Development of an Automated Process for the Production of Enriched Bakers' Salt

Roy F. Quinn,
Diamond Crystal Salt Co.,
St. Clair, Michigan

ABSTRACT

Increasing sales of an Enriched Bakers' Salt developed by Diamond Crystal Salt Company dictated the necessity of changing from previously used conventional batch blending procedures to a semi-continuous blending process both to increase production rates and decrease costs. Automatic batch blending was selected over previously used continuous conveyor type blenders for other products because of necessity for tight quality control and uniformity of color of the finished product.

Mechanical and electrical problems associated with an automatic batch system such as relay failures, scale design and premix feed characteristics necessitated redesign of parts of the original equipment as purchased from the supplier.

Evaluation of the blending performance of the automated system required use of analytical techniques for vitamins which were new to the salt industry. Quality control measures include daily analyses of selected samples and retention of samples for a period of three months. Each batch of vitamin premix is also analyzed before release for production.

INTRODUCTION

Background. The development of Enriched Bakers' Salt like any new product has encountered many unforeseen difficulties. This paper covers those which were the most difficult to solve or those which had the most effect on the final product. This covers not only the mechanical problems associated with the process development but also some of the analytical problems associated with maintaining the quality of the product, which is of major importance in our business.

Reasons for Developing Product. The development of an enriched bakers' salt appeared promising since a cost analysis showed that we could produce the product and sell it to the bakeries at a cost to them less than buying the two ingredients separately. By combining the two ingredients we would also save the baker time in preparation of the then used vitamin wafers which required crushing and dissolving in water before they could be added to his dough. In addition, as the vitamins were incorporated with the salt there was less chance that the baker would forget to add the vitamins to his mix.

PRODUCT PRODUCTION

Ingredients Selection. The first problem to be solved was selection of the ingredients to be used in production of the proposed product. The first formulas developed consisted of thiamine hydrochloride, riboflavin, niacin and ferrous sulfate as the source of iron.

Since the initial selections were made we have changed to thiamine mononitrate as it has more thiamine per gram for the same cost and has better stability to heat and humidity.

Ferrous sulfate was initially chosen since it was felt that a water soluble material would disperse better in the bread dough. However, the ferrous sulfate gave two problems: the first was segregation and the second was that it had an acidic pH and caused deterioration of the inner ply of kraft paper in the bag. The iron source was changed to ferric pyrophosphate, a much finer powdery material which coated on the salt particles uniformly solving the segregation problems. There were no packaging problems with it either.

Initially 6% excess of ingredients was proposed as sufficient to meet the contents requirement. Subsequent tests showed the necessity for a larger excess and 10% was chosen. Amounts of materials for a 1,000-lb. batch are shown in Table No. 1. Both 6% and 10% figures are given for comparison purposes.

Table 1. Initial Formulas for Enriched Bakers' Salt

	6% Excess		10% Excess	
Ingredient	70-A	90-B	70-A	90-B
Thiamine Mononitrate (gms)	101	101	104.5	104.5
Riboflavin (gms)	37	47.5	38.5	49.5
Niacin (gms)	636	636	660.0	660.0
Ferric Pyrophosphate (gms)	1,908	1,908	1,980.0	1,980.0
Fine Flake salt (lbs)	994	994	994	994

Stability Tests. As this was a new use for vitamins, for which no history was available, the first information necessary was their stability in a salt mixture. The stability tests were run for us by the vitamin supplier on mixtures made up by Diamond Crystal. This procedure was followed since at the time we had no personnel experienced in vitamin analysis, and tests by an outside concern are also accepted more readily by prospective customers.

The tests included both normal storage at 25°C. and accelerated storage at 38°C. The normal storage tests were run for six months and the accelerated storage tests were run for 30 days. The reason for accelerated tests was to obtain quick results which would give reasonable assurance that the product would remain stable in storage and usage by the customer. The rule of thumb in correlating the two is that tests run at 30°C. for two weeks are equivalent to four weeks at 25°C. For each 10°C. rise in temperature above 30°C. the time element is doubled, i.e., 40°C. for two weeks is equivalent to eight weeks at 25°C. The accelerated storage tests in this case were equivalent to 13 weeks of normal storage.

The results of the stability tests are given in Table No. 2.

Table 2. Product Stability Tests

	Bag	As Blended	Initial	3 Months	6 Months	Accelerated
Thiamine (mgs/lb)	95	104.5	103	100	97	103
Riboflavin (mgs/lb)	35	38.5	39	41	38	39
Niacin (mgs/lb)	600	660.0	650	653	647	643

The results of the tests showed that little deterioration of the product would occur in six months of normal storage. The thiamine used was in the form of the hydrochloride and showed the greatest decline percentagewise. For this reason the change was made to the mononitrate form which exhibited equivalent stability to the other vitamins in subsequent tests. Storage tests in bags were also made later with similar results to those listed in the table.

Batch Blending. The initial production of product was made by conventional batch blending procedures using a J. H. Day D-10 ribbon type blender with a center discharge. For a 1,000-lb. batch of finished product the operator would weigh out each ingredient, charge the blender, and mix it for a specific length of time. The possibilities for error in this procedure were soon found to be numerous varying from short weights to the extreme possibility of leaving out an ingredient completely.

In order to eliminate these possible errors the development of a master mix of the vitamins and iron was undertaken.

Past experience in our company with similar types of powdery materials indicated that it might be possible to blend them in a ribbon type blender. This method was found to be practical and the final procedure was to mix the materials in a ribbon type blender for a three hour period. Table No. 3 gives the ingredients for the 70-A and 90-B type mixes.

Table 3. Master Mix Formulas

Ingredient	70-A Lbs. /Mix	90-B Lbs. /Mix
Thiamine Mononitrate	15 lbs. 2 oz.	15 lbs. 2 oz.
Riboflavin	5 lbs. 12 oz.	7 lbs. 2 oz.
Niacin	94 lbs. 10 oz.	94 lbs. 10 oz.
Ferric Pyrophosphate	284 lbs.	284 lbs.

The development of the master mix eliminated the possibility of complete absence of any one vitamin and increased the accuracy of addition by the operators as a larger weight of material was weighed out where any small inaccuracies in weight meant less in the final product. The development of a master mix was also essential for a continuous blending type of operation.

Automatic Blending. As the production of Enriched Bakers' Salt increased, it became evident that a better method of production would have to be installed in order to increase the production rate and also reduce production costs. Previously used continuous blending systems had consisted of a mixing conveyor into which the amounts of ingredients were controlled by feeders.

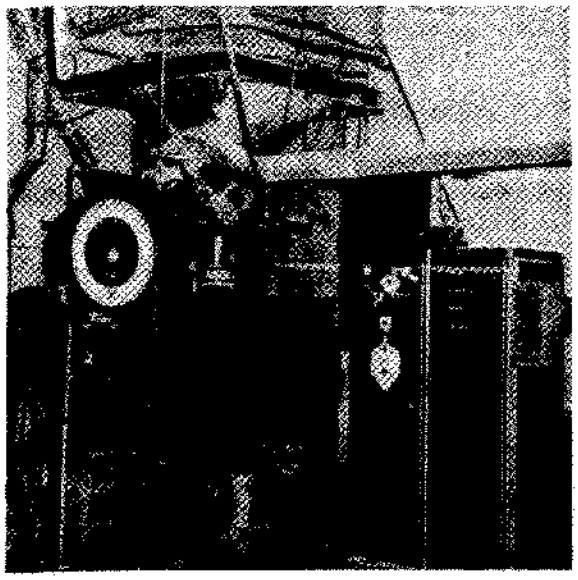
With the yellow-colored E.B.S. salt there was a contamination problem if it was to be blended in equipment used for other types of salt. There were also potential stability problems with the E.B.S. as some of the ingredients used for anticaking purposes in other salt products have a deleterious effect on certain of the enrichment ingredients. Plant physical layout also made it difficult to install an entirely separate conveyor type continuous blending installation.

While the above reasons are important they could have been overcome by proper selection of equipment and training of operators. Our original selection of a ribbon type batch blender resulted in production of an intensely yellow-colored product which was reproducible from batch to batch and as there is resistance to changes in a product once it is established it was decided to stay with this type equipment and determine if the operation could be automated.

Purchased Equipment. Investigation disclosed that the Toledo Scale Co. of Toledo, Ohio, had electrical control units for this type of automated operation available.

The equipment purchased from the Toledo Scale Company consisted of the electrical control system, scales for the salt and vitamins, and a dual speed syntron vibrating feeder for the vitamins. The J. H. Day model D-10 ribbon type blender, syntron vibrating feeder for the salt scale, Eagle Signal Timer, and aluminum storage bin were furnished by other companies to Diamond Crystal's specifications. The installation of the equipment was done by Diamond Crystal personnel. Toledo personnel were present on start-up of the equipment. An overall view of the equipment as installed is shown in Photograph No. 1 on the following page.

As installed the equipment had several safety devices to prevent malfunctioning with resulting production of nonstandard product. The safety devices as shown in Fig. No. 1 included



Photograph No. 1.

magnetic cutoff switches A_1 and A_2 on the salt scale tied in with the electrical circuits so that the system could not cycle unless a full load of salt was indicated. The vitamin scale had a photoelectric eye system, B, to control the weighing of vitamin master mix and not let the system cycle unless the correct amount of master mix was weighed out. There was also a zero speed switch, G, on the blender shaft which stopped the cycle if the blender should stop, from power failure or other cause, such as a broken drive chain, preventing another load of salt and vitamins from being dumped in the blender.

Vitamin Scale Problems. Start-up of the system involved unforeseen problems as will most start-ups of new equipment. The vitamin scale gave a particularly bad problem in that the solenoid which was supposed to open the gate did not function correctly because of poor design in the linkage. This was solved by changing the angle of the solenoid mounting on the scale bucket by placing a plate under it as shown in Fig. No. 2. The vitamins also hung up in the scale bucket giving

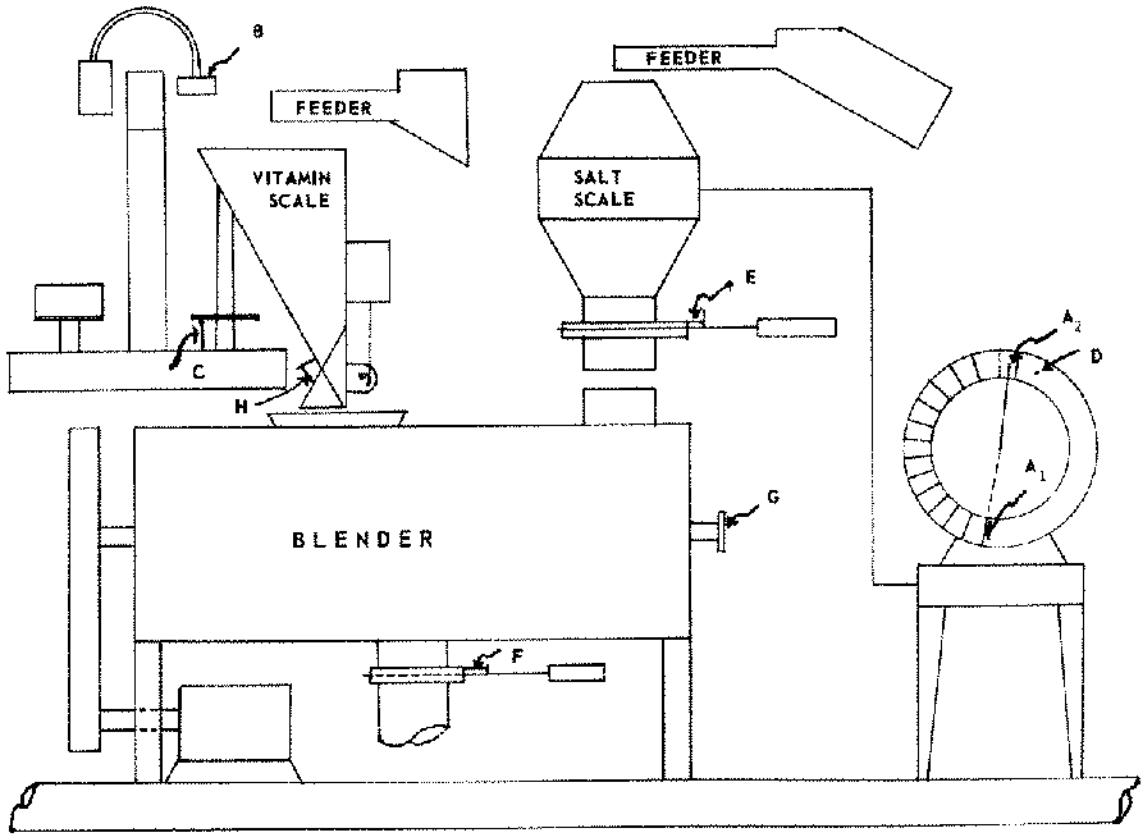


Figure 1. Diagrammatic Layout of Installation Showing Safety Features.

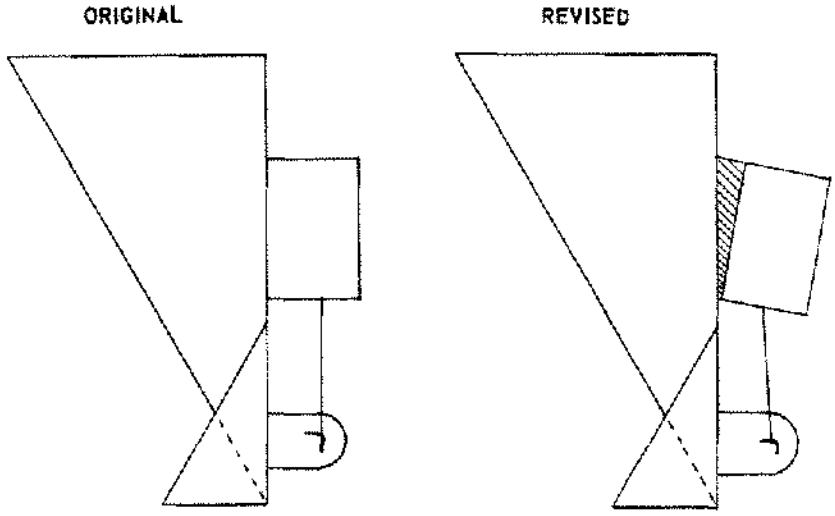


Figure 2. Vitamin Scale Solenoid Revision.

incomplete discharge causing substandard product necessitating reblending of the product. This was solved by placing a small vibrator, on the scale bucket, which was activated each time the scale gate opened. A microswitch was placed on the scale gate to ensure it was shut before weighing out another load.

The photoelectric eye system on the vitamin scale has been changed since the original installation. Originally the system was set up so that a light beam from the opposite side of the scale was on the photocell when the scale was empty and as the vibrating feeder fed vitamins into the scale bucket a fan or piece of metal moved into the path of the light cutting it off and putting the vibrating feeder into a slower rate of feed to finish filling the scale. The scale was full when the end of the metal piece passed the photocell and allowed light to again fall on the photocell which then by signal to a relay stopped the feed of the vitamins. If we had been feeding a free-flowing material with this type of set up it would have worked all right, but the vitamins are not what could be termed free-flowing and tended to occasionally fall off in chunks large enough to cause a slight bounce in the scale. If this happened just as the fan cut off the light from the photocell the backlash after the lump of vitamins dropped in the scale would cause the fan to go back and allow light to fall on the photocell indicating to the control center that the scale was full even though it wasn't. Unless seen by control laboratory personnel in the immediate area this would result in substandard product.

The first modification was to place microswitches on the scale (C on Fig. No. 1) to prevent the cycle from starting if the scale did not have the correct weight of vitamins in it. These have now been changed to mercoid switches which are less susceptible to dirt and moisture. This corrected the substandard product problem but the difficulties with the photocell system remained.

The fan shape has been revised as shown in Fig. No. 3 by cutting down on the length of it to minimize backlash problems. The original installation gave short weights of three to four ounces if it cut off too soon while the new shape gives less than an one half-ounce variation which is within our 10% overage and will not result in substandard product.

In the initial installation we were experiencing trouble maintaining sufficient current generation by the photocell due to the light having to pass through two layers of glass in the scale which tended to become dirty and cut the generated current to the point where erratic signals were sent to the control center causing false operations. A photoreflective type system has now been installed where one layer of glass has been eliminated by putting the photoreflective tape on the inner surface of the glass behind the fan and the light source is in the same body with the photocell. In operation the light reflects back from the tape and activates the photocell. The photocell system now has sponge rubber around the edges of it to cut down on the dust getting on the lens or the layer of glass between it and the photoreflective tape. Even with these modifications it has been found

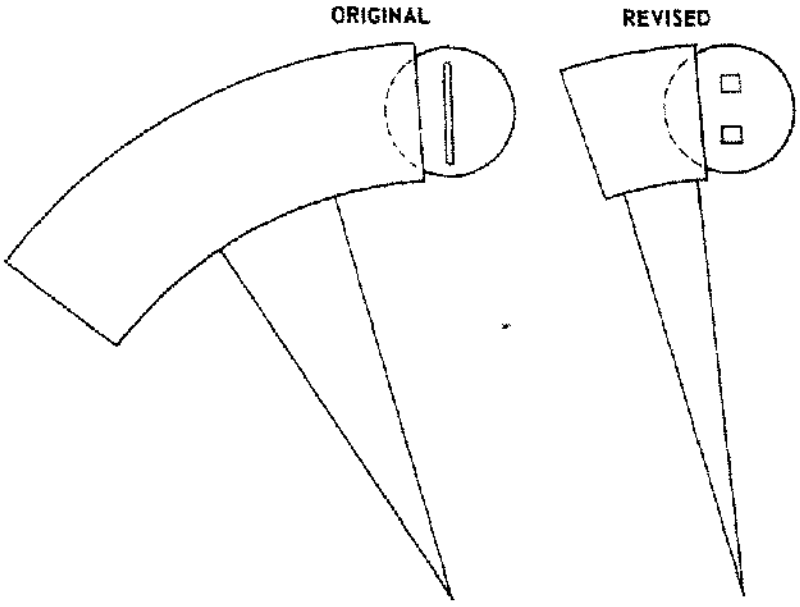


Figure 8. Vitamin Scale Fan and Photocell Revisions.

necessary to purchase a spare scale and to change scales every three months to prevent signal problems from developing. A Microammeter has been added so that the amount of signal current being generated is known.

Relay Circuits. In conjunction with these changes three ratchet type relays in the electrical circuits were changed to electrical interlocking type relays for better reliability. One bad disadvantage of the ratchet type relays was that if the electrical current should fail the ratchets would reset and the cycle would be disrupted and anything could happen up to discharging a complete load of salt and vitamins on top of salt already in the blender when the current was restored. In actuality the ratchet type relays were completely eliminated from the circuits and not replaced. Their functions were in part taken over by other relays already in the circuits whose functions were also revised.

The entire interlock and power control circuits were revised from those originally furnished by the Toledo Scale Co. The circuits have been simplified and made more reliable. The circuits have been separated into safety interlock and power-operating circuits so that no safety interlock circuit relays carry operating current. The performance of the electrical circuits has been excellent since these revisions. All design revisions were made by Diamond Crystal personnel.

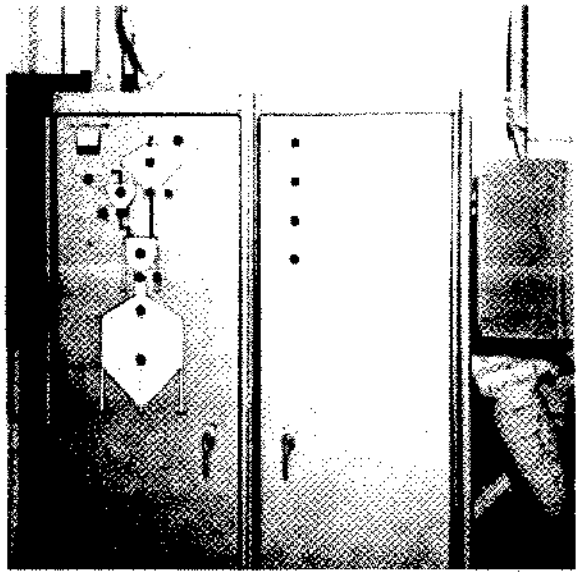
Safety Interlock Changes. The major problems associated with the system were in the safety interlock circuits and the vitamin scale. In addition to the changes made to correct these problems other safety features have been added. On the salt scale system changes have been made and interlocked electrically in the system to make sure that the system does not cycle when the scale is overfilled (overload switch D on Fig. No. 1), due to failure of the mercury magnetic switches on the scale indicator dial.

On the salt scale discharge gate which is operated by a pneumatic cyclinder a microswitch was placed so that if the gate is not completely closed the salt feeder will not start. A small air vibrator on the scale runs on the same circuit and is quite noisy so that this condition is soon noticed and corrected.

On the blender discharge gate a microswitch (E on Fig. No. 1) was placed so that the cycle would not start unless the gate was completely closed. This ensures that no unblended salt gets into the finished product storage bin.

Cycle Control. Control of the entire operation of the system is by the Eagle Signal Timer which is run by a synchronous motor. In operation the timer sends a signal to the control circuits

to start filling the two scales. When these are full the safety interlocks then allow the timer to start the blending cycle by dumping the scales. If either of the scales are not at the correct weight the safety interlocks prevent start of the cycle. The timer at the end of the blending cycle of 17.5 minutes opens the discharge gate of the blender for two minutes to allow discharge of the product. At the end of the two-minute period the timer closes the gate and resets to the start of the cycle and dumps the next load of vitamins and salt in the blender. The salt and vitamin scale are refilled while the blender is mixing the previous batch so that there is no waiting period once discharge of the blended product is completed. The entire cycle takes 20 minutes with 30 seconds allowed for charging of the blender. There is a 20-second time delay between the sale scale dumping and the vitamin scale dumping to prevent the vitamins from being dumped under the salt and also to prevent the inrush of air with the dumping of the salt from carrying some of the vitamins out into the surrounding room. The Eagle Signal Timer is wired so that if the power supply should fail for any reason the cycle is held in whatever position it is in, and when the power is restored it then completes the cycle as programmed. The outside of the control cabinet has a schematic diagram on it as shown in Photograph No. 2 which shows the operations being performed by means of lights.



Photograph No. 2.

QUALITY CONTROL

Analytical Procedures. The production of a new type of product requires the development of control procedures in order to ensure that preset specifications are met. In production of Enriched Bakers' Salt this meant development of methods of analysis for materials which had never been used in our production before. The methods of analysis for the vitamins were adapted from methods supplied by the manufacturers of the vitamins. Adaptation consisted of simplications which eliminated many unnecessary steps which were necessary where the procedures were used in the presence of interfering materials. The presence of salt did not interfere in any way with the determination of the vitamins. For analysis of the thiamine and riboflavin it was necessary to purchase a fluorometer.

For control purposes the analysis of riboflavin was chosen as it is present in the least amount and also is the most easily determined. Analysis requires only that the sample be dissolved in water, diluted to the required concentration, placed in the fluorometer for reading and then compared to known standards. Experience has shown that if the riboflavin is present in the correct amount the others will be also.

The analysis of thiamine and niacin are more involved. In the case of thiamine it must be first converted to thiochrome which fluoresces and can be measured whereas thiamine does not. Known standards of thiamine must be carried through the same procedure at the same time as the unknowns as the conversion to thiochrome is not quantitative in the strict analytical sense which rules out running one standard and comparing subsequent samples to it. Niacin also requires strict adherence to a time schedule as the color developed in the analysis by the addition of ammonia and cyanogen bromide reaches a peak at a given time after the addition and fades rapidly. This necessitates running samples one by one rather than adding the color developing reagents to a number of samples and then reading them in the colorimeter. The niacin analysis is actually run using a stop watch to time the color development. For the three vitamin analyses an accuracy of plus or minus 5% is considered to be all that is attainable. The reproducibility of a given amount of vitamin in a sample may run better than this when run by one person but wider variations

can be found when different operators make the analysis. The iron analysis presents no problem as any of a number of standard colorimetric methods may be used for its determination.

Product Quality Assurance. The first step in assuring that the finished product shipped out meets product specifications is exercised in control of the vitamin master mix. Each batch of master mix receives a number which identifies it for control purposes. A sample of each batch of master mix made is brought to the quality control laboratory. The laboratory personnel check the master mix for all vitamins and iron before it is released to the production department for use in manufacturing operations. The master mix is prepared for analysis by blending it with salt in a laboratory blender in the same ratio as used in production of the product in the plant. The mixture of salt and master mix is then checked by the standard method of analysis. This method eliminates the necessity of weighing out very small samples of master mix which would be necessary if the master mix itself were analyzed.

Samples of product are taken directly from the automatic blender each shift for checking of the riboflavin content. A sample is also analyzed when changing types of product. When the product is packaged from the storage bin a sample is taken from each pallet load of 20 bags. The code number from the bag which identifies the date of packaging and the serial number of the bag as drawn is placed on the sample container. These samples are then retained by the quality control laboratory for a period of three months. One sample from each shift's set of samples is selected and thiamine and riboflavin determined. A composite is made from these selected daily samples on a weekly basis and the niacin and iron are determined. Past practice when the automatic system was first installed was to determined all ingredients daily. Experience has shown that the revised method assures the production of a product meeting all specifications. All packaged production is held until it has been checked by the quality control laboratory and found to meet specifications on thiamine and riboflavin. If a sample does not meet specifications the sample from the preceding and following pallets are checked to determine the extent of the deficiency and the necessary portions of that day's pack are taken and reblended with additional vitamin master mix.

These procedures may appear to be quite elaborate but they have proven very reliable in practice in maintaining the quality of the finished product. In 1964 we did not have a single complaint on the vitamin and iron content of the product. With the government regulations which govern content of vitamin enriched products it is felt that such control procedures are justified. Such a record also is a valuable tool for our Sales Department in the promotion of the product to prospective customers.

SUMMARY

A new type of blending process has been installed and placed in operation with a rated capacity of 240,000-100 lb. bags per year. The original electrical control system was completely redesigned after purchase in order to improve reliability and to add a number of safety interlock features not originally present to prevent production of substandard product.

Quality control procedures were developed to ensure that no substandard product was shipped to customers. Complaint history has shown the effectiveness of the applied procedures.

Whether a similar type of system would be installed again would depend on the circumstances. The present system was installed in order to isolate the production of Enriched Bakers' Salt from other products and prevent cross contamination which would have resulted in complaints on both types of salt. The installation also resulted in a cost savings of $3,000 per year in labor costs over conventional batch blending procedures based on the production rates at the time of installation.

Acknowledgment is made of the help and information supplied by the personnel of Diamond Crystal Salt Company's St. Clair, Michigan, plant and especially of the information on the electrical circuits supplied by Melvin Leverenz, Technical Service Engineer and Nelson DeLisle, Electronics Technician.