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I INTRODUCTION

During the period covered by this report the principal investigators were William P. Jesse and John J. Spokas. Each has devoted one hundred percent of his time on projects covered by this S R S A throughout the period being reported and will continue to do so to the conclusion of the present contract period on August 31, 1972.

The research in the area of Ionization of Gases conducted by William P. Jesse will be reviewed rather briefly in Section II. William Jesse will be retiring from full-time research at the end of the present contract period. A suitable replacement who might carry these studies forward is not available. Therefore our program dealing specifically with fundamental studies of the ionization of gases by energetic alpha and beta particles is being suspended at this time. A final report covering this phase of our program will be submitted at the conclusion of the current contract period.

The work of the past year on Special Problems in Nuclear Instrumentation will be treated in Section III. This portion of our program has been the responsibility of John J. Spokas. The work involved mixing of special plastics, techniques of plastic fabrication, 0.5 cc ionization chamber development, basic electrometer research with special reference to application to environmental chambers, and environmental chambers per se.

II PRELIMINARY REPORT OF RESEARCH ON THE IONIZATION OF GASES AND THE AVERAGE ENERGY TO MAKE AN ION PAIR

William P. Jesse

Since, as was mentioned in our last year's report, I expect to retire from full-time research at the end of the 1971-72 contract, it would seem most logical to present a full report of the year's activities at that time, thus including the additional research of the summer months. It would hence appear futile to present any extended report at this time. The following is thus to be regarded as a brief summary of the work carried out up to the present time.

All the experiments of this year on the ionization of gases were carried out in the high temperature chamber, which has been developed and was described in some detail in the report of last year. In spite of formidable difficulties the chamber with its teflon insulators has performed with reasonable reliability.

IONIZATION MEASUREMENTS IN MERCURY VAPOR WITH BETA PARTICLES AND THE MEAN ENERGY TO FORM AN ION PAIR

The results of these experiments were discussed in some detail in our last report and have since been published [Jour. Chem. Phys. 55, 3603, October 1971]. A reprint of this paper will be included in our final report. Any further discussion here would thus seem redundant.

IONIZATION MEASUREMENTS IN WATER VAPOR WITH BETA PARTICLES AND THE MEAN ENERGY TO FORM AN ION PAIR

As was pointed out in our last report, it should be of interest to biologists to have a reliable value of W , the mean energy to form an ion pair in water vapor.

To this end measurements were made in the high temperature chamber on the vapor of water which had been distilled into the chamber. These measurements followed the technique used for pure mercury vapor. The ionizing agent was again the beta particles from ^{63}Ni and a comparison in relative ionization was made with the chamber filled with pure argon. The best values obtained were $W_{\text{H}_2\text{O}} = 29.7 \pm 0.2 \text{ eV/ion pair}$, relative to argon taken as $W = 26.4 \text{ eV/ion pair}$.

This is slightly lower value than the value 29.9 eV/ion pair obtained by Adler and Bothe [Z. Naturforsch 20a, 1700 (1965)] with the beta particles from ^{63}Ni . Here a relative ionization comparison was made with air with W taken to be 33.8 eV/ion pair .

A similar result of $29.9 \pm 0.5 \text{ eV/ion pair}$ was obtained by Booz and Ebert [Strahlen-therapie 120, 7 (1963)] obtained relative to air ($W=33.8 \text{ eV/ion pair}$). The ionizing source in this case consisted of X-rays of 100 to 300 KV.

For comparison with the ionization values for H_2O vapor in our experiments a few tentative measurements were made with the vapor of D_2O under the same conditions. The isotopic purity of the D_2O was estimated as 99.7 % by the manufacturer.

The ionization vs vapor pressure curves for D_2O were found to be about two percent higher than those for H_2O in the plateau region. This is in general agreement with the

ratio obtained in a similar comparison of deuterated and undeuterated hydrocarbon gases [Jour. Chem. Phys. 38, 2774 (1963)]. The present measurements in water vapor, however, do not have the very high precision attained in the hydrocarbon gases.

IONIZATION STUDIES IN MIXTURES OF ARGON AND MERCURY VAPORS

These experiments were discussed at some length in our last report. A pool of mercury is enclosed in an atmosphere of argon in the chamber, and the total ionization is measured as the vapor pressure of mercury increases with rising chamber temperature. The ionization, relative to that in pure argon, is then plotted as in previous experiments against the atomic concentration of mercury in argon.

Such experiments at high temperature are extremely difficult to carry out with the high accuracy of measurement desired, and so far the results obtained must be regarded as preliminary. More accurate measurements seem to be possible and are now in progress.

As was pointed out in our last report, the monatomic mercury molecule should offer a great simplification in interpretation of results, since we have no losses from possible intramolecular reactions which may occur if polyatomic hydrocarbon gases are used as contaminants for argon.

From our experiments so far in mercury-argon mixtures the following trends seem to emerge. Complete confirmation of these must wait on the further more accurate measurements now in progress.

In the mercury-argon mixtures, as in previous experiments [Phys. Rev. 100, 1755 (1955)], as the concentration of mercury molecules increases the observed ionization

increases over that found in pure argon. This increase is at first rapid and then slower until finally a relatively constant maximum ionization current value is attained. This maximum ionization value is about 30 percent higher than that for pure argon. This increase is somewhat less than the 43 percent predicted by Platzman's approximate empirical formula.

It is interesting to note that the 30 percent maximum increase is almost exactly the same as that obtained by Hurst and his co-workers and by ourselves for acetylene in argon. This was the highest increase for any hydrocarbon contaminant in argon so far found by the Hurst group.

A search has been made for a possible pressure effect in mercury-argon mixtures. Preliminary measurements were made over a range of mixture pressures from 30 to 90 cm of Hg. This would indicate that in the curve relating ionization current to mercury concentration the ionization rises more abruptly at the origin the greater the pressure of the mixture. In the notation adopted previously [Phy. Rev. 100 page 1758 (1955)], the ratio K_i/K_d is larger for higher mixture pressures. Here K_i is proportional to the cross section for ionization, and K_d is proportional to the cross section for the alternative radiative process.

The exact mode of variation of the ratio K_i/K_d with pressure is so far not precisely determined. It is hoped that more accurate measurements will determine this point.

The ratio K_i/K_d , calculated from our preliminary curves, is found to be relatively small in mercury-argon mixtures. This ratio is several times smaller than that previously found for acetylene-argon mixtures for alpha particle ionization (See reference above). Thus the mercury molecule does not show here in argon the very high value of the ratio K_i/K_d found in mercury-helium mixtures.

III SPECIAL PROBLEMS IN NUCLEAR INSTRUMENTATION

John J. Spokas

The major effort of the past year was divided among four principal projects; (1) mixing special plastics for applications in dosimetry, (2) development of small 0.5 cc ionization chambers, (3) extending the capability of the Shonka vibrating fiber electrometer, and (4) studies of the application of large, 4 to 16 liter, ionization chambers to the measurement of environmental radiation. The progress achieved in each of these four areas over the past twelve months is reported separately below.

MIXING CONDUCTING PLASTICS

Last year the goal was set to mix approximately 300 pounds of air-equivalent plastic. The plan called for operating around the clock for a full work week using three separate teams. None of the crew had been intimately involved with mixing before, although one member did have prior experience with the equipment. Considering the relatively scanty notes available on the operation and the lack of experience, the mixing project was highly successful. The operation was set up for one full week, Monday thru Friday, at the conclusion of which 256 pounds of new mix was achieved.

The air-equivalent mixture, designated C-552, is relatively simple since it contains three components, polyvinylidene fluoride, carbon and silica. However, rather high temperatures are required to plasticize the polyvinylidene fluoride which still remains quite viscous. Higher temperature cannot be employed to reduce the viscosity because of thermal decomposition which can be violent under certain conditions.

The procedure used in mixing the C-552 was as follows. The correct proportions of the three ingredients were placed in gallon jars and mixed by rolling, twenty minutes or so in each direction. The homogenized dry powder is then fed directly into the mixing chamber by means of a small screw-auger. The mixer is the automatic reciprocating type which was developed by Dr. Shonka in our laboratory and it has been described in some detail in previous reports.

The weight in per cent of each component and the origin of the material are given in the table below.

INGREDIENTS IN C-552

<u>Component</u>	<u>Weight percent</u>	<u>Source</u>
Polyvinylidene fluoride	78.40	Kynar powder Grade 201 F Penwalt Corp.
Carbon	20.75	Vulcan XC-72 pellets Cabot Corp.
Silica	0.84	Cab-o-sil M-5 Cabot Corp.

Taking into account the atomic composition of each component, the atomic percentages of the elements in the final mixture are easily determined. The results are : Hydrogen-26.86 ; Carbon-45.81 ; Oxygen-0.31 ; Fluorine- 26.86 ; and Silicon- 0.15 .

There are several parameters of the apparatus which can be varied and which govern the mixing cycle. Some of these parameters are : temperature of mixing chamber, extrude and feed times, length of travel (stroke) of the mixing screw, and the orifice size in the extruding die of the mixer.

The importance of the various settings of the mixer controls is not completely apparent. For, example, the notation found on file, "controller set at 475 °F but barrel runs at 500 °F" puzzled us for a considerable while. The temperature controller for the mixing chamber was actually set at 450 °F at the outset. However, it was noticed that the actual chamber temperature was 540 °F. Evidently the heaters were never cutting in, as more than sufficient heat was being generated through the action of mixing. The temperature controller may just as well have been set at 0 °F. The point is, the temperature at which the controller was set had nothing to do with the actual temperature of the barrel, as the system was operating. One thing this result reveals is the tremendous load on the motor which turns the mixing screw. All the heat required to plasticize the plastic component evidently was being derived from the mechanical output of the screw motor.

Over the first two days of mixing the production rate was about 2 1/2 lbs per hour. This is a relatively low rate. Varying the extruding time from 2 to 5 sec had virtually no effect on the overall mixing rate. Likewise increasing the stroke to 1 1/4 " from 3/4 " yielded no significant increase in the rate. The nozzle on the mixer was changed to one having an orifice 5/16 " diameter. The original nozzle had an orifice of 3/16 " diameter. This latter change did produce some significant changes.

One important result of the larger orifice was a drop in the temperature of the mixing chamber to 450 °F. The larger orifice also resulted in a significant increase in the speed of the reciprocating action of the mixer. But despite this large temperature drop and the faster reciprocating action the overall mixing rate was unchanged.

The larger orifice did yield one important benefit. The loading of the mixer drive motor was reduced, which necessitated turning on of the chamber heaters to maintain the temperature at 500 °F. Up to this point, the main drive chain had snapped twice and

the contacts on the motor reversing relay had burnt out. These problems did not recur subsequently, doubtlessly because of the reduced stress on the drive motor.

Apparently the extremely fine powder is not handled well by the mixer. A simple confirmation of this notion can be seen in the following. To feed 1.2 lbs of ground previously mixed C-552 thru the mixer required just 3 min. The same amount of finely divided ingredients required 27 min. In this test, the various controls on the mixer were unchanged, but we have a nine-fold faster rate for the coarser premixed powder.

In light of this demonstration, each 1.2 lb portion of raw ingredients was charged with 1/3 lb of ground C-552. The idea is to give the mixer a substance with a degree of body thus enabling the mixing screw to work itself more readily thru the material. This technique further reduced the stress on the mixer, nearly doubled the rate of mixing, and was therefore followed for the balance of the run. The dry fine powder mixture, wherein the carbon has not yet been worked into the plastic, does not give the mixing screw a substance that holds itself together. Much slipping must occur which is not at all free of friction and which is the source of the great amount of heat generated in the mixer.

The new mix was tested regularly for electrical conductivity. Despite the alterations mentioned above, the conductivity always showed up nearly the same. Between a pair of points one inch apart along a piece as extruded from the mixer the resistance was approximately 200 Ohms. Subsequently several parts were molded from the new mix. It seemed to respond precisely as the previously mixed C-552 in every respect. The new batch seems to have a higher electrical conductivity which would imply that the carbon actually has been worked more thoroughly into the plastic.

It is planned to test the use of an extruder in series with the mixer in the future. The plasticized material would be extruded directly into the mixer. Thus the mixer

would not have to contend with dry ingredients. This ought to allow the same degree of mixing as well as greater speed and less stress on the mixer.

SMALL CHAMBER DEVELOPMENT

This is a continuation of work discussed in last year's report. Our objective is to develop a series of 0.5 cc transfer chambers. There would be mainly three distinct chambers in the series. One would be constructed of air-equivalent materials, another of muscle-equivalent materials, and the third one would be constructed of magnesium, because of its neutron insensitivity. The air-wall chamber would be used as a secondary standard in measuring the Roentgen-value of fields consisting primarily of gamma rays. The muscle-wall chamber would provide the researcher with a means to determine the true muscle dose in the case of the gamma, neutron, and mixed gamma-neutron fields. The magnesium chamber would be used to isolate the gamma component of a mixed gamma-neutron field. It is anticipated that these chambers will have sufficient uniformity and reliability to serve as secondary standards. The muscle and magnesium chambers would also find application in depth-dose studies in phantoms and cadavers. The 0.5 cc chamber work represents a collaboration with Frank S. Williamson of Argonne National Laboratories and Major David M. Verrelli of the Armed Forces Radiobiology Research Institute.

The size of the chamber reflects a compromise between small size for depth dose measurements and adequate sensitivity, high enough to yield one percent accuracy in measurements. For the usual gamma and neutron spectra in which these chambers would be used, the sensitivity is directly proportional to the ionizing volume of the

chamber. The chamber response must be sufficiently great to swamp the spurious cable currents associated with the hundred feet of cable which may separate the chamber from the electrometer. A number of prototypes of each of the air, muscle and magnesium chambers have been completed. Testing of the prototypes has begun at AFRRI, ANL and here at IBC. The results of the tests to date have been most encouraging.

The air, muscle and magnesium chambers have identical geometry. The chambers are attached to the end of a length of microdot coaxial cable. The muscle and magnesium units are provided with two gas connections to allow the passage of a special gas thru the chamber during measurement. A muscle equivalent gas would be circulated thru the muscle chamber and argon and carbon dioxide have been used in the magnesium chambers. The air chambers are provided with small breathing holes which ensure equilibrium with the ambient atmosphere. The present electrode configuration of the 0.5 cc chambers is illustrated by the sectional view of the magnesium chamber in Figure 1.

The air chambers were the first to be fabricated. The completion of twelve prototypes was reported last year. Tests conducted on these units have not revealed any failings. Spurious currents were found to be of the order of 10^{-15} Amperes at shell potentials of 900 Volts. The collector was supported in these units by ultra-sonic welding to a small polyvinylidene fluoride button. Since this technique could not be employed in the magnesium chambers, a modification was made in the design. In the new arrangement the collector is merely forced into the guard electrode and is held secure thru the use of a locking taper.

Ten magnesium units were completed following this new design. The shell thickness was increased to one millimeter for these first magnesium units as well as all sub-

sequent 0.5 cc chambers which have been completed. Polyethylene was used for the collector-guard and shell-guard insulators. The shell-guard insulator is injection molded directly around the guard electrode. The collector-guard insulator is similarly molded on to the collector. The slight shrinkage of the plastic serves to hold the insulators firmly in place.

These units performed well as far as electrical behavior was concerned. The magnitude of the ionization current was appropriate to the materials used and the size of the chamber. However, several of the chambers were not entirely gas tight. This problem was traced to the fit of the shell. Electrical connection to the shell was simply made by a few strands of five mill wire forced between the shell and HV insulator. This leakage difficulty has been circumvented by drilling a small hole into the edge of the shell and forcing a length of Cu-Be wire into the hole. The HV lead is merely soldered to this Cu-Be shell lead. Attaching the high voltage lead in this manner does not interfere with the seal of the shell to the chamber.

It was believed that the geometry of the insulators would effectively inhibit any significant neutron response from recoil protons produced in the insulators. Although no evidence of any recoil proton contribution was clearly observed, it was decided to test this point experimentally. To this end, several chambers were made in which polyvinylidene fluoride (Kynar) was substituted for polyethylene. The hydrogen concentration in polyvinylidene fluoride is 50 % of that in polyethylene. A comparison of the neutron response of two chambers each having a different insulator would enable one to assess accurately the recoil proton contribution.

A pair of such chambers were first compared in the pure gamma field of the gamma

room in Bldg. 202 at A N L . The chambers gave readings within one percent of each other in this case. The chambers were then transferred to the high flux room of the Janus reactor also in Bldg. 202. In this latter situation, the polyethylene chamber showed a 10 % higher response. This seemed to give a distinct proton recoil effect. However, one must suspend this conclusion pending further tests. One of the chambers used in this test showed a gas leak for reasons mentioned above. Argon gas was circulated thru the chambers connected in series in these tests.

The fabrication of 0.5 cc muscle chambers was not expected to present any problems after the air chambers were completed. Friction welding, ultra-sonic welding and electrical welding had been successfully done with A-150, muscle-equivalent conducting plastic, and polyethylene. Furthermore, A-150 is far easier to mold in comparison to C-552. Despite this, several problems were encountered in the fabrication of the muscle chambers. These problems were solved and eleven units have been completed. Eight of these have been sent to Verrelli and Shosa at AFRR and to Frank Williamson at A N L for critical testing. The manner in which the problems were met are detailed below.

The H V insulator was bonded to the conducting plastic guard electrode by means of friction welding in the case of the air chambers. The same method proved to be quite a challenging problem in the case of the muscle chambers. This was a most surprising result in view of the fact that polyethylene and A-150 have been friction welded quite successfully in a number of places in our previous work. However, there is one essential difference. In the past one was always dealing with a butt weld. In that situation the surfaces to be joined are planar and one rotates one piece with re-

spect to the other about an axis perpendicular to the plane of contact. In the 0.5 cc chambers the interface between the high voltage insulator and the guard electrode is cylindrical in shape. To allow the two pieces to be friction welded, the cylinder is tapered slightly. For certain rotational speeds and applied force one could obtain a partial weld. But there was a significant variation from piece to piece.

In view of these difficulties a alternative approach was sought for bonding the high voltage insulator to the guard. One approach, which is rather slow but effective, is compression bonding. In this technique a polyethylene bushing is forced on to a close fitting A-150 rod. The combination is then loaded into a simple compression mold and heated to approximately 300°F. An hydrostatic pressure of 5000 psi is maintained in the mold. If the mold is sufficiently tight to prevent any flashing of the plastic during this process, no distortion of the A-150 polyethylene boundary will occur. In this manner uniform bonding is consistently achieved.

A problem was encountered with electrically welding the high voltage lead to the conducting plastic shell. Higher voltages were required than in the case of air chambers. More importantly, the shell was distorted somewhat in the process and the seal between the shell and the chamber was destroyed. Ultra-sonic welding of the shell to the H V insulator was attempted. Several horn configurations were tested. After much experimentation it was possible occasionally to obtain an adequate seal.

This problem of sealing the shell to the chamber derived from the distortion of the shell during electrical welding of the H V lead to it. Another means of attaching the H V lead may eliminate the distortion and obviate the need to seek special means of sealing the shell. One approach would be to mold the shell with a suitable lead in it.

This was tried and seems to be entirely adequate.

The background currents were measured in seven separate chambers at shell potentials of 300 Volts. The maximum background current observed was 2×10^{-15} Amperes. Two of the units had a background current less than 2×10^{-16} Amperes. The chambers can be operated at shell potentials of 1000 Volts. The background currents are somewhat higher at the maximum shell potential. Some chambers show, however, background currents of less than 10^{-15} Amperes at 1000 Volts. For the vast majority of applications, particularly in radiation therapy, the background currents quoted above would be entirely negligible.

Further tests of these chambers are in progress. Some preliminary measurements were reported by Verrelli and Shosa of AFRRl at the May 1972 meeting of the Radiation Research Society in Portland, Oregon.

ELECTROMETER IMPROVEMENTS

The vibrating electrometer [Rev. Sci. Instr. 35, 1046 (1964)], invented by Dr. Francis R. Shonka and produced commercially for a time by Coleman Instruments, has a number of inherent advantages. These advantages stand out particularly when one is faced with the task of measuring extremely feeble currents such as those produced in an ionization chamber by background radiation. Unfortunately, one has not the full benefit of these advantages since the instrument provided only discrete readings.

The heart of the electrometer is a quartz fiber covered with a thin layer of gold, which is situated in a strong alternating field produced by a pair of electrodes called the binants. The three electrodes are in a planar arrangement inside the cavity in

a metal block. The binants are 180 degrees apart. The gold-coated quartz fiber is 90 degrees from either binant with its free end in the center of the gap between the ends of the binant. Figure 2 shows in part a schematic drawing of the electrode configuration.

When the instrument is properly balanced, this configuration is extremely sensitive to small constant potentials on the fiber. The presence of a potential on the fiber is manifested by a vibration of the fiber at the frequency of the voltage impressed on the binants. The customary frequency has been 60 Hz. A small microscope which is an integral part of the electrometer is focused on the fiber. One then sees the effect of the potential on the fiber in terms of a vibration and adjusts a compensating potential to make the fiber stationary. The compensating potential either is introduced in the circuit under study or is impressed on the binants.

One obtains, in this manner, readings which are discrete. That is, readings which apply only to the particular moment when balance was achieved. There is no provision for continuous monitoring. This seriously limits the usefulness of the electrometer. Any noise in the system would impair accuracy. By taking a number of distinct readings, noise can be indeed be averaged. This is, however, a laborious and time consuming procedure. Being restricted to discrete readings makes it impossible to clearly see response times in the system under study unless the response times are in excess of 10 min or so.

An automatic balancing system for the Shonka electrometer has been devised and tested. It involves very little in the way of additional apparatus and has proved to work exceptionally well. Actually, the new system affords, for the first time, the opportunity to determine the great capability of the Shonka electrometer.

Automatic balancing was achieved by detecting the vibration of the quartz fiber by means of a special photocell. The signal from the photocell is amplified, then phase-sensitively rectified in a servo-motor. The servo-motor drives the contact of slide-wire potentiometer which provides the compensating, or in this case a feed-back, potential. Figure 2 gives a diagram of the complete system. The photocell is located in the focal plane of the electrometer microscope and is the only change that must be made to the electrometer.

The photocell consists of two lead sulphide photo-conducting films (Eastman Kodak Co. Extron detectors) each approximately 3 mm square and deposited side-by-side on a glass substrate. The films have one electrode in common. Thru their separate electrodes, one cell is biased at a positive potential (30-90 Volts) , the other at an equal negative potential.

When the fiber vibrates because of its finite potential, it does so with a definite phase. For example, if the fiber potential is positive, it is attracted by the binant which at the moment is negative and is repelled by the positive binant. A half-cycle later the fiber will be deflected in the opposite direction as the binant potential reverse. The current emerging from the common cell electrode will thus have a polarity which reflects the position of the fiber, which position is determined by the fiber and the binant potentials. Consequently, the phase of the photocell current is governed directly by the sign of the fiber potential.

The amplified photocell output is impressed on one of the windings of a servo-motor,

a reference voltage being maintained on the other winding. A photocell signal of one phase causes the servo to run in a particular direction, while the opposite phase causes the servo to run in the reverse direction. The servo-motor is mechanically coupled to a slide-wire potentiometer whose output is coupled to the electrometer in such a way as to oppose the initial off-balance fiber potential. In this manner the fiber is maintained quite precisely at rest, despite the fact that potentials may appear on the fiber for various reasons. The feed-back voltage indicates continuously the instantaneous fiber potential and can be monitored on a strip-chart recorder or other convenient recording device.

In the first automatic balancing system actually assembled, a Brown recording potentiometer was employed. The Brown recorder provided the servo-amplifier, servo-motor, and slide-wire potentiometer needed for the automatic electrometer system described above. At the same time, the Brown recorder allowed a continuous tracing of the instantaneous fiber potential. The portions of Figure 2 boxed in with a dotted line are contained in the standard recording potentiometer.

The standard recorder is a DC instrument although it uses an AC servo-motor. A converter or chopper, driven in synchronism with the reference voltage of the output servo-motor, converts a DC input voltage to an AC voltage. In the present situation the basic signal is already AC thru the action of the electrometer itself. In a real sense, the electrometer-photocell combination performs the function normally performed by the chopper. Hence, the chopper is unnecessary and is actually removed from the recorder. The photocell signal is then coupled directly to the servo-amplifier.

The servo-amplifier usually has a transformer input in order to better match the commonly encountered low impedance signal sources to the high input impedance of a vacuum tube amplifier. Initially a FET pre-amplifier and phase shifter was used to obtain a better match between the photocell and amplifier and to provide compensation for undesired phase shifts in various stages of the system. This worked quite satisfactorily. It was determined subsequently that no phase adjustment was necessary when the input transformer was by-passed. Further, a reasonably good match exists directly between the photocell and the first amplifier stage. Accordingly the pre-amplifier and phase shifter were discarded along with the input transformer of the amplifier.

The speed with which the electrometer will automatically respond to changes in fiber potential is limited by the speed of the servo-motor when the feed-back is via the binants. Should it be desired to insert the feed-back via a resistor for monitoring current, it may be necessary to by-pass the resistor with an appropriate capacitor in order to prevent oscillations around the feed-back loop. This is only a problem when using measuring resistors somewhat higher than 10^{10} Ohms.

The feed-back voltage can be coupled to the input thru a capacitor thus effecting a Townsend bridge arrangement. Here there usually is no problem with feed-back oscillations. By impressing the feed-back on the electrometer input, whether thru a resistor or capacitor, there is the advantage of holding the electrometer input precisely at zero potential. Using the binants for introducing the feed-back loses this advantage but in several ways is a simpler arrangement.

One final point should be mentioned. The lamp providing illumination to the fiber

must be operated off a DC source. This must be done since otherwise alternating signals will appear in the photocell output which will interfere with those due to the vibrating fiber.

Presently, the dominant noise in the system is photocell dark current. Simply increasing the illumination of the fiber should reduce the noise and further increase the sensitivity of the system.

The system in its present form has been compared to a Cary Model 31 vibrating capacitor electrometer with regard to radiation sensitivity. Each electrometer was observed with its input open-circuited but electrostatically shielded. In this test, the Shonka electrometer exhibited one sixth of the response of the Cary for the same external radiation intensity.

An abstract [AEC Report COO-323-27] has been submitted for the second international symposium " The Natural Radiation Environment II " to be held in Houston, Texas, August 7-11, 1972 . This paper will discuss the automatic Shonka electrometer system with specific reference to use with environmental ionization chambers.

ENVIRONMENTAL IONIZATION CHAMBERS

The effort of the past year in this area consisted primarily in fabricating several 8" diameter chambers. The reason for doing this was to ensure that the techniques of fabricating large spherical shells out of our conducting plastic could be actually carried out. Eleven chambers were successfully completed and are awaiting vacuum and electrical testing.

In the new chambers, two changes were made in the geometry of the HV and collector insulators. These changes are shown in the drawings in Figure 3. Figure 3 (a) shows the previous geometry of the insulators. Figure 3 (b) shows the arrangement adopted in the chambers constructed this past year. Two features are to be noted. One is the proximity of the collector skirt to the guard electrode, and the other is the presence of some solid insulator in the field of the collector and shell electrodes. A third feature which is not apparent from the drawing is that the last step in fabrication was the friction welding of the guard ring assembly, including the HV insulator, collector and collector insulator, to the shell.

Chambers constructed as shown in Figure 3 (a) occasionally showed erratic and excessive leakage. This may be caused by microscopic particles lodged between the collector skirt and guard. Dr. John Rose, who retired from Argonne National Laboratory a few years ago, has had considerable experience with chambers of this type. He has reported that the chambers invariably exhibit a weak transient current after a change of the shell potential. One must wait for this transient to die out before accepting readings from a chamber especially when dealing with background levels of radiation. This phenomenon is believed to be associated with the solid insulator immersed in the collector-shell field. The insulator geometry shown in Figure 3 (b) avoids these problems and was adopted in the chambers fabricated this past year.

The collector is supported by a polystyrene bushing which has a double taper. The bushing is forced into a matching tapered hole in the guard. The collector stem is likewise tapered and forced into a matching taper in the bushing. This provides a solid

vacuum tight feed-thru for the collector lead as well as support for the collector.

In the new chambers, the same polystyrene bushing is used but it is inserted in the guard from the opposite side. This was done so that the bushing and collector could be set in place as the last step in fabrication.

By putting the polystyrene bushing in last, it is then possible to use a four-piece cylindrical sleeve over the cylindrical projection of the guard while welding it to the shell. The sleeve is subsequently dismantled and withdrawn from the shell thru the opening in the guard. The sleeve served to position the guard centrally with respect to the opening in the spherical shell and also prevented a bead of plastic from appearing on the inside of the weld. Such a bead might provide a bridge between either the shell and the guard or shell and the collector. Beads resulting from welding have been known to produce shorts within these chambers. By following this sequence of steps it was also possible to inspect the inside of the chamber before inserting the collector and collector insulator.

The detailed radiation response of the chambers remains to be determined. It would be very interesting to know whether the new geometry has indeed reduced the mysterious transient following a change of chamber potential. This and other questions pertaining to the characteristics of these environmental chambers are planned for the future.

Figure 1 0.5 cc Magnesium Chamber

Figure 2 Self-balancing Shonka electrometer arrangement.

Figure 3 Collector mounting in environmental chambers.