**An Alternating Sample Changer and an
Automatic Sample Changer for Liquid
Scintillation Counting of
Alpha-Emitting Materials**

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AN ALTERNATING SAMPLE CHANGER AND AN AUTOMATIC SAMPLE
CHANGER FOR LIQUID SCINTILLATION COUNTING
OF ALPHA-EMITTING MATERIALS

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AN ALTERNATING SAMPLE CHANGER AND AN AUTOMATIC SAMPLE CHANGER
FOR LIQUID SCINTILLATION COUNTING OF ALPHA-EMITTING MATERIAL

John H. Thorngate

ABSTRACT

Two sample changers are described that were designed for liquid scintillation counting of alpha-emitting samples prepared using solvent-extraction chemistry. One operates manually but changes samples without exposing the photomultiplier tube to light, allowing the high voltage to remain on for improved stability. The other is capable of automatically counting up to 39 samples. An electronic control for the automatic sample changer is also described.

INTRODUCTION

McDowell⁽¹⁾ developed combined solvent extraction-liquid scintillation methods of alpha particle spectroscopy to fulfill needs for measuring low levels of transuranic materials. At low levels, long times were required to count samples so that the time required to change samples was not a limiting factor in the measurements. As a result, most of the subsequent instrument developments related to this technique were made for low-level counting. For example, the addition of pulse-shape discrimination to decrease background response.⁽²⁾

Two factors developed, however, that have made improved sample changing techniques necessary. A number of experiments were performed to study the liquid scintillators and the detector systems.^(3,4,5) During these studies, instabilities were observed in some types of photomultiplier tubes after the application of the high voltage. In fact, the phototube type that gave the best combined performance of pulse-height resolution and pulse-shape discrimination had the poorest stability.⁽⁴⁾ McDowell's⁽¹⁾ original detector system required exposing the phototube to light each time a sample was changed which meant cycling the high voltage off and on. To alleviate this problem, a sample changer was designed that incorporated a "light lock" to prevent light from reaching the phototube during sample changes. For convenience, it was also built to allow alternating from one sample to another and was, thus, identified as the "alternating" sample changer.

A number of researchers found that the relative simplicity of the solvent extraction chemical procedures used for sample preparation made these techniques useful in experiments that did not necessarily involve low levels of alpha emitting materials. A good example of such an experiment would be one studying the uptake of an alpha emitting substance in animal tissues.⁽⁶⁾ The samples that evolve from such an experiment are not necessarily low-level and sample-changing time can become a significant portion of the total counting time so an automatic sample changer was developed that could accommodate up to 39 samples. An electronic system to control the sample changer was also designed.

Both sample changers were designed to accommodate standard 10 X 75 mm culture tubes; the sample holder adopted by McDowell.⁽¹⁾ Normally, samples are sealed with corks coated with a silicone rubber cement.⁽⁵⁾ In the changers to be described, small iron screws or tacks are inserted in the corks and magnets are used to hold the samples.

ALTERNATING SAMPLE CHANGER

A photograph of the alternating sample changer is shown in Fig. 1. The figure also shows a sample in the loading position. An "exploded" view of the parts of this sample changer is shown in Fig. 2. Since both of the sample holding positions have identical parts, only one is shown in detail. The parts are identified in Table 1. Detailed drawings of the components are given in Figs. 3 to 6 in which the parts are identified with the same numbers as in Fig. 2, and Table 1. These numbers are also included, in brackets, throughout the description of the assembly of the sample changer. The exploded view does not show the details of the photomultiplier (PM) tube mounting and housing. Both sample changers use the same arrangement for housing the PM tube so the details are given only once, with the automatic sample changer. Table 1, also gives the figure numbers for the exploded view and detailed drawings. For the photomultiplier tube housing the exploded view drawings are given in the section on the automatic sample changer which uses the part numbers given in Table 1. The O-rings required are not shown in the drawings so Table 2 lists them and their related parts, for both sample changers. The O-ring dimensions given in Table 2, and throughout the text, are in inches.

ASSEMBLY (Figure 2)

The first step in the assembly of the alternating sample changer is to fasten a small magnet into each of the plungers [10]. Silicone rubber cement works well for this purpose. Any small magnet that will fit into the plunger and that is strong enough to lift the samples can be used. Next, slip the plunger screw [11] through the plunger-screw retainer [12] and run this screw into the plunger. Press fit this assembly into the bottom of the plunger slide [8]. Put a 3/32 wall (W), 3/4 outside diameter (OD) O-ring on the plunger slide and place the plunger-housing cap [7] onto the slide from the top. Cover the plunger slide with the plunger-slide cap [9] and hold the cap in place with a set screw. Insert this entire combination into the plunger housing [6] and hold it in place with the set screw in the plunger-housing cap [7]. Now, insert the plunger housing through the plunger base [5] and place a 1/8 W, 1 OD O-ring on the bottom of the plunger housing. Assembly of the plunger unit is completed by bolting the plunger base onto the slide [3]. An identical procedure is followed to assemble the second plunger unit, which mounts on the other side of the slide.

Final assembly is begun by putting a 1/8 W, 1 OD O-ring in the groove on the bottom of the base plate [2] and bolting the plate to the reflector [1]. Put two O-rings, one 1/8 W, 1 OD and the other 1/8 W, 2 1/4 OD, in the grooves on the top of the base plate and put the slide into place on top of them. These two parts are held together by six 8-32 bolts each covered with a nylon slide bearing [4].

As mentioned above, the assembly of the PM tube housing and details on the assembly of the reflector are given in the discussion of the automatic sample changer (See Figure 9).

OPERATION

To operate the alternating sample changer, pull the slide completely to one end and lower the plunger to its lowest position. Lift a sample, with some type of iron fitting in its cork, until the iron contacts the magnet in the plunger. An ordinary thumb tack set in the cork is low cost, easy to install and is reusable. Laboratory tests with the system used small, self-tapping screws which stay in the cork better than the tack but are more difficult to obtain and to install.

Once the sample is in place, pull the plunger all the way up and move the slide to the other limit of its travel. This places the sample above the hole in the reflector. To count, lower the plunger holding the sample to its bottom position. The water, used in the reflector as a light coupling medium, redistributes throughout the reflector and water reservoir (described in more detail in the section on the automatic sample changer). Moving the slide positioned the other plunger to take up a second sample. After counting the first sample, remove it from the counter by reversing the procedure just given; simultaneously placing the second sample above the hole in the reflector.

AUTOMATIC SAMPLE CHANGER

Two photographs of the automatic sample changer are shown in Figures 7 and 8. Exploded views of its assembly are given in Figures 9, 10, and 11. The first of these (9) shows the assembly of the PM tube housing and the

reflector; parts used for the alternating sample changer as well. All of the parts are listed, by number and name, in Table 3. The detailed drawings of the parts are shown in Figures 12 to 19.

The automatic sample changer was not designed to prevent light from striking the PM tube during the sample-changing sequence so this unit must be housed in a light-tight enclosure, which is not shown. However, the changer was designed so that the enclosure could be opened between sample-changing cycles. As before, culture tubes are used to hold the samples, but a cassette is provided that will hold up to 39 samples and which can be changed as a unit, much like the slide holder on a slide projector.

ASSEMBLY

This section begins with a description of the assembly of the reflector and PM tube housing; parts that are common to both sample changers.

Reflector (Figure 9)

Thoroughly clean the reflector [21] with scouring powder, rinse with distilled water and dry, inside and out, with ethyl alcohol. Use a dilute KOH solution for final cleaning of the reflecting surface. After this is rinsed and dried thoroughly, place the reflector under a heat lamp, reflecting surface up, until it is warm, or even hot, to the touch. Keep the reflector under the heat lamp and form the reflecting surface by spraying on five or six thin coats of Eastman 6080 white reflectance paint. Each coat should dry before the next is applied. The final coating will not be smooth and should not be made so. A simple aspirator is good for

applying the reflectance coating but a disposable capillary pipet with a rubber suction ball on it has also been used successfully. Leave the reflector under the heat lamp until it is completely dry, about half an hour.

After the reflector cools, it can be assembled. First, screw the sample rest [22] up through the hole in the bottom of the reflector until it is high enough so that a sample tube will rest entirely on it and not on the reflecting surface. Once the sample rest is positioned properly, seal the 1/4 inch holes in the bottom and side of the reflector by inserting 1/4-20 set screws coated with silicone rubber cement (See Figure 9). The final piece mounted on the reflector assembly is a 1/8 N.P.T. to 1/4 inch tubing fitting. It goes into the threaded hole on the reflector with Teflon tape used to seal the pipe thread. This fitting holds a black plastic tube that connects the reflector to a reservoir for distilled water. This reservoir is not shown in any of the construction drawings but can be seen in Figure 7. Its design is not critical except that it must not be taller than the reflector assembly (4 inches).

Photomultiplier Tube Housing (Figure 9)

Seal the PM tube to the reflector assembly with clear silicon rubber cement. This must be allowed to cure for at least 24 hours before proceeding with further assembly of the PM tube housing. Remaining assembly involving the PM tube must be done carefully to prevent breaking the silicon rubber seal.

After the cement has cured, place the magnetic shield over the PM tube. Attach a grounding wire to the magnetic shield and bring it back to

the PM tube socket. (This assumes that the PM tube is operated with positive high voltage.) The magnetic-shield support [36], a Teflon spacer used to center the PM tube and the magnetic shield and to hold the shield in place, is put in place next.

Begin assembly of the PM tube housing [32] by placing it through the PM-tube-housing support [33] and putting a 1/8 W, 3 1/4 OD O-ring over the protruding end of the housing. Slide the housing over the PM tube and magnetic shield and fasten the support to the reflector assembly with six 6-32 bolts.

Mount the PM tube socket in the PM-tube-socket holder [37] and install this part on the PM tube. To close the end of the PM tube housing, slide the PM tube housing end-plate holder [34] over the back end of the housing and put another 1/8 W, 3 1/4 OD O-ring over the back end of the housing. Then, fasten the end plate [35] onto the holder with six 6-32 bolts.

This completes the assembly of the parts that are used in both sample changers.

Door Mechanism (Figure 9)

Continue assembly of the automatic sample changer by bolting the slide base [20] to the reflector assembly with a 3/32 W, 1 OD O-ring between them. Assemble the door mechanism by screwing the door screw [18] into the door [19]; fixing it in place with the set screw in the door. The drive mechanism for the door has two ball bearings, each 0.75 inch OD, 0.225 inch ID and about 0.25 inch wide. Place one bearing onto the screw, then screw on the door pulley [16] followed by the second

bearing. Place the door drive belt, a 1/8 W, 5-3/4 OD O-ring, on the pulley at this point. Mount these parts on the base plate [1] by putting the door in the groove on the bottom of the base plate. Hold the bearings in place by bolting the bearing blocks [17] to the top and bottom of the base plate. Finally, put a 3/32 W, 1 OD O-ring on the top of the slide base [20] and bolt it to the base plate [1] with 8 round-headed 6-32 bolts.

Sample Drive (Figure 10)

The mechanism that rotates the sample cassette is also mounted beneath the base plate. A 1 RPM motor drives this system and mounts on the bottom of the turntable base plate [24] which fastens to the base plate [1] with two turntable-base-plate brackets [23]. Flat-head 6-32 bolts are used to hold these brackets. Mount the turntable drive capstan [25] on the motor shaft, with the capstan above the turntable base plate, and fix it in place with a set screw. A 1/8 W, 2-1/4 OD O-ring fits on the capstan to provide sufficient friction to drive the turntable bearing [27]. Run a 6-32, pointed set screw up through the bottom of the turntable bearing-cup [26], mount the cup on the top of the turntable base plate [24] and put the turntable bearing [27] into the cup. The set screw is held in place with a jamb nut and supports the weight of the turntable bearing, the turntable [28] and the sample cassette. Bolt the turntable [28] to the top of the turntable bearing with three flat-head 4-40 screws. When assembled, the turntable should go into the large hole in the base plate [1] so that its top is 1/16 in. below the top of the base plate.

The turntable has two offset holes in the top for 10-24 set screws that serve as locating pins for the sample cassette. This is done to ensure that the cassette can be placed on the turntable in only one way. Reproducible alignment between these parts is important because the sample changer is designed to locate successive samples over the reflector by an optical system that uses 40 sets of holes drilled through the flange on the bottom of the turntable. As shown in the detailed drawings of the turntable (Figure 17), there are seven concentric rings of holes on the turntable flange. The inner six rings provide a two digit, BCD, indication that can be used to identify each sample unambiguously; the outer ring of holes is used to position the turntable. A light emitting diode and a phototransistor are used to detect the position of the outer holes. The spacing between the rings is 0.1 inch, the same as that between the rows of holes in standard punched paper tape. This spacing was adopted so that light source and photodiode matrices designed for paper tape readers could be used to provide the sample number data. A computer or microprocessor, using these data, could select only certain samples for counting or control counting times to suit each sample. Having forty positions requires samples to be located in 9° increments which is not difficult to accomplish because there are standard dividing heads for milling machines that use a 40 to 1 ratio.

Sample Cassette (Figure 10)

The sample cassette is made of three parts; the sample holder [31], the sample-holder slide [30] and the slide retainer [29]. Only 39 holes are drilled through the sample holder for samples (Figure 18) so that

the slot on the sample-holder slide has a position without a sample to allow changing full cassettes. This is position zero and would usually be placed over the reflector when cassettes are changed. The slot in the sample-holder slide fits over the door [19] which protrudes above the base plate [1] the same amount as the thickness of the sample holder slide.

To assemble the sample cassette, place the sample-holder slide retainer[29] through the sample-holder slide [30] and bolt it to the sample holder [31]. Guide holes, drilled in the bottom of the sample-holder slide retainer, mate with the 10-32 set screws mounted in the turntable.

Magnet Lift Assembly (Figure 11)

Most of the parts shown in the exploded view in Figure 11 are required to lift the samples into and out of the reflector although the mount [6] for the motor that operates the door is also a part of this section. Begin assembly by bolting the two magnet-lift base-plate supports [2] to the base plate [1], then bolt the magnet-lift base plate [3] to the top of the supports. Bolt the magnet guide-tube mount [7] to the magnet-lift base plate and insert the magnet-lift guide tube [8] into it. This last part is held in place with set screws.

A 10 RPM motor is used to operate the magnet lift. Bolt it to the magnet-lift drive-motor mounting plate [4] and fasten the magnet-lift pulley [9] to its shaft with a set screw. Next, mount the magnet-lift idler pulley [10] in the magnet-lift idler with a short bolt. Before continuing, bolt the door-drive motor-mounting plate [6] to the

magnet-lift pulley mounting plate [5]. Then, hold the idler and magnet-support pulley [12] in place with bolts between the magnet-lift drive-motor mounting plate [4] and the magnet-lift pulley mounting plate [5]. Two one-inch long spacers are also bolted between the top corners of these plates. Fasten this whole section to the top of the magnet-lift base plate [3]. The magnet-lift guide tube [8] will be between the two plates [4 and 5] and must be adjusted so that its top is just below the magnet support pulley [12].

Make the electromagnet by winding eight layers of #30 Formvar magnet wire onto the magnet core [14] and covering it with heat shrinkable tubing. Screw the assembled magnet into the magnet holder [13]. Solder a length of fine cable, of the type used in the pen drives of X-Y recorders, to an 8-32 bolt and screw it into the top of the magnet holder. Lower the magnet into the magnet-lift guide tube [8] and pass the cable over the magnet support pulley [12], under the magnet-lift idler pulley [10] and wind it onto the magnet-lift pulley [9]. A small screw, or solder, can be used to hold the cable to the magnet-lift pulley.

To finish the assembly of the unit, mount an 1800 RPM motor on the door-drive motor-mounting plate [6]. Fasten the door-drive pulley [15] to the motor shaft with a set screw and bring the O-ring, used as the door-drive belt, up through the slot in the magnet-lift base plate and set it over the pulley.

OPERATION

Samples to be counted are put in culture tubes, deoxygenated by sparging with dry argon and sealed using a cork treated with clear

silicon rubber cement. (This cement should not contain acetic acid.) An iron screw or tack must be inserted in the top of the cork. Once this is done, the samples can be placed in the sample cassette and the cassette put on the turntable of the sample changer.

The sample-counting sequence starts by rotating the first sample into position over the reflector. Normally, this sample would be in the first position but, if it was not, the sample changer is designed to rotate the cassette until it finds a position that does have a sample. This is done by the electronic circuits to be described later but could be done using the sample position numbers coded on the turntable, if a computer was operating the system. When a sample is in position, the magnet lowers until it reaches the metal in the cork. The drive for the magnet continues to play out cable until it is slack. If there is no sample in the cassette at the position over the reflector, the magnet-drive logic senses this by stopping after a preset elapsed time.

When the cable goes slack, the electromagnet is turned on and the magnet and sample are raised until the lift mechanism reaches an upper limit switch. This switch starts the door in motion to uncover the opening to the reflector. When the door reaches the open position, the magnet lowers the sample onto the sample rest in the reflector and the cable once again goes slack. (If this does not occur, the magnet drive system has a limit switch that will stop its downward motion.) The slack cable turns off the electromagnet and reverses the magnet drive which runs until it reaches its upper limit. This time the upper limit is the signal to close the door. A "door closed" signal starts the counting system.

At the end of the counting interval, the door is opened and the magnet lowered until it reaches the top of the sample. At that point the magnet turns on and is lifted to extract the sample from the reflector. When the magnet reaches its upper limit, the door closes and the sample is lowered into its position in the cassette. A slack cable indicates the sample is in the cassette and the magnet is turned off and raised to its upper limit. After the magnet reaches its limit, the cassette is rotated to the next position and the entire process is repeated until all of the samples are counted.

The system to detect the position of the cassette was already discussed; the other limit switches used on the prototype were simple insulated contacts that were grounded by the door, by the magnet-lift idler, or by bolts set in the side of the magnet-drive pulley respectively. No details of these switches are shown since any subsequent builder of a sample changer of this type might prefer something else.

CONTROLLER

A relatively sophisticated controller is needed to make the sample changer perform the proper sequence of motions. A photograph of the unit built to test the prototype sample changer is shown in Figure 20. Something simpler would be possible if the system was controlled by a computer or microprocessor.

Besides the limit switches on the sample changer, several other switches are needed. A univibrator is included for each switch so that the signals to the controller always have a fixed height and length as well as a minimum of problems due to switch "bounce". (See Figure 21.)

All of the univibrators were built using 556 dual timers to reduce cost and power consumption. They were run at 5 volts to be TTL compatible.

Most of the logic signals used are shown in Figure 21. A "go" and a "stop" signal derived from push-button switches start (or resume) and stop the operation of the sample changer respectively. The LED and phototransistor circuit is the one for positioning the turntable. Slack limit pulses are generated by a slack cable in the magnet drive system and the upper and lower limits on the magnet drive pulley both produce the same logic pulse.

A simple circuit provides the signal that shows the door is fully open, but the signal to show that it is closed is more complicated. In the door-closed circuit, a signal is generated if the door does not reach its closed limit within a fixed time. This signal indicates failure of the door to close which could allow light to strike the PM tube or could indicate that a sample is not properly seated in the reflector. The latter could happen if the changer failed to remove the previous sample. Failure of the door to close within the proper time suspends operation. An LED indicator was included to indicate when the door is not seated in its closed position.

Another pushbutton control is called return-to-zero (RTZ). It allows interrupting the counting sequence at any time in a logical manner. When this signal occurs, the sample changer follows the same procedure that occurs after a sample has finished counting except that the changer goes into a quiescent state (called zero in the sequencer) rather than going on to the next sample.

Two additional signals used to control the sample changer are shown in Figure 22. The "auto stop" signal is presumed to come from the counting system when all of the samples have been measured. The "initialize" signal resets the sequencer to the quiescent state without any of the intermediate steps encountered when an RTZ pulse occurs. Initialization is used primarily when the system is first turned on.

The other circuits in Figure 22 provide: the signal to return to the first step (RT1) in the sample changing sequence, the reset signal and the signals that show that no sample was found in a given location of the cassette (NB1 and NB2). Also shown are two more LED indicators, a power-on pilot light and an indicator that shows that the changer is in its automatic sequence (ON).

Details of the sequencer are shown in Figure 23. This circuit is basically a ring counter composed of 556 timers most of which are operated as bistable elements. The zero, or quiescent state, is when all of the bistables are turned off. There are 14 steps in the normal sequence with the eighth being the count. An LED indicator is included to show when a count is proceeding. To stop the count requires an external signal.

How the signals from the sequencer control the functioning of the sample changer is apparent from Figures 24 and 25. Various sequence conditions require the three motors to be on or off and going forward or reverse. Logic circuits, that are primarily OR gates, select which motor is running and in which direction. Each motor has one relay to turn it on and another to determine its direction of travel. When reverse motion is required, the signal to turn the motor on is generated by the

reverse relay. The motors coasted for some time after they were turned off which could result in mispositioning or possible damage to the sample. Therefore, a braking system was included that puts the proper amount of direct current on the motor after it is turned off. This signal comes via the motor on/off relay but is limited to a pulse so that excessive energy will not be dissipated in the motors when they are not running. The pulse circuits involved use 556 timers and are referred to as "brake timers" in Figures 24 and 25. The magnet control and drive circuits are also shown in Figure 25. Once again, one-half of a 556 timer is used as a bistable element.

The final figure (26) shows the power supplies. For simplicity they use integrated circuit regulators whenever possible. The supply for braking the motors has a choke input filter to reduce the power dissipated by the regulator. A switch for the power to the motors allows the system to be turned on and initialized without having any of the motors running. Without this, the random state in which the sequencer comes on could have a motor operating in a way that might damage the system or a sample. For absolute protection from power interruptions, this switch should be replaced with a latching relay operated by a momentary switch. The capacitors for the motors are not shown nor are the motor types given because this will depend upon availability and preference.

ACKNOWLEDGMENTS

Building prototypes of instruments of this type is a complicated and demanding task. I was fortunate to have the help of several fine craftsmen. L. A. Lee not only machined the parts for the device as originally designed but also rapidly made the modifications necessary to make the designs work. E. T. Loy did most of the work to make the "as built" drawings shown in the report from the rough construction sketches. C. P. Littleton did the mechanical assembly of the controller and also built the power supplies. Without the help of these craftsmen, these sample changers could not possibly have been designed, built and tested in the 15 months available.

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Table 1. Numbers and Names of Parts for the Alternating Sample Changer

Part Number	Name of Part	Figure Number	
		Exploded View	Detailed Drawing
1	Reflector	2	6
2	Base Plate	2	5
3	Slide	2	6
4	Slide Bearings	2	5
5	Plunger Base	2	5
6	Plunger Housing	2	4
7	Plunger-Housing Cap	2	5
8	Plunger Slide	2	4
9	Plunger-Slide Cap	2	5
10	Plunger	2	5
11	Plunger Screw	2	5
12	Plunger-Screw Retainer	2	5
13	Photomultiplier-Tube-Housing Support	9 [33]	3
14	Photomultiplier-Tube Housing	9 [32]	6
15	Photomultiplier-Tube-Housing End- Plate Holder	9 [34]	4
16	Photomultiplier-Tube-Housing End Plate	9 [35]	4
17	Photomultiplier-Tube Magnetic-Shield Retainer	9 [36]	4
18	Photomultiplier-Tube Socket Holder	9 [37]	4

Table 2. List of O-Rings and Their Associated Parts
(Dimensions in Inches)

Part Number	Name of Part	O-Ring Size		
		Wall	Outside Diameter	
ALTERNATING SAMPLE CHANGER				
2	Base Plate	Top	1/8	2 1/4
			1/8	1
		Bottom	1/8	1
5	Plunger Base	1/8	1	
8	Plunger Slide	3/32	5/4	
13	Photomultiplier-Tube-Housing Support	1/8	5 1/4	
15	Photomultiplier-Tube-Housing End-Plate Holder	1/8	3 1/4	
AUTOMATIC SAMPLE CHANGER				
15,16	Door-Drive Pulley, Door Pulley	1/8	5 3/4	
20	Door Base	Top	3/32	1
		Bottom	3/32	1
25	Turntable-Dirve Capstan	1/8	2 1/4	
33	Photomultiplier-Tube-Housing Support	1/8	5 1/4	
34	Photmultiplier-Tube-Housing End-Plate Holder	1/8	3 1/4	

Table 3. Numbers and Names of Parts for the Automatic Sample Changer

Part Number	Name of Part	Figure Number	
		Exploded View	Detailed Drawing
1	Base Plate	9, 10, 11	12
2	Magnet-Lift Base-Plate Support	11	13
3	Magnet-Lift Base Plate	11	16
4	Magnet-Lift Drive-Motor Mounting Plate	11	14
5	Magnet-Lift Pulley-Mounting Plate	11	14
6	Door-Drive Motor-Mounting Plate	11	13
7	Magnet Guide-Tube Mount	11	15
8	Magnet Guide Tube	11	16
9	Magnet-Lift Pulley	11	13
10	Magnet-Lift Idler Pulley	11	17
11	Magnet-Lift Idler	11	17
12	Magnet Support Pulley	11	15
13	Magnet Holder	11	15
14	Magnet Core	11	15
15	Door-Drive Pulley	11	15
16	Door Pulley	9	15
17	Bearing Blocks	9	16
18	Door Screw	9	19
19	Door	9	16
20	Door Base	9	14
21	Reflector	9	14
22	Sample Rest	9	18
23	Turntable Base-Plate Brackets	10	13

Table 3. (cont'd.) Numbers and Names of Parts for the Automatic Sample Changer

Part Number	Name of Part	Figure Number	
		Exploded View	Detailed Drawing
24	Turntable Base Plate	10	16
25	Turntable-Drive Capstan	10	15
26	Turntable-Bearing Cup	10	15
27	Turntable Bearing	10	15
28	Turntable	10	17
29	Sample-Holder Slide Retainer	10	13
30	Sample-Holder Slide	10	18
31	Sample Holder	10	18
32	Photomultiplier-Tube Housing	9	19
33	Photomultiplier-Tube-Housing Support	9	17
34	Photomultiplier-Tube-Housing End-Plate Holder	9	17
35	Photomultiplier-Tube Magnetic-Shield Retainer	9	12
37	Photomultiplier-Tube Socket Holder	9	12

PHOTO 6121-76

Fig. 1. Alternating Sample Changer: Photograph.

Fig. 3. Alternating Sample Changer: Construction drawing photomultiplier-tube-housing support.

Fig. 3. Alternating Sample Changer: Construction drawing of photomultiplier-tube-housing support.

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ORNL-DWG 77-7557

Fig. 2. Alternating Sample Changer: Exploded View.

8
MATE PLAIN 2-REGO
SCALE 1"=1"

NR 28 (1405) DRILL TUBE
6-EQUIVA HOLE ON 3-625
P.C.

15
MATE 6061 T-6 AL.
1-REGO SCALE 1"=1"

17
MATE TEFLOW
1-REGO SCALE 1"=1"

18
MATE 6061 T-6
1-REGO SCALE 1"=1"

NO REPRESENTATION OR WARRANTY, EXPRESSED OR IMPLIED, IS MADE THAT THE USE OR DISCLOSURE OF ANY INFORMATION, APPROPRIATE, AS SHOWN OR PROVIDED HEREON IN THESE DRAWINGS MAY NOT INFRINGE PATENT RIGHTS OR OTHER RIGHTS OR LIABILITY IS NOT MADE WITH RESPECT TO THE USE OF, OR FOR DAMAGES, ARISING FROM THE USE OF, ANY INFORMATION, APPROPRIATE, OR FROM OR PROVIDED HEREON IN THESE DRAWINGS. THE DRAWINGS ARE NOT TO BE USED FOR OTHER PURPOSES, AND ARE TO BE RETURNED UPON REQUEST OF THE DRAWING CONTRACTOR.		GENERAL SPECIFICATIONS UNLESS OTHERWISE SPECIFIED 1. BREAK ALL SHARP EDGES 2. TYPE, GRADE, OR FINISH OF MATERIAL MAY BE CHOSEN BY FABRICATOR 3. FINISHED SURFACE FINISH SHALL NOT EXCEED (ASA B46.1-1962) ☒		PLUNGER SLIDE SPECIFIC SPECIFICATIONS FRACTIONS - $\frac{1}{64}$ DECIMALS - .002 ANGLES - SCALE 1"=1"		<table border="1"> <thead> <tr> <th colspan="2">NO.</th> <th colspan="2">REVISIONS</th> <th colspan="2">DATE</th> <th colspan="2">APPROVED</th> </tr> <tr> <th>BY</th> <th>DATE</th> <th>BY</th> <th>DATE</th> <th>BY</th> <th>DATE</th> <th>BY</th> <th>DATE</th> </tr> </thead> <tbody> <tr> <td>LOY</td> <td>2-1-77</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>DESIGNED</td> <td>DATE</td> <td>APPROVED</td> <td>DATE</td> <td>APPROVED</td> <td>DATE</td> <td>APPROVED</td> <td>DATE</td> </tr> <tr> <td>CHECKED</td> <td>DATE</td> <td>APPROVED</td> <td>DATE</td> <td>APPROVED</td> <td>DATE</td> <td>APPROVED</td> <td>DATE</td> </tr> </tbody> </table>				NO.		REVISIONS		DATE		APPROVED		BY	DATE	BY	DATE	BY	DATE	BY	DATE	LOY	2-1-77							DESIGNED	DATE	APPROVED	DATE	APPROVED	DATE	APPROVED	DATE	CHECKED	DATE	APPROVED	DATE	APPROVED	DATE	APPROVED	DATE
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REFERENCE DRAWINGS		NO.
THE RISE NATIONAL LABORATORY OPERATED BY UNION CARBIDE CORPORATION ONE INCH, TENNESSEE		
RDS 7710		NO.
ALTERNATING SAMPLE CHANGER SUBMITTED: _____ RECEIVED: _____ APPROVED: _____ HPD 2664 D		

Alternating Sample Changer: Construction drawing of plunger housing, plunger slide, photomultiplier-tube-housing end plate, photomultiplier-tube-housing end-plate holder, photomultiplier-tube magnetic-shield retainer and photomultiplier-tube socket

2

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PARTS LIST		STOCK NO.	MATERIAL
PART	QTY	NO.	DESCRIPTION
1	2		3/8-20 R.H. SCREW FULL THREAD
3	1		1/2-20 (120%) DRILL THRU 6-EDGE, 120° POINT, 1/2" DIA. 1.250 A.C.
11	1		1/2-20 (120%) DRILL THRU 5-1/2" DIA., 120° POINT TAP 1.40 A.C.
12	1		1/2-20 (166) DRILL THRU
13	1		1/2-20 (166) DRILL THRU
14	1		1/2-20 (166) DRILL THRU
15	1		1/2-20 (166) DRILL THRU
16	1		1/2-20 (166) DRILL THRU
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21	1		1/2-20 (166) DRILL THRU
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26	1		1/2-20 (166) DRILL THRU
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94	1		1/2-20 (166) DRILL THRU
95	1		1/2-20 (166) DRILL THRU
96	1		1/2-20 (166) DRILL THRU
97	1		1/2-20 (166) DRILL THRU
98	1		1/2-20 (166) DRILL THRU
99	1		1/2-20 (166) DRILL THRU
100	1		1/2-20 (166) DRILL THRU

Alternating Sample Changer: Construction drawing of base plate, plunger screw, plunger base, plunger-slide cap, plunger-housing plunger, plunger-screw retainer, plunger base and slide

2

Fig. 6. Alternating Sample Changer: Construct tube housing reflector and slide.

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PHOTO 6117-76

Fig. 7. Automatic Sample Changer: Rear view photograph.

PHOTO 1537-77

Fig. 8. Automatic Sample Changer: Front view photograph.

Fig. 9. Automatic Sample Changer: Exploded view of reflector, photomultiplier tube housing and door assembly.

Fig. 10. Automatic Sample Changer: Exploded view of turntable drive and sample cassette assemblies.

Fig. 11. Automatic Sample Changer: Exploded view of magnetic sample life assembly.

1

PARTS LIST				
PART	QTY	REQ	DESCRIPTION	STOCK SIZE

37
MATERIAL 6061 T-6 AL
1-REQ SCALE 1"=1"

USE 19 (106) DRILL
1/8 DIA

USE 25 (136) DRILL
THRU 3-HOLES. TAP
0-53 UNC

36
MATERIAL TEFLON
1-REQ SCALE 1"=1"

USE 28 DRILL THRU
1-HOLE. CHAMFER NEAR
SIDE .015 X .005 DIA
USE 36 (106) DRILL THRU 8-HOLE
TAP 6-32 UNC

USE 28 (140) DRILL THRU
6-HOLE

1
MATERIAL 6061 T-6 AL
1-REQ SCALE 1"=1"

REFERENCE DRAWINGS		NO
FOR MORE INFORMATION CONTACT BY UNION CARBIDE CORPORATION CHATTANOOGA, TENNESSEE		
DRAW 7110		
AUTOMATIC SAMPLE CHANGER		
SUBMITTED	APPROVED	REMARKS
HPD	2645 B	

NO	REVISIONS		DATE	APPROVED	APPROVED
	DATE	SUBMITTED			
1	1-2-77				
2					
3					
4					
5					
6					
7					
8					
9					
10					

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GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED
1. BREAK ALL SHARP EDGES
2. TYPE, GRADE, OR FINISH OF MATERIAL, WHEN CHOSEN BY FABRICATOR
3. UNFINISHED SURFACE FINISH SHALL NOT EXCEED 1/32" DIA 1/16" DIA

VALUES UNLESS OTHERWISE SPECIFIED
FRACTIONS - 1/16
DECIMALS - .005
ANGLES -
SCALE 1" = 1"

Automatic Sample Changer: Construction drawing of base plate, photomultiplier-tube socket holder and photomultiplier-tube magnetic-shield retainer.

2

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PARTS LIST				
PART	QTY	NO.	DESCRIPTION	STOCK NO.

NE 30 (.110) DRILL
THRU ONE SIDE TAP
G-32 UNC

③
MATE DRAW 1-REQD
SCALE 1"=1"

NE 25 (.1425)
DRILL THRU 2- Holes
G-32 UNC 2" x .005"
DIP

NE 30 (.110) DRILL
THRU TOP G-32 UNC
TYP 1-PLATE

③
MATE DRAW 1-REQD
SCALE 1"=1"

NE 30 (.110)
DRILL THRU 2- Holes
G-32 UNC TYP 1-PLATE

②
MATE DRAW 1-REQD
SCALE 1"=1"

REFERENCE DRAWINGS	NO.
SEE DRAWING 7710 OPERATED BY UNION CARBIDE CORPORATION ONE HOLE, TUNNELS	
DRAW NO. 7710	

GENERAL SPECIFICATIONS		TOLERANCES UNLESS OTHERWISE SPECIFIED		REVISIONS				DATE		APPROVED	
UNLESS OTHERWISE SPECIFIED		FRACTIONS		NO.		DATE		APPROVED		DATE	
1. BREAK ALL SHARP EDGES		DECIMALS		1-1-77		DATE		APPROVED		DATE	
2. TYPE, GRADE, OR FINISH OF MATERIAL, WHEN CHOSEN BY FABRICATOR		ANGLES		DATE		APPROVED		DATE		APPROVED	
3. FINISH: SURFACE FINISH SHALL NOT EXCEED 100A D81. 1001		SCALE 1"=1"		DATE		APPROVED		DATE		APPROVED	

AUTOMATIC SAMPLE CHANGER

DESIGNED	APPROVED	DATE
HPD	2636 D	1977

nger: Construction drawing of door-drive
, magnet-lift pulley, turntable base-plate
er slide retainer and magnet-lift base-plate

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Fig. 15. Automatic Sample Changer: Construction drawing of magnet tube mount, magnet core, magnet holder, magnet support turntable-bearing cup, turntable-drive capstan, turntable and door-drive pulley.

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PARTS LIST			
PART	DWG NO	REQD	STOCK SIZE
DESCRIPTION		MATERIAL	

NO 23 (156) DRILL
1/16 DR TAP 8-32
N.C. TYPE RA END

(15)

MATL TEFLON
1-REQD SCALE 1"=1"

(12)

MATL BRASS 1-REQD
SCALE 1"=1"

NO 25 (110) DRILL
THRU. TAP 6-32 N.C.

NO 13 (089) DRILL 3 EQUA
SPA HOLES ON 400 A.C.
TAP 1-10 N.C.

(21)

MATL BRASS 1-REQD
SCALE 1"=1"

(25)

MATL BRASS 1-REQD
SCALE 1"=1"

ASSEMBLY	
REFERENCE DRAWINGS	NO
ON ROSS ENGINE LABORATORY OPERATED BY UNION CARBIDE CORPORATION OAK RIDGE, TENNESSEE	
Dwg NO 7710	
AUTOMATIC SAMPLE CHANGER	
HPD	2638 D

GENERAL SPECIFICATIONS		TOLERANCES UNLESS OTHERWISE SPECIFIED		REVISIONS		DATE		APPROVED	
UNLESS OTHERWISE SPECIFIED		FRACTIONS - 1/16		NO		DATE		APPROVED	
1. BREAK ALL SHARP EDGES		DECIMALS - 0.005		DRAWN		DATE		APPROVED	
2. TYPE, GRADE, OR FINISH OF MATERIAL MUST BE CHOSEN BY FABRICATOR		ANGLES - 9°		CHECKED		DATE		APPROVED	
3. MACHINED SURFACE FINISH SHALL NOT EXCEED 125 A.S.M.F. 1957		SCALE 1"=1"		DATE		APPROVED		DATE	

ger: Construction drawing of magnet guide-
re, magnet holder, magnet support pulley,
turntable-drive capstan, turntable bearing

2

1000
100

US 28 (1405) DRILL THRU 2-HOLE

MATL 6061 T6 AL
1-REED SCALE 1"=1"

PARTS LIST					STOCK SIZE	MATERIAL
PART	QTY	NO	RECD	DESCRIPTION		

US 29 (136) DRILL THRU
TAP 6-32 U.C

MATL BRASS 1-REED
SCALE 1"=1"

US 35 (110) DRILL
TAP 6-32 U.C. TYP
EN END

US 28 (1405) DRILL
THRU 2-HOLE

US 19 (166) DRILL
THRU 2-HOLE

MATL 6061 T6 AL
1-REED SCALE 1"=1"

MATL 2002.063 WALL DRAW
TURNING
1-REED SCALE 1"=1"

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REPRODUCED OR TRANSMITTED IN ANY FORM OR BY ANY MEANS,
ELECTRONIC OR MECHANICAL, INCLUDING PHOTOCOPYING, RECORDING,
OR BY ANY INFORMATION STORAGE AND RETRIEVAL SYSTEM, WITHOUT
THE WRITTEN PERMISSION OF THE UNION CARBIDE CORPORATION.

GENERAL SPECIFICATIONS
UNLESS OTHERWISE SPECIFIED
1. BREAK ALL SHARP EDGES
2. TYP. CHAMF. OR FINISH OF
MATERIAL MAY BE CHOSEN
BY FABRICATOR
3. UNFINISHED SURFACE FINISH
SHALL NOT EXCEED
1000 DPM 1-1000

REFERENCE UNITS
FRACTIONS - 1/16
DECIMALS - 0.05
ANGLES - 0.5
SCALE 1"=1"

NO	REV	DATE	APPD	APPD
1	1-N-77			
2	1-N-77			
3	1-N-77			
4	1-N-77			
5	1-N-77			

REFERENCE DRAWINGS		NO	
ONE HOUR RUNNING LABORATORY OPERATED BY UNION CARBIDE CORPORATION ONE HILL, TENNESSEE			
		BLUE NO 7710	
AUTOMATIC SAMPLE CHANGER			
SUBMITTER		APPROVED	
HPD		2659 D	

Automatic Sample Changer: Construction drawing of door, bearing
black door pulley, magnet-lift base plate, magnet guide tube
turntable base plate.

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Fig. 17. Automatic Sample Changer: Construction drawing of photomultiplier-tube-housing support, photomultiplier end-plate holder, magnet-lift idler and magnet-lift

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ger: Construction drawing of turntable,
housing support, photomultiplier-tube-housing
jet-lift idler and magnet-lift idler pulley.

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2

Automatic Sample Changer: Construction drawing of sample holder, plate-holder slide, photomultiplier-tube housing and plate and the rest.

HPD	261	D
Automatic Sample Changer		
Part No. 7710		
General Engineering Corporation		
1000 Broadway, New York 10003		
Drawing No. 7710		
Scale: 1/2" = 1"		
Date: 10/1/60		
By: [Signature]		
Check: [Signature]		
Title: [Signature]

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Fig. 19. Automatic Sample Changer: Construction drawing of photomultiplier tube housing and door screw.

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PARTS LIST			
PART NO.	QTY. REQ.	REV. REQ.	DESCRIPTION (QTY., DIM., ETC.)

<p>TUBING</p>			
<p>1-REQD</p>			
<p>1-REQD</p>			
<p>UNLESS OTHERWISE SPECIFIED</p> <p>FINISHES: 1. _____</p> <p>ROUNDS: 2. _____</p> <p>ANGLES: 2. _____</p> <p>SCALE: _____</p>		<p>GENERAL SPECIFICATIONS</p> <p>Unless Otherwise Specified:</p> <p>1. Break all sharp edges 1/8" max.</p> <p>2. Type, grade, or finish of material may be chosen by fabricator.</p> <p>3. Roughness height of machined surfaces shall not exceed _____.</p> <p>(Finish symbols and height values are in accordance with ASA B46.1-1956.)</p>	
<p>REFERENCE DRAWINGS</p>		<p>DWG. NO.</p>	
<p>AUTOMATIC SAMPLE CHANGER</p>			
<p>OAK RIDGE NATIONAL LABORATORY</p> <p>OPERATED BY</p> <p>UNION CARBIDE NUCLEAR COMPANY</p> <p>DIVISION OF UNION CARBIDE CORPORATION</p> <p>OAK RIDGE, TENNESSEE</p>			
<p>DESIGNED</p>		<p>ACCEPTED</p>	
<p>DATE</p>		<p>DATE</p>	
<p>HPD C 2662</p>		<p>REV.</p>	

Sample Changer: Construction drawing of photomultipliering and door screw.

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PHOTO 1538-77

Fig. 20. Automatic Sample Changer: Controller, photograph.

Fig. 22. Automatic Sample Changer: Controller, schematic diagram of the miscellaneous control circuits.

Fig. 24. Automatic Sample Changer: Controller, schematic diagram of the magnet motor and sample motor controls.

Fig. 25. Automatic Sample Changer: Controller, schematic diagram of the door motor and magnet controls.

ORNL-DWG 76-17678

Fig. 26. Automatic Sample Changer: Controller, schematic diagram of the power supplies.