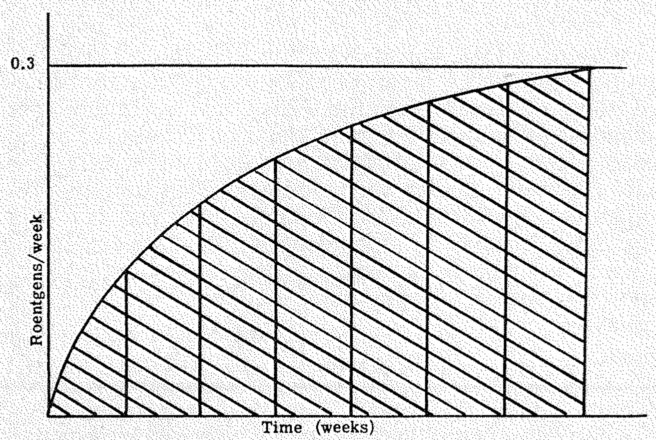

FIGURE 5. Showing the gradual build-up to a maximum permissible exposure due to the fixation of a radioisotope in the body from the air or from drinking water.

shipment of the beta-emitting P^{32} isotope as a Group III shipment because of the Bremsstrahlen produced in the walls of the shipping containers. (A Group III shipment is one that can be shipped without any special precautions regarding how it is handled or where it is located in the plane. The radiation at the surface of such a package must not exceed 10 mr per 24 hours so that it is safe to place film shipments immediately against a Group III shipment for 24 hours.)

Often in the design of a shield it is desirable from the standpoint of cost, weight, or convenience to leave one side off a shield or to use a maze type portal. In such cases, the entrance to all high radiation areas should be restricted by means of a partition and locked door. "Sky shine" from a hot cell without one of its sides and reflection of radiation through the maze portal in these cases must be taken into account in determining the unsafe areas that must be blocked off for protection of personnel.

Another difficulty in the design of shields is to prevent the development of small holes in the shield and the consequent emergence of beams of radiation. One of the best methods of searching for beams from a radiation shield is to place sensitive films over suspected parts of the shield and study the resulting radiograph. Small defects in the X-10 pile shield and in shipping containers have been located with the film method after other methods of detection failed.

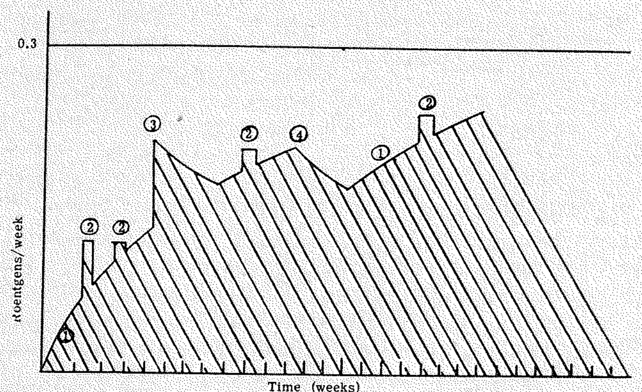

FIGURE 6. Showing a combination of exposures as follows:
1. Drinking water exposure.
2. Single external exposures.
3. Single internal exposure from smoking a contaminated cigarette.
4. Beginning of a two-week vacation period.

As explained above, one of the principal hazards from radiation results when radioactive material is in such a form that it may be taken into the body. One of the requirements of a shield and its associated parts is that it prevent not only the radiation but also radioactive gases, fumes and dusts from escaping into areas where damage may result. In some cases the sources of radiation are sealed in metal jackets or glass ampules. For example, the pile slugs are sealed in aluminum cans; radium is sealed in platinum, brass or glass holders; and radioisotopes are often shipped in an inner gasketed stainless steel container. Such precautions are desirable but usually are not sufficient. This is attested by the fact that chemical vessels, radium sources and pile slugs eventually, due to one cause or another, develop leaks. No completely satisfactory solution has been found for this problem. Some of the efforts that have been made in this direction consist of the following:

Atom	Energy Given to Atom (Mev)	Energy of Electron With Same Velocity as Recoil Atom (ev)
Hydrogen	1.0	544
Carbon	0.286	13
Nitrogen	0.251	9.8
Oxygen	0.223	7.6

FIGURE 7. Average energy given to Tissue Atoms by a 2 Mev Neutron and energy of an Electron having the same velocity as the Recoil Atom.

1. Place the source container or inside of the shield under a negative pressure with respect to the area outside the shields. For example, the X-10 pile and "hot cells" are always maintained at a negative pressure.
2. Place multiple coverings about the source of radioactive material. For example, liquid and gaseous sources when shipped are placed frequently in glass containers that are in turn sealed in gasketed stainless steel holders and absorbent material placed between these holders and the surrounding lead shield.
3. Make provision to catch a liquid radioisotope in case of a spill. For example, place stainless steel catch pans under containers and connections that may leak. Line the floor and walls of "hot cells" with lead or stainless steel and locate sumps where they are needed.
4. Permit a minimum number of service and experimental holes in the design of a shield.

From the above it is obvious that every effort must be made to prevent the radioactive contamination of a shield and if such contamination is possible, the surface material of the shield should be such that it can be decontaminated in a minimum time with the smallest effort and with a negligible exposure to persons.

There are many other requirements of a shield, such as radiation resistance, general durability, strength, low weight and cost. These factors are of interest to everyone and not a matter of special interest to the health physicist, so will not be discussed here.

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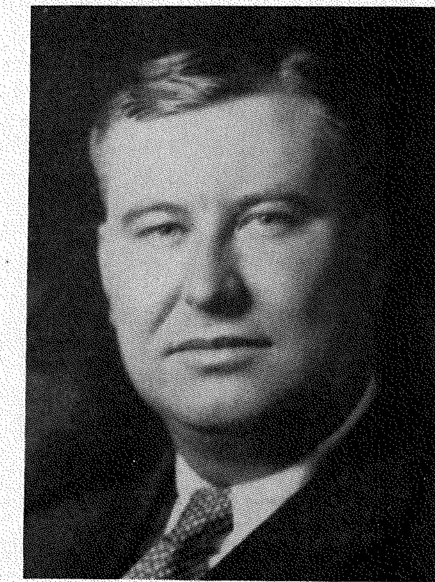
SEDIMENTATION IN DILUTE SOLUTIONS

By J. W. BEAMS



DR. BEAMS

Abstract

The air-driven air-supported vacuum type ultracentrifuge has been improved to give better speed and temperature control. Also the centrifuge cell which contains the material to be centrifuged has been redesigned to give a minimum and repeatable distortion in the centrifugal field. The sedimentation is measured optically by an interferometer method which balances out repeatable mechanical distortions of the centrifuge cell. The method is applicable to very dilute solutions where the effect of molecular interaction on the sedimentation is reduced to a minimum.

Article

Although the general theory of sedimentation in real liquids has never been worked out completely, a good theory does exist for sedimentation in ideal incompressible liquids. Mason and Deaver (Reference 1) solved this problem for the uniform gravitational field in 1924 while Archibald (Reference 2) solved it for a sector shaped centrifuge cell in 1938. Fortunately, as shown by Svedberg (Reference 3) a quarter of a century ago, the theory becomes comparatively simple for sedimentation in a centrifuge cell for two important special cases. In the first of these cases he assumes that the molecules or particles are uncharged and that the centrifuging process is continued long enough for equilibrium to be established, i.e., until the sedimentation is balanced by diffusion. Under these conditions

$$(1)\ M_e = \frac{2\,RT\ \ln C_1/C_2}{(1-Vd)\ \omega^2(r_1^2-r_2^2)}$$

and where M_e is the molecular weight, C_1 and C_2 are concentrations at distances r_1 and r_2 from the axis of rotation respectively, d the density of the solution, V the partial specific volume of the substance, R the gas constant, T the absolute temperature and ω the angular velocity of the centrifuge. If the particles are charged or the solution is an electrolyte and the molecules are dissociated, equation 1 can be corrected to take this into account (Reference 3). Also when the centrifuge cell contains a number of substances in sufficiently dilute solution equation (1) gives the concentration of each substance as a function of the radius independently of the others. Consequently, by determining the concentration in the cell at different radii it is possible to find the distribution of particle or molecular weights in the solution. This equilibrium method gives very reliable values of M_e as it is based directly upon thermodynamic reasoning. On the other hand, especially in the case of large molecular weight compounds the time required for equilibrium to be established in the centrifuge cell (the order of weeks in many cases) is comparatively long. This places severe demands upon the centrifuging technique as it requires the temperature and rotor speed to remain extremely constant and the observing apparatus to remain calibrated for long periods of time. Also no decomposition or other chemical change should take place in the solution.

In the second special case treated by Svedberg, this long centrifuging time is avoided by observing rates of

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He is a member of the American Physical Society, American Optical Society, American Association for the Advancement of Science, National Academy of Sciences, American Philosophical Society, and the American Association of Physics Teachers. He has published numerous papers in the field of physics.

Dr. Beams has been awarded the Franklin Institute Potts Medal, and has been honored by Phi Beta Kappa and Sigma Xi. He is one of the few Southeastern educators to serve on a subcommittee of the National Advisory Committee for Aeronautics.

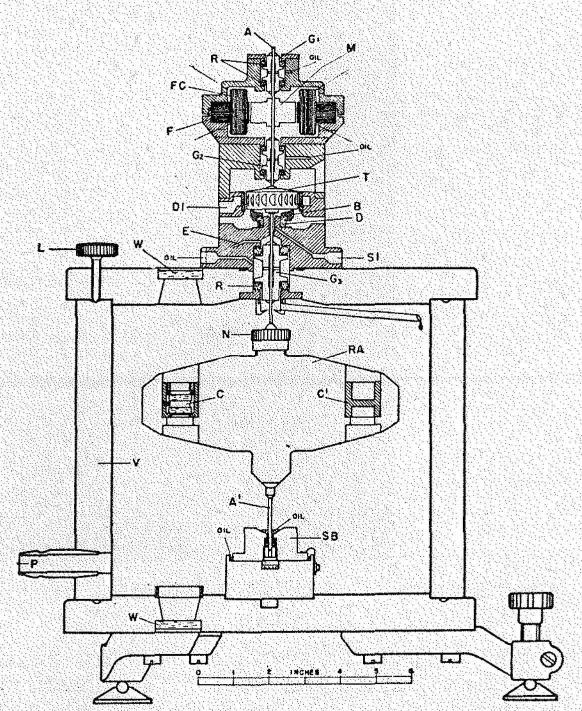

FIGURE 1. Schematic drawing of Ultracentrifuge used successfully at the University of Virginia.

sedimentation. In this method, both the molecular weight M_s and the centrifugal field must be large enough to give a sedimentation velocity that can be measured directly. If the particles or molecules are unchanged and the solution is ideal and dilute and if the experimental conditions are such that molecular or particle reflection from the ends of the sedimenting column can be neglected, then the sedimentation force per mole may be equated to the frictional force per mole:

$$M_s\,(1 - Vd)\,\omega^2 r = f\frac{dr}{dt}$$

If the frictional force $f = RT/D$ where D is the diffusion constant.

$$(2)\ M_s = \frac{RT}{D(1\text{-}Vd)}\ \frac{dr/dt}{\omega^2 r} = \frac{RT}{D(1\text{-}Vd)}\ S$$

where S is the velocity of sedimentation and is usually expressed in Svedberg units, i.e., in units of centimeters per second per unit field of force multiplied by 10^{13}. If the centrifuge cell contains several molecular species, each species gives rise to a distinguishable boundary between the solvent and the sedimenting column so that dr/dt and hence S can be measured for each of the molecular species. As the time of centrifuging increases this sedimenting boundary is progressively broadened by diffusion. However, theory shows that the position which the boundary would have occupied had there been no diffusion is the radial distance where the concentration is one-half that in the unaffected sedimenting column adjacent to the boundary. In the case of comparatively large molecular weight compounds this blurring of the boundary due to diffusion is comparatively small. In cases where the sedimentation constant S is independent of concentration, from a measure of this boundary spreading the diffusion constant D can be measured although it is now common practice to make the measurement outside the centrifuge in a separate experiment.

Although the above statement of the theory is brief and in certain parts incomplete, it does indicate the experimental requirements that must be met if the results are to be reliable. In the first place the rotor speed of the centrifuge must be accurately measurable and should be held as constant as possible since the angular speed ($\omega = 2\pi n$ where n is the number of revolutions per second) is squared in both equations (1) and (2). ω must also be made as large as the mechanical strength of the rotor will permit.

Furthermore, the rotor should be free of mechanical vibrations and must possess a sector shaped centrifuge cell so arranged that the sedimentation can be observed and measured while the rotor is spinning. Another important requirement is that the centrifuge cell must be free of all convection and stirring. This in turn requires the temperature of the cell to be extremely uniform. A centrifuge which meets these specifications is usually called an ultracentrifuge. Fortunately, beginning with the pioneering work of Svedberg and his students, a number of different ultracentrifuges have been devised by different workers which meet a part or all of these specifications but no attempt will be made here to discuss the relative merits of the different designs. Instead a brief description will be given of an ultracentrifuge used successfully in our laboratory for several years (References 4 and 5). It is shown schematically in Fig. 1. Essentially this ultracentrifuge consists of a large centrifuge rotor located inside a vacuum-tight chamber, a small air-driven air supported turbine situated above the chamber and a thin flexible shaft which fastens them together and is in their common vertical axis of rotation. The flexible steel shaft, A(0.1 inch) and A^1(0.1 inch) turn in the closely fitting coaxial oil gland bearings G_1, G_2 and G_3 and a loosely fitting guide bearing SB. G_1, G_2 and G_3 are mounted in flexible neoprene rings as shown and are oil sealed. G_3 is lubricated and sealed with a low vapor pressure oil free of dissolved gases so that a high vacuum can be maintained in the steel vacuum chamber V. The guide bearing serves only to prevent "swinging" of the rotor during acceleration and deceleration of the rotor at low speed. The rotating members are supported by the air cushion formed between the plastic collar B and the air driven turbine T. This plastic collar is fastened to a flexible neoprene support D. The centrifuge rotor RA is an ordinary "oval" shaped analytical rotor with the center of the cell C, which contains the material to be centrifuged, 65 mm from the axis of rotation. The cell C^1 is a matched counter balance for C. The cell C is made sector shaped (12 to 14 mm useful radial length) with plane parallel crystal quartz windows cut perpendicular to the optic axis for observing the sedimentation optically. The permanent magnet M, fastened to the shaft together with the field coils FC (with laminated cores) provide a means of both accurately controlling and measuring the speed of the centrifuge.

To operate the centrifuge the vacuum chamber and rotor RA are thermostated to the desired running temperature by cooling coils in the walls and top of V (not shown in Fig. 1). The solution to be centrifuged is next

placed in the vacuum-tight centrifuge cell C which is tightly sealed and placed in RA. Oil under pressure is then circulated through G_1, G_2 and G_3 and the vacuum chamber evacuated to less than 10^{-5} mm of Hg through P. Electrical condensers are next connected in series with the field coils with the proper capacity to make the circuit resonate at a frequency a few cycles above the desired running speed. Compressed air is next admitted to the air support at a pressure (10 to 15 lbs/in^2) which permits the rotating members to turn freely. The driving air is then applied through DI to the turbine T which accelerates the centrifuge rotor until electrical resonance starts (very abruptly with frequency) and the reaction is such as to brake the rotating magnet. If then the driving air pressure is set just above that necessary to maintain the desired speed the resonance circuit will absorb the surplus energy and the rotor speed will be maintained constant. With an ordinary Foster pressure regulation valve in the air line the rotor speed is found to remain constant to better than 0.1 percent for long periods of time without attention. It might be noted that this type of speed control may be applied to almost any type of rotating machinery where precise speed control is required. With the above apparatus the centrifuge speed is limited only by the mechanical strength of the rotor RA. With a Duraluminum ST 14 rotor the maximum speed used is around 1200 r.p.s. although 1000 r.p.s. is the normal operating speed.

A number of methods have been used for observing optically the density of the material in the centrifuge cell as a function of the centrifuge radius while the centrifuge is spinning (References 3 and 5). They depend either upon the absorption of the light by the material in the cell or upon the variation of the index of refraction with density in the cell. Except for certain special cases the refractive index method is superior to the absorption method and is in more general use. Lamm (Reference 3) developed a method in which a scale is

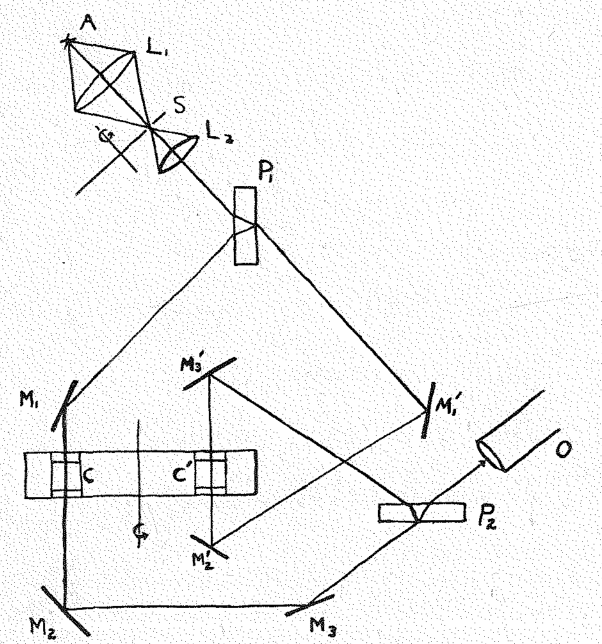

FIGURE 2. Schematic drawing of Interferometer Arrangement under development at the University of Virginia.

photographed through the centrifuge cell. From the distortions in the images of this scale the change in refractive index along the centrifuge cell is determined. A number of other workers (Reference 6) have developed methods of measuring the change in refractive index along the cell based essentially upon the Toepler Schlieren scheme. These various methods have proven most satisfactory for all experiments where the concentration of the solute in the centrifuge cell is not too small. However, they have all proven inadequate in some recent researches where it is necessary to work with extremely dilute solutions.

It will be recalled that in the absence of a general theory of sedimentation in real solutions it was necessary to assume that the sedimentation occurs in ideal solutions and that the solvent was extremely dilute. Also no account was taken of solvation and other effects which are known to occur usually in unknown amounts. Fortunately for many very important molecular species such as most of the soluble proteins in which the molecules in solution do not get entangled or interfere with each other, the concentration in the centrifuge cell may be high without affecting the results. Also the solvation effects can be estimated or are shown to be small. The reliability of the results obtained under these conditions is shown by the fact that the value of the molecular weight obtained by the centrifuge equilibrium method (eq.1) and by the rate of sedimentation method (eq.2) comes out to be approximately the same. Also the value of the molecular weight M_s obtained by the rate of sedimentation method at different concentrations is roughly the same. On the other hand, there are a large number of very important substances which do show a change in the molecular weight M_s when the concentration is reduced. As a result it is highly important to measure their molecular weights M_s in as dilute solution as possible so that an extrapolation to infinite dilution can be approximated and their molecular properties studied. This variation in the measured value of M_s with dilution is believed to be due to the interaction, tangling or coiling of molecules which are very long.

In order to experiment with solutions dilute enough to prevent this molecular interaction more sensitive methods of measuring the density gradient in the centrifuge cell obviously must be developed. An attempt to do this was started at the University of Virginia before the war but had to be postponed until 1946 when it was again undertaken in collaboration with Mr. I. G. Foster. In these experiments, various types of interferometers have been used to measure the index of refraction along the centrifuge cell. These methods have proven to be not only extremely sensitive but simple to use. However, because of the high sensitivity the standard centrifuge cells used previously with the older methods were found to distort so badly in the high centrifugal fields that the resulting interferometer fringes could not be interpreted. As a result, the principal problem has become the design of a centrifuge cell that would show a minimum and repeatable distortion in the centrifugal field. Clearly the distortion cannot be eliminated entirely due to elastic strain but the problem can be solved if these strains could be compensated for by the interferometer method itself.

A number of cells were first made with crystal quartz spacers as well as windows. These cells gave the repeatable performance required but crushed when the centrifuge reached about 500 r.p.s. Cells were next made with crystal quartz windows and stainless steel spacers. The stainless steel spacers were carefully hardened and their faces were optically ground and polished until they were plane and parallel to less than one-fourth wave length of sodium light. The spacers and windows were cemented and clamped tightly together in a Duraluminum shell. These cells have stood up successfully at about 1000 r.p.s. which is sufficiently high for the required experiments.

Several interferometer modifications have been tried so far but it has not yet been determined which is superior. Actually, it is probable that the best method will be determined by the centrifuging problem at hand. At the present time the method shown schematically in Fig. 2 is under development at Virginia. Monochromatic light (Mercury light with filters) is focused on a rotating disc shutter S by the lens 1_1 and made parallel by the lens L_2. It is then split into two light beams of equal intensity by "half silvered" interferometer plate P_1. The first beam traverses the path $M_1CM_2M_3P_2$ and the second beam traverses the path $M^1{}_1M^1{}_2C^1M^1{}_3P_2$. These two light paths are equal in optical length and are recombined by the "half silvered" glass interferometer plate P_2 which is "matched" to P_1. The interference fringes are either viewed in a telescope or recorded by a camera at O. It will be observed that this is one of the modifications of the Michaelson interferometer. Also it will be noted that the light beam in one arm of the interferometer travels downward through the centrifuge cell C while the other beam travels upward through the identical centrifuge cell C^1. This arrangement permits the parts of the light beams passing through the outer portions of the centrifuge cells to interfere with each other respectively. This same thing can of course be done by proper image reversing prisms at the proper places in the optical paths. The light paths $CM_2M_3P_2$ and $C^1M^1{}_3P_3$ are made as short as possible.

In the experiment the cell C contains the solution to be studied and the matched cell C^1 contains only the solvent. In this way if the two cells C and C^1 are strained in the same way, this distortion is approximately balanced out. The rotating shutter S is used to allow the light to pass the system only once per revolution. This avoids two sets of interference fringes but is not always necessary.

Although the above interferometer method of observing the sedimentation is still under development there is no doubt that this type of apparatus will permit the determination of the molecular weight M_s and the sedimentation constants in much more dilute solution than the older methods. Also the new type of centrifuge cell is superior to the older type. As a result eventually it should be possible to greatly reduce or eliminate intermolecular influence on the rate of sedimentation even with very long or "coiled" molecules.

The writer takes much pleasure in acknowledging his indebtedness to Messrs. F. W. Linke and P. Sommer, instrument makers who constructed the apparatus, and to Dr. I. G. Foster and Mr. Melvin Cruser, who assisted with some of the experiments. Also he has received some useful suggestions concerning the interferometer from Dr. C. R. Larkin.

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Notice

The Journal welcomes letters to the editor commenting on any item published, or on general scientific or editorial policies. Letters intended for publication must be signed and should give the writer's position and address.

An A. C.-Operated High Gain Amplifier and Power Supply

By ROBERT T. NIESET AND FREDERICK H. SCHMIDT

In many physiological investigations it is necessary to have high gain amplifiers with good frequency response from 10,000 cycles down to 1/2 or 1/4 cycles per second. In general, battery operated D.C. amplifiers have been used. Battery operation has been imposed by the susceptibility of D.C. amplifiers to drift, by the extremely low ripple voltages that may be introduced through either heater or plate circuits of the initial amplifier stages, and by the low internal impedences which a common power supply must have to prevent feedback in a multistage high gain amplifier.

A resistance-capacity coupled amplifier with a regulated A.C. power supply thus eliminating the expense and inconvenience of batteries, is described in this paper. The capacitance coupling eliminates drift. The introduction of ripple noise through the heater circuits is obviated by a choice of tubes and circuit conditions so that the filtered and regulated D.C. output of the power supply can be used to heat the cathodes. Low output impedance and low noise output of the power supply is secured by the design of a regulator with high inverse feedback.

The characteristics of the power supply are:

Source impedance for direct current—0.3 ohm

10% change in line voltage

10% change in load

0.003% in out-

put voltage

Output voltage ripple—300 microvolts R.M.S.

Fig. 1. shows the diagram of the power supply. A 6SJ7 pentode tube is used as the voltage amplifier. Its cathode is maintained at a constant voltage by means of a balanced amplifier arrangement, comprising the 6SJ7 and one triode section of a 6SN7. The output of the 6SJ7, instead of feeding the 807 grids directly is coupled through a cathode follower stage. With this arrangement, the 807 grid circuit impedance is low—40,000 ohms. The 807 is susceptible to grid current trouble if the grid circuit impedance is high. Voltages for the amplifier stage, cathode follower stage, and screens of the 807 tubes are obtained from a separate power supply which is regulated with VR tubes. 47 ohm resistors are inserted in the cathode leads of the 807 regulators in order to prevent parasitic oscillations.

Unless all returns are brought to one point on the chassis, serious trouble will be encountered with third harmonic of the line frequency appearing as output ripple. This is particularly true if the power transformers are mounted with the bottom lamination against the chassis. The chassis would then be a lamination itself and would carry relatively large circulating alternating currents. All return leads should be made to a heavy copper strip which is grounded to the chassis at one point only.

The long-time stability is determined mainly by the VR tubes and the resistor-condenser circuit in the amplifier tube grid. C_5 must have very high leakage resistance. A good quality oil-filled condenser is entirely satisfactory. However, since the differential amplifier circuit is R-C coupled, some long-time drift of the power supply can be tolerated with no ill effects.

The power supply is also used to feed the filaments of the amplifiers, R_{10} and R_{11} drop the output voltage from 150 to 48.

Figure 2. is the diagram of the differential amplifier circuit. V_1 and V_2 comprise the Toennies differential circuit. V_1 is a pentode connected 12SJ7 used as a cathode follower and the other is a triode connected 12SJ7.

Assume an equal positive potential is applied to both grids. The potential across the common cathode resistor will rise, but by an amount less than the grid potential, because of the fact that the gain of a cathode follower stage is always less than one. Thus the grid of V_2 rises somewhat more than the cathode does, with

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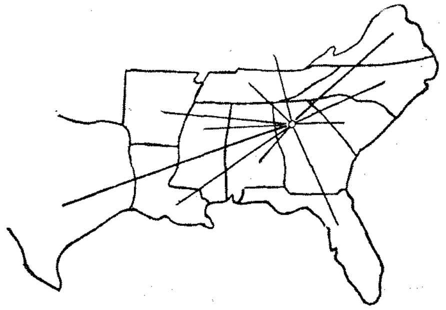

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Volume 1 JANUARY, 1949 Number 1

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A portrait of Dr. Wm. G. Pollard made especially for the Journal by artist W. O. Traywick, of the High Museum and School of Art, Atlanta. (See story on page 18).

Editorial Section

JANUARY, 1949

Volume 1 Number 1

A Beachhead

With this first issue, the *Journal of Southeastern Research* joins the crusade for the encouragement of scientific research and the development of the engineering profession in the Southeastern United States. Once barely kept alive by a few never-say-die pioneers, this crusade now is gathering momentum throughout the area—from Richmond to Dallas, and from Nashville to Miami. It deserves the maximum support of all interested in the future of the South.

As every cause needs a champion, so this crusade needs a voice to speak in its behalf. The scientists of the Southeast have long felt a need for a technical journal through which they could attack common problems and reflect mutual achievements. Furthermore, they have needed a device by which unity of thought and action could be obtained when needed. The *Journal* is designed to fill this need.

No one familiar with the task confronting the South will expect the *Journal* to push the crusade to a successful conclusion after a brief and easy campaign. Just as Reconstruction required great time and tremendous effort, the development of a new Southeast technologically the equal of other sections will tax our patience and energy. We have just begun the struggle. With this first issue, the *Journal* has simply established a beachhead.

Objectives

We have set as our general objective the encouragement and promotion of research in engineering and related sciences in the Southeastern states. Specifically, we will work to furnish wider recognition of the work of Southeastern engineers and scientists, to strive for the improvement of opportunity for the individual scientist in this region, to seek greater public and private support of scientific research, to encourage closer cooperation between science and industry, and to obtain unified action on common problems.

To reach these objectives, the *Journal* will cooperate with all existing groups having similar aims.

States Included

After some deliberation, it was decided to include the following states in the special coverage of the *Journal:* Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas, and Virginia. Of course, it was difficult to determine the exact boundaries of the region which we wished to represent before the technical "public." Perhaps Kentucky should be included. Perhaps the western part of Texas does not fit into the region.

Regardless of the precise limits of state boundaries, our interest is in representing those areas which think alike and desire to act in unison.

Invitation to Contributors

All sections of the *Journal*—Editorial, Technical, and News—are open to contributors interested in the advancement of scientific research in this area. We invite and encourage Southeastern engineers to do more writing, more reading, more criticizing, more discussing, more thinking about mutual affairs. We know that the entire region will benefit from increased activity in the field of technical writing, just as the whole nation will benefit from the full development of the human and material resources of the Southeast.

The Advisors

In the case of a publication covering many highly-technical fields, it is impractical to attempt to assemble an editorial staff capable of handling all technical contributions which might be received. For this reason, it is customary to establish an advisory group consisting of men who are specialists in various fields and who are in touch with still other experts in other fields. Thus, a great breadth of experience and special knowledge can be brought into action without burdening any one individual.

To assemble such an advisory group for this new journal, the Editor during the past few months contacted some 25 to 30 men occupying positions of leadership in scientific and educational institutions in the Southeast. Their reactions to the announcement of plans for the new undertaking were varied but significant.

Several university officials reported that research activity in their institutions was so limited that they could be of little assistance. Others stated that teaching and administrative duties consumed all their time, leaving too little for research. One research director felt that he could not serve without compensation. Several wished to withhold their support until the project was farther along, presumably to see whether it would succeed.

It is a tribute, therefore, to the men and institutions listed on page five that these men generously agreed to serve before the success of the *Journal* was assured. Theirs is the outlook of the true research man. They had the insight to realize the need for the publication, the imagination to recognize its possibilities, and the willingness to risk the effort.

It is one thing to support a project which is only an idea—another to jump on the bandwagon when the groundwork has been laid and success seems likely. While the Editor will henceforth seek the assistance and cooperation of all, he will always be particularly indebted to those who helped during the first few months.