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THE COMBOMAT

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THE COMBOMAT

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Summary:

The ^{L.C.E.}"COMBOMAT" is a system installed at RAND wherein persons requiring small amounts of computation may set up the work directly for an I.B.M. Card-Programmed Electronic Calculator. These persons are able to get all the information required for use of the system from a short manual in which no previous familiarity with computing machinery is assumed. The Card-Programmed Electronic Calculator setup currently in use employs an eight-place floating decimal and operates on mark sensed cards prepared by the customer. However, it is emphasized that the term, ^{L.C.E.}"COMBOMAT", refers to a system rather than to a particular Card-Programmed Electronic Calculator setup and that the wiring may be as simple or as complex as the installation using the system requires. ||



The Combomat is a system installed at RAND whereby customers with computation jobs which fit into a certain loosely defined class may program the calculations directly for the Card-Programmed Electronic Calculator. That is, any person in the company who has a job in this category may code it for one of the C-P E C setups and submit it directly to the IBM Section for processing, by-passing the procedure preparation which normally takes place within the Numerical Analysis Department. This class of jobs considered appropriate for the Combomat will be discussed later.

Briefly, the process works as follows:

1. The customer marks mark sense cards to accomplish the calculation he requires. These cards are printed for Combomat use.
2. He submits these, along with a form which describes the order in which the cards are to be used, to the IBM Section.
3. A machine operator who is familiar with Combomat work "senses" the cards and expands the deck to a convenient size.
4. The cards are run through the C-P E C and the printed results delivered to the customer along with his original cards.

In theory, the customer obtains all the information required concerning machine operation and coding from a 14-page manual prepared by the Numerical Analysis Department. However, in practice a consultation is usually necessary before a customer's first job is in shape for IBM processing. Quite often the single briefing suffices and the ideal arrangement is reached where the customer submits the cards directly to the IBM Section and no analysis time is required by the Numerical Analysis Department.

The derivation of the name Combomat is somewhat interesting. Some years back when Northrop had the prototype machine it was sometimes called the "Combo". The "mat" suffix comes from words like "laundromat". Instead of paying for both the use of laundry machinery and the services of people who work in the laundry, in a "laundromat" one pays only for the use of the washing machine and the clothes drier. In using the Combomat, rather than employing the services of an analyst plus the "Combo", one buys only the use of the C-P E C plus a minimum of operator time. Hence, a Combomat system makes possible handling of a tremendous number of machine jobs without putting any additional strain on an analysis staff.

At RAND there is a particular need for this kind of service. Not many of the various research divisions have a relatively steady hand-computing work load throughout the year. The load is apt to be light much of the time but extremely heavy at several times during the year. Hence few of the divisions can afford to keep a large staff of hand-computers. The Combomat provides a solution to this problem. It is believed that the Combomat is, in any case, much more economical than a central pool of hand-computers since the C-P E C's are installed at RAND and the regular continuing machine work suffers very little by interrupting it to do Combomat jobs. Every effort is made to get Combomat work done in 24 hours. Generally, jobs which are submitted in the afternoon are processed and out by the next morning. This is made possible by the fact that the RAND IBM Section works three shifts and has two C-P E C's with two identical Combomat setups.

The setup currently in use employs an eight-place floating decimal, where the power of ten is stored beside the number. That is, the actual power of ten plus fifty is stored beside the number. The power of ten is translated fifty units to make certain that any algebraic sign associated with the number and its power of ten represents the sign of the number. This limits the true powers of ten to the range -50 to + 49.

For Combomat work the C-P E C is represented as having only sixteen positions of storage. The manual does not mention the tab storage. This omission is made for two reasons. First, the instructions for use of the system would be somewhat more complicated if an explanation of the two kinds of storage were required. Also, some storage positions must be available to take care of sub-routines which the customer may need.

Operations available to the Combomat customer are multiplication, division, addition, and transfer. The last operation is used for shuffling numbers from one storage to another or from a card to storage. Allowance is made for reading the answer from one card into Channel A, Channel B, or both for the succeeding card. The setup actually has several other operations but it was deemed wise to restrict the operations allowed in Combomat work in the interest of simplicity. In addition to the four Combomat operations, some additional functions of the setup are:

1. Operations which compute $(AB + K)$, $(BK + A)$, $(A/B+K)$, and $(K/B + A)$ where A and B refer to the conventional channels and K must be read from the card.
2. Two special operations which are used in obtaining common logs and antilogs respectively. One of them puts the power of ten associated with a number on the number part of channel C and the other takes a number out of scientific notation separating the whole number and decimal parts.
3. Provision for switching from the ordinary control field to an alternate control field on the basis of a negative balance obtained in the 604. Some means of making a decision is the operation requested most often by customers. With this current method of decision-making a seven column alternate control field is required to make use of the decision. This is not possible with the system of submitting data now in use.

By far the knottiest problem associated with installing a Combomat system is that of writing a useable manual to be distributed to prospective customers. It is extremely difficult for one familiar with the machines to write a manual using language which will be understandable to the layman and yet, unless the writer understands the functions of the setup, he is not really qualified to do the job. The current manual is a third attempt and is still a "preliminary draft". The first draft was tried on some selected members of the Numerical Analysis Department. They prepared a lengthy list of suggested additions and criticisms all of which were then incorporated into the second version. This one received a more general distribution throughout the company and a second list of additions and criticisms was obtained. This second list was screened carefully and all of the changes deemed desirable were made. This gave rise to the present manual.

Several questions arise in installing the system. Perhaps the first is how are the raw data to be submitted? Three methods of presentation were considered. They were: mark sense cards, cards keypunched by the customer on keypunches spotted in the various departments, and manuscripts prepared by the customer for keypunching by IBM Section keypunch operators. Each of the methods has its advantages and disadvantages. The mark sense card system was chosen because it was felt that it would require a minimum of effort on the part of the IBM Section and hence disrupt the flow of regular work least. One disadvantage connected with using mark sense cards is that on the first job submitted by a particular customer often difficulty with the "sensing" is encountered — his marks are either too light or he fails to put some of his marks in the ovals provided. This is a problem which fixes itself as the customer submits more and more jobs. Also, mark sense cards effectively add a restriction of using only 27 columns. It was found necessary to restrict reading in from the card to only one channel because of this. Requiring one and only one mark per mark sense

column so that blank column and double punch detection may be used further restricts the system. The idea of spotting keypunches around the RAND building was eliminated because it was suspected that too much time would be consumed in instructing people in the use of the keypunch and in removing cards jammed in the machine. Further, it was felt that customers would make more errors keypunching than card marking. The manuscript approach was discarded because it did not seem in keeping with the aim of placing as little of the burden of the work on the IBM Section as was absolutely necessary.

Another question which arises is how are the answers to be presented? A listing is a natural product of C-P E C computation so that it is certainly one "painless" method of returning results. Selective listing may prove more useful than listing all cards, however. This has been handled informally through notes on the expansion form. Another possible way of transmitting answers is by summary punching. It was decided to install the system without mentioning this possibility and to see if there was much demand for it. To date the demand has been slight.

Another problem which arises is that of devising a sure-fire completely mechanical system whereby the customer can communicate to the operator the order in which the cards are to be used. At the outset this sounds like a trivial problem since one might argue that a sequence number will suffice. In practice, however, to minimize card marking some of the sub-decks are used over and over again while some are used less frequently and some may be used only once. This makes it imperative to have a communication scheme which is completely flexible. It was found that the section of the manual which explains this scheme, the expansion form section, was the most difficult to write. The word "expansion" is used because the form gives the operator a clue on how many copies of which sub-decks to prepare in order to have a deck of convenient size for running the job. This form actually constitutes a translation of the flow diagram which shows the structure of the calculation. Concentration

on making this section clear "mushroomed" it into the longest section in the manual. Further, more comments of "unclear" have been received from customers regarding this than regarding any other section. It is hoped that this is due to the content of this portion of the paper rather than to how it is written.

A final consideration in installing the system is to what extent sub-routines are to be used. By sub-routines are meant decks already prepared to compute particular functions. The use of these decks is encouraged. In fact, almost every Combomat job processed uses at least one of the sub-routines. The library of such decks was started with a few very basic ones and some have been added as the need has arisen. Mr. Cecil Hastings, Jr. has been of invaluable aid in developing efficient approximations for needed sub-routines. Sub-routines currently available to Combomat customers include $\log_{10}x$, $\log_e x$, 10^x , e^x , \sqrt{x} , $\sin x$ (x in degrees), $\sin x$ (x in radians), $\cos x$ (x in degrees), $\cos x$ (x in radians), $\sin^{-1}x$ (degrees), $\sin^{-1}x$ (radians), $\cos^{-1}x$ (degrees), $\cos^{-1}x$ (radians), $\tan^{-1}x$ (degrees), and $\tan^{-1}x$ (radians).

A few random observations about the system follow:

It is emphasized that the name, Combomat, refers to a system rather than to a particular machine setup - that the setup used may be as naive or as sophisticated as necessary to meet the needs of the installation using the system. One group may feel that a floating decimal with its coding simplifications is necessary while another may feel that it is very willing to substitute log and exponential operations for the floating decimal features. A Combomat system may be used equally well with either setup.

Just as some jobs are better suited for a parallel type of calculation rather than a serial type, some jobs are better suited for Combomat work than others. The ratio of the amount of input required to the amount of arithmetic required is a good index of

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the suitability of the job for Combomat computation. If this ratio is small, the job probably may be done efficiently using a Combomat system. Of course, this is a fairly good index for judging all C-P E C jobs but its value is even more critical in Combomat work since only one number enters the machine at a time. Pilot studies for large machine computations, iterations, and some kinds of small parameter studies are best suited for the Combomat. As far as volume of work is concerned, it is felt that jobs which fit in the large hand computation or small machine computation categories go most efficiently in the Combomat system.

It has been observed that on some Combomat jobs, especially the smaller ones, it pays to do the job "stupidly". That is, it pays in elapsed time with negligible loss in machine time to use the first workable program which occurs to the coder. He may well waste considerably more time than the job warrants in searching for an optimum program. This is emphasized in the manual.

It is felt that the system would be very worthwhile even if jobs were accepted from members of our immediate department only. Many jobs are received which in the past have been considered border-line cases where the calculations may be done about equally efficiently on either desk calculator or IBM machinery. At present, more and more of these jobs are finding their way to the C-P E C within the framework of the Combomat. This occurs because the analyst may do a little rapid coding and "wash his hands" of the job until he is presented with the results.

In April, 191 hours of C-P E C time were logged on Combomat jobs exclusive of the time logged on work for members of the Numerical Analysis Department. Note that this is almost eight full 24-hour days. In May, only 65 hours of such time were logged. The 191 hours were due largely to only two contributors while the 65 hours represented work from more customers.

An example of a small parameter study which was done efficiently with the Combomat is the following. It was required to compute

$$F = P_1 [1 - (1 - C_1 F_1 F_2)^{P_2}]$$

$$\text{where } F_1 = e^{\frac{-P_3 F_3}{C_2}},$$

$$\text{where } F_2 = e^{\frac{-P_1 P_4}{C_3 F_1}},$$

and where F_3 is a polynomial function of P_1 . Here the C 's indicate constants, the F 's indicate computed functions, and the P 's indicate parameters. The routine involved evaluating F_3 , then F_1 , then F_2 , and finally F . This was done for 3660 parameter combinations. The job as coded by the customer took about 30 machine hours. A very similar job done by hand computers in the customer's division took 280 man hours. This job was longer than what is believed to be the optimum length for a Combomat job although it does show a very favorable ratio of Combomat time to hand-computing time.

Another example of an efficient Combomat job is the following. The customer required calculation of

$$\phi_L = \sum_{j=L+1}^{\infty} A_j \rho^{j-L-1}$$

$$\text{and } \phi_L^* = \sum_{j=L+1}^{\infty} j A_j \rho^{j-L-1}$$

where $A_j = (2\eta A_{j-1} - A_{j-2})(j+L)^{-1}(j-L-1)^{-1}$,

$A_L = 0$, and $A_{L+1} = 1$. Here 16 combinations of η , ρ , and L were used. The customer set up the problem so that the inputs

were read in and then a computation deck was run over and over again each time computing terms for each of the summations. This process was continued until a final term was less than a specified value. Summations for each parameter set took approximately ten terms to reach the desired accuracy. One hour of C-P E C time was logged on this job and it is believed that it would have taken much longer doing the work on desk calculators. The fact that this calculation was of a recursive nature made it extremely easy for the customer to code as well.

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