Increased Rate of Analysis by Use of a 42-Cuvet GeMSAEC[1] Fast Analyzer

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Sample analysis rate for a GeMSAEC Fast Analyzer is directly proportional to the number of sample cuvets contained in each rotor. GeMSAEC Fast Analyzers are available having either 15-, 16-, or 30-place rotors. To increase the sample analysis rate, an advanced GeMSAEC Fast Analyzer has been designed and fabricated that uses a 42-place rotor. The 42-place rotor, in order to accommodate the increased number of cuvets, is a modified enlargement of the previously described 15-place rotor [N. G. Anderson, *Science* **166**, 317 (1969)]. The hardware of the 42-place system is fully compatible with the existing GeMSAEC computer module, and existing software used in the 15-place system has been modified for use with the 42-place system. Results obtained for various chemical and enzymatic analyses are discussed.

Additional Keyphrases *rapid clinical analyses • dedicated computer • FOCAL programs • precision • accuracy • low sample volume • low reagent costs*

In a recent series of papers, N. G. Anderson et al. at the Oak Ridge National Laboratory have introduced a new concept in the rapid analyses of many biological compounds of clinical interest (*1–8*). The basic principles described in these papers have led to the development of the GEMSAEC Fast Analyzer. This instrument gives promise of increasing both the rate at which many clinical and biochemical analyses may be performed and their precision and accuracy.

The analysis rate of a GEMSAEC Fast Analyzer is proportional to the number of cuvets contained in each rotor. GEMSAEC Fast Analyzers are available having either 15-, 16-, or 30-place rotors. To determine the feasibility of increasing the sample throughput rate by use of a greater number of cuvets per rotor, an advanced 42-place GEMSAEC Fast Analyzer (G-IIIA) has been designed and fabricated at the Oak Ridge National Laboratory. The object of this report is to describe the design and fabrication of this system and to report preliminary analytical results obtained with it.

Materials and Methods

Instrumentation

G-IIIA system. The complete 42-place GEMSAEC Fast Analyzer system is shown in Figure 1, and a close-up of the analytical module is shown in Figure 2.

Rotor. As with the 15-place rotor previously described for the G-IIC Fast Analyzer (*8*), the 42-place rotor is constructed of stainless steel, glass, and Teflon (Figure 3).

In addition to the increased number of cuvets, the greatest difference between it and the 15-place rotor is the replacement of the 0.5-in. Pyrex windows used in the latter with windows constructed of 0.083-in.-thick "Chemcor" glass. This is a special glass developed by Corning Glass Works for use in the Lunar Landing Module; at a comparable cost it improves the physical strength of the windows without sacrificing optical quality. Both the 15- and 42-place rotors are operable down to wavelengths as low as 330 nm (Figure 4).

When the 42-place rotor is assembled, the individual cuvets are formed by compressing the 10-mm-thick Teflon annulus containing 42 slots between the two Chemcor windows, by the process previously described (*1, 8*). It was found that after disassembling and reassembling the rotor several

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[1] The acronym GEMSAEC, pronounced "gem sack," is derived from the major sources of support, which are the National Institute of *G*eneral *M*edical *S*ciences and the U. S. *A*tomic *E*nergy *C*ommission.

[2] The Molecular Anatomy (MAN) Program is supported by the National Institute of General Medical Sciences, the National Cancer Institute, the National Institute of Allergy and Infectious Diseases, and the USAEC.

[3] Operated by Union Carbide Corp. Nuclear Division for the USAEC.

times, the individual cuvets leaked. This problem was solved by placing two thin Teflon gaskets between the Chemcor windows and the Teflon annulus before reassembling the rotor.

The rotor is coupled to a hollow shaft, which makes use of spring-loaded lip seals to supply air, vacuum, and water to the rotating rotor. In addition, for temperature monitoring, two thermistors are imbedded in the rotor next to two cuvet windows 180° apart, and their leads connected to slip rings on the shaft for contact with the thermistors' external circuitry.

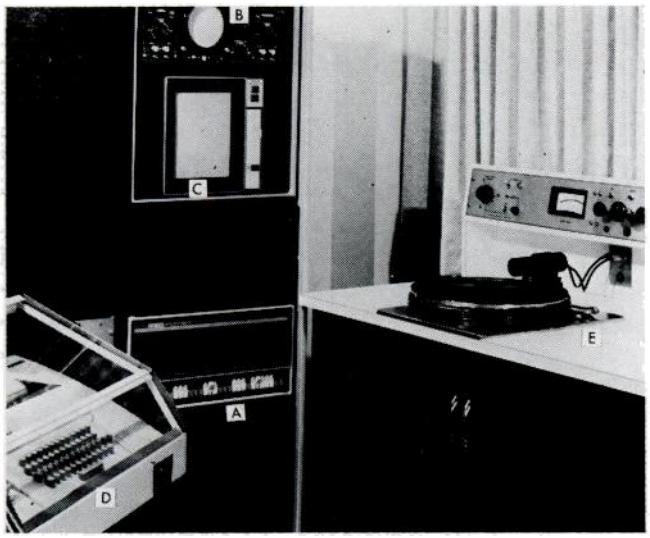


Fig. 1. Complete G-IIIA GEMSAEC Fast Analyzer

The data-handling module on the left is composed of (A) PDP-8/I computer; (B) oscilloscope; (C) storage display scope; and (D) teletypewriter. The analytical module (E) is shown on the right

Fig. 2. Analytical module of the G-IIIA GEMSAEC Fast Analyzer

(A) Cuvet rotor enclosed within a peripheral drainage ring that excludes light and dust and provides operational safety; (B) photomultiplier and filter holder; (C) photomultiplier voltage and light intensity controls; (D) air, water, and vacuum control values; (E) rotor speed control and indicator; and (F) 42-place transfer disk

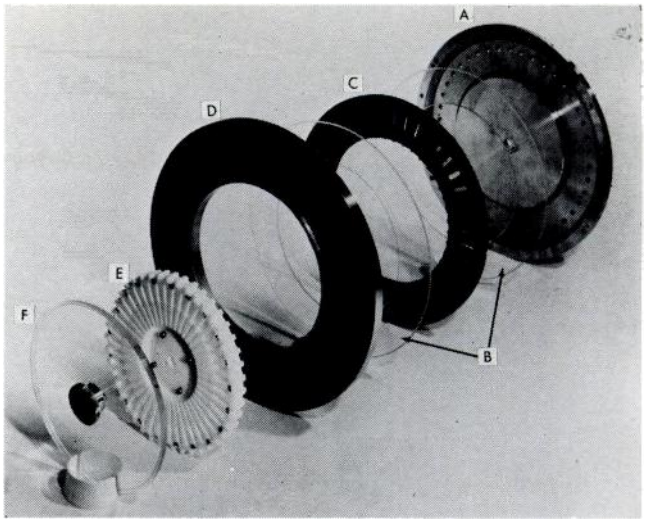


Fig. 3. Disassembled G-IIIA rotor

(A) Lower rotor housing; (B) lower and upper 0.083-in. Chemcor glass windows; (C) filled Teflon cuvet spacer; (D) upper rotor housing; (E) 42-place Teflon transfer disk; and (F) rotor sealing cover

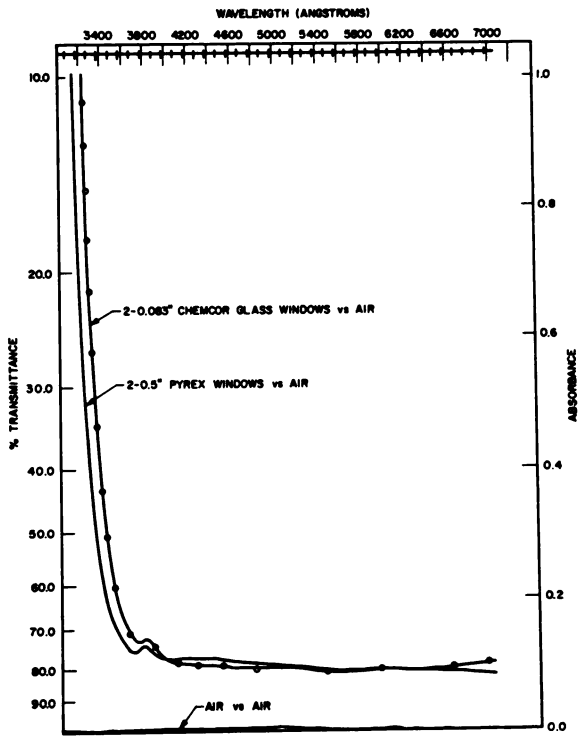


Fig. 4. Absorption spectra of Chemcor and Pyrex glass windows used in the fabrication of 42- and 15-place GEMSAEC Fast Analyzer rotors

Spectra were obtained with a Cary-14 recording spectrophotometer

In Figure 5 assembled 42- and 15-place rotors are compared; it is obvious from the increased size and mass of the 42-place rotor that a larger motor is required for its operation. Consequently the $^1/_4$-hp, 115-V dc motor used in the 15-place system was replaced with one of 1 hp. The mounting and placement of the motor is illustrated in Figure 6. To accommodate the larger motor, the

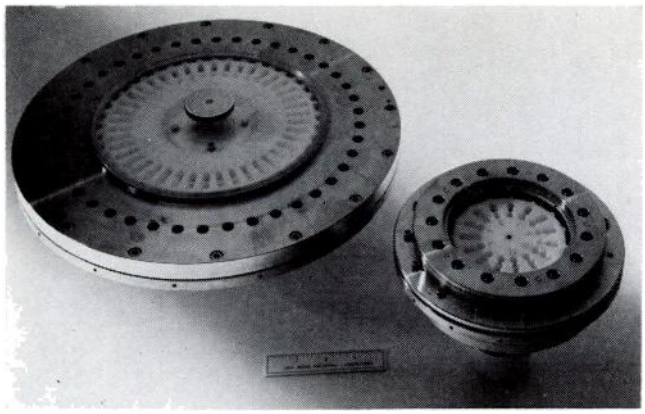


Fig. 5. Comparison of G-IIIA and G-IIC rotors

The 42- and 15-place transfer disks are shown in place in their respective rotors

capacities of the acceleration and braking circuits were increased. As with the earlier systems, a three-position switch, in addition to the autotransformer speed control, was provided settings marked *stop*, *run*, and *accelerate*. For fast acceleration a special circuit was provided that accelerates the rotor from rest to 1000 rpm in 4.6 s and to 1500 rpm from 500 rpm in 6.2 s. For safety, owing to the increased size and mass of the 42-place rotor, a shutoff circuit was provided to prevent operating the rotor over 1700 rpm. A braking circuit was also provided to allow braking from 1500 rpm to 1000 rpm in 6.8 s, and from 1000 rpm to 500 rpm in 10.4 s.

The rotor spins within a stainless-steel drain ring, which serves both as a rotor shield and as a collecting ring for the waste liquid from the rotor. The waste liquid is drained from the individual cuvets to the collecting ring via drainage siphons previously described (*2*) and from the collecting ring through either of four drainage ports that are connected by tubes to a waste-container bottle in the lower part of the cabinet (Figure 6).

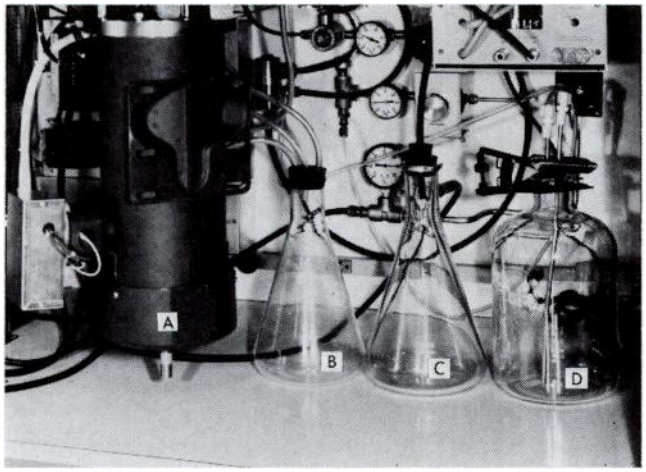


Fig. 6. Inside of the lower cabinet of the G-IIIA GEMSAEC Fast Analyzer

(A) 1-hp, 115-V dc motor; (B) liquid waste bottle; (C) vacuum trap; (D) wash liquid bottle; and (rear) gauges representing air, water, and vacuum pressures

By totally enclosing the rotor in a cavity within the drainage ring, extraneous light and dust are excluded. The temperature of the rotor may be maintained by controlling the temperature of the cavity. This temperature control was accomplished by placing coils of copper tubing around the external wall of the drainage ring, insulating the entire cavity, and circulating liquid through them from a constant temperature bath. Studies indicate that a temperature differential of less than 0.5 °C can be maintained by using this method. For the enzymatic analyses discussed later, the temperature of the rotor was maintained at 30 ± 0.5 °C.

Optical system. The G-IIIA GEMSAEC uses the same 340–770-nm optical system as the G-IIC system (*8*). It includes a commercial microscope light source. The light intensity is adjusted with a potentiometer mounted on the control panel (Figure 2) and the light beam is directed by a mirror through the rotating cuvet windows to the photomultiplier. A type 1P28 or R136 photomultiplier, mounted in a suitable housing, was used with a filter holder mounted in front of the photomultiplier tube. To obtain light of the desired wavelength, interference filters were placed in the holder. For each filter, the light source intensity and the photomultiplier voltage must be adjusted to obtain a sufficient signal level without saturating the photomultiplier.

The oscilloscope displays the light transmittance of 42 cuvets rather than 15 (Figure 7). In both instruments the upper base line represents 0% transmittance (infinite absorbance), while the full-scale signal obtained with cuvet 1 represents 100% transmittance (zero absorbance). The signals from the other cuvets are compared with the 100% transmittance signal of cuvet 1 to obtain their relative transmittance. These values are then mathematically converted to absorbance values by the computer and used for calculations by the FOCAL programs, which are described elsewhere (*9*).

Synchronization signals. As with the 15-place GEMSAEC systems, the control of the oscilloscope display and the computer input requires a number of different signals. The circuits and hardware necessary to obtain these signals have been reported previously (*8*). The same system is used in both the 15- and 42-place GEMSAEC's with the exception that in the latter the synchronizing disk containing 42 slots is moved to the top of the motor to provide easy access for servicing.

Air, vacuum, and water signals. As reported earlier (*2*) the cuvets may be emptied by means of drainage siphons contained in each cuvet. To drain the siphons, air is applied to the center of the rotor during rotation. By applying a vacuum to the center of the rotor, air can be drawn back through the siphons to produce mixing. In the earlier 15-place system the air and vacuum, as well as water for flushing the rotors, were supplied through the

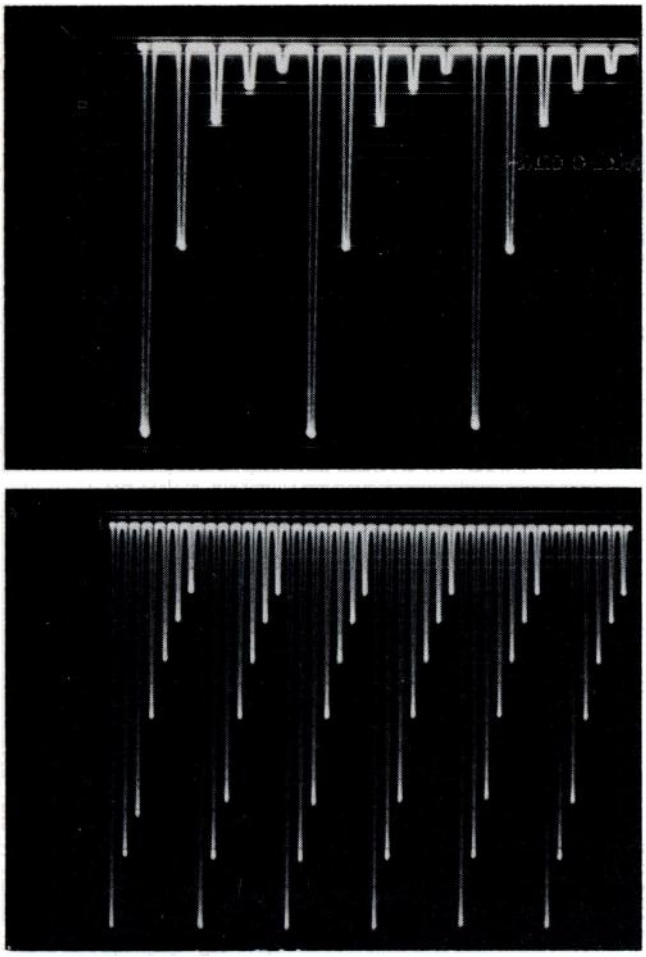


Fig. 7. Comparison of photomultiplier signals obtained from the G-IIC and G-IIA Fast Analyzers

The first cuvet in each case is filled with water. The remianing cuvets are filled with a repeating series of potassium chromate standard solutions

top of the rotor. In the 42-place system the air, vacuum, and water originally were supplied through the bottom of the rotor, via its hollow shaft. Spring-loaded lip seals were used to provide the necessary sealing surfaces. However, we later found that, because the water and air lines share a common shaft, application of the air tends to vaporize residual wash water left in the shaft. This resulted in fogged cuvet windows and required a complete cleaning and drying of the rotor. Thus in practice only air and vacuum were supplied through the hollow shaft of the rotor; wash water was supplied by means of the transfer disk. The air and vacuum lines were provided with regulators and solenoid valves controlled from the console (Figures 2D and 5). The air pressure is set at 1.72 $\times 10^5$ N/m^2 (25 psi), and house vacuum is used.

Transfer disk. The transfer disk used with the G-IIIA rotor is shown in Figure 8. In practice, the innermost cavities are filled with reagent (as much as 0.4 ml), and the middle cavities with sample (from 0.010 to 0.05 ml). The outermost cavity is used as a mixing and transfer chamber. [Note: For a schematic representation of how reagent and liquid are actually transferred, the reader is directed to Figure 1 of reference 7.] As with the 15-place transfer disk (*8*), the inner and middle row of cavities slope outward 15° from vertical and transfer during rotation into the outer row of cavities that slant inward at 15°. These outer cavities transfer radially outward through small holes that slant upward 20° from horizontal in a radial direction, thus transferring all fluid simultaneously to the cuvets by centrifugal force. A pin in the bottom of the rotor plate matches a hole in the transfer disk, ensuring correct indexing of the disk in the rotor.

Computer data system. The G-IIIA GEMSAEC Fast Analyzer utilizes the same computer system as the earlier G-IIC analyzer (*3*). This system, as seen in Figure 1, is built around a PDP-8/I computer having 8K words of 12-bit core memory and 64K words of 13-bit (12 bits + parity) disk memory. The computer is equipped with a photoelectric paper tape reader (Digitronics, Albertson, N. Y. 11507), ASR 33 Teletype, eight-channel analog signal multiplexer, analog-to-digital converter, digital-to-analog converter, 60-Hz real-time clock, 12 output relays and control, 12 relay contact sensors, 611 storage display scope, and RM 503 oscilloscope (both of the last two from Tektronix, Portland, Oreg. 97005). The computer also includes appropriate buffering hardware plus special analog and digital circuits to interface the computer to the GEMSAEC Fast Analyzer.

The programs used with the GEMSAEC Fast Analyzer are developed around FOCAL, Digital Equipment Corporation's (Maynard, Mass. 01754) conversational language. Three basic programs are required for routine use of the instrument: a calibration, an end-point, and a rate-reaction program.

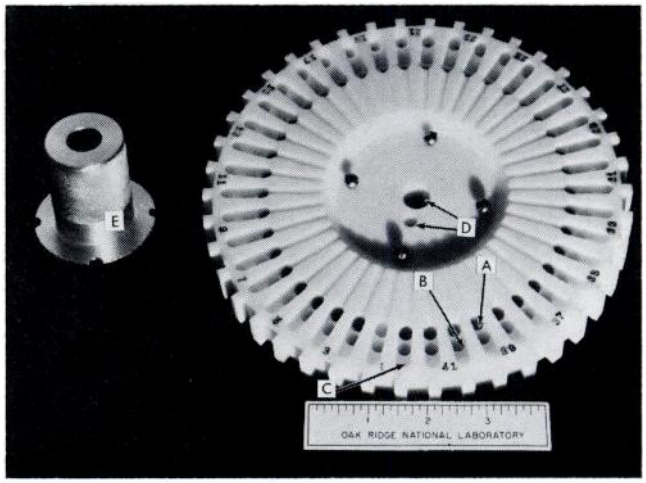


Fig. 8. Teflon 42-place transfer disk used in the G-IIIA Fast Analyzer

(A) Reagent cavity, here filled with 400 μl of biuret solution; (B) sample cavity; (C) mixing and transfer cavity; (D) centering and indexing holes; (E) positioning tool used for carrying, placing, and removing transfer disk from rotor (engages four screws shown in middle of transfer disk)

With the calibration program, absorbance of each cuvet is read from 2 to 100 times, and the mean values and relative standard deviations (cv) of these readings are printed by the teletype in both millivolts and absorbance units. The absorbance values, taken vs. a dark-current reading on the photometer with the cuvets full of water or reagent, are automatically subtracted as a blank for each determination in subsequent runs.

The end-point program was used in the analysis

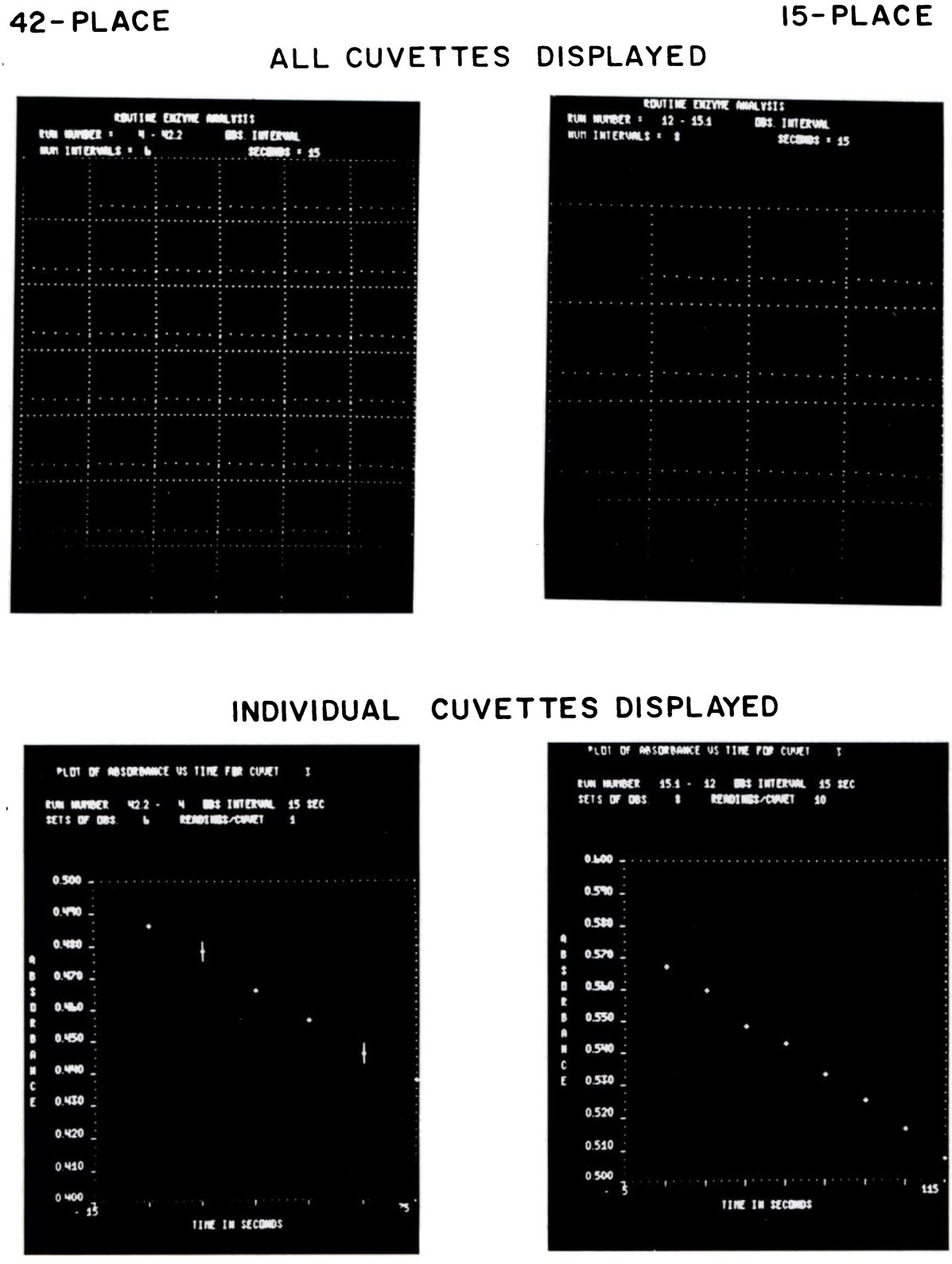


Fig. 9. Enzyme rate plots of absorbance vs. time, obtained from both the G-IIIA and G-IIC GEMSAEC Fast Analyzers

In the upper two figures the plots of all the individual cuvets are displayed simultaneously. With the aid of an additional FOCAL program, the operator is able to display the individual rate plot of the desired cuvet. As an example, in the lower figures cuvet 3, contained in each of the upper figures, is displayed individually

of serum for its protein, albumin, and glucose content. This program requires the analysis of four standard solutions of increasing concentration per transfer disk. A standard curve is prepared from the results obtained from these solutions, and the concentration of the constituent in each serum sample is calculated from it. These calculations, as well as the final listing of these concentrations, are all done by the computer. With this program 37 samples may be analyzed per 42-place transfer disk.

The third basic program used for rate analyses was used in these studies to determine serum enzyme activities. It calculates the change of absorbance per minute, within the preset time interval, which is then multiplied by a preset enzyme factor to convert change in absorbance to enzyme units. The enzyme factor includes the molar absorptivity of the absorbing species, the sample volume, total reaction volume, and dilution and temperature correction factors when necessary.

In developing the chemical procedures described later, we used two additional research programs to obtain the program constants required by the end-point and rate-reaction programs. The first is a modified rate program that determines absorbance time, outputs these values in a tabular format on the teletype, and plots them vs. time for all 42 cuvets on the display scope. The second program allows the operator to view the plot of absorbance vs. time for each individual cuvet. The display scope outputs for these two programs, from both the 42- and 15-place systems, are seen in Figure 9. The top displays, in which all absorbance plots are shown, were obtained with the tabular absorbance program. A similar display is obtained with the rate-reaction program. This type of display has been found to be quite useful for diagnostic purposes, because the operator can tell quickly if a problem exists in any or all of the individual cuvets.

Using the individual-cuvet display program, the operator is able to view individually the absorbance plot for each cuvet. The usefulness of such displays for developmental purposes is obvious. The operator can quickly ascertain if an incubation period is necessary or when a reaction is complete; but, more importantly, the linear portion of an enzymatic reaction can be rapidly determined. For example, the reaction plot shown in Figure 9 was obtained from a series of LDH-P reactions; it is immediately evident that the reaction rate is linear in the 20- to 120-s interval of the reaction. Note again that these last two programs are useful mainly for development purposes. Their major advantage is providing program constants for use in the routine analytical programs mentioned earlier. The development of these programs has been previously reported (*9*, *10*).

Table 1. Reaction Volumes and Methods Used in the Clinical Analyses of Various Blood Constituents, with a GeMSAEC Fast Analyzer as the Analytical Tool

Blood constituent	Reagent volume, μl	Sample volume, μl	Reference no.
Protein	400	10[a]	(*6*, *11*)
Albumin	400	10[a]	(*12*, *13*)
Glucose	400	2.5[b]	(*14*)
Enzymes			
AP	400	20	(*15*)
CPK	400	50	(*16*)
LDH-L	400	50	(*17*)
LDH-P	400	20	(*18*)
SGOT	400	50	(*19*, *20*)
SGPT	400	50	(*21*, *20*)

[a] Actually 200 μl of a 20-fold serum dilution, which is equivalent to 10 μl of whole serum.

[b] Actually 50 μl of a 20-fold serum dilution, which is equivalent to 2.5 μl of whole serum.

Clinical Chemical Determinations

Assays studied. Standard clinical methods for serum protein, albumin, and glucose, and for the serum enzymes, AP, CPK, LDH-L, LDH-P, SGOT, and SGPT, were adapted for use in the GEMSAEC Fast Analyzer (Table 1). For the analysis of serum protein, we used the biuret method of Weichselbaum (*11*), as modified for GEMSAEC analysis by Hatcher and Anderson (*6*), and for serum albumin the Haba dye-binding method of Ness et al. (*12*), as modified for GEMSAEC analysis by Pruitt (*13*).

Reagent kits, marketed under the trade name "Stat-Packs," were purchased from Calbiochem, Los Angeles, Calif. 90036, for the analysis of serum enzymes. The two vials contained in each individual kit were reconstituted with distilled water, mixed, and diluted to a combined volume of 20 ml. Depending on the analysis, 0.4-ml aliquots of the appropriate reagent are metered into the reagent cavities of the 42-place transfer disk by manual actuation of a Hamilton Precision Liquid Dispensor (Hamilton Company, Whittier, Calif. 90608). The required volumes of serum are pipetted into the sample cavities by means of an Oxford Sampler Pipette (Oxford Laboratories, San Mateo, Calif. 94402). The reagent and sample volumes required for the individual analyses are listed in Table 1 along with the methods that have been adapted for use in the GEMSAEC Fast Analyzer.

The serum protein, albumin, and glucose were analyzed as end-point reactions by utilizing the FOCAL end-point program, which requires the analysis of four standard solutions per transfer disk. In addition to the analysis of four standard solutions, the routine end-point reaction program requires various program constants. These are listed in Table 2, and have been obtained with the use of the FOCAL research program mentioned earlier.

Table 2. Computer Operating Parameters Required for the Analysis of Various Blood Constituents by Means of a GeMSAEC Fast Analyzer

Analysis	Delay interval, s	Observation interval, s	No. sets of observations	No. readings per interval	Total analysis time, min	Type of reaction
Protein[a]	90	30	1	10	2.0	End point
Albumin[a]	90	30	1	10	2.0	End point
Glucose[a]	90	30	1	10	2.0	End point
Enzymes						
AP	0	15	10	10	2.5	Rate
CPK	120	20	6	10	4.0	Rate
LDH-L	0	20	6	10	2.0	Rate
LDH-P	0	15	8	10	2.0	Rate
SGOT	0	15	12	10	3.0	Rate
SGPT	60	20	6	10	3.0	Rate

[a] Computer program requires the use of four reference solutions, which represent serum concentrations of 50, 100, 150, and 200 mg/100 ml for glucose and 2, 4, 6, and 8 g/100 ml for both protein and albumin.

With regard to the determination of various serum enzyme activities, the research programs were extremely useful in obtaining the program constant required by the routine rate-reaction program (Table 2). Figure 10 illustrates the results obtained for the six enzymes analyzed with use of these programs. The linear interval for each reaction rate, whether it be an increasing or decreasing rate, is immediately obvious. The cursors evident in the individual plots indicate the intervals that were used to obtain the program constants listed in Table 2 for each enzyme analysis.

Sample preparation. Blood serum was used for all analyses. For the protein, albumin, and glucose analyses, the serum was diluted 20-fold with distilled water, as were the reference solutions. For determining the activities of the various serum enzymes, whole serum is analyzed. Sample volumes required for the individual tests are listed in Table 1. In samples with high or low enzyme activity, these values may be decreased or increased accordingly.

Operating procedure. Reagents and samples are manually loaded into their respective cavities in the transfer disk, as described earlier. The operator uses the teletype to call the required program from the memory disks; it is then automatically loaded into the fast memory core of the computer. The required program constants and identifying information are added to the program through the teletypewriter. The computer then gives a "ready-for-analysis" signal. The loaded transfer disk is placed in the rotor and properly indexed. To prevent lateral splashing of liquid in the transfer disk, the rotor is gradually accelerated to 300 rpm using the autotransformer control, then rapidly accelerated to 1100 rpm using the acceleration switch. The switch is turned to "off" and the rotor allowed to decelerate to 500 rpm. During this braking interval, vacuum is applied in a series of pulses, which results in drawing a stream of small air bubbles through each cuvet. The turbulence produced by these minute air bubbles streaming through the cuvets causes complete mixing, and has been found to be absolutely necessary in the operation of the 42-place system. After reaching 500 rpm the rotor is again rapidly accelerated to 1000 rpm and then decelerated to the normal operating speed of 500 rpm to remove the bubbles. At this time the computer program is started by manually closing a relay contact. After the analyses are complete, air is applied to the center of the rotor to empty it through the drainage siphons. The rotor is then stopped and wash water added to both the sample and reagent cavities of the transfer disk, with a wash bottle. By using the rotor operational procedure described above, the water is transferred to the cuvets, which are then emptied as described. It was found that only one wash cycle was required between analyses.

Results and Discussion

To determine the precision of the 42-place GEMSAEC Fast Analyzer, we analyzed multiple aliquots of a single serum sample, obtained from a healthy individual, for the various blood constituents listed in Table 1. This resulted in 41 determinations for each of the enzyme analyses and 37 each for the serum protein, albumin, and glucose analyses. The results from these analyses are listed in Table 3. The mean values were within the normal ranges for all nine blood constituents.

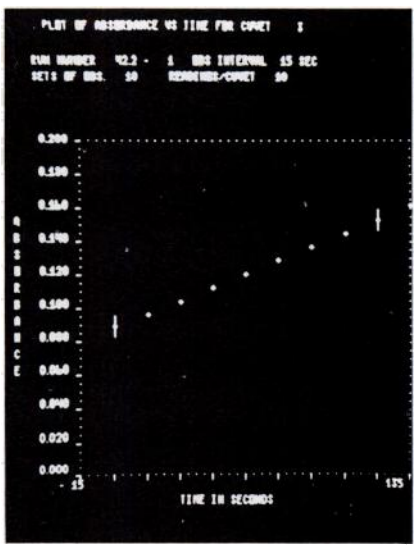
The coefficient of variation (CV) for these multiple analyses ranged from 0.5% to 5.9%; seven analyses having CV's of 2.1% or less.

The SGOT and SGPT coefficients of variation, 5.9 and 4.7%, were the highest observed in these studies. The low activity of these enzymes probably accounts for their higher coefficients of variation, since the values obtained for their activities (13.4 and 11.0 U/liters) correspond, respectively, to absorbance changes of only 0.008 and 0.006 absorbance units per minute.

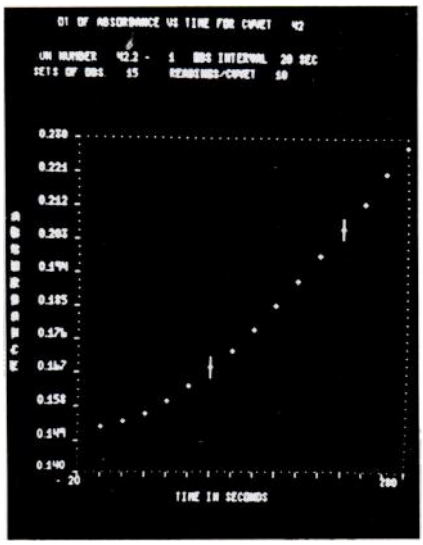
Table 3. Analytical Results Obtained from Multiple Analyses of a Single Serum Sample by Using the 42-Place GeMSAEC Fast Analyzer

Analysis	No. analyses	Analytical results: Mean	Analytical results: CV, %	Sample volume, μl	Reagent cost, in cents per test	Time: Min/disk	Time: Samples/h[a]
Protein	37	6.79 g/100 ml	0.7	10	0.1	16	139
Albumin	37	3.48 g/100 ml	0.7	10	0.1	16	139
Glucose	37	91.2 mg/100 ml	0.5	2.5	6	17	131
Enzymes							
AP	41	44.1 U/l (30°C)	1.1	20	4	18	137
CPK	41	25.6 U/l (30°C)	1.6	50	10	20	123
LDH-L	41	55.2 U/l (30°C)	2.1	50	4	19	129
LDH-P	41	147.1 U/l (30°C)	1.3	20	3	17	145
SGOT	41	13.4 U/l (30°C)	5.9	50	4	17	145
SGPT	41	11.0 U/l (30°C)	4.7	50	5	19	129

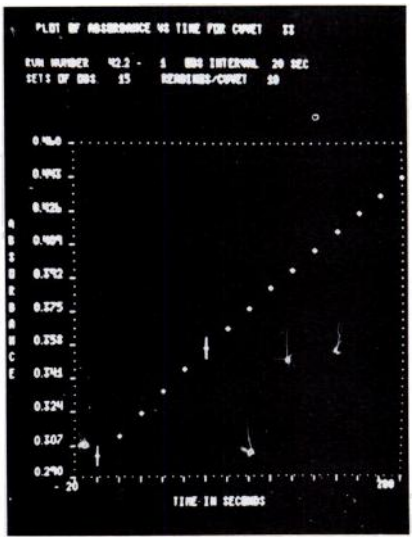
[a] Extrapolated values.



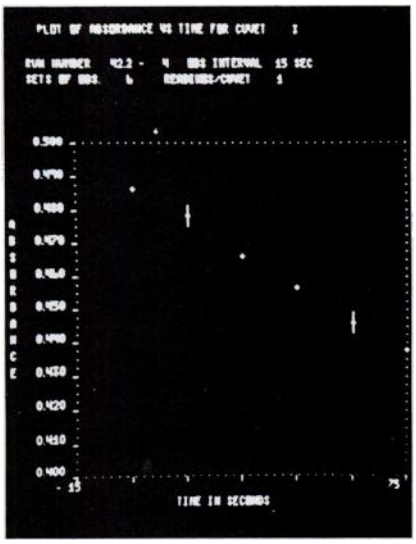
AP



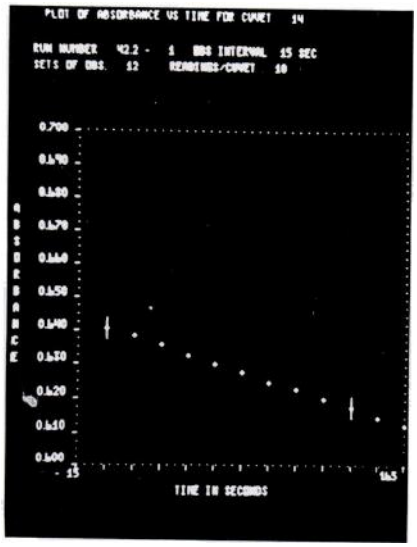
CPK



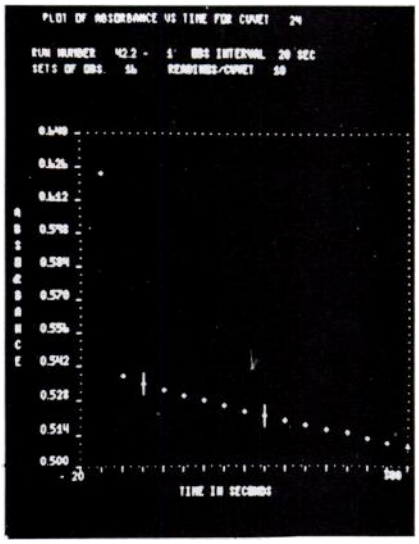
LDH-L



LDH-P



SGOT



SGPT

Fig. 10. Individual rate plots of absorbance vs. time obtained from various serum enzymes

The intervals indicated by the cursors were used to obtained the operating parameters listed in Table 2

This study also illustrates other advantages of the GEMSAEC Fast Analyzer over conventional systems. One advantage is that the required sample volume per analysis is considerably smaller in a GEMSAEC Fast Analyzer. Samples as small as 2.5 to 50 μl can be assayed precisely and accurately in a GEMSAEC Fast Analyzer. For example, the total sample volume required for a single determination of the nine blood constituents analyzed is only 0.3 ml; with 0.6 ml of serum, duplicate analyses may be performed. Thus a GEMSAEC analyzer would allow more total chemical determinations on less sample. The medical implications from this advantage are obvious.

With the GEMSAEC Fast Analyzer, reagent cost per analysis is lower, as compared with conventional methods. The GEMSAEC requires only a small volume of reagent per analysis, and, because the reagents are dispensed discretely, little is wasted. The reagent cost per analysis for the serum enzymes and serum glucose, in which reagent kits were used, ranged from 4¢ to 10¢. If these kits are used according to the manufacturer's recommended manual methods, the reagent cost for the same analyses ranges from 27¢ to 85¢ per analysis. Thus the GEMSAEC Fast Analyzer can decrease reagent costs by a factor of 8 to 10. For determinations not requiring the more expensive enzyme reagents, such as protein and albumin analyses, reagent costs are less than 0.1¢ per analysis. Total reagent cost for analysis of a serum sample—a single value for each of the nine determinations listed in Table 3—would be less than 37¢.

The time required from the start of reagent preparation to the final washing of the cuvets was noted for each analysis; it ranged from 16 to 20 min per transfer disk. Extrapolating to an hour basis, this corresponds to a sample analysis rate of 123 to 145 samples/h. To determine the actual number of samples per hour that can be analyzed with the 42-place GEMSAEC Fast Analyzer, reference serum ("Caltrol," Calbiochem) was repeatedly analyzed for its LDH-P activity. Using the program constants and parameters listed for this analysis in Tables 1 and 2, it was possible to analyze four 42-place transfer disks in 59 min, which is equivalent to an analysis rate of 164 samples/h. The mean activity of the 164 analyses was 182.1 U/liter (30.0°C), with an observed coefficient of variation of 1.9% (Table 4).

For comparative purposes an equal number of aliquots of the same reference serum were analyzed for their LDH-P activity by using the 15-place GEMSAEC Fast Analyzer. This number of samples required the use of 12 15-place transfer disks, which required 91 min for analysis, or a sample throughput rate of 108 samples/h. The mean value for the enzyme activity was 177.6 U/liter (30.0°C), with an observed coefficient of variation of 2.1%.

Thus essentially the same analytical results and precision were obtained with either system. The 42-place system has the advantage of being able to analyze 164 samples/h, as compared with 108 samples/h for the 15-place system, an increase of approximately 50%. This increase is actually greater when one considers that the samples and reagents were semiautomatically loaded in the 15-place disks, while in the 42-place disks they were loaded manually. An automatic reagent and sample loader is currently under development, and its use should considerably increase the analysis rate of the 42-place system.

These studies indicate that the sample throughput rate of a GEMSAEC Fast Analyzer can indeed be increased by increasing the number of cuvets in an individual rotor. They also indicate that this rate can be further increased in both the 15- and 42-place systems by automating several functions of the GEMSAEC system. Thus, automation of sample and reagent loading and of cleaning and drying of the rotor between runs would increase the sample throughput rate in both the 15- and 42-place GEMSAEC Fast Analyzers. We are evaluating automated modules to perform these functions in a 15-place system. In addition, an automated sample and reagent loader for the 42-place system is under development.

In summary, these studies indicate that the sample throughput rate of a GEMSAEC Fast Analyzer can be increased by increasing the number of cuvets per rotor. They have also confirmed several of the advantages of the GEMSAEC systems over conventional methods. With a GEMSAEC Fast Analyzer many low-cost analyses may be performed on a minimal volume of sample with high precision and accuracy. In addition, since the samples are all analyzed in parallel, they are started at the same time. This is especially advantageous in determining enzymatic reaction rates where is it desirable to initiate all the reactions simultaneously. Obviously, an analytical system offering these advantages should have an immediate application in a clinical laboratory. Consequently, both a 15- and a 42-place GEMSAEC Fast Analyzer have been placed in the Clinical Laboratory of the Health Division of the Oak Ridge National Laboratory for testing and evaluation under routine conditions.

Table 4. Sample Analysis Rate of a 42- vs. a 15-Place GeMSAEC Fast Analyzer

Rotor capacity	Time required for 164 samples, min[a]	Sample rate per hour	Results	
			Mean, U/l, 30°C	CV, %
42-Place	59	164	182.1	1.9
15-Place	91	108	177.6	2.1

[a] 164 samples, equivalent to four 42-place and 12 15-place transfer disks. The first position in each disk is used for reference purposes.

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