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APPLICATIONS OF THE ZERO GRAVITY SPACE  
SHUTTLE ENVIRONMENT TO PROBLEMS IN FLUID  
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# FUTURE UTILIZATION OF SPACE

## Silverton Conference on Applications of the Zero-Gravity Space Shuttle Environment to Problems in Fluid Dynamics

SILVERTON CONFERENCE ON  
APPLICATIONS OF THE ZERO-GRAVITY SPACE SHUTTLE ENVIRONMENT  
TO PROBLEMS IN FLUID DYNAMICS

SUMMARY OF PROCEEDINGS  
OF CONFERENCE HELD IN SILVERTON, COLORADO  
NOVEMBER 6-8, 1974

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Edited by  
Melvin Eisner  
Professor of Physics, U. of Houston  
1974

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## LIST OF PARTICIPANTS

Dr. Joe Allen	Johnson Spacecraft Center - NASA
Dr. A. L. Copley	New York Medical College
Dr. Melvin Eisner	University of Houston
Dr. Leonard Finegold	Drexel University
Dr. Myrle Hendershott	University of California (Scripps Institute of Oceanography)
Dr. J. R. Pellam	University of California (Irvine)
Dr. Milton Plesset	California Institute of Technology
Dr. Melvin Saffren	Jet Propulsion Laboratory
Dr. R. L. Sani	University of Illinois
Dr. Geoffrey V. Seaman	University of Oregon Medical School
Dr. H. A. Snyder	University of Colorado

PROGRAM  
 SILVERTON CONFERENCE ON  
 APPLICATIONS OF THE ZERO-GRAVITY SPACE SHUTTLE ENVIRONMENT  
 TO PROBLEMS IN FLUID DYNAMICS

November 6-8, 1974

November 6 - Wednesday

9:00 - 12:00 noon

Introductory Remarks	-	Dr. Melvin Eisner
Introductory Remarks	-	Dr. Joe Allen
Problems in Biorheology	-	Dr. A. L. Copley
Geophysical Fluid Dynamics	-	Dr. H. A. Snyder
Fluidity in Membranes	-	Dr. L. X. Finegold

Lunch break

3:00 - 6:00 p.m.

Separation Methods Favored by a Space Environment	-	Dr. G.V.F. Seaman
JPL Program in Fluid Mechanics in Zero-g	-	Dr. Melvin Saffren

Dinner

8:00 p.m. film session

November 7 - Thursday

9:00 - 12:00 noon

Geophysical Fluid Dynamics	-	Dr. Myrle Hendershott
Nonlinear Stability Problems	-	Dr. R. L. Sani

Lunch break

3:00 - 6:00 p.m.

Superfluid Helium	-	Dr. J. R. Pellam
Bioconvection	-	Dr. Milton Plesset
Recent Research and Results in Blood Flow	-	Dr. A. L. Copley

Dinner

8:00 p.m. film session

November 8 - Friday

8:30 - 11:00 a.m. - Plenary Session

## INTRODUCTION

The Space Shuttle will usher in a new era of space exploration and make possible for the first time the exploitation of many areas of science and of applications. Many of these areas are well recognized and the planning of appropriate payloads is progressing accordingly, for example the Large Space Telescope in the area of astronomy. However, in other areas of interest, particularly those areas not yet associated with past space flights to any degree, there is very little awareness of, or plans for utilization of, the unique flight opportunities which the Shuttle space transportation will offer. Since the ultimate economic success of the Shuttle depends to some degree on its total usage, it is in the direct interest of the Shuttle program to identify hitherto unrecognized areas of possible science and applications payloads and to interest potential users in exploring the possibilities of developing these payloads. Further it is necessary to understand as early as possible the demands which will be placed on the orbiter, the Spacelab, and their respective subsystems by these potential payloads. This will help assure that the design of these key elements of the Space Transportation System be as responsive as possible to the needs of the ultimate users. For these reasons, the conference summarized here was held.

## FLUID STUDIES IN ZERO GRAVITY

The topic selected for consideration by this study group involved the possible utilization of the zero gravity resource for studies in a wide variety of fluid dynamics and fluid-dynamic related problems.

There have been several previous studies<sup>1</sup> dealing with the utility of the zero-g environment for fluid studies and one might argue that the field has already been covered exhaustively. There are nonetheless continuing active research programs whose results supply new insights and allow new perspectives for viewing the relevance of zero gravity fluid experiments. For example, recent studies of density variations in liquid mixtures<sup>2</sup> have demonstrated both the rapid formation of non-equilibrium concentration gradients near the critical solution point and the relatively long times required for achieving the equilibrium density profile in the presence of gravity. One might speculate that the full significance of the zero gravity environment to the field of fluid studies is yet to be evaluated.

Participants with interests in classical fluid mechanics, biological fluids, geophysical fluids, cryogenic fluids and management of fluids in engineering processes were invited to participate in this study session. An effort was made to select participants who had considerable amount of overlapping interests in order to provide a stimulus for meaningful dialogue.

### A. Study Session Format

The study sessions were held in the isolated, small, town of Silverton located in the San Juan mountains of Southwest Colorado. The facilities of the Grand Imperial Hotel were reserved exclusively to provide for lodgings, meals and meeting rooms for the conference. The constant close association of the participants enforced by these arrangements provided a fertile environment for reflective, interactive, critical interchanges among the participants. The stark beauty of the surrounding San Juan mountains provided a site for both recreation and relaxation for the participants at times between sessions.

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<sup>1</sup>Fluid Physics Thermodynamics and Heat Transfer Experiments in Space, F. T. Dodge et al., NASA-CR-134742, Jan. 1975.

<sup>2</sup>Sandra C. Greer, et al., Phys. Rev. Lett. 34, 250(1975).

Round table discussions were held for the first two days of the meeting in the course of which each participant presented a survey of areas of his field of interest in which the zero gravity resource of space might prove to have useful applications. Films of "life in zero gravity" in general and of fluid experiments in particular, carried out in Skylab, were shown in the evening session.

The final session was used to summarize, evaluate and consolidate the previous days' discussion. Emphasis was placed on identifying experiments and applications where the zero-g environment would be of particular significance. Later as this summary of conference proceedings was being prepared, the possible experiment requirements themselves were compared to the shuttle payload accommodations and Spacelab payload accommodations documents in order to surface any potentially serious mismatch between user requirements and transportation system capabilities. With the possible exception of a potential credibility gap concerning the specimen suggested under 4f in the next section, it can be stated that no inherent problem is foreseen in accommodating adequately any of the experiments suggested here. A possible conflict which could arise was one of total dimension, or of experimental size, for the modelling investigations. The ultimate size of the experimental equipment required will depend on detailed scaling analyses.

## B. Suggested Experiments

In the course of the discussions many experiments were considered. Although most of the suggested experiments had not been studied in critical detail and were put forth as examples of possible areas of experimental investigation, they are nonetheless of interest since they provide some guidance on estimating the demands which may be placed on the shuttle by a set of experiments whose implementation appears to have some scientific interest.

A group of experiments whose concepts were discussed in some detail are described in the following section.

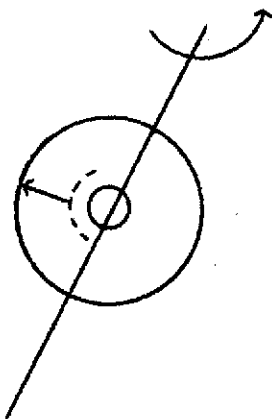


AREA: GEOPHYSICAL FLUID MODEL EXPERIMENTS

Experiment: *Modelling of the Circulation of the Earth's Core*

Description:

A sphere covered with a thick layer of liquid is rotated about an axis. Radial stratification effects are simulated by application of radial electric fields or by radial sound fields. Modelling of the circulation of the Earth's core could be done by observing stream lines in nonconducting fluids and observation of magnetic fields generated in conducting fluids. Normal modes of the inner and outer core system could be investigated with such a model and the possibility of verifying the predictions of existing numerical studies of the linear problem would be of great interest.



The simulation of the Earth's magnetic field dynamo may be possible with this model although it is not evident that proper scaling of flows can be achieved in a reasonable sized model.

Although there are some laboratory studies of flows using stratified spinning cylinders, present studies are unable to get at radial stratifications.

\* \* \* \* \*

Experiment: *Simulation of general circulation of ocean-atmosphere system on rotating sphere*

Description:

Large scale ocean current flows and the coupling between atmospheric winds and mean ocean currents could be studied in a model system consisting of a rotating surface featured sphere with thin liquid ocean-like layers. Proper treatment of the effect of bottom features of the ocean on circulation and currents requires stratification which can be simulated either electrically or acoustically.

The model could be used to study wind generated waves and the momentum transfer from the wind to the mean motion of the ocean.

AREA: FLUID DYNAMICS EXPERIMENTS

Experiment: *Exploiting the reduced intersurface tension in He<sup>3</sup> - He<sup>4</sup> mixtures to amplify and hence make visible effects arising from the presence of quantized rotation in the He<sup>4</sup> rich superfluid droplets.*

Description:

Although there exists a large amount of literature dealing with quantized vorticity in superfluid helium, unambiguous experimental observation of these quantized vortices is lacking. In zero-g the normally phase separated components of He<sup>3</sup> - He<sup>4</sup> mixtures can form droplets and coalesce. Through suitable choice of concentrations and temperatures the surface tension at the interface between the He<sup>3</sup> rich and He<sup>4</sup> rich regions can be made extremely small so that one might hope to see a deformation of the surface on a He<sup>4</sup> rich drop where a quantized vortex line reaches the surface.

Comments: A rather difficult experiment but worth attempting.

\* \* \* \* \*

Experiment: *Study the behavior and properties of fluids and fluid mixtures in the vicinity of critical points.*

Description:

The effect of gravitationally induced concentration and density gradients on the behavior of fluids in the vicinity of their critical points can be marked and can produce changes in the local critical behavior in inhomogeneous systems. Although the static effects of gravitational fields probably may be calculated adequately, the dynamic effects do not appear to be so readily handled, giving impetus to the utility of carrying out critical point studies in the zero-g environment.

In measuring thermal conductivities of gases, it is difficult to obtain truly convectionless conditions because

of the gradients in density arising from the applied temperature gradients. The behavior of the thermal conductivity of gases in the vicinity of the critical point is of fundamental interest for scaling parameters. Measurement of thermal conductivity of gases under convectionless conditions should be readily accomplished in zero-g.

\* \* \* \* \*

Experiment:     *Measure viscosity of a variety of fluid systems, for which gravitationally induced sedimentation effects preclude making such measurements on Earth.*

Description:

Flows of liquids carrying coarse heterogeneous materials are greatly affected by sedimentation resulting from gravitational forces. Rheological studies carried out in zero gravity would provide information of fundamental interest. Useful applications might be found in systems in which clay flakes, pulp fibers, or red blood cells are suspended.

AREA:             PROCESSING EXPERIMENTS

Experiment:     *Mass Transfer Processes (Separation of particles or aggregates of large size or high density by partitioning or by counter current distribution in two-phase aqueous polymer systems).*

Description:

The separation of particles or aggregates of large size or high density by partitioning or by counter current distributions in two-phase aqueous polymer solutions is difficult when gravitational forces overwhelm the forces associated with the surface charge of the particle or aggregate. However, this difficulty would not be present in the zero gravity environment of space. Separations of varieties of bacteria or cells from one another are typical applications of this technique. The material to be separated is introduced into the interfacial region separating the two solution phases.

\* \* \* \* \*

Experiment: *Electrokinetic separation of large particles*

Description:

Attention is drawn to some large systems to which electrophoretic separation techniques in zero gravity could be applied. These include intact nerve cells (giant axons of squid or lobster) or cellulose and polyethylene fibers.

The electrokinetic information would be of interest in problems of fiber flocculation, interfiber bonding, and deposition of sizing agents.

AREA: BIOPHYSICAL & PHYSIOLOGICAL EXPERIMENTS

Experiment: *Observe long time adaptive behavior in zero-g of single cell microorganisms which ordinarily exhibit negative geotaxis.*

Description:

On Earth, negative geotaxis causes these microorganisms to swim upwards towards the surface. The resulting denser surface region rich in the microorganism is unstable and convection currents induced by the instability redistribute the organisms to the deeper regions from which they again seek the surface. It would be of interest to study the adaptive behavior of these organisms in the zero-g environment.

Comments:

This is a straight forward experiment which should provide definitive results. Although there would be considerable interest in understanding the mechanism by which these organisms sense the direction of gravity, such studies are much more difficult and should not be the goal of the initial experiment.

\* \* \* \* \*

Experiment: *Hemodynamics of the microcirculation of human subjects living in a space environment using standard sampling techniques.*

Description:

The aim of these experiments is to study the effect of zero gravity on parameters such as the available blood

volume, red blood cell and plasma transit times, red cell life span changes in erythrocyte geometry and size, variation of blood pools and hematocrit in various parts of the body. The experiments would require a few weeks of observation of subjects in space and would use standard techniques.

The effects of zero gravity environment on the circadian biological rhythms associated with parameters such as the concentration of plasma proteins might be an additional area of interest.

\* \* \* \* \*

Experiment: *Monolayer culture of fragile cells on suspended microspheres*

Description:

There are many cells which can only be cultured on monolayers. Although these can be cultured on the surfaces of biocompatibly coated neutrally buoyant spheres on Earth, the growth of the cells would normally disturb the neutral buoyancy, causing the spheres to sediment, hence the advantage of a zero-g environment. This cell culturing technique would be useful for production of pharmaceuticals and viral vaccines. One would like to prepare cells in kilogram quantities which would require about 20 to 30 liters of solution volume.

\* \* \* \* \*

Experiment: *Hemorheological aspects in relation to an environment at zero-g*

Description:

Sedimentation of red blood cells in the circulation is known to occur in blood of healthy subjects and is more pronounced in a number of pathological conditions. This is reflected in the vitro test of the erythrocyte sedimentation rate. It is also known that this sedimentation effect is due to the aggregation of red blood cells. Such aggregated cells affect the flow properties of blood, particularly at very low rates of shear. Studies are proposed to find out whether and to which extent zero gravity environment affects the aggregation of red blood cells, as

well as the flow properties of blood in steady and oscillatory shear, particularly at rates of shear below  $10^{-1}$   $\text{sec}^{-1}$ .

The proposed studies in zero-g environment promise to be applicable to a number of diseases and pathological conditions affecting the cardiovascular system, and the results may suggest new therapeutic approaches in their management.

\* \* \* \* \*

In addition to these studies, a listing of the experiments which were proposed in the course of the study sessions is set forth below. Although not all the experiments cited are necessarily novel or feasible, nor have they been critically evaluated, they serve to indicate the scope of interests and concerns of the participants.

#### 1. Geophysical Fluid Model Experiments

- a. Modelling of the Circulation of the Earth's Core.
- b. Modelling of general circulation of ocean-atmosphere system on rotating sphere.
- c. Modelling of wind driven ocean flows.
- d. Modelling of large scale ocean flows with ocean floor modelling.

#### 2. Fluid Dynamics Experiments

- a. Exploiting the reduced intersurface tension in He<sup>3</sup>-He<sup>4</sup> mixtures to amplify and hence make visible effects arising from the presence of quantized rotation in the He<sup>4</sup> rich superfluid droplets.
- b. Study the behavior and properties of fluids and fluid mixtures in the vicinity of critical points.
- c. Measure viscosity of a variety of fluid systems, for which gravitationally induced sedimentation effects preclude making such measurements on Earth.
- d. Modelling of nonlinear flow in rotating drops.
- e. Modelling of free surface stability--dependence on surface tension, local g, and rapidly varying fluid acceleration.
- f. Modelling of finite amplitude oscillation and mode coupling.
- g. Measurement of thermal conductivities, K, of gases under truly convectionless conditions, measure K near critical point for studying scaling parameters.

- h. Damping of large drops of Non-Newtonian liquids.
- i. Study of quantized vorticity using  $\text{He}^3\text{-He}^4$  two-phase drop.

### 3. Processing Experiments

- a. Mass Transfer Processes (Separation of particles or aggregates of large size of high density by partitioning or by counter current distribution in two-phase aqueous polymer systems).
- b. Electrokinetic separation of large particles.
- c. Combustion of a fuel drop.
- d. Stability of liquid-liquid systems with low interfacial tension.
- e. Dielectrophoresis.
- f. Chemical reactions in the diffusion controlled limit.

### 4. Biophysical & Physiological Experiments

- a. Observe long time adaptive behavior in zero-g of single cell microorganisms which ordinarily exhibit negative geotaxis.
- b. Hemodynamics of the microcirculation of human subjects living in a space environment using standard sampling techniques.
- c. Monolayer culture of fragile cells on suspended microspheres.
- d. Hemorheological aspects in relation to an environment at zero-g.
- e. Gravity sensors -- physiological and molecular details in animacules and in plant membranes.
- f. Study of hypertension in humans, use animal like a giraffe.
- g. Physiological Studies (Hemodynamics of the microcirculation--available blood volume, red blood cell and plasma transit times, red cells life span--variation of blood pools and hematocrit in various parts of the body--alteration in erythrocyte geometry/size).
- h. Efficiency of biosynthesis and contact inhibition.
- i. Relationship of circadian biological rhythms to a microgravity environment.

In the course of the study session the participants expressed their opinions and evaluation of possible relevance and significance of broad areas of the proposed research programs. A sampling of these comments provides a valuable guide to the typical attitudes, and priorities of the participants, especially those with little previous contact with the space research program. Accordingly, selected edited comments have been included in this report in Appendix A.

## CONCLUSION

The study sessions served several useful purposes. Those of the participants who had little previous experience with the space program and the operational modes in which it might be available to them were made aware of its potential and were stimulated into considering the utility of its application to a variety of problems in their field of interest. A critical discussion of the relative merits of a variety of experiments was carried out, and although great caution was expressed of doing experiments "just to see what will happen" in zero-g, it was also realized that there exists a plethora of interesting phenomena whose elucidation requires, or is greatly facilitated by, the zero-g environment.

The ideas, interchanges, and interactions which took place in the small but highly interactive group of participants should be widely diffused by the participants to their professional colleagues and continuing studies in this mode could serve a useful function in maintaining a link between potential users and the space program.

The ideas for experiments developed during the 2½-day meeting were, in all cases cited here, intriguing. The purpose of the meeting was not to pass scientific judgement on the importance or relevancy of each individual suggestion, nor to study in detail the technical feasibility of carrying out each experiment aboard the Shuttle/Spacelab system. It was rather to serve as a forum for open exchange of ideas among shuttle designers and potential shuttle users; in this regard it was quite successful.



APPENDIX A  
DISCUSSIONS OF SUGGESTED EXPERIMENTS AND COMMENTS

## SUGGESTED EXPERIMENTS AND COMMENTS

DR. MYRLE HENDERSHOTT

I would like to make some comments on the configurations and experiments that have been suggested. The one which in a sense is closest to some of my interests is the one that Dr. Snyder mentioned, radial stratification simulated dielectrical fields, something which I wasn't really aware that you could do very well with axial rotation. It has a lot of interesting applications, one which wasn't mentioned except perhaps in passing, but which is of seismological interest is the question of normal modes of the inner and outer core of the earth. That's a problem that seismologists are presently working on numerically. It is conceivable that it would be nice to have a laboratory model of that. There are theoretical studies of the spin-up of radially stratified and axially rotating spherical systems which show effects mildly different from what happens when you spin-up cylinders; one might very well try to do some laboratory work with those because the theory is rather difficult to do in any but a linear sense. The dynamo problem for the liquid looks very tough to me, I would guess it's difficult to get into the range of parameters that one has to get into to. First of all, to see the dynamo effect, but perhaps secondly even to see the kind of turbulence that's perhaps important to the dynamo stability. But, I don't know enough about that to be sure. Large scale modelling of the ocean in a sense suffers from the same difficulty. If you try to do it without stratification, the results aren't very realistic, because the stratification really controls the interaction between the surface circulation and the bottom topography. If you put in stratification then you have the additional worry that you may not in fact be modelling the eddies in the ocean properly and one now believes that it is those eddies which really are very important in driving the largest scale parts of the flow. So it's kind of a difficulty in all sorts of models although they are tremendously attractive from a conceptual point of view. The second class of experiments that I like, although I don't know if it's even possible to do them, are experiments in which you take a drop with perhaps minimal surface but held together perhaps in an acoustic fashion in the way that Dr. Saffren was mentioning and you look at its interior flow and you push it very far. I like the idea of studying turbulence in a drop like that because it seems to me it frees you from the dissipation that always goes with solid walls. On the other hand, I'm constrained to say that that suggestion is wildly speculative and I think you would have to make very

careful evaluation as to just what kind of flows you might see in such systems before you went off and planned an experiment. Nevertheless it might be an attractive place to do certain kinds of turbulence. I would like to think about that a little more. The general problem of large amplitude oscillations of drops, which is fun and interesting not only for itself, but because it seems like it's a nice model of a system in which you have nonlinear complicated mode coupling and perhaps it's a system in which you can do the laboratory equivalent of your theoretical calculations most easily. The systems that I know where one couples modes nonlinearly is in certain atmospheric systems where it's really hard to do the corresponding laboratory experiment. The calculations are sufficiently complex that one would like some experimental guidance. This is a situation, rather different from some of those but nevertheless it is a mode coupling system where you probably could do the laboratory experiments rather easily in zero gravity and it might be nice to simply explore the problem very carefully as sort of a sample nonlinear coupling problem where you really have some good laboratory control. The last thing that I wanted to make some remarks on, again it's speculative, is the question of free surface stability. It seemed to me, that there was some support for this I think, during the discussion, that if one studies the stability of drops or the surface of a container of fluid which you shake, or perhaps shake and centrifuge gently to simulate the effect of gravity, you might be able to do some interesting studies of free-surface stability. Maybe you could reach the point where you could really parametrize the formation of drops from the gravity, from the acceleration field that you could infer from measured ocean waves spectra. This would be awfully nice if you could go that far, it would help you in the ocean, in saying something about collections of water vapor across the ocean surface. And then there is the general application to the wave breaking problem. On the other hand, these things can probably be done on the ground, like a number of things that were mentioned, the advantages provided by zero-g seem technical rather than truly conceptual. A general remark, very faint, but I think it's important anyway, in looking for useful zero-g experiments I think one has to be very careful in thinking of laboratory experiments to be sure that you are able to model all the scales carefully, of course it's true not only in zero-g but in laboratory experiments, but one's enthusiasm for doing things in a new situation sometimes makes you forget that you've really got to model all the scales right or you're going to get nutty results. Finally there were things which were completely outside my field of competence to evaluate and all I can say is gee, they sure look like fun. I thought the bile convection experiment looked like a wonderfully interesting

experiment. The idea of surface control processes in general is perhaps the most natural non-biological thing that one can do in zero-g. It really looks to me like that's the candidate for innovative experimentation. My fancy was caught by some of the (what I would call) gross physiological studies. I like them because I could simply understand the idea of changes in available blood volume, residence time of red cells, pooling of blood, these seem to be areas where there is some precedent for getting interesting results already and one would almost surely want to continue with them.

\* \* \* \* \*

DR. MILTON PLESSET

I think that the experiments with drops, even newtonian liquid drops will be interesting, even though one may be able to predict much of the phenomena on the basis of theoretical calculations. There has been some criticism of the idea of using non-newtonian liquids. I think that this hasn't been thought through enough by me at least, and I think that there will be some interesting results with non-newtonian liquid drops and even if we take a liquid where we think we know the constitutive relation we are still going to get some surprises in the zero-g experiment, however it's also true that we need some more work on the ground before one designs the experiment. Mel Saffren mentioned an experiment on the combustion of a fuel drop. It would be extremely helpful to the people who are concerned with the problems of combustion, not to be troubled by the gravitational convection effects; so that one really can hope to learn a great deal about the combustion process from experiments in zero-g.

\* \* \* \* \*

DR. R. L. SANI

There is an interfacial region in most liquid-liquid systems where charged double layers and interfacial tension effects are important. In a 1-g environment gravity is a big force compared to the other two, especially compared to anything you can generate from the double layer, however in a zero-g environment one can study effects which arise from electrical forces due to the perturbation of the double layer at the interface and the interfacial tension. Most

systems of this type in experiments on earth, exhibit spontaneous emulsification, therefore it would be interesting to use the zero-g environment to study some of the properties and dynamics of these systems with the aim of developing models for spontaneous emulsification. It is conceivable that some unexpected effects might occur especially since we seldom think about double layers on interfaces and the forces associated with them because they are pretty small usually.

In many systems of interest for engineering applications, where you're trying to pass a species through the liquid-liquid interface; the gravitational buoyancy forces dominate the surface tension and the electrical forces so that it is very difficult to separate the effects arising from these forces. Consequently theoretical models designed to include surface tension and double layer effects are difficult to check. From a practical standpoint, not being an experimentalist, and knowing some of the theories that have been proposed, I can say that there have been no definitive experiments performed which demonstrate the effects of these small forces.

The sphere is a good configuration to work with in space and I can see some good experiments there, such as the stability of rotating bubbles from a static sense, but I'm not convinced that one couldn't calculate some of those things by enough brute force on earth, however I think these are worthwhile experiments, and obviously ones that can be done.

In the area of wave dynamics there are a lot of interesting things that can be done but again I think some care should be exercised because I think one could calculate many of the effects adequately. Non-newtonian drops, I don't know, I guess I am biased in a sense. Studies of wave dynamics on a non-newtonian drop would undoubtedly lead to interesting configurations. But I think you should pick something for which you know the constitutive relationship. Because I think it would be a hopeless mess to work with oscillations on a non-newtonian bubble and try to deduce the constitutive relation from this experiment.

Another interesting experiment for the zero-g environment would be to study the stability of a free drop. Perhaps an annular region or a drop could be doped with some radioactive material so that you get a uniform generation of heat and one looks at the instability of the surface. An annular region might be heated from both sides but that appears more difficult to do.

It struck me that a nice experiment that could have been done in Skylab would have been to take a bubble and suspend it and then just take a pencil with a hot point and heat the bubble surface at one point. You should get a surface wave initiated at this point and what you will get is essentially a capillary wave going across the surface. It would be very nice if one could generate large waves, but even small waves would be interesting, since you will have well defined initial and boundary conditions.

I think the proposed experiment to locate vortex lines on a helium drop appears to be quite difficult to do. I think a geodynamo model is something that probably should be eventually flown, although it appears to be a difficult experiment too, and it's uncertain that you will get the results which are of interest; there is real controversy here as to whether it will ever work. I do not believe that experiments which model ocean circulation would be worthwhile since the driving forces are very dependent on the air-sea interactions, and it would be difficult to model in the effects of turbulence and wave generation adequately and I don't think it will tell you anything very definitive about what the flow is on earth.

Experiments involving electrophoresis have been proposed and it occurs to me that the natural things to try for the same reasons, for uncharged particles would be a dielectrophoresis experiment. Instead of using uniform electrical field, you would use a non-uniform electrical field and observe the effect of the field gradient forces on the induced dipoles. There are some occasions where people are interested in looking at chemical reactions in the diffusion controlled realm, primarily catalytic reactions where you have a spherical catalyst sitting in a medium in which the species have to diffuse to the catalytic surface to react and if you have a fast reaction going on on the catalytic surface the mechanism is completely controlled by the diffusion to the surface. Most times you want to avoid such regimes, but there are some interesting things that one can investigate in the diffusion limit, namely some of these highly exothermic reactions on catalysts surfaces where there are three steady states predicted, two of which are stable and one of which isn't. It is like a flame with a blown out state, a middle state which is unstable and a state which you can see. You get the same thing in catalytic reactions on spherical surfaces, but you don't have the complicating factor that the actual size of the sphere is changing all the time as you would in a burning drop.

## DR. A. L. COPLEY

Different manifestations of the flow of blood in the microcirculation and macrocirculation are briefly presented. The occurrence of the plasmatic zone (a cell-free layer near the vessel wall) is shown. The width of this zone was found dependent upon the velocity of blood flow at the affected site. The zone is divided between a) more or less immobile layer nearest to the inner lining of the vessel wall which is considered to consist of fibrin (so-called endo-endothelial fibrin film, EEFF) and b) the mobile layers.

The decrease in apparent viscosity of blood in contact with fibrin--the so-called Copley-Scott Blair Phenomenon--as compared to glass surface is marked (about 20%). Physiologically, this proposed EEFF is considered to constitute a major factor in aiding the circulation in particular in the microcirculation.

In the living blood vessels this phenomenon was considered in relation to the characteristics of blood flow to be due to electrostatic or electrokinetic forces upon red blood cells due to the fibrin film or the endothelial cells covering or surrounding them. The plasmatic zone may be markedly influenced by the negative charge of the EEFF.

Blood clotting was discussed in all its possible three occurrences as it may block the circulation, occlude vessel lumina partially or completely, and lead to the pathological condition or disease of thrombosis.

To the two main processes of blood clotting cellular aggregation and fibrin formation with subsequent polymerization, gelation and crosslinking, a newly proposed process is discussed, viz. the aggregation of fibrinogen and other plasma proteins.

In vivo this is pictured as process beginning with the adsorption of fibrinogen to the EEFF with a subsequent growth process of protein layer upon protein layer until the vessel site is partially or completely obstructed. This aggregation of fibrinogen is considered to initiate thrombus, (i.e. intravascular clot formation) prior to platelet aggregation or fibrin polymerization and also to initiate the arrest of hemorrhage or so-called hemostasis.

A number of findings are presented on surface viscosity--viscous resistance defined as a value calculated from an average of the torque derived from the bulk of the test fluid plus that of its polymolecular surface layers. (The Weissenberg rheogoniometer was used for these studies).

Experiments at 0-g environment on the aggregation of fibrinogen and of cellular elements may prove to be useful, and, if applied to human subjects, may lead to the setting up of hospitals at space shuttle stations.

Other findings related to the flow properties of blood at very low or abnormal rates of shear down to  $0.0009 \text{ sec}^{-1}$ , as found following surgical operations, organ transplantation, i.e. following stoppage of blood flow and its resumption.

Viscoelasticity findings of blood and protein surface layers are presented. The latter are correlated to the patency of blood vessels.