



Stacked end to end, these Fig Newton cakes would reach from New York to Philadelphia. More than one million pounds are baked daily, using a process computer to direct batching of the ingredients.

Industrial electronics

Take two tons of flour . . .

Nabisco's batching system, the first in the baking industry to be controlled by a computer, keeps cookie quality and taste consistent

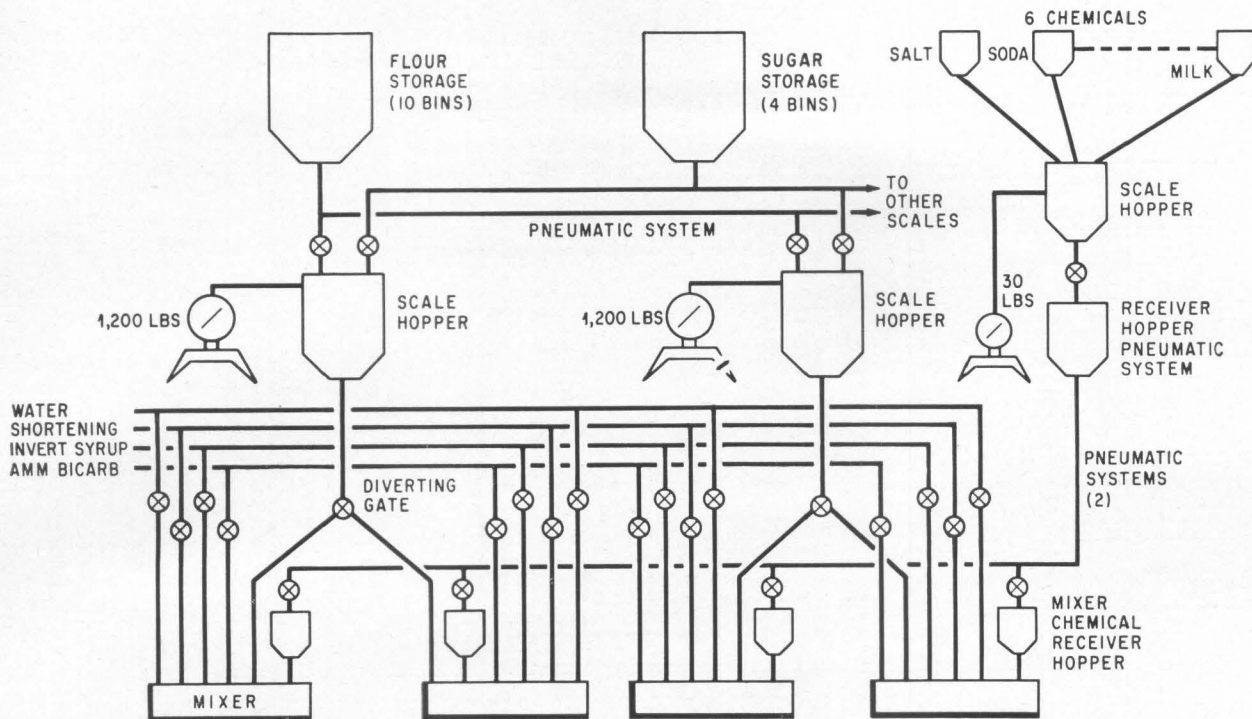
By Louis S. Gomolak
Industrial Electronics Editor

Every day the world's biggest biscuit baker, the National Biscuit Co., turns out nearly 400 miles of Premium Saltine crackers, using a digital computer to control batching. Batching is a process which brings together, in correct sequence, the near-ton of ingredients required for each batch. (Although computer-controlled batching is widely used in the cement and petroleum industries, its use in baking is new.

In early 1962 when Nabisco received bids for a control system for a new addition to its Chicago

bakery, one stood out like a chocolate cookie in a bag of marshmallows. Instead of quoting on an analog system, the Systems Design division of the Foxboro Company, Foxboro, Mass., proposed digital computer control.

Computers are new in the highly competitive food processing industry, which is governed by taste whims and impulse buying. Nabisco plunks down over three-and-a-half million dollars a year for research on the cookie and cracker with the new taste, the different appeal.



Tons of ingredients are delivered from the storage bins to the scale-hoppers, weighed, and then dumped by gravity flow into mixing machines. All pneumatic systems are computer controlled.

The black specter haunting every baker is that today's cookie may not taste like yesterday's. Taste variation can kill a line faster than my three-year old can gulp down an Oreo. Nabisco sees computer-controlled batching as a giant step toward uniform quality—identical taste in each variety of the 17 million cookies and crackers coming out of the ovens daily.

The process computer also controls batching of all the ingredients used to bake over a million and a half pounds of Fig Newtons—enough to stretch from New York to Philadelphia, if no one nibbles—every sixteen working hours. Ingredient delivery is computer-controlled, too, in the daily production of 70 thousand pounds of Oreo cream sandwiches, 55 thousand pounds of Ritz crackers, and a veritable mountain of Cheeze Nips, Triangle Thins and snack varieties.

A Saltine, as an example, goes through five major processing steps before it can be shipped: batching the dry and liquid ingredients; mixing; shaping the dough; baking and packaging. Nabisco's computer system, at the present time, controls the batching process—a sticky web of timings and sequences demanding strict quality control.

Flour flows

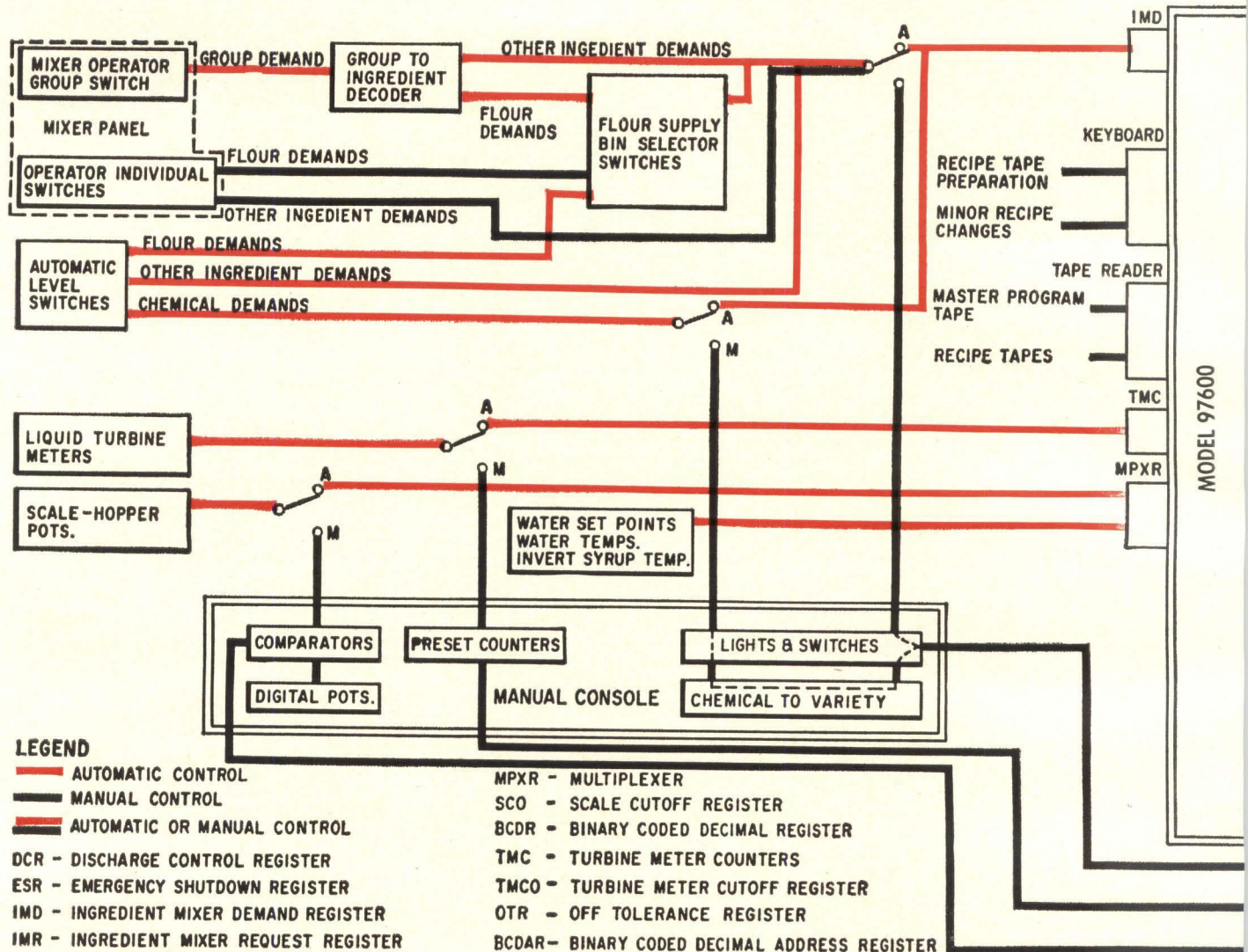
The constant in baking is the recipe. To achieve consistent results—the housewife in a closet-sized kitchen or the master baker in a mile-long facility must follow a recipe for amount of ingredient, sequence of batching, mixing and baking time.

There are twenty dry and chemical ingredient storage bins at the Chicago bakery. These hold tons of three types of flour, granulated sugar, 4X (confectioners) sugar, and chemicals such as milk powder, salt, soda and the like. These main bins are filled by the carload, pneumatically. They are not under computer control.

The process computer enters the picture by selecting, metering and controlling the weight of large quantities of ingredients, a thousand pounds or more at a time—at an accuracy of one pound in twelve-hundred—delivering them from the bins to scale-hoppers, 1,200 pound capacity receptacles containing a weight-scale. As shown in the diagram above, dry ingredients are conveyed pneumatically, but while the scale-hoppers are common to each bin, they can be fed from only one bin, one ingredient at a time. This allows accurate weight control and, in case of a valve failure, prevents ruining a number of batching processes by massive over-delivery of an ingredient.

Probably the toughest systems design problem was sequencing—operating the nine dry and liquid ingredient delivery systems to a 0.1% accuracy. There is a total of 16 steps for just one system actuation. These include actuating and getting feedback signals from valves, motors, blowers, electro-pneumatic and electrical mechanical devices.

The normal sequence is to weigh an ingredient, compare its value to one stored in the computer memory, then discharge it from the fourth floor



LEGEND

- AUTOMATIC CONTROL
- MANUAL CONTROL
- AUTOMATIC OR MANUAL CONTROL

- DCR - DISCHARGE CONTROL REGISTER
- ESR - EMERGENCY SHUTDOWN REGISTER
- IMD - INGREDIENT MIXER DEMAND REGISTER
- IMR - INGREDIENT MIXER REQUEST REGISTER

- MPXR - MULTIPLEXER
- SCO - SCALE CUTOFF REGISTER
- BCDR - BINARY CODED DECIMAL REGISTER
- TMC - TURBINE METER COUNTERS
- TMC0 - TURBINE METER CUTOFF REGISTER
- OTR - OFF TOLERANCE REGISTER
- BCDAR - BINARY CODED DECIMAL ADDRESS REGISTER

Automatic delivery begins when a mixer-operator selects a switch position for ingredient group signals. These are decoded into specific ingredient

demands and treated by the computer on either a chronological or priority basis. Demands are satisfied by output signals to ingredient-selecting

bin, using gravity flow, into a third floor mixing machine. While only one ingredient can be delivered to one scale-hopper at a time, two types of flour and two types of sugar, can be, and are, moved simultaneously, to four different scale-hoppers. As the computer sees demands for the various dry ingredients, it starts and stops the four systems, and delivers the required ingredient to one of seven scale-hoppers which are fed by each system.

The chemicals have a system of their own because they are weighed in small quantities—as bakeries go—of up to 30 pounds, versus 1,200 pounds for the flours or sugars. The chemicals are also delivered as a sub-batch to the individual mixer chemical receiver hopper, located just above each mixing machine.

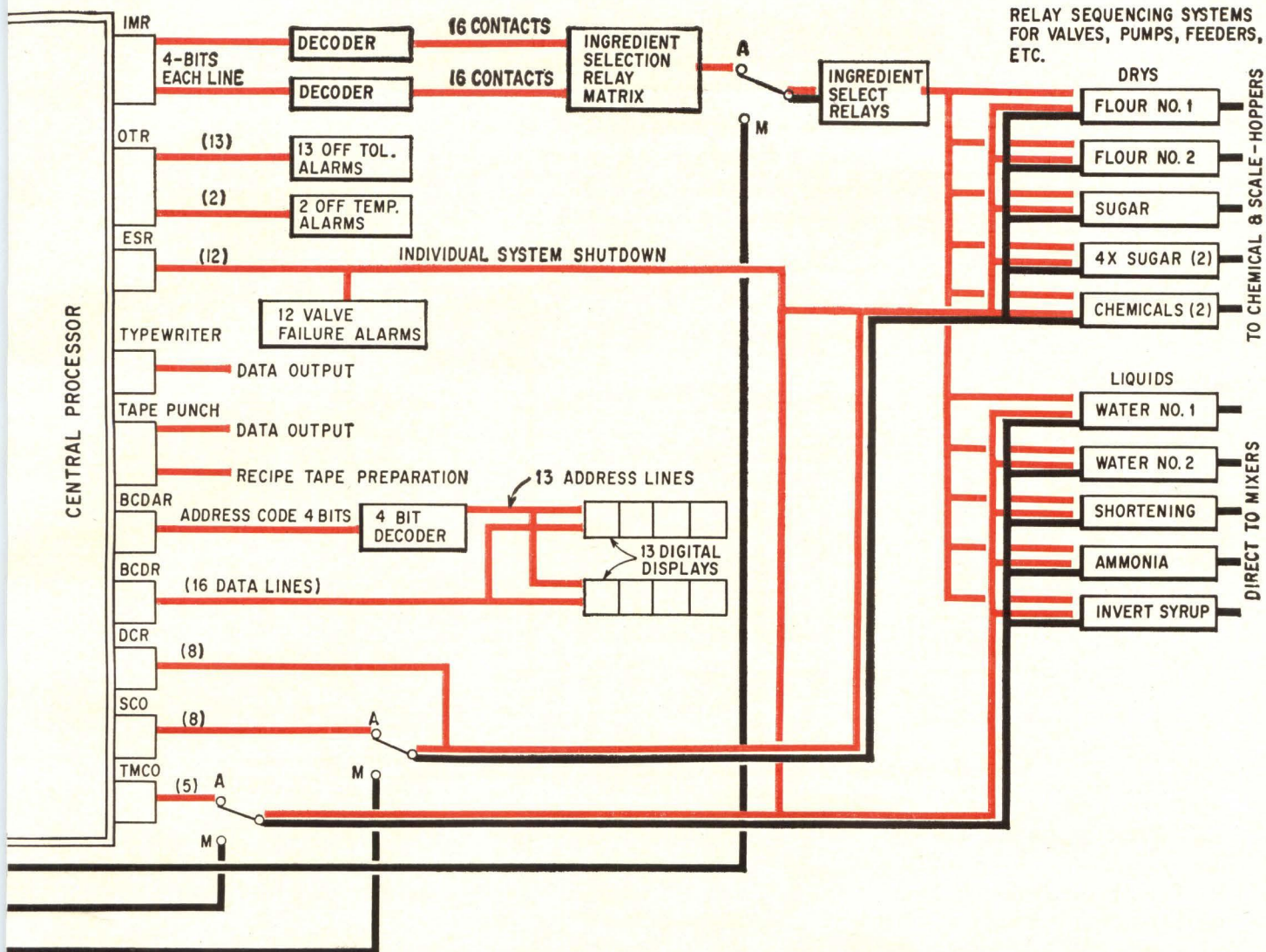
The liquids used—water, shortening, invert syrup (a viscous sweetener) and ammonia bicarbonate—are each delivered directly from their source to the mixing machines. They can be delivered to a mixer one at a time or three or four

simultaneously; the sequence of mixing might call for, say, water to be mixed with flour, then add shortening and ammonia bicarbonate, mix, add granulated sugar, mix and so on.

Nabisco does not want to rely completely on computer control yet, so mixing time is still under control of the mixer operator. Although the semi-automatic portion of the control system has been in use since May of 1963, and the computer system has been on-line since January 1, 1964, Nabisco feels the system is still experimental. If it works to their expectations, there are thoughts of extending computer control to include mixing time, the multi-temperature 300-foot long ovens, and possibly even to packaging.

The all-knowing computer

The Ingredient Metering Control System includes both computer- and operator-actuated networks as illustrated in the diagram at the top of this page. There is no manual back-up system; the operator-initiated process and the computer



relays. The computer continuously monitors the dry or liquid ingredients, shutting the systems down when the correct weight has been delivered,

and dumping the dry ingredients into the mixing machines. The liquids go directly into the mixers, channeled from their sources by the computer.

system use the same bank of ingredient select relays.

The computer is Foxboro's model 97600 Central Processor, which is an integral unit of its 97000 Digital Industrial Process Control System. The Central Processor is functionally equivalent to Digital Equipment Corp.'s PDP-4. The 97600 was custom designed by Digital to specs drawn up by Foxboro's Digital Systems division at Natick, Mass.

By the ton

Mixer ingredient control divides into three major operations—dry ingredients, chemicals, and liquids.

Mixing a batch of cookie or cracker dough means blending almost a ton of various dry and liquid ingredients for specified periods—sixteen different times a day. Early each morning, the mixer superintendent programs pinboards, located at the back of each mixer-operator control panel. The panels are attached to each of the eleven giant mixing machines. On the face of the panel is a selector

switch marked group one, two, three and four, plus a reset position. Each group number specifies certain ingredients, both dry and liquid. For example, group one could be flour and water, group two shortening and granulated sugar, etc. The four groups represent the sequence of various ingredients into the mixing process; totaled they are the recipe for, say, Saltine crackers.

As the bell for work rings, each mixer-operator starts a batching sequence by turning the selector switch to group one. The outputs of the pinboard energize relays. A contact of the relay supplies the specific ingredient demand signals to the computer. These demands go, in the case of flour, to the Flour Supply Bin and Pneumatic System Selector Switches which further decode the flour signal to select a specific bin for use that day. The other group-one ingredient demand, for water, goes directly to the Ingredient Mixer Demand register. All demands are processed on either a chronological or priority basis by the computer, being determined by both the master and recipe programs

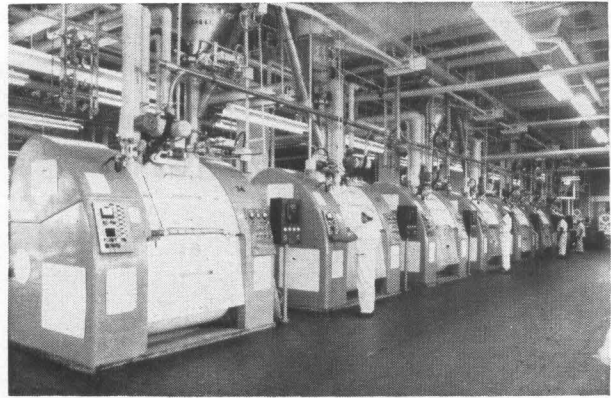
stored in a 4,000 word, 8-microsecond cycle, 18-bits per word memory. The master program calls for the 88 ingredient-demand input channels to be scanned once every ten seconds; the weight measurement channels are scanned once every four seconds during a measurement sequence.

The computer stores these demands and satisfies them (as soon as all previous demands for a specific ingredient system have been cleared from the output registers) by sending coded signals through the Ingredient Mixer Request register.

The output of this register is an eight-bit binary signal, which is divided and sent to two four-bit reed-relay decoders. Relay logic is used throughout the system, except for the computer which is solid-state. Relays were used principally because of the high price of high-power-rated semiconductors. The output of each four-bit decoder is sixteen discrete signals (using all possible combinations of four-bits). These signals are applied to the horizontal and vertical lines of a 16 x 16 matrix called the Ingredient Selection Relay Matrix which selects one of up to 256 ingredient-mixer combinations.

Working with the Ingredient Mixer Request register is a single-bit register, not shown in the control diagram, called the GO flip-flop. This register powers the relay decoder contacts, after a delay of five to ten milliseconds. The delay allows the contacts to settle down after the relays are energized. These relays handle all ingredient selection for the eleven mixers; false signals could select ingredients for one mixer through contacts that had been set for another mixer. After the delay, power is applied to the decoder contacts via the GO flip-flop, by the computer. This actuates the desired relay in a bank of latching-type Ingredient Select Relays which provide power to start up the required pneumatic delivery system.

The pneumatic system moves, say, flour from a storage bin to a scale-hopper. On the mixer-operator's control panel a green "In Operation" light is illuminated. The computer monitors the weight once every four seconds if all pneumatic systems are in operation—more often if system load de-



Batches of ingredients, weighing a ton, are mixed in eleven giant mixing machines, pictured here. Just above each is a chemical receiver-hopper for salt, soda or milk-powder.

creases to one or two systems. It compares the signal (zero-to-ten volt range) from a potentiometer on the scale to a weight value stored in its memory. When the scale-hopper potentiometer signal, which comes through a multiplexer, reaches a pre-programmed value, the computer sends out an inlet valve-closing signal through the Scale Cutoff register. By the time the valve actually closes, the exact amount of flour, plus or minus a pound will have been delivered to the scale-hopper. After thirty-seconds delay during which the flour particles suspended in air settle out, the computer again takes a look at the in-scale weight, compares it to the in-memory value and displays the actual weight on a binary-coded-decimal input digital display on the control room panel. If the flour weight in the scale-hopper is within the stored value, the computer sends a scale discharge signal through the discharge register automatically discharging the flour into the mixing machine.

The over-weight problem

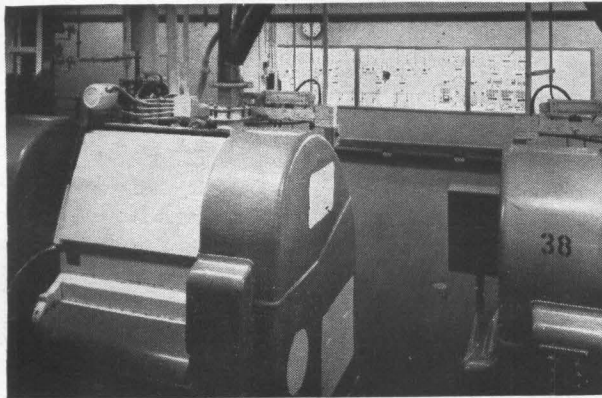
Before an Ingredient Select Relay is energized, the computer checks the scale-hopper for an off-tare condition—any unaccounted for weight. This might be ingredients left from a previous load or, as has happened, of monkey-wrenches left by workmen after a repair job. If the scale is off-tare, the value is printed out and also displayed on a digital readout. A supervisor, after having cleared up the trouble, pushes a Scale Advance button, ordering the computer to override the off-tare signal and energize the ingredient select relay.

If the scale-hopper inlet valve does not close within a stored time delay, a feedback signal is routed to the computer. The signal activates the Inlet Valve Failure Alarm through the emergency shutdown register. The appropriate pneumatic system is shut down and this information is printed out for the panel operator. The operator, having notified maintenance, then resets the off-tolerance register via the Advance button and clears the emergency shutdown register via an entry to the

Recollections of a process engineer

■ The case of the white avalanche

To discover exactly how much the pneumatic systems, under computer control, were delivering, Nabisco conducted pre-start-up tests of different types of scale-hoppers. A huge cart called a dough trough was rolled under one scale-hopper. The hood of this scale-hopper fitted tightly over the top of the dough trough and it was impossible to tell what, if anything, was going into the cart. Once, somebody forgot that 1,200 pounds of flour were already in the trough and commanded the computer to deliver another 1,200 pounds of flour. It did. When the trough was rolled away, a fine white avalanche roared down. It was like trying to fit ten pounds of jello into a six-ounce glass.



White-room precautions are taken to keep ever-present dust out of control panel and computer rooms. This is the forty-foot control room panel, as viewed from between two mixing machines.

computer on the teletypewriter.

Add ten pounds of salt

The chemicals are controlled in the same manner as the flour ingredients. The differences in chemical selection and delivery are that chemicals are delivered as a sub-batch to the chemical mixer receiver hopper, and that the computer gets only a demand for chemicals for, as an example, mixer number one.

Stored in the computer, when the recipe punched tapes are run at the beginning of the day, are the various types of chemicals and combinations of types for each mixing machine. The chemicals—salt, soda, milk powder, meal, and others—are weighed (and compared to memory value) one at a time and discharged by computer signal into the large pneumatic system receiver-hopper. When all ingredients for mixer number-one are in this receiver-hopper, a computer generated signal activates the pneumatic system, sending the sub-batch to the mixer chemical-receiver hopper. At the specified time in the recipe mixing sequence the mixer operator presses a Chemicals Discharge button on the mixer control panel, dumping the chemical sub-batch into the mixer.

In the chemical delivery system the computer controls vibratory feeders which carry the chemicals from their individual supply bins to the pneumatic system receiver scale-hopper. Thus, there is no need for an inlet valve failure check as in the flour and sugar systems. There are both off-tolerance and off-weight sequences. The mixer operator can accept the off-tolerance or off-weight condition by later reapportioning the other ingredients. This is done by going into the memory through the teletypewriter keyboard and changing the ingredient values for this particular batch—the same is true for flour and sugar.

Liquid systems

The liquids—water, shortening, ammonia bicarbonate and invert syrup—are piped directly

from storage, or city water lines to the mixing machines, at specified times in the recipe mixing procedure.

In each of the five liquid systems, two for water because of the large amounts used, there is a turbine meter. This is a device with a propeller located in the pipe. As the liquid sweeps by the propeller turns. Using magnetic pick-up, the turbine meter sends a series of pulses—16 equal a tenth-of-a-pound—directly into the computer Turbine Meter Counter.

When the pulses total the cutoff weight stored in memory, the computer generates a shutdown signal through the Turbine Meter Cutoff register closing the inlet valve. After a delay the computer checks back to see that the valve has closed. Then the computer compares the actual metered liquid weight with the desired weight stored in memory. The actual weight is always displayed at the end of each metering cycle on a digital display on the control room panel.

The liquid shortening and ammonia bicarbonate systems are straightforward operations; the water and invert syrup systems are not.

In the invert system, the amount of weight delivered per unit volume depends upon temperature. When temperature rises, syrup viscosity increases. Stored in the computer memory is an invert correction table. The computer monitors the invert temperature, using resistance bulbs, about once every second and, using the table, corrects the weight for the number of pulses coming from the turbine meter.

In the water system the story is more complicated. Every recipe specifies one of three water temperatures—some cookies need hot water, some ice cold, others normal tap water. When the computer receives a demand for water, it selects one of three set point water temperature generators located on the control room panel. (There is about a three or four percent difference in water weight over a temperature range of 35° to 180° F.)

The computer selects the right set point and starts the water flowing, continuously comparing

■ The case of the cavitating chemicals

One of the pre-start-up problems involved measuring the chemicals in the high production hoppers. The measurement devices are merely level switches. When covered with material, a torque is developed to hold the level switch contact open. However, this rotating switch (a paddle-wheel type of device) causes cavitation with some types of chemicals. When this happens, the paddle encounters no torque and causes the switch contact to close (as it does on low-level when the level of material drops below the paddle).

When cavitation occurred in the mixer chemical receiver hopper, a new chemical demand signal was sent to the computer. Since the computer can't detect between a genuine low-level signal and one caused by cavitation, it supplied a second batch of chemicals.

The solution was to add new circuitry which allows only one chemical demand signal per batch to be created.

the actual water temperature to the set point. Until water temperature and set point coincide, all water goes to drain.

The water is handled by two three-way valves, under control of an analog temperature controller attached to a resistance bulb near the valves.

There is about one-hundred and fifty feet of piping from the three-way valves to the mixer inlet valves. By the time water travels this far it can change temperature. This could be disastrous in a tightly specified recipe. To avert wastage of batch, there is, near the mixer inlet valves, an interlock analog temperature controller. Signals from resistance bulbs come to the controller from the mixer-inlet valve area and also from the three-way valve area.

The computer activates the three-way valves but does not begin counting turbine meter pulses right away. The computer first monitors the temperature at the three-way valves and also the action of the interlock controller. When the temperature is right at the three-way valves, the computer sends a signal to close the drain valve. This signal will not take effect until the interlock controller also signals the valve that the temperature is the same throughout the system. The computer then closes the drain valve, opens the mixer-inlet valve and counts turbine meter pulses.

If the actual metered weight is out-of-tolerance when compared to the memory value, an off-weight

alarm is actuated. The off-weight is typed out and the computer blocks further use of that particular water system. Pushing the liquid system Advance button on the control room panel will reset all registers and release the system for new demands.

If the mixer inlet valve does not close, after the computer checks back, an inlet valve failure alarm is sounded, the system is shut down, and the condition is printed out. The panel room operator must then push the Advance button and clear the emergency register via a keyboard entry.

When all ingredient groups have been loaded into the mixer at their proper time, each ingredient in its proper sequence, the operator switches the group selector to reset. This tells the computer the batch is completed. Batch data can now be printed out if desired.

Right now Nabisco has almost more data than cookies. The company is now examining the data to find out if it can optimize the control process.

Nabisco is presently installing another pair of the giant mixing machines to feed a new three-hundred-foot-long oven. Batching process control is more complicated than either Nabisco or Foxboro anticipated; as has been the case with every process newly placed under computer control. Nabisco is studying ways to optimize control and gain memory space.

If they can't, they say the memory system may have to be expanded to accommodate increased control functions.

■ The case of the dusty contacts

Dust is a real problem in a bakery. Sugar dust, flour dust, chemical dust, dust dust and more dust. In the pulverizer room where Nabisco refines granulated sugar to make its own 4X confectioners' sugar, the dust is so fine that drawing even the smallest arc would produce a sizable explosion. Electrical equipment, motors, etc. must be explosion-proof.

The potentiometers, switches, relays and other kinds of equipment are so-called dust-proof but, because they require periodic adjustment, they are not hermetically sealed. The flour, sugar, and other kinds of dust build up into some extremely effective insulation.

During the initial phases of system start-up, the computer occasionally failed to cutoff the feeding operation to a scale at its cutoff value. Upon investigation it became apparent that not enough current was drawn by the measuring system to break down the dust film formed on the potentiometer winding. (Good systems design requires low currents through voltage devices such as potentiometers if high accuracy is to be maintained.)

The solution was to use a capacitor between the wiper and one end of the scale potentiometer. The capacitor was the energy source for a reversing current during scale discharge. This current reversal broke down the film formed on the potentiometer.

Since many field logic conditions must be fed back into the computer and since all computer inputs are low-voltage d-c, the most straightforward scheme would be to use low-voltage d-c on the field relay contacts. However, to counteract the dust problem, 110v a-c is used for these contacts, with buffer-relays supplying the low-voltage d-c feedback into the computer.

No hands

There is one more system which is connected to the process computer. At the present time, Nabisco is running a number of high production mixing machines. When the scale-hoppers for these mixers signal the computer that ingredient level is low, the computer searches its memory for ingredient type and delivery sequence, then activates the right pneumatic system, on a priority basis. The high production mixers must be satisfied before any non-priority system demands are met. It is more important to keep high production going than to fill the demands for those products made in batches.

The computer also controls the liquids and chemicals for a continuous Oreo cookie system. These demands are automatically generated by level switches. These ingredients are supplied on a batch basis to large hoppers which furnish a continuous supply to the Oreo system. When the new batch has been delivered, the bakery management can, if desired, have a print out of that particular batch, or any batch for that matter.

Almost no hands

If for some reason the computer is not functioning, system operation is initiated by an operator in the control room. Under semi-automatic control the mixer-operator still uses the selector switch to initiate the batching process. When the group

ingredient signals are decoded by the pinboard relays, the individual dry ingredient demand signals come into the control room panel and light various ingredient lights. The panel operator pushes an ingredient Start button which energizes the same Ingredient Select Relay equipment that a computer signal would have actuated.

For the desired weight of the dry ingredients the operator adjusts a manual potentiometer, with digital readout. Then the pneumatic system automatically delivers the ingredient to the mixer specified and when the desired value is reached a comparator amplifier on the panel sends a systems shutdown signal to the pneumatic system. The operator can then take a look at a vacuum-tube voltmeter calibrated in pounds—zero to 1,200—and if the weight is within specification push a scale discharge button.

For liquids, the panel operator adjusts the pre-set knobs on the system's Veeder-Root counters for the desired liquid weight. When the pre-set and turbine meter counts reach coincidence, the counter generates a shutdown signal.

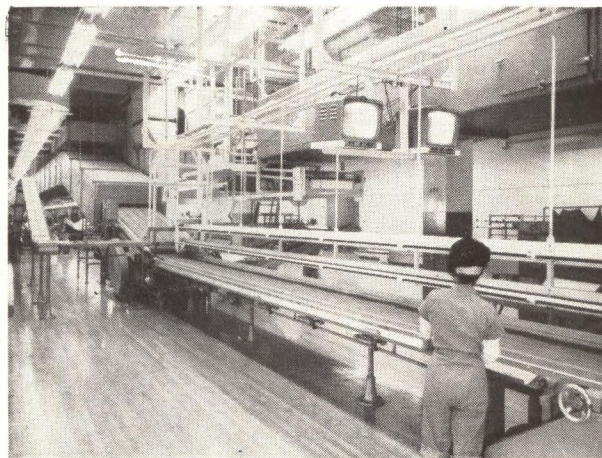
For the chemicals, the operator must go through two steps. He sets up manual potentiometers for the different chemicals and switches a selector to the specific mixing machine. Next he watches the indicators and when they light up for the various chemicals, he pushes a Chemical Start button. When the last chemical of the chemical sub-batch is in the pneumatic system receiver hopper, the pneumatic system will automatically deliver the sub-batch in the manner already described.

One option the mixer-operator has, during either computer or semi-automatic control, is that of demanding any dry ingredient in advance. By turning a mixer-panel hold-discharge switch to hold, and then switching the selector to the next group, the operator commands the computer to deliver the ingredient whose demand is first recognized, and weigh it. But the automatic discharge signal is blocked by the mixer-operator's hold. When switched to discharge, the scale-hopper will dump into the mixer. This is one way in which the operator can have ingredients waiting, until a mixing operation is completed. It is also the way the operators schedule their coffee and smoke breaks.

For some time to come

Many problems have yet to be ironed out before complete bakery computerization becomes a reality. Nabisco's installation is now running, on-line, throughout two 8-hour shifts per day. Over a sixteen-hour period the control system produces, with uniform quality from a batching standpoint, millions of cookies and crackers daily. While there are other bakery computer systems—see box at right—Nabisco's computer-controlled batching is the first major advance in the baking industry toward absolute quality control by computer direction.

The author thanks Ralph Guimond, Bob Benson, and Wendell Young, of Foxboro and George Quinn and John Gude of Nabisco, for their assistance.

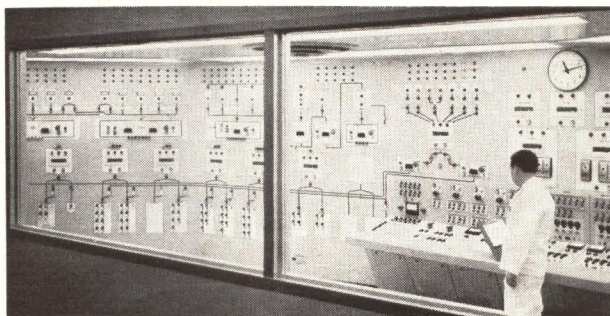


Cooling tunnels, at left, have closed-circuit tv cameras strategically placed throughout. Operator watches potential trouble areas during cooling of cookies.

Computers in bakeries

There soon will be three computers in the baking industry. Nabisco's has been operating on-line since January 1. A GE-225 data processor calculating formulation, including nutritional values and farm purchasing prices, has been in operation since late '63 for recipes at Pillsbury Company's Minneapolis bakery.

The third will be the system now being installed in the Kitchens of Sara Lee. According to E.E. Kuphal, Director of Facilities Planning for the bakery, the Honeywell 610 computer will be delivered sometime this month and on-line operation of the mixing and batching sequences should start in late July at the earliest. Closed-loop control of the 150-foot-long ovens will begin after sufficient data has been logged to determine exactly how to control the eight different temperature zones. Warehousing freezer operations should begin this month.



Checking the daily baking schedule during the period last year when Nabisco used only the semi-automatic control system. Although the processes may be actuated from the panel, delivery of the ingredients is still automatic.