Introduction of a Vickers M300 analyser into the routine service of a hospital laboratory

2 Tests, methods, evaluation

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SYNOPSIS A Vickers M300 analyser has been introduced into a busy hospital laboratory; a profile of 13 biochemical tests is currently provided. Analytical performance has been assessed over one year of routine service operation, and mechanical performance has been assessed over two separate three-month periods. At its best, the M300 achieves high standards of precision and accuracy and has the advantage of unrivalled speed.

Enzyme assay methods are less satisfactory than the kinetic assays in current use. Random analytical errors occur and are difficult to detect. The restricted facilities of the integral process-control computer are inadequate for effective quality control.

The Vickers M300 analyser is a high-capacity, multi-channel, discrete analysis system, designed to carry out up to 20 different chemical tests on each blood plasma sample, operating at a rate of 300 samples per hour. The main features of the analyser have been described, and its performance in a formal evaluation programme reported, by Bick *et al* (1973).

One of these analysers has been installed at the Middlesex Hospital Medical School to provide a routine service to the Middlesex Hospital and its associated hospitals and district. Details of the installation and operation of this analyser are given in the preceding paper (Buckley-Sharp *et al*, 1976).

The purpose of this paper is to report the tests used and the reasons for their selection, the methods used, and the evaluation of these methods in routine use over a period of one year (January to December 1974). In addition, we report two surveys of the mechanical performance of the M300 analyser: the first, in association with other users and with the Department of Health and Social Security (DHSS), was concerned with causes for delays in processing samples; the second, on our own initiative, was concerned with lost results and the need to recalculate results.

Selection of Tests

A decision was made that a full range of tests would

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be provided from the outset instead of gradually working up to full capacity. This simplified liaison with clinical staff. Fifteen methods were selected for preliminary assessment of linearity, precision, and accuracy: these were sodium, potassium, chloride, urea, calcium, phosphate, total protein, albumin, total and direct-acting bilirubin, alkaline phosphatase, aspartate aminotransferase (AST; GOT), hydroxybutyrate dehydrogenase (HBD), cholesterol, and uric acid. After careful consideration, glucose was not included because it was felt that, since measurements are made on unpreserved, and usually non-fasting, samples, the information would be at best of limited usefulness and, at worst, dangerously misleading. The 15 tests were used during a pilot study of the routine service (Buckley-Sharp *et al*, 1976). By the time the full service began for all wards, the profile had been reduced to 13 tests by omitting (a) the HBD on the grounds that this specific 'isoenzyme' was an unjustifiable expense in a general profile, and (b) the direct-acting bilirubin, since most total bilirubin results were normal, and the direct-acting result proved helpful in only a minority of the residual cases.

Methods

Table I shows the current profile of 13 tests, set out in channel order. Paradoxically, channel 1 is the reaction unit at which the sample arrives last. In most cases, the methods are those developed by

Channel Number	Test	Units*	'Normal' Range	Method Note	Vickers Method	Reference
1a	Cholesterol	mg/dl	150-270	Acetic anhydride/sulphuric acid	120	Zurkowski (1964)
1b	Total protein	g/dl	6.3-8.1	Biuret	010	Weichselbaum (1946)
2a, 2b	Uric acid	mg/dl	1.5-6.0	Uricase/copper neocuproine	132	Morgenstern <i>et al</i> (1966)
3a, 3b	Alkaline phosphatase	KA/dl	3-12	Phenyl phosphate	040	Kind and King (1954)
4a, 4b	spare	—	—	—	—	—
5a, 5b	Total bilirubin	mg/dl	up to 0.8	Alkaline diazotisation	110	Jendrassick and Grof (1938) and Billing <i>et al</i> (1971)
6a, 6b	AST (GOT) @ 35°C	iu/l	up to 30	NADH (uv)	—	Henry <i>et al</i> (1960) and Buckley-Sharp (1974)
7a	Calcium	mg/dl	8.8-10.2	Cresolphthalein	090	Gitelman (1967)
7b	Albumin	g/dl	3.2-4.5	Bromocresol green	—	Trinder (1973)
8a	Chloride	mmol/l	91-106	Mercuric thiocyanate	100	Schoenfeld and Lewellen (1964)
8b	Urea	mg/dl	up to 40	Urease/Berthelot	030	Fawcett and Scott (1960)
9a	spare ¹	—	—	—	—	—
9b	Phosphate	mg/dl	2.0-4.0	Malachite green/molybdate	—	Stevens and Yeomans (1975)
10a	'BUI' ¹	—	zero only	OD @ 405 nm	—	Stevens (1974)
10b	Sodium and potassium	mmol/l	132-145 3.3-4.5	Flame photometry	230	—

Table I Tests, units, 'normal' ranges, and methods in use

¹'BUI'—'Blood Unsuitability Index' is processed on chemistry channel 10a, but because sodium and potassium occupy printing channels 10a and 10b, the BUI is printed in channel 9a.

*SI units were introduced in this laboratory only in November 1975.

Vickers Ltd, either unchanged or with only minor modifications.

Blank assays are required for four channels (uric acid, alkaline phosphatase, bilirubin, and AST); one further channel, in fact the one which is anyway spare on the flame-photometer unit, is used simply to read the absorbance of diluted plasma at 405 nm in order to check for haemolysis, lipaemia, or turbidity ('BUI' in table I). Since the flame unit measures sodium and potassium on the same sample, the present profile (table I) occupies 17 of the available (20) chemistry channels.

The method initially used for AST (Vickers method 061) is quite unsuitable. The basic assumptions of that method do not hold at high levels of activity, resulting in high levels giving low or zero results. Details of the method which has been developed to overcome this difficulty (Buckley-Sharp, 1974) will be given elsewhere: it will report activities up to about 200 iu/l (at 35°C), with higher activities consistently flagged as outside the system's limits.

The phosphate method initially recommended used molybdenum-blue, but poor precision resulted from inconsistent dissolution of a protein precipitate. The present method, based on the liberation of dye from a molybdate-malachite green complex, has been substituted and has been reported elsewhere (Stevens and Yeomans, 1975).

Other Methods

A creatinine method is currently being tested on channels 4a and 4b. At present its precision at low levels is not very satisfactory

It is hoped that it may later be possible to include a bicarbonate (total CO₂) assay in place of the chloride, but the cost of the proposed enzymatic method is currently prohibitive.

Methods for glucose using glucose oxidase (Vickers method 140), hydroxybutyrate dehydrogenase (modified from Vickers method 070 for lactate dehydrogenase), and for direct-acting bilirubin were all found suitable for routine use, if required.

Urine Analyses

Where, previously, equipment has been used for both serum and urine analyses, there is some difficulty in transferring the serum analyses to the M300 if the other equipment must be kept ready for urine analyses. After evaluating the relevant M300 methods, urine calcium and phosphate are routinely measured on the M300. Urine urea is not measured on the M300 due to the uncontrolled contribution of urine ammonia to the Berthelot reaction; urine sodium and potassium, often requested with urea, are more conveniently done on a separate flame-photometer. The experimental creatinine method is suitable for urine analyses but the poor precision at low levels rules out its use for clearance measurements. Urine uric acid is infrequently requested in our laboratory and is not done on the M300.

Quality Control Procedures

Calibration of the M300 involves using water-containing vials (baseline) and assayed-serum vials

with stated values for each channel (single-point calibration). This calibration is immediately followed by assayed-serum vials with various levels for each channel, to check accuracy and linearity.

Unassayed pooled horse serum is used to check drifts and to examine within-day precision. Five vials precede the patients' samples: five pairs of vials are scattered among the patients' samples; and five vials follow the patients' samples.

At random points during each run are placed (a) further accuracy-check samples identical with those used immediately after the main calibration (see above), and (b) accuracy-check samples submitted independently by the biochemist in charge of the laboratory (LRW).

After the run a statistical evaluation is made of the drift control samples, and the accuracy check results are entered to cumulative records and inspected.

Analytical Performance

In order to evaluate within-day precision, the laboratory records were extracted retrospectively and the results for the drift control samples scattered among the patients' samples were extracted onto punched cards. Records could not be traced for a few of the days over the period 2 January to 31 December 1974. Where, on a given day, a channel had not been reported due to unacceptable drift, those data were ignored. The collected data were analysed by analysis of variance (ANOVA) using the BREAKDOWN subprogram of the Statistical Package for the Social Sciences (SPSS) (Nie *et al*, 1970; Nie and Hull, 1972): the analysis was by date and therefore pro-

vides within-day variances, converted here to within-day standard deviations. Such analyses make no prior assumptions about the individual daily means.

Table II (part a) shows the results of this analysis. Grand mean and grand standard deviation results indicate the ranges of experience included and hence the typical levels at which the precisions apply.

Inspection of our individual daily standard deviation results (not shown) indicated that the estimates of precision in table IIa were markedly affected by a relatively few days on which very poor precision was achieved. Accordingly, for each channel for each day, provided that at least two samples were available, the daily standard deviation was converted to a standard error, and for each channel the best two-thirds of days (based on lowermost standard errors) were kept for repeat analysis of within-day precision. The results of this analysis are shown in table II (part b). While the ranges of data included, as shown by the grand means and grand standard deviations, are comparable in the two parts of table II, the precision estimates in part b are all significantly better (variance ratio test) than those in part a.

Between-day precisions have been estimated by analysing results from three quality control sera—Versatol Low, Wellcome (latterly the Wellcome Autoset used to calibrate the M300), and Versatol High—included in each run. The data for the period 2 January to 31 December 1974 have been extracted onto punched cards: the batch numbers in use were also recorded. Analysis was again by ANOVA using the BREAKDOWN subprogram in SPSS (Nie *et al*, 1970; Nie and Hull, 1972), but the within-serum-batch standard deviations provide the between-day

Test	Units	Part a: All available data				Part b: Best two-thirds of days			
		Within day SD	df	Grand Mean	Grand SD	Within day SD	df	Grand Mean	Grand SD
Cholesterol	mg/dl	7.36	1784	109.25	21.78	4.77	1269	103.34	19.22
Total protein	g/dl	0.13	1874	6.08	0.57	0.07	1267	6.04	0.57
Uric acid	mg/dl	0.24	1846	5.15	2.11	0.14	1270	4.87	2.07
Alkaline phosphatase	K A/dl	0.84	1826	16.69	4.25	0.50	1276	15.58	3.37
Bilirubin	mg/dl	0.09	1817	0.47	0.25	0.06	1247	0.43	0.23
AST	iu/l	6.15	1761	139.59	36.76	3.76	1279	130.50	32.95
Calcium	mg/dl	0.13	1880	11.26	1.28	0.09	1280	11.25	1.20
Albumin	g/dl	0.09	1881	1.94	0.25	0.06	1270	1.90	0.20
Chloride	mmol/l	1.53	1861	93.43	3.50	0.88	1290	93.35	3.04
Urea	mg/dl	2.51	1838	57.47	12.83	1.23	1264	56.49	13.46
Phosphate	mg/dl	0.14	1842	2.18	0.56	0.07	1297	2.06	0.46
Sodium	mmol/l	1.64	1755	141.29	6.43	1.15	1265	141.02	6.29
Potassium	mmol/l	0.13	1773	4.04	0.29	0.06	1258	4.03	0.25

Table II Analysis of drift control samples to give estimates of within-day precision

The within-day standard deviations, at the stated degrees of freedom, have been obtained from an analysis of variance (ANOVA). The grand means and grand standard deviations show the ranges of experience in these drift control analyses. Part a shows results for all available data January to December 1974; part b shows results from the best two-thirds of days, based on daily standard errors of means for each channel.

precision estimates without making assumptions on the batch mean results. Table III presents the results for each serum giving the between-day standard deviation results together with the grand means and grand standard deviations to show the ranges of experience encountered. Using the list of the best two-thirds of days for each channel, obtained as part of the drift control analyses (see above), the between-day analyses were repeated. There were no relevant changes in the estimates.

Although Versatol sera have published assayed results included with each batch, and although these sera are used for day to day accuracy checks, it was thought that external quality control would be a preferable way to examine accuracy. The laboratory subscribes to both Birmingham ('National') and Wellcome national quality control schemes. All available information was obtained for M300 samples reported back to the laboratory during the 12-month period January to December 1974. The number of results varied slightly by channel. Each reported result was transformed to a deviation, being the signed deviation of our result from the national mean result. For alkaline phosphatase, national results in iu/l were converted back to King-Armstrong units/dl (divide by 7.1): for AST, national results in iu/l at 25°C were converted back to iu/l at 35°C at which level our results are reported (multiply by 1.81). The M300 truncates every printed result to the number of decimal places requested by the operator. Therefore, in forming these deviations, the national means were *first* truncated to the same level: eg, our result 138, national mean 139.8, deviation - 1.

Having formed these individual deviations, their

means estimate accuracy while their standard deviations are further estimates of between-day precision. These results appear in table IV. Combining the Versatol and Wellcome sera daily quality control results of Table III gives composite estimates of between-day precision, with which the standard deviations of the national deviations can be compared. Given the hypothesis that these numbers (n in table IV) of deviation results are drawn from distributions with means zero, and dispersions equal to the between-day precision estimates, then the standard error of the mean for a sample of size n is given by dividing the composite between-day standard deviation by $\sqrt{n}$. If the observed mean deviations are now divided by these standard errors, then the results may be interpreted as z-scores (table IV): thus—

$$z\text{-score} = \frac{\text{Mean deviation} \times \sqrt{n}}{\text{Composite between-day precision}}$$

Consideration of some of the results in table IV appears later, in the discussion.

Mechanical Performance

A log is kept of mechanical failures, but it is used as an *aide-mémoire* rather than an accurate and comprehensive reference. Downtime was specifically surveyed in conjunction with the DHSS, as part of a wider survey of all users. For the purposes of that study, downtime was defined as 'delay or loss of results during a run, the cause of which occurred between the time that specimens entered the laboratory and the time that reports were prepared', while a run was defined as 'a period of operation during

Test	Units	Versatol Low				Wellcome (Autoset)				Versatol High			
		SD	df	Grand Mean	Grand SD	SD	df	Grand Mean	Grand SD	SD	df	Grand Mean	Grand SD
Cholesterol	mg/dl	5.7	233	80.7	6.09	11.0	220	176.0	39.3	11.0	237	186.0	20.4
Total protein	g/dl	0.27	249	3.74	0.28	0.17	235	7.65	0.92	0.26	250	7.74	0.42
Uric acid	mg/dl	0.63	241	3.87	0.63	0.67	224	6.91	1.00	0.60	246	8.29	0.81
Alkaline phosphatase	KA/dl	0.85	238	4.16	0.94	1.6	223	25.8	14.6	2.0	242	23.4	2.38
Bilirubin	mg/dl	0.14	245	0.33	0.15	0.38	233	5.10	0.95	0.37	250	6.02	0.46
AST	iu/l	5.9	219	13.4	6.62	11.0	208	89.3	24.9	7.9	214	79.7	12.0
Calcium	mg/dl	0.17	250	7.33	0.19	0.22	236	11.2	0.44	0.26	252	12.5	0.32
Albumin	g/dl	0.15	250	2.16	0.15	0.16	235	3.07	1.15	0.19	252	4.36	0.22
Chloride	mmol/l	1.7	248	79.4	1.79	1.8	231	105.0	2.12	2.0	249	117.0	2.17
Urea	mg/dl	2.7	247	25.8	2.98	5.9	234	152.0	23.0	7.3	244	163.0	7.48
Phosphate	mg/dl	0.22	242	2.11	0.23	0.33	231	3.94	0.82	0.66	225	8.24	0.69
Sodium	mmol/l	2.2	235	121.0	2.31	2.0	226	146.0	2.45	1.9	238	147.0	2.56
Potassium	mmol/l	0.11	243	2.94	0.11	0.16	228	5.53	0.35	0.17	239	6.90	0.17

Table III Between-day precision estimates for the whole of 1974, based on Versatol and Wellcome sera; each serum shown separately

Precisions are shown as the within-batch (by serum batch number) standard deviations, obtained from analysis of variance (ANOVA). Grand means and grand standard deviations show the range of experience in the analyses.

Test	Units	Range of National Means	n	Deviations		Composite between-day SD	z-score
				Mean	SD		
Cholesterol	mg/dl	142-213	29	+ 6.40	13.8	9.40	+ 3.66
Total protein	g/dl	6.0-7.9	29	+ 0.09	0.12	0.24	+ 2.01
Uric acid	mg/dl	4.5-10.9	23	+ 0.01	0.52	0.63	+ 0.07
Alkaline phosphatase	KA/dl	7.6-19.4	26	+ 1.51	1.87	1.59	+ 4.84
Bilirubin	mg/dl	0.4-0.6	29	- 0.12	0.20	0.32	- 2.01
AST	iu/l	31-72	20	- 3.15	7.28	8.30	- 1.69
Calcium	mg/dl	8.3-12.0	32	- 0.01	0.25	0.22	- 0.25
Albumin	g/dl	3.1-5.6	27	- 0.18	0.18	0.17	- 5.50
Chloride	mmol/l	88-106	30	- 0.20	2.19	1.86	- 0.58
Urea	mg/dl	21-125	33	- 0.70	4.03	5.62	- 0.71
Phosphate	mg/dl	3.5-7.8	32	- 0.06	0.38	0.43	- 0.78
Sodium	mmol/l	121-153	33	+ 0.59	2.89	2.06	+ 1.64
Potassium	mmol/l	3.3-5.7	31	- 0.08	0.13	0.15	- 2.96

Table IV Analysis of accuracy, using samples submitted via national quality control schemes

For each channel is shown the range of national means, mean and standard deviation of the individual deviation results, the composite between-day standard deviation based on all internally used Versatol and Wellcome sera, and the overall z-score (see text) for the year. Data from all of 1974.

which results were actually being analysed'. These definitions therefore exclude any fault, however serious, which was cured without delaying a run. The survey lasted from February to April 1974 inclusive, and the logged events have been classified in table V. There were 42 such events on 61 working days although we have not analysed the occurrence of simultaneous faults. Bick *et al* (1973) noted causes for lost runs and the numbers and proportions of individual results lost. Realizing that our joint survey with other users and the DHSS did not include this information, we conducted a prospective survey to determine the causes and results of mechanical and methodological failures.

Fifty-seven runs involving 7978 patients' samples were included in the survey, which lasted from 1

November 1974 to 31 January 1975. Losses were grouped into (a) total channel loss, where no results were produced for that channel in a run; (b) partial channel loss where results for that channel stopped at some point during a run; and (c) channels requiring re-calculation because of drift or a fault in the main calibration. The error rates varied widely by channel and are shown in table VI. Since sodium, potassium, and urea are guaranteed to be supplied in all circumstances, the loss rates show how much extra work was involved in supplying these results using other equipment. During this time there were many difficulties with flame stability, resulting in considerable drift of sodium and potassium. AST suffered from a reagent failure and later from a bad photometer.

	n	Reaction Rotor Units	n
Main Console		Index/Datum failure	3
Carousel vial collector	3	Probe tip (eg, bent)	1
Vial magazine (eg, jam)	2	Torque on drive too high	1
Dilutor tower	4	Rotor touching covers	1
Vial reader error	4	Syringe/Valve jam	3
Computer and Peripherals		Dilutor tower	1
70 v power switch	1	Photometers	
Interface board	1	Rotary valve jam	1
Form feed on printer	1	Bulb failure	1
Printer went to standby	1	Split vacuum line	1
Sykes cassette recorder	2	Coaxial cable	1
Program corruption ¹	2	Reagents	
Miscellaneous		Ran out (run length)	1
Viols stuck together	1	Deterioration of standard	1
Leaking air line	2	Operator error	1
Total power failure ²	1		

Total: 42 events in 61 working days

Table V Events causing downtime over three-month period 1 February to 30 April 1974

For definition of down-time, see text. Losses of results due to unacceptable precision of accuracy are not shown here.

¹These were most likely caused by power line surges: the PDP-8L has no power fail monitor.

²Due to the local authority drilling through the main supply: this error has since been repeated!

Test	Total Losses			Partial Losses			Drift/Recalculation			Overall		
	Runs	Samples	%	Runs	Samples	%	Runs	Samples	%	Runs	Samples	%
Cholesterol	2	281	3.5	2	111	1.4	0			4	392	4.9
Total protein	0			0			0			0		
Uric acid	1	115	1.4	2	106	1.3	0			3	221	2.8
Alkaline phosphatase	0			2	65	0.8	4	470	5.9	6	535	6.7
Bilirubin	2	290	3.6	1	128	1.6	3	182	2.3	6	600	7.5
AST	3	450	5.6	2	29	0.4	9	519	6.5	14	998	12.5
Calcium	0			0			1	20	0.3	1	20	0.3
Albumin	0			0			2	190	2.4	2	190	2.4
Chloride	0			1	20	0.3	1	20	0.3	2	40	0.5
Urea ¹	2	338	4.2	0			0			2	338	4.2
'BUI'	0			0			0			0		
Phosphate	1	162	2.0	1	3	0.0	2	120	1.5	4	285	3.6
Sodium ¹	3	454	5.7	2	57	0.7	5	394	4.9	10	905	11.3
Potassium ¹	3	454	5.7	2	57	0.7	3	255	3.2	8	766	9.6

Table VI Total channel losses, partial channel losses, drift/recalculations required, and overall failures for each channel

Data from 57 runs, with 7978 samples, showing runs involved, samples involved, and percentages of samples involved.

¹Channel guaranteed to be supplied using other equipment, if necessary.

Table VII shows the mechanical classification of faults during the prospective survey with the numbers of samples and the percentages of all results involved. The faults are similar in nature and number to those shown in table V: both surveys were of the same length of time.

Discussion

The Vickers M300 is a very high capacity analyser. A single run can comprise up to about 400 samples, of which slightly under 350 would then be patients' samples. Acquisition of the necessary work is the only way of making the machine cost-effective (Buckley-Sharp *et al*, 1976), but, so far, our selection of tests has had to be a compromise between the requirements for inpatients of an acute general hospital and the requirements for longer stay inpatients and for outpatients.

The chemical methods suggested by Vickers Ltd were found to be suitable in most cases, and they show linearity over the required ranges. Notable exceptions were the methods for AST and phosphate. The feasibility of certain methods has had to affect the choice of tests, thus, total CO₂ would be preferable to chloride but for the great expense of the former method. The inability to obtain reliable blood glucose values, since any added preservative would affect the results on other channels, is a further disadvantage, but this problem is not unique to the M300. The methods for enzyme analysis (even the modified AST method (Buckley-Sharp, 1974)) are not as satisfactory as modern reaction-rate methods:

Cause	Runs	Samples	% Results Lost
Reagent	2	183	0.18
Syringe	5	324	0.31
Leaks	2	338	0.33
Rotor indexing	2	202	0.19
Blocked reagent line	4	555	0.54
Probe (eg, bent)	2	65	0.06
Flame	2	674	0.65
Other	6	779	0.75
Total	25	3120	3.01
As above, but excluding losses for Na, K, urea		1760	1.70

Table VII Causes for lost results (ie, excluding drifts and recalculations), with numbers of samples affected, and percentages of total results lost

Data from 57 runs, with 7978 samples, expecting 103 714 results.

some work on true kinetic methods for the M300 is in progress at other centres.

The M300 can be efficiently used for some urine analyses, thus freeing other equipment and staff. This applies particularly to calcium and phosphate. The M300 calcium method is linear up to 30 mg/dl (7.5 mmol/l), and most urine calcium assays can be done on neat urine; phosphate and creatinine assays on urine both require that dilutions be prepared.

Precision (both within-day and between-day) and accuracy are adequate, as judged over the whole of 1974, during which time the M300 was providing a full routine service. At its best the M300 is capable of performance equal to or superior to other multi-channel analysers, and it has the advantage of un-

rivalled speed; but there is room for further improvement. Some of the results for within-day precision in table IIa compare unfavourably with those of Bick *et al* (1973). Their results were obtained by formal evaluation while ours are taken from 12 months of routine use. We have removed the effect of outlying 'bad' days (table IIb) to show typical performance.

Alkaline phosphatase does not appear to be very precise, and there is a fairly consistent positive bias ($z = +4.8$). Part of the difficulty with this channel is the range of activity which it is desired to measure. The computer's analog-to-digital converter (ADC) has 10-bit precision (1024 steps), each step corresponding to around 10 mV at the photometer. Photometers do not usually have better precision than twice to three times this level (SD 20-30 mV) so that to use more than about 500 steps is beyond the equipment's normal resolution. To avoid a number of plasma dilutions, our alkaline phosphatase method is set to give values up to about 100 King-Armstrong units/dl with one decimal place, ie, about 1000 steps. There is a compromise between precision and the direct measurement of high levels of activity.

Albumin has shown a consistent negative bias ever since the method was installed. As far as can be seen, the effect is to compute a result of about 90% of the albumin stated by some other methods. While this is not entirely satisfactory, it is at least constant and precise. We have given our clinical users specific information on albumin levels as measured by our M300, including a nomogram for modifying the plasma calcium based on the concurrent albumin result.

Chloride showed some drift during the first half of the year but this has stabilized. Urea suffered from reagent problems also during the first half of the year. Sodium was reading slightly low during the first half of the year, but later there was a marked drift upwards to give the overall positive bias shown. Potassium has read slightly low throughout but this may be due purely to result truncation. The latter part of 1974 was marked by serious problems with the flame photometer.

Mechanical performance of the machine has improved with time, and major breakdowns are infrequent. Careful preventive maintenance is of the utmost importance. The high operating speed copes with delays since even a large workload can be quickly analysed once the fault is corrected. The results for analyses lost during runs (table VI) should not be taken too literally. They demonstrate the order of magnitude of the difficulties but there is a tendency for an individual channel to evolve a problem which then takes a variable time to settle,

after which the channel performs well again.

There is total dependence on quality control checks to ensure that the machine has functioned satisfactorily and that there have been no systematic errors. It may be added that any serious random error involving individual channels for individual samples can be detected only by an experienced observer scanning the individual reports, and possibly not even then.

Since the analysis results for samples are printed during the run and the quality control checks can only be completed afterwards, any correction procedure which is then required on the basis of quality control data must lead to manual correction of reports. Such an arrangement is not compatible with the high workload needed to make the M300 effective. There are some facilities for reading the cassette tape, making corrections, and reprinting, but these are time-consuming. Separate computer power is needed for a more careful surveillance of the M300's operations; the present standard package is, however, suitable for the basic mechanical operations of the machine. Some users of M300 analysers have acquired enhanced configurations of the integral processor: we have made proposals for enhancements using a separate computer to bridge the missing functions on the present M300 to more general purpose laboratory data processing facilities.

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