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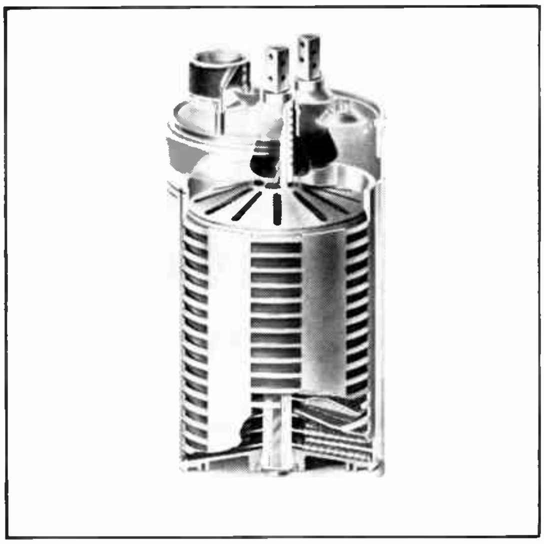
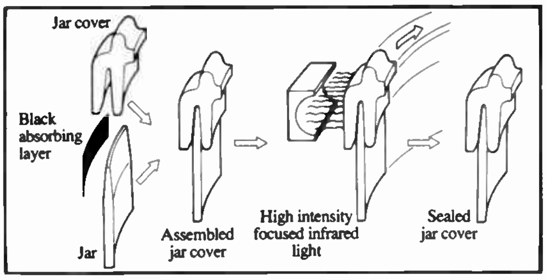
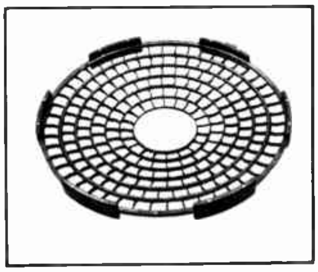
# WESTERN ELECTRIC REPORTS



A cutaway view of the new lead-acid battery. For use in the Bell System, four types—each with a different ampere-hour capacity—will replace the 60 configurations currently in use over the same capacity range.



In the sealing process, focused infra-red light is absorbed in a carbon black coating at the jar-cover interface, causing localized melting of the plastic.



The positive grids are designed so that as corrosive growth occurs the space between hoops remains constant. Thus contact with the paste is maintained and electrical capacity actually increases with age as corrosion produces additional lead-dioxide material.

## Developing a new lead-acid battery.

Every year, Bell System telephone companies spend over $30 million to buy and maintain the lead-acid batteries they use as intermediate sources of standby power during emergencies.

So they know just how susceptible all lead-acid batteries are to problems caused by corrosion. Problems such as gradual loss of capacity, short- circuits and cracking that could result in acid leaks and occasional fires.

That's why Bell Labs and Western Electric engineers recently undertook the first major improvements on what is essentially a 100-year-old design.

The result: a revolutionary, cylindrical lead-acid battery with a jar and cover fabricated from an improved flame-retardant, impact-resistant polyvinylchloride. The bond between jar and cover is leakproof due to a new infra-red sealing process.

Inside the battery are circular, cone-shaped grids cast of pure lead rather than a lead alloy, then stacked horizontally in a self-supporting structure. Positive grids are cast with large grain-size to minimize corrosion. They're then filled with a paste (tetrabasic lead sulfate) whose rod-like particles interlock for maximum mechanical stability.

These new features required new manufacturing techniques. For example, how could potential suppliers best mass-produce positive plates of the required grain-size and paste the grids rapidly and efficiently, given their conical shape and the new oxide material's crystal structure?

Western Electric's Purchased Product Engineering organization and Bell Labs set up a design capability line at a company subsidiary, Nassau Smelting & Refining.

Using machinery developed at Western Electric's Kearny Works, they refined production methods and materials that made it possible for a supplier to produce the new battery economically, in commercial quantities and to Bell System specifications.

And Western Electric plans to achieve still further savings through a continuing cost-reduction program.

**Conclusion:** Close cooperation between Bell Labs and Western Electric has resulted in the creation of a superior lead-acid battery. Its expected useful lifetime is at least 30 years—double that of even its best predecessors. It lowers maintenance costs substantially. And its unusual design virtually eliminates the hazard of fire due to mechanical failure.

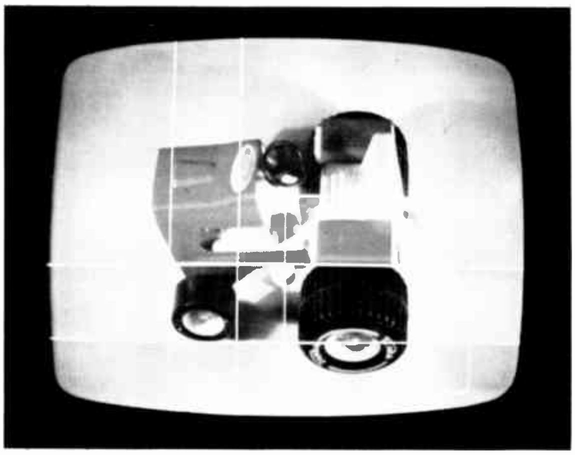
**Western Electric**

**We make things that bring people closer.**

## the cover

*Scale-model railroaders may believe they are seeing silhouettes of K-gauge locomotives arrayed on the cover. Not so. They are Sweden's modern electric locomotives and subway traction units featured in the article beginning on page 53. Art Director Taylor deviously chose to portray them at K-scale, however*

**spectrum**



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IEEE spectrum MARCH VOLUME 11 ☐ NUMBER 3

# Spectral lines

## Energy crisis: seeking the real alternatives III

While we were addressing the possibility of modeling the world energy situation, or more practically parts of it ("Spectral lines," Jan., Feb. 1974), the Britons had cast aside any such ambitions in favor of pragmatic solutions. They had to! By January, many industries had been cut to a three-day week or by other means had been restricted to drawing no more than 65 percent of normal power from the mains.

To keep factory output at relatively high levels, ingenious, if jury-rigged, methods had be be employed. During a visit to British electronics and electrical equipment manufacturers just a few weeks ago, we saw factories, on their "power-off" days, lighting assembly benches using temporarily rigged strings of 60-watt, 110-volt incandescent lamps suspended just inches above the workers' heads. The lamps were powered directly (yes, dimly!) from 24-volt aircraft power generators. The same generators were used to power 24-volt soldering irons. (When the auxiliary supplies failed, soldering ceased except for a few stations hooked up to auto batteries.) Elsewhere in factories, propane gas lamps provided a modicum of light, a few fluorescents were run from 110-volt auxiliary generators, and some executive offices were lit from auto batteries. Elevators were often blacked out.

Housewife-assembly workers were inclined to take what they assumed to be a temporary situation with "true grit," although those forced to work the Thursday through Saturday "week" griped that "you can't buy your Sunday joint [roast] on Monday."

Despite the power cuts and short work weeks, British managers are astonished that production levels continue in many cases at 85 to 90 percent of normal. Some managers reason that, before the crisis, industry had grown fat and happy. Power was wasted, and workers were not producing at top efficiency. "Things will never be the same," said one, but he acknowledged that, if the short week continued too long, upon return to "normalcy" readjustments in production rates might wreak havoc with morale and employer-employee relations.

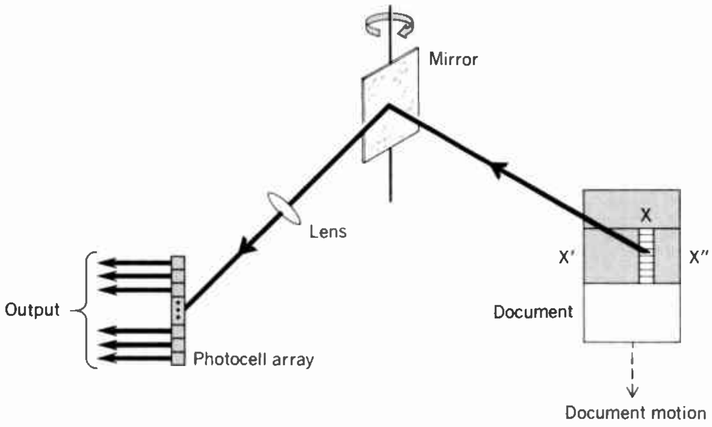
The Government-imposed restrictions were not applied universally; exemptions for critical industries and operations of a continuous nature were permitted. Thus, during our visit, lights were bright and work went ahead full tilt at Kent Automation, makers of computerized digital control systems. At Mullard, operations meeting the definition of "continuous processing" have been exempted from the three-day work week but are required to subsist on 65 percent of the normal power drawn from the mains, supplemented by auxiliary power. (Some companies have elected to use part of their heating fuel oil allotment to run auxiliary generators.)

Material shortages and anticipated shortages are related to the energy crunch, too, though when and where such shortages will strike is not clear. "We feel like we are at the end of a very long dog," said an official at Mullard, where shortages are anticipated in paper and packaging materials, petrochemical-based parts, and steel. But in many cases production has not yet been affected because of large stockpiles. At the opposite end of the production line, a 20-week order backlog at a British instrument maker is due in part to the energy-caused production cutback, but is also the result of unusually high order rates, thought by the company's executives to be an artificial situation caused by over-ordering by its distributors in anticipation of a future shortage.

Britain's energy travails (which were heightened as the coal miners' strike took effect in mid-February) may help guide other affluent nations as they too feel the pinch of the energy shortage. The extremes to which British industry has been forced in order to comply with restrictions already in effect may suggest ways to bring computers and electronics to bear to help increase the efficiency of power use. Simple sensors might be used to avoid wasting power in overdrying in certain materials processing. (In one known case a secondary power savings would occur; the yield of flour is related to the moisture content of the grain as processing begins.)

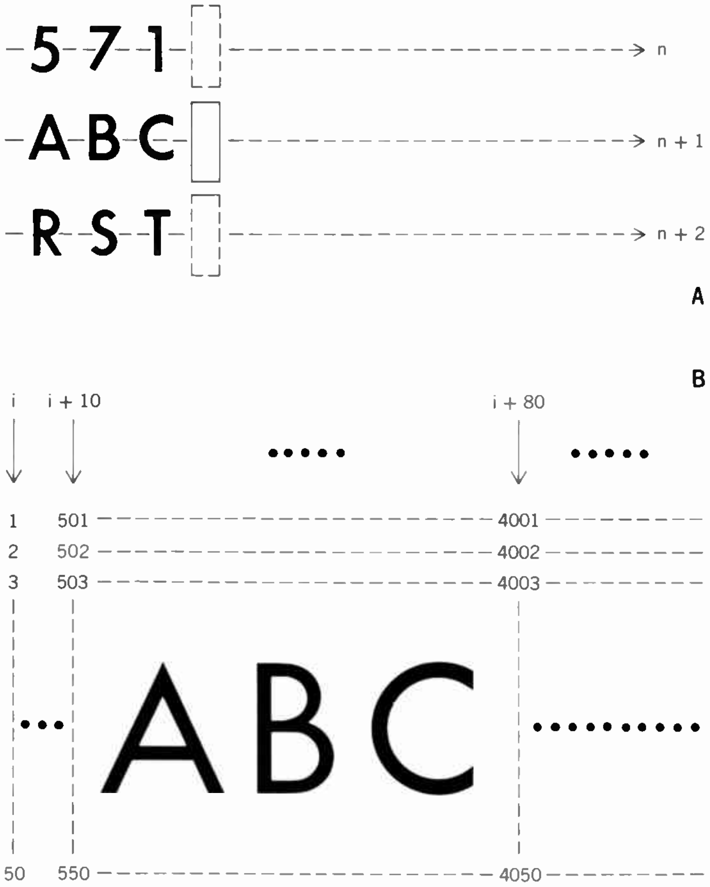
If it seems the British are enmeshed in immediate problems to the exclusion of the future, such is not the case. The Council for Environmental Science and Engineering, a body set up by some 21 British science and engineering societies, notes that it's not just the short-term industrial and commercial problems that must be dealt with, but that R&D problems of frightening complexity need urgent attention through programs such as those embarked upon by Britain to rearm before World War II. The council recommends the setting up of ministries to bring the talents of leading engineers, industrialists, and scientists to bear upon the problem. In words that ring familiar, it scolds the Government for failing to take steps "that go far enough to match up to the gravity of the situation facing the country."—*Donald Christiansen, Editor*

The vidicon, shown schematically in Fig. 3B, is a low-cost TV pickup tube that is adapted easily for OCR use. The complete field of view is focused onto the face of the tube. A photoconductive surface inside the tube face causes the formation of a charge distribution whose density at every point is proportional to the intensity of the incident illumination at that point. Varying the currents in a set of deflection coils causes an electron beam to move across the tube face in such a way that it traces out a raster-scan pattern on the back of the photoconductive surface. The electron beam neutralizes the charge distribution adjacent to the photoconductive surface at each point scanned. The current required for this purpose is proportional to the accumulated charge density at that point, which in turn is proportional to the intensity of the incident light that produced the charge. Since the output of the amplifier at any point is proportional to the neutralizing current required at that point, the amplifier output is also proportional to the incident-light intensity.



**[4] Photocell array used for electrooptical conversion.**

**[5] Hybrid scanning is partly mechanical and partly electronic and gives a modified raster scan. Three scan pattern lines (A) and the order in which the image elements appear in the output for line n + 1 only (B).**



Since scanning is produced electronically and no moving parts are required, the vidicon is capable of scanning at much higher rates than can be achieved with a mechanical system. Furthermore, the photoconductive surface integrates the light arriving at each point from the time the electron beam discharges a given point to the time it next discharges the same point. This integrating action results in a better signal-to-noise ratio than can be achieved by mechanically scanned devices which sample, instantaneously, each point in the raster for a short interval of time.

By contrast to the vidicon, which is a passive scanner, the flying-spot scanner is an active electronic scanning device. As illustrated in Fig. 3C, a CRT produces a high-intensity spot of light which is focused by a lens to create a single point of illumination on the object containing the characters to be read. A multiplier phototube senses the light reflected from the object and produces an output that is dependent on the reflectivity of the point on which the spot is focused. Movement of the CRT spot in a raster pattern results in an output resembling that of the vidicon. But unless the raster pattern is traced out relatively slowly, there will be no integration effects such as with the vidicon scanner. The operating speed of the flying-spot scanner, therefore, lies between that of the mechanical and vidicon scanners.

Active scanners have also been built using laser illumination. In a laser scanner, the CRT spot is replaced by a laser source. Scanning is accomplished mechanically using rotating mirrors and document motion to produce the raster pattern. A multiplier phototube measures the reflected light from the document in the same manner as in the flying-spot scanner.

An array of photocells arranged either in a single row or in a two-dimensional matrix or retina has also been used successfully for electrooptical conversion. In the single-row arrangement, which is more common, a vertical strip *X* is focused onto the array as illustrated in Fig. 4 and each element of the strip is imaged onto one of the photocells. A rotating mirror causes the field of view to move across the document or object from *X'* to *X''*. The output of the scanner is a set of electric signals corresponding to a set of rows on the object, each signal resembling the output obtained from a single photocell scanner. Document motion permits successive strips to be scanned until the entire document has been examined.

In the two-dimensional retina, outputs corresponding to a complete two-dimensional area of a document are available simultaneously. The area chosen usually covers a single character at a time. Other character-containing areas are then examined sequentially using mechanical scanning and document motion.

## Hybrid scanning

The availability of monolithic self-scanned line arrays makes feasible a mode of scanning that is partly electronic and partly mechanical. A self-scanned array consists of a row of 50 to 512 photodiodes, each of which is connected to a capacitor. The capacitors, which are connected to a single output line through a multiplexer, the photodiodes, and the multiplexer itself are all fabricated on a single integrated circuit chip. As with the unscanned array (Fig. 4), a vertical strip $X$ is focused onto the array with each element of the strip imaged onto an individual photodiode. During exposure, the photodiode charges its capacitor at a rate that depends on the intensity of the incident illumination. During readout, the multiplexer samples the voltage resulting from the charge that has accumulated on each capacitor and transfers it to the output line. The capacitors are discharged as their voltages are read. A rotating mirror causes the field of view of the array to move across the document or object from $X'$ to $X''$ (Fig. 4).

The scan pattern that results is a modified raster scan as illustrated in Fig. 5. Figure 5A shows the array "sweeping" across three character-containing lines on the object. Figure 5B shows the order in which the image elements appear in the output for line $n + 1$ only. Vertical scanning (1 . . . 50, 51 . . . 100, etc.) is accomplished electronically within the array, as already described. The horizontal scan, by virtue of which column $i$ becomes column $i + 1$, is implemented by the rotating mirror. The motion of the document implements the scanning of successive strips ($n$, $n + 1$, $n + 2$) until the entire document has been examined.

The self-scanned array possesses many of the advantages of the vidicon, such as rapid electronic scanning and an integration effect. At the same time, it also has the inherent reliability and long-life characteristics of solid-state devices.

The recent development of an LED array permits the construction of an active hybrid scanner. The array consists of a row of LEDs, each of which can be turned on to produce a tiny spot of light which is then focused onto the document. Pulsing each LED in sequence causes a spot of light to scan effectively across a small part of the document and results in the same scan pattern as obtained by using a self-scanned photodiode array as shown in Fig. 5. A rotating mirror, similar to that in the passive hybrid scanner, is used to implement the horizontal scan (column $i \rightarrow i + 1$) and document motion causes successive strips ($n$, $n + 1$, etc.) to be scanned. A multiplier phototube or photodiode is used to detect the intensity of the light reflected from the document and operates in the manner previously described for the flying-spot scanner. The operational characteristics of the active hybrid scanner are similar to those of the flying-spot scanner. In addition, it also possesses the high reliability and long-life characteristics of solid-state devices.

## Line-following scanning

A basic pattern that characterizes line-following scanning is illustrated in Fig. 6. (It should be noted that, of the various scanners thus far described, only the flying-spot scanner can be used for line-following scanning.) A coarse raster scan is initiated and followed until the presence of a character is sensed when a change in contrast is detected. The scan direction is then modified so that a downward helical scan is traced out until the symmetry of the output is disturbed, at which time there is a change in scan direction and/or scan pattern.

As shown in Fig. 6, when the scan reaches the character 5, it encounters at once a lack of symmetry caused by the horizontal bar at the top. This lack of symmetry is noted in a memory and a downward helical scan is initiated. Halfway down, another discontinuity is encountered and the scan moves to the right, tracing out the path shown in the illustration. When the scan reaches the tail of the 5, it returns to the top of the character and proceeds to trace out the horizontal bar. It then returns to the coarse raster scan mode and proceeds until the next character is located. Each character in the field of view is processed similarly.

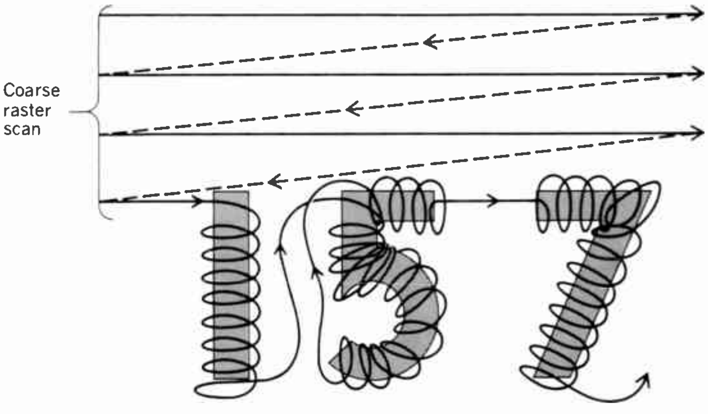
The output of a line-following scanner consists of a set of features—lines, curves, corners, intersections, and the like. For any given character, such features are relatively invariant whatever the print font or handprinting style. The line-following scanner is, therefore, used to best advantage when large numbers of type fonts or print styles must be accommodated. Its high cost prohibits its use for applications involving only a small number of stylized type fonts.

The features that make up the output of the line-following scanner for each character are processed by recognition logic to determine which of an allowed set of alphabetic or numeric characters has been scanned. Feature extraction logic can be used to produce features from a raster scanner output.

## The preprocessor

The preprocessor converts the output signal of the scanner into a form that can be used by the recognition logic for character identification. Two steps—quantization and feature extraction—may be involved, depending on the nature of the system. The quantizer converts the analog signals produced by the scanner into digital signals representing light and dark areas and may also include noise elimination and normalization logic. The feature-extraction logic

[6] Basic pattern for line-following scanning.



reduces the scanner or quantizer output to feature sets from which the characters can be more reliably recognized.

## Quantization

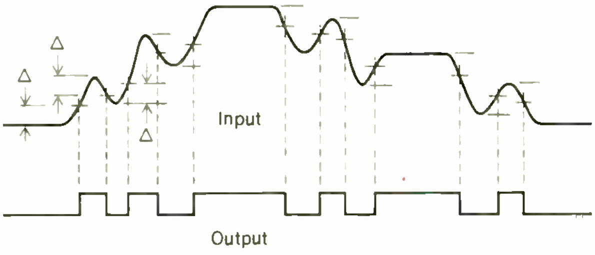
In the simplest of systems, the quantizer is merely a circuit whose output is a logical 1 or 0, depending on whether the input is below or above a preset threshold level. Since scanner signals are rarely as well defined and noise free as those depicted in Fig. 2B, however, more sophisticated quantizers are often used. It is possible, for instance, to vary adaptively the threshold level to compensate for input-signal changes resulting from a changing background level. Alternatively, the quantizer can be designed to change state in response to input changes of a certain preset magnitude—that is, to respond to changes in contrast, as illustrated in Fig. 7.

After the signal has been quantized, it may still possess undesirable components due to noise, imperfect inking of the character being scanned, inability of the quantizer to provide sufficient compensation for varying background levels, and so forth. The result may be a character whose digitized representation contains random noise, has broken lines, or has varying line widths, as illustrated in Fig. 8A. To eliminate such potential sources of error, noise removal, gap filling, and line-thinning logic are often employed. Noise removal may consist of simply eliminating 1's (or 0's) which occur in small isolated groups but are otherwise completely surrounded spatially by fairly large areas of 0's (or 1's) as shown in Fig. 8B.

Gap filling can consist of extending all line endings by a small amount and detecting if any two lines merge, as shown in Fig. 8C. The extensions for all line endings which merge are then retained, thereby reconnecting the broken line segments. A potential hazard of this procedure is that occasionally a gap which should be present is erroneously filled.

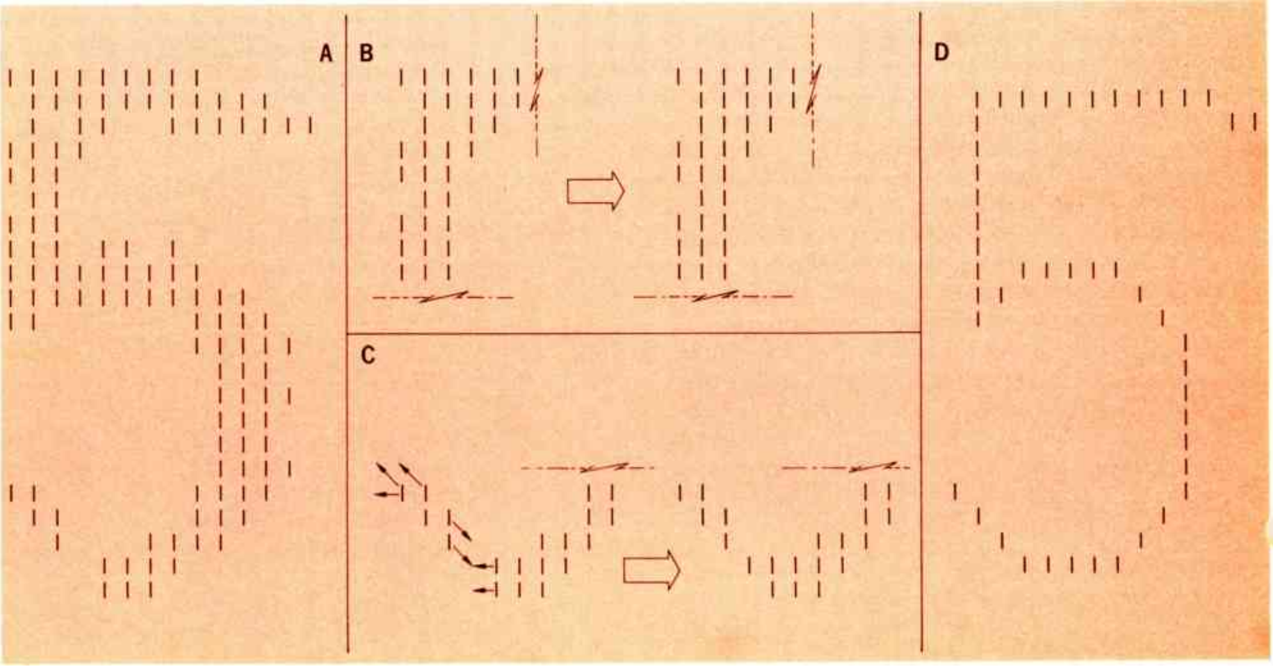
Line thinning is a normalization procedure which causes all lines to be thinned down to a prespecified width. An example of line thinning is shown in Fig. 8D in which all lines are thinned to a single picture element in width. Line thinning preserves the geometry of each character while reducing the variability between scanned characters. In many cases, line thinning simplifies considerably the task of feature extraction and recognition logic.

The degree to which these procedures are incorporated into the quantization logic depends on the variability which can be expected in the input images and the number of fonts to which the OCR system will be subjected. If several fonts are to be read by a raster scanner, feature extraction logic is often used. In such cases, output of the quantizer is fed first to feature-extraction logic instead of being fed directly to the recognition logic for character identification.



[7] Contrast-dependent quantization of scanner signal.

[8] Digitized representation of character 5 contains random noise, broken lines, and varying line widths (A); effect of eliminating 1's or 0's that occur in small isolated groups (B); gap filling (C); and line thinning (D).



## Feature extraction

The raw data provided by the quantizer output, for all but the line-following scanner, consists of a large quantity of binary information. To simplify the task of the recognition system, feature extraction is often used to reduce the amount of data which is presented to the recognition logic. Ideally, the features which are chosen by the OCR system designer should provide for invariant feature extractor outputs for each character, regardless of the font being read. Unfortunately, complete invariance has not been achieved even with highly sophisticated quantization and feature extraction logic. Feature extraction errors are caused by skewed inputs, distortion, variations in fonts, noise, and less than ideal scanners. As a result, several different types of features are used in OCR systems. These include geometric features—such as lines, line endings, and curves—and nongeometric features—such as densities or eigenvalues.

Geometric feature extraction is the most obvious, and most sophisticated, type of feature-extraction logic used in OCR systems. It reduces the quantizer output to a set of geometric features—horizontal and vertical lines, diagonals, corners, arcs, line endings, and the like. This feature set, along with a description of the relative location of each feature, is fed to the recognition logic for further processing.

Methods used for geometric feature extraction vary, depending on the type of scanner and quantizer used. Line-following scanners output geometric features directly. Referring back to Fig. 6, note the motion of the scanning trace as it follows the outline of the number 5. The upper-left-hand corner of the character is located first and scanning proceeds downward along the vertical line. As the loop of the 5 is reached, the information that there is a short vertical line at the upper-left part of the character is stored in the memory of the OCR system as part of the feature set. Then, as the scanner proceeds to trace out the loop of the 5, the information that there is a lower-left corner at the left-central part of the character is also stored in the memory. The process continues and the information about the arcs and the line ending and their locations is also saved. The scanner then returns to the top to scan the remaining part of the 5. As the horizontal line is traced out, the upper-left corner, the horizontal line, and the line ending are each found and stored in the memory. Thus, in the case of the line-following scanner, the output is very naturally in the form of a set of geometric features.

One way in which geometric features can be generated from the output of a raster scanner is by sequentially positioning a set of "masks" over every part of the scanner output. The mask for detecting an upper-left corner, for example, is shown in Fig. 9, along with the position on the character 5, where it elicits a positive response. In effect, every 16-element square in the scanned image is examined. Only those that are dark (or binary 1) in all but the four lower-right elements confirm the presence of that particular corner feature. Suitable masks are used for detecting other geometric features in the same way. It should be noted that the 4 × 4-size mask is used for illustration only; 5 × 5 is also commonly used.

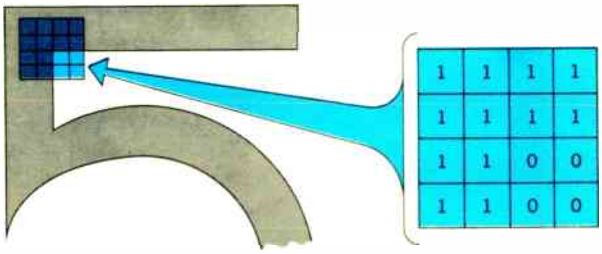
Density feature extraction is another technique that is used in OCR systems. It is based on the density of binary 1's in predetermined regions of an image. As an example, the character-containing area can be divided into a set of strips and the number of 1's in each strip counted. Information as to whether or not a preset threshold is exceeded in each of the strips is then fed to the recognition logic.

Figure 10 illustrates the application of density feature extraction to the character 5. Thresholds have been established such that three or more 1's in any row and four or more 1's in any column produce a 1 output. Unlike geometric feature extraction, the output code that results from density-feature extraction need have no direct relationship to character geometry. The technique is a relatively simple one which can only be used with a single, highly stylized font intended for the purpose.

## Recognition logic

The recognition logic performs two functions. It locates the characters and, if necessary, separates them from one another. It then identifies each character by one of several classification schemes.

Where a unique location is provided for each character in advance, the task of locating characters and separating them from one another is simplified greatly. One way of doing this is through use of preprinted boxes. An example of part of a document prepared in this manner is shown in Fig. 11A. The boxes are preprinted on the document in a color invisible to the scanner and each character is then typed or printed

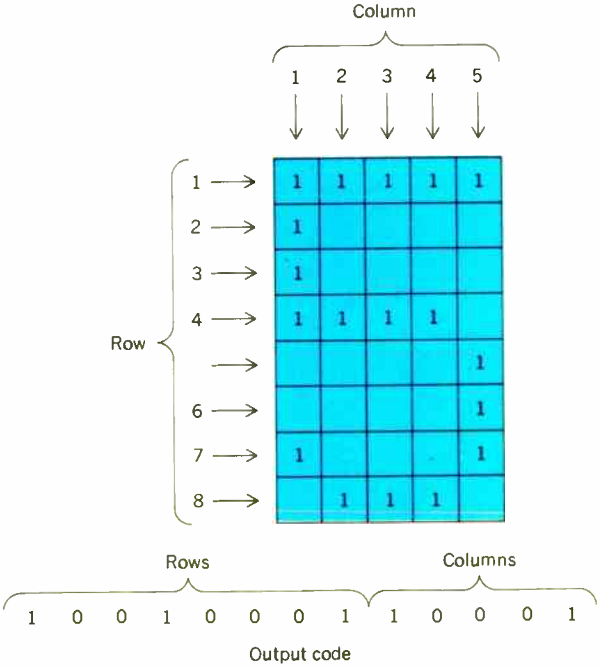


Superposition of mask on character

Upper-left-corner mask

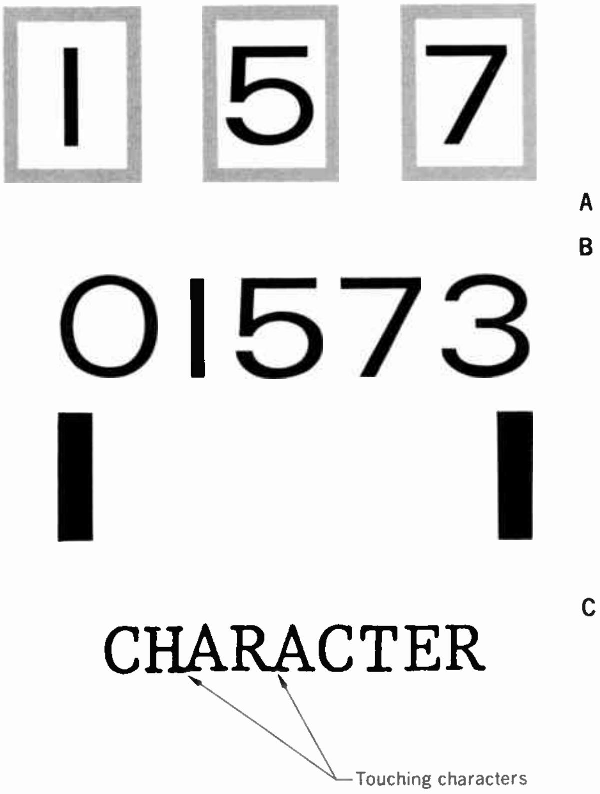
**[9] Use of a mask to detect the upper left corner of a 5.**

**[10] Density feature detection scheme for character 5.**



completely within one of the boxes. Since the location of each box is known by the OCR system, it examines only the areas within the boxes for valid characters.

Another technique makes use of locating marks or bars as in the example shown in Fig. 11B. In this case, the character-location logic associated with the scanner searches the document for the bars. After they are found, the separation logic examines the area adjacent to the bars for the characters. As shown in the figure, the area above the bars contains exactly five characters whose height, width, and spacing are known. Thus, locating and separating the five characters is a relatively simple task. The bars can also be used to detect and correct for character skew if it occurs. The amount of skew is measured by determining the angular difference between the bars and a true horizontal or vertical line. The character data are then rotated electronically to remove the skew prior to processing by the recognition logic.

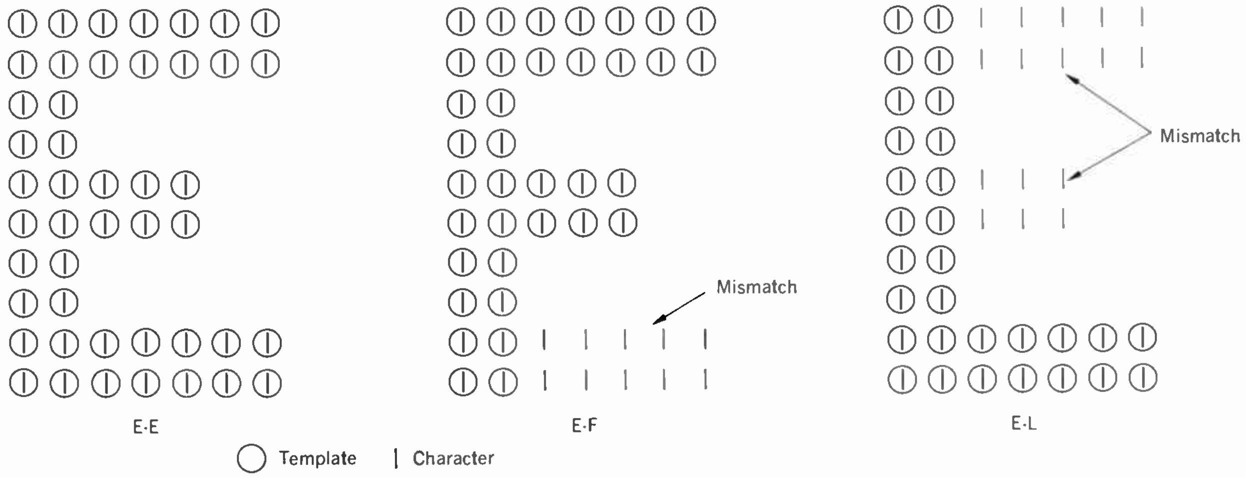


[11] **Preprinted boxes in color invisible to scanner (A) or preprinted bars (B) provide unique locations for characters. Even clear typewritten characters can touch or overlap (C) and can cause problems.**

Where no prior constraints are placed on character position, the task of character location and separation becomes more difficult. As Fig. 11C shows, even very clear typewritten characters often touch or overlap. Character separation in this case is usually accomplished in two steps. The obvious breaks between words and groups of characters are searched for by examining the data for the narrow vertical spaces which often occur between pairs of characters or between words. Then the data between the spaces are examined by the recognition logic in an attempt to identify each segment as a set of valid characters. This procedure often yields several possible interpretations, each with a certain probability of being the correct set. Calculating the probability that each interpretation is the correct one, and choosing the character set with the highest probability, completes the task.

Many classification algorithms have been devised for processing scanner and preprocessor output data. One of the simplest ones compares directly the quantized scanner output data with a stored representation or template of each character and selects the closest match. Figure 12 illustrates the application of this technique to identification of the character E under ideal conditions. Proper alignment of scanner output with the E template is seen to result in complete registration. The best possible alignment of the input data with the F and the L templates, on the other hand, yields poor registration. The bottom of the E is mismatched in the case of the F template, and the center and top of the E are mismatched in the case of the L template. In the presence of noise or optical distortion, registration will be incomplete in virtually all cases. Recognition must then be completed on the basis of a "best match" using a criterion such as the minimum Hamming distance between the classifier input and the set of stored templates. Because of its susceptibility to noise and distortion, this classification scheme is used only for relatively clean data obtained from well-separated characters.

**[12] Template-matching character classification.**



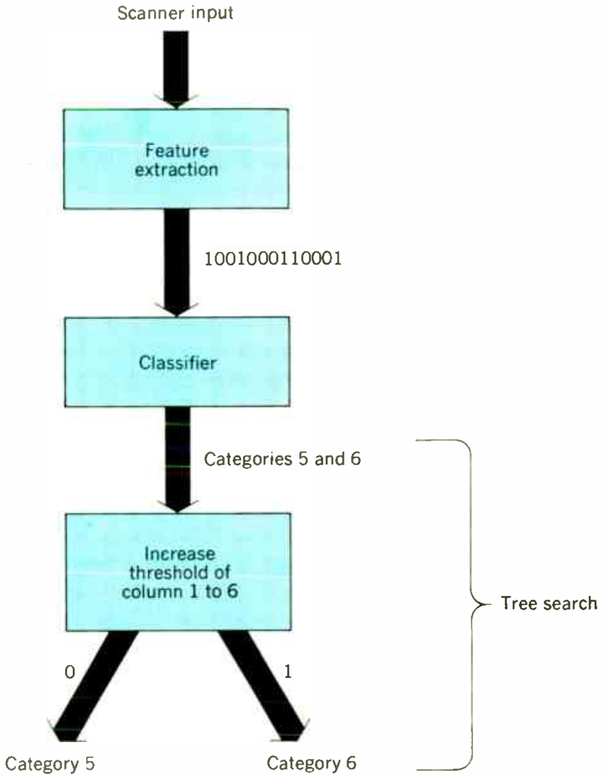
Another classification scheme is based on the use of nongeometric features such as the density features described earlier. Output of the feature-extraction logic is a binary vector, each bit of which represents the density of a particular segment. This vector is compared to a set of stored vectors in the recognition logic to eliminate all but a small subset of possible categories. In an ideal system, the subset would consist of a single category, and a unique classification would result. In practice, however, some ambiguity normally exists and further processing is required. A new threshold may be established for one or more of the segments, for example, and the change in output used as a new criterion for classification. The result is a tree search of the type shown in part in Fig. 13. If this search does not produce a unique classification, the character is placed in a reject category. Then, either the system operator is notified that an ambiguity exists which he must resolve manually or, if sufficient redundancy is present in the data, context correction (to be described later) can be used to identify the reject.

The most sophisticated classification algorithms employ some form of geometric-feature matching. The classifier has available a stored description of each character in a format that is compatible with the preprocessor output. The operation of such a classifier is illustrated in Fig. 14, where a typical output feature set is compared with stored character descriptions for the letters E and F. Features 1 through 5 and feature 7 of the scanned character are found in the descriptions for both E and F; feature 6 is present only in F. One would conclude, then, that the scanned character is an F. This conclusion can be reinforced by examining those features in the stored lists (identified by bullets) that do not appear in the preprocessor output. It will be noted that five features of the letter E, but only two of the letter F are missing. If the number of mismatches for each letter is subtracted from the number of matches,

$$E: 6 - 5 = 1$$
$$F: 7 - 2 = 5$$

it becomes obvious that the probability of the character being an F is much greater than the probability of its being an E. This type of procedure usually leads to more conclusive results than correlation based only on matching output features and can be readily extended to any alphabetic or numeric character.

In the technique just described, the features are assigned weights of either +1 or −1. Features that are detected and belong to a particular character are assigned weights of +1. Features that are detected but do not belong to the character as well as all undetected features are assigned weights of −1. To improve the operation of the system, the weights can be allowed to take on any value between +1 and −1. Features that are more crucial to the recognition of a particular character are then assigned greater weights in the stored description of the character. In a similar manner, features that may cause erroneous results are assigned lesser weights or even zero weights in the stored descriptions. The weights used in such a system can be chosen using a training procedure in which a set of training characters is presented to the scanner and the weights adjusted adaptively until all of the characters can be correctly identified. Then, the performance of the trained system is measured using a set of test characters which is chosen to be as representative of typical input data as possible. If the performance when using the test characters is considered acceptable, then the system has been adequately trained; otherwise, the training is repeated using a different training set. This procedure is continued until the performance of the system is acceptable. If it is discovered that the weights corre-



[13] **Character classification based on density-feature extraction is a type search procedure.**

[14] **Geometric-feature matching character classification.**

Preprocessor output

| | | |
|---|---|---|
| 1. | Top | Horizontal bar |
| 2. | Left | Vertical bar |
| 3. | Center | Horizontal bar |
| 4. | Upper left | Upper left corner |
| 5. | Left center | Lower left corner |
| 6. | Lower left | Vertical line end |
| 7. | Center | Horiontzal line end |

Stored character descriptions

E

| | | |
|---|---|---|
| | Top | Horizontal bar |
| | Left | Vertical bar |
| | Center | Horizontal bar |
| ● | Bottom | Horizontal bar |
| | Upper left | Upper left corner |
| | Left center | Lower left corner |
| ● | Left center | Upper left corner |
| ● | Lower left | Lower left corner |
| ● | Upper right | Horizontal line end |
| | Center | Horizontal line end |
| ● | Lower right | Horizontal line end |

Number of matches: 6
Number of mismatches: 5

F

| | | |
|---|---|---|
| | Top | Horizontal bar |
| | Left | Vertical bar |
| | Center | Horizontal bar |
| | Upper left | Upper left corner |
| | Left center | Lower left corner |
| ● | Left center | Upper left corner |
| ● | Upper right | Horizontal line end |
| | Lower left | Vertical line end |
| | Center | Horizontal line end |

Number of matches: 7
Number of mismatches: 2

sponding to one of the features are very small after the system has been trained, this feature can be discarded since its effect upon system performance will be negligible.

Other techniques have been developed for classifying characters in OCR systems. However, many of these techniques are based on using complex features and mathematical transformations that are beyond the scope of this discussion. The interested reader is referred to the reading list below.

## Context correction

If the preprocessor output for a character does not correlate closely with any of the stored descriptions, or if it correlates approximately equally with two or more of the descriptions, it is highly probable that a classification error will be made. Since such errors can be costly, it is preferable to place the character into a reject category. Then, one of several alternate strategies may be followed:

1. The complete document can be rejected and held for manual processing by a human operator.
2. The rejected character can be displayed on a monitor, enabling an operator to insert his interpretation via a manual keyboard. The remaining characters are then processed by the OCR system. The operator merely aids the system whenever it encounters a rejected character.
3. If sufficient redundancy exists, it may be possible to apply context correction to rejected characters. Consider an application wherein the names and descriptions of products are to be read from a warehouse inventory form. Since only a limited number of product names and descriptions exist, context correction can often be used. For example, if one of the words being scanned designates a color, then an allowed set of colors might be: red, yellow, orange, green, blue, violet, brown, white, and black. If the character sequence *REE* was read—the asterisks denoting rejected characters—the system could determine that the closest match is GREEN, since no other valid sequence matches *REE* as closely. Even if the first and last characters were read incorrectly so that QREEH were the result, context correction could still yield GREEN, since Q and G, and H and N are pairs of similar characters which have a high probability of being confused. Context correction cannot be used in a situation wherein adjacent characters are unrelated. Examples of such data include serial numbers from airline tickets, utility company invoice stubs, and so forth. However, context correction is a powerful technique for improving the reliability of an OCR system whenever it can be used.

Until several years ago, most OCR systems were completely implemented using hardware techniques. Now, because of the decreasing cost of computers, computer software is being used to an ever greater extent to implement some of the information-processing parts of OCR systems. Character separation logic, classification logic, and context correction logic are now quite commonly developed in software. This technique provides more flexibility for modifying algorithms, especially during system development. Quantization logic, feature extraction logic, and character location logic can be constructed using either software or hardware techniques, although the latter are still more common for these functions. The trend toward increased use of software can be expected to continue as computer costs decrease even further.

## For further reading

### Pattern recognition:

Nagy, G., "State of the art in pattern recognition, *Proc. IEEE*, vol. 56, pp. 836–862, May 1968.

Cheng, G. C., Ledley, R. S., Pollock, D. K., and Rosenfeld, A. (eds.), *Pictorial Pattern Recognition*. Washington, D.C.: Thompson Book Co., 1968.

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Rosenfeld, A., *Picture Processing by Computer*. New York: Academic Press, 1969.

### Optical character recognition:

Holt, A. W., "Comparative religion in character recognition machines," *IEEE Computer Group News*, vol. 2, pp. 3–11, June 1968.

Sheinberg, I., "The INPUT 2 document reader (a new optical character recognition system)," *Pattern Recognition*, vol. 2, pp. 167–173, Sept. 1970.

*Automatic Pattern Recognition*. Washington, D.C.: National Security Industrial Association, 1969.

Balm, G. J., "An introduction to optical character reader considerations," *Pattern Recognition*, vol. 2, pp. 151–166, Sept. 1970.

### Preprocessing and feature extraction

McCormick, B. H., "The Illinois pattern recognition computer—Illiac III," *IEEE Trans. Electronic Computers*, vol. EC-12, pp. 791–813, May 1963.

*Conf. Record, Symposium on Feature Extraction and Selection in Pattern Recognition*, IEEE, New York, N.Y., 1970.

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# Riding Sweden's slick rail system

## An on-the-scene report reveals how this 11 400 kilometer system is kept smoothly running

Ever since I was a kid of twelve, riding the old iron-horse-drawn *Twentieth Century Limited* (New York Central's crack train between New York and Chicago), I've dreamed of riding up front in the locomotive cab. And the kid in me never grew up; the dream persisted—unfulfilled. So, imagine the thrill of being ushered by my ASEA (the Swedish opposite number of General Electric) host into the cab of an SJ Rc 2 class mainline locomotive, hauling an express train from Stockholm to Uppsala. The driver tooted the typically European high-pitched whistle, and we glided silently—without the jolt one expects in U.S. trains—out of Stockholm's Central Station. The 67-km-long ride was as different from the Penn Central's lurch, jerk, stop, stagger, and start as day is from night.

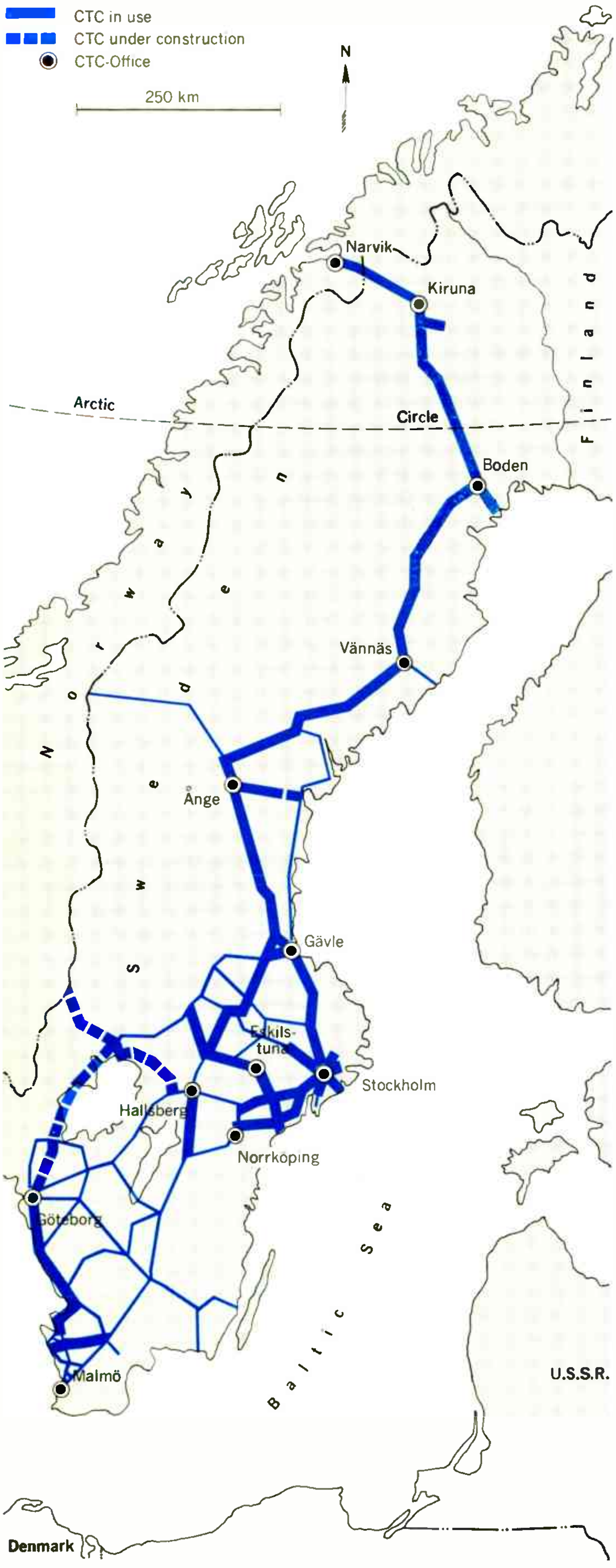
**Gordon D. Friedlander** Senior Staff Writer

And this was only the beginning of the fulfillment of my boyhood fantasies: the next day I found myself in the cab of a class X1 multiple-unit train making the run on the suburban line from Märsta to Stockholm Central (about 35 km). Later, I rode in the cab of a brand-new dc chopper-controlled subway (SL Tunnelbana) car along a short section of test track at the Stockholm maintenance yards. On the day I was in Stockholm, the cars were taken into the depot to be cleaned up before going into service. The SL states that its experience with the new rolling stock has been favorable.

And before my three-week European investigation, through five countries was completed, I'd repeated my Swedish experience by riding "up front" across a good segment of the map of Western Europe—but

General view of driver's cab of Rc 2 locomotive, showing the instrument console and the tractive effort control lever, located on the desk below the center of the instrument panel.

[1] Map of centralized traffic control (CTC) installations in Sweden. Note that CTC extends 1800 km, from Malmo in the south to Narvik (Norway) in the far north.



that's another story to be the subject of subsequent articles in this series.

## Statens Järnvägar (SJ)

Sweden is a sparsely populated Scandinavian nation of 450 000 $\text{km}^2$, with a total population of 8 million people. Its geographical configuration extends about 1600 km in a generally north–south direction, and the average width of the country is about 300 km, east to west. Only about one eighth of Sweden's land mass lies north of the Arctic Circle; almost the entire country, however, is subject to severe weather conditions that are common during the long winters on the Scandinavian peninsula. The bulk of the population is found in the southern one third of the nation, principally in the Stockholm metropolitan area (population about 1.5 million), Gothenburg (500 000), Malmö (200 000), and Västerås (120 000).

Although the total length of the SJ (Swedish State Railways) is only 11 400 route kilometers, it is the "longest" railway line in Western Europe (more than 1800 km), extending from 25 km south of Malmö, in the south, to Narvik, Norway, some 200 km north of the Arctic Circle. Also, the total distance of Sweden's electrified system is about 7500 route kilometers, thereby making it one of the longest in Europe.

At present, 61 percent of the SJ is electrified with a catenary system that carries 15 kV at $16\frac{2}{3}$ Hz. Some 93 percent of the total traffic—passenger and freight—is hauled by electric traction; the remainder is diesel-electric. The SJ rolling stock includes a total of 2500 locomotives in mainline and yard-switching service, the large majority of which are all-electric.

The double-track mainlines of Swedish Railways are (1) Stockholm to Malmö, (2) Stockholm to Göteborg (Gothenburg), and (3) Stockholm to Uppsala. Not to be ignored, however, is the 1800-km-long major freight artery from Malmö to Narvik that is used for the transport of iron ores and timber.

The maximum speed for passenger trains is generally 130 km/h on double-track lines and 100 km/h along single-track routes. Freight trains are restricted to a 90-km/h top speed.

Welded rail is used extensively on both single- and double-track mainlines, and both concrete and wooden crossties are employed. Mainline rail generally weights 50 kg/m for passenger and freight service. However, 60-kg/m rail serves the ore-carrying lines in the north where 25-tonne axle loads are the maximum permissible.

## Swedish strengths

At this point, the reader might well inquire: Why does Sweden rate an article based on such a relatively small total rail system? Well, first of all, you may be surprised to learn that, despite the country's population (about the same as New York City's), each 14 route kilometers of mainline track serves some 10 000 people. Another surprising statistic is that there are more than 3 million people in the Stockholm–Göteborg mainline corridor. More importantly, the SJ mainlines, commuter rail service, arterial local and long-distance bus lines, and the SL (essentially the Stockholm subway) form a highly coordinated and efficient transportation grid with the city of Stockholm as its hub. Similar transportation grids—minus subway systems—are to be found in the metro areas of Göteborg and Malmö. But perhaps the first and foremost reason for including Sweden in this series is to be found in Swedish traction.

This Scandinavian nation produces some of the finest and most advanced traction equipment, suburban-line multiple units, and subway vehicles. The smoothness of the traction in starting and accelerating to set speed on the SJ equipment is truly impressive. Further, there is no discernible discomfort as the Rc 2 locomotives take the slack out of the passenger coaches on leaving Stockholm's Central Station. And the braking on SJ trains is accomplished equally effortlessly.

As for the multiple-unit (MU) trains, the noise levels are remarkably low. And the subway system is similarly impressive. The performance characteristics and ease of control of the new chopper-controlled cars seem very good. As it is, the older cars in regular service on the SL line are far more comfortable and quieter than even New York's finest.

Another interesting thing in Sweden (and many other European countries) is the fact that there is only one man in a mainline locomotive's cab—the driver. There is no "fireman," as required by union work rules in the U.S., or "third man" aboard.

And the efficiency of the Swedish rail system is testified to by ASEA's foreign sales—it is providing locomotives for the state railways of Romania, Austria, Norway, and Yugoslavia, in addition to the SJ and the Swedish private railway (TGOJ). Also, ASEA has tested locomotives in Norway (see *IEEE Spectrum*, Aug. 1972, pp. 63–64) for possible future use in the mountain division of the Canadian Pacific Railway in the event that company decides to electrify its mainline passenger and freight service between Calgary and Vancouver.

And still another reason for writing about the SJ is that it introduced centralized traffic control (CTC) in large portions of its network (Fig. 1) many years ago, principally on single-track lines and with equipment based upon relay techniques. But as the passenger and freight traffic became very heavy within the Stockholm metro area, stricter specifications and requirements had to be introduced in the development of a new generation of CTC systems in 1971. This development work was carried out by Telefonaktiebolaget L M Ericsson, Stockholm, working in close collaboration with the SJ. The installation, placed in operation in the fall of 1971, controls train movements between some 50 stations within a radius of about 40 kilometers (now being extended to 150 km) from Stockholm's Central Station. It will be described in detail later in this article.

## Thyristor locomotives and MU train sets

Thyristor-controlled locomotives, affording maximum wheel-rail adhesion and tractive force, combined with minimum maintenance, have been running in regular service in Sweden since early in 1965. At present, there are 150 ac thyristor locomotives either in service or on order, and 104 two-coach thyristor train sets (with MU controls at each end) in operation in the Stockholm area. The latter suburban trains have been running daily since late in 1967.

By way of background, ASEA's experiments involving the application of thyristors to traction duty had made so much progress, by the end of 1963, that it was possible to place a thyristor-controlled mainline locomotive in regular operation during 1964. Subsequently, the SJ placed an order for 20 similar locomotives, to be designated as class "Rc 1." They were designed for a maximum speed of 135 km/h and an output of 3600 kW. The experience acquired from the Rc 1 class between 1967 and 1969 led to modifications being made in the subsequent two classes of locomotives, Rc 2 (1969), and Rc 3 (1970). The principal modification was the introduction of harmonic filters and the reduction of the number of converter bridges in series from three to two. However, the only basic difference between these classes of locomotives is the maximum speed of 135 km/h for Rc 2 (Fig. 2), and 160 km/h for Rc 3. Some of the data for the Rc 2 and Rc 3 locomotives are contained in Table I.

**Electric equipment, in general.** The Fig. 3 diagram of the main circuits—from pantograph current collector to traction motors and grounding transformers—is greatly simplified for description and following the current direction flow from catenary to ground. The roof equipment of the Rc 2 and Rc 3 locomotives includes the pantographs (1), the line isolators (2), new air-blast main circuit breaker (3), lightning arrester (4), and roof busing (5). The pantograph has double carbon pans and it is raised to the overhead conductor by a combination compressed-air and tension-spring system. The main circuit breaker is an air-blast type; its interrupter and operating piston are integrally constructed. The opening and closing impulses are imparted by means of an insulated pneumatic link. The combined interrupter and operating mechanism has only one moving part, consisting of the break contact and operating piston on a common rod.

The main transformer is of the shell type, with a fixed ratio between the primary and secondary windings. The total weight of the transformer is only 7125 kg, including the oil coolant.

**Thyristors.** The Fig. 2 diagram indicates that the armatures of each traction motor are fed from two

### I. Principal data for thyristor locomotives, classes Rc 2 and Rc 3

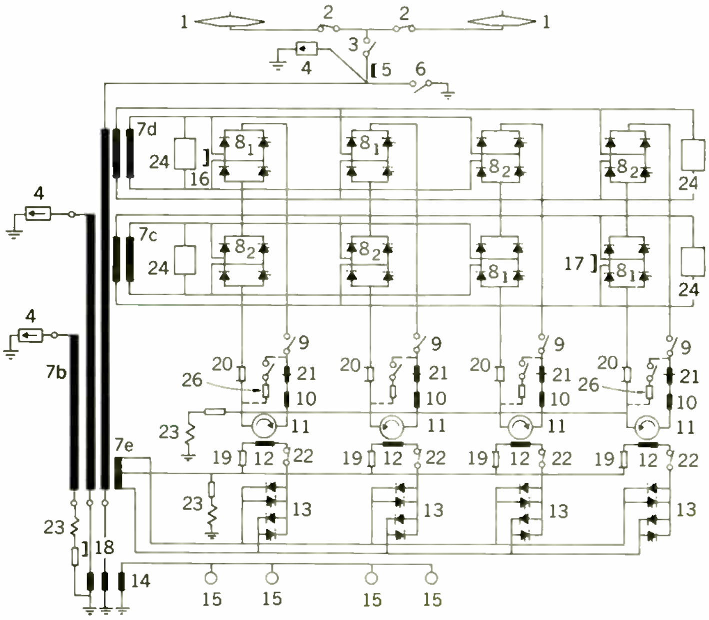
| | Rc 2 | Rc 3 |
|---|---|---|
| First delivered | 1969 | 1970 |
| Maximum speed, km/h | 135 | 160 |
| Line frequency and voltage | $16\frac{2}{3}$ Hz | 15 kV |
| Height (pantograph down), meters | 4.5 | 4.5 |
| Maximum width, meters | 3.15 | 3.15 |
| Length over buffers, meters | 15.52 | 15.52 |
| Weight, excluding dynamic braking, tonnes | 76.0 | 76.0 |
| Weight, including dynamic braking, tonnes | 80.0 | 80.0 |
| Axle load, including dynamic braking, tonnes | 20.0 | 20.0 |
| Number of traction motors | 4 | 4 |
| Gear ratio | 87:26 | 106:37 |
| Continuous transformer rating, kVA | 3910 | 3910 |
| Traction motor control | Thyristors | |
| Transmission | ASEA hollow shaft motor drive | |
| Auxiliary machines | 3-phase motors, 50 Hz | |
| Brakes | Disk, on all wheels | |

**[2] "Showcase" unit of the SJ—the ASEA-built class Rc 2 thyristor-controlled locomotive is used for mainline passenger express service, primarily in Sweden. Similar (diode) versions of this locomotive have been exported to Yugoslavia, Romania, and Norway for mixed traffic (freight and passenger) service. Thyristor locomotives, similar to the Rc 2, were sold to Austria.**

**[3] Simplified line diagram of the traction circuits for the Rc 2 and Rc 3 locomotives.**

Legend:

| | |
|---|---|
| 1 | Pantograph |
| 2 | Isolator |
| 3 | Main circuit breaker |
| 4 | Lightning arrester |
| 5 | Roof bushing, with current transformer |
| 6 | Grounding switch |
| 7 | Main transformer |
| 7a | Winding for train heating, 1000 V |
| 7b | Winding of auxiliary machinery converter, 220 V |
| 7c, 7d | Winding for thyristor bridges |
| 7e | Winding for field supply |
| $8_1$ | Nonuniform thyristor bridge 1 |
| $8_2$ | Nonuniform thyristor bridge 2 |
| 9 | Traction motor isolator |
| 10 | Smoothing reactor |
| 11 | Traction motor, armature |
| 12 | Traction motor, field winding |
| 13 | Thyristor converter for field supply |
| 14 | Grounding transformer |
| 15 | Grounding brush |
| 16–18 | Current transformers |
| 19–20 | Shunts |
| 21 | Measuring transducer |
| 22 | Isolator |
| 23 | Grounding current resistor and relay |
| 24 | Capacitor for telefilter and power factor correction |
| 25 | Braking contactor |
| 26 | Braking resistor |



nonuniform converter bridges in series, and the thyristor branch in the bridges has four thyristors in parallel. Further, the diode branch contains five diodes in parallel. Thus, altogether, there are 16 thyristors and 20 diodes in each traction motor converter for armature current. Each traction motor field has its own converter bridge which has one thyristor in each branch (four thyristors per motor field). The thyristors and diodes are oil cooled.

The two bridges of the armature converters are controlled in sequence. In the initial period of start-up, when power is applied to the locomotive, the traction motor voltage is continuously increased from zero to half the maximum traction voltage by means of controlling the firing angle of the thyristors in the first bridge. During this period (Fig. 4A), the armature current also passes through the diodes in the second bridge. In the next period—the increase to maximum traction motor voltage—the second bridge is controlled in the same manner (Fig. 4B) in the advance to full voltage. But, simultaneously, the first bridge remains fully phase advanced (that is to say, the thyristors act as diodes), and the motor voltage thereby attains its full value. During the latter control period, the current in the traction motor field is at its full value in order to achieve the highest power factor. Following that, the field weakening to the desired speed occurs, with the armature converter acting as a diode rectifier.

The converter, itself, is installed on-board, adjacent to the main transformer. The oil-cooled thyristors, diodes, and associated auxiliary components, such as fuses and reactors, are grouped together in draw-out trays. The thyristors are clamped to a common bar that contains an internal oil channel; and the diodes are arranged in a similar manner.

The qualities afforded by the thyristor converter are principally (1) maximum smoothness in tractive effort and (2) optimum adhesion on the poor rail contact conditions that are experienced in mountainous terrain, especially in snow and icing situations. During tractive-effort tests conducted in Norway in 1971, the results achieved by an Rc were very well received by representatives of Canadian Pacific Rail.

The CPR people stated that the thyristor locomotive was capable of hauling a train 50 percent heavier than their standard diesel-electric locomotives presently in use in the mountain division between Calgary and Vancouver.

**Traction.** The Rc traction motor was developed from the type installed in the mixed-traffic silicon-rectifier locomotive that was first delivered to the SJ in 1962. In the new motor, the commutating flux is separated from the main flux in a special laminated circuit. This design produces a minimum of damping of the commutating flux, while a certain desirable damping of the main flux is obtained. Each Rc class locomotive is fitted with four traction motors (with an individual continuously rated output of 900 kW), one on each axle.

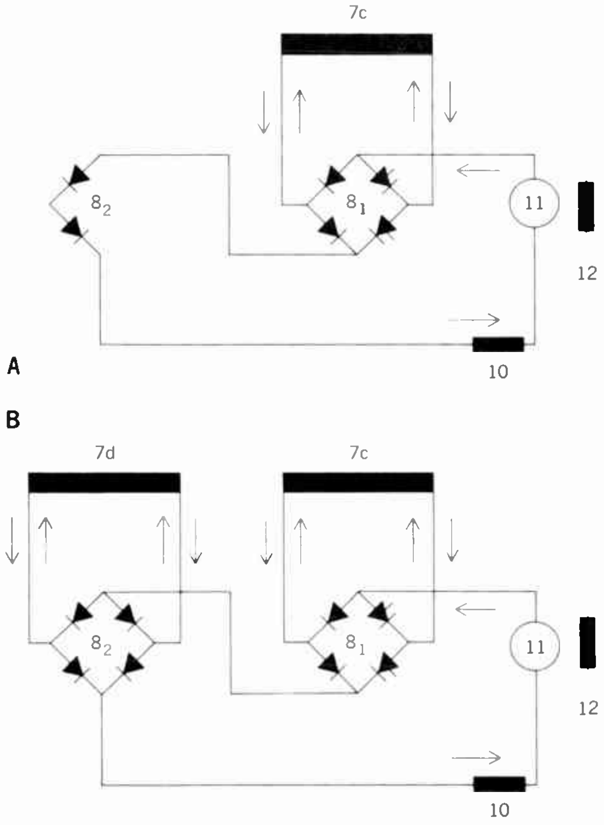
The armature thyristor converters (8) in Fig. 2, are controlled as a joint unit for all armatures while the field converters (13), in the same illustration, are individually controlled. The load sharing* between the traction motors is accomplished by means of the motor fields, which are automatically controlled (Fig. 5) so that the armature currents will be equally large.

Separate excitation of the traction motor offers the best possibilities for slip control, even in the initial slip stage, since such a motor cannot overspeed when the motor field is maintained unchanged. The load sharing, therefore, has been made sufficiently slow so that it does not have time to intervene for sudden slipping in the wheels. If this should occur, the intervention of the load sharing is limited to prevent overspeed.

The locomotive is maneuvered with two rheostats in the driver's cab, one for the speed control (the dial at the lower right shown in the title illustration, p. 53), and one for the current limit that represents the "maximum tractive effort control" (the tractive effort control lever is shown on the driver's desk in the title illustration below the center of the instrument console).

The Fig. 5 block diagram shows how the speed $n$, the motor current $I_A$, the motor voltage $U_M$, and the field current $I_F$ are controlled. After these values have been set, the locomotive—and the train—is accelerated with the maximum motor field (base field) and with the set current until the set, or preselected, speed is reached. If this lies within the range for maximum motor field, which is below the base speed of the motor, phase retardation occurs down to the armature current level at which the tractive effort of the locomotive balances the total train resistance. If the train resistance increases, the speed decreases. This consequently gives a signal to the speed regulator to increase the motor current until the preselected speed is reached once more. These conditions are shown by the unbroken lines in Fig. 5.

**Dynamic braking and control.** Rc-class locomotives can be equipped with dynamic-resistor braking,

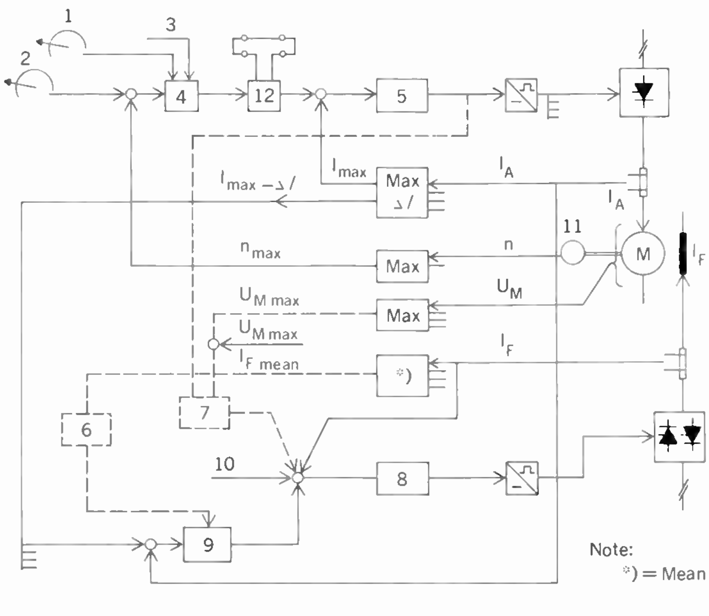


[4] A—Diagram of first thyristor bridge during the increase to one half of the maximum traction motor voltage. (Note: for callout identification, refer to Fig. 3.) B—Second thyristor bridge during the increase to maximum motor voltage.

[5] Block diagram of the Rc 2 and Rc 3 locomotive circuits.

Note:

| | | | |
|---|---|---|---|
| 1 | Current limit | 7 | Field-weakening control |
| 2 | Speed | 8 | Field control |
| 3 | Line voltage | 9 | Load-sharing control |
| 4 | Speed control | 10 | Basic field control |
| 5 | Armature current control | 11 | Speed transmitter |
| 6 | Slip limitation | 12 | Transmission link |



Note:
*) = Mean

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* Sharing of the load between the four traction motors, for correction of differences in wheel diameters and excitation curves, is accomplished through the control in the individual field circuits (dashed lines in Fig. 5). The highest motor current, $I_{max}$, is selected as a reference for the other motors. If any motor picks up a current $I_A$ which is so small that $(I_{max} - \Delta I - I_A)$ will be more than zero, it receives, via the load control, a correction signal for the reduction of the field current. The EMF of the motor concerned is then reduced so that the current can rise.

which has a continuous rating of 4 × 600 kW (for the traction motors on four axles) and a peak rating of 4 × 1000 kW for a period of 20 seconds. As indicated by the dotted lines in Fig. 3, each motor is retarded across its own braking resistor.

The braking resistors are divided mechanically into two units that are arranged in the machinery compartment adjacent to the modular units for the second and third traction motors, if dynamic braking is specified. Further, in such a modified configuration, the battery is moved to the underframe, and the battery charger is placed adjacent to the rotary converter.

The cooling air is introduced at the bottom of the locomotive's body and is drawn up by a fan through the resistor and exhausted through openings in the roof.

When the dynamic brake-control option is installed, there is no separate brake controller; instead, the driving controller (title illustration) is modified to include the brake controller as well. From the "zero position," the tractive effort is steplessly controlled by pushing the control lever forward; however, the braking effort is controlled by *pulling* the control lever from the zero position. When braking dynamically, the lever first passes a well-defined notch B1, at which point all circuits are connected for braking (without any braking effort necessarily being applied). This can be especially advantageous on long downgrades where, occasionally, no braking effort is needed. But, since the braking connection is retained as a backup safety measure, the locomotive can be dynamically braked repeatedly whenever necessary.

At the peak rating, the dynamic braking effort represents 15-percent adhesion and corresponds to a maximum current of 1250 amperes. But whenever the braking current exceeds 970 amperes, visual and audible alarms remind the driver that this condition must not exceed 20 seconds' duration. Simultaneous operation of the dynamic and pneumatic brakes of the locomotive is not possible, but the following combinations of locomotive/train braking can be achieved:

1. Dynamic braking only
2. Dynamic braking of the locomotive and pneumatic braking of the train
3. Pneumatic braking only of both the locomotive and the train

In addition, the locomotive may be braked pneumatically by means of the locomotive brake, whether or not other brakes are applied.

Thyristor control has, of course, affected both the configuration and type of controls in the driver's cab as well as the operation of the motor. The conventional controller handle is replaced by two devices:

- A small handwheel for speed setting
- A lever for setting tractive effort (or the tractive and braking effort) as indicated in the title illustration

Only two electrical analog instruments are used for the traction circuit: a voltmeter for the line voltage, and an ammeter for the traction motor current (which is also used for the braking current when dynamic braking is an installed feature).

**Body and bogie (truck) construction.** The body and underframe is an all-welded self-supporting steel structure. To facilitate repair work, the longitudinal beams in the underframe are designed as open channels. The body is designed to withstand a simultaneous compressive shock of 100 tonnes on each buffer. No special base plates or pedestals are needed for the electric equipment because the modules are bolted

[6] Train of two-coach Class X1 sets is shown in the station at Marsta, a suburb of Stockholm.

directly to a flush-plate floor. The modules are installed and removed, with minimum effort and facility, through three large openings in the locomotive's roof.

Since Sweden is a relatively flat country topographically, dynamic braking has not been incorporated on Rc locomotives in domestic use. However, to reduce the costs of mechanical brake maintenance, disk brakes have been adopted. From all available evidence, disk brakes require less maintenance and servicing than the conventional "shoe" or "block" brakes. In special instances, however, the disk brakes can be supplemented by an auxiliary tread brake.

## Thyristor-controlled train sets

Around 1965, the SJ, after tests conducted with trial three-coach MU train sets, ordered a total of 102 modified two-coach sets (to meet the specifications shown in the box below) for suburban shuttle service in the Stockholm metro region. The delivery of the first sets, designated as Class X1, began in the autumn of 1967; the order was completed in February 1971. Figure 6 is a shot of a train of such sets in the station at Märsta.

Actually, the controls, thyristor converters, transformers, traction motors, and disk braking of the X1 sets are quite similar to those of the Rc 1 locomotives. In all of the two-coach sets, one car is the motor coach and the other is the driving trailer (since both cars contain a driver's cab). The thyristor converter used is common to all four traction motors in the motor coach. To achieve the highest possible power factor, the armature current converter is divided into three bridges, each fed from an individual transformer winding. In this design, regenerative braking (no major grades along rights of way) was not deemed necessary. Thus, the bridges contain diodes in two branches; the other two branches consist of thyristors.

The thyristor-control equipment and the separately excited traction motors permit the adhesion to be effectively utilized while minimizing the risk of slip. Therefore, starting is smooth even though the average rate of acceleration (0.6 m/s$^2$) is high. Disk braking is applied at all axles to produce smooth and even deceleration. The brakes, however, cannot lock because installed monitors generate an automatic signal that decreases the braking effort on any axle indicating a too rapid decrease in rotation.

**Maintenance and repairs.** Traction equipment on the SJ is checked regularly and on a scheduled basis. For example, the Rc-class locomotives are subjected to a daily inspection of pantographs and high-voltage equipment. A weekly check inspection includes the just-mentioned gear, plus the brake disks. There are

### Stockholm's suburban services

Back in 1964, all bus, train, and subway services were integrated into one organization called "AB Storstockholms Lokaltrafik," or "SL." [This arrangement is roughly equivalent to the Metropolitan Transportation Authority (MTA) and its operation of suburban trains over the Penn Central and Long Island Railroad tracks in the New York City metropolitan region.]

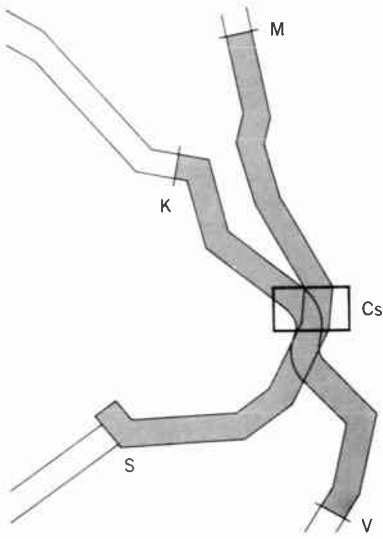
Prior to this transit coordination scheme, the Swedish State Railways (SJ) had planned a changeover from locomotive-hauled trains to suburban multiple-unit (MU) coaches. It was decided at that time that the train sets would be operated in shuttle service by SJ on a contract basis for the new organization following the merger. At the same time, the SJ ordered three triple-coach train sets on a trial basis. The trains had a maximum speed of 100 km/h and an output rating of 1140 kW. The tests conducted on these train sets indicated that their acceleration characteristics and maximum speed were insufficient and that improved performance was required.

The accompanying sketch shows that portion of the SJ's track system in the Stockholm metro area over which suburban shuttle service operates. The major portion of this service runs over the same track utilized by long-distance express trains running to and from Stockholm. Therefore, the time schedules of the local suburban traffic had to be modified and adapted so that the mixed service could run without interruption. For example, the total scheduled time, including all stops, en route from Marsta to Sodertalje, and return, was set at three hours.

The train sets required for the suburban services operating under such constraints had to meet the following requirements:

- Maximum speed, 120 km/h
- Average acceleration on level, tangent track, 0.6 m/s$^2$ to 100 km/h
- Average deceleration on same track, 0.9 m/s$^2$

Cst—The Central Station in Stockholm
K—Kungsängen
M—Märsta
S—Södertälje
V—Västerhaninge



**Shuttle services across Stockholm.**

- Passenger-carrying capacity of about 300 per two-coach set
- Maximum number of coaches, 10 (5 two-coach sets) per train
- Maximum number of passengers per train, 1500

The suburban service operates on a minimum headway of 15 minutes during peak hours, but only along a portion of the lines in and out of Stockholm. The normal headway is 30 minutes on all lines.

three maintenance inspections in depot workshops:

1. After 15 000–17 000 km of road service
2. 45 000–50 000 km
3. 135 000–150 000 km

The first major overhaul, including traction motors and brushes, takes place in SJ workshops after 400 000 km of mainline road service. Subsequent major overhauls and repairs are made at 800 000 and 1.2 million km and, thereafter at 400 000-km intervals to (hopefully) 2.4 million km.* Thus far, however, no Rc locomotive has covered that much ground. The life expectancy of the locomotive itself is more than 30 years.

## Frequency converters for traction duty

About 50 years ago, the first frequency converters were delivered to the SJ for the power supply of railways. This was the result of a Swedish government decision which implied that, during the continued electrification of the SJ, electric power would be taken from the three-phase national power network. Thus, the traction substations were designed as converter stations in which electric energy was converted from 6 kV, three phase, 50 Hz, to 16 kV, single phase, $16\frac{2}{3}$ Hz.

The majority of the converter sets are the rotary type; that is, motor-generators in which both motor and generator are synchronous machines. The motor is normally designed for a low power factor (0.7) to make reactive power supply possible to the three-phase network.

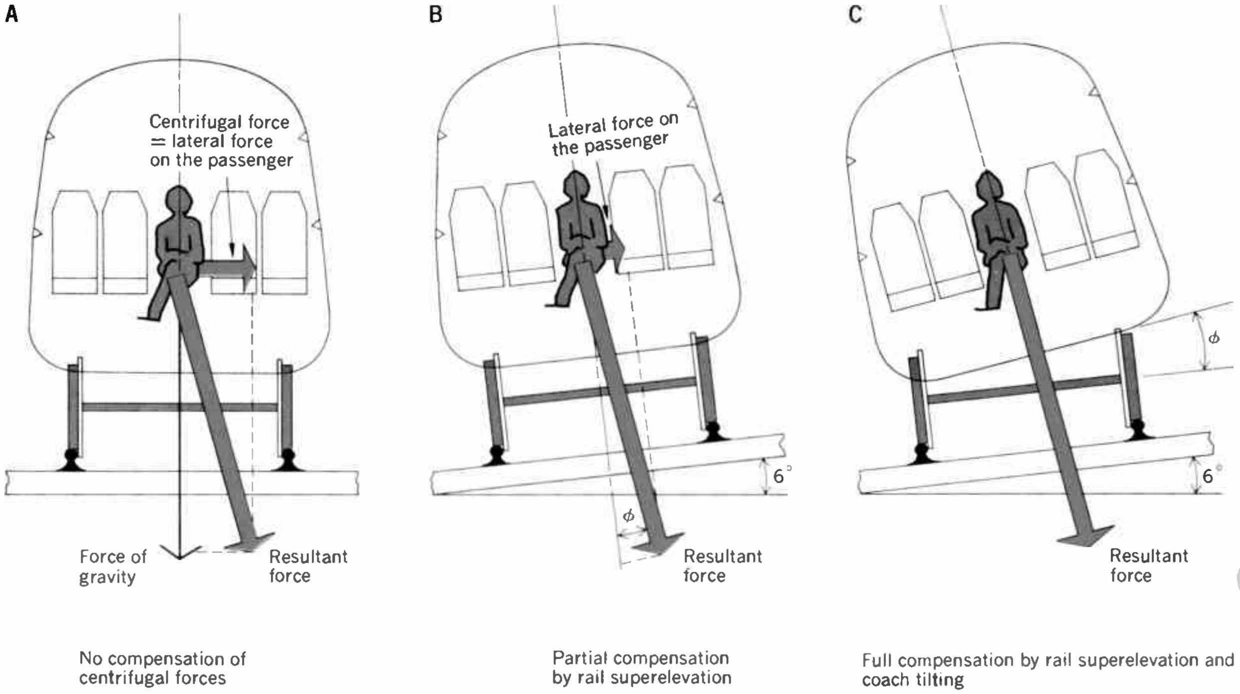
Near the end of the 1960s, power electronics had become so advanced that it was possible to design a technically and economically feasible converter for traction duty (by incorporating modern thyristor technology). In 1969, the SJ ordered a prototype converter, having an output of 6 MVA, which was sufficient for supplying existing locomotives. Tests conducted by the SJ in cooperation with the Swedish State Power Board and the National Telecommunications Administration, over a two-year period, confirmed the higher efficiency, reduction in substation losses, and very short starting time advantage (vis-à-vis the rotary converter) of the static converter design. Static converters, capable of supplying continuous single-phase power of 15 MVA, will be delivered to the SJ this year.

## High speeds for SJ passenger traffic

During discussions with top officials of the SJ in Stockholm, it was admitted that passenger traffic in Sweden has decreased over the past decade. Although the principal competition has come from domestic air travel, the increase in private motor vehicle ownership has also cut into rail travel revenues. But six years ago, SJ officials sensed the need—even in a nation of only 8 million people—for higher speed interurban train service to attract more interest in rail transportation.

Despite the low population figure, 40 percent of the total (more than 3 million) reside in the 450-km-long Stockholm–Göteborg corridor. Delegations from the SJ visited Great Britain, Austria, the U.S., and Japan to acquire a first-hand knowledge of the advanced concepts being employed abroad. The SJ people soon realized, for example, that it would not be economically feasible—or necessary—to build a special new right-of-way similar to Japan's Tokaido line

[7] **Forces acting on a railway coach when traveling through a curve. A—Lateral force is greatest, and there is maximum passenger discomfort due to centrifugal force if there is no superelevation of the rails. B—Partial compensation for the effects of centrifugal force are accomplished by superelevating the rails by 6 degrees (maximum). C—Full banking compensation and maximum passenger comfort is ensured by both superelevation of the rails and tilting the coach body by an additional angle $\phi$.**



No compensation of centrifugal forces

Partial compensation by rail superelevation

Full compensation by rail superelevation and coach tilting

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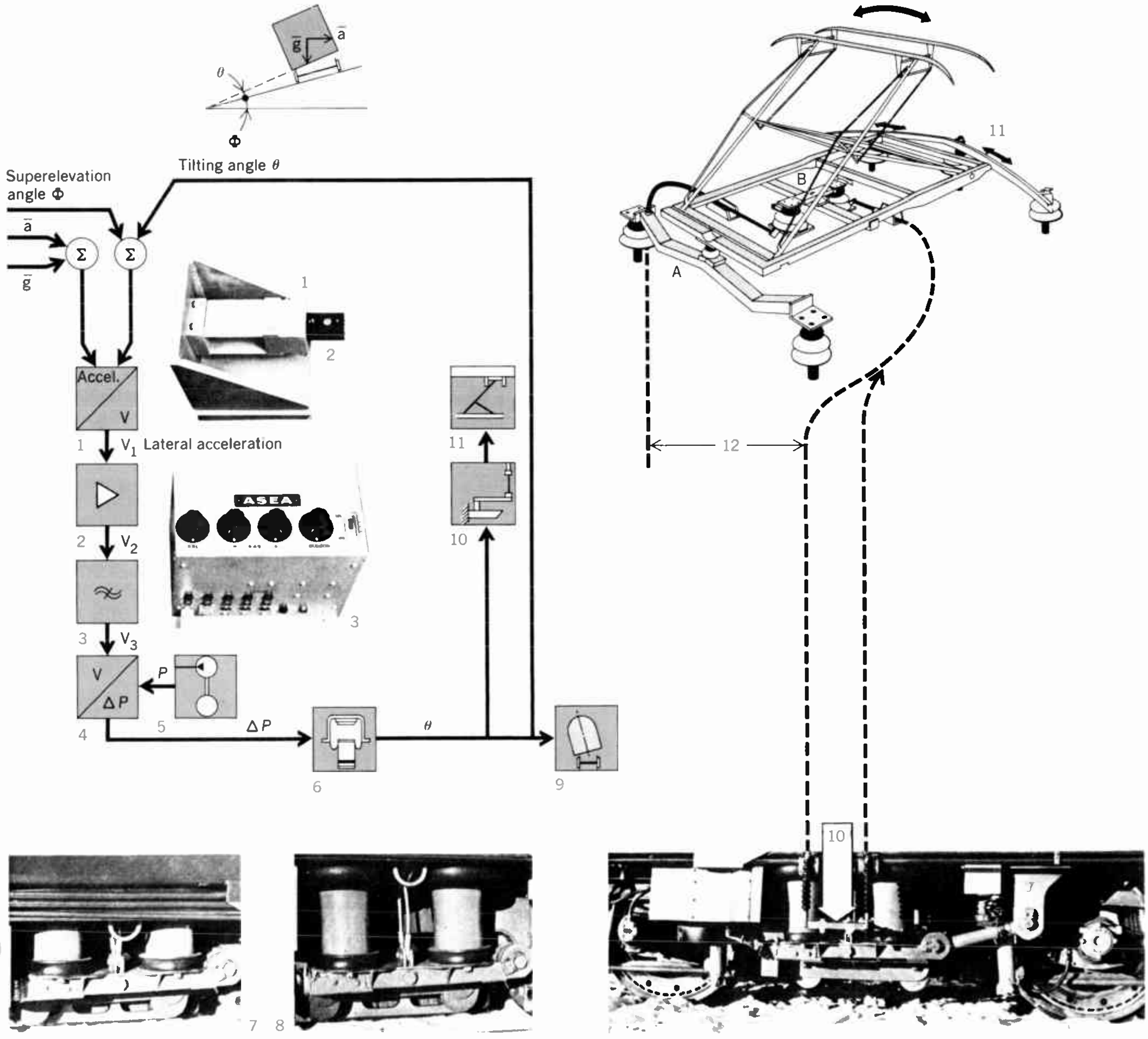
* Normally, the first commutator overhaul is made after 1.2 million km. But at present some motors are running without any overhaul at 1.2 million km and SJ hopes that there will be no need for this servicing before 2.4 million km.

(Tokyo to Osaka), along which 60 trains, in each direction, carry 250 000 passengers daily at speeds up to 210 km/h. Therefore, the Swedish railway people decided that it would be far more practical to design high-speeed vehicles to accommodate existing rights of way than to rebuild existing mainlines to suit high-speed vehicles. To achieve this objective, four good dynamic properties are required of the vehicles:

- Low axle loadings
- Low center of gravity

**[8] Tests were conducted in 1970 on Class X1 coach sets equipped with special tilting and instrumentation gear. The components shown in the diagrams and photos included: ACCELEROMETER—the pendulum or accelerometer (1) consisted of a damped mass forming part of a servo circuit. The mass was deflected by the lateral acceleration and was returned by a solenoid. The current through the solenoid was a measure of the acceleration. An amplifier (2) was included for more precise measurement. FILTER—the response and sensitivity were adjusted with the filter (3) and set to the most suitable values for the track. ELECTROPNEUMATIC UNIT (4)—the solenoid current actuated, via electronic circuits and power amplifiers, a number of valves in unit 4 for the distribution of air from a compressor (5) to the air-actuated springs (6) of the bogie. AIR SUSPENSION— the air springs (6), (7), (8) were the rolling diaphragm type. The spring system gave the car body a 1-Hz natural frequency. TILTING—this was accomplished by compressed air fed into the air springs (8) on one side, while the air on the opposite side of the bogie (7) was exhausted. The car body returned to its normal position when the amount of air on each side of the coach had been equalized. PANTOGRAPH—the pantograph (11) had to maintain its normal position, with respect to the overhead conductor, irrespective of the tilting angle; thus, the transmission elements (12)—one on each side—were resiliently secured to the bogie frame (10) and transmitted the difference in height between the bogie and the coach body to an arm pivoted at (B) in the pantograph frame. (The latter was also pivoted to the substructure at A.) When the coach was running along tangent (straight) track, the vertical springing produced only a rotating movement around B; but, if the coach body was tilting, the difference between the body and the bogie was unequal with respect to the sides of the coach.**

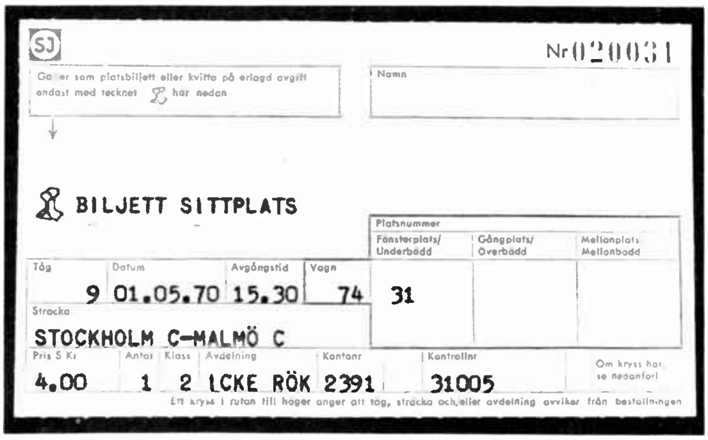


- A means for tilting, or canting, the coach's body into curves
- Low unsprung mass on axles (this implies that the axles be relieved of as much weight as possible from traction motors, brakes, etc., and be, themselves, as light as possible)

Figure 7 shows the forces acting on coaches when traveling through curves under three discrete design conditions affecting both track and vehicle. As may be seen in Figs. 6B and 7C, railway curves are "superelevated" (banked) to compensate for centrifugal forces that occur at normal train speeds. At higher speeds, the track superelevation does not suffice; thus, the passenger is aware of an unpleasant lateral force. Banking of the coach body while the train is running through a curve (Fig. 7C) reduces the discomfort experienced by passengers.

[9] Computer terminal at Stockholm's Central Station ticket booking office is part of extensive automated ticket issuance and accommodation network employed by the SJ. When a passenger requests a specific day, train, and compartment, the booking clerk keyboards the order. In 15 seconds' time, the ticket, or seat reservation, is printed out.

[10] Typical seat reservation ticket printout. In this case, the car number is 74, and the seat number is 31, in a 2nd class carriage from Stockholm Central Station to Malmö.



SJ

Nr 020031

Gäller som platsbiljett eller kvitto på erlagd avgift endast med tecknet har nedan

Namn

BILJETT SITTPLATS

| Tåg | Datum | Avgångstid | Vagn | Platsnummer Fönsterplats/ Underbädd | Gångplats/ Överbädd | Mellanplats Mellanbädd |
|---|---|---|---|---|---|---|
| 9 | 01.05.70 | 15.30 | 74 | 31 | | |

Sträcka: STOCKHOLM C–MALMÖ C

| Pris S Kr | Antal | Klass | Avdelning | Kontonr | Kontrollnr | Om kryss har se nedanfor |
|---|---|---|---|---|---|---|
| 4.00 | 1 | 2 | ICKE RÖK | 2391 | 31005 | |

Ett kryss i rutan till höger anger att tåg, sträcka och/eller avdelning avviker från beställningen

Full compensation of the centrifugal force by means of superelevation of the track is not possible. Trains have different speeds and also must be able to negotiate a curve at reduced speeds without excessive lateral force in the opposite direction. Also, freight trains operating at low speeds would cause excessive wear on the track if the superelevation is too high. Instead, the lateral acceleration is overcome by artificially canting the coach inward.*

One of the MU trains (Class X1) in commuter service in the Stockholm area underwent tests in 1970. The train was equipped with air suspension and special banking equipment (see Fig. 8). In these tests, a maximum tilting angle ($\phi$) of 5° was used. This permitted the train to be run at speeds 30 to 35 percent higher than normal. During a test run on the Stockholm–Göteborg mainline, the train attained a speed of 222 km/h.

The canting is controlled by an accelerometer, which senses the lateral acceleration, and the tilting angle of the coach's body is automatically controlled by a servo system that adjusts the air pressure in the springs of the air-suspension system. Also, a new type of pantograph was employed. The experiments indicated that train speeds can be substantially increased along lines containing numerous curves. If the tilting angle is increased to about 9° (which is quite feasible with trains of advanced design), the speed through curves can be increased from 45 to 50 percent above normal. Table II lists the travel time and distances between cities along the SJ mainline; the travel time is based on a maximum speed of 220 km/h, and represents a 40- to 50-percent time saving compared with present schedules.

## Details of the CTC office, Stockholm

In the early 1960s, all local traffic within the Stockholm area began to be coordinated an operated by the AB Storstockholms Lokaltrafik (SL), a company formed by the Stockholm County Council. At present, the SL area extends to Stockholm's suburbs. The inner suburban ring is already controlled from a large interlocking machine situated in the CTC office at Stockholm Central Station. When the CTC system is installed to accommodate its full capacity, it will remote control trains within a 22 000-km² area. The tracks, under CTC control in this region, carry a mixed traffic of suburban trains, freight, and long-distance passenger trains. Today, the remote-controlled area comprises 130 route kilometers; it will ultimately extend to about 500 route kilometers. Right now, there are 56 remote-controlled field stations, but, eventually, there will be 100, including "double crossovers." This feature permits express

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* It is generally accepted in railroad practice that lateral acceleration (centrifugal force) should not exceed 0.5 m/s². Canting only affects the running characteristics of the coach marginally in other respects.

trains to pass slower trains between two stations on double-track lines. Thus, the Stockholm CTC office will be able to control a large number of train movements within this extensive area.

From the CTC office, it is possible to meld the long-distance trains, on their way to and from Stockholm, into the intervals in the timetable permitted by the local traffic. This coordination is, of course, arranged at the time the schedules are prepared. Allowance must be made, however, for adjustments so that unforeseen events will not disrupt the heavily trafficked timetables.

To simplify the work of CTC operators, the Central Station office is equipped with a train-describer system and a stored-program-control train-routing system. Each CTC operator is responsible for one half of the control area, with the Central Station forming the natural boundary line between the northern and southern regions.

In the CTC office there is a semicircular track display diagram, almost 20 meters long, showing the remote-controlled field stations and the lines between them. The information required by the CTC operator for monitoring and control of train movements is displayed by lights on the track diagram. Each lamp represents a unit—for example, a point, a signal, or a section of track.

When a CTC operator is informed by the track display light that a control signal must be transmitted, he does this by keying a series of digits on a keyboard console. If the control relates, for instance, to the establishment of a route, the operator first keys the two-digit code number of the field station he wishes to contact. When the number of the field station has been entered, a light begins to flash on and off alongside the name of the field station on the track diagram. He then keys the two-digit numbers for signals at the beginning and the end of the route. The lamps, representing the two units, start to flash. When the operator has verified the keying of the correct digital code, the control signal is transmitted to the field station by pressing an "execute" button. When the signal is received at the field station, the points on the route between the two selected signals are automatically operated to correct positions, the route is locked and the signal aspect at the entrance to the route is cleared. Following this action, track indications are transmitted to the CTC office. Thereupon, a fixed green light is displayed as the analog wayside signal at the start of the route, and white lights are shown in the proper point-position lamps as the train approaches the route-end signal. All control signals received via the CTC are checked with respect to safety by the local interlocking before they are executed.

The digits remain displayed on the keyboard digital display after the control signal has been transmitted; they are not "erased" until a new control code is keyed. All numbering is logically arranged on the analog principle: the station numbers run in consecutive order, starting from Central Station.

### Electronic reservation system

Since April 1, 1970, an electronic reservation system called SNAP has been in operation on the SJ. It is a real-time system that permits passengers to make seat, sleeping accommodation, and "couchette" reservations on all trains in domestic service, on trains running from Sweden to foreign countries, and to Sweden from Norway and Denmark. About 5 million reservations are handled annually; the maximum capacity of the automated system is 6000 per hour.

From a central processor located in Tomteboda (3 km northwest of Stockholm's Central Station), a far-flung transmission network, utilizing the communication lines of the SJ as well as the lines of the Swedish Telephone and Telegraph Company, extends throughout the country (the latter lines serve travel agencies that are situated outside SJ premises). The major booking offices and agencies are equipped with computer terminals (Fig. 9). More than 200 terminals at 154 reservation offices in Sweden, Norway, and Denmark are connected to the network.

The terminals have been built to SJ specifications by the Siemens Company in Germany. At the computer center, the communication lines are connected to a modified IBM 360/40 communication computer (called the IBM 3968). This computer, in turn, is interfaced with an IBM 360/50 main computer, with a core storage of 384K bytes. All of the reservation system's files are stored in an IBM 2314 disk storage. To reduce the downtime of the system, there is a backup system of identical computers.

The standby communication computer is used off line for testing programs for various railway applications; and the main backup computer is employed off line in applications such as payroll preparation, inventory control, and accounting.

Figure 10 shows a typical seat reservation printout that is given to a passenger traveling from Stockholm to Malmö. This operation is usually completed in a matter of seconds after the passenger gives the operator his oral request. The system is now being extended to handle also the printout accounting of tickets.

### Metropolitan subway/rural service

The SL is a unique, complex, and comprehensive transit mix of subway (Tunnelbana), bus (Buss), con-

### II. Projected schedules for high-speed SJ mainline trains

| Line | Distance, km | Travel, h | Time,* min |
|---|---|---|---|
| Stockholm–Goteborg | 456 | 2 | 26 |
| Stockholm–Eskilstuna | 116 | | 51 |
| Stockholm–Vasterås | 111 | | 44 |
| Stockholm–Sodertalje | 35 | | 15 |
| Stockholm–Norrkoping | 182 | 1 | 00 |
| Stockholm–Linkoping | 210 | 1 | 17 |
| Stockholm–Malmo | 599 | 3 | 22 |
| Goteborg–Malmo | 303 | 1 | 50 |
| Stockholm–Uppsala | 66 | | 22 |
| Stockholm–Gavle | 180 | 1 | 00 |
| Stockholm–Sundsvall | 413 | 2 | 31 |
| Stockholm–Ostersund | 550 | 3 | 15 |
| Stockholm–Umeå | 655 | 5 | 41 |
| Stockholm–Luleå | 1130 | 7 | 31 |
| Sundsvall–Ostersund | 196 | 1 | 18 |

* For express trains operating at a maximum speed of 200 km/h, plus a 4-percent travel-time reserve for intermediate stops

[11] Train of type C7 "chopper"-controlled dc subway cars in service operation on the SL Tunnelbana.

necting boat or ferry transport (Batlinje)—linking the many islands in the Stockholm metro area—and SJ suburban commuter lines.

The Tunnelbana, which began its initial service in 1949, now comprises some 75 route kilometers (along five main and three branch lines), with 74 stations stops that are situated from a few hundred meters to two kilometers apart. The system is being expanded in successive stages over an additional 35 route kilometers. New lines are 100 percent underground; old lines are only 33 percent underground.

During peak hours, Tunnelbana trains run on about 5-minute average headways, and about 2-minute headways in the central part of the system. Typical travel times along principal route lines are

- Vällingby–Bagarmossen—22.9 km, about 44 minutes
- Ropsten–Fittja—23.4 km, about 39 minutes
- Hässelby Strand–Farsta Strand—29.0 km, about 55 minutes

**SL rolling stock.** At the present time, the Tunnelbana has more than 700 MU cars in revenue service; by 1976, this figure will increase to more than 900. The vehicles are of several vintages, with varying performance, weight, braking, suspension, and traction motor characteristics and specifications.

The majority of the subway cars in operation (designated as types C1 through C5) were built between 1949 and 1967. The vehicles in these classifications are equipped with standard dc traction motors with resistance steps.

The later vehicles (type C6 through C9) are equipped with dc chopper-control motors similar to those used in the BART cars. Figure 11 shows a train of C7 cars in service in Stockholm.

**The rural train network.** Back in the 1950s, the SJ began ordering MU rolling stock for a comprehensive network of trains for handling light passenger traffic between small towns in Sweden. These train sets also serve on "feeder" lines to larger towns and cities, and they may often be seen on sidings alongside mainline stations where passenger connections are made to and from long-distance express trains. Also in that decade, similar motor-coach sets were used for intercity service between Stockholm and Göteborg, and Stockholm and Malmö. (The writer can well remember riding one of these trains, in 1955, nonstop from Göteborg to Stockholm in what seemed to be record time!)

The author wishes to thank the engineers and technicians of ASEA Inc., the SJ and SL for their courtesy, hospitality and technical assistance during his visit to Sweden last September.

This is the kickoff piece of a five-part series on European mainline railways, suburban commuter lines, and urban mass transit in the five countries (Sweden, West Germany, Switzerland, France, and Great Britain) visited by the author for first-hand coverage—an *IEEE Spectrum* "on-the-spot" exclusive.

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# Why Japan succeeds

## A unique capital investment technique, a dedicated labor force, and a knack for backing the right "technological horse" make Japan "go"

Twice this century Japan has emerged on the global scene as a major power. The first time, after its exclusion from world markets and access to raw materials, it sought its place in the world through military prowess, only to find itself engaged in a suicidal war with the United States and the whole of Asia. Incendiaries and then two atomic bombs reduced the grandiose Empire it had built to the pile of ashes that was Tokyo, Osaka, Hiroshima, and Nagasaki in August 1945. At Potsdam, the victors decided that Japan should rise again only as a peaceful democracy without arms and without an armaments industry.

Today Japan is not only the first industrial power to achieve an advanced stage of economic development without the continuing impetus of military expenditures, but it has one of the fastest growing economies in the world and has become the third largest industrial power after the U.S. and the U.S.S.R.

Like other industrialized countries, however, the Japanese now find themselves faced with an entirely new set of problems. Just as the Japanese people are getting their first taste of affluence, all that they have been working so hard to build suddenly seems threatened by gaping shortages of raw materials and energy. Urban congestion, transportation snarls, pollution, and inadequate housing have been aggravated by the pace of economic activity and rising per capita incomes. Full employment, the ultimate goal of the welfare state, has been escalated to become overemployment, with attendant steep rises in wages fueling the forward thrust of inflation.

In the process, the dual economic structures, which combined the forces of large and small industries in a unique synergistic matrix, have been strained. Mounting production costs and operating overhead have wiped out the comparative advantages of many small- and medium-sized labor-intensive Japanese factories—the kind that have provided the characteristic sharp competitive power in domestic and world markets. And as Japan's large-scale enterprises respond to rising costs by shifting production abroad, many small, dependent subcontractors, who have neither the financial nor the management resources to follow, are faced with critical problems of survival.

To complicate matters, many of the products that set the pace of Japanese growth in recent years have passed the peak of their respective life cycles. At the same time, sources of new technology seem to be drying up, as the know-how gap with the United States and Western Europe closes. Whether Japanese industry can continue the pace of innovation without the massive injections of outside technology has become a serious question—one that hangs, like the sword of Damocles, over the frontal lobe of the Japanese economy.

Add to this the explosive international dimension of raw materials and energy shortages, the rising tide of protectionism against Japanese competition in advanced industrial countries, Japan's new found need to invest abroad, the disruptive influences of world monetary chaos, and the nagging problems of security in Asia and it seems the Japanese, themselves, are dangling. . .over a viper's nest.

In the past, the postwar world constellation of power was such that Japan could pursue its interests best through a passive posture in international relations. But this is clearly no longer possible. To resolve the problems of Japan's new "international" era will require statesmanship and diplomatic skills of an order that in Japan's case has yet to be tried and tested.

This litany of Japanese economic woes may be music to the ears of embattled corporations and economic policy makers in "stagflation"-wracked Western countries—although, historically, competition from Japanese products has provided many Westerners with a convenient explanation for the difficulties of more than one industry—but such jubilation is likely to be shortlived. Problems of these dimensions are not new to the Japanese economy. An equally impressive list of "obstacles of growth" could be compiled (and often was) for almost any period in the last 100 years of Japan's history. Just before World War I, for example, in the face of tremendous problems of modernization, Japanese manufacturing was growing at two to three times the average rate in Western countries. It continued to grow, despite compelling logic that it could not, and has become a phenomenon that is still with us in a much more developed form.

This strongly suggests that in Japan we are confronted with an industrial system quite different from others—one whose wellsprings are to be found in deeper, more abiding characteristics than those to which Japanese success is commonly attributed. To compete successfully with this system, those of the Western world must seek to understand its unique characteristics and how they fit together into a pattern of economic growth. That is the central purpose of this article. Let's begin by dispelling some myths or misconceptions that tend to obscure the vision of anyone looking seriously for the reasons for the "Japanese Miracle."

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### Three myths about Japan's economy

The first misconception that needs to be dispelled is the image of Japan as an encroaching exporter, whose main purpose in life is to sell its manufactured goods abroad. The appearance of an enormous variety of Japanese products in world markets in recent years certainly creates this impression. Yet in 1970 Japan took only fourth place in international trade—exporting, in round figures, $19 billion worth of goods. Thus, it trailed, by a large margin, the U.S. ($43 billion) and Germany ($34 billion) and was slightly behind Great Britain and only somewhat ahead of France and Canada. In terms of percentage of total output, Japan exports less than any of the countries of Western Europe.

This is not to say that exporting has a trivial role in the Japanese economy. Far from it. To an extent unequalled by other leading global economic powers, Japan is resource-poor and must import most of her raw materials and food in order to survive. The exporting of products made from these resources is essential to Japan as payment for her imports. As Koji Kobayashi, president of Nippon Electric, puts it, "Japan is really a country of conversion; we must export manufactured goods, otherwise we can't pay for the resources we don't have at home."

But contrary to conventional wisdom, Japanese manufacturers do not make their money in foreign markets. Their main bonanza is at home—Asia's first mass consumer market. Exports are not seen primarily as a source of profit, but as an outlet for production that cannot be sold at home—from an industrial plant that must operate at capacity to make ends meet. By exporting this "surplus production," Japanese manufacturers can keep their unit production costs down and thus realize greater profits on the home market.

Herein lies the secret of Japanese pricing policies. Just as we must reject the misconception that foreign trade is the moving force behind Japan's industrial and economic power, we must disabuse ourselves of the convenient notion that dumping is what makes Japanese products so competitive internationally. Norihiko Shimizu, a director of the Boston Consulting Group, says bluntly: "Japan's pricing policies can in no way be termed dumping. They constitute a powerful competitive weapon in capturing and holding market share."

Since profits on exports are not the primary goal for Japanese managements, and since corporate growth is more important than profits (for reasons I'll touch on later), the system enables companies to be highly flexible in their market penetration tactics. "When there's sharp competition and we want to introduce our best products, we make a sort of sacrifice hit in the initial sale," admits Mitsubishi's managing director Morihisa Emori. But this is far from a policy of systematic dumping. Nor does it explain the excellent performance of an increasing number of quality Japanese products that are selling in the upper ranges of the price spectrum.

Still a third myth about Japan's competitive power lingers. This is the commonly held assumption that lower prices of Japanese export products, and hence economic growth itself, are attributable to cheap labor. This may have been partly true as late as the 1950s, when industry could draw needed manpower from the agricultural sector where underemployment was widespread. But as the economy expanded, this labor source dried up. Moreover, Japan's population growth rate has been declining for some time. As the country has become more urbanized and affluent, more and more young people have opted for higher education instead of entering the work force from high school.

All this has added up to a labor shortage and, as a result, Japanese wages have tripled in the last decade—climbing at an average of 15 percent per year. In some industrial sectors where Japan competes strongly on a worldwide basis, such as steel and heavy machinery, wages have surpassed those of some European countries. In other sectors, like electronics, Japanese firms have been forced by high domestic wages to follow the example of some Western countries and build plants in lower labor-cost areas like Taiwan, Korea, Hong Kong, and Singapore. In short, the myth of cheap labor as a reason for the cutting edge of Japan's competitive power can no longer be sustained.

## The Japanese system

In looking beyond these myths to the realities behind Japan's success, we must begin by focusing on the basic characteristics of the Japanese economic model, which in turn is only a part of a very special sociopolitical system all of whose parts interact to stimulate growth.

The primary factor contributing to Japan's rise to its position as the world's third industrial power since World War II has been the country's political stability. Since 1945, the Liberal Democratic Party, which favors an economic system based on a free competitive market, has held the reins of government—except for a short period (1947-1948) when the opposition Socialists were in power. Under the conservative governments formed by the Liberal Democrats, business has enjoyed a large measure of freedom—but freedom effectively channeled by a unique admixture of government participation in the business of business.

This system, which Jack Morton of Bell Telephone Laboratories once termed a sort of "national participative management," works roughly like this: The Economic Planning Agency of the Prime Minister's Office plays a central policy-making role, preparing long-range plans for economic expansion and indicating where government action and support should be focused. Influenced to some extent by this advice, the Ministries and various independent agencies develop their own plans, each in constant consultation with the business world through advisory committees of business leaders and through three prestigious (and powerful) business groups—the *Keidanren* (Japan Federation of Economic Organizations), the *Nikkeiren* (Japan Federation of Employer's Organizations), and the *Doyukai* (Japan Committee for Economic Development).

The Cabinet also issues "white papers" on various subjects of public policy, such as science and technology or environmental pollution, and these are accepted as guides by government agencies, business associations, and private firms. So, too, with the directives —sometimes called "administrative guidance"—issued by the government agencies themselves. Though often extralegal in the strictest sense of administrative jurisprudence, they are, with rare exceptions, followed by the financial, commercial, and industrial communities as though they carried the full force of law.

In broader terms, implementing industrial policy in Japan is an exercise in economic strategy inspired more by Friedrich List and Ferdinand von Steinbeiss, who fashioned the early German approaches to industrial promotion, than by either Adam Smith or Karl Marx. It is a rational, distinctly pragmatic strategy, unfettered by ideological considerations. It's a strategy that seeks to concentrate available resources in industries where demand is likely to continue high over fairly long periods, where technological progress is rapid, and where labor productivity is apt to rise swiftly. Two Ministries play the essential coordinating role in this operation—the Ministry of Finance and the Ministry of International Trade and Industry (MITI)—so we need to look briefly at how they function together.

Industrial investment in Japan is financed in a way that is puzzling to occidentals—mainly through massive bank credits. However, since private capital demands in an ever-expanding economy exceed the resources of Japanese commercial banks, these banks draw regularly and permanently on the funds of the Bank of Japan for lending operations. The Bank of Japan, in turn, is controlled by the Ministry of Finance. Thus, Japanese business in effect has access to the borrowing power of the entire country—at least for those activities that contribute to attainment of overall national goals. Moreover, the Bank of Japan has traditionally followed a low interest rate policy that permits (indeed, encourages) Japanese companies to assume debt-to-equity ratios of 4:1 and more—a policy considered to be most unsound by conventional Western financial standards. As a result of these liberal lending policies, over 80 percent of the capital resources of Japanese industry is in the form of bank credits vs. about 40 percent in the U.S.

This "unconventional" attitude toward debt on the part of both lender and borrower helps explain why Japanese managements are more interested in growth than in profits. Through its practice of heavy overdrafts, a bank becomes for all practical purposes a participant in the enterprise to which it lends funds, and interest on its money becomes the paramount concern. The company is quite content since, as a recent First National City Bank report puts it, ". . . interest is a pre-tax expense, whereas dividends to stockholders are an after-tax drain. In an environment where cash is such a precious commodity, the dividend tends to bite more heavily into corporate liquidity than an interest payment which can be used to offset tax liabilities." In addition, the system conspires to downplay stockholder demands and free industry to focus its main efforts on meeting domestic and international competition—an enviable advantage.

In most Western countries, much of the driving capital force for industrial growth comes from public stock or bond issues. In Japan, personal savings deposits are a far more important source of growth capital. In recent years, such savings have been running close to 20 percent of disposable income vs. about 8 percent in the U.S. Rather than invest their savings in the stock market, Japanese usually deposit them in banks (or the Post Office) which channel them into investments in the form of bank loans to business. It is estimated that Japanese industry generates roughly half of its growth rate from this source.

The reasons why the Japanese maintain such a high savings rate are part and parcel of the subtler characteristics of their country's success story and so ought to be touched upon here. For one thing, the Japanese are by tradition diligent and frugal, and this tradition—stemming in part from the country's resource-poor nature—is reinforced by preferential taxes on savings deposits Then, there is the system of semiannual bonuses, amounting to as much as half a year's pay, which tends to encourage employees at all levels to save money. Another motive for saving is Japan's inadequate social security system; Japanese find it necessary to save for old age and for the education of their children. Finally, the use of installment credit is not widely developed in Japan, so people tend to accumulate needed funds before buying high-ticket items flowing from Japan's prolific consumer industry.

## Where MITI fits in

I noted earlier that Japan's economic strategy is a highly pragmatic one that seeks to concentrate resources in the most promising industries, and here is where the Ministry of International Trade and Industry enters the picture. In a fast-growing economy like Japan's, banks must pick growth industries and businesses if they are to maintain and expand their share of business. And in judging what makes a growth industry, banks receive convenient guidance from MITI—each of whose bureaus is responsible for a particular segment of industry. The guidelines that MITI provides become the banks' chief criteria for lending operations. MITI in turn reinforces its judgment by protecting those industries and enterprises selected for encouragement through a system of quantitative restrictions on imports and controls on the introduction of foreign technology.

To make all of this a bit more specific, consider the oil refining industry. Here, MITI exercises direct control of the installation of toppers, crackers, and reformers. Once each year, MITI formulates the national demand-and-supply position on petroleum products for the five years ahead, which in turn determines the total capacity of toppers to be built. Within this capacity, MITI approves applications for topper installation, thus enabling it to keep a fair balance between national and foreign-owned petroleum companies, as well as between supply and demand of various petroleum products.

This same pattern of government—industry participation in industrial policy making occurs in petrochemicals, steel, electronics, and telecommunications—as indeed in all other industries. In cases of steel and petrochemicals, MITI's control is exercised mainly to avoid over-investment—making it easier for firms to obtain the full advantage of large-scale plant—and to encourage strategic industry reorganization when that is deemed desirable. Other Ministries such as Posts and Communications, Agriculture and Forestry, and Transportation are also involved in policy formulation and implementation for industries within their sphere of competence.

To the Western observer, it may seem that MITI and the Ministry of Finance exercise a pretty heavy-handed control over the economy. However, their administrative leadership is not authoritarian. At its root lies the peculiarly Japanese harmony between government and business and the system of consensus that such harmony makes possible. Yet within the framework of this consensus—through which industrial policies are formulated only after the most careful and thorough discussion with all parties involved—firms are encouraged to compete freely with one another. To many observers, myself included, it is precisely this seemingly contradictory interplay of government intervention and fierce interfirm rivalry that has assured Japan's high economic growth and the successive appearance of export industries with strong international competitive power.

The Japanese economic system, then, resembles neither Soviet Communism nor the Western variants of capitalism. It has the dynamism of capitalism, but attempts to eliminate the worst uncertainties of risk taking and the wastefulness of "excessive" competition. It also succeeds where communism has so conspicuously failed—in providing the necessary inducements for the individual to harness his efforts to the furtherance of the society's interests in such a way that he ultimately benefits (both psychologically and materially) far more than if he followed his own inclinations. Within this context, economic growth has become Japan's top national objective, and all political issues are subordinate to it.

## The employment system

With this picture of Japan's unique capital-investment and policy-making system before us, let's turn now to the second key factor that shapes the country's economic success—the way she uses her vital labor force.

Most Westerners are by now aware that Japanese companies follow a practice of employing their people—workmen and salarymen alike—for life, and that career progress is determined primarily by education and seniority. This tradition is reflected in a paraphrase of an oft-quoted maxim, "In the West, the employer buys a skill, but in Japan, the company adopts a man." Less well-appreciated, however, is the fact that Japanese employees are expected (and trained) to perform a wide variety of jobs at their respective levels, from plant to plant or branch to branch, depending upon where the action is. By and large, the Japanese employee is expected to be more of a generalist than a specialist (though this pattern is shifting as industry becomes more highly technological and the need for specialists thus becomes more acute). The result is a much higher flexibility and mobility of labor *within* the company than is possible in the West—an enviable advantage when you are competing with firms all over the world.

The tradition of lifelong employment leads to another advantage: the loyalty of employees is not subject to the ambivalence that characterizes workers' attitudes in other countries. Workers are not torn between the productive unit on the one hand and the labor unions on the other. Loyalty to the firm is first and foremost, though, again, this pattern is shifting under conditions of severe labor shortage—particularly among employees of small- and medium-sized firms who are less apt to receive the benefits of company housing and equitable wage increases enjoyed by those who work for the major corporations.

Labor is organized along company union lines, and the leadership of the large national federations has relatively little influence over the rank-and-file worker. Consequently strikes are rare, and usually only symbolic, so that Japanese companies are never forced to default on deliveries because of labor dis-

### More on MITI

Every industrialist/technologist who knows Japan knows MITI. Japan's Ministry of International Trade and Industry is a driving force behind the nation's development of technology, and it plays a vital role in the setting of technology policy, too. The arm of MITI charged with administering such activities is the Agency of Industrial Science and Technology. Through this agency, too, MITI operates some 16 research institutes and laboratories, as well as a standards department.

MITI's stated aim is to respond to the country's needs for higher standards of living. To achieve this, top priorities are assigned to urgent problems involving environmental protection, technology assessment, and the use of technology in "social development."

An important mechanism through which Japan is able to address such problems is MITI's National Research and Development Program, a program established in 1966 to focus funds and manpower on specific areas. For example, Japan's "superhigh-performance electronic computer systems" project was begun in 1966 and completed in 1971. Before completion, about $10 million had been funneled into the project by the National R&D Program. Two other projects launched in 1966 involved MHD generators and the removal of sulfur from stack gas and fuel oil. By 1971, the MITI Program had initiated six more projects. Except for a project concerning olefin products, which was suspended last year following review of the results to date, all of them are ongoing today. One—an important project scheduled to run at least through 1978—concerns pattern information processing. Like both the MHD project and the high-performance computer project, this one benefits from the work done at the Electrotechnical Laboratory, one of MITI's previously mentioned laboratories and the government's only research organization specializing in electricity and electronics.

R&D conducted by ETL on the MHD project involves superconducting magnets, electrode and refractory insulating materials, and operational testing of a 1000-kW MHD generator. The pattern information processing project, still in its early stages, encompasses information recognition systems themselves as well as associated components and materials.

Two other current MITI projects, both begun in 1973, are one on steelmaking and the other on motor vehicle traffic control technology. But MITI's ruptions. Ability to deliver on time has frequently been decisive when competing for markets with American or European suppliers. The Swiss automobile market is a case in point. Japan's leading car manufacturers, Toyota and Nissan, command the best dealers in the country simply because the strike-bound British industry has not been able to assure its dealer networks a continuing supply of automobiles.

Japanese manufacturers also can count on a literate and well-educated work force. Not widely understood is the fact that learning was already more broadly disseminated in Japan at the time of the Meiji Restoration (1868)—when the country decided to industralize itself thoroughly—than in contemporary Europe and the U.S. Today, Japan's literacy rate is 99.8 percent, the highest in the world, and the percentage of the population completing secondary education far exceeds that of its closest rivals, the U.S. and Canada. As for higher education, Japan has doubled the number of students graduating from its 900 universities and colleges in the past decade. But more important, the proportion of engineering and economic graduates—the prime movers of innovation in technology and management—has increased sharply in recent years.

Apart from good education, job security, a harmonious relationship with management, and loyalty to his firm, the Japanese worker is distinguished from his Western counterpart by a sturdy and abiding love for work. Although there are signs of dissuasion among some of the younger generation, a man's worth is still mainly judged by the performance of his responsibilities. Each Japanese knows that his associates, family, and neighbors expect his best effort. In such an achievement-oriented social setting, it's not surprising that rigid quality-control measures have been espoused with almost religious fervor in the postwar period. The Japanese worker understands clearly that it's not enough to work harder, he must also work better. (This attitude also extends to women employees, who comprise 40 percent of the work force.)

As a result, Japanese manufacturers rarely encounter workers' resistance to rapid technological change. For Japanese at all levels of the corporate "family," the logic of technological innovation is compelling: better products mean that the company will prosper; Japan will benefit from economic growth and more-competitive exports; and each individual contributing to the process will, in turn, have a higher standard of living.

This exceptional willingness to adapt to change is partly due to the Japanese preference for teamsmanship—the corollary of group loyalty. At the management level, decision-making is by consensus, which entails collective responsibility for results. If a plan succeeds, as many clearly do, no one individual is likely to be given the credit. If anyone is boastful or demands personal credit, there will be disharmony in the group and this is intolerable in Japan's social structure. Thus, all important goals—whether of workmen or managers—are group goals, and all energies of members of the group are directed to their achievement.

To Westerners this seems like an intolerable situation, against which the individual—especially the "young tiger" who wants to get ahead fast—must eventually revolt. In the face of many long-standing predictions that this system cannot survive as Japan modernizes, it appears to be as strong as ever. Interfirm mobility in the salaryman class is hardly greater than it was a decade or two ago, despite the demands of new technology, the introduction of management concepts from the West, and the proliferation of joint ventures with Western firms. Indeed, many foreign businessmen vow that they will change all this "non-

efforts don't stop here. In addition to carrying out projects that are officially part of the National Research and Development Program, MITI promotes private R&D. Since 1950, it has granted subsidies amounting to more than $62 million to private enterprises for technological development of some 3500 items. Recent subsidies have been directed toward the study of pollution-free processes—specifically, for the production of NaOH, heavy oil, and pulp.

Adverse consequences of the application of technology led MITI, in 1971, to begin a study of technology assessment. Its extremely modest $3300 budget that year was raised to the (still modest) figure of $50 000 in 1973.

Anticipating a proliferation of the use of computers by government bureaucrats, in 1968 MITI established its Group of Technical Exports on Computer Utilization, to study ways to use computers within the government itself. Some 27 ministries and agencies are represented in the group.

Joint research involving private companies and MITI's research institutes is undertaken through contracts that are aimed at eventual production of commercial products. In some cases, the government laboratories conduct contract research for private companies that find it impossible to do their own. The institutes also carry out tests for certification required by law for instruments, electrical appliances, and the like.

While MITI, through its setting of technology policy, its subsidizing of R&D, and its administrative assistance to Japanese companies—sometimes in cooperation with other governmental agencies—has undoubtedly helped put Japanese industry in a favorable position *vis à vis* their international competitors, not every Japanese company views such aid as universally good. A notable dissenter is Sony, whose top executives assert that the Japanese government did nothing but "spoil the big companies" and save some firms that were on the verge of bankruptcy. Sony is not inclined to specify how much of its sales dollar should go to R&D. "There's no more foolish a question," thinks Sony's chairman, Masaru Ibuka. One does not conduct R&D "as a hobby," he says. It may be necessary to invest in R&D "just one step short of bankruptcy" if that will achieve a particular goal, which, in turn, may assure survival of the company. At Sony, the goals are selected by top-level management, not by the researchers or even the director of R&D, says Dr. Ibuka. One could infer that Sony executives do not want the government setting their company's goals, either.—*Donald Christiansen* sense" when they first set up shop in Japan, but a recent survey by the Japan Federation of Employers' Associations shows that most foreign firms and joint ventures still follow the traditional employment system.

## The role of technology

The third crucial element in Japan's success is the ability of the country's leaders to make productive use of modern technology. It's all well and good to have a carefully orchestrated plan for capital investment in the right industries, and an employment system that ensures that those industries function efficiently. But rapid growth also requires, indeed is built upon, a continuing input of adaptive new technology.

Ever since the late 1860s, when Japan decided to protect herself from foreign domination by developing her own industrial power, new technical ideas have been sought from all over the world. The stratagem was a natural one, for, a thousand years earlier, the Japanese imported a whole civilization from China. In the early years of modernization, which began roughly a century ago, Japanese government and business leaders demonstrated their acumen in the management of change by developing a system of shaping existing technology to Japanese conditions that must be rated high as an innovation in organizational behavior. In his book, *Japan: The Story of a Nation*, former ambassador Edwin Reischauer describes this system accurately: "The world was one vast schoolroom to them, but they chose what and where they would learn and how they would use the knowledge to change life in Japan."

In the realm of technology, the world still is one vast schoolroom for the Japanese and it doubtless always will be. But it would be a mistake to continue with the time-worn notion that the Japanese are mere copiers of Western ideas. Rather, they must be thought of as adroit *selectors* and exceedingly clever *developers* of technical applications, wherever they find them.

Latter-day examples of this phenomenon are legion—from shipbuilding and steelmaking to petrochemicals and telecommunications. The consumer electronics industry, however, provides a particularly vivid example—in the case of the Sony Corporation. In a recent interview, Sony's cofounder and chairman, Masaru Ibuka, put it succinctly when he said, "You Americans were clearly ahead of us in transistor research, but you didn't know what to do with it." Sony quite clearly did. With an initial capital of $450, and operating in a shabby, two-story building in Tokyo, Sony engineers developed the first commercial transistor and then succeeded in packaging it into pocket-sized radio sets. From there, the company went on to develop a $1 billion business that includes a highly diversified range of transistorized audio, television, and videotape equipment.

In the same interview, Ibuka went on to reflect his confidence that Japan's industrial system will not run out of competitive steam in the world marketplace: "There will always be something for Japan to do which other nations cannot do. There will always be openings."

Such openings have not been lacking in Japan. Of the 10.4-percent average annual growth rate of the Japanese economy from 1955–1970, it's estimated that 4.6 percent was due to progress in technology. In other words, technological innovation was responsible for *nearly half* the economic growth each year. Imported technology (mainly from the U.S.) unquestionably played an important role here, but Japan's own efforts in technological development have been more substantial in recent years than most people realize. In 1969, for example, R&D expenditures accounted for 1.49 percent of Japan's GNP—well over *six times* the total payments for imported technology. By 1975, at present rates of increase, outlays for R&D will be four times the 1969 level, reaching 2.3 percent of GNP.

It must be understood that Japan's commitment to developing industrial R&D is very real. Even though a smaller percentage of GNP is being spent on R&D than in the U.S. (2 percent vs. about 3.5 percent), there already exists a cadre of nearly a quarter million scientists and engineers working in the industrial sector (roughly one-quarter of the U.S. figure). Thanks to the aftermath of World War II and the continuing U.S. military presence in the Far East, there is far less preoccupation with defense expenditures (1 percent of GNP vs. about 7 percent for the U.S.), and much of the money the government does spend on R&D—roughly one quarter of the country's total outlay—is industrially oriented.

By 1985, latest estimates show total outlays for new technology will have risen to more than $80 billion annually, or 4 percent of anticipated GNP. Comparing this with the 3 percent spent in the U.S. back in 1967, when the American economy was *smaller* than the Japanese economy is likely to be in 1985, we obtain a measure of what to expect from Japanese industry in the way of technological innovation in the future.

## The management of change

Japanese industrial policy over the past 20 years has been, at bottom, a judicious blending of the three elements I've been discussing—a unique capital investment program, a vital labor force, and cleverly selected technology—into an overall scheme of continuing and deliberate structural change of the economy.

The key to success in both private business and for a nation as a whole is to switch as rapidly as possible into those new products for which demand can be expected to increase most rapidly and for whose production available resources combine to assure the highest possible comparative advantage. By realistically interpreting market potential in the near term, Japanese industrial policy has quickly and efficiently transferred resources into the manufacture of products meeting two criteria: those having relatively *high income elasticity of demand* (i.e., products, like fancy cameras or pocket-sized electronic calculators, that people will snap up when their income rises even slightly) and those having *low price elasticity of demand* (i.e., products, like color TVs or small cars, that people will buy almost regardless of price). The first of these new-product-selection criteria has assured rapid growth of sales without the need for price cutting, while the second has allowed near-monopolis-

## For further reading

Japan's success has spawned a wealth of literature that attempts to analyze the reasons behind it. The following selections are recommended as basic; they avoid the realm of the specialist.

First, Peter Drucker's article, "What we can learn from Japanese management," in the March–April 1971 issue of the *Harvard Business Review* contrasts Japanese and Western management while touching on many aspects of Japan's industrial system. Must reading for the manager with time to read only one or two items. Also in this category is James Abegglen's "The economic growth of Japan," in the March 1970 issue of *Scientific American*, which presents a lucid account of the Japanese scheme of industry–government cooperation and the economic policies that make it work.

For a deeper look, three books are suggested: P. B. Stone's short volume *Japan Surges Ahead* (Preager, 1969, $6.95) is particularly valuable because it presents the "story of an economic miracle" in chapters instantly accessible according to one's interest. Robert Guillain's *The Japanese Challenge* (Lippincott, 1970, $8.50) is a longer, more analytical account of Japan's rebirth from the ruins of the War. Edwin Reischauer's *Japan: The Story of a Nation* (Knopf, 1970, paperback $4.95) is a very readable and complete account of Japan's early history and modernization.

*The Structure and Operation of the Japanese Economy* (Wiley, 1970, $9) by K. Bieda presents an incisive and up-to-date analysis of the factors which make the Japanese economy work. In *Japanese Society* (Random House, 1971, paperback $2.95), T. Ishida describes a technological society competitive with the most advanced Western nations, yet still in harmony with its historical traditions. In *Japan's Managerial System: Tradition and Innovation* (M.I.T., 1968, paperback $3.95), M. Yoshino provides a comprehensive though somewhat academic picture of a vital element in Japan's success.

*Business Strategies for Japan*, edited by Abegglen, contains an insightful lead chapter called "What makes Japan grow?" (Voyages Press/Tokyo, 1971, $8; available from the Boston Consulting Group, Boston, Mass. 02106). Ballon's *Doing Business in Japan* (Tuttle, 1968, $5.50) opens with an interesting chapter on "Japanese ways" and Part 2 devotes four chapters to "The economy." And *The World of Japanese Business* (Kodansha International, 1969, $6.95) by Adams and Kobayashi, looks at the subject from both the Western and Japanese perspective.

Finally, a specific but interesting account of operations at one company (Matsushita) is Louis Kraar's "A Japanese champion fights to stay on top," in the December 1972 issue of *Fortune*.

tic prices to be charged. Both have fueled the engine of economic growth.

The trick the Japanese have mastered (and others have not) is never to become so wedded to any particular industry that they cannot switch quickly to something else once that industry has lost its comparative advantage [illegible] world markets—either as a result of changing market demand or rising production costs.

Although this orchestrated restructuring of the economy takes place continuously, three stages are clearly identifiable since 1945. In devastated postwar Japan, industrial policy was aimed at encouraging labor-intensive industries, like cotton textiles, machinery, and agriculture, that produced the basic necessities of life. In the early 1950s, emphasis was shifted to "infant" industries, producing more sophisticated goods such as cars and trucks, machine tools, petrochemicals, and electronics. Now a third stage has been introduced that is giving accent to advanced-technology industries like telecommunications, computers, new synthetics, and even nuclear energy and aircraft.

All along the way, industries that have ceased to be competitive have—with the remarkable cooperation of management and labor—been systematically retired and interred with the record achievements to which they contributed. Products like foodstuffs, cotton textiles, and electronic components have been replaced by imports from less-developed countries all over the world—particularly Asia—thus freeing Japanese labor for higher-value-added production that can sustain the rapid rise in per capita income. (In 1960, Japan ranked 23 in per capita income; by 1970, she had moved into fifteenth place in the world, and by 1980 could well place third—just below Sweden and the U.S.)

By focusing on the right industries at the right time, by marshaling an energetic and dedicated labor force to serve them, and by encouraging innovative use of the latest technology, Japan has been able to achieve remarkable increases in productivity. In the manufacturing industries, the rise has run at an average of 9 percent per year over the decade 1960–1970. This in turn contributed strongly to the country's economic growth rate of well over 10 percent per annum during this period.

In specific industries, Japan's rising productivity has been able to crack positions that once seemed impregnable. The classic case is steel. By rebuilding its mills, using the latest technology, and locating them at coastal points with automated handling facilities of huge ore carriers, the Japanese steel industry made giant strides in productivity—170 percent in a single decade, as against only 20 percent in the U.S. Other industries—petrochemicals, heavy machinery, electronics—scored high productivity gains in the same period, but the pace has slackened a bit in the face of recent economic difficulties. Last year, for example, overall productivity rose by a disappointing 6.7 percent—still a respectable figure by most Western standards.

Such rises in productivity, and the widespread acceptance of the changing needed to achieve them, clearly shows that Japan's managerial system is by no means a lifeless bureaucratic one. Nor does its dynamism depend exclusively upon the vitality of younger managers. Most Japanese companies retire their managers at age 55 to make room for the high achievers among their younger men, but top-ranking executives are often excepted from this rule. Indeed, Japan's older executives have been in the vanguard of change in recent years. To cite just one example, the chairman of Ishikawajima-Harima Heavy Industries, Toshiwo Doko, took on the *additional* task of revitalizing Toshiba—Japan's seventh largest manufacturing firm (and part of the IHI group)—just as he was about to turn 70.

The Japanese management system also gains strength and flexibility from the fact that its managers are able to operate pretty much on their own. That is, equity shareholders have little or no influence on corporate behavior. The banks, which provide the financial resources, assure management a large measure of freedom from stockholder interference. Moreover, the banks themselves are not controlled by *their* owners, but by employed managers as well as by the Ministry of Finance and the Bank of Japan. In short, the Japanese economy is operated by professional managers in a kind of managerial capitalism. This assures agreement between business and government on basic objectives (growth ahead of profit, for example, as noted earlier), and thus sets the stage of the harmonious industrial policy making and execution necessary for the effective management of change.

## Outlook for the future

As our discussion thus far has indicated, the Japanese economic system has the resiliency and the necessary mechanisms to find ways of growing, even in adversity. Moreover, past experience has shown that current Japanese estimates of 8–10-percent annual growth through 1985 can be accepted as reasonable, the troubles of the past year notwithstanding. Consequently, I think it reasonably certain that over the next 15 years we will see the following changes take place:

- Japan will give higher priority to internal development. The domestic market, which has provided the primary impetus for growth over the past two decades, will become an even more important factor—but the emphasis will shift to meeting increasing demand for social amenities.
- Public investment will become relatively more important as a factor stimulating demand and economic growth. Housing and public construction will be major growth areas. Massive outlays for new technology will spur innovation in priority growth industries, so that the need for imported technology will wane somewhat.
- Computers, telecommunications, and education will become important foci of industrial policy, which will seek to shift resources into building the sinews of an information society.
- Industries specializing in labor-saving and pollution-control equipment will produce some of the world's most important advances in these fields, as Japan's labor shortage continues and concern for the environment grows.
- Demand for consumer goods will increase steadily, in cadence with rising wages and salaries and with the increasing innovativeness of industries serving this market.
- Investment of capital and know-how overseas will swing upward as Japan concentrates on the development and processing of vital raw materials beyond her borders and continues to transfer labor-intensive industries to developing countries.
- Exports will continue to outpace the world average, but growth will be at a decreasing rate, as Japan becomes more sensitive to the impact of her export activities on the countries she depends upon for survival.
- Imports will grow more rapidly than in the past, as Japan becomes one of the world's major markets for manufactured goods and adopts import policies more consistent with her position as one of the world's top three economies.
- Finally, foreign investment capital will be welcomed more warmly than in the past, simply because it will be needed if Japan is to maintain its pace of industrial growth while *simultaneously* improving its quality of life in areas like housing, transport, education, and environmental pollution—all domains left untended in the rush for more productive capacity in past years.

Will Japan succeed in implementing these anticipated changes? I believe so. At the outset of this article I stressed the importance of understanding the basic characteristics of the Japanese industrial system. Many of these, as we have seen, are uniquely Japanese. But one common thread runs through all of them—an enduring commitment to change.

Though not unique to Japan, this commitment has been pivotal in Japanese thinking for over a century. Through change Japan has achieved its identity, its permanence, its independence from the West. What we have been witnessing, in fact, is not so much the Westernization of Japan as the Japanization of Western culture, institutions, and technology. Despite surface appearances that Japan's economy is being shaped by the ineluctable forces of modernization into something approximating the American image, the Japanese way persists.

In the final analysis, the Japanese are less inhibited than the U.S. about change, and about the future, simply because they have accepted the necessity for continuity with the past. Indeed, it is the thrust of the past that provides much of the momentum for change. It is their anchor in the past, in the cultural values and social structures which it has bequeathed, that enables the Japanese to accept continuing change, and to change so abruptly at times. This is what gives strength and resiliency to the Japanese economy—and why the Japanese are likely to succeed in finding solutions to the new set of problems that have arisen as a result of rapid economic growth.

**Gene Gregory** served in the U.S. Foreign Service for several years in the Far East and Washington. He has also been a Ford Foundation Scholar, publisher, entrepreneur, and consultant. While in Japan, Mr. Gregory has worked closely with firms like Sony, Toshiba, Pioneer, and Sharp, helping them devise strategies for penetrating markets in Southeast Asia and techniques for transferring technology to developing countries in this area. In what he terms a "leisurely odyssey," Mr. Gregory studied chemical engineering at the University of Washington and Georgetown; foreign service at Georgetown; international studies at Johns Hopkins, and Southeast Asian subjects at Cornell University. He contributes regularly to the *Far Eastern Economic Review*, and is a member of the editorial board of the *Asian Quarterly*.

**Reprints of this article (No. X74-033) are available at $1.50 for the first copy and $0.50 for each additional copy. Please send remittance and request, stating article number, to IEEE, 345 E. 47 St., New York, N. Y. 10017, Att: SPSU. (Reprints are available up to 12 months from date of publication.)**

# Design decisions through simulation

## Continuous and discrete-event techniques are not necessarily mutually exclusive; they may work well together

With present day simulation tools, problem definition is no longer the property of the privileged computer-oriented few, but is available to users such as engineers, analysts, designers, and managers. Simulation, in short, is capable of providing an intelligent base for engineering design decisions.

For example, the U.S. Department of Transportation has been seriously investigating the possibilities of personal rapid transit systems. These systems are being considered for use in cities as large as Denver, Colo., but seem most appropriate for smaller cities. System stations are jointed by a fixed guideway network on which automatically controlled driverless cars operate. These cars have a flexible schedule and are stored in anticipation of passenger demands.

As each passenger boards an available car, he presses a button indicating to which station he wants to travel. The car then goes, by the shortest possible route, to that station. This scheme may be implemented by railway-type cars—possibly automatic—running on tracks, or by small buses running on city streets.

Several critical problems arise in the overall system design. For example, the demand for vehicles at a particular time and station might be greater than the supply. Weather changes, Christmas shopping, or athletic events could cause large numbers of passengers to appear suddenly, but it could take an appreciable time to summon available vehicles from other stations. Since supplying a large number of standby vehicles would be very expensive, scheduling procedures (algorithms) are needed to maintain acceptable levels of service with a reasonable total number of vehicles.

Although this complex, demand-modulated system cannot easily be evaluated by analytic techniques, simulation has provided significant information about the kind of performance that can be expected. An important mode of simulation for this system has been to keep operation more or less responsive to passenger demand, while changing vehicle sizes and guideway topology. Under these conditions, system performance characteristics, service, and equipment costs can be meaningfully evaluated. A different set of simulation problems is offered by computer systems design.

### Computer-augmented-command and control

Consider a military, tactical computer whose task is to review and present information for a command and control center. Such a computer is required to perform real-time functions as well as off-line computation. It uses a large number of different programs, each of which must be brought into operation at an appropriate time. Demands on the system are not known in advance. System performance can be greatly impaired by selection of program priorities inappropriate to the mix of problems that actually present themselves.

The overall job of simulation is to give some insight into the performance of the system under conditions that are likely to occur in actual operation, and to give some indication of changes that need to be made. If program selection were a randomly distributed process, system information could be readily obtained either by straightforward analytic methods or by a very simple simulation. For example, simulated program subroutines could be treated individually, then later combined as separate, independent events.

Actually, the activity of this system appears to be a series of event-sequences that depend heavily on immediate past history and program interrelationships as well as computer parameters such as storage size. This activity is far from random behavior, and a simulation that treats the unique properties of realistic event-sequences is necessary.

Determining the physical location of programs has been found to be a key simulation problem for this system. Most of the programs reside in slower-speed mass storage, while a smaller number of programs—those in current use—are in high-speed storage. Real-time system response depends heavily on how often a needed program is found already to be in high-speed storage.

Through simulation, it becomes apparent that the system has an activity threshold, above which performance becomes degraded. Worst-case rather than average performance is therefore found to be critical, and it becomes a major goal of the simulation to determine the degree to which worst-case conditions can be anticipated and remedial action effected. This is especially important since any loss-of-data failures in this system are considered to be catastrophic.

### The promise of simulation

Simulation played a similar role in both of the examples we have discussed. In each case, its main contribution was a fuller understanding of a very complex design problem—an understanding that was far deeper than any that could have come from analysis based on random-events assumptions.

The inputs to these simulations represented the

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**Julian Reitman** Norden

Engineering Center. Founder societies, in addition to IEEE, are the American Society of Civil Engineers; American Institute of Mining, Metallurgical and Petroleum Engineers; American Society of Mechanical Engineers; and American Institute of Chemical Engineers.

Associate societies include the American Society of Heating, Refrigerating and Air Conditioning Engineers; Illuminating Engineering Society; Society of Women Engineers; and the Society of Municipal Engineers of the City of New York.

## IEEE asks technical exchanges with China

When IEEE INTERCON '74 meets in March in New York, the presence of representatives from the Chinese Academy of Science and the Chinese Societies of Electrical and of Electronics Engineers will mean that formal invitations from IEEE to these groups to attend U.S. meetings of interest to them have borne fruit. This is the latest in a series of efforts dating back to 1964 by the IEEE's Intersociety Relations Committee's Subcommittee on Scientific and Cultural Exchanges to establish communications with peer groups in the People's Republic of China.

Although attempts at such exchanges thus far have not met with unqualified success, some progress has been made. For example, in July 1973, the secretary general of the Chinese Society of Electrical Engineers accepted a unilateral offer of IEEE publications on an exchange basis for one year. Unfortunately, the People's Republic is unable to reciprocate at present because it has not as yet reinstituted electronics publications.

Also, in October, a group of Chinese computer experts visited the U.S. under the auspices of the National Academy of Sciences. As a result, IEEE has initiated correspondence with the president of NAE suggesting the coordination of these and similar visits with the professional societies in the future. In addition, on an unofficial level, informal contacts have been made with Chinese-American engineers and scientists who have visited China as tourists or as official guests.

Other nations, and other groups in the U.S., have also begun to make overtures toward setting up cooperative ventures with the People's Republic of China, and the ISRC welcomes evidence of such exchanges in fields of interest to the IEEE.

## S-NPS will honor outstanding students

Nominations are open for the IEEE Nuclear and Plasma Sciences Society's student awards recognizing outstanding achievements in, and contributions to, the field of nuclear or plasma science and technology.

Up to four awards of $200 each and a one-year S-NPS membership are available to U.S. undergraduates who have completed one year of college in nuclear or plasma science.

An award of a certificate and $500 will be made to a non-U.S. scholar who plans further study in the United States in nuclear or plasma science.

April 1 is the final date for the submission of letters of nomination; these should provide a concise narrative basis for the award, including a description of the nominee's contributions to the field, an indication of scholastic achievements, and evidence of future promise. Membership in IEEE or the Nuclear and Plasma Sciences Society is not required.

Nominations should be sent to A. J. Stripeika, Lawrence Livermore Laboratory, P.O. Box 808, L-151, Livermore, Calif. 94550. The awards will be conferred at the end of May.

## Koepfinger chairs IEEE Standards Board


J. L. Koepfinger

Joseph L. Koepfinger (SM), protection and communications engineer at the Duquesne Light Company, Pittsburgh, Pa., has been appointed Chairman of the IEEE Standards Board for 1974, succeeding Robert D. Briskman.

A member of the Standards Board since 1972, he has been active on various committees of the IEEE Power Engineering Society, and is chairman of the East Central Area Reliability Protection Panel.

Mr. Koepfinger received the B.S. degree in electrical engineering in 1949 and the M.S. degree in 1953, both from the University of Pittsburgh. He has been employed by Duquesne Light since 1949.

## Trinkle is named to Conference Board

Robert C. Trinkle (A) has been named to fulfill a two-year term as a member of the IEEE Conference Board of Directors, which has principal responsibility for IEEE INTERCON. He is president of Trinkle Sales Company, Cherry Hill, N.J., and current national president of the Electronic Representatives Association.

Conference Board members serve three-year voluntary terms in office. Mr. Trinkle replaces R. M. Janowiak, who resigned for business reasons.

## Behn Award will be bestowed at INTERCON

IEEE INTERCON in New York City has been chosen as the occasion for the presentation of the 1973 IEEE Award in International Communication in honor of Hernand and Sosthenes Behn. Vladimir A. Kotelnikov (F), vice president of the U.S.S.R. Academy of Sciences, will receive the plaque, certificate, and $1000 during the Directors' Reception on Tuesday, March 26.

The award citation reads: "For fundamental contributions to communication theory and practice and for pioneering research and leadership in radar astronomy." Dr. Kotelnikov's biography appeared in *IEEE Spectrum* for January, page 92.

## 'Materials' issue needs contributions

Papers are being solicited for the tenth annual special issue on materials of the *IEEE Transactions on Parts, Hybrids and Packaging*, which is scheduled for December 1974.

Suggested topics for papers include thick and thin films, substrates and dielectrics, passivating and encapsulation materials, materials for sensors, materials for displays, high-mobility materials, surfaces and interfaces, degradation effects in materials, electrical contact materials, methods for controlling the properties of materials, and material processing.

Proposed titles must be submitted by May 1, and four copies of finished manuscripts by June 1, to the guest editor: Dr. David F. Barbe, Code 5214, Naval Research Laboratory, Washington, D.C. 20375. Manuscripts should be prepared in accordance with the "Information for Authors" guide, which appears on the inside back cover of the *Transactions*.

## 1974 catalog of standards is issued

The new 32-page IEEE Standards 1974 Catalog is now available. Listing more than 350 standards by subject as well as in numerical sequence, it includes the many American National Standards published by IEEE. The IEEE Standards cover test methods, practices for electrical installations, units, definitions, graphic symbols, letter symbols, and applications methods.

Single copies of the catalog may be obtained free of charge from the IEEE Standards Department, 345 East 47 Street, New York, N.Y. 10017.

system designers' best estimates of the actual load the system could be expected to carry. In the case of the transportation simulation, this data described the anticipated number of passengers appearing at each given station—over a 7–8 hour period—and attempting to reach another given station. In the case of the military computer simulation, the input was a scenario that presented a mix of command and control problems that the system designers felt was likely to occur in actual system operation.

Simulation of large-scale systems, based on realistic expected inputs, is capable of dealing with design difficulties that are otherwise extremely hard to overcome. For example, systems, like those for mass transporation, typically involve complex interrelationships; the transportation service must satisfy passengers, and simultaneously cope with freight, maintenance, and operating personnel demands.

## Iterative simulation is practical

Because of the complexity, vagueness of boundaries, uncertain definitions and nonquantifiable requirements of large systems, initial problem definition for their simulation is necessarily inadequate. However, if an initial, incorrect system model can be evaluated quickly and cheaply, the results can be compared with initial expectations of system behavior. The model can then be modified and new results compared to refined expectations. With this feedback process, the simulation can be iterated to reduce the discrepancy between the behavior of the currently defined system and eventual system operation goals. In time, updatings of the system model should show convergence toward fulfilling real-world requirements.

For example, one possible design objective for a personal rapid transit system is that the vehicles should be used to 50 percent of their capacity—going full and returning empty. However, early simulations of the system gave lower utilizations. Subsequent changes to the simulation—in such factors as the minimum distance allowed between vehicles and their speed—showed how utilization could be improved.

Convergence is a process of discovery in which preconceived notions about the system are often shattered. For example, it was found that a 50-percent change in vehicle speed had a trivial effect on transit system utilization. Such counterintuitive results can be extremely important to system designers.

## Separate data and structure

Large systems require large amounts of data, as well as complex data structures, and need convenient methods to express functional interrelationships. In the past, simulation models for these systems have generally been constructed so that the data is imbedded in the model structure. It has been common practice to interleave in a single punched-card deck both data and logical structure information.

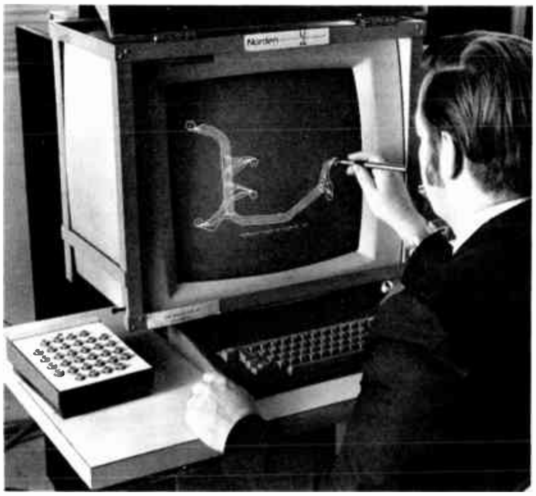
In this situation, every change in the data—and there may be many such changes—can mean a difficult updating and debugging procedure for the entire model. This is awkward and time consuming.

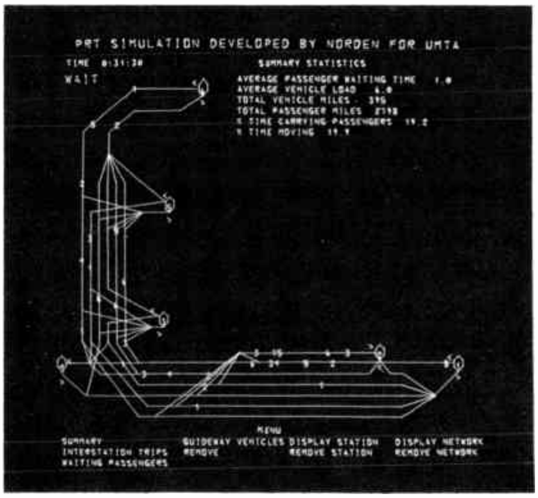
A more satisfactory approach is to separate the data from the logical structure of the model. For example, a transportation model with imbedded data might include the quantity six as the "number of stations," while a model with separate data would call for a number from the current data file when it needs

### Dynamic display of personal transportation

An IBM 2250 display of a personal transportation system is shown at the left; the operator is using a light pen to select a particular station. The round-button keyboard on his left allows him to perform functions such as deleting or adding traffic paths, and starting or stopping the simulation.

On the personal transportation system display, at the right, stations are shown as numbered hexagons. One-way traffic flow direction is indicated by caret marks, and each of the numbers on the lines indicate the origin of a given vehicle (on lines entering stations) or its destination (on lines leaving stations). This is a dynamic display, generated by an extended version of the GPSS simulation language. The graphic presentation tracks changes in the modeled system, as the simulation proceeds. Thus, the numbers representing vehicles move from station to station as the vehicles move.




PRT SIMULATION DEVELOPED BY NORDEN FOR UMTA

TIME 0:31:30

WAIT

SUMMARY STATISTICS

AVERAGE PASSENGER WAITING TIME 1.0
AVERAGE VEHICLE LOAD 4.0
TOTAL VEHICLE MILES 395
TOTAL PASSENGER MILES 2198
% TIME CARRYING PASSENGERS 19.2
% TIME MOVING 19.9

MENU
SUMMARY
INTERSTATION TRIPS
WAITING PASSENGERS
GUIDEWAY VEHICLES
REMOVE
DISPLAY STATION
REMOVE STATION
DISPLAY NETWORK
REMOVE NETWORK

to know how many stations are to be used.

With this separation, models can be quickly rerun using different data without changing the logical model structure. Likewise, a number of different models can share the same data bank.

## Simulation languages

Simulation methods and examples discussed in this article deal mainly with an approach—called discrete events simulation—that began with efforts at Bell Telephone Laboratories to study queuing and communications networks. These simulations evolved into analyses of computers, transportation, industrial planning, and other limited resource allocation systems, and these broad applications encouraged the development of discrete event simulation languages such as GPSS, SIMSCRIPT, and SIMULA.

However, the earliest attempts at simulation were by control system engineers, using analog circuits and computers to implement continuous rather than discrete-event simulations. To ease the transition from analog to digital computation, a number of computer simulation languages have evolved, including MIMIC, MIDAS, PACTOLUS, CSMP, and CSSL. The use of continuous simulation has been appreciably broadened from engineering to societal problems through the efforts of J. Forrester and his exposition of the Industrial Dynamics family of simulations using the Dynamo language.

Continuous and discrete-events techniques are not necessarily competitors. In fact, one of the most exciting prospects in simulation is the future joint use of these two techniques. Progress has already been made in tying the GPSS discrete-events language to the CSMP continuous-simulation language. In a transportation simulation, for example, CSMP can be used to provide continuous data on the dynamics of each vehicle, while GPSS controls the simulation and establishes the sequence of events, logical interaction, and resource allocation. In this combined simulation environment, continuous characteristics can be changed in response to changing logical situations, so that highly complex systems can be simulated both with regard to detail and overall policy.

The capabilities of such a combined simulation might even be extended to real-time control of operating systems, perhaps along the following lines: GPSS already includes a simulated clock, and this clock can be made to track real time. If this is done, then sensor information can be directly fed into the simulation model. For example, data from an actual station could be fed into the personal rapid transit model. With the remaining stations added, the simulation program could then serve as a control program for actual system operation.

In a practical sense, it is not often possible to carry out continuous simulation of all elements in a large system. The problem is that available funding is generally inadequate to cover the costs of such detailed work. The tendency is, therefore, to move towards coarse discrete-event simulations, which provide—at relatively low cost—operational models for sensitivity studies and a means for refining the system design. These economic limitations focus attention on the notion that most systems are sensitive only to a limited number of parameters. This leads first to the thought that it is unwise to pay for more information than will actually be used, and then to a policy that concentrates simulation resources where they seem most needed. After all, the simulation can always be modified later.

### For further reading

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Introductory volume covering the broad range of discrete event and continuous simulation.

3. Kiviat, P. J., Villaneuva, P., and Markowitz, H. M., *The SIMSCRIPT II Programming Language*. Englewood Cliffs, N.J.: Prentice-Hall, 1968.
Detailed description of SIMSCRIPT II.

4. Dahl, O. J., and Nygaard, K., *SIMULA—A Language for Programming and Description of Discrete Event System Introduction and User's Manual*. Norwegian Computer Centers, 1967.
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Detailed description of the GPSS language.

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Description of a program structure for the GPSS language.

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Description of how system simulation has been used in several areas.

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Emphasis of statistical considerations associated with simulation.

10. Reitman, J., Ingerman, D., Katzke, J., Shapiro, J., Simon, K., and Smith, B., "A complete interactive simulation environment GPSS/360-NORDEN," *4th Conference Applications of Simulation*. New York, 1970.
Fuller description of the interactive GPSS.

## The Fortran problem

It would probably be correct to state that more discrete-event simulations are carried out in Fortran than in any of the simulation languages mentioned above. This seems unfortunate since personnel costs for programming Fortran simulations can be five to 20 times as large and take longer to achieve full operation than efforts using languages specifically designed for simulation.

One major reason for this disparity is that simulation languages give the user error indications in terms of modeling problems, while Fortran error statements are keyed to the problems of computer system operation. Fortran allows little opportunity for quick changes, modification, or manipulation of models, since each new, desired simulation function must be programmed anew.

In contrast, simulation languages like GPSS, already contain provisions for most of the needed functions, including representation of parallel events, establishment of a logical model structure, a clock for advancing time, and provisions for gathering system statistics.

The unpleasant fact is, however, that large computer installations in a number of organizations do not support *any* simulation languages, and thus force the use of inappropriate but available languages such as Fortran or Cobol.

## Extended GPSS

The three most widely used discrete-event simulation languages are GPSS, SIMSCRIPT, and SIMULA. Of these three, GPSS has been shown to be the easiest for engineers to learn and use. GPSS has a structured format for quick replacement and modification of code. It is an interpretative language whose diagnostic messages relate directly to the code, and it possesses an inherent statistics-gathering system.

Over the last few years, using GPSS as a foundation, our group at Norden has systematically extended its simulation capabilities. Data storage and manipulation using random access devices, dynamic display while the simulation is in progress, and selective statistical and text report-outputs are among the more important extensions that have been made.

The GPSS data structure has been modified to allow separation of data from the logical structure of simulation models. The data is stored on a disk in matrix form. In a personal rapid transit system simulation for example, these data included vehicle characteristics, headway between vehicles, passenger capacity, station loading berths or tracks, system geometry, and timing relationships. Implementation of this data base required no change in the GPSS language structure; additional control cards directed data storage and retrieval.

Use of such a data base cuts the cost of inputting, since data are entered in a single operation and only once rather than each time the models are used. Since data for the extended version of GPSS are stored in matrix form, several matrix manipulation features are added. One of these enables matrices to be arithmetically processed by a single statement. For example, add the rows of one matrix to the columns of another and store the result in a third.

## Interactive simulation

The original version of GPSS was designed to run in a batch-processing environment, where each simulation run was input and processed as a separate job. This involved considerable turnaround time and was an uneconomic use of skilled manpower.

However, for effective simulation, a number of different members of the design team need to get a clear picture of how various system factors change. The information they need is often complex and difficult to define precisely. When the only access to the simulation process is through computer-language specialists, it is very cumbersome for the simulation team to conduct a dialogue with the simulation process.

For more effective dialogue, it is necessary to use the language of the problem and force the computer system to be compatible with both the basics and nuances of the problem. For example, when considering the current contents of high-speed storage, it is often useful to change the portions of the program that are permanently resident and observe the repercussions—or to observe how long it takes to dissipate the transients generated when switching from one mode of operation to another. (Many systems operate as a sequence of transients without ever reaching steady state.)

A batch-processing mode of operation is not suitable for this kind of interaction. For this reason, the extended version of GPSS provides for interactive CRT and teletype access to the simulation process. With these, the user can edit inputs, debug errors, execute simulations, and view model outputs. An example of the use of interactive capabilities is discussed in the box labeled "Dynamic display of personal transportation."

To permit user interaction with the simulation during execution, a set of graphic macros (special program segments) have been imbedded within GPSS. With these, the user can terminate the simulation if it does not seem to be performing correctly. He can then look at output statistics and decide whether to continue or terminate execution. With other macros, the user can construct a dynamic pictorial representation of the system using a display unit and watch it change as the simulation progresses. Since the user can also enter data and commands while the simulation is executing, he can actually control decision-making during execution.

These dynamic display macros also make it possible to control the simulation by questionnaire. Here, the structure and definition of the problem are established in advance, during program development. Then, during execution, the user is asked a series of key questions. Based on his response, the simulation —or a portion of it—is executed. In this environment, the person guiding the simulation need know nothing whatsoever about GPSS or even about computers. All he has to do is answer questions that have been set up in advance and a possibly unique simulation will run, using his input parameters.

**Julian Reitman** (SM) received his B.E.E. in 1949 from City College of New York and his M.E.E. in 1954 from New York University.

After designing airlines computer-communication systems for Teleregister Corp., Mr. Reitman joined the Norden division of United Aircraft Corp.

Since 1961, he has directed system analysis studies at Norden, and has supervised the implementation of improved system simulation techniques for systems analysis.

Mr. Reitman is currently teaching the System Simulation course at the University of Bridgeport. He is the author of *Computer Simulation Applications*, published by Wiley in 1971.

Mr. Reitman has presented and published numerous papers on simulation and systems analysis to IEEE, ACM, and Simulation Conferences. He was general chairman of the 1968 Winter Simulation Conference and the 1969 chairman of IEEE's Systems Science and Cybernetics Group. He is associate editor of *IEEE SMC Transactions for Simulation.*

**Product design**

# The computer: now it's a component!

## Large-scale integrated circuits spawned the CPU on a chip, but it raises questions of who designs what

Minicomputer manufacturers are beginning to face a choice not unlike one that confronted the automobile industry a decade ago. At that time, the significant inroads made by small, foreign cars into the U.S. market forced Detroit to counter with small cars of its own, in order to maintain its domestic share of the business. For auto buyers, it wasn't merely a question of size, but one of economics. Small cars were less expensive to own and operate, yet could still perform their basic function of transportation, albeit with less comfort and fewer amenities.

While minicomputer manufacturers are not yet feeling strong competition from tiny, large-scale integrated (LSI) microprocessors (which are much lower in hardware cost, but also slower and less sophisticated), the inevitable progress of solid-state technology may one day make these devices viable competitors for minicomputers.

Even now, the cost of microprocessors is so low (several hundred dollars for the circuits that comprise a basic working system), that some traditional low-budget minicomputer applications may already be threatened. Also important is the emergence of a host of new applications that could not previously justify the cost of computer control. Some examples are control of simple machines, processing data from laboratory instruments, automatic testing, and localized control and preprocessing of data from computer peripherals.

As a result, minicomputer manufacturers must now rethink their traditional roles as designers and builders of central processing units (cpu's) to deal with the new competitive climate that threatens low-cost minis. Digital Equipment Corp., a manufacturer of logic modules and minicomputers (both of which may compete with microprocessors, in the opinion of this writer, though Digital disagrees) has approached this new challenge by integrating a microprocessor family into its logic module product line. In addition to offering a microprocessor, this move also closes a gap that has traditionally existed between minicomputers and logic modules, in that small modules with computing capabilities are available as systems components at a moderate price. It also provides a possible new marketing direction for minicomputer manufacturers by serving the engineer who desires microprocessor economy, but is unable to provide the substantial hardware and software effort required to convert standard microprocessor chips into small, general purpose computers.

Computer manufacturers already have the technical backup and distribution networks to serve this type of user, especially in the area of complete system design and special software support. Some semiconductor manufacturers are also developing these capabilities by offering substantial software libraries and packaging processor chips, memory circuits, and other major system components on ready-to-use modules.

Today's MOS-based microprocessors are less sophisticated than the minicomputers built from bipolar ICs, in that they are substantially slower, have smaller instruction sets, and fewer features. But for applications that can accept these deficiencies, the microprocessor hardware cost can be extremely attractive for tight budgets.

The Logic Products Group at Digital became interested in microprocessor ICs in mid-1972 when it realized that for certain terminals and data acquisition systems, the design cost of upgrading performance with standard circuits would be prohibitive, but that the job could be done economically with microprocessors. This was based on *substituting programming effort for substantial design work* and replacing logic gates with memory. It was also felt that many design engineers throughout the industry understand the value of microprocessors for their own projects and would be willing to pay the additional cost of purchasing a fully supported set of circuit modules, rather than investing the cost and time necessary to do-it-themselves with the basic microprocessor chip sets.

A corporate decision was accordingly made to develop a microprocessor line called the PM (programmable module), that would be compatible with the company's already extensive line of logic modules. This would offer latitude to the user in selecting either fixed or programmable logic and enhance the variety of modules available for his application.

### Design tradeoffs

In designing the processor family, the engineers stressed the goals of circuit simplicity, low cost, and minimal processing overhead. Another important decision was the selection of commercially available processor chips instead of attempting to develop new, custom devices. The sacrifices in speed and instruction repertoire in standard devices compared to what could have been done in custom ICs were considered insignificant for most potential applications. Also important were the availability and reliability of an ex-

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**Gerald Lapidus** Associate Editor

isting family of processor circuits, which also is second-sourced.

The circuits selected were Intel Corp's 8008-1 cpu chips, which are P-channel MOS devices having a typical instruction time of 12.5 μs and a repertoire of 48 instructions. To these circuits, Digital has added additional functions and interfacing to its standard line of logic modules, and mounted them on circuit boards that are compatible with the standard modules.

Why buy a microprocessor from Digital if it can also be purchased from Intel? Digital answers by holding up its catalog of several hundred M-series logic modules with which the microprocessor already is compatible. With it, the DEC customer can purchase much of the peripheral hardware he may need for the microprocessor system and avoid a major interfacing effort. All such modules are electrically and mechanically compatible with the processor modules.

Intel also offers microprocessor circuits built on standard modules (or the engineer can buy only the IC chips) and like Digital it offers software and program development aids, but it does not provide the variety of standard peripheral modules available from Digital. However, the added features of Digital's product raise the price above that of Intel's.

Therefore, the choice facing the microprocessor buyer comes down to purchasing the lower-cost processor offered by Intel and handling the additional design work himself or spending more on a Digital processor in exchange for the availability of a wide range of compatible, peripheral modules.

Standardizing the interface to external devices was based on considerations relating to cost and usability. Bussing structures similar to those found in the company's minicomputer lines were considered, with a view toward making the processor compatible with Digital's line of minicomputers and peripherals. However, the planners in the Logic Products Group believe that the processors will generally be used in dedicated, stand-alone configurations (having no communications requirements) and therefore the additional hardware cost and system overhead required by these bussing structures would not be warranted. The best choice appeared to be simply to provide data and control signals at external terminals in a standard format, to minimize any special interfacing required by the user. However, since the teletypewriter is almost the universal peripheral device for small computers, the PM designers included a serial line interface for teletypewriters.

In selecting the pc board size, a standard quad module form factor was chosen. Larger areas could accommodate more circuits and therefore provide additional functions, but it was felt that the smaller packages offer greater flexibility and permit the user to satisfy his needs without the necessity of buying more computing power than is necessary. Another reason for the compact size is to assure that the circuit boards fit into as many different types of enclosures as possible.

Because of the small module size, it was decided not to include the memory circuits in the processor module. This also adds flexibility because memory modules may be sized upwards from as few as 256 bytes of 8-bit read-only memory or 1k bytes of random access storage.

## Additional modules added

Four types of modules added to the basic processor were memory (RAM and PROM) modules, the external event detection module, the foundation module, and the monitor/control module. The external event detection module provides for detection of power failure and branching to the appropriate subroutine and it may be used to process external interrupts. In the case of power failure, a signal indicating a low dc supply voltage or the loss of ac power can activate

## Enter the microprocessor module

With circuits, which once would have filled many equipment cabinets, now reduced to a handful of ICs, the formerly awesome computer (in the form of a microprocessor) is today being looked upon simply as a system component, taking its place with power supplies, instruments, transducers, etc. Of course, the similarity exists only in size and possibly cost, not necessarily in complexity or importance. Digital Equipment Corp's embodiment of this component, the PM, includes the Intel 8008-1 central processor chip, a metal oxide semiconductor (MOS), large-scale integrated circuit which is essentially an elementary 8-bit programmable processor. This circuit contains a bidirectional dataport, complete instruction decoding and control logic, an arithmetic unit capable of multiple precision arithmetic, a state counter, an address stack, an accumulator and scratch pad memory, and I/O control logic. The circuits added by Digital to this module support the operation of this LSI circuit with an 800-kHz two-phase clock, an 884.8-kHz clock, a 4-channel input multiplexer, data and memory bus gating, expansion of I/O control and state counts, interrupt and restart control logic, and an asynchronous, full-duplex communication line controller.

The module can buffer and latch 14-bit addresses for memory selection and can be interfaced with up to 16k bytes of read-write and read-only storage. Processing capabilities include 48 instructions with 12- or 50-μs execution times, implemented on chips having 8-bit parallel arithmetic units, seven 8-bit data registers, and stacks of eight 14-bit address registers with program counters to allow seven levels of subroutine nesting.

Semiconductor read-write memory modules can be specified in 1k, 2k, and 4k 8-bit configurations, using Intel 2102 devices. Memories are static so that no clocking or refreshing is necessary, and operation requires only single +5 Vdc power supplies. The modules provide 14-line address decoding, and feature lines for memory-read, memory-write, address expansion, data ready during read, and data accepted during write.

PROM modules feature sixteen 24-pin DIP sockets to accommodate storage increments of 256 8-bit bytes, up to a total of 4k bytes. Intel 1702A chips, which can be electrically programmed and can be erased by exposure to ultraviolet radiation, are used.

a battery backup power source to protect the contents of the random access memory in the event of a power failure and initiate subroutines for an orderly shutdown.

The foundation modules are a series of 16 wire-wrappable circuit boards that provide the user with the ability to build his own logic circuits on boards that are compatible with the processor in terms of physical size and connectors.

The monitor/control module provides testing and readout capabilities for system development and diagnosis. The unit is designed for bench use and can be connected to the processor modules through a standard cable. It provides switches and LED indicators for interrogating microprocessor timing signals, loading of address data, and for display of addresses and memory contents. Internal scratchpad memories and bootstrap routines stored in ROM permit testing of programmable modules independently of memories.

The main reason for building all of the conventional front panel switches, indicators, and associated circuits (for driving readouts and addressing) on a separate module relates to cost savings. Since these processors are expected to be used in dedicated systems, the only occasions in which a front panel is normally used are system development and maintenance. Therefore, the user need purchase only the minimum number of these modules required to service a large number of processors.

Although the limited instruction set and memory capability of the microprocessor keeps the cost low, programming the machine requires the services of a host minicomputer, in this case, Digital's PDP-8. The assembler—run on a PDP-8 with a minimum of 4k words of memory—produces a punched-tape program for entry into the processor (by use of loader program resident in the monitor/control module). The standard PDP-8 PAL editor program provides text editing capabilities.

## Where processors will be used

With cost and flexibility probably the most important factors in selecting a microprocessor system over other approaches, the company cites the following example of a typical application in which a processor would be advantageous.

Consider a control system for a stand-alone industrial machine. A microprocessor specified for one such application—consisting of a single cpu module, 1.5k bytes of programmable read-only memory (PROM), four interface modules, mounting hardware, and a power supply—costs $1330 (in quantities of 100). A typical minicomputer meeting the same requirements would cost $2600 and would require approximately the same interfacing and software effort. Digital further states that if the system designer set out to develop the system beginning with the processor chips alone, the design and fabrication efforts would make the project much more costly. Hardwired logic also would be rejected due to the high costs of circuit development and debugging.

Microprocessors are alternatives to hardwired circuits for many control-oriented functions. Use of standardized programmable components eliminates the need to develop special purpose circuitry, simplifies modifications during product evolution, shifts the focus of design effort from hardware to software, enhances reliability as a result of using fewer components and interconnections, and increases uniformity within a series of products. Such factors yield functional and economic benefits, in the form of greater flexibility, shorter design time, and lower hardware costs. The crossover point between fixed and programmable logic depends on application details, but recent estimates tend to favor microprocessors when the number of packages approximates 40.

A broad class of potential applications involves the use of microprocessors as dedicated controllers, to add intelligence to operating equipment. An obvious example is a data terminal, where local processing can provide high levels of interactivity with operators and can reduce traffic burden on communication channels. Machines for industrial, commercial, and consumer use also are likely candidates. In such cases, the equipment can be given capabilities for adapting to loads or demands, operating in a variety of modes, and performing monitoring and control functions automatically. As an illustration, microprocessors on industrial knitting machines could be used to implement safety interlocks, count pieces for inventory, select stitching parameters and threads, and detect worn or broken needles. Someday, microprocessors on home washing machines will regulate cycle characteristics and detergent usage to match load requirements and water parameters such as temperature or hardness.

Distributed processing for control and communications systems is gaining favor. By placing minimal logic capabilities at points where data are gathered and decisions are applied, burdens and dependence on central processors and communication links could be reduced, resulting in significant overhead savings. The concept is gaining acceptance in the chemical processing industries, for example, where addressable valves can operate in local control loops, requiring only the exchange of priority status messages and set-point commands with control stations.

### A microprocessor on the move

Of the many possible applications of microprocessors in manufacturing, one of the most common may be control of conveyor lines, in which objects or materials are automatically moved from station to station without human intervention.

One such application involves the removal of an empty container from a conveyor belt, placing the container in a loading station, filling it with material, and then placing it back on the conveyor so that it may proceed to the next location. The operating sequence requires vertical and horizontal movement of the container, detection of limit stops, monitoring of clamping positions, dolly traversing, generating a signal when the container has been filled, and counting containers.

This system can be implemented with a complex array of relay logic, but the use of a microprocessor results in considerable saving in hardware cost and greatly improves the system's reliability.

# The energy outlook: ways to go

## The issues are complex; the solutions not obvious. But both conservation and inspiration will play key roles

Most of the knee-jerk scapegoat-seeking that characterized the attitudes of many during the initial months of the energy crisis has apparently passed. In late January, at two different meetings, *Spectrum* found a new, practical approach to the energy crisis being offered—one that didn't try to pit industry vs. industry or Government vs. industry, but that admitted *general* responsibility for our sociotechnical quandary and went on to grope for a consensus policy.

Inevitably, many of the panelists at the two meetings presented predictable positions—particularly when the discussion turned to means of implementing agreed upon objectives—but in terms of those objectives, an undeniable consensus of the participants called for both conservation of energy and the Federally controlled development of new energy sources. And one further intention: to return the price of energy to a figure that reflects its true cost.

These objectives may not seem revolutionary, but the low-keyed gatherings of previously antagonistic interests is. Consider the make-up of the panel of the 1974 IEEE Winter Power Meeting session, "Energy Conservation and the Total Public Interest," held in New York. Under moderator and session chairman Howard C. Barnes of American Electric Power were John H. Gibbons, Director of the Office of Energy Conservation, U.S. Department of the Interior; Louis H. Roddis, Jr., vice chairman of the Consolidated Edison Company of New York; Lawrence I. Moss, president of the Sierra Club; and John W. Simpson, president of Westinghouse Power Systems Company.

An even more extensive mix of interests was represented at the National Academy of Sciences forum, "Energy: Future Alternatives and Risks," held in Washington, D.C. Like Noah, NAS had gathered an ark full of leading figures—engineers, scientists, economists, educators, philosophers, geologists, and environmentalists, among others, all of whom participated in a two-day discussion of the energy crisis, its true nature, complexities, and remedies, both short term and long term.

### Where are we; how'd we get here?

Although neither of the two conferences were called to discuss past sins, neither could completely ignore the causes of the energy crisis. Oddly, perhaps, at both the Winter Power Meeting session and at the NAS convocation, it was a Government spokesman who provided perspective on the roots of the energy crisis.

Thus, in New York, addressing power engineers, OEC director Gibbons noted that the era of "cheap energy," along with its concomitant environmental damage, is gone for good. Simultaneously, in Washington, D.C., William Simon, administrator of the Federal Energy Office, was explaining to the NAS forum:

"At some risk of exaggeration, let me begin by asserting that our energy problems are largely the result of mistaken policies of the Federal, state, and local governments. For years we have been sacrificing the long-run interests of our nation to secure short-run objectives such as unrealistically low prices, wasteful patterns of consumption, and the too rapid application of environmental controls and restrictions. Now, unfortunately, we are paying for these policies."

And Simon's colleague, John Gibbons, went one step further, noting that the U.S. represents but 6 percent of the world population, yet consumes one third of this planet's energy resources. From 1940 to 1960, Gibbons pointed out, the demand for energy in the U.S. doubled, even though the population of the country increased by only 40 percent. With statistics like these, it didn't require a great prophet to predict that a day of unpleasant reckoning was approaching.

But our failure of foresight is clearly attributable to more groups than Government alone. Speaking at the NAS forum, Philip Sporn, consultant and former president of American Electric Power Company from 1947 through 1961, agreed that Federal, state, and local governments had been remiss. He also added to the list: electric utilities for failing to pay enough attention to fuels, gas utilities for overexpanding their gas-heating markets based upon inadequately priced gas supplies, the oil industry for failing to provide a backup for indigenous oil supplies as their reserves began to decline, the coal industry for letting itself be discouraged by talk of coal as an obsolete fuel, and the automobile manufacturers for paying little or no attention to the effect of increasing engine horsepowers on the demand for gasoline.

And underlying many of the energy policies, both in government and in industry, according to NAS guest, Richard J. Gonzalez, consulting economist specializing in petroleum economics, were logical decisions based upon false assumptions. For example, the conclusion of the Cabinet Task Force on Oil Imports in its 1970 report was that "the landed price of for-

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### How to use less oil

In order to dampen demand beyond just the effect of higher prices, very specific measures have to be introduced by government, particularly in connection with personal transportation, says S. Fred Singer, professor of environmental sciences at the University of Virginia, who provided the table on p. 85. In urban areas, a significant increase must be made in the use of buses, small cars must be emphasized, and the automobile load factor must be increased.

One way to accomplish some of these measures is to charge drivers fully for all the external costs that they place upon others through the use of streets for driving and parking, and through the noise and pollution which are inflicted upon pedestrians. In lieu of use taxes for streets, one might have heavy charges for parking, but at the same time provide faster, more convenient bus service.

A measure that would cut consumption considerably and also lower the accident rate would be to raise the driving age from 16 to 18 years. The efficiency of cars can and will increase when the consumer demand becomes clear. Smaller cars are certainly a step in the right direction and can be encouraged by various measures, such as taxes. The load factor of cars can be increased by car pooling which in turn can be encouraged by providing faster lanes for driving or special parking privileges to those cars used for car pools. Intercity passenger traffic and freight transport will go to rail transportation if the proper incentives are provided or if the present disincentives are removed.

In the generation of electricity, the use of oil has increased more rapidly than any other fuel in the past few years, partly because of pollution problems with coal. This trend must be reversed and can be reversed by a more sensible application of emission standards that take advantage of geographical and meteorological factors, without harming the contemplated ambient pollution standards. Ways must then be found for using more coal and nuclear energy for electricity production, and especially for increasing the efficiency of generation from its present 35 to 40 percent to beyond 50 percent. "Dual-cycle systems" based on low-BTU gas produced from coal and using a gas turbine as the first stage may provide the best approach. These systems, which are efficient in small sizes, lend themselves also to the construction of "total-energy systems," which in turn save on transmission costs and provide a way of using waste heat for industrial, commercial, and even residential heating.

Solar energy can and should be used, even at this stage, for hot water in residential and commercial applications. Eventually, it should become economical for space heating and air-conditioning.

Finally, the sensible use of natural gas, especially for residential and commercial space heating, would eliminate a large amount of the fuel oil use in the U.S. But since natural gas is also a fossil fuel in short supply, several steps would have to be taken:

1. Deregulation of the price of natural gas would switch it away from intrastate use and make it economic only for residential and commercial applications, but uneconomic for electric power generation and for process heat in industry.
2. A higher wellhead price would also encourage drilling up of gas fields and searching for gas in deeper formations. Although gas is often associated with oil, deep wells beyond 5000 meters are more likely to contain just gas and would not be pursued unless the price is right.
3. Another large potential resource is the degassing of coal beds, a new and rather unexpected source which should now be economically feasible.
4. A higher cost of gas would also encourage efforts to obtain it from tight formations where underground explosions must be used; from offshore sources where drilling costs and transportation costs are much higher; from Alaska and the Arctic where gas may have to be transported in the form of LNG or in the form of methanol before it can be delivered to the final user.

eign oil by 1980 may well decline and, in any event, not experience a substantial increase."

### Is the energy crisis temporary?

There was relatively little support at the forum for the premise that the energy crisis is temporary and that we would soon return to abundant fuel supplies at low prices. Federal Energy Administrator Simon, for one, said: "The U.S. economy must adapt from a low-cost, abundant energy base to a high-cost, scarce energy base. It is important that the American people realize that the current shortage is not a temporary aberration. Scarce, high-cost energy will be the rule for many years, if not indefinitely. The occurrence of the boycott merely means that we must reorder our priorities and modify our life styles now, and not a few years from now."

Alvin M. Weinberg, recently appointed director of the new Energy Research and Development Office of the Federal Energy Office and another of the NAS forum participants, said that the energy crisis might be temporary if certain technological miracles took place. "Up till now," Dr. Weinberg stated, "our country's social and dynamic structure was based on the assumption of unlimited energy. But the thermodynamic limits, at least in the short term, have caught up with us. If these limits are long-term limits also, then the present social and economic upheavals caused by energy shortages are not temporary transients: they presage a profound change in the way much of our industrial society does its business. If the limits can ultimately be overcome by one or another of the technological miracles I have mentioned [geothermal, fission, fusion, solar, etc.], then what we are experiencing now must be regarded as temporary: we can eventually get back, if not to business as usual, then to business not much less usual then now seems to be possible."

The goal of energy self-sufficiency by 1980, as envisioned in the Administration's Project Independence also had little support. Said Con Ed vice chairman, Louis Roddis, to the IEEE Winter Power Meeting participants: "President Nixon's target date of 1980 for fuel independence and self-sufficiency is unrealistic." To bolster his reasoning, Roddis asserted that the "exotic fuels and systems" are a "long way off." For example, FBRs, nuclear fusion, solar energy, and coal gasification will not solve the problems of 1980—let alone 1974.

A notable exception to Roddis's "majority view-

## Energy conservation measures

| | Immediate | 1975–80 | 1990 |
|---|---|---|---|
| **Transportation** | | | |
| Personal car | Less driving, car pooling | Smaller car, efficient car | Better transit systems and urban design |
| Freight | Greater use of rail | | |
| Aviation | Higher load factors | | |
| **Electric Generation** | Revise rate structure to increase efficiency of utilization | Increase nuclear construction rate | Nuclear breeders |
| | Gas turbines; natural gas, then low-BTU gas from coal | Increase conversion efficiency | |
| | Provide low-pressure steam for heating and process steam | Off-peak power into methanol fuel (fuel cells for peaking power) | |
| **Residential and Commercial** | | | |
| Space heating | Lower temperatures | Include solar<br>Better insulation | Better design of buildings |
| Air conditioning | Use less. Use more efficient units | | |
| Lighting | Use less | Fluorescent | |
| Hot water | Use less | Include solar | |
| **Industrial** | Greater efficiency but also less growth of energy intensive products | Process changes<br>Recycling | |
| | Process steam from electric generating plants | | |

5. Finally, synthetic natural gas (SNG) can be made from coal by a variety of processes. It may eventually be possible to produce it *in situ* and save the mining costs involved in the present production process.
6. But if we want to cut oil consumption and make the U.S. less dependent on imports, then we must oppose the production of gas from naphtha and similar feed stocks, as well as the import of LNG. The latter is especially bad since it involves very large capital outlays which would tie us to using LNG as a base load fuel rather than for peak-shaving.

point" was voiced by NAS guest, S. Fred Singer, professor of environmental sciences at the University of Virginia. He said that he felt the goal was entirely realistic, notwithstanding the doubts expressed by many in the energy community. "In fact," Professor Singer stated, "the goal might be reached sooner than 1980, principally because of the rapid escalation of the costs of energy, and assuming that the present price of oil will be maintained. The higher price will dampen the demand for energy and increase the supply, provided a free market is allowed to operate with a minimum of government interference."

### Will conservation balance supply/demand?

The question of the effectiveness of energy conservation measures seemed, at both meetings, to have raised the most debate. Bruce C. Netschert, vice president, National Economic Research Associates, Washington, D.C., cautioned the NAS forum not to be overly optimistic about the role of conservation in solving the energy problem. He said there could be no doubt that conservation has reduced—and will continue to reduce—demand. But, he stated, it is important to distinguish between the short and long run. In the short run, conservation will reduce demand to the point where it matches available supply because there is no alternative. In the long run, however, according to Dr. Netschert, we need both conservation and increased supply from new domestic energy sources. The reason that, in the long run, demand cannot be reduced to match an inadequate supply is the distinction between conservation measures now being followed and what is economically justified in the long run. The allocation now being applied and the rationing that may follow can, for example, lead to unemployment and loss of income. In the longer run, Dr. Netschert feels, we can conserve our fossil fuels not through allocation or rationing but by the use of alternatives, such as solar energy, and through greater efficiency in energy use. But, he warned, conservation must be pursued as a goal. The lifting of the oil embargo might be worse than its instigation if the result is that the American public clamors for an end to all conservation and a return to *status quo ante bellum*.

If Dr. Netschert's view of the benefits affordable through energy conservation seems cautious, AEP assistant vice president, Howard Barnes' view, at least in regard to some of the current efforts to conserve energy, is critical. According to Barnes, who is also past chairman of the Power Engineering Society, the PES does not approve of some of the popular notions of what constitutes real conservation. For example, it goes along with the elimination of garish and unnecessary nighttime advertising sign illumination, but it certainly would not approve of decreasing the lighting for the elderly who, based on a study of student lighting requirements, would be ill served by such an action. The Society also opposes a curtailment of room air conditioning, since this would have an adverse effect upon the very young as well as the very old during periods of extreme summer heat. And finally, Barnes felt that the commonly held belief that voltage reduction, presently being employed by many utilities, is an energy saver is fallacious; it does not reduce the thermal requirements for heating, cooking —or the needs of industry. Motors just run slower and less efficiently, while the eventual watt-hours remain the same.

But few participants of either of the sessions were as negative as Barnes. Clearly, the U.S. Government has taken a diametrically opposed position, believing that energy conservation can be effective both in the short and long terms. Thus, OEC Director Gibbons presented the power engineers with the following list of short- and long-term measures:

For the short term:

1. Decreased level of illumination in buildings (except in "heat-of-light" equipped structures).
2. Lowering of building temperatures through "night setback" thermostats.
3. Continued year-round daylight-saving time.
4. Surcharges for excessive use of electric energy and heat energy derived from fossil fuels.
5. Mandatory "labeling" program for electric appliances, giving consumer information as to device efficiency and current consumption.
6. "Retrofit" of poorly designed buildings and structures with inadequate thermal insulation.

For the long term (1985–2000 and beyond):

1. A goal for attaining a 50-percent savings by the development of new industrial processes in aluminum reduction, steel smelting, cement manufacture, and other basic industries.
2. Widespread use of electric heat pumps and provision for "interfuel substitutibility" (when a shortage in one fuel develops, the use of a substitute fuel can be almost immediately used by means of a versatile fuel-interchangeable generating, heating, and industrial-process system).
3. Aim for the leveling of peak-load demand periods by more efficient energy allocation (load-leveling techniques that will be more basic-load dependent).

## Meanwhile, back in the home . . . . and office

The cooperation of the public in conserving energy has been widely reported and is apparently paying off. According to Con Ed's Louis Roddis, the statistics are as follows: The company's analysts have projected a 15-percent cut in use of electric energy as essential; so far, about 10 percent of that goal has been realized. He feels (and this viewpoint won't be shared by Con Edison's consumers) that higher unit costs for electric power will "serve as an incentive to customers in trimming their electric energy demands."

Further, less publicized—but equally effective commercial and industrial efforts—are underway. Vice chairman Roddis told the power engineers that inhouse economics are being practiced by Con Edison at its 4 Irving Place (New York City) head office. He also contended, in a mild rebuttal to Howard Barnes' opinion, that, since Con Edison serves a high incandescent lighting load in its service area, voltage reduction does help to conserve energy.

Another example of current industrial efforts was cited at the NAS convocation: a program has been undertaken by E. I. du Pont de Nemours and Company in assisting 110 other industrial organizations to reduce their energy consumption by an average 15 percent. Some other examples given at the forum were: the use of heat exchangers to save heat usually lost in exhaust air in buildings, insulating of steel furnaces, turning off machinery when not in use, and increasing efficiency of energy conversion in electric power generating plants.

Energy conservation measures for the present, for the 1975–80 period, and for 1990 are shown in the table in the editorial box on page 85. The table, and its accompanying interpretation, was prepared by Professor Singer.

## Environmental controls and the energy supply

Here again, some controversy emerged. Chauncey Starr, president, Electric Power Research Institute, told his NAS audience that the gross impact of environmental controls is to impede the availability of energy "by imposing constraints on fuels, increased capital costs, or decreasing utilization efficiencies." The impacts of environmental controls, he said, are determined principally by the availability of commercial technology to meet the requirements.

But in a discussion period that followed Starr's presentation, a member of the audience noted that a recent survey disclosed that delays in nuclear power plant construction were less than 10 percent attributable to environmental constraints. Another discussant emphasized that the real problem was in obtaining the capital to pay the greatly increased costs necessary to meet environmental demands.

The views of these members of the NAS audience were being supported, before the power engineers in New York, by Sierra Club president Lawrence I. Moss. He also stated that nuclear plant construction has not been primarily blocked by environmentalists, claiming that only 3½ percent of such construction has been actively opposed by conservationist groups, while the remainder of the delays and postponements in licensing have been caused by labor difficulties, escalating construction costs, unsafe design, etc. Moss further reminded the power engineers that, in 1969, the trans-Alaska pipeline was rejected on the basis of faulty design and would have ruptured under certain adverse climatic and geophysical conditions.

A more middle-of-the-road position, however, was offered to the NAS forum by Lee C. White, chairman, Energy Policy Task Force, Consumer Federation of America (and former head of the Federal Power Commission from 1966–1969), who said that the need for energy might well require a delay in achieving environmental objectives. But, he cautioned, even though most environmentalists have recognized the legitimacy of the request to delay achievement of some air- and water-pollution-control objectives, it is essential that postponements be on a case-by-case basis rather than across the board. Suspensions should be for a specified term, preferably as short as possible, and effective monitoring should be used.

That compromise is in the air can be no better seen than in Lawrence Moss's surprising position—one that counters the official policy of the Sierra Club of which he is president—in favor of the construction of nuclear generating plants over the return to coal-fired thermal facilities. (Moss, incidentally, holds an M.S. degree in nuclear engineering from M.I.T.) Thus, it can safely be said that nearly all the participants at both the Power and NAS meetings seemed to accept the premise that environmental demands would have to be delayed somewhat or modified to meet the present crisis but that it was vital that we do not return to an environment-be-damned attitude.

## A Federal Department of Energy?

And what of the development of new sources of energy? At the IEEE Winter Power Meeting, the panel seemed more interested in cementing the bonds of friendship than in entering what might have been a pitched battle over the future direction of resource development. Predictably, for example, Westinghouse Power Systems Company president John W. Simpson advocated an increasingly greater dependence upon nuclear generating plants, especially the new generation of fast-breeder reactors that are on the near horizon, asserting that these plants would be environmentally safe, reliable, and capable of generating electric energy at acceptable costs.

As for the Government view, John Gibbons suggested, for the mid-term (1974–1985), that the U.S. concentrate on:

1. Expanding the supply of fossil fuels by better techniques in the strip mining of low-sulfur-content coal, in coal gasification processes, and extraction of oil from shale and tar sands.
2. Stepping up R&D in alternative energy sources such as nuclear fusion, geothermal energy, fast-breeder reactors, and the identification of technologies to decrease energy use per capita.
3. Proceeding with the construction of the North Slope pipeline, and additional pipelines if new deposits are discovered in the Arctic to make this feasible.

But it was at the NAS forum where the overall question of future directions was best discussed. There, many of the forum participants stressed the need for a national energy policy and several suggested a Federal Department of Energy to administer that policy. No one, however, presented the case for such a department more clearly and succinctly than Philip Sporn. He first outlined seven actions that should be taken:

1. Establish a national energy policy as the first and foundation step by setting up an ad hoc commission charged with that responsibility.
2. Obtain a better understanding of energy as a central component in the functioning of a modern society.
3. Add to the supply of oil by: increasing the production rate of our oil wells to the highest level consistent with efficiency; expediting the Alaskan pipeline construction; organizing a crash drilling program on the Eastern and Western continental shelves; setting up three oil-shale demonstration plants in different localities, each of 100 000-barrels-per-day capacity and, as work progresses satisfactorily, upscale by a factor of three, with a goal of one billion barrels of oil per year; and negotiating with the Canadian government and industry to set up a cooperative program, half the oil-shale size as just described, based upon the Canadian Athabasca tar sands.
4. Accelerate the construction of nuclear power by clearing up the environmental tangle; simplifying the siting program for future atomic power by setting up, as a demonstration, three atomic reactor installations using dry cooling towers; streamlining the AEC licensing process; and by accelerating R&D on electrifying main energy application areas, especially heating and transportation.
5. Increase the supply and use of coal with a crash program of ten coal-fired generating plants of 4000-MW capacity each that will each burn 10 million tons of coal from new mines.
6. Increase the supply of natural gas by organizing a crash program on the Eastern and Western continental shelves; setting up three coal gasification demonstration plants (gasifying either coal or lignite), each of 500 million cubic feet per day capacity; and establishing three low-BTU coal gasification plants.
7. Organize a research program to make possible the implementation of the national energy policy as quickly and economically as possible.

Dr. Sporn would put the responsibility for executing his program in a Department of Energy at cabinet level. The main function of the new department would be to give assurance to the country of an always adequate, reliable, and economic supply of energy. Its commissions would have these responsibilities:

A Commission of Liquid Energy would license domestic companies engaged in the drilling, extraction, and gathering of all domestic and foreign crude oil and the building and operation of refineries, both domestic and foreign, including gasification and liquefaction. Also included would be a program for reorganizing the entire business of liquid energy as a regulated utility operation.

A new Commission on Coal would be organized to cover the mining of coal, oil shales, and other oil-yielding minerals as well as the disposal of discarded overburden and residues.

A new Joint Committee on Energy would maintain contact between the Department of Energy and the Congress. The Committee would hold annual hearings at which it would inquire into the performance of the energy industry.

A Research Division would be established that would entrust the responsibility for research to the industry most heavily involved, manufacturers of equipment for that industry, the staffs and laboratories of the Research Division as well as those of industrially organized operations brought in on an ad hoc basis, and educational institutions. The Research Division would issue yearly a report on research and would present it at the annual hearings before the Joint Committee on Energy.

# The mobilengineer

## The IEEE member is a mover: geographically, job-wise, and, sometimes, upward in management

"Engineering is basically a giant jobshop, and the individual engineer has to follow the action to forge a financially and professionally successful career."

Hardly cynical bitterness or the opinion of an irresponsible job-hopper, the advice comes from a veteran engineer (now an engineering manager at a major Long Island aerospace firm) whose resumé lists eight job changes over the past 24 years. The son of noncollege parents, this engineer presents a background—from a small-town childhood to his move to the city to seek not only suitable employment, but continuing technical education and job flexibility—that closely matches the statistical data gathered by IEEE's Manpower Planning Committee in a recent survey of 5000 U.S. members above the grade of Student.

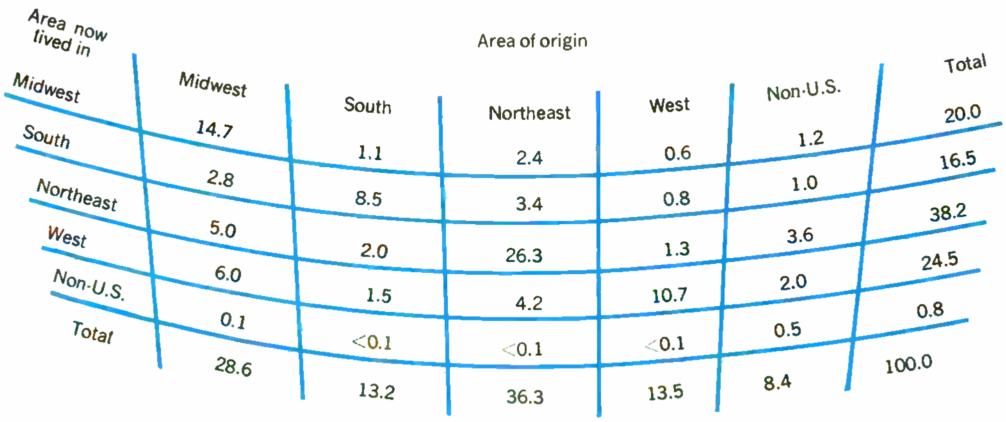
### Family affair

Participants' names were selected randomly from 100 000 addresses, and the surprisingly large number of members who returned their questionnaires (3279) indicates that career patterns are of considerable interest. According to the survey, the typical IEEE member has a median age of 40 and has belonged to the IEEE for 13.6 years. He is a member of at least one IEEE Group or Society (46 percent of the sample even hold membership in some other technical society besides the IEEE) and he has practiced engineering for 16.7 years. He grew up in a rural, small-town, or suburban environment (only 36 percent of the sample came from a city) and his parents are unlikely to have been educated past high school (23 percent completed grade school only and just 29 percent graduated college). Parental occupations break down into:

**Walter R. Beam** Consultant

| | |
|---|---|
| • Professional person | 25 percent |
| • Skilled laborer/craftsman | 24 percent |
| • Merchant or businessman | 23 percent |
| • Semiskilled | 12 percent |
| • Clerical employee | 7 percent |

This family background data seems to suggest that electrical/electronics engineering work is particularly appealing to the young man from a rural or blue-collar family who, with limited means and influence, perceives the career as a likely path to a more sophisticated and rewarding life.



[1] IEEE manpower survey data shows many engineering graduates from Midwestern colleges eventually migrate to the Northeast and West for employment (figures are in percent).

| Area now lived in \ Area of origin | Midwest | South | Northeast | West | Non-U.S. | Total |
|---|---|---|---|---|---|---|
| Midwest | 14.7 | 1.1 | 2.4 | 0.6 | 1.2 | 20.0 |
| South | 2.8 | 8.5 | 3.4 | 0.8 | 1.0 | 16.5 |
| Northeast | 5.0 | 2.0 | 26.3 | 1.3 | 3.6 | 38.2 |
| West | 6.0 | 1.5 | 4.2 | 10.7 | 2.0 | 24.5 |
| Non-U.S. | 0.1 | <0.1 | <0.1 | <0.1 | 0.5 | 0.8 |
| Total | 28.6 | 13.2 | 36.3 | 13.5 | 8.4 | 100.0 |

# What to see at INTERCON '74

## Choose from 40 technical sessions, exhibits from the USSR and other countries, Group/Society programs, and special events

"Getting down to business in 1974" is a fitting theme for INTERCON because of New York's position as a major center of electronics activity. Recent statistics indicate that 40 percent of all U.S. electronics dollar sales are made within a 500-mile radius of New York City, with buyers of materials, components, instruments, fabrication machinery, communications equipment, and computers numbering more than 400 000 in this area.

INTERCON '74 will be held from March 26 through March 29, Tuesday through Friday. The exhibits will be at the New York Coliseum and the technical program at the Statler Hilton Hotel. In addition, a number of special events are planned for Monday, March 25, the day preceding the official opening.

About 250 exhibitors from the U.S. and abroad will fill some 400 booths with products covering the breadth of the electronic industry. On the first floor of the Coliseum will be components, solid-state circuits, production, fabrication, and packaging equipment. On the second will be instrumentation, computers, peripherals, and communications equipment.

Of special interest at the Coliseum will be a display of electronic products and export-import services of the Soviet Union, the first such IEEE exhibit. The V/O Electronorgtechnika (Amtorg Trading Corp of New York) display will cover export and import of general purpose analog and digital computers, peripherals, control equipment, and data acquisition equipment. Products offered only for export include vacuum tubes, discrete semiconductors, ICs, SHF instruments, gas-discharge devices, camera and oscilloscope tubes, multipliers, photocells, ferrite elements, resistors, and capacitors. The United Kingdom, France, West Germany, and Japan will also be represented. In addition, the Coliseum will house IEEE's Technical Film Theater offering nearly 20 outstanding scientific and engineering films on a daily basis. A new feature this year, the Management Film Theater, will show movies written and produced by nationally recognized management analysts, behavioral scientists, and executives. The topics include the effective executive, management by objective, management discontinuity, motivation and productivity, and organization renewal. Since the in-depth treatment of these subjects require film running times of up to two hours, it will not be possible to repeat them. A schedule of showings will appear in the INTERCON program.

The technical sessions begin on Monday with a new feature—special sessions organized by various IEEE societies and groups on subjects ranging from social and economic concerns to design problems. The main event of the technical program will be 40 sessions concentrated in five high-interest subject areas: solid-state electronics, computers and information, instruments, communications, and marketing and finance. (For details refer to "INTERCON '74: getting down to business," *IEEE Spectrum*, p. 90, Feb. '74.) The scheduling of these sessions also is new this year in that the traditional four day program has been concentrated into three days (Tuesday, Wednesday, and Thursday) so that out-of-town visitors leaving on Friday need not miss any sessions.

In addition to the daytime program, two special evening sessions are planned. Monday evening's topic, "Affluence and Effluence," will take up the question of whether an affluent society must also be wasteful. Slated for the following evening is an interesting discussion of parapsychology, covering phenomena for which physical laws do not provide adequate explanations, but which have received the attention of serious investigators.

Other elements of the program are a distributors' conference on Monday, a workshop on manufacturing technology (Monday and Tuesday), and a series of short courses to be held on Tuesday through Friday.

**Gerald Lapidus** Associate Editor

### Where to register, how to get there

Registration booths will open at 8:30 a.m. on Monday (March 25) at the Statler Hilton Hotel and at 8:30 a.m. at the New York Coliseum. Exhibit hours (Coliseum) are 10 a.m. to 6 p.m. on Tuesday, Wednesday, and Thursday, and 10 a.m. to 3 p.m. on Friday. There is no advance registration.

Free shuttle bus service will be provided between both locations at approximately 15-minute intervals from Tuesday through Friday. The first bus will leave at about 9:30 a.m.

The New York Coliseum is located at Columbus Circle, where Broadway and Eighth Avenue intersect (near E. 59 St.). The Statler Hilton is on Seventh Avenue between 32nd and 33rd Streets, across from Pennsylvania Station (the main New York station for Amtrak trains, the Long Island Railroad, and the New Jersey commuter trains). For attendees arriving by car, garage parking in the vicinity of both the Statler Hilton and the Coliseum is in short supply and legal street parking virtually nonexistent. If the parking garages near the Coliseum are filled, drive several blocks north to Lincoln Center and park in its cavernous facilities. Incidentally, it is helpful to remember that Seventh and Eighth Avenues are one-way streets. Seventh Avenue is southbound (downtown) and Eighth Avenue is northbound (uptown).

For those entering New York by bus, the midtown Port Authority Bus Terminal is at Eighth Avenue and 40th Street, not far from the hotel.

# New product applications

## Programmable calculators compatible with standard instruments

The Tektronix 21/53 and 31/53 are calculator-based instrumentation systems using the TEK 21 and TEK 31 programmable calculators, respectively.

The 21/53 and 31/53 enable many of the company's low-cost TM500 series instruments having a BCD output (the DM501, DC501, DC502, and DC503) to be read by the calculator under program control. The calculators may also control external equipment. With these capabilities, the 21/53 or 31/53 can automatically acquire and store data, perform statistical analyses of these data, and list the data on the optional calculator printer. The system also has provisions for powering any of the standard TM500 plug-ins.

Typical of the applications to which these systems may be applied are automatic data collection from laboratory experiments, automatic counting and sizing of produced goods, monitoring of heating and air conditioning efficiency, stimulation and measurement of equipment or component performance, calibration of medical radiotherapy equipment and monitoring of patient vital signs, and monitoring of pollutant levels (with limit alarm provisions).

The system components include the TEK 21 or TEK 31 calculator with any of its presently available options; a modified 3-plug-in TM500 mainframe; an interface plug-in; and software for data acquisition and analysis.

Among the basic features of the system: up to two numerical inputs can be acquired from two digital multimeters or two digital counters; two output signal lines can be activated for controlling external equipment; and a standard software package is provided that can be used for data logging (on printer) and data capture (in TEK 31 calculator registers) with selectable sampling rates.

Capabilities vary depending on which version of the calculator is used and the options that it incorporates. A 21/53 system with a printer can perform the following tasks: data logging on the printer at a preset sampling interval or under operator control; data monitoring and programmed decision making; mathematical operations on input data such as integration, differentiation, transformation, statistical reduction; and output stimulation and regulation of external equipment.

The 31/53 system with a printer can accomplish all of the 21/53 operations plus: direct data capture (3-4 samples per second) in registers, stored for later printout; graphic analysis or computation; extensive statistical reduction and regression analysis of input data; operator prompting and output labeling of interactive operator controlled measurements, such as in calculator based testing and evaluation; and long-term data monitoring and storage of data on magnetic tape.

A single 21/53 or 31/53 system can work with two TM500 plug-ins (housed in a separate cabinet). In most applications, at least one plug-in is a multimeter or counter that will be read by the calculator. The other might be an amplifier (which might be required for use with transducers) or a function generator to stimulate a device under test.

The software, recorded on magnetic media, allows the operator to select the number of samples to be taken, the sampling rate, and data limits to allow data collection to be terminated.

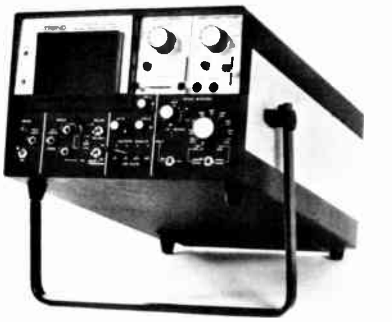
The 21/53 calculator system is priced at $2895 and the 31/53 system sells for $3995 (both about $1100 over basic calculator prices).

For more information, contact Tektronix, Inc., P.O. Box 500, Beaverton, Org. 97005.

**Circle No. 40 on Reader Service Card**

**Calculator driving optional 4661 X-Y plotter in laboratory application.**

## Data signal analyzer separates speed error from distortion



**The Telegraph and Signal Analyzer, manufactured in England by Trend Communications, Inc., has a CRT input data waveform display.**

The Telegraph and Data Signal Analyzer is designed to aid in the installation, evaluation, and maintenance of data communication networks. Typical applications are: to measure the distortion on data-terminal signals; to monitor data exchanged between two terminals when they are in an on-line mode; to measure signal distortion; and to give parity error counts.

The instrument can make three types of error counts. Odd or even parity errors can be counted in 5- or 8-unit start-stop characters. Element or block errors can be counted in a specified pseudorandom pattern, while the total number of blocks received can also be counted—in a second counter—allowing an error rate to be established. Finally, three-character errors can be counted in certain specified message sequences, and a character error-rate assessment made.

The unit can accept both high-level telegraph and low-level data signals. High-level signals can be measured in either series or shunt mode. In shunt measurements, a shunt termination switch can select an impedance of 1K ohms or 100K ohms, accepting signals up to ±150 volts, double current or single current of either polarity, as selected by a front panel switch. In series measurements of high-level signals, a series impedance of 18 ohms is presented and signals of up to ±150 mA can be accepted, double current or single current of either polarity. The input for low-level signals accepts bipolar signals in the 3–25-volt range and has an impedance of 4.7 ohms. The input threshold level is fixed to operate at ±3 volts.

The instrument operates over a temperature range of 2°C to 40°C ambient, in relative humidity between 40 and 90 percent. Dimensions are 6 × 9 × 18 inches. Weight is 25 pounds. Although the unit is portable, the design permits mounting in a standard 19-inch rack. The price, including the error counter option is $2840; without the error counter, $2310. Delivery is 60 days.

For further information, contact W and G Instruments, Inc., 6 Great Meadow Lane, East Hanover, N.J. 07936.

**Circle No. 41 on Reader Service Card**