.8
82	56	20.1	1	1.1	17	4.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	74	4.3
83	7	2.5	9	9.9	56	14.4	12	2.9	29	10.7	0	0.0	0	0.0	0	0.0	113	6.6
84	27	9.7	0	0.0	68	17.4	1	0.2	40	14.8	0	0.0	0	0.0	0	0.0	136	7.9
85	1	0.4	0	0.0	2	0.5	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	3	0.2
86	27	9.7	0	0.0	53	13.6	0	0.0	51	18.8	0	0.0	0	0.0	0	0.0	131	7.6
87	7	2.5	0	0.0	7	1.8	0	0.0	1	0.4	0	0.0	0	0.0	0	0.0	15	0.9
95	0	0.0	0	0.0	3	0.8	0	0.0	2	0.7	0	0.0	0	0.0	0	0.0	5	0.3
OTHS	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
ALL	273	100.0	91	100.0	390	100.0	415	100.0	271	100.0	109	100.0	160	100.0	0	0.0	1714	100.0

TABLE 59.

PACIFIC
PROTEIN MEAN BY BLOCK AND TERMINAL
ACCUMULATED BY UNLOAD DATA

OCT 8--OCT 14, 1972
GRADE:1 CW
ORIGIN: ALL

BLOCK	AWP	PUB	PAC1	SWP	UGG	VIT	CGE6	OTHS	ALL
					MEAN PROTEIN, %				
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	12.45	0.0	0.0	0.0	12.45
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	13.54	13.50	13.96	13.56	13.92	13.48	13.53	0.0	13.57
23	0.0	0.0	0.0	14.00	0.0	0.0	0.0	0.0	14.00
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	13.43	0.0	0.0	13.30	0.0	13.32
29	14.20	13.20	13.50	13.37	13.04	0.0	13.64	0.0	13.54
31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	13.70	14.50	13.89	14.01	14.05	13.18	0.0	0.0	13.91
39	12.90	14.16	13.76	13.64	13.30	13.37	13.60	0.0	13.74
41	0.0	0.0	13.04	0.0	12.60	0.0	11.70	0.0	12.79
43	13.42	0.0	13.15	13.60	13.49	13.48	14.10	0.0	13.48
45	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	13.55	14.44	14.25	13.76	13.75	14.15	13.63	0.0	13.88
49	0.0	12.50	12.10	13.23	13.33	13.73	0.0	0.0	13.38
90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
61	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
62	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
63	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
64	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
71	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
77	13.13	12.90	12.93	13.40	13.00	0.0	0.0	0.0	13.12
78	13.63	14.20	13.60	13.64	13.44	0.0	0.0	0.0	13.59
79	13.89	14.20	14.09	13.81	13.77	0.0	0.0	0.0	13.92
81	12.93	12.80	12.87	13.36	13.53	0.0	0.0	0.0	13.11
82	12.91	14.10	13.46	0.0	0.0	0.0	0.0	0.0	13.05
83	13.10	13.48	13.41	13.77	13.66	0.0	0.0	0.0	13.50
84	12.25	0.0	12.95	12.90	12.90	0.0	0.0	0.0	12.91
85	12.50	0.0	12.80	0.0	0.0	0.0	0.0	0.0	12.70
86	13.70	0.0	13.74	0.0	13.91	0.0	0.0	0.0	13.80
87	13.03	0.0	13.47	0.0	13.00	0.0	0.0	0.0	13.23
95	0.0	0.0	12.73	0.0	12.35	0.0	0.0	0.0	12.78
OTHS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ALL	13.22	13.65	13.47	13.61	13.52	13.70	13.45	0.0	13.50

simultaneously accumulates the protein content of the Unload sample to form a cumulative Unload mean over the entire protein range. Then, the program, when supplied with the desired sub-grade Unload means, reads directly from the frequency table the sub-grade minimum required for the high-protein sub-grade. If this sub-grade contains less than 1% of the total distribution the sub-grade is not segregated; the assumption being that it would be uneconomical to segregate such a small quantity. The minima for the remaining sub-grades are calculated as the difference of the product of the cumulative percentage and the cumulative Unload mean at various levels in the frequency distribution, divided by the difference in the percentage of the carlots at the two levels.

The computer output shows the sub-grade minima, the sub-grade means, and the distribution of the carlots among the sub-grades. The frequency distributions are also printed so that the user can estimate the effect of changing the sub-grade minima without resorting to the computer. The sub-grade minima obtained in Table 56 represent the optimum minima even when the unload information is available. Therefore, the sub-grade minima obtained in Table 56 provide a yardstick against which the actual sub-grade minima in effect at the time can be compared.

The data presented in Table 57 show the results of the actual segregation for the port as a whole and for the individual elevators at that port. Columns 2, 3, 4 show the sub-grade minima (multiplied by 10) which were actually used to segregate the carlots for that particular time period. It should also be noted that the computer program allows the flexibility of using a different set of sub-grade minima for each individual elevator.

In the top section of Table 57, the number of carlots unloaded at each individual elevator, and the carlot distribution and percentage distribution among the individual sub-grades within each elevator are shown. The last six columns show distribution data for various combinations of sub-grades.

The middle section of Table 57 presents data on the Unload sample mean protein content for the main grade and the sub-grades for each terminal. It should be noted that the carlots are allocated to the sub-grade on the basis of the Primary sample protein but the sub-grade means are based on the Unload sample protein data. Therefore, the protein misplacement of carlots that occurs in practice is built into the mean data.

The lower section of Table 57 contains three independent items; the Primary sample mean protein content for the main grade and the sub-grades, the standard deviation of the difference between Primary and Unload samples for both the main grade and the sub-grades, and the percentage of all carlots for which the Primary sample protein was not available. Also presented in Table 57 are the number of carlots and mean protein content for the shipments of each Railway Company. It was noted in an earlier section that a protein imbalance between the Railways give rise to differences between terminal elevators.

Table 58 presents data on the origin of carlots by Railway Block, and on destination by unload elevator. It is interesting to note that carlots from an individual Block may constitute only a small fraction of the entire shipments and yet contribute a large proportion of the unloads at a specific elevator. Transportation logistics cause this heavy concentration of elevator receipts, over a short period, to be from a limited geographic origin.

Table 59 shows the mean protein content of carlots by Block and Unload elevator. The mean protein content clearly varies from Block to Block and from elevator to elevator within Block. The data shown in Tables 58 and 59 usually provide an explanation of the between elevator differences observed in Table 57.

A computer program is also available that produces a modification of Table 57. In Table 57, the sub-grade minima in effect at the time the carlots were unloaded are used to allocate the Primary samples among the sub-grades. In practice, carlots are occasionally allocated to sub-grades contrary to the sub-grade minima in effect at the time. To simulate this practical operation, a computer program which produces a modification of Table 57 was designed. In the modified table the carlots are allocated to the sub-grades on the basis of the sub-grade in which they were binned in practice. Then, by comparing the original output for Table 57 with the modified form, the effect of binning carlots contrary to the sub-grade minima can be examined. Generally speaking, strict adherence to the sub-grade minima results in the most efficient use of available protein in the long run. However, in the short-run, because of the sequence in which carlots are unloaded it may be necessary to bin some carlots contrary to the sub-grade minima in order to minimize the differences between elevators for a particular sub-grade.

In summary, the C.G.C., in establishing the sub-grade minima and in controlling the segregation operations has information available from the following sources.

Firstly, the mean protein, and possibly the frequency distribution, calculated on the basis of the C.W.B.'s shipping programme provides a general assessment of what is likely to be encountered in the next few weeks.

Secondly, the Primary transmission data provide an estimate of the mean and the distribution of the carlots in transit to the terminals. A change in the estimates of the sub-grade minima obtained from this data should signal the possible need to adjust the sub-grade minima.

Thirdly, the Primary mean protein content of the daily carlot unloads in each sub-grade should also indicate whether or not the current sub-grade minima are adequate.

Fourthly, when the unload protein data become available, it is possible to establish what the optimum sub-grade minima were for that period, and to compare the actual minima with the optimum minima.

Finally, all the above estimates should be confirmed by the protein tests made on the export cargoes for each individual sub-grade.

With the normal flow of grain from country elevators to terminals, and with a port mean which is close to the mean of the middle sub-grade control of protein segregation should be relatively simple and effective. However, it becomes more and more difficult as the C.W.B. disrupts the normal flow of grain in an attempt to maximize the amount available in a particular sub-grade. In such situations, the C.G.C. could probably achieve better control by changing from the even to the half segregation system or vice versa. However, it is not clear as to who makes this decision, - the C.W.B. on the basis of its sales contracts, or the C.G.C. because it controls protein segregation and grading; probably some compromise by agreement.

The efficiency of the entire protein segregation is dependent to a large extent on the accuracy of the Primary sample proteins since, they and they alone, are used to segregate the carlots into the protein sub-grades. The Primary samples are not official samples; they are taken by country elevator agents and not by the C.G.C. staff.

When the Primary sample protein is not available at unload time the carlots must be segregated on the basis of the mean protein content for its station of origin. The accuracy of the Primary sample protein and the station means can be measured by comparing them with the Unload sample protein for the same carlot. A computer program which makes these comparisons was prepared and a sample copy of the output is shown in Table 60.

Table 60 consists of three sections; in the first section paired Primary and Unload proteins are compared, in the second section station means and the corresponding unloads are compared, the third section is

TABLE 60. LAKEHEAD DIFFERENCES BETWEEN PRIMARY AND UNLOAD PROTEINS

NOV 2--NOV 9, 1972
GRADE: 1 CW
ORIGIN: ALL

DIFFERENCE	UNLOAD AND PRIMARY			UNLOAD AND STATION MEAN			ALL SAMPLES		
	NUMBER	FREQUENCY %	CUMULATIVE %	NUMBER	FREQUENCY %	CUMULATIVE %	NUMBER	FREQUENCY %	CUMULATIVE %
0.0	334	13.0	13.0	20	7.2	7.2	354	12.4	12.4
0.1	603	23.5	36.5	60	21.7	29.0	663	23.3	35.7
0.2	522	20.3	56.8	39	14.1	43.1	561	19.7	55.4
0.3	408	15.9	72.6	31	11.2	54.3	439	15.4	70.9
0.4	263	10.2	82.9	31	11.2	65.6	294	10.3	81.2
0.5	162	6.3	89.2	18	6.5	72.1	180	6.3	87.5
0.6	89	3.5	92.6	23	8.3	80.4	112	3.9	91.5
0.7	63	2.5	95.1	13	4.7	85.1	76	2.7	94.1
0.8	37	1.4	96.5	8	2.9	88.0	45	1.6	95.7
0.9	17	0.7	97.2	10	3.6	91.7	27	0.9	96.7
1.0	19	0.7	97.9	3	1.1	92.8	22	0.8	97.4
1.1	11	0.4	98.4	7	2.5	95.3	18	0.6	98.1
1.2	13	0.5	98.9	8	2.9	98.2	21	0.7	98.8
1.3	4	0.2	99.0	1	0.4	98.6	5	0.2	99.0
1.4	3	0.1	99.1	1	0.4	98.9	4	0.1	99.1
1.5	8	0.3	99.5	1	0.4	99.3	9	0.3	99.4
1.6	1	0.0	99.5	1	0.4	99.6	2	0.1	99.5
1.7	3	0.1	99.6	0	0.0	99.6	3	0.1	99.6
1.8	2	0.1	99.7	0	0.0	99.6	2	0.1	99.7
1.9	2	0.1	99.8	1	0.4	100.0	3	0.1	99.8
TOTAL	2564	99.8	99.8	276	100.0	100.0	2840	99.8	99.8
WTG. MEAN	0.27			0.40			0.28		
OVER	6	0.2	100.0	0	0.0	100.0	6	0.2	100.0
GRD TOTAL	2570	100.0	100.0	276	100.0	100.0	2846	100.0	100.0
CORRE	0.84			0.70			0.82		
S.D. OF D	0.39			0.53			0.40		

PROTEIN MEANS %

	CARS, %	UNLOAD	PRIMARY	STATION	PRIMARY + STATION
PAIRED SAMPLES	90.3	13.42	13.49		
PRIMARY MISSING	9.7	13.35		13.46	
ALL SAMPLES	100.0	13.42			13.49

the combination of the first and second sections. Within each section, frequency distributions based on the absolute difference between the paired observations are established. Also shown is the correlation and the standard deviation of the difference between paired observations.

In the lower portion of Table 60, the percentage of carlots segregated on the basis of the Primary (paired samples) and on the basis of station means (Primary missing) are shown. The corresponding mean protein contents are also given.

The program also provides the facility for printing out detailed records of paired observations that differ by more than a given amount, say 1.0% protein. Then, if the original samples are available, duplicate protein determinations can be made on both the Primary and Unload samples. This provides a method of checking the errors due to sampling and analysis. The use of laboratory check samples also provides an additional method of checking the sampling and analytical error of work done by the C.G.C. staff.

After almost two years experience with protein segregation it can truly be said that the C.G.C. possesses a satisfactory system for segregating protein sub-grades at terminal positions, and for delivering cargoes of sub-grades which can be depended upon to meet the protein guarantee. Therefore, the Canadian Grain Commission's main objective has been successfully achieved.

From the viewpoint of the Canadian Wheat Board, marketing flexibility would be increased if it were possible to bring forward from farms and country elevators wheat of a specific protein sub-grade. Further research might be profitably directed in this direction.

For the grain industry as a whole, it would be desirable if procedures could be developed whereby protein premiums could be reflected back to producers. An initial step in this direction might involve a premium, based on the average protein content of wheat shipped from individual country elevators within a year, being incorporated into producers final payments.

While the main objectives of protein segregation have been successfully accomplished, there is little doubt but that improvements will be made as more and more experience is obtained. Moreover, procedures will also be developed for dealing with problems that may arise, such as a sudden change in the protein content from year to year.

VI. SUMMARY AND CONTRIBUTION TO KNOWLEDGE

1) The research reported in this thesis was designed to aid the Canadian Grain Commission in the development of a system for using protein content as a factor in grading Canadian wheat. Carlot surveys made by the Commission since 1940 were selected as the most suitable for preliminary studies. These surveys represent a five percent stratified sampling of the carlots of wheat unloaded in the western division in each crop year. For each selected carlot data on origin; unload destination and date; and on quality factors such as grade, bushel weight, protein content, and moisture were available. The records for the three most recent years, representing a period of average protein content (13.7%) and of current marketing distribution, and subsequently those for seven other years representing a range of annual protein means of 12.6 to 14.4, were transferred to magnetic tape, edited and the errors detected were corrected by computer.

2) Carlot survey data had previously been summarized each year, but only by origin, i.e., primarily by province and crop district. Computer programs were written to provide tabulated summaries, for both eastern and western movements, by unload area and by individual elevators within each unload area. While the tables dealt mainly with mean levels for protein and bushel weight, and with the numbers and percentages of carlots in each grade, frequency distributions and their standard deviations were also examined. A comprehensive and detailed picture of the

situation to be faced in introducing protein content as a grading factor was thus developed.

3) When the work was started the Commission had already proposed a system involving combining current grades Nos. 1 and 2 Northern to make a new grade, No. 1 Canada Western, to be divided into three sub-grades with the following constant protein ranges: over 14.2%, 13.0 to 14.2%, and under 13.0%. No. 3 Northern and part of No. 4 Northern were to be combined to form a second new grade with similar protein sub-grades. Computer programs were developed to facilitate study of this and similar proposals in terms of means for protein content and bushel weight, and percentage distribution of the principal grade among sub-grades. The original proposal and a number of three sub-grade, four sub-grade, and some two sub-grade systems, all involving different but constant protein ranges for the sub-grades, were examined. Each system was imposed on data for selected years representing a wide range of protein levels. Results were considered unsatisfactory because of the wide variation in the amounts of wheat entering each sub-grade, and the considerable variation from year to year in the mean protein content for each sub-grade, especially the highest and lowest. However, it was established that if the main grade was divided into three suitable sub-grades these would have protein means differing by approximately 1%.

4) A more promising system was developed which involved promotion at terminals of higher protein carlots from one sub-grade to the next higher sub-grade. In a three sub-grade system, the substantial increase

in the amounts of grain entering the upper and middle sub-grades, and the uniformity of the protein means for these sub-grades, were obviously attractive. It was also clear that in years of high protein level the lowest sub-grade would disappear, and that a still higher sub-grade would have to be added; and _vice versa_ for low protein years. In effect, the idea of constant protein ranges for sub-grades was discarded in favour or aiming at constant protein means for sub-grades; and this idea gave promise of meeting a currently developing consensus that Canadian wheat should be offered at guaranteed levels of 15% (when available), 14% and 13%, or possibly at 14.5%, 13.5% and 12.5%.

5) These studies also demonstrated a fairly consistent difference in protein level between wheat unloaded at Thunder Bay and at the Pacific Coast, with the former about 0.3% higher. Reasonably consistent differences also occurred between terminals at each port. For example, Saskatchewan Pool terminals unloaded wheat of a higher mean protein content than Manitoba Pool elevators at Thunder Bay, and at a higher than the Alberta Pool terminal at the Pacific Coast. There was also a tendency for terminals served only by the C.N.R. to unload wheat of lower protein content than those served by the C.P.R., or by both railways. These matters also deserved consideration in developing a system of protein segregation of carlots of wheat.

6) The Canadian Grain Commission had proposed that No. 2 Northern of less than 60 lb. per bushel be excluded from the new top grade. Investigation showed that, because of an inverse correlation between

protein content and bushel weight, No. 2 Northern of 59 and 58 lb. would be withdrawn mainly from the higher protein sub-grades, and therefore substantially less of these would thus be available for sale. The eventual compromise involved excluding only wheat of less than 59 lbs. per bushel.

7) A study of possible differences in moisture content among protein sub-grades was also undertaken but showed no significant association between protein content and moisture content.

8) At this stage of the research, in December of 1970, the Canadian Grain Commission introduced its proposed system of requiring country elevator agents to take a "Primary" sample of each carlot of wheat as it was loaded. This sample, for carlots moving east, was mailed to Winnipeg, and samples for carlots moving west were mailed to Calgary. Protein determinations were made and results were transmitted to Thunder Bay and Vancouver before the car arrived to permit segregation on the basis of protein content. "Unload" samples taken by the Commission's staff at unloading were also analyzed. Accordingly, a new set of data, with paired Primary and Unload proteins, theoretically for every carlot, became available for study. Since the same principles apply at all ports, it seemed advisable to concentrate on Pacific Coast data since problems are greater at the Pacific Coast because of the rapid transfer of wheat from rail to ship. Data for shipments made during eleven weeks were obtained (about 10,000 carlots), and in four of these weeks cars were "pooled"; i.e., allocated to terminals without regard to shipper,

to speed up transport by avoiding sorting over the hump in the yards. Additional problems were brought to light during study of the new set of data.

9) Since some 20% of the carlots were unloaded before the Primary results were available, it was necessary when the Primary was missing, to substitute the station mean for the shipping point. A twenty car floating mean was first proposed. Comparisons were made with shorter floating means, and with damped means, by comparing the standard deviations of the difference between the selected mean and the protein content of the next carlot shipped. A damped ten-car mean (nine times the old mean plus the protein value for the next carlot, all divided by ten) appeared the most accurate, and also reduced the computations considerably.

10) The objective was now to produce a system involving binning basis the Primary protein, or station mean, to provide three sub-grades (and a possible low-protein remainder) that could be exported at guaranteed protein levels of 15.0, 14.0 and 13.0%, or at 14.5, 13.5, and 12.5%. Moreover, the accuracy of the system had to be monitored with Unload proteins representing official samples taken by the Commission's staff. A computer program was developed for establishing the successive sub-grade minima, basis Primary proteins, required for target sub-grade means, basis Unload proteins; it involved a cumulative mean of the Unload protein from the high end of the frequency distribution and testing after each 0.1% increment until the mean fell to the desired level, which was

recorded before restarting the cumulative mean for the next sub-grade. Percentage distribution of carlots among sub-grades was recorded, and the printout also drew the frequency distribution diagram and recorded the standard deviation. A sub-routine to this program was written to monitor individual elevators, and this permitted different sets of Primary sub-grade minima to be used with different elevators, depending on the protein mean for each terminal's unloads. The printed table recorded protein means, basis Unload protein, for each sub-grade at each elevator, together with the percentage distribution among sub-grades. Some such program is obviously required for centralized control of binning in individual elevators. But, also for use as a feedback loop for adjusting sub-grade minima, the time lag between Unload and determination of Unload protein must be minimized, and the protein means must change slowly rather than abruptly.

11) It became apparent that the error of the protein determination, a single analysis on a single sample, affected the results; if the target mean for a sub-grade is higher than the mean for the main grade the sub-grade minima need to be higher than the earlier results indicated, whereas the reverse is true if the sub-grade target mean is less than the main grade mean. A search of the literature showed that this type of problem, selection of a segment with a desired mean from one end of a frequency distribution, had been investigated. The mathematical model was adapted to the present problem. Given the error of the determination, the standard deviation for the distribution, and the mean, it was possible

to calculate the Primary mean for each sub-grade required to produce a given Unload mean. It was also shown that a safety factor of 0.25%, basis Unload protein, was required to ensure 99% reliability in meeting a guaranteed level for export (i.e., a sub-grade Unload mean of 14.75% for a 14.5% guarantee). This system, of required Primary means, appears useful if the control of binning is decentralized to the port, or possibly to the level of individual terminals.

12) It was established, as would be expected, that each system of sub-grades repeats itself precisely for each decrease of 1% in the mean protein content of the main grade, provided that the distribution otherwise remains unchanged. For example, the Primary mean and minimum, and the amount of the guarantee 14.0% sub-grade, for a 13.5% mean for the main grade, are precisely duplicated for a guaranteed 13.0% sub-grade, when the mean for the main grade is 12.5%. Accordingly, the range of sub-grades that can be made available for export in any crop year will depend on the mean protein content of the available wheat, and substantial changes must occasionally be expected in successive years.

13) Since the Canadian Wheat Board directs shipments from 48 "Railway Blocks", and from 5 to 10 "Train Runs" in each Block, Block and Train Run numbers were added to the 12 weeks data. The mean protein content for Blocks and Train Runs, and the distribution within Blocks, and for selected groups of Blocks, were also examined. Considerable differences in the protein means for Train Runs were found within Blocks,

and wide differences exist in Block means. Distributions within Blocks tended to be more peaked than distributions representing say, a normal weeks unloads at the Pacific Coast. It is apparent that the Canadian Wheat Board can so direct shipments that the protein level for the carlots unloaded at the export position are more closely peaked around the target mean. However, such biasing of the distribution creates obvious difficulties for the segregation of carlots into three sub-grades of a specific protein content. These difficulties could be more readily overcome if it were possible to predict Unload means and distributions on the basis of the number of cars ordered from each Train Run, or possibly each station. Detailed study of this matter was prevented by lack of records for shipping dates, and by the considerable difference that exists in the time lag between shipping and unload.

14) Proper binning by sub-grades depends primarily on the accuracy of the Primary sampling including the analysis. A computer program was developed to monitor Primary sampling by comparing protein data for paired Primary and Unload samples, for paired station means and Unload samples when the Primary sample is missing, and for both sets combined. The printout tabulates the cumulative percentage of pairs differing by 0, 0.1, 0.2, etc., percentage units, together with the standard deviation of the difference. In one experiment, duplicate Unload samples were studied together with corresponding Primary samples; standard deviations of the difference were 0.40 for paired Primary and Unload samples, and 0.33 for paired Unload samples. Additional monitoring can be

provided by tabulating, or punching cards, by computer, for all primaries that differ from the unload by more than a predefined value, say 1% protein. Similar records can be provided for all carlots lacking primaries. Possible cases of recurrent careless sampling or failure to submit samples could thus be identified.

15) The new top grade No. 1 Canada Western red spring wheat became effective August 1, 1971, and sub-grades with guaranteed protein levels of 15.0, 14.0 and 13.0% were introduced at Thunder Bay on the same date. Sub-grades of guaranteed protein levels of 14.5, 13.5 and 12.5% were introduced at the Pacific Coast on January 1, 1972. The second new grade No. 2 Canada Western red spring wheat, with similar protein subgrades, was introduced on August 1, 1972. The studies reported in this thesis contributed to the development of the protein segregation system now in use, and the principal objective of the research has therefore been achieved.

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A P P E N D I X

TABLE A-1. MEANS FOR EACH UNLOAD AREA
YEAR: 1968-69
UNLOAD: ALL.

GRADE: ALL.
ORIGIN: ALL.

UNLOAD		1 NOR.	2 NOR.	3 NOR.	4 NOR.	NO.5	NO.6	FEED	GARNETS	OTHERS	ALL	1+2	1--4
		GRADES											
NUMBER OF SAMPLES													
LAKEHEAD		458	1051	1082	761	400	136	35	0	0	3923	1509	3352
PACIFIC		586	1297	366	930	341	4	0	5	0	3529	1883	3179
CHURCHILL		12	520	37	0	0	0	0	0	0	569	532	569
GOV. ELEVATORS		48	12	66	146	140	15	0	0	0	427	60	272
DOMESTIC		108	225	95	41	11	0	0	0	0	480	333	469
ALL AREAS		1212	3105	1646	1878	892	155	35	5	0	8928	4317	7841
DISTRIBUTION FOR WESTERN CANADA, %													
LAKEHEAD		5.13	11.77	12.12	8.52	4.48	1.52	0.39	0.0	0.0	43.94	16.90	37.54
PACIFIC		6.56	14.53	4.10	10.42	3.82	0.04	0.0	0.06	0.0	39.53	21.09	35.61
CHURCHILL		0.13	5.82	0.41	0.0	0.0	0.0	0.0	0.0	0.0	6.37	5.96	6.37
GOV. ELEVATORS		0.54	0.13	0.74	1.64	1.57	0.17	0.0	0.0	0.0	4.78	0.67	3.05
DOMESTIC		1.21	2.52	1.06	0.46	0.12	0.0	0.0	0.0	0.0	5.38	3.73	5.25
ALL AREAS		13.58	34.78	18.44	21.03	9.99	1.74	0.39	0.06	0.0	100.00	48.35	87.82
DISTRIBUTION WITHIN UNLOAD AREAS, %													
LAKEHEAD		11.67	26.79	27.58	19.40	10.20	3.47	0.89	0.0	0.0	100.00	38.47	85.44
PACIFIC		16.61	36.75	10.37	26.35	9.66	0.11	0.0	0.14	0.0	100.00	53.36	90.08
CHURCHILL		2.11	91.39	6.50	0.0	0.0	0.0	0.0	0.0	0.0	100.00	93.50	100.00
GOV. ELEVATORS		11.24	2.81	15.46	34.19	32.79	3.51	0.0	0.0	0.0	100.00	14.05	63.70
DOMESTIC		22.50	46.88	19.79	8.54	2.29	0.0	0.0	0.0	0.0	100.00	69.38	97.71
ALL AREAS		13.58	34.78	18.44	21.03	9.99	1.74	0.39	0.06	0.0	100.00	48.35	87.82
PROTEIN CONTENT, %													
LAKEHEAD	MEAN	13.72	13.69	13.92	13.96	14.08	14.23	14.36	0.0	0.0	13.87	13.70	13.83
	S. DEV	0.88	0.80	0.92	0.99	1.03	0.83	0.70	0.0	0.0	0.92	0.83	0.90
PACIFIC	MEAN	13.64	13.34	13.46	13.55	13.10	12.83	0.0	12.68	0.0	13.43	13.43	13.47
	S. DEV	0.76	0.91	1.06	1.30	1.38	0.61	0.0	0.80	0.0	1.08	0.87	1.04
CHURCHILL	MEAN	13.97	13.66	13.81	0.0	0.0	0.0	0.0	0.0	0.0	13.67	13.66	13.67
	S. DEV	0.27	0.59	0.60	0.0	0.0	0.0	0.0	0.0	0.0	0.58	0.58	0.58
GOV. ELEVATORS	MEAN	13.45	13.11	13.96	14.54	13.32	13.69	0.0	0.0	0.0	13.86	13.38	14.14
	S. DEV	0.66	0.82	0.82	0.67	1.48	1.42	0.0	0.0	0.0	1.18	0.70	0.86
DOMESTIC	MEAN	13.96	14.43	14.31	13.98	12.15	0.0	0.0	0.0	0.0	14.21	14.28	14.26
	S. DEV	0.78	0.55	0.58	1.40	1.78	0.0	0.0	0.0	0.0	0.84	0.67	0.75
ALL AREAS	MEAN	13.70	13.59	13.84	13.80	13.56	14.14	14.36	12.68	0.0	13.70	13.62	13.71
	S. DEV	0.81	0.85	0.96	1.18	1.35	0.93	0.70	0.80	0.0	1.01	0.84	0.96
BUSHEL WEIGHT, LB.													
LAKEHEAD	MEAN	63.29	62.26	60.94	58.74	56.54	53.11	46.63	0.0	0.0	60.29	62.58.	61.18
	S. DEV	1.19	1.42	1.55	1.85	2.15	2.35	3.48	0.0	0.0	3.22	1.44	2.18
PACIFIC	MEAN	63.84	62.83	61.62	59.44	57.55	54.00	0.0	62.80	0.0	61.46	63.15	61.89
	S. DEV	1.05	1.47	1.78	1.75	2.22	2.94	0.0	0.84	0.0	2.62	1.43	2.28
CHURCHILL	MEAN	63.00	63.42	62.14	0.0	0.0	0.0	0.0	0.0	0.0	63.32	63.41	63.32
	S. DEV	0.60	1.04	0.95	0.0	0.0	0.0	0.0	0.0	0.0	1.08	1.03	1.08
GOV. ELEVATORS	MEAN	64.23	63.42	60.53	58.73	56.64	53.40	0.0	0.0	0.0	58.89	64.07	60.35
	S. DEV	1.06	1.16	1.36	1.50	1.74	2.56	0.0	0.0	0.0	3.06	1.12	2.53
DOMESTIC	MEAN	63.80	61.40	61.44	60.05	59.55	0.0	0.0	0.0	0.0	61.79	62.17	61.84
	S. DEV	1.30	1.85	1.65	1.55	1.37	0.0	0.0	0.0	0.0	2.03	2.03	2.02
ALL AREAS	MEAN	63.64	62.64	61.13	59.11	56.97	53.16	46.63	62.80	0.0	60.96	62.92	61.63
	S. DEV	1.16	1.52	1.63	1.81	2.18	2.38	3.48	0.84	0.0	2.98	1.49	2.25

TABLE A-2. MEANS FOR EACH PROVINCE
YEAR: 1968-69
UNLOAD: ALL.

GRADE: ALL.
ORIGIN: ALL.

PROVINCE		1 NOR.	2 NOR.	3 NOR.	4 NOR.	NO.5	NO.6	FEED	GARNETS	OTHERS	ALL	1+2	1--4
NUMBER OF SAMPLES													
MANITOBA		155	363	484	262	129	29	1	0	0	1423	518	1264
SASKATCHEWAN		698	2018	992	1113	382	97	34	0	0	5334	2716	4821
ALBERTA		359	724	170	503	381	29	0	5	0	2171	1083	1756
WESTERN CANADA		1212	3105	1646	1878	892	155	35	5	0	8928	4317	7841
DISTRIBUTION WITHIN PROVINCES, %													
MANITOBA		10.89	25.51	34.01	18.41	9.07	2.04	0.07	0.0	0.0	100.00	36.40	88.83
SASKATCHEWAN		13.09	37.83	18.60	20.87	7.16	1.82	0.64	0.0	0.0	100.00	50.92	90.38
ALBERTA		16.54	33.35	7.83	23.17	17.55	1.34	0.0	0.23	0.0	100.00	49.88	80.88
WESTERN CANADA		13.58	34.78	18.44	21.03	9.99	1.74	0.39	0.06	0.0	100.00	48.35	87.82
DISTRIBUTION WITHIN GRADES, %													
MANITOBA		12.79	11.69	29.40	13.95	14.46	18.71	2.86	0.0	0.0	15.94	12.00	16.12
SASKATCHEWAN		57.59	64.99	60.27	59.27	42.83	62.58	97.14	0.0	0.0	59.74	62.91	61.48
ALBERTA		29.62	23.32	10.33	26.78	42.71	18.71	0.0	100.00	0.0	24.32	25.09	22.40
WESTERN CANADA		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	0.0	100.00	100.00	100.00
DISTRIBUTION FOR WESTERN CANADA, %													
MANITOBA		1.74	4.07	5.42	2.93	1.44	0.32	0.01	0.0	0.0	15.94	5.80	14.16
SASKATCHEWAN		7.82	22.60	11.11	12.47	4.28	1.09	0.38	0.0	0.0	59.74	30.42	54.00
ALBERTA		4.02	8.11	1.90	5.63	4.27	0.32	0.0	0.06	0.0	24.32	12.13	19.67
WESTERN CANADA		13.58	34.78	18.44	21.03	9.99	1.74	0.39	0.06	0.0	100.00	48.35	87.82
PROTEIN CONTENT, %													
MANITOBA	MEAN	13.04	13.02	13.31	13.36	13.69	13.99	15.50	0.0	0.0	13.27	13.02	13.20
	S. DEV	0.91	0.72	0.69	0.75	0.78	0.74	0.0	0.0	0.0	0.78	0.78	0.76
SASKATCHEWAN	MEAN	13.99	13.93	14.28	14.28	14.23	14.30	14.32	0.0	0.0	14.11	13.95	14.09
	S. DEV	0.64	0.64	0.75	0.89	1.06	0.86	0.68	0.0	0.0	0.78	0.64	0.75
ALBERTA	MEAN	13.40	12.92	12.74	12.96	12.85	13.75	0.0	12.68	0.0	12.99	13.08	13.01
	S. DEV	0.78	0.87	1.05	1.37	1.40	1.21	0.0	0.80	0.0	1.13	0.87	1.05
WESTERN CANADA	MEAN	13.70	13.59	13.84	13.80	13.56	14.14	14.36	12.68	0.0	13.70	13.62	13.71
	S. DEV	0.81	0.85	0.96	1.18	1.35	0.93	0.70	0.80	0.0	1.01	0.84	0.96
BUSHEL WEIGHT, LB.													
MANITOBA	MEAN	63.83	63.21	61.04	59.13	56.97	53.52	48.00	0.0	0.0	61.01	63.39	61.61
	S. DEV	0.90	1.19	1.76	1.90	2.16	2.35	0.0	0.0	0.0	2.86	1.15	2.28
SASKATCHEWAN	MEAN	63.39	62.26	60.96	58.61	56.38	53.13	46.59	0.0	0.0	60.72	62.55	61.31
	S. DEV	1.23	1.54	1.49	1.60	2.04	2.41	3.53	0.0	0.0	2.99	1.55	2.23
ALBERTA	MEAN	64.05	63.41	62.40	60.22	57.57	52.90	0.0	62.80	0.0	61.53	63.62	62.53
	S. DEV	0.98	1.15	1.46	1.70	2.17	2.32	0.0	0.84	0.0	2.96	1.14	2.02
WESTERN CANADA	MEAN	63.64	62.64	61.13	59.11	56.97	53.16	46.63	62.80	0.0	60.96	62.92	61.63
	S. DEV	1.16	1.52	1.63	1.81	2.18	2.38	3.48	0.84	0.0	2.98	1.49	2.25

TABLE A-3. ELEVATOR UNLOADS
YEAR: 1968-69.
UNLOAD: PACIFIC

GRADE: 01 +02,
ORIGIN: ALL

TERMINAL	MONTH												QUARTER				TOTAL
	8	9	10	11	12	1	2	3	4	5	6	7	1	2	3	4	
NUMBER OF SAMPLES																	
SASK. POOL	70	67	49	36	19	25	28	27	15	65	29	16	186	80	70	110	446
ALTA. POOL	87	71	44	29	30	19	39	35	21	37	46	33	202	78	95	116	491
U.G.G.	37	27	30	4	13	18	21	11	8	32	20	11	94	35	40	63	232
PAC. 3	17	9	15	2	7	4	8	3	1	13	1	0	41	13	12	14	80
PAC.1	86	74	46	16	17	29	38	34	14	48	33	18	206	62	86	99	453
BURRARD	11	16	0	5	0	7	9	1	0	9	2	1	27	12	10	12	61
PR. RUPERT	10	12	7	0	0	0	0	0	0	0	0	0	29	0	0	0	29
VICTORIA	10	19	7	9	2	2	12	4	0	6	4	0	36	13	16	10	75
OTHERS	1	11	0	0	1	2	0	1	0	0	0	0	12	3	1	0	16
TOTAL	329	306	198	101	89	106	155	116	59	210	135	79	833	296	330	424	1883
DISTRIBUTION, PERCENT OF GRADE																	
SASK. POOL	3.72	3.56	2.60	1.91	1.01	1.33	1.49	1.43	0.80	3.45	1.54	0.85	9.88	4.25	3.72	5.84	23.69
ALTA. POOL	4.62	3.77	2.34	1.54	1.59	1.01	2.07	1.86	1.12	1.96	2.44	1.75	10.73	4.14	5.05	6.16	26.08
U.G.G.	1.96	1.43	1.59	0.21	0.69	0.96	1.12	0.58	0.42	1.70	1.06	0.58	4.99	1.86	2.12	3.35	12.32
PAC. 3	0.90	0.48	0.80	0.11	0.37	0.21	0.42	0.16	0.05	0.69	0.05	0.0	2.18	0.69	0.64	0.74	4.25
PAC.1	4.57	3.93	2.44	0.85	0.90	1.54	2.02	1.81	0.74	2.55	1.75	0.96	10.94	3.29	4.57	5.26	24.06
BURRARD	0.58	0.85	0.0	0.27	0.0	0.37	0.48	0.05	0.0	0.48	0.11	0.05	1.43	0.64	0.53	0.64	3.24
PR. RUPERT	0.53	0.64	0.37	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.54	0.0	0.0	0.0	1.54
VICTORIA	0.53	1.01	0.37	0.48	0.11	0.11	0.64	0.21	0.0	0.32	0.21	0.0	1.91	0.69	0.85	0.53	3.98
OTHERS	0.05	0.58	0.0	0.0	0.05	0.11	0.0	0.05	0.0	0.0	0.0	0.0	0.64	0.16	0.05	0.0	0.85
TOTAL	17.47	16.25	10.52	5.36	4.73	5.63	8.23	6.16	3.13	11.15	7.17	4.20	44.24	15.72	17.53	22.52	100.00
PROTEIN CONTENT, %																	
SASK. POOL	14.02	13.98	13.54	13.55	13.68	13.64	13.54	13.77	14.04	13.95	13.76	13.88	13.88	13.61	13.74	13.89	13.81
ALTA. POOL	13.49	13.43	12.90	12.84	12.69	13.05	12.87	12.95	13.08	12.85	13.04	13.15	13.34	12.84	12.95	13.01	13.11
U.G.G.	13.60	13.67	13.40	12.75	13.11	12.99	12.98	13.01	13.49	13.47	13.09	13.33	13.56	13.01	13.09	13.32	13.33
PAC. 3	13.45	14.04	13.55	13.55	13.37	13.70	12.92	13.17	12.40	13.98	14.10	0.0	13.62	13.50	12.94	13.99	13.56
PAC.1	13.76	13.72	13.37	13.21	12.88	13.24	12.97	13.24	12.84	13.25	13.19	12.87	13.66	13.13	13.06	13.16	13.36
BURRARD	13.75	14.02	0.0	12.90	0.0	13.70	13.43	14.80	0.0	13.83	13.50	13.50	13.91	13.37	13.57	13.75	13.72
PR. RUPERT	12.53	13.57	13.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.13	0.0	0.0	0.0	13.13
VICTORIA	13.71	13.88	13.67	14.09	14.25	14.40	13.34	12.85	0.0	13.52	13.05	0.0	13.79	14.16	13.22	13.33	13.67
OTHERS	13.60	14.44	0.0	0.0	13.10	12.70	0.0	13.70	0.0	0.0	0.0	0.0	14.37	12.83	13.70	0.0	14.04
TOTAL	13.67	13.76	13.33	13.28	13.09	13.32	13.10	13.26	13.31	13.51	13.26	13.26	13.62	13.24	13.19	13.38	13.43

TABLE A-4. MEANS FOR TWO DIVIDES (OVERS)
YEAR: 1962-63
UNLOAD: ALL, LAKEHEAD, PACIFIC.

GRADE: 01+02
ORIGIN: ALL

PROTEIN	NO. OF SAMPLES			DISTRIBUTION, %			PROTEIN, %			BUSHEL WEIGHT, LB		
RANGE, %	ALL	LAKEHEAD	PACIFIC	ALL	LAKEHEAD	PACIFIC	ALL	LAKEHEAD	PACIFIC	ALL	LAKEHEAD	PACIFIC
17.0 & OVER	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.9 & OVER	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.8 & OVER	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.7 & OVER	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.6 & OVER	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.5 & OVER	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.4 & OVER	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.3 & OVER	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16.2 & OVER	1	1	0	0.02	0.07	0.0	16.20	16.20	0.0	62.00	62.00	0.0
16.1 & OVER	3	3	0	0.07	0.20	0.0	16.13	16.13	0.0	62.67	62.67	0.0
16.0 & OVER	4	4	0	0.09	0.27	0.0	16.10	16.10	0.0	62.50	62.50	0.0
15.9 & OVER	4	4	0	0.09	0.27	0.0	16.10	16.10	0.0	62.50	62.50	0.0
15.8 & OVER	5	4	0	0.12	0.27	0.0	16.04	16.10	0.0	61.80	62.50	0.0
15.7 & OVER	6	4	2	0.14	0.27	0.05	15.98	16.10	15.70	62.17	62.50	64.00
15.6 & OVER	14	7	3	0.32	0.46	0.14	15.76	15.89	15.63	61.64	62.14	61.67
15.5 & OVER	22	12	5	0.51	0.80	0.27	15.67	15.72	15.59	61.59	61.75	62.20
15.4 & OVER	34	14	10	0.79	0.93	0.53	15.57	15.68	15.49	61.68	62.00	62.30
15.3 & OVER	57	23	17	1.32	1.52	0.90	15.46	15.53	15.41	61.51	61.61	62.00
15.2 & OVER	81	38	21	1.88	2.52	1.12	15.39	15.40	15.37	61.41	61.55	61.71
15.1 & OVER	119	53	31	2.76	3.51	1.65	15.29	15.32	15.28	61.50	61.55	61.97
15.0 & OVER	162	63	46	3.75	4.17	2.44	15.22	15.27	15.19	61.61	61.65	62.13
14.9 & OVER	230	99	70	5.33	5.90	3.72	15.12	15.16	15.09	61.67	61.73	62.25
14.8 & OVER	306	110	90	7.09	7.89	4.78	15.04	15.07	15.03	61.73	61.60	62.34
14.7 & OVER	405	156	121	9.38	10.34	6.43	14.96	14.98	14.94	61.75	61.55	62.36
14.6 & OVER	525	206	162	12.16	13.65	8.66	14.89	14.83	14.85	61.88	61.68	62.39
14.5 & OVER	655	260	205	15.17	17.23	10.89	14.80	14.81	14.78	61.97	61.70	62.45
14.4 & OVER	807	315	268	18.69	20.87	14.23	14.73	14.74	14.69	62.08	61.74	62.55
14.3 & OVER	995	394	328	23.05	26.11	17.42	14.65	14.65	14.62	62.19	61.84	62.65
14.2 & OVER	1188	466	410	27.52	30.88	21.77	14.57	14.58	14.54	62.26	61.91	62.73
14.1 & OVER	1400	542	489	32.43	35.92	25.97	14.50	14.51	14.47	62.33	61.98	62.75
14.0 & OVER	1614	618	576	37.39	40.95	30.59	14.44	14.45	14.40	62.38	62.02	62.73
13.9 & OVER	1831	701	657	42.41	46.45	34.89	14.37	14.38	14.33	62.44	62.09	62.73
13.8 & OVER	2035	770	742	47.14	51.03	39.41	14.31	14.33	14.27	62.48	62.11	62.81
13.7 & OVER	2257	839	835	52.28	55.60	44.34	14.25	14.28	14.21	62.55	62.15	62.87
13.6 & OVER	2461	910	924	57.01	60.30	49.07	14.20	14.23	14.15	62.60	62.22	62.91
13.5 & OVER	2666	978	1004	61.76	64.81	53.32	14.15	14.18	14.10	62.65	62.24	62.95
13.4 & OVER	2864	1058	1036	66.34	70.11	57.67	14.09	14.12	14.05	62.69	62.30	62.99
13.3 & OVER	3019	1101	1158	69.93	72.96	61.50	14.05	14.09	14.00	62.73	62.33	63.02
13.2 & OVER	3176	1159	1224	73.57	76.81	65.00	14.01	14.04	13.96	62.76	62.36	63.05
13.1 & OVER	3320	1222	1278	76.91	80.98	67.87	13.97	13.99	13.92	62.78	62.39	63.07
13.0 & OVER	3453	1267	1339	79.99	83.96	71.11	13.93	13.96	13.88	62.79	62.40	63.08
12.9 & OVER	3578	1314	1399	82.89	87.08	74.30	13.90	13.92	13.84	62.81	62.43	63.09
12.8 & OVER	3682	1345	1460	85.29	89.13	77.54	13.87	13.89	13.79	62.83	62.45	63.10
12.7 & OVER	3759	1363	1509	87.07	90.32	80.14	13.84	13.88	13.76	62.84	62.47	63.11
12.6 & OVER	3834	1382	1556	88.81	91.58	82.63	13.82	13.86	13.72	62.85	62.48	63.12
12.5 & OVER	3902	1399	1601	90.39	92.71	85.02	13.80	13.84	13.69	62.87	62.50	63.13
12.4 & OVER	3961	1413	1639	91.75	93.64	87.04	13.78	13.83	13.66	62.88	62.51	63.13
12.3 & OVER	4012	1426	1672	92.93	94.50	88.79	13.76	13.82	13.63	62.89	62.52	63.14
12.2 & OVER	4068	1437	1715	94.23	95.23	91.08	13.74	13.80	13.60	62.89	62.53	63.14
12.1 & OVER	4111	1445	1740	95.23	95.76	92.83	13.72	13.79	13.57	62.90	62.53	63.14
12.0 & OVER	4150	1455	1777	96.13	96.42	94.37	13.70	13.78	13.54	62.90	62.54	63.14

TABLE A-5. MEANS FOR TWO DIVIDES (UNDERS)
YEAR: 1962-69
SUBGROUP: ALL, LAKEHEAD, PACIFIC.

GRADE: 01+02
ORIGIN: ALL

PROTEIN RANGE, %	NO. OF SAMPLES ALL	NO. OF SAMPLES LAKEHEAD	NO. OF SAMPLES PACIFIC	DISTRIBUTION, % ALL	DISTRIBUTION, % LAKEHEAD	DISTRIBUTION, % PACIFIC	PROTEIN, % ALL	PROTEIN, % LAKEHEAD	PROTEIN, % PACIFIC	BUSHEL WEIGHT, LB ALL	BUSHEL WEIGHT, LB LAKEHEAD	BUSHEL WEIGHT, LB PACIFIC
UNDER 17.0	4317	1509	1893	100.00	100.00	100.00	13.62	13.70	13.43	62.92	62.58	63.15
UNDER 16.9	4317	1509	1893	100.00	100.00	100.00	13.62	13.70	13.43	62.92	62.58	63.15
UNDER 16.8	4317	1509	1893	100.00	100.00	100.00	13.62	13.70	13.43	62.92	62.59	63.15
UNDER 16.7	4317	1509	1893	100.00	100.00	100.00	13.62	13.70	13.43	62.92	62.58	63.15
UNDER 16.6	4317	1509	1893	100.00	100.00	100.00	13.62	13.70	13.43	62.92	62.58	63.15
UNDER 16.5	4317	1509	1893	100.00	100.00	100.00	13.62	13.70	13.43	62.92	62.58	63.15
UNDER 16.4	4317	1509	1893	100.00	100.00	100.00	13.62	13.70	13.43	62.92	62.58	63.15
UNDER 16.3	4317	1509	1893	100.00	100.00	100.00	13.62	13.70	13.43	62.92	62.58	63.15
UNDER 16.2	4316	1508	1893	99.98	99.93	100.00	13.62	13.70	13.43	62.92	62.58	63.15
UNDER 16.1	4314	1505	1893	99.93	99.80	100.00	13.62	13.70	13.43	62.92	62.58	63.15
UNDER 16.0	4313	1505	1893	99.91	99.73	100.00	13.62	13.69	13.43	62.92	62.58	63.15
UNDER 15.9	4313	1505	1893	99.91	99.73	100.00	13.62	13.69	13.43	62.92	62.58	63.15
UNDER 15.8	4312	1505	1893	99.88	99.73	100.00	13.62	13.69	13.43	62.92	62.58	63.15
UNDER 15.7	4311	1505	1893	99.86	99.73	100.00	13.62	13.69	13.43	62.92	62.58	63.15
UNDER 15.6	4303	1502	1890	99.68	99.54	99.84	13.61	13.69	13.43	62.92	62.58	63.15
UNDER 15.5	4295	1497	1878	99.49	99.20	99.73	13.61	13.68	13.43	62.92	62.58	63.15
UNDER 15.4	4282	1495	1873	99.21	99.07	99.47	13.60	13.68	13.42	62.93	62.58	63.15
UNDER 15.3	4260	1486	1866	98.68	98.48	99.10	13.59	13.67	13.41	62.94	62.59	63.15
UNDER 15.2	4234	1471	1862	98.12	97.48	98.38	13.59	13.66	13.41	62.95	62.60	63.15
UNDER 15.1	4150	1456	1852	97.24	96.49	98.35	13.57	13.64	13.40	62.96	62.61	63.17
UNDER 15.0	4155	1444	1837	96.25	95.93	97.56	13.56	13.63	13.39	62.97	62.62	63.17
UNDER 14.9	4087	1420	1813	94.67	94.10	96.28	13.53	13.61	13.37	62.99	62.63	63.13
UNDER 14.8	4011	1390	1793	92.91	92.11	95.22	13.51	13.58	13.35	63.01	62.65	63.19
UNDER 14.7	3912	1353	1762	90.62	89.66	93.57	13.48	13.55	13.33	63.04	62.69	63.20
UNDER 14.6	3792	1303	1720	87.84	86.35	91.34	13.44	13.51	13.30	63.06	62.72	63.22
UNDER 14.5	3662	1249	1678	84.83	82.77	89.11	13.41	13.47	13.27	63.09	62.76	63.23
UNDER 14.4	3510	1194	1615	81.31	79.13	85.77	13.36	13.43	13.22	63.11	62.79	63.25
UNDER 14.3	3322	1115	1555	76.95	73.89	82.58	13.31	13.37	13.18	63.14	62.84	63.25
UNDER 14.2	3129	1043	1472	72.48	69.12	78.23	13.26	13.31	13.13	63.17	62.87	63.26
UNDER 14.1	2917	967	1394	67.57	64.08	74.03	13.20	13.25	13.07	63.20	62.91	63.28
UNDER 14.0	2707	921	1307	62.61	59.05	69.41	13.13	13.19	13.01	63.24	62.96	63.31
UNDER 13.9	2486	808	1226	57.59	53.55	65.11	13.06	13.11	12.95	63.27	63.00	63.34
UNDER 13.8	2282	739	1141	52.86	48.97	60.59	13.00	13.04	12.89	63.31	63.06	63.37
UNDER 13.7	2059	679	1049	47.72	44.40	55.66	12.92	12.97	12.81	63.32	63.06	63.37
UNDER 13.6	1856	599	959	42.99	39.70	50.93	12.85	12.90	12.74	63.33	63.12	63.38
UNDER 13.5	1651	531	879	38.24	35.19	46.68	12.77	12.82	12.67	63.34	63.19	63.37
UNDER 13.4	1452	451	797	33.66	29.89	42.33	12.68	12.72	12.60	63.36	63.23	63.36
UNDER 13.3	1298	408	725	30.07	27.04	38.50	12.61	12.65	12.53	63.35	63.24	63.35
UNDER 13.2	1141	350	659	26.43	23.19	35.00	12.53	12.57	12.46	63.35	63.28	63.31
UNDER 13.1	997	297	605	23.09	19.92	32.13	12.44	12.46	12.40	63.38	63.37	63.31
UNDER 13.0	864	242	544	20.01	16.04	28.89	12.36	12.35	12.34	63.41	63.48	63.32
UNDER 12.9	730	195	484	17.12	12.92	25.70	12.27	12.22	12.27	63.42	63.55	63.31
UNDER 12.8	635	164	422	14.71	10.87	22.46	12.18	12.11	12.19	63.43	63.60	63.30
UNDER 12.7	559	146	374	12.93	9.68	19.86	12.11	12.04	12.12	63.44	63.58	63.32
UNDER 12.6	482	137	327	11.19	9.42	17.37	12.03	11.94	12.05	63.42	63.60	63.29
UNDER 12.5	415	110	282	9.61	7.29	14.98	11.95	11.87	11.98	63.39	63.55	63.27
UNDER 12.4	354	96	244	8.25	6.36	12.96	11.88	11.80	11.92	63.35	63.54	63.25
UNDER 12.3	305	83	211	7.07	5.50	11.21	11.81	11.72	11.85	63.33	63.57	63.21
UNDER 12.2	249	72	168	5.77	4.77	8.92	11.72	11.65	11.77	63.31	63.53	63.18
UNDER 12.1	206	64	135	4.77	4.24	7.17	11.65	11.59	11.69	63.32	63.52	63.21
UNDER 12.0	167	54	106	3.87	3.58	5.63	11.56	11.51	11.60	63.36	63.57	63.23