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Data processing of the output from a Vickers M300 clinical chemistry analyser

Principles and implementation

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A suite of data processing programs is described, which takes the results' log from a Vickers Medical Ltd M300 clinical chemistry analyser; corrects phasing errors; allows various types of recalibration (recalculation) of the data; and delivers the results to a general purpose laboratory data filing system (PHOENIX/ACHILLES). An important problem with the data is that results may be unphased with respect to their identification data for mechanical reasons. The principles underlying rephasing, and other requirements for handling the M300 data are described, together with the processes used by the operator.

Deliberately, no ammendments were made to the supported software for the integral computer in the M300 analyser. The new software supplements the analyser by allowing the operator to summarise the corrections to the data which would have been made under manual conditions: the required corrections are then completed by the computer.

About 70 working days were required to complete the programs: this was much more than has been required to program data handling for several other analysers which do not have phasing problems.

Business BASIC Clinical Chemistry Data General NOVA3 PHOENIX/ACHILLES laboratory data processing system Vickers M300

1. INTRODUCTION

A Vickers M300 analyser was installed in this laboratory in 1973, forming part of the routine clinical chemistry service. A report on this installation, and an evaluation of the quality of the results, has been published [1]. When discussing the data processing requirements for the M300 ([1], p. 334), the following opinion was expressed:'Since the analysis results for samples are printed during the run and the ... checks can only be completed afterwards, any correction procedure... must lead to manual correction of reports... There are some facilities for reading the cassette tape, making corrections, and reprinting, but these are time consuming... The present standard package is ... suitable for the basic mechanical operations of the machine...' (abbreviated)

A similar opinion was given elsewhere ([1], p. 326).

While the original intention was to complement the M300 with an adjacent on-line computer, a more realistic analysis, and a desire to bring the benefits of data processing to the rest of the laboratory, have resulted in the use of a separate computer to which data is transferred after the analytical run, using the worktape log written by the M300. The principles which underlie the usability of this log, and the actual implementation of a working suite of programs, form the substance of this report.

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2. SYSTEM ENVIRONMENT — M300 AND COMPUTERS

The M300 is a very fast analyser, completing 1 analytical cycle every 12 s: all the test results for a single sample become available, and are printed, in a single cycle. To achieve this synchronisation of results, the machine is mechanically phased (fig. 1). The pathlength (in machine cycles) between the sampling point (1C) and the point at which the vial accession is read (1E) is arranged to be identical to the pathlength through the main sample distribution system (1F) and every reaction rotor unit (RRU) (1G etc). As the sample spends a longer time in distribution before being delivered to the later RRUs, this requires that later RRUs are set up to have a shorter analytical pathlength. The adjustment of pathlength on an RRU is made by moving the photometer pickup point relative to the sample dispensing position.

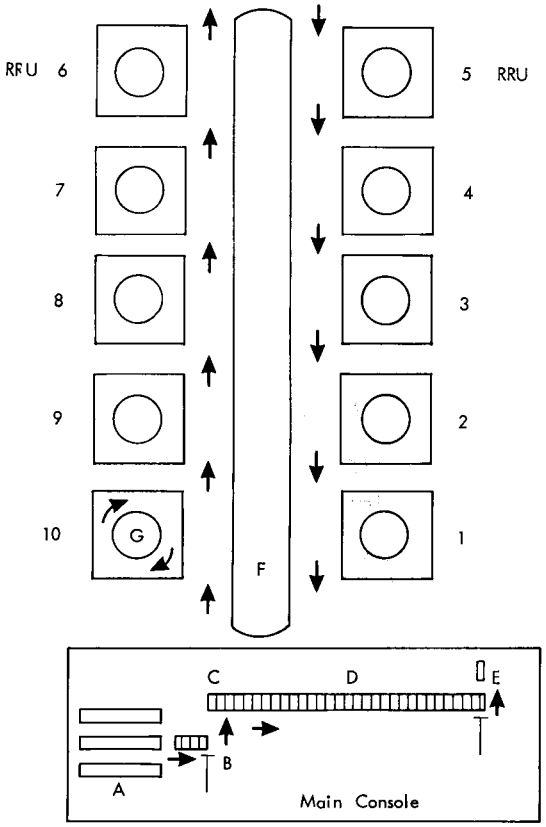

Fig. 1. Schematic layout of the M300 analyser, showing sample transit: (A) vial magazines; (B) vial transfer; (C) vial sampling point; (D) vial track; (E) vial accession reader; (F) sample distribution train (receives samples from C); (G) reaction rotor unit (RRU) (takes samples from F).

By way of comparison, a Technicon SMA6-60 or SMA12-60 is also mechanically phased by the insertion of calibrated delay coils into the flow-path of each channel. On the other hand, a Technicon SMA-II is electronically phased: the integral computer identifies the first result in each channel, and sets of results are defined by relative position in the channel.

Mechanical phasing of the M300 eliminates any requirement for the integral computer to store multiple sets of results, but conversely, greatly increases the complexity of any supplementary programs, because these must now include all the facilities to rephase the results data. The M300 can become unphased during analyses in 2 important ways: by a 'data conservation', and by an 'RRU failure', for each of which there are several detailed causes. It is sufficient to note that the result for a test printed on one report may in fact belong on another report; also that the vial accession shown with one set of results may belong to a completely different set of results on another report. Since the printed report is a subset of the machine log, such problems apply equally to the log and to any data sent to another computer via an on-line connection.

The M300 analyser contains a PDP8 computer, with printer, and a Sykes Compucord CC100 (5 ips) magnetic tape cassette drive [1]. During the analytical run, a machine log is written to a work-tape on the cassette drive.

For general purpose data processing, mainly filing, the laboratory uses a Data General NOVA3 computer, with disk, model 6053 visual display units (VDU), and a Sykes Compucord CC120 (12 ips) magnetic tape cassette drive installed with the CC100 compatibility feature (this uses the longer interrecord gaps needed by the CC100). This cassette drive is not a standard Data General product, but the operating system provides a particularly simple way of writing special purpose device driver programs in Assembler language [2].

The NOVA3 computer runs under the mapped NRDOS operating system, using the Business

BASIC language [3]: a similar language product is available from Data General [4]. The device driver for the cassette is incorporated into BASIC during system generation, and is available to applications programs via the standard Assembler call (UCALL statement). The applications system used is PHOENIX/ACHILLES [5], one of a number of derivations that have been made from the PHOENIX laboratory data processing system [6,7]. The cursor control features of the Data General model 6053 VDUs are widely used in these programs to help the operators by fixing the layouts of data on the screen.

In the following sections, we describe the 4 main divisions of the data processing suite, which has been more extensively documented in [8].

3. M300 MACHINE LOG — CONTENTS, READING PROCEDURE

Provided that the operator has opened the log tape, and set the necessary switches, the M300 will write one tape block of data for every machine cycle. If a data communications interface is fitted, data in the same format will also be sent to the communications line.

The data is derived from 228 12-bit words in the PDP8. An even number of words is essential as each pair of 12-bit words is sent to the tape as a set of 3 8-bit characters; the drive computes and writes additional parity bits, and checks these on reading. When reading, the software expects to receive a synchronisation character followed by the 342 ($228 \times 3/2$) data characters of the block. The reading program collates each set of 3 data characters from the tape, reconstituting them as a pair of 16-bit words in the NOVA3. The 12 low-order bits receive the original PDP8 data, but further processing is required:

(i) To convert 6-bit ASCII character data to 8 bits;

(ii) To convert numeric values which may be negative to make these conform to 16-bit notation.

The precise contents of the recorded data are specified by Vickers Medical Ltd [9]: a relevant summary has been adapted from the specification and is given in table 1, in order of occurrence in the data block. Should it happen that a data error

TABLE 1
Summary of the contents of the M300 worktape log

Field name	Description
RUN	Flag shows whether the M300 was running
DATE, TIME	Each pair of 6-bit ASCII characters for DATE has to be converted to a pair of 8-bit ASCII characters in the NOVA3
VIAL ACCESSION	Several formats are encountered 00000 Baseline calibration vial 99990 Standard calibration vial *****n* Control vial of type *n* (*n*=1–9) *nnnn*0 Patient vial (*nnnn*=0001–4999) *nnn**9 Urine/Dilution vial (*nnn*=001–099) ***** Unlabelled vial or no vial. But, interpreted as end-of-baseline/standard group if immediately following a baseline/standard, respectively
VOLTAGES	Raw photometer voltage from 20 channels (0–1023)
RESULTS	Values from 20 channels. A negative result is possible, and these are converted from 12-bit to 16-bit 2's complement notation by propagating the sign bit.
HEADINGS	Titles for 20 channels: ASCII (see DATE)
UNITS	For 20 channels: ASCII (see DATE)
STANDARD MEAN VOLTAGE	For 20 channels: Valid only post-calibration
DECIMAL POINT	Places for chemistry results for 20 channels
STANDARD GIVEN VALUE	User assigned values for 20 channels
RESULTS MODE	The RESULTS may be in: Raw voltages (RESULTS=VOLTAGES) Difference voltages (above average baseline) Chemistry values (i.e., see UNITS)
MAIN CONSOL	1 bit on/off
RRU STATUS	10 bits on/off
Other	A variety of flags give the status of parts of the M300, and give reasons for failure; generally related to the 'F' series of error codes printed at the M300 console

is encountered on reading the block from tape, the position of the error in the block is noted and the data accepted only for complete data groups before the error. Four data groups are recognised for this purpose:

(i) Including the vial accession;
(ii) Including the voltages;
(iii) Including the results;
(iv) Including all status information.

Data groups not recovered from the tape are set to a default condition: in the worst case, the results for the block in error have to be keyed manually to the main ACHILLES system.

It is imperative that every single machine cycle in the run is logged to the worktape. Ensuring this has allowed us to correct phasing errors even at the start of the run where they affect the normal M300 calibration. The M300 printout then shows bizarre results, but these can be completely recalculated in a few minutes using the recalibration procedures in this suite (see below).

There is considerable redundancy in the log: e.g., every block carries the headings, units, decimal places, and standard given values (see table 1). When the log is read, all this information is recorded once only in a pair of header records on the disk file CAS.IP (fig. 2). Each tape data block is copied to disk, omitting the redundant information which results in a considerable saving in space. Many of the status flags are also omitted. But, specially kept are the flags showing which parts of the M300 (main console and RRUs) were in operation, and a 'data conservation' flag assembled from all the condition flags causing this state.

One particular complication of the log arises because the log for a cycle is written part-way through the following cycle. Should a failure condition occur at the very start of this following cycle, an error flag is set in the log for a cycle which completed quite normally. A favourite situation is for the data conservation flag to be set in a block on the log when the condition arises from a vial transfer jam (fig. 1B) for the next vial to be sampled. The final block on the log also has the RUN flag (table 1) turned off because the log is written after the machine stops.

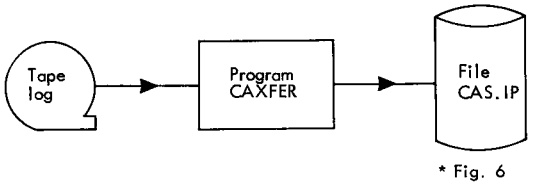

Fig. 2. Reading the M300 tape log into a disk file. Program CASXFER accesses the cassette tape drive via the Assembler language driver (CCDRV) and interrupt handler (CCINT) programs.

4. RESULTS REPHASING — PRINCIPLES AND METHODS

The product from reading the machine log is a disk file (CAS.IP, fig. 2). The data records in this file each hold a vial accession, and results. The objects of this next stage of processing are:

(i) To convert the vial accession into an internal laboratory accession number recognisable in any part of our laboratory;
(ii) To ensure that any results which are out of step with their vial accession are restored to the appropriate records.

To understand how results may get out of step with their correct vial accession, it is necessary to recite the process by which a sample record is normally obtained. Figure 1 shows a schematic layout of the M300 analyser. A vial is taken into the analyser (fig. 1A–C), and the sample from the vial is taken (1C, F), and delivered in turn to each of the 10 reaction rotor units (RRUs) (1F, G etc.). The vial meanwhile passes along the track (1D) to the accession reader (1E). The whole system is mechanically phased so that the results become available from every RRU at the same time as the vial accession is read. Once a sample has been delivered onto an RRU, the result will be measured and stored unless there is an RRU fault causing it to stop.

If the main console becomes jammed, then no more vials are sampled (fig. 1C), no more vials are read (1E), and samples being distributed to the RRUs (1F) progress no further: but, the RRUs continue to process samples already delivered. This is known as 'data conservation', and is shown diagrammatically in the upper part of fig. 3. Any

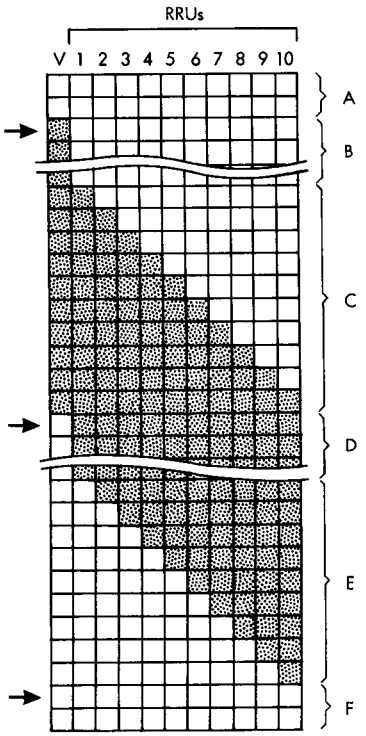

Fig. 3. Diagrammatic representation of the availability of results during data conservation (DC): open squares show available data: toned area shows meaningless data; columns for vial accession (V) and 10 RRUs; rows show successive log records; (A) pre-DC; (B) vial accession not available but RRUs continue; (C) RRUs successively cease to give results, followed by halt; (D) M300 restarted with recovery of vial accessions; (E) RRUs successively recommence giving results; (F) total recovery.

records produced during data conservation will have the DC flag set in the log, and will have results but no vial accession (fig. 3B). Left to itself, the machine will complete the analyses of those samples already delivered to RRUs, and will then stop. During data conservation, the point is reached where there is no longer a meaningful result from RRU-1, as no sample was delivered there. The next record will have no results from RRU-1 and RRU-2. Successive records will have no results for additional RRUs until there are no longer any meaningful results: shortly afterwards the machine stops (fig. 3C). An RRU may be running up to 3 chemistry channels: the correspondence between RRU and chemistry channel determines the appearance of the printout and the place in the log record where these effects are found, but this correspondence does not affect the discussion here which is based only on the mechanical layout.

When the main console has been unjammed, the M300 can be started again, and log records are written with the DC flag off. To start with, vials are passing through the vial reader (fig. 1E), but there are no meaningful results from the RRUs (fig. 3D) because not enough time has elapsed for new samples to be analysed. Thus the vial accessions which should have been read earlier (but were not because of the data conservation) now appear in log records with no meaningful results. A point is reached (fig. 3E) when a meaningful result appears from RRU-1 together with that sample's vial accession. In the next cycle, there will be meaningful results from RRU-1 and RRU-2. In successive cycles there will be additional results until a point of total recovery is reached (3F): the effects of the data conservation have then completely passed through the system.

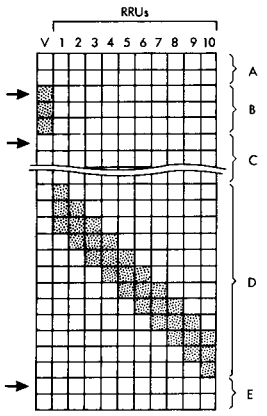

Fig. 4.

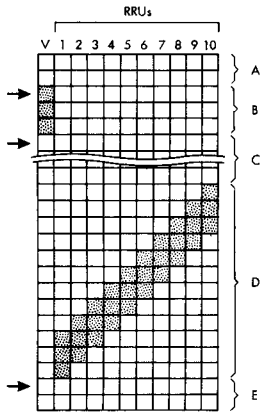

Fig. 5.

Fig. 4. Modification to fig. 3 to show the effect of restarting from data conservation (DC) before all RRU analyses are finished: vial accession (V) and RRU results against time—toned area shows meaningless data; (A) pre-DC; (B) vial accessions not available but RRUs continue; (C) DC cleared by restart but vial accessions do not belong to concurrent results; (D) RRUs stop giving valid results, and then recover; (E) total recovery.

Fig. 5. Modifcation to fig. 4 to show the effect of reversed RRU numbering introduced in later production models of the M300. RRU-10 is the first to stop giving valid results, and the first to recover: (A–E), see fig. 4.

It is permissible to restart the M300 before it has stopped from data conservation. In this case, vial accessions and the reappearance of results will be shifted down only by the number of cycles for which the data conservation condition remained in effect. The modifications which this case introduces to fig. 3 are shown in fig. 4. There will be some records where none of the results belong to the concurrent vial accession (fig. 4B, C), and other records where only some results belong to the vial accession (4D). Once meaningful results start to reappear, they are always associated with their correct vial accession. Figure 4 also shows more clearly that the matching algorithm must slide together the data columns by eliminating meaningless fields, and that the distance of the slide is identical for every column.

Later production models of the M300 (e.g., that installed at St Thomas' Hospital, London) were built with the RRU numbering in the opposite direction to our own. Hence, during data conservation, results are lost first from RRU-10, and last from RRU-1. The modifications which this introduces to fig. 4 are shown in fig. 5. The operator using these programs is specifically asked about the direction of RRU numbering. Adjustments are then made to the algorithm, so that results from either type of M300 can be processed using the same programs.

When the M300 printout was used as the patient's report, a data conservation had to be sorted out manually by crossing out the incorrect values and moving the correct values to fill the spaces. The data processing suite allows the operator to specify the position and length of the recovery slide process, but then completes it in a fraction of the time required for a manual correction. Also, multiple occurrences of data conservation are handled with no extra effort. All these are data movements which operators find very difficult to perform and check manually.

The second reason for results being out of step with their vial accession is an 'RRU failure', the commonest cause of which is mechanical jamming of the RRU. The affected RRU is halted until the problem is solved, and it can then be restarted. Any log records written between the RRU failure, and its restart will have the RRU run flag off.

An RRU failure affects a considerably larger group of results than merely those which should have been printed during the immediate failure period. In this group, some of the first results may be missing because they were not aspirated into the photometer; some of the intermediate results may be wrong: e.g., because none or double quantities of a reagent were dispensed; and some of the last results will be missing because the sample passed the RRU (fig. 1F) without being dispensed onto the RRU. Also, because the RRU stopped while other RRUs continued, the group of results may be relatively shifted in the log records. The exact size of the whole group is a function of the RRU number (position), since each RRU has a different analytical pathlength (see section 2). When the RRU numbering is reversed (see above

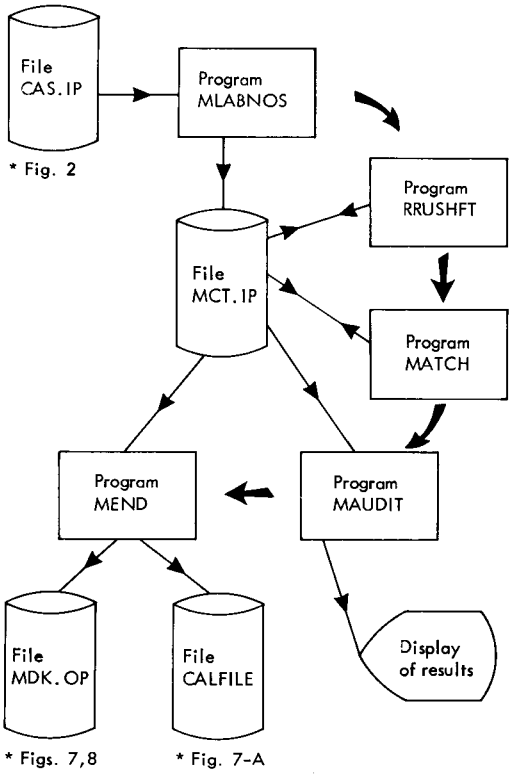

Fig. 6. Rephasing of results. The disk file from the tape log is copied with conversion of vial accession to internal laboratory accession numbers. The data is corrected for any RRU failures and data conservation, and is then written to new output files. The programs must be run in the order shown.

and fig. 4, 5), the size of this group is a different function of the RRU number. A standard operating procedure is adopted locally whereby every RRU runs with its 60-position rotor index matched to every other rotor. In an RRU failure, the affected rotor is always moved to rematch its index position as it restarts. This means that correct results are not relatively shifted in the log, and all that is needed is to delete wrong results. This simplifies the manual correction of results during an RRU failure, but the programs have been written to allow computer processed relative shifting of the results series as an alternative to the physical shifting of the rotor as outlined above.

It is possible for an RRU failure to occur during a data conservation. Results arriving from the failed and restarted RRU may then be incorrectly aligned with the disappearance–reappearance boundaries (fig. 3–5). Correction of the effects of an RRU failure must therefore be completed before the data conservation is dealt with. Otherwise, valid results will be lost completely, and any relative shifting of the results from the affected RRU could not be specified by a single value. These considerations dictate the necessary order of tasks during the processing of the data to ensure correct result phasing (fig. 6).

The information on file CAS.IP is read by program MLABNOS, and processed 1 record at a time. The vial accession is converted to a laboratory number or an alternative defining the ultimate destination of the data (e.g., control, urine). Blank vials retain the identity *****, and are deleted later (see program MEND). As each record is processed, the data conservation flag is examined: if it is set, then the operator confirms the exact start and end of the data conservation (fig. 3–5). For the reasons previously given, the flag is not a perfect guide to these positions. The initially processed output is written to a new disk file MCT.IP.

Program RRUSHFT is run next. It examines the RRU on/off flags (see table 1) for the occurrence of RRU failures. A table of tests establishes which chemistry analyses are being run on each RRU. If an RRU failure is found, the operator may examine the data in the affected group of results; he may shift the results relative to the rest of the log; and he may delete any affected data item. Alterations are made directly to the MCT.IP file.

Program MATCH is run next. It searches for any data conservation states within file MCT.IP (as already confirmed by the operator using program MLABNOS). If any are discovered, then all displaced results are matched with their appropriate laboratory numbers. MATCH handles all single or multiple data conservations without requiring any further operator instructions.

Program MAUDIT can be used to list any records from MCT.IP so that the operator can audit the correct completion of all shifting and matching processes.

Program MEND discards blank accession records (*****), and copies the remainder of the file MCT.IP to a new file MDK.OP. Copies of the voltages from all baseline and standard vials are also written to CALFILE. The results are now correctly phased with one another, and with their correct laboratory accession numbers. Each result is either a numeric value, or a code indicating 'assay failure', the latter arising if results have been deleted because of an RRU failure.

5. STATISTICS AND RECALIBRATION

From this point, results are always considered by test and not by RRU. Results may be inspected, and may be modified. This stage is used to control acceptance of each test column as a complete group, and the processes involved are shown in fig. 7.

The STANDIS program (fig. 7A) displays the baseline and standard voltages held on CALFILE. Mean voltages for each vial group are calculated, and the operator may examine the effect on the means of eliminating outliers. The operator may decide that a test requires recalculation, in which case the mean baseline and mean standard voltage for the test are noted from the display.

The MSTATS program (fig. 7B) locates the control records in MDK.OP and reports the data values for these records, with statistics (mean, standard deviation, number of results) for each control type. This is an improvement on the sup-

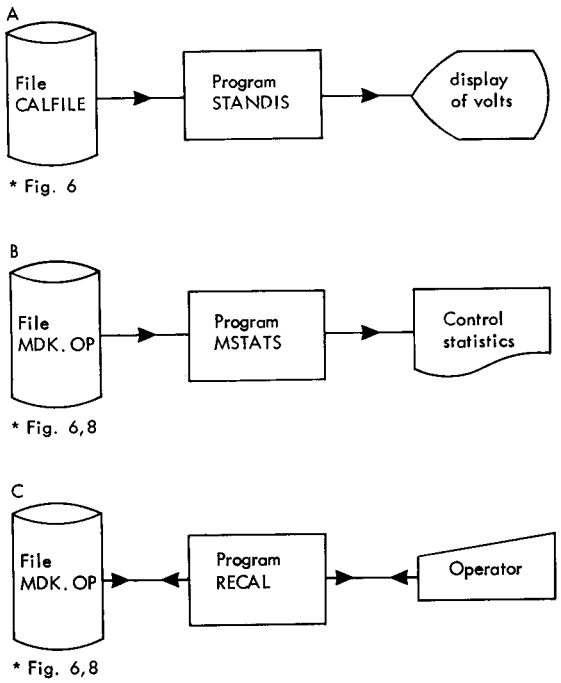

Fig. 7. Statistics and recalibration: (A) display of baseline and standard vial voltages; (B) analysis of statistics on control vials; (C) recalibration of results.

plied M300 statistics program because:

(i) The data is shown;

(ii) The M300 program cannot handle unphased results data.

MSTATS may be run before and/or after any results modifications, and can therefore be used to confirm any changes.

The RECAL program (fig. 7C) allows the operator to perform a variety of modifications to the test data. The operator specifies a test, and also the range of accessions to be affected. Three types of action are then possible. A voltage recalibration requires the entry of a baseline voltage and a standard voltage, while the standard given value is obtained from the original log (table 1): the program recalculates the result data field from the corresponding photometer voltage field.

A chemistry recalibration requires the operator to enter a value in chemistry units which is to be added to the result data field (a negative value effects subtraction): adding a value of zero is a convenient way of examining the data. A substitution changes the result field into:

(i) A state implying 'still requested; i.e., to repeat';
or

(ii) A state implying 'assay failure'; i.e., no repeat';
or

(iii) 'Greater than ⟨value⟩' or 'less than ⟨value⟩' where the operator gives the value to be used.

A feature of all substitutions is that the effect can be limited to a particular numeric range of original results.

6. DISPOSAL OF RESULTS

Figure 8 shows the disposal of the accepted data into the laboratory's general purpose filing system. Three classes of data record are present in file MDK.OP, and these are sent to different destinations by program MOPW.

Data from controls, including baseline and standard vials, are sent to a historical quality control file. They are later salvaged and added to the master quality control records of the M300, which span the complete use of the M300 since 1974. The analysis of the first complete year of these records has been published [1].

Data from urine samples, and any dilutions, are printed, and are recovered by the operator for

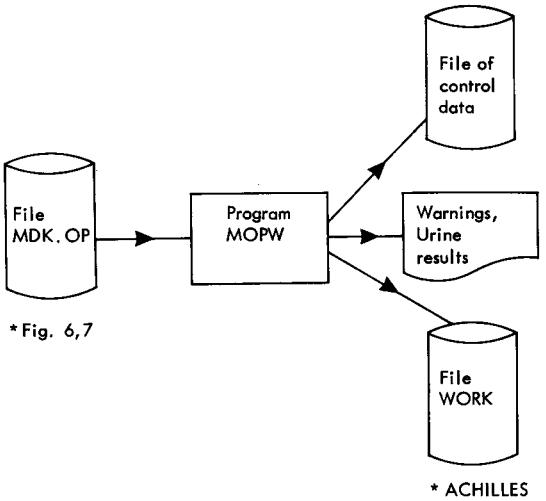

Fig. 8. Results disposal to the PHOENIX/ACHILLES system. Each record from file MDK.OP is delivered to its appropriate output destination.

further calculations before manual entry to the main filing system. These samples are recognised in the log by having vial accessions in the series *nnn**9 (see table 1). Warning messages are also printed if any result lies above the M300 system limit (photometer voltage > 10.20; i.e., higher than can be handled by the analog–digital converter). Dilutions are scheduled for the next run based on these warning messages.

Data from patients' samples are transferred to the WORK file in the PHOENIX/ACHILLES system [5,6]. The data are then subject to all the approval, reporting, enquiry, and other procedures of that system. Where an M300 system-limit warning message is issued for a patient's test (see above), no result is transferred, and ACHILLES expects a repeat analysis to be completed later.

7. DISCUSSION

Early in the production life of the M300, several authors reported ideas for M300 data processing to the Vickers Users Group [10–14]. It is interesting that none of those authors, including M.D.B.S., give any indication of being aware at that time of the complexity of rephasing the results data. In the evaluation from this laboratory, the mechanical failure report for a 3 month period ([1], p. 332) showed 10 events which would cause an RRU failure, and 10 more events which would cause data conservation (also other events which would cause loss of a channel of results or a complete machine halt). It was therefore clear to us from the start of serious design work that rephasing was an essential facility.

As a first principle in supplementing the data processing facilities of the M300, it was decided to make no ammendments of any kind to the software supplied and supported by Vickers Medical Ltd. This ensured that the M300 would always be available as a stand-alone instrument capable of completing and reporting its own work if necessary. In any case, the M300 integral computer has insufficient core store, and none of the random-access backing store which is needed to rephase results data in the way which we have established is required. Other M300 users have adopted larger configurations of the integral computer, and these may be used, e.g., to collate a patient identity with the results. Later production models of the M300 also use the PDP8E and related computers, which are capable of more expansion than the earlier PDP8L computers. In any case, we remain satisfied that it would never have been feasible to write (in PDP8 Assembler language) the equivalent of the software reported here, on any existing configuration of M300 computer.

Figures 2 and 6–8 show that the data being processed is copied successively from file to file. In order of processing these are the tape log, CAS.IP (fig. 2, 6), MCT.IP (fig. 6), MDK.OP (fig. 6–8), until finally the results are placed in WORK (fig. 8). This might seem inefficient and time consuming: each of these disk files (except WORK) is typically > 30 000 bytes in size. However, this progression allows the operator to recover quickly from any erroneous use of the programs by merely restarting one step earlier than the error. There is also a facility for holding complete versions of CAS.IP, which may then be recalled and processed as training exercises. This accustoms the operator to all the program facilities without requiring a steady stream of live problems from the M300 itself!

As far as possible, the terminal dialogue is designed to replicate the decisions which the operator would make in sorting out the data manually. In a manual situation, the operator determines the nature of the fault and its position, and then rectifies it by handwriting moved or revised results onto the reports. With the computer, the programs guide the operator to state what he would have done if using a pen; but the rectification is then completed by the computer. The operator is given ample opportunity to audit the finished product. Not that the operator is allowed unfettered licence. Only series of results which the log shows to be unphased may be rephased. We also took the opportunity to restrict the available result modification functions (program RECAL) to those which we considered valid. Thus, a voltage recalibration is intended to recover from outliers in the baseline or standard vial voltages, and we do not allow the operator to respecify the given value of the standard.

At an early stage, we considered the possibility of making rephasing a completely automatic process. We argued that if one machine could disorganise the data while taking the trouble to log its mistakes, then another machine could quite easily reverse the process. This proved not to be so, even though the principle (reverse cryptography) historically marks the commencement of modern electronic data processing. Lacking a total specification for the M300 operating program, it was necessary to relate empirical observations of M300 function to the contents of the log. Our greatest difficulty was then to formulate an unambiguous set of terms in which to describe and discuss these findings. Even had an M300 emulator been written, it would be put out of date by changes to the supported M300 software, and it would also have been an untestable program in the absence of a guaranteed total spectrum of all possible M300 errors. Therefore, an operator-dependent system remains the only design robust enough for production use.

When the data is moved into the ACHILLES system, each test column of results has passed its quality control checks. The data may still require further checks for the plausibility of each set of results by sample/patient, since flyer results and transpositions may escape quality control checks. It was suggested that a plausibility check program would be useful, but there had not been established in this laboratory any comprehensive multichannel plausibility model which could have been used to pass or reject sets of results. Faced with a requirement to develope both the program and the model, it was clear that the only possible type of program would be an interpreter executing a separate user-declared plausibility model successively on each sample's data. The model would furthermore require its own high-level language, perhaps borrowing elements of SPSS [15] (especially SELECT IF, REJECT IF, COMPUTE, and DO REPEAT), but possibly requiring more complex structures including conditional branches. It became very clear that there was insufficient computer time to process the workload through a plausibility model, using an interpreter, itself written in an interpreted language (Business BASIC [3]).

Many analysers can be relied upon to keep their data phased at the reporting/logging stage, and writing programs to accept their logs has proved much simpler. The quantity of software reported here is certainly not a requirement imposed by the ACHILLES system [5]. Programs to read data from a Technicon SMA-Plus, a Technicon SMA12 -60, a Beckman ASTRA-4, a Coulter-S with differential handsets, and for a Hitachi 706D have each required $\leqslant 1$ week of programming work. In complete contrast, it took ~ 70 working days to design and write this group of programs for the Vickers M300. Much the largest part of the work was in the development of the rephasing procedures. Yet when the M300 works without mechanical failures, none of these rephasing procedures are needed. The M300 analyser remains unbeaten for speed of analysis and quality of results, while the software reported here gives the operators confidence that results can be assigned to the correct samples, and bridges the data to a comprehensive computer filing system.

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