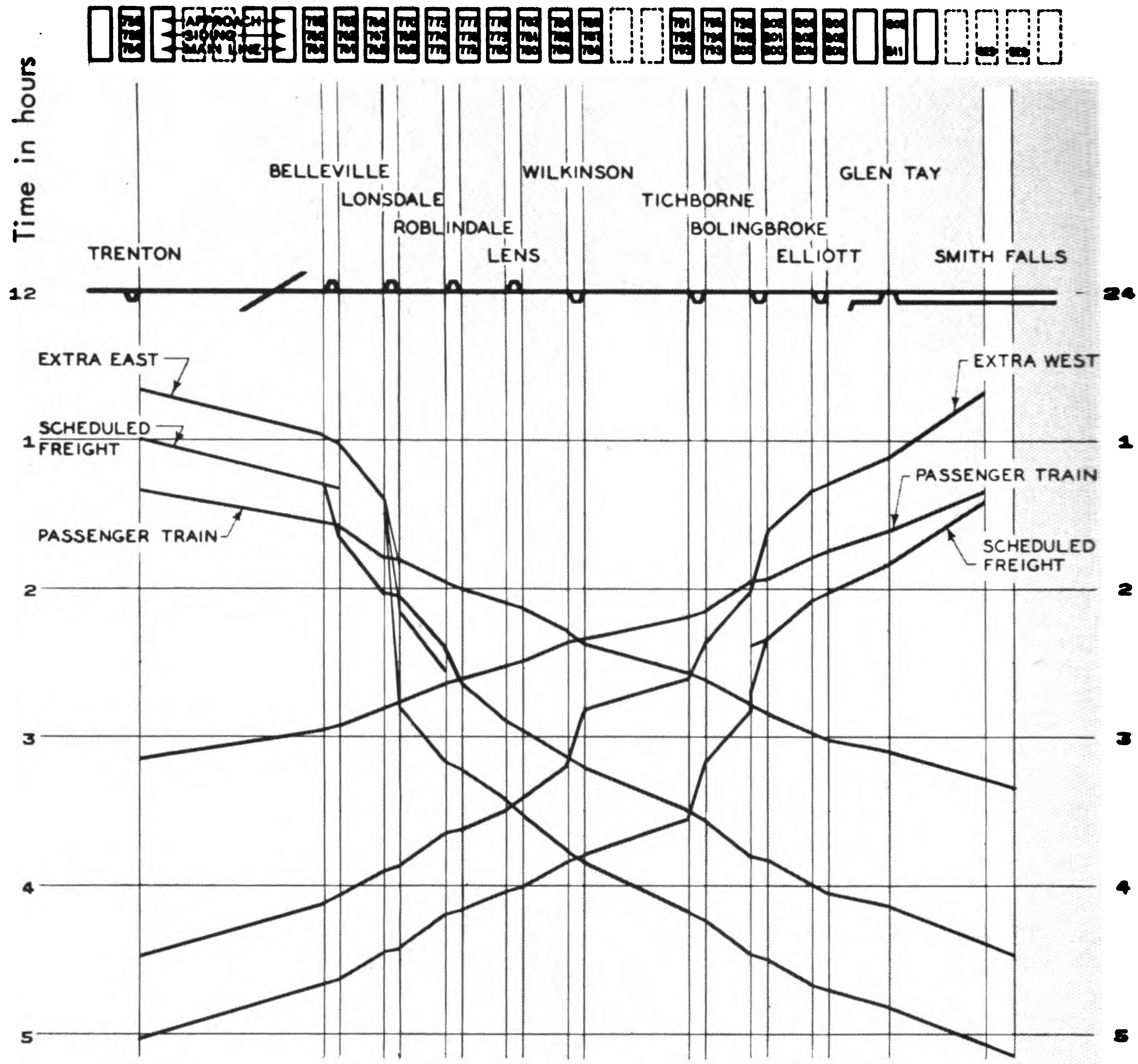


Train graph of the Belleville subdivision of the Canadian Pacific is the basis for the computer simulation of train operations.

Computer Simulates Train Operation

THE IDEA of using computers to predict train performance is not new. For example, prior to 1944, Professor D. R. Hartree employed the differential analyzer at the University of Manchester to study scheduling problems on the British Railways. At about the same time the Pennsylvania used a special purpose analogue computer for producing time-distance curves. Because of the limited capacity of these early machines, each train was dealt with separately and the performance of the railroad as a whole could be built up only by patching together the curves obtained for individual trains. Interferences between trains could not be treated automatically.

With the introduction of medium and large scale automatic data processing machines, it has become possible to simulate the operation of a completely integrated railroad system comprising the tracks, a multiplicity of trains, the signal system, and the operating rules. Stimulated by an inquiry from engineers of the Canadian Pacific, the General Railway Signal Company established a project to investigate the possibilities of using the IBM 650 to simulate railroad operations. The group actively engaged in this work consisted of W. R. Smith, L. L. Garver and R. T. Coupal. In July 1958 a meeting was held in Montreal with Canadian Pacific personnel to discuss the broad objectives of the project. At this time operating data and track parameters for the Belleville subdivision were made available to the GRS group. In September 1958, the first simplified computer program of simulated train movements was completed and demonstrated to the Canadian Pacific engineers. By January 1959 a second, more sophisticated, program was completed. This program is the basis for this article.

DATA FOR PUNCHING CARDS for a complete change in track and signal layout may be prepared from prints of the layout in one-half day.

The computer used in this project may be visualized as comprising three functional units: a magnetic drum memory, arithmetic unit and the program register. The magnetic drum memory has a capacity for storing 20,000 digits (numbers 0 to 9) in groups of ten. Each group with a sign is considered a word, making a total of 2000 words. A word is located on the drum by a 4-digit address. The arithmetic unit performs multiplication, division, addition and subtraction. This unit can locate and use information stored on the memory drum without destroying the information. Further, it is capable of placing the results of its computations in the memory. The program register controls the sequence of operations performed by the arithmetic unit. The program register can recognize when the result of any operation is zero or non-zero, plus or minus, and can also examine any digit of a word for an 8 or 9. With these features, logic may be programmed into the computer. The transferring of information from punched cards into the memory and the punching of information from the memory into blank cards is also controlled by the program register. The sequence of instructions interpreted by the program register is called the program.

RESULTS OF THE COMPUTER PROGRAM

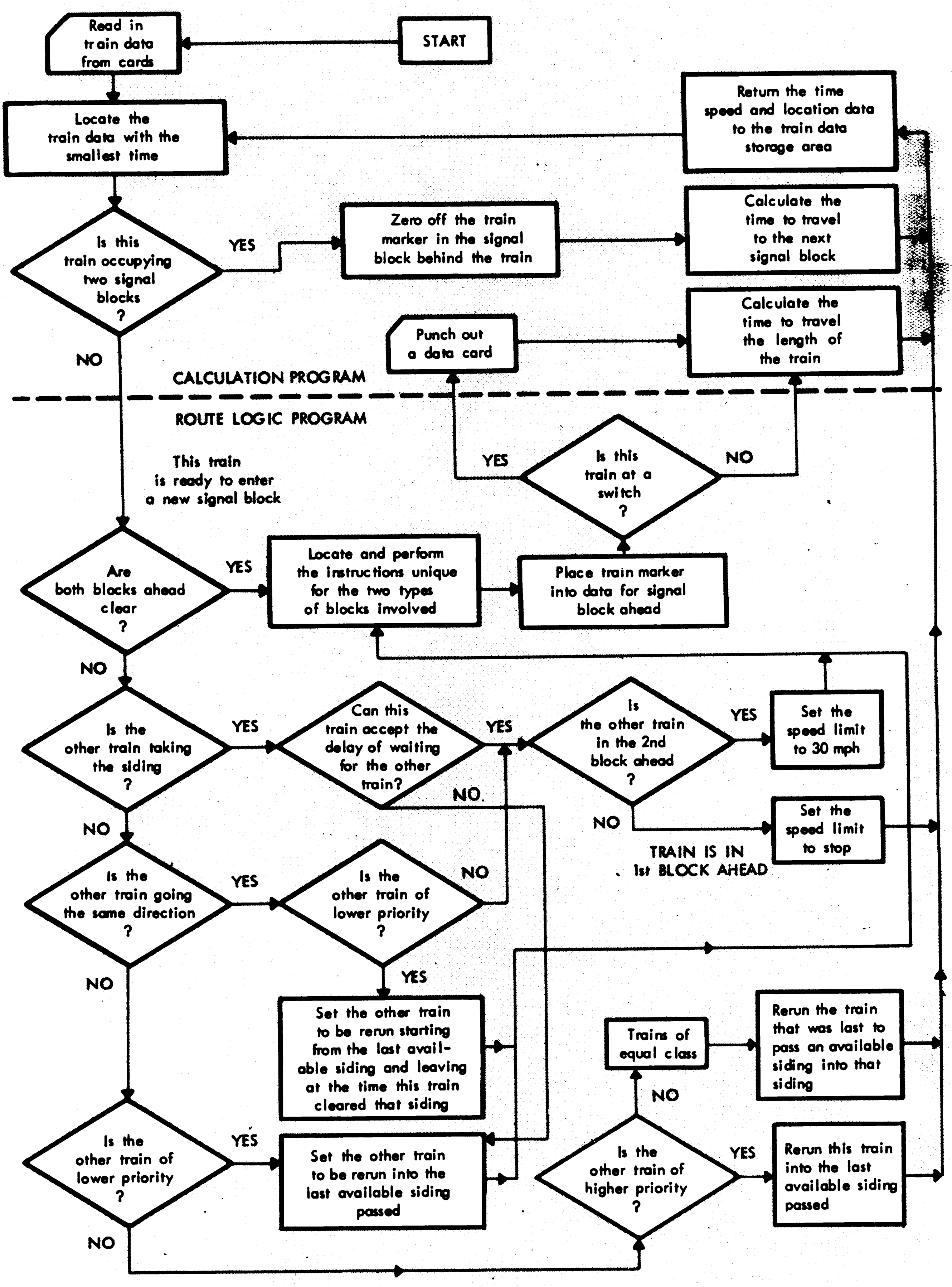
1 **A computer program (list of instructions to the computer) has been devised that is generally applicable to any section of railroad.**

2 **The program has been applied specifically to the Belleville subdivision of the Canadian Pacific. Train graphs have been obtained for a variety of operating conditions. A typical situation (opposite page) represents the movements of six trains over the subdivision in a five hour interval.**

3 **Sufficient experience has been obtained to justify the original belief that simulation by computer is a powerful tool for planning railroad operations. Changes in the signal system, centralized traffic control equipment, track layout, motive power, or scheduling can be tried out without incurring the expense or inconvenience of modifying the real physical plant. The best arrangement can be found and expensive wrong decisions eliminated before actual changes are introduced.**

4 **The IBM 650 requires approximately eight minutes to simulate the movement of one of many trains over 140 miles of track. To simulate traffic over a subdivision for a week would require approximately eight hours. With the IBM 705 available to the Canadian Pacific, this program would operate ten times faster. The additional storage capacity of the 705 offers the possibility of further development of the program.**

Simulation of railroad operation is accomplished in the following way. The railroad is regarded as being divided into sections, the boundaries of which are established by signal locations. These are, of course, the signal blocks. A space on the memory drum is assigned to each signal block. This will be called a memory block. Just as in the case of the actual railroad, the memory block associated with a signal block may be either occupied or unoccupied. Occupancy of a memory block is represented by the presence of a group of four digits called a marker. The marker serves the dual purpose of identifying the train producing the occupancy and giving the location in the memory of data pertaining to that train. As the simulation progresses, markers move from memory block to memory block, into sidings and out of sidings, analogously to the way in which trains



g. 2 Simplified flow diagram of the program logic for the computer that works out train operation.

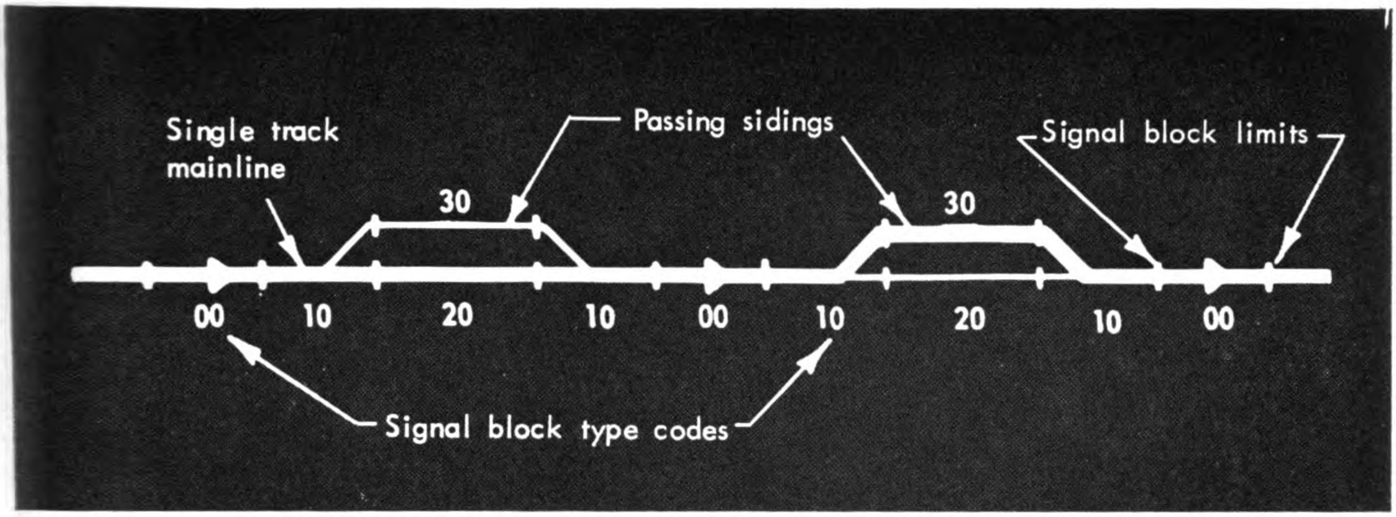
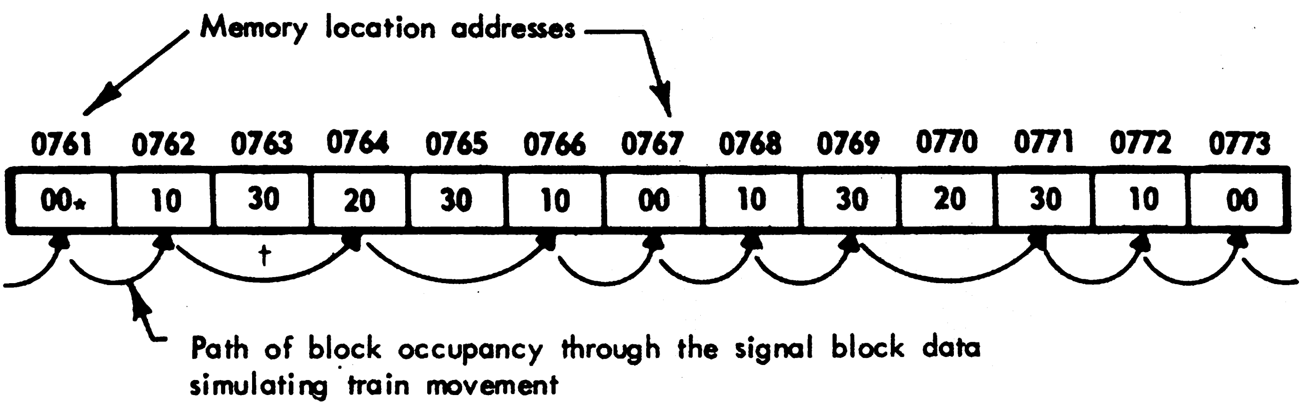


Fig. 1 Heavy line is path of simulated train. Below: * Only first two of 10 digits are shown in each memory location. † Sections not used . . .



. . . by the train are skipped in the memory. Two 30 sections are used to allow 2 trains to use same siding when direction and length permit.

would move on the railroad itself.

Figure 1 illustrates this action. The top diagram shows the track layout. The two-digit numbers associated with the signal blocks are used to describe the character of the block. For example a "00" block is a main line block with no switches; a "30" block is a siding section and so on. The corresponding memory blocks on the computer drum are shown in the lower diagram of the figure. The four-digit numbers above the blocks are simply the addresses or "names" of the memory spaces on the drum. For example memory block 0761 corresponds with the main line block at the extreme left of the upper diagram. Similiarly memory block 0762 is the main line approach block to the left-hand siding.

As an illustration, the heavy line in the upper diagram shows the path of a train to be simulated, while the curved arrows on the lower diagram show the progress of the marker representing that train through the array of memory blocks.

To determine when the markers are to be moved, in other words when signal blocks become occupied or vacated, the progress of the train is computed in accordance with the Davis formula. In brief, the acceleration is calculated by dividing the mass of the train into the difference between the tractive effort and the total resistance comprising both friction and gravity. Increments in speed and displacement are obtained on the assumption that acceleration is constant for a 6-second interval. By summing these increments, it is possible to determine the speed and position of a train at any time.

The most sophisticated portion of the computer program has to do with decisions that are made in accordance with restraints imposed by the signal system and by the operating rules—particularly those rules relating to train priority. Some idea of the kinds of decisions that need to be made and the sequence in which they are encountered can be obtained by examining Figure 2. As an illustration of the constraints imposed by the signal system, it is to be noted that before a marker can be advanced into a block, it is necessary to examine the occupancy of that block and of the next one beyond it in the direction of traffic flow. If these two blocks are unoccupied, the marker can be moved ahead. If on the other hand only one vacant block exists between the marker and a preceding marker, the speed of the train represented by the following marker must be reduced to the approach level, namely 30 mph. In the case of interference between trains having different priorities, the decision making becomes more complex although the logic is well defined.