IEEE

CONFERENCE RECORD OF 1976 28th ANNUAL CONFERENCE OF ELECTRICAL ENGINEERING PROBLEMS IN THE RUBBER AND PLASTICS INDUSTRIES

April 5-6, 1976

76CH1058-7-IA

IEEE

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1976 TWENTY-EIGHTH ANNUAL CONFERENCE OF ELECTRICAL ENGINEERING PROBLEMS IN THE RUBBER AND PLASTICS INDUSTRIES

Papers presented at the Twenty-Eighth Annual Conference
Akron, Ohio
April 5-6, 1976

Sponsored by the
Rubber and Plastics Industries Committee
of the IEEE Industry Applications Society
and the IEEE Akron Section

List Price: $8.00

Available from
IEEE Service Center
445 Hoes Lane
Piscataway, N.J. 08854

Printed in USA

Library of Congress Cat. Card No. 73-856-33

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ELECTRICAL ENERGY MANAGEMENT AT GOODYEAR

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General Program

The conservation of energy has always been prominent in the minds of those who make up the Corporate Engineering Organization at Goodyear. Originally, this was a cost savings aspect. Since mid-1971, however, it has been top priority for the Corporation.

In 1971, through a corporate-wide letter, Goodyear established an extensive and systematic approach to energy management. The overall program now involves over 100 operating facilities, with each plant program revolving around two basic areas, mechanical and electrical energy conservation.

Guidelines have been established for conservation of all plant utilities and submitted to each plant with a request for suggestions and comments. Following this the initial program was formulated and put into operation for the year of 1972. The comments in this article will be confined to the conservation program associated with electrical energy.

This program has two main objectives:

- The reduction of peak demand to alleviate generating capacity overload and reduce power billings from commercial sources.

- Reduction of energy consumption to lessen the impact of the fuel shortage and at the same time, to reduce operating costs.

The concern over peak demand from commercial sources involves the figure tabulated under maximum demand on a company's monthly billings. This figure is normally derived from the integration of the actual fluctuations over a fifteen or thirty minute period. The suggested procedures for reducing this peak demand include re-scheduling of plant production operations to reduce this Integrated Peak Average. Goodyear has found that in its operations, the peak average is normally established within a ninety-minute period in either the first or second shift of a three-shift operation. The use of a graphic wattmeter or ammeter can assist in evaluating the possibility of a shifting plant load by re-scheduling production.

Figure 1 shows the kW demand curve for a typical small plant. The maximum demand established on the first shift is approximately 2822 kW, the demand established on the second shift is 1612 kW, and on the third shift, it is 720 kW. By transferring the Banbury or the extruder to the third shift, a reduction in demand of approximately 1000 kW can be realized. The demand charge, in this case $1.35/kW, can be reduced by $1,350 per month, for a savings of $16,200 per year.

Of course, each plant varies. In addition, it is not always possible to negotiate a change in production schedules; possible labor repercussions must be checked, and increased costs due to higher night pay must be considered.

However, this is an area where sufficient potential exists to justify close investigation. The goal is to set up production so that the maximum demands established on each shift are approximately equal. A graphic wattmeter set up to monitor the complete plant on a normal 24-hour basis can be used to quickly determine whether a given plant has potential savings in this area.

Reducing instantaneous peaks associated with drives which may be started simultaneously is another area for investigation. This can be accomplished by staggering the startup of large motors at the beginning of a shift operation. In most squirrel-cage and synchronous drives, the instantaneous peaks are between six and twelve times the rated full-load current of the drive. This is not a serious burden, in that the starting time associated with these drives is three to six seconds; the real value will depend on the number of large drives that might normally be started within the same time period.

Reducing the flow of reactive current requires maintaining the plant power factor as close to unity as possible. This goal is accomplished by adding power capacitors to major drives and distribution systems. In general, capacitors should be applied directly to large induction drives by connecting them to the load side of the motor starters.

Using this system, the capacitors are automatically switched on and off with the motors. This insures the plant will not suffer from high voltage during weekend periods when the load is low. The system is aided by the use of synchronous motors designed to operate at a leading power factor (automatic field control can be utilized with synchronous drives).

The prinicpal benefits to be derived from operating a plant power system at unity power factor are minimizing heat losses in transformers, feeder cables and busducts; increasing available transformers, cables and bus ducts capacity and reducing energy and demand charges on utility billings.

The use of emergency stand-by generators and demand limiting meters and/or programmable control systems can reduce the maximum established kW demand. Demand meters are designed to integrate the demand over a given interval -- ten minutes, fifteen minutes, or thirty minutes. The interval selected should be the same interval being used by the area utility.

The meter can be set at a particular limit. It will begin to integrate the demand and, part way through the metering interval, will forecast whether or not the demand limit set on the meter will be exceeded if power continues to be utilized at the same rate.

If the limit will be exceeded, an alarm contact is closed before the end of the integrating interval. This alarm contact can be used to sound an audible alarm or to automatically trip out selected loads; it is also possible to pick up selected isolated loads with an emergency generator.

In industrial operations, a peak demand can be established each day within a thirty to sixty minute period at the same time of day. A plant emergency generator can be used effectively in such instances which are common in rubber manufacturing facilities.

Reducing energy consumption requires operating all plant utility and production equipment at maximum efficiency. This includes minimum heating and air conditioning and shutting off chillers, pumps and fans when not in use as well as maintaining the equipment in good operating condition to minimize losses. It means eliminating production operations that are not proven necessities, and minimizing scrap products which require additional runs on large drives such as Banburys, mills, calenders and tubers.

A thorough review of all lighting practices and procedures can yield significant savings, as well, In most of our operations, the lighting load is approximately 10 percent of the total energy used by the production facility. Goodyear investigations revealed that plant lights are often left "on" in unoccupied areas or actually switched "on" over large areas when a task involved only a small area of the plant. Lights were left in the "on" position even though natural light would provide more light than the lighting system. In office areas, lights turned "on" in the morning, in most instances, were left "on" all day, even though the average time of occupancy would be four to six hours.

The specific lighting program arrived at by Goodyear included the turning off of lights or removal of fixtures that were not being used or were unnecessary. Individual offices were directed to extinguish lighting sources when the occupant expected to be gone longer than 15 minutes. Fixtures were removed in aisle-ways and in storage facilities. Security lighting was reduced to a minimum with automatic timers and photocell controls installed to insure that lights were not operating under daylight conditions.

An example of a concrete approach to a reduction in lighting is a program implemented in May, 1973 that resulted in real and significant savings in electrical energy. Figure 2 shows the total monthly consumption was reduced from 1.1 million kW in 1973 to 800,000 kW in May, 1974 - a reduction of 30 percent.

The specific consumption shown in Fig 3 bears out the same trend. This plant reduced a recorded 73 kW/1000# of compound and fabric to roughly fifty by May, 1974 - a reduction of approximately 31 percent.

All data must be reviewed in conjunction with production levels however, as a reduction of production could generate a reduction in energy with no real effort in efficiency. An added benefit of Goodyear's lighting management program has been the reduction of energy consumption associated with air-conditioning. requirements.

Electric Power Consumption Trends In the Rubber Industry

With the advent of the radial and steel reinforced rubbers, tougher stocks and more sophisticated construction techniques have become necessary. While these tires have brought about product performance improvements, they have also required greater energy input per pound of product.

Extended product performance may result in less energy input per pound over the life of the product, but this doesn't change the need to evaluate the energy input per equivalent pound of product. A pound of rubber in a new tire in 1960 required one-half of one kilowatt-hour in its creation. Contrast this with a tire being manufactured in 1975, which requires three-quarters to one kilowatt-hour for each pound manufactured, assuming the same plant operating efficiency -- a fifty percent increase.

The total plant energy requirement for annual production will vary because of factors such as plant size, product mix, and OSHA and EPA requirements. When evaluating a plant's progress in conserving energy, all of these factors must be accounted for. The energy required to meet OSHA and EPA regulations are readily determinable, and specific consumption of a plant, (kilowatt-hours consumed per pound of product) can be established by maintaining records of energy consumption and total annual production over a given period of years. The calculations for equivalent production based on product mix, is again determinable, however, a large change in the type or character of the product will require extensive calculations.

Example

As an example, for a given plant, 1975 is being compared to a base period of 1971. The actual production in 1971 was 125 million pounds, but the equivalent production based on product mix was 128 million pounds.

If, in 1971, the total energy consumed was 770,000 million Btu's, the actual specific consumption would be 6160 Btu's per pound, and the equivalent specific consumption would be 6015 Btu's per pound. The difference in specific consumption is due to product mix-- 145 Btu's per pound. In 1975, this same plant produced 158 million pounds of product, and has an equivalent production of 206 million pounds due to product mix.

If the total energy input in 1975 was 1,014,000 million Btu's the actual consumption would be 6418 Btu's per pound and the equivalent specific consumption would be 4922 Btu's per pound. This provides a difference in specific consumption due to product mix of 1496 Btu's per pound. The net difference in specific consumption of 1971 vs 1975 would then be 1351 Btu's per pound of product. A credit of slightly over 200,000 million Btu's would be generated against 1975 production. This credit would be taken into account when comparing the efficiency of the plant operation in 1975 vs that of 1971.

It is clear that a number of facts must be available to determine equivalent production due to product mix, especially the exact electric energy required to manufacture the different specifications and types of tires. In the case of Goodyear, load charts are obtained each year on the various production units required for manufacturing tires, such as Banburies, calenders, tubers and mills. Breakdowns are established between passenger, truck, earthmover, farm, industrial, motorcycle tires and such miscellaneous items as tubes, flaps, and bladders.

In addition to this, the breakdown, for example, of a passenger tire must include such differences as bias-belted, fabric, radial and steel radial. With this information, it is then possible to analyze actual production and establish an equivalent production figure so energy per pound of product can be related to an established base.

A Look into the Future

What changes will be made in Goodyear's operations to improve efficiency in energy consumption? Already mentioned are plans to increase efficiency of utility and production equipment. Also, better elimination of waste energy will be accomplished through both corporate efforts and local plant engineering departments.

Energy consumed for lighting requirements will be reduced. Giant strides have been made by eliminating marginal sources, and in the near future, still more efficient lighting sources will be utilized. Over the past twenty years, Goodyear has moved from incandescent lighting (at twenty lumens-per-watt) to mercury vapor (forty-three lumens-per-watt) to metal halide and 800 milliampere flourescent lights (approximately seventy-five lumens-per-watt). High-pressure sodium, which produces 107 lumens-per-watt, is now coming into use, and Goodyear is evaluating the possibility of low-pressure sodium, which will produce some 150 lumens-per-watt. These figures are representative of maintained lumens including the ballast where applicable.

Corporate Task Forces

When Goodyear initiated its energy management program in 1971, it communicated with local organizations, utilizing the mails and phone system for responses and follow-ups. This, in itself, was not sufficient to reach the goals the Corporate Engineering organization was convinced were accessible. For this reason, the program was supplemented early this year with a team of engineers making on-site plant visits. This high-caliber group is reviewing the scope of the program, the goals each plant was expected to accomplish, and is making arrangements for data accumulation and follow-up.

For years, data has been accumulated that would ascertain the plant performance relative to specific consumption and specific demand. However, in very few instances, did the data exist to analyze particular sections of the plant, such as mixing, calendering, tubing and curing departments. Goodyear now has pinpointed metering devices that will indicate energy consumption for selected departments. Goals can now be established for each department so as to be in line with the plant goals. Each department's performance will be analyzed on a six-month basis to determine progress.

By breaking down individual operations, laxness in any one portion of the total plant can be corrected. Team efforts are being assigned to larger plants initially, and should complete surveys of all domestic plants within twelve to eighteen months. A follow-up can then be made on a selective basis and possibly on an annual basis. At stake is the potential worldwide savings each year of 15 million gallons of oil by 1977. Goodyear has established computer programs for the processing of data and the facilitating of information flow between Corporate Engineering and the individual plants.

Communications, too, is a very essential part of the conservation program: feature articles in employee publications are regularly provided, and shareholders are advised of goals and progress through the annual report.

Goodyear's efforts in electrical energy conservation have already established annual savings of energy in its domestic plants of 700 billion Btu's, which represents roughly five million gallons of oil required for commercial generators.

FIGURE 1 - TYPICAL SMALL PLANT DEMAND

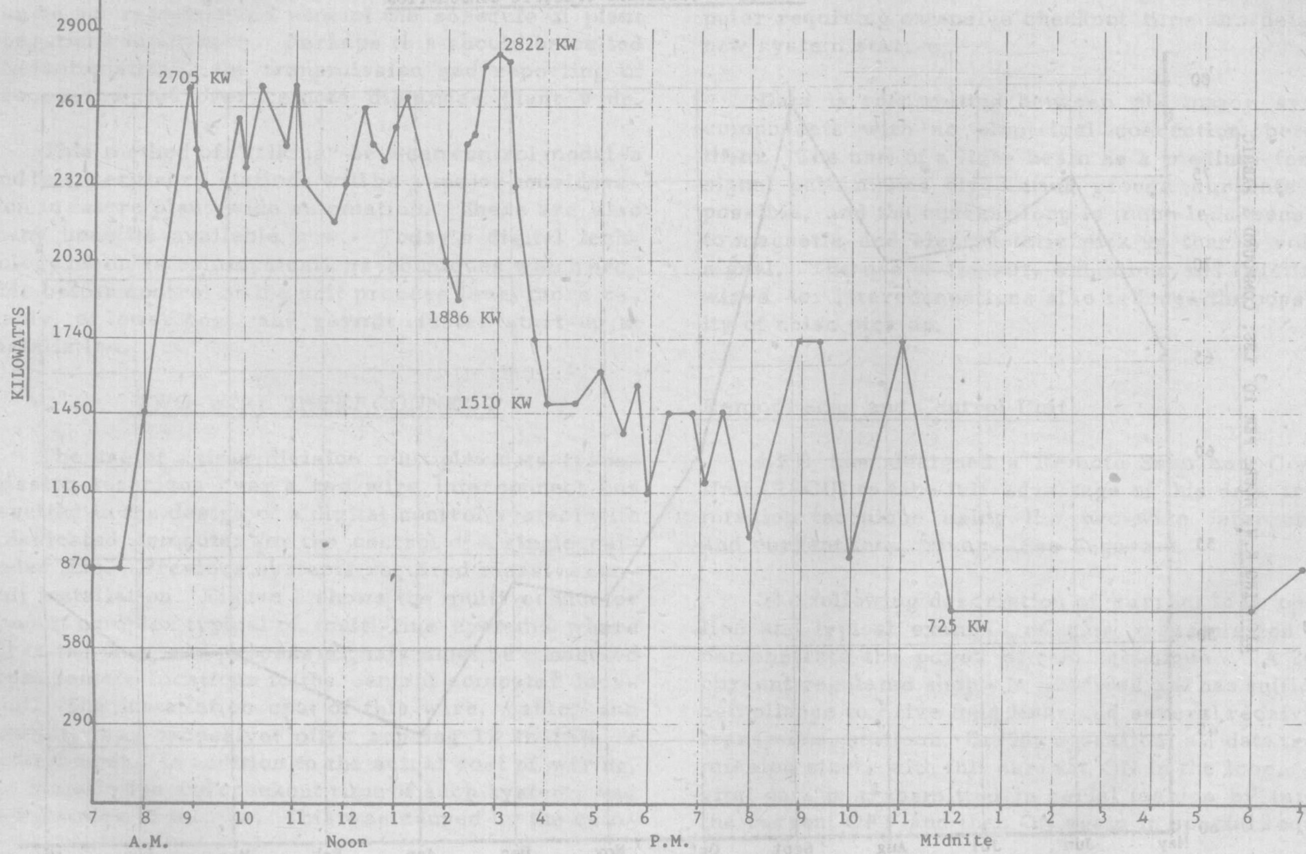


FIGURE 2 - LIGHTING CONSUMPTION

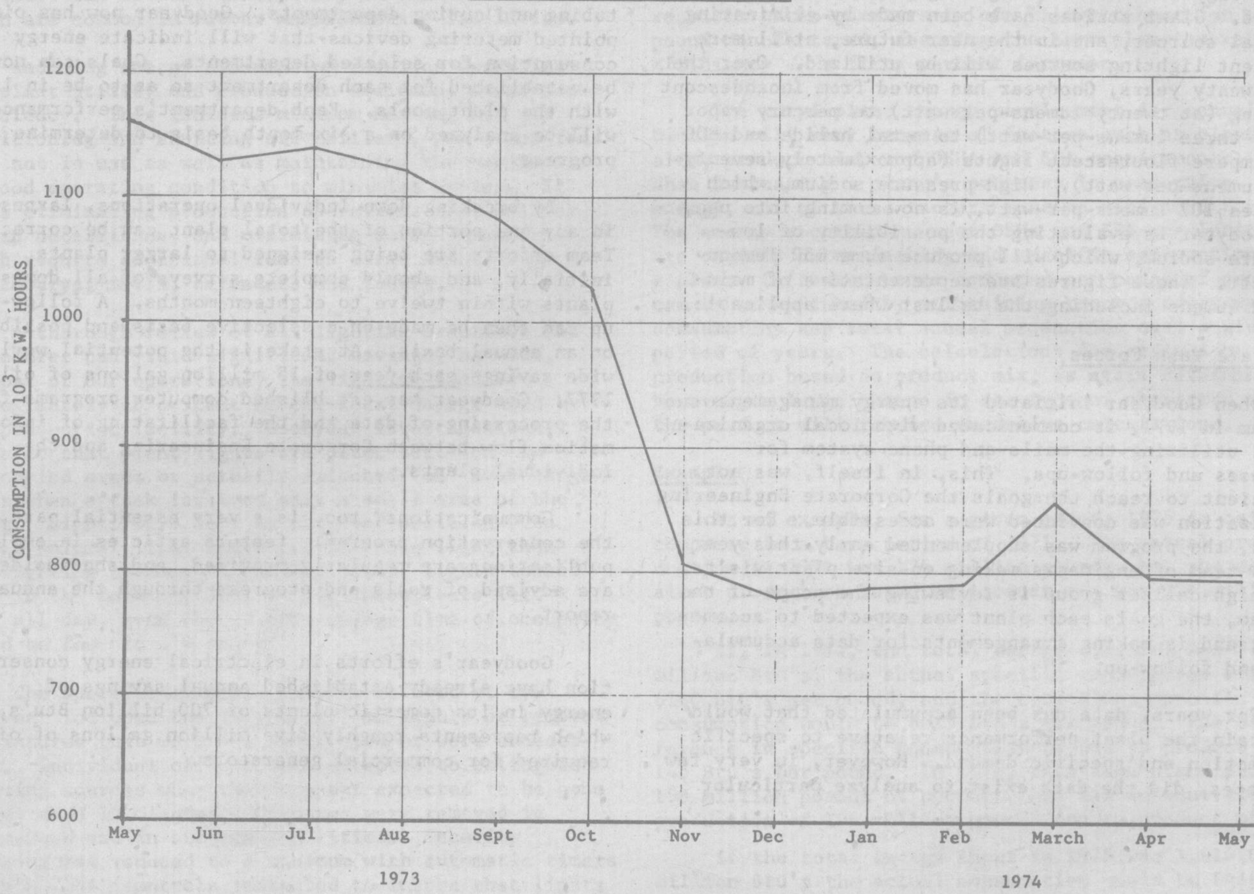
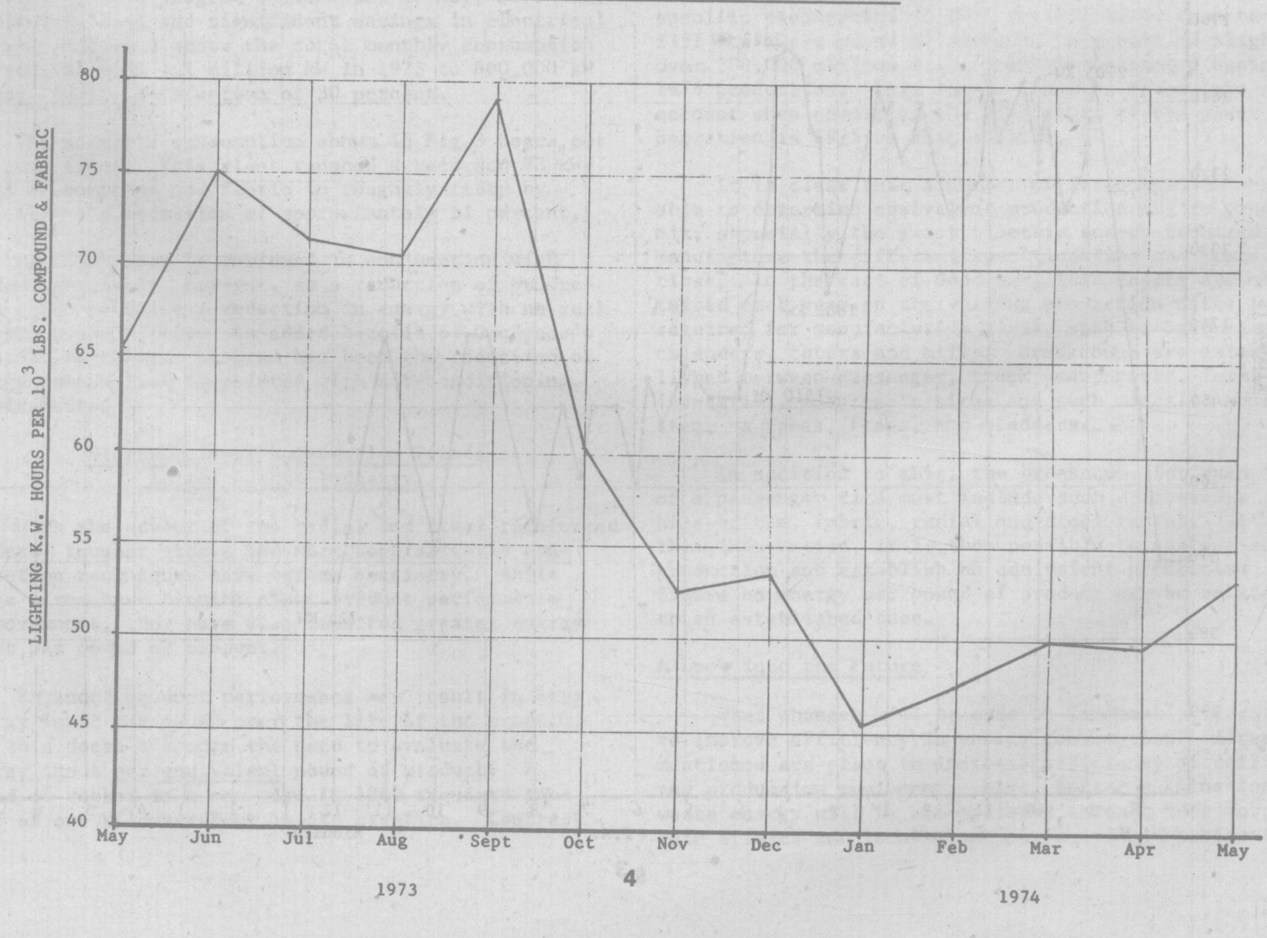


FIGURE 3 - LIGHTING SPECIFIC CONSUMPTION



TIRE PLANT OF THE FUTURE AND TODAY'S END TOWARDS THAT GOAL

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SUMMARY

Digital Control Systems installed today must anticipate the future requirements for plant wide automation. A typical standard control system has been designed that utilizes the latest state-of-the-art technology that is extremely effective in plant operations. This technology will be widely used in future control applications, both at the unit process control level and total plant automation.

INTRODUCTION

The type of communications used is an important part of the consideration for plant wide automation. The future operation of process plants will include many automated mechanisms and processes controlled by programmed micro-digital electronics. The size of the digital controller will depend on the complexity of the unit process being controlled. Reporting process data back to a central plant supervisory control will record the past performance of all processes. An extension of this concept will include two-way communications. The central station will be able to transmit as well as receive. Process values and commands can be set remotely and control the schedule of plant operations in advance. Perhaps this should be called "Telautomation", the transmission and reporting of process control over remote distances plant wide.

This method of "talking" between control modules and to supervisory stations will be a major consideration in future plant-wide automation. There are also many benefits available now. Today's digital technology includes communications techniques which provide better control at the unit process level more reliably, at lower cost, and permit faster start-up at installation.

TWO-WIRE INTERCONNECT

The use of a time division multiplex data transmission technique over a two-wire interconnect has resulted in the design of a digital control system with a dedicated computer for the control of a single calender line. Previous systems required massive conduit installation. Figure 1 shows the multi-conductor conduit complex typical of multi-line systems where all of the plant and process signals must be connected from remote locations to the central computer location. The installation cost of this wire, cable, and conduit, was excessive; often running 12 to 15% of system cost. In addition to the actual cost of wiring, the installation and checkout time of such systems was in the order of months. This was caused by the complexity of the system and, to a great extent, by the grounding and the noise problems associated with connecting low-level plant process signals over long wires to a central location.

Major improvements are available by designing a digital system using a high-speed serial data transmission system over a single pair of wires. This technique has generally been used in telephone and telegraph communications very successfully for many years. The modern marriage of this technique with computer software is extremely effective. System elements can be interconnected by a shielded pair of twisted wires, reducing the cost of installation wiring to less than 2% of the system costs. System components can be remotely located conveniently and wherever required by process needs. System checkout time can be reduced from months to a matter of days. This is made possible through the use of one dedicated computer per line and the two-wire interconnect with photo-isolation. The use of photo-isolation utterly eliminates ground loop problems which are a major cause of errors in input signals to the computer requiring extensive checkout time and delaying new system start-up.

Data is transmitted between all major system components with no electrical connection between them. The use of a light beam as a medium for the signal path makes circulating ground currents impossible, and the current loop is much less sensitive to magnetic and electrostatic pick up than a voltage signal. The use of conduit, shielding, and twisting of wires for interconnections also reduces the possibility of noise pick up.

Remote Scan and Control Unit

LFE has designed a Remote Scan and Control Unit (RSCU) to take full advantage of this data transmission technique using the two-wire interconnect and current loop driver. See Figure 2.

The following description of current loop operation and typical example of data transmission will demonstrate the power of this technique. A 20mA current regulated supply is provided and has sufficient compliance to drive long lines and several receiver/-transmitter stations. During operation, all data transmission starts with full current ON in the loop. Digital data is transmitted in serial fashion by turning the current OFF and then ON again in special sequential code at a high rate of speed. For example, in the diagram, the coded information turns ON transmitter "A" and controls the flow of current through the loop. At receiver "B", there is a light emitting diode, (LED), in an optical isolator. This diode turns ON and illuminates a photosensitive transistor in the receiver unit. This receiver transistor in a separate and electrically isolated circuit conducts current ON and OFF and creates an identical signal on the output side of the receiver/photo-isolator. Thus, there is no electrical or ground connection between the "A" transmitting input and the "B" receiving output. In a similar manner, but at a different time. when "A" is not transmitting, "B" transmitter can function to turn OFF the current loop and ON again using the same digital code, and "A" receiver can sense the current through a second LED and photosensitive transistor. "A" receiver is also electrically isolated.

RELIABILITY

The overall system reliability is further enhanced by the automatic checks and balances designed into the hardware and software in supporting the two-wire interconnect. A brief description and example of data communications is provided to enhance the understanding of the reliability features.

The operation of the serial data transmission depends on the operation of the asynchronous receiver/transmitter module at either end of the two-wire interconnection. This module converts parallel digital information automatically into sequential transmission of 1's and 0's corresponding to current ON and current OFF in the loop. Normally, all transmission begins with current ON which is the "1" condition. The content of the data to be transmitted in typical systems includes process values normally expressed in binary form, special functions or commands in code, and the more common numbers and letters used for display and printout. A standard ASCII Code, (American Standard Code for Information Interchange), has been in use for some time and consists of 128 different letters, numbers, symbols, and code functions expressed in seven binary bits. Typical code values are shown below for the numerical value 1, the $ symbol, and the letter E.

TYPICAL ASCII CODE

SYMBOL	ASCII BINARY	ASCII OCTAL
1	0110001	061
$	0100100	044
E	1000101	105

This binary set is most commonly summarized in octal form for convenience as shown. Data is transmitted at the rate of 4800 baud, (bits per second). The bits are sent in groups of 11 bits each forming a character (See Figure 3). Two or more characters are required to express some process values. Starting from the normal current ON position, the first bit is always a 0 start bit followed by seven information bits, a parity bit, and two stop bits. The receiver/transmitter unit module includes a local clock that runs at 16 times the rate of the bit transmission. This permits an automatic sensing of the time period of each bit to determine a "0" and "1" condition. The circuit senses one-half bit from the first current OFF wave front and at the center of each bit period thereafter. This data transmission code can actually be seen in operation (See Figure 4). Because of the speed, only the zero level current and 20mA current are visible. This display shows the letter "E" in ASCII Code with the least significant bits transmitted first, left to right. The start bit, the parity bit 9, and the two stop bits at the end are also visible. A similar example of data transmission showing transmitting and receiving over the same two wires is shown in Figure 5. In this example, in order to see the complete messages over the longer time period, the actual code of the characters is less visible. The transmit command message starts on the left when the first current off condition occurs. Current is ON during the center wait portion for the message returned; and the full message received back is on the right. In this example, the transmit command made a request of the operator's panel, channel one, to determine the condition of the operator pushbuttons. The translation of the message received is as follows: the first number 1 confirms the actual channel responding, the second number 7, indicates that the quality of the bits transmitted is correct. The blank following the number 7 indicates that no button has been pushed in this instant of time. The last symbol is a stop code indicating the end of the message.

This high-speed data transmission is extremely effective. For example, 200 data points representing each 0.3 inches of profile measurement on a 60" sheet could be transmitted over two wires in less than .5 seconds. In order to achieve such high rate of speed, many different checks and balances are used to maintain the reliability of the data. Parity check is a common digital technique used to provide a check on whether a data bit has been lost in transfer. The parity of the transmitted message is calculated and a parity bit is added as a "1" or "0" to make the number of 1's total to an odd number. When the message is received, the parity of the seven data bits is again measured, and the received parity is compared with the newly computed parity. If they agree, the message is accepted as meeting the parity check. The second check on reliability is to measure the framing of the character. The system automatically verifies that a correct stop bit was received after the correct number of data bits.

At the systems level with several communications channels, each channel has a number. The transmitted message contains the channel number from which information is requested. The message received contains the channel number of origin. These two numbers are compared and must agree for acceptance of a message. An additional provision in the software improves the reliability of the system. If any message exchange fails the test, the message is retried three times before accepting the failure. All of the checking and retrying operations happen in an instant, and no messages are permitted that fail the quality checks. A communication failure results in a service alarm and does not allow for any misoperation of the system.

It is virtually impossible for the system to cause a spurious control command to the process. Once a message has been received as an output of the system, the output channel is designed to complete the output control and terminate automatically as intended. If any system failure occurs during an output command, the command will be executed properly or terminated in a fail safe mode.

Maintainability

Overall system uptime is established by the most reliable system configuration and design coupled with easy maintainability. Internally, within the operator's console, the two-wire interconnect is used in a further important way. (See Figure 6). The computer is connected to the various RSCU modules through a multiplexer board. The communication system consists of six different boards, mechanically mounted in cabinets, and connected by simple cable loops and small connectors. Maintenance is provided on a board replacement basis. For example, when the communication system fails as described above, there is an automatic message printed as to which channel of the system has failed to respond properly. In each case, a channel consists of one complete printed circuit card. Each board is simply removed by operating a mechanical latch and disconnecting the cable loop connector. When the new board is plugged in, the system automatically restarts and is available for operation. This system of on-line diagnostics plus the electrical isolation of all system elements by the two-wire interconnect, insures the reliability of the data and maximum up time operation.

Diagnostics Program

In addition to the automatic system diagnostics, a typical system is supplied with a diagnostic tape cassette that can exercise every function of each RSCU channel of operation and quickly identify any faulty operation. The video screen shows a series of patterns and symbols that can easily be inspected visually for any faulty operations. The Smart Scan Unit can be checked for all functions of shutter operations, sensor position, scan limits, and in addition, by a reference signal, test the entire measurement channel. The Operator's Panel can be checked by sensing all the buttons and lights in sequence. The Process RSCU boards, digital and analog, are also automatically checked by jumping the outputs to the inputs and sequentially testing each circuit. The multiplexer board has a special communication diagnostic that can send messages and check replies including all of the hardware and software quality checks. All communications current loops can be analyzed and an automatic printout of performance obtained.

SYSTEM CONFIGURATION

Figure 7 shows a typical LFE PROFITMASTER Control System making use of the two-wire interconnect and photo-isolation. All major system components are pre-wired at the factory and fully system tested. The entire wiring requirement for the signal lines for system operation is the two-wire cable to the sensor frame and the two-wire cable to the computer console. This permits complete flexibility in mounting the sensor frame on-line where space is at a premium and further permits mounting the computer remotely in a convenient location up to 1000 feet away from the line operator's console. All additional system wiring connections from the process may be connected locally over short cable runs directly to the operator's console on-line. The overall result is a minimum requirement for cabling and a maximum in system reliability.

A view of the Operator's Console of the 5610 Calender Control System (See Figure 8), demonstrates the simplicity of the system. The operator may obtain complete communication with the process through the operator's console. The video display provides not only graphical displays of process variations but alphanumeric messages as well. Through the control panel, the operator can enter target values, select different video displays, control the scanning sensor, and select a number of different control schemes including Nominal Control, Yield Optimization Control, and Crown Control. Both Screwdown Control and Roll Bending or Cross Axis Control are available.

PLANT-WIDE AUTOMATION

Modern digital control installed on unit processes in the plant may be interconnected to a central supervisory computer system over a similar two-wire interconnect to each process. Tubers, curing presses, blenders and mixers, force variation grinders, primary and secondary calender control systems, feed mills, tire building machines, and even final inspection stations and warehousing could all be coordinated through the two-wire interconnect communication link. (See Figure 9). This would permit better reporting of current and daily operating performance. It would optimize the operation of all plant unit processes through transmitted commands and facilitate scheduling of the operations at each station throughout the plant. Finally, Plant Wide Automation would control the materials through each process from raw form to each operation to finished goods and warehousing.

This would not come about over night, but through an organized effort to properly control each unit process and by providing the simplest two-wire connection to the central station. It is not at all unreasonable to expect that at some future time mechanized robots will be used at selected machinery locations to reduce the level of manual labor currently required in tire plants. Even now robots are widely used and under advanced development in Japan at this time. In Japan, a dozen companies, several universities, and at least three trade associations are heavily involved in Computer Aided Manufacturing, (CAM). Additional efforts are taking place in Europe.[1]

Fig. 1 Conduit to Remote Computer Required with Previous Systems

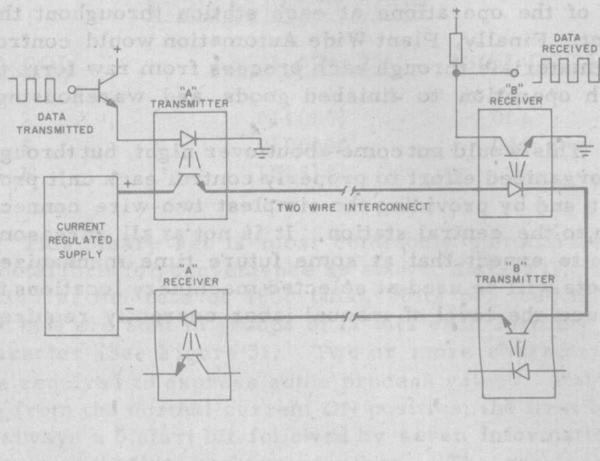

Fig. 2 Current Loop--Two-Wire Interconnect

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1. Modern Plastics, 1975, "By 2000, computers will be running un-manned processing plants."[1]

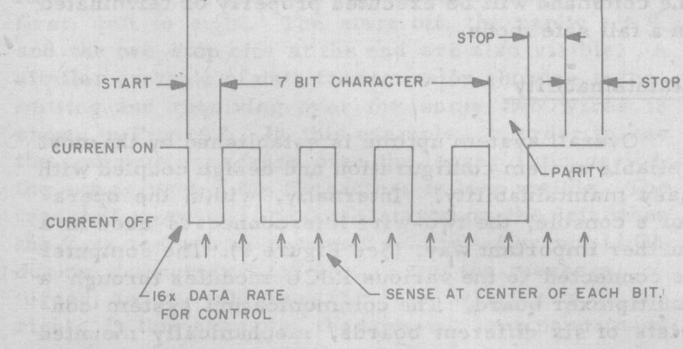

Fig. 3 Typical Data Format for Two-Wire Transmission

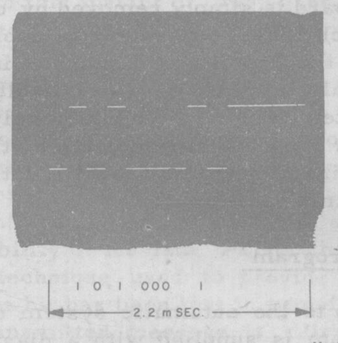

Fig. 4 Actual Photo of Code Letter "E" Transmitted over Two Wires and Displayed on Oscilloscope

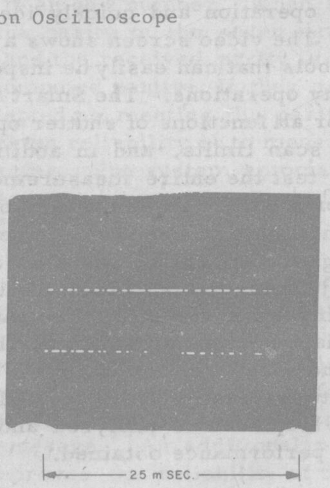

Fig. 5 Actual Photo of Code Messages Transmitted and Received over the Same Two Wires and Displayed on Oscilloscope

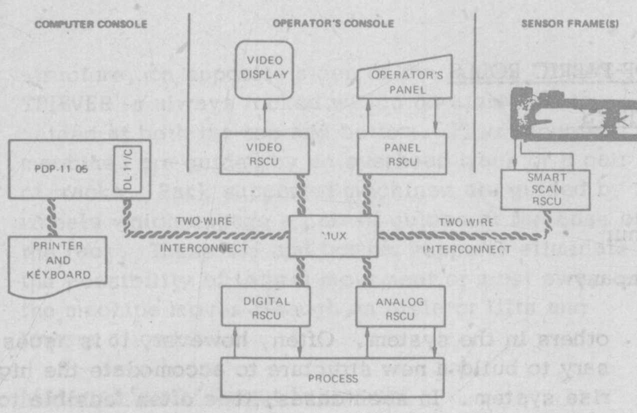

Fig. 6 PROFITMASTER System Block Diagram

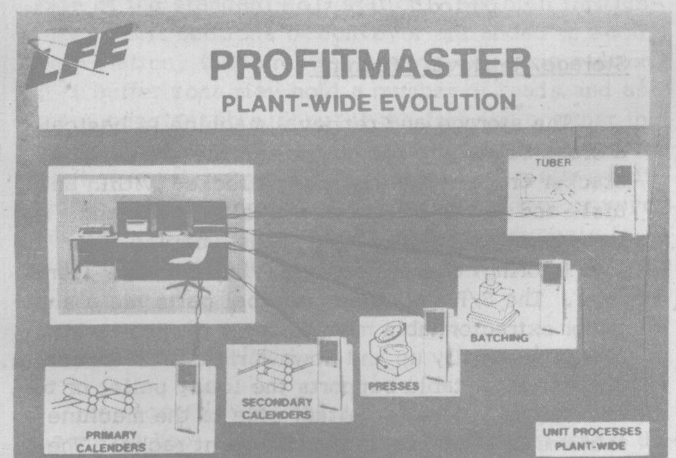

Fig. 7 Typical PROFITMASTER System

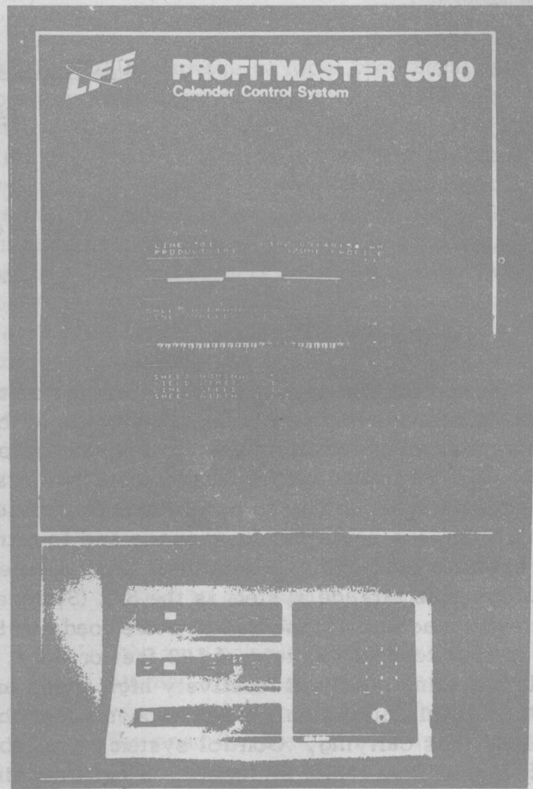

Fig. 8 5610 Calender Control System

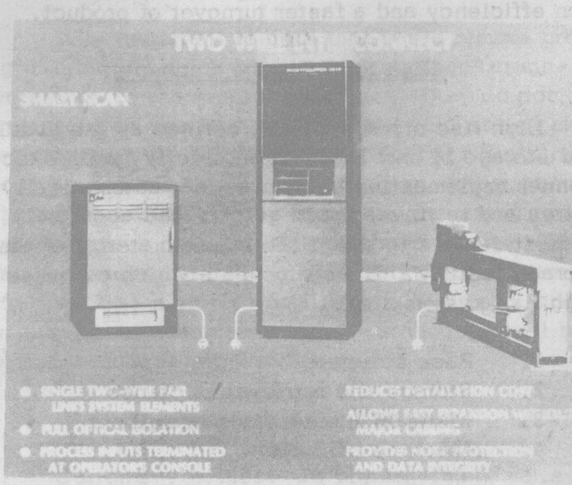

Fig. 9 Typical Stage of Evolution of Plant Wide Automation

AUTOMATIC STORAGE OF FABRIC ROLLS AND TREAD TRAYS

by

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Summary

The application of modern automatic material handling methods such as high-rise storage with inventory control is ideally suited to the storage of fabric rolls and tread trays. Implementation of such system offers the ability to store thousands of loads at a tremendous saving in floor space and to retrieve any specific load within a minute or two. Cornerstone of a high-rise storage system is the S/R (Storage/Retrieval) machine engineered to store loads weighing up to 5 tons to a height of 100 feet or more, while traveling safely at relatively high speed and working within aisles only a few inches wider than the load it is carrying. Control systems available for S/R machines range in sophistication from simple on-board relay controls to full computer systems wherein the S/R machine receives commands from a process computer causing the motors to start, accelerate, slow, stop and reverse. Computer controlled systems track the material from receiving through storage and subsequent retrieval, thus maintaining a firm grip on inventory and material flow. This results in substantial gains in production efficiency and a faster turnover of product.

High Rise Storage Concepts

High rise storage may be defined as the handling and storage of unit loads in an orderly, well-executed manner implementing equipment that automatically stores and retrieves loads quickly and accurately, and without damage to either the stored material or the storage facility. The components which comprise a high rise system are:

1. Rack structure
2. Storage and retrieval machines
3. Material input-output equipment
4. Machine controls

Rack Structure

In an average high rise storage application, the rack structure is a component representing 45%-65% of the total system cost. It is therefore important to review with great care the type of rack structure to implement. Whenever the high rise is to be installed in an existing building, a free standing rack structure is used. This implies that rack sections are bolted to the floor and connected at the top to the rack section on the opposite side of the aisle. This, in effect, makes each aisle and its racks independent of the others in the system. Often, however, it is necessary to build a new structure to accomodate the high rise system. In such cases, it is often feasible to design a rack supported building. This concept was initially pioneered in Europe but is now becoming a popular implementation method in America. In such systems the building support is designed directly into the rack structure. It is only necessary to add the roof and hang outside walls. The main advantages of a rack supported building are:

1. Lower construction cost
2. Speed of erection - with a conventional warehouse, the racks are installed upon completion of building erection. There are two phases of construction: first the building then the racks. In a rack supported building, there is only construction phase since erection of the building and the racks is done concurrently.
3. Depreciation - the racks are classified as equipment (capital expenditure) and thus may be depreciated over a faster period.

Storage/Retrieval Machine

The storage and retrieval machine is basically a cross between a fork truck and the bridge type stacker crane. The machine is locked within an aisle and moves on wheels traveling back and forth hoisting and lowering loads, moving them into (storing) and out of (retrieving) storage openings. The S/R machines principal parts are a shuttle or extractor table mounted on a carriage which moves vertically up and down a rigid mast structure. The extractor table supports the load, pallet or tub, and can be indexed to either side of the machine to retrieve or store loads from adjacent racks. The mast is stationary but is supported by a frame which rides on one or more wheels. Motors and machine controls are mounted on the frame or mast structure, usually near the floor to simplify preventive equipment maintenance. S/R machine stability is attained by designing either floor mounted or rack supported units. If the RETRIEVER is floor mounted, the most common approach is to have the frame be the bottom. The wheels roll along a single raised rail mounted in the center of the aisle or along a pair or rails on opposite sides of the aisle. When the machine is rack supported, the wheels roll over a pair of rails which are mounted on top of the rack structure, on opposite sides of the aisle. The RETRIEVER is always locked within an aisle and is guided at both the top and bottom. Floor mounted machines are guided by an overhead track or a pair of tracks. Rack supported machines are guided by wheels which engage a pair of guides at the base of the rack. These top and bottom supports eliminate the possibility of lateral movement or mast sway as the machine moves through an aisle or lifts and lowers a load.

Material Input/Output Equipment

Success of a high rise system depends heavily on how loads are brought to the storage area and how they are taken away. An important aspect of material flow which must be considered is the handling and transfer of material in the immediate storage area, and delivery systems which move material from the high rise to and from the production areas of the plant. A basic system implements stationary pickup and discharge stations (P&D) located on each side of the RETRIEVER aisle. One P&D is normally used for incoming loads, the other for outgoing material. Deliveries of loads to and from the P&D platforms can be by driverless tractors, transfer carts, fork lifts or overhead cranes. As throughput rates increase, however, it may be necessary to implement two level P&D stations on both sides of an aisle. Input is thus on one level, output on another. With this type of arrangement, two incoming and outgoing loads can be staged at one time. Newer machines with increased horizontal and vertical speeds have changed the design of the standard P&D station. For high throughputs, short sections of conveyor are added to each P&D station, thus creating a short queueing station. This buffer zone may hold a number of loads and assures constant throughput if the fork lift or other input mechanism become delayed. Subsequent development of input/output systems now ties together individual conveyor spurs to form an integrated conveyor network. Materials can be moved continuously to and from the storage area, to and from each individual aisle.

S/R Machine Controls

In recent years, the greatest innovations to S/R machines have not been in the area of mechanical design but increased sophistication in machine controls. Since a S/R machine must be told what to do and where to go, there must be method of entering command information so that the control logic can effect execution of the specific movement desired. This command input is by either local or remote programming. Local programming implies that instructions to the machine are input directly into a control console mounted on the machine. The commands are generally entered via pushbuttons, dials or thumbwheel switches, but card readers can also be mounted on the console to accept commands from conventional Hollerith cards. The advantage of local programming is its economy, the major disadvantage is the requirement for the storage machine to return to head of the aisle after execution of a command so that the next command can be entered. If the operator controlling the machines is busy at some other aisle, the machine is not in use and throughput efficiency will suffer. Obviously, it is not practical to have the operator constantly moving back and forth between aisles for a large system with a large number of storage machines. For such applications, the remote programming mode is recommended. The logic to effect machine movement is now mounted at the remote console. Remote programming is more expensive than local but much more flexible. Its advantages are:

1. All commands are entered and transmitted to any number of storage machines from a central console.
2. Two way communications with each storage machine can be maintained anywhere within the aisle. This eliminates the need for the S/R machine to move to a home position to receive new command information.
3. Remote consoles may be equipped with card readers, thus permitting a single operator to program several storage machines from one reader at the same time. This enables the operator to input up to an hour or more of command cycles and leave the area.

It is important to note that basic remote programming consoles handle only command transmissions to the storage machines, they do not maintain an inventory of product being stored and retrieved in the facility. Whenever the function of command transmission and inventory management is combined at a remote console, one steps to implementation of an on-line computer system. Such systems represent the most sophisticated approach to operating high rise facilities. Additional comments about computer control warehouses will be made a little later.

High Rise Storage Applications

Currently, in most tire plants, fabric rolls are tagged for identification and stored on carts in miscellaneous open areas within the plant. These rolls are generally 5 - 8 feet in length, have a diameter of up to 4 feet and may weigh as much as 4000 lbs. When the time comes to retrieve specific rolls to feed bias cutters or other production equipment, it is often difficult to locate the required fabric. On occasions, rolls of fabric become lost or forgotten in storage. This resulted in large loss of revenue since old fabric looses tackiness and must often be reclassified as scrap material. The shortcoming of conventional storage is thus, that it does not provide orderly first-in, first-out accessibility of material combined with fixed, known location. Implementation of a high rise storage system, which may be constructed in a plant area with under 20 foot ceiling, will assure immediate location of every fabric roll and can insure material rotation. Product flow in such a facility might have tuggers bringing the roll to the system on carts. The rolls are then placed on "A" frames at one of the pickup and discharge stations at the head of the aisle by the operator using an overhead hoist. From these temporary drop off points, the rolls are picked up by the RETRIEVER and stored into the selected opening. The system can be under complete computer control, all locating and selecting of storage openings for the RETRIEVER to store and remove loads is done by computer logic. The operator can key in a request for a storage opening on a remote computer terminal located at the high rise storage area. He receives a storage location response in the form of a computer printout. For a retrieval of a load from the system, the operator keys in his request and the computer printout shows him the location of the oldest stock in the system.

Another material in a tire plant of perishable nature is radial tire tread. Hence, it makes good sense to include treads on special storage units in the high rise system. They are handled pretty much as fabric rolls are except the tread pan is stored minus its wheeled dolly.

The advantages offered by a high rise system are:

1. Improved inventory control
2. Great space saving
3. Reduced time spent getting loads in and out of storage
4. Diminution of scrap material

The applications just discussed -- tire fabric, and tire treads -- are, in my opinion, ideal material handling situations for high rise implementation.

Another application in the rubber industry is storage of tubs of pelletized master batch. Also, all of the materials to be charged into the mixers can be handled in an automatic tub feed system. The pelletized master batch is stored in tubs and placed into a high rise storage area. As required, specific tubs of chemicals or master batch can be brought out to make final mix. Here again, the main advantage is to keep material at the operator's fingertips at all times.

If you feel that high rise storage systems merit further investigation for possible implementation in your applications, I would like to leave with you a set of prime considerations that must be evaluated when designing the optimum layout.

1. Is the system to be installed in an existing building?
2. Is there a rack limitation?
3. How much floor space is available?
4. What is the floor load capacity?
5. What are the throughput rates?
6. How many loads are to be stored?
7. How large are the loads?
8. How much do they weigh?
9. What is the load height?
10. What type of container should be used?
11. Should additional storage be planned for future expansion?
12. What equipment control sophistication is required?
13. Must fire prevention restrictions be considered?

The designer takes these factors, balances them with the various types of storage and handling equipment available, and comes up with his best system.