Papers and Originals

Automation in Clinical Chemistry,* with Special Reference to the AutoAnalyzer†

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Brit. med. J., 1964, 2, 895-899

Several chemical laboratories in hospitals have reported workloads which have been increasing by approximately 15% per annum—that is, doubling every five years—and the trends of the published figures indicate that chemical tests will continue to be required on an increasing scale for a number of years (Wootton, 1962; Eaton and Lathe, 1963; Whitby, 1963). As Wootton (1962) has pointed out, increases in workload can be met by hospital chemical laboratories in a limited number of ways. These are: (1) increases in staff establishment, (2) improvements in the existing manual techniques, (3) use of semi-automatic and automatic equipment, and (4) various combinations of 1, 2, and 3.

Oakley (1964) drew attention to the shortage of trained medical laboratory technicians, and the correspondence which followed publication of his article noted especially the grave shortage of trained technicians in hospital chemical laboratories. It would be difficult, therefore, to handle increasing workloads solely by increasing staff establishments, even if space were available, since trained technicians would have to spend progressively larger parts of their time supervising the performance of more junior members of staff, to the detriment of their other duties.

Considerable increases in efficiency, measured in terms of the number of tests performed daily by each technician, can be achieved by widespread adoption of work-simplification procedures. These include improved administrative arrangements within the laboratory—for example, for the processing and distribution of specimens prior to analysis—as well as the introduction, where appropriate, of auto-zero pipettes, automatic pipettes and burettes, mechanical shakers, flow-cell colorimeters, etc. These applications of work-simplification all constitute a form of automation.

An alternative to work-simplification has been provided by automatic methods, in which some process which was formerly performed by hand is taken over by a machine. Mechanical devices can assist at various stages in analytical procedures—for example, in the manipulations required for chemical reactions to proceed, in the measurement of the intensity of a colour, or in the calculation and presentation of results. One or more of these stages can be performed automatically or semi-automatically, and the degree to which mechanical aids are used in any one laboratory technique determines whether the process can be described as fully or partially automated. Few clinical chemistry laboratories at present make use of fully automated procedures, but many use mechanical devices to achieve partial automation. In this connexion the most important single piece of apparatus which has been introduced in recent years has been the AutoAnalyzer (Skeggs, 1957). The applications of this

instrument featured prominently in two symposia on automatic chemical analyses (Furness, 1960; Johnstone, 1962), and Tárnoky (1961) gave a preliminary review of its effects upon clinical biochemistry in this country. Marsh (1963) states that it is the only apparatus designed for the automatic analysis of individual samples which has been used for a sufficient period in clinical chemistry laboratories to allow a proper rating of its capabilities.

Manual or Automatic

Automated analytical processes offer several advantages to chemical laboratories in hospitals, since their adoption allows repetitive processes to be performed with greater reproducibility, and allows heads of departments to contemplate rising workloads with less need for additional staff and working space, as well as sometimes with relatively small increases in laboratory running costs. Automation, if widely introduced, should make standardization of techniques between laboratories more probable, but the greatest single advantage offered by these processes is that technicians who are less highly trained can, if properly instructed, handle the workload carried by automated equipment with little supervision for the majority of each working-day, thereby allowing skilled staff more time to perform their other duties. These general points in favour of automation need to be taken into account when considering the specific relevant factors which may influence a decision whether to convert a particular manual procedure to its automated counterpart. These specific factors are considered.

Both the size and the distribution of laboratory workload for the test are important. Obviously, a test would be less likely to be considered for automation if it was requested infrequently. Equally, it might be impracticable to use an automated technique to perform a test which, though requested in considerable numbers, was needed sporadically and often urgently throughout the day—for example, blood glucose—unless it was justifiable to allocate a single piece of automated equipment solely to the performance of this test. Most automated laboratory apparatus works best when it can be applied to techniques which can be performed in batches, and it may be possible to plan the work of the laboratory with this aim deliberately in view—for example, Rose (1963).

The size of the workload and the exacting nature of the manual technique have to be taken into account conjointly. Work-simplification may make manual procedures less exacting, and, if only one or two steps of the manual procedure are critical, selected pieces of equipment—for example, automatic pipette, recording spectrophotometer—may improve the repetitive performance of demanding steps, thereby maintaining accuracy when large numbers of specimens are being handled. However, if the technique involves a large number of such steps—for example, some of the colorimetric methods for deter-

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mining activity of serum enzymes—partial or complete automation of the method would be worth considering at a relatively small total workload.

Specificity of methods must be considered, as it is sometimes impossible to reproduce all the steps of manual techniques in the corresponding automated procedures. For instance, Lloyd's reagent was employed to improve the specificity of serum creatinine determinations (Owen, Iggo, Scandrett, and Stewart, 1954), but adsorption of creatinine on Lloyd's reagent is omitted from these determinations when performed on the AutoAnalyzer. However, it may be justifiable to sacrifice some degree of specificity in a method in return for a greater degree of reproducibility, when large numbers of specimens have to be analysed. In contrast to these relatively unspecific automated methods, there are occasions when an automated technique allows tests to be carried out that could not be performed manually. One example of this latter category is the application of the AutoAnalyzer to continuous analysis *in vivo* (Butterfield, Sargeant, and Whichelow, 1964). There may also be techniques that are so exacting that their continued manual performance artificially restricts demand, since the issue of results may be so slow that they come to serve only a confirmatory or educational purpose (Jonnard, 1960); in such instances the introduction of a quicker automated method may reveal a hitherto unsuspected demand for the investigation.

Counting the Cost

When comparing the cost of manual and automated methods the latter may appear at a disadvantage because of large capital expenditure and maintenance and running costs, all of which can be accurately appraised. However, the expense of automated methods must be seen against the saving in salaries of those additional staff who would otherwise have been required, bearing in mind that extra laboratory space would probably be needed earlier and in greater amount to house extra staff than to provide room for additional equipment. Growing staff establishments increase the administrative problems caused by holidays, sickness, resignations, etc., whereas the corresponding disadvantages of automatic instruments—that is, breakdowns—can be minimized by efficient servicing facilities. Economic comparisons of manual and automated methods can be misleading unless they take account of all these facts, but the Abstracts of Efficiency Studies in the Hospital Service No. 31 (1962), which compared the performance of several chemical analyses by manual methods and by the AutoAnalyzer, concluded that economic justification for the purchase of this apparatus was unnecessary if accuracy and reliability of analytical results were of paramount importance. These considerations are of paramount importance in clinical chemistry.

Retention of Manual Procedures

Even after it has been decided to convert a manual technique to its automated counterpart it is advisable to retain alternative manual procedures wherever possible, for the following reasons:

1. To train staff, who may some time need to work elsewhere—for example, in a smaller laboratory which has little or no automatic equipment.
2. For the analysis of emergency specimens. It may take too long to start up an automated technique—for example, the AutoAnalyzer flame unit—for the analysis of a single specimen outside routine hours. Similarly, if a laboratory uses its automated equipment on a time-table—for example, Rose (1963)—it may be inconvenient to interrupt a batch of analyses to perform a single determination of another kind.
3. To cover unforeseeable breakdowns of automatic equipment, so as to allow for the immediate analysis of important specimens at all times.

4. For the analysis of small samples, if the automated method requires appreciably larger volumes than the corresponding manual method. One disadvantage of the single-channel AutoAnalyzer, for instance, was that it often required much more sample than the equivalent manual techniques. This limited its usefulness for paediatric work, but that disadvantage has been partly overcome by the development of multi-channel AutoAnalyzers, by pre-dilution of samples, and by the use of micro-tubing and micro-cells.

The AutoAnalyzer

During the past six years the AutoAnalyzer has come to be widely used in hospital chemical laboratories in Britain. It has proved an invaluable instrument, and it would be no exaggeration to state that the National Health Service now depends in large part upon AutoAnalyzers for the provision of its service requirements for chemical diagnostic tests. Approximately 25 different techniques of importance in clinical chemistry have been adapted with variable success to the AutoAnalyzer, and Skeggs (1960) looks forward to the day when all techniques used in a clinical chemistry laboratory can be applied to the AutoAnalyzer or to other automated apparatus.

The AutoAnalyzer was fully described by Skeggs (1957), and the way it works is considered only briefly here. The instrument consists of a series of components, or "modules," which replace, stage by stage, many of the operations that would otherwise be performed manually in the techniques of clinical chemistry. The first component is a sampler unit, which carries standards and specimens on a turntable, and presents these one by one for analysis. The next component is a multi-channel proportioning pump, which draws samples and reagents into the system by compressing a number of plastic tubes; the different amounts of these various liquids are controlled by the internal diameters of the individual tubes which replace the pipettes of manually performed analyses. In many techniques carried out with the AutoAnalyzer, after leaving the pump, these tubes are joined to form two main streams of liquid, one containing the sample and a suitable diluent and the other containing the reagents for the chemical reaction. The contents of the two streams are each mixed and then pumped at identical speeds through the dialyser component, where deproteinization is effected. In the dialyser, diffusible compounds pass from the protein-containing sample stream across a semi-permeable membrane into the reagent stream; the latter stream of liquid next passes to a thermostated time-delay coil in a heating-bath, where a colour is developed, and the coloured solution then enters a flow-cell colorimeter, the response of which is shown as a continuous record on a chart. The components mentioned in this description are not all required for every type of analysis, and in some determinations other components may be added or substituted.

Individual standard solutions and samples from patients appear on the chart record as a series of peaks. Samples remain discrete during their passage through the different AutoAnalyzer components because (1) they are fed into the system in series; (2) there is an interval between the aspiration of each specimen while the pick-up tube of the sampler unit is aspirating air and the turntable is rotating; (3) non-wettable materials are used for transmitting liquids wherever possible—for example, pump-tubing and connecting tubing; and (4) the fluid stream is not continuous, but is broken up at frequent and regular intervals by bubbles of air (these bubbles are removed before the fluid enters the flow-cell in the colorimeter). The number of analyses that can be performed hourly by the AutoAnalyzer varies with the method, but can be as many as 60.

As commonly used, the AutoAnalyzer does not completely automate the analytical process. Apart from loading samples on to the sample plate, supervision of the instrument is necessary to ensure that it is performing the analyses satisfactorily, and the series of peaks on the record chart has to be identified in terms of the individual samples, and the results have to be

calculated in terms of a standard curve. Two of the main sources of error in the use of the AutoAnalyzer are connected with the identification of peaks and the calculation of results from the recorder tracings. These errors can be reduced by the use of suitable digital print-out devices, or by feeding the voltages from the recorder into a computer (E. Cotlove, 1964; L. C. Payne, 1964: private communications).

The single-channel AutoAnalyzer can often provide an automated alternative to manual techniques when workloads become excessive but few laboratories can afford one AutoAnalyzer for each test. This either implies time-tabling of workloads (Rose, 1963) or use of the twin-channel or multi-channel instrumental complexes, which are relatively less expensive than the equivalent number of single-channel units. Multi-channel instruments allow the various techniques included in the combination to be kept available for longer periods, and are economical of sample when compared with combined demands of single-channel instruments performing the same range of tests.

Multi-channel Machines

Several laboratories in Britain now use four-channel AutoAnalyzers for commonly requested serum electrolyte determinations (sodium, potassium, chloride, and bicarbonate), and Skeggs (1963) has developed an eight-channel instrument which will carry out sequential analyses on a single sample of serum. The results from this eight-channel instrument are presented graphically on a pre-printed chart, which can be torn off and sent to the ward for direct insertion into the patient's notes. Twenty specimens are analysed each hour, including standards and controls, so that theoretically one person can supervise the performance of eight different analyses on approximately 120 samples from patients during an eight-hour working-day.

There are, however, disadvantages in combining too many chemical analyses into one multi-channel automated complex. Not only does the instrument need much greater skill on the part of the operating personnel, but the consequences of even temporary breakdowns can be very far-reaching. Moreover, the eight-channel AutoAnalyzer (Skeggs, 1963) has certain specific drawbacks. The maximum rate of analysis of 20 specimens an hour, for instance, is achieved at the expense of omitting blanks on the determinations of total protein and albumin in serum, whereas Niall and Owen (1961) showed the importance of including these blanks. Furthermore, the analyses include both urea and electrolyte determinations, but urea determinations often have to be repeated on a diluted specimen because of high results in uraemic patients, and dilution of serum specimens disturbs the response of the flame detectors in the determination of sodium and potassium concentrations.

When selecting tests for combination into a multi-channel instrument, account should be taken of how often they are collectively required on individual patients. The eight-channel AutoAnalyzer (Skeggs, 1963) performs the following determinations: albumin, total protein, chloride, bicarbonate, sodium, potassium, glucose, and urea. Requests are frequently received for determination of the four electrolytes and of urea on individual patients, but it is not often that these five determinations need also to be correlated with simultaneous observations of glucose, total protein, and albumin. Apart from the four-channel electrolyte AutoAnalyzer, which is already widely used in hospital laboratories, therefore, it might be worth combining instruments for the performance of "package deals" such as a range of "liver-function tests"—for example, bilirubin, alanine aminotransferase, thymol turbidity, and albumin—or a range of "bone tests"—for example, calcium, phosphate, and alkaline phosphatase—and other combinations could be designed to meet particular requirements.

The main disadvantage of combining several automated determinations, as in the eight-channel AutoAnalyzer (Skeggs,

1963), is the risk taken by a laboratory in placing so much of its total workload on to one comprehensive instrument, and one of the principal advantages of the single-channel AutoAnalyzer is that it causes relatively minor hold-ups in the issue of results when temporarily out of service. An important use of the eight-channel AutoAnalyzer (Skeggs, 1963), or of other large combinations of units which may be developed in the future, could be for the non-urgent analysis of specimens from patients on whom "screening procedures" are being carried out, or for analyses on apparently healthy individuals on whom biochemical "profiles" are being performed as part of regular checks on health. Under such conditions, where there is no immediate pressure for the issue of results, the eight-channel AutoAnalyzer could prove an extremely efficient instrument and a major labour-saver.

In the foregoing discussion, distinction has been drawn between "screening procedures" and "package deals." Many laboratories nowadays offer package deals in which several related tests are carried out whenever any one of that group is requested; the main purpose of package deals is to simplify the handling of large workloads. Screening procedures, on the other hand, involve the performance of a standard group of, say, twenty chemical tests on all patients when first admitted to hospital, no matter what the diagnosis in each patient may be. Some laboratories in Scandinavia are intending to adopt this approach, or have indeed already begun to adopt it (G. Jungner, private communication, 1964), and the practice is regarded as economical in terms of the time of bed occupancy. The justification of "screening" all new admissions to hospital with a range of chemical tests is that, in a large percentage of these patients, some or all of the tests included in the "screen" will be asked for at some stage of the hospital admission. By regularly performing all these tests on all patients as soon as they are admitted, the results of the "screening" tests can be available to clinicians at the earliest possible moment and so assist in the earlier diagnosis of illness.

Both screening procedures and, to a less extent, package deals may detect abnormal results of chemical investigations before a patient has developed symptoms clearly referable to such abnormal results, and this early detection of chemical abnormalities should be of value in medical research. The more widespread adoption of the screening approach and the greater use of package deals could result in a considerable upsurge in the already rapidly rising workloads of hospital chemical laboratories. Such a development will demand even closer attention to the help offered by work-simplification devices and to the possibilities of more complete automation of analytical procedures. In the present context this would probably mean much greater use of the AutoAnalyzer.

Disadvantages of the AutoAnalyzer

Most experience with the AutoAnalyzer in British clinical chemistry laboratories has been with single-channel instruments, and the help they provide in coping with expanding workloads is widely recognized. Some of the disadvantages of the AutoAnalyzer have received less publicity, but need to be considered, as otherwise the foregoing paragraphs might suggest that the wholesale adoption of AutoAnalyzers would solve all the problems facing clinical chemistry in hospital laboratories to-day, at the same time as providing for the growing workloads of the future.

AutoAnalyzer components are expensive. This applies both to the capital cost of new equipment and to the maintenance costs of replaceable spare parts and of major servicing. Some of the high price of new equipment can presumably be attributed to the cost of developmental work, but it is difficult to understand, for example, the discrepancies between the costs of similar recording units obtained from different suppliers; and Shepp, Messerly, and Bornstein (1964) have developed a low-

cost read-out component to replace the colorimeter and recorder normally purchased as part of an AutoAnalyzer.

As an instruction course, the suppliers provide training to a suitably qualified operator from the hospital or department to which an AutoAnalyzer is to be delivered, but the standard training course for hospital chemical laboratories in the United Kingdom covers in detail only the use of the AutoAnalyzer for glucose and for urea determinations, whereas many laboratories are by now employing AutoAnalyzers for a large number of other purposes—for example, for flame photometry. Special instruction courses are arranged for purchasers of complex equipment such as the amino-acid analyser, and there is a place for a wider adoption of this principle. Not every laboratory can afford to send a member of its staff away for one week to attend an instruction course and then allow a long time on his return for him to establish the technique in his own laboratory. Alternatively, follow-up visits by representatives of the manufacturers might be arranged to places where “non-standard” equipment has been recently purchased.

Servicing and Replacements

Once a method has been automated in a laboratory, that department becomes extremely dependent upon the long-term efficient working of the technique, and this demands efficient servicing arrangements. With AutoAnalyzers, instruction in elementary servicing forms part of the training course, and purchasers are told that any major breakdowns, or difficulties that they are unable to correct either in terms of this elementary instruction or from servicing manuals, may be discussed by telephone with a member of the firm. A 24-hour-day replacement service is available by telephone, and parts or components are said to be available for immediate dispatch. Many laboratories, however, having experienced breakdowns could recount incidents where they have had to wait several days for replacements, and this department has certainly had such experience; recently a recorder was out of action for five days pending receipt of a replacement capacitor. It is difficult to communicate satisfactorily with maintenance engineers by telephone, and the suppliers of AutoAnalyzers could reasonably be asked by the Ministry of Health, when negotiating any new central contract, to guarantee a service organization that would provide engineers who could visit laboratories when faults developed. Such an organization would probably need to be offered in addition to the 24-hour-day replacement service already adopted by Technicon Instruments Co., since delays in repair of equipment of any magnitude can be very serious for hospital chemical laboratories. The extreme dependence of this laboratory on AutoAnalyzers, coupled with shortcomings of existing servicing arrangements, has resulted in a decision to carry a complete replacement for each of the components which experience has shown most often give rise to trouble; but this expensive duplication of capital equipment cannot obtain for many smaller hospital laboratories which are probably equally dependent upon these instruments.

Tests in the Field

Several examples could be quoted of methods which have been publicized as being applicable to the AutoAnalyzer before their suitability has been thoroughly established. For instance, the early methods for the determination of serum cholesterol had to be considerably modified as a result of experience “in the field,” and Rose (1963) said that he had encountered difficulties in his first attempts to work a number of the different analyses which he investigated; he stated that modification of the AutoAnalyzer methodology had often been necessary, particularly in the case of calcium determinations. Technical difficulties may therefore constitute another major source of delay in the introduction of a newly purchased AutoAnalyzer which has been

obtained for the automation of a particular advertised technique. “Field trials” in the type of work performed by hospital chemical laboratories are essential, and these can be properly carried out only in users’ laboratories; but it would seem preferable for these field trials to be carried out by private arrangement in a limited number of laboratories before the new technique is widely publicized and instruments are sold specifically to perform these new tests.

Little stress should be placed on the criticism that a particular automated technique may not be as specific when conducted on the AutoAnalyzer as the corresponding manual method that it has replaced. Although this may constitute a definite disadvantage, it is one of the factors which the head of a laboratory should have weighed before deciding to convert a manual technique to its automated equivalent, and is a criticism that is not necessarily peculiar to the AutoAnalyzer. Emergency analyses have already been considered, and provide one of the reasons for the maintenance of alternative manual procedures. They can give rise to questions about analytical specificity if the result of the manually performed techniques do not closely correlate with the results obtained by the AutoAnalyzer. For instance, in grossly uraemic subjects manual and automated techniques do not always agree (Kenny, 1962). It may be necessary, therefore, for each laboratory to record different normal ranges, depending on whether a particular analysis is performed on the AutoAnalyzer on one occasion and by a manual technique on another. This is an unsatisfactory state of affairs, and should not be accepted without question. It suggests that either the manual or the automated technique, or both, merit careful reassessment.

Human Factors

One more disadvantage is considered. It is perhaps the most insidious, but is not necessarily confined to the AutoAnalyzer. Although one of the principal advantages claimed for the AutoAnalyzer is that it can be operated with a minimum of supervision by a relatively untrained technician, faults can creep in during a run of determinations, and it is essential for the operator to be able to recognize these faults, or for regular supervision by more experienced staff to be available. Because minding machines can be so boring (Raffle, 1963) instruments should preferably be rendered completely foolproof and the results of their actions presented in a form which can be immediately entered on to laboratory record cards and issued to the clinician. Skeggs (1960), in fact, looks forward to the time when a completely automatic clinical chemistry laboratory will become a reality, but this ideal will be acceptable only if the automated processes can be automatically controlled (Raffle, 1963), as otherwise the wholesale adoption of automation, in the form of AutoAnalyzers or alternative equipment, will introduce boredom and lead to inefficient and inaccurate running of the automated analytical processes. Another danger of the complete adoption of automated techniques is that the staff required to operate machines will lose, or never acquire, the chemical knowledge and manual dexterity required for other laboratory work, and may thus be prevented from obtaining higher qualifications, or be debarred from employment in other less automated departments.

Discussion

The advantages of automation in hospital chemical laboratories are considerable. At present, apart from work-simplification procedures, it very largely depends upon the use of AutoAnalyzers. The only other instrument with comparable versatility is the Robot Chemist,¹ but this has so far had only limited testing “in the field” (Marsh, 1963) and will not be available for trial on 50-cycle electric current until 1965 at the

¹ Research Specialties Co., Richmond, California.

earliest (R. M. Noller, private communication, 1964). The possible uses of the Robot Chemist were reviewed by Marsh (1963), and it may become a direct competitor of the AutoAnalyzer, although the latter instrument has already established itself and shown its capabilities and limitations during extended periods of use.

Gas-liquid chromatography is another multi-purpose analytical technique which comes under the heading of automation and which will undoubtedly become of increasing importance in hospital chemical laboratories. Already this technique has exhibited its potentialities in the field of steroid analyses and in toxicology, both of which constitute subjects of growing interest to clinical chemists.

As workloads rise, the efficient handling of departmental records becomes increasingly important, if results are to be issued as quickly as possible from the laboratory (Wootton, 1962). Some progress has been made in the application of electronic methods of data-processing, and further advances may be expected in the near future. At the National Institutes of Health (Cotlove, private communication, 1964) a punch-card/electric-accounting-machine system has been in use since October 1962, and a programme has been developed for the transfer of punch-card data to magnetic tape for storage and retrieval in printed formats by means of a digital computer. McKay, Lotito, Seligson, and Wogrin (1964) have adapted a photoelectric colorimeter to a computer programme, using analogue or digital computers singly and combined, and have employed it for haemoglobin estimations. At University College Hospital, London, a computer has been adapted for use with the AutoAnalyzer (Payne, private communication, 1964).

The successful introduction of computers for the handling of chemical laboratory data will remove a major source of error from the conduct of repetitive analyses, and will assist greatly in the more complete automation of these processes. At present, for instance, the AutoAnalyzer automates the chemical part of the analysis, but most laboratories have still to correlate the individual samples with peaks on a record chart, after which results have to be calculated and entered manually in the laboratory records and on report forms. The reading and subsequent calculation of results from the record charts have to be corrected for any drift in the instrument, and there are many stages where errors can occur. Computers can assist with all these problems (Smith, 1964), but their introduction will increase the dependence of chemical laboratories upon complex equipment which will need satisfactory arrangements for servicing and maintenance. As hospitals come to rely increasingly on automation the best way of providing first-class support will have to be decided, and may well demand a central organization of electronic and mechanical service engineers in each major hospital or hospital group, this body of expert staff being provided with the necessary testing equipment and repair facilities and available on a 24-hour-day basis (Alt, 1963).

To justify such expensive developments, so far as clinical chemistry laboratories are concerned, it will become increasingly necessary for people who depend upon the investigative facilities offered by these laboratories to play their part in ensuring that supporting departments can work as efficiently as possible. Most hospital chemical laboratories in this country find that

the bulk of their workload derives from in-patients, and that specimens from these patients arrive sporadically throughout the day. If the advantages of automation are to be fully exploited most of this workload will need to be delivered in the morning to allow systematic planning of laboratory work, and attention to this simple requirement should mean that most of the workload from in-patients will be analysed and reported without major difficulty on the day when specimens are received.

Summary

The advantages of automation in hospital chemical laboratories are considered, and the various factors which need to be taken into account before deciding whether or not to automate a particular manually performed technique are reviewed. The most important semi-automatic instrument at present used by these laboratories is the AutoAnalyzer, and the advantages and disadvantages of this apparatus are considered, in terms of both single-channel and multi-channel instrumental complexes.

It is stressed that some of the disadvantages of automation which have revealed themselves as a result of using AutoAnalyzers on a growing scale are not necessarily peculiar to the AutoAnalyzer, and the importance of adequate servicing and maintenance arrangements is emphasized.

For the future, the growing use of chemical tests for "screening programmes" is forecast, and it is suggested that this will mean that workloads will increase by more than the present rate, which averages approximately 15% per annum. The problem of handling data, which is already well recognized, is briefly discussed in terms of the anticipated application of computers.

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