NAVAL RESEARCH REVIEWS

DECEMBER 1976

PROFILES IN SCIENCE

Dr. James Van Allen

Dr. James Van Allen is Professor of Physics and Head of the Department of Physics and Astronomy at the University of Iowa. For 24 years Dr. Van Allen has been an outstanding ONR contractor.

During the formative days of the Office of Naval Research, he was associated with Captain Conrad and Alan T. Waterman. He supervised development of the Aerobee sounding rocket and conducted the first experiments with it in the fields of cosmic rays, solar ultraviolet, atmospheric ozone and geomagnetism from the White Sands Proving Ground and from the U.S.S. Norton Sound.

His twenty-four year contractual relationship with the Office of Naval Research dates from 1952, when the ONR supported his development of a simple scheme of balloon-launched rockets for making high altitude physical measurements in a very inexpensive way. The 1952, 1953, 1954, and 1955 series of such flights in the Arctic and the 1957 series in the equatorial and Antarctic areas made the first direct observations of the electron beams that cause aurorae and of the electrical currents flowing in the polar ionosphere. They also provided the first comprehensive latitude survey of the primary cosmic ray intensity above the appreciable atmosphere.

Professor Van Allen and his students developed the radiation instrumentation that was flown on the first successful American satellite Explorer I. His observations with this satellite and with Explorer III a few weeks later constituted the discovery of the radiation belts of the earth, the Van Allen belts. This work and subsequent observations of the effects of high altitude atomic bursts of the Argus and Starfish tests delineated the basic physical properties of the magnetosphere of the earth and the radiation limitations of all manned and unmanned spacecraft in earth orbit. Since that time Van Allen and his colleagues and students at the University of Iowa have participated in 26 space missions around the earth and to the planets Venus, Mars, and Jupiter. They have built six scientific satellites in their own laboratories, including a series called Injun satellites sponsored by the ONR.

In October Dr. Van Allen received the Navy's Distinguished Public Service Award at ceremonies marking the 30th Anniversary of ONR.

Circulator and Respiratory Changes Following Electrolytes

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and Clifford M. Herman, Capt., MC, USN

Introduction

There is a critical question in resuscitation from trauma, "Is human serum albumin really necessary for resuscitation?" The experience of many surgeons in the last decade has been that resuscitation can be achieved successfully with blood and salt solution with the addition of little albumin. If this is the case, it is an important observation not only from the medical point of view but also from the financial one. The economics of the situation are as follows: a bottle of albumin solution, 50 gms of albumin in a liter of salt solution, costs approximately $100. The dextrans cost approximately $3.00 per liter. Salt solution alone costs approximately $1.00 per liter.

The problem of the possible need for albumin can be reduced to two questions: (1) Can an equivalent degree of resuscitation be achieved with either albumin or salt solution: (2) Does either fluid produce respiratory failure or pulmonary edema? We have been trying to answer these questions over the past years with the support of the Office of Naval Research. This paper is an account of our work.

Methods and Materials

Circulatory Studies (1)

Adult male baboons, *Papio doguera,* weighing between 18 and 30 kilograms were used as the test animals. For each experiment, to facilitate handling, the baboon was tranquilized while still in a cage with an intramuscular injection of 1 milligram of 1-phenylcyclohex piperidine hydrochloride per kilogram of body weight.

Insertion of Monitoring Catheters: Each baboon initially underwent a thoracotomy on the left side under endotracheal anesthesia

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produced with nitrous oxide-oxygen-succinylcholine chloride. Siliconized vinyl catheters were placed in the thoracic aorta by way of the left subclavian artery, which was sacrificed, and through purse string sutures, into the pulmonary artery and both atria. The catheters were filled with 1,500 U.S.P. units of a concentrated heparin solution. The free ends were ligated and subcutaneously placed on the lateral aspect of the left side of the thorax.

Preliminary Procedures: After a two - three week recovery period, the baboon was again tranquilized. Any additional general anesthetic, necessary to maintain a lightly anesthetized condition, was given intravenously in the form of 25 milligram increments of pentobarbital sodium. Under local anesthesia, a plastic siliconized catheter was inserted through the femoral artery into the thoracic aorta and through the femoral vein into the vena cava. The baboon was then placed in the prone position, the anterior thoracic wall being protected by padded axillary supports. Under local anesthesia, the four ends of the thoracic catheters were exposed, the remaining concentrated heparin solution aspirated, and the catheters filled with 1.5 cubic centimeters of dilute heparin solution. Each thoracic catheter was connected to a pressure transducer and, by means of a preamplifier and a direct writing, multichanneled polygraph, pressures were continuously recorded from the four thoracic catheters. The transducers were positioned approximately at the level of the right atrium. Each pressure recording system was calibrated against a mercury manometer before and after every study. The baboons were not heparinized.

Experimental Mode. Hemorrhage: The study was divided into three periods: baseline; hemorrhagic shock; and resuscitation. After a 30 minute baseline period, hemorrhagic shock was induced by removing blood through the femoral artery catheter into a sterile plastic bag containing 67.5 cubic centimeters of acid citrate dextrose solution, at a rate adjusted to reduce mean arterial pressure to 60 millimeters of mercury during a 15-minute interval. This pressure was maintained for 60 minutes. Additional blood was then removed during a five-minute period to further reduce mean arterial pressure to a level of 40 millimeters of mercury for 70 minutes. Pressure was regulated by withdrawing or returning blood as required.

Treatment Groups: On the day prior to study, each baboon was placed in one of four treatment groups by random selection. Treatment began in all groups at the completion of the shock period and was partitioned into four 30-minute intervals, T_1, T_2, T_3, and T_4. These intervals were alternated with 30-minute observation periods. Each of the four treatment groups will be discussed separately.

No Treatment - Group 0. These baboons received no treatment after the end of the shock period.

Whole Blood - Group 1. The shed blood was reinfused into these baboons and additional amounts of freshly drawn, citrated, group specific, homologous baboon blood were given as required during treatment periods T_1 through T_4. The blood, when given, was infused at an average rate of 130 cubic centimeters per minute. A maximum of 250 cubic centimeters was drawn from each donor. The criteria for infusion of all test fluids will be described in detail.

Colloid - Group 2. Baboons in this group received, as required, an infusion of 5% human serum albumin in saline solution during treatment periods T_1, T_3, and T_4, at an average rate of 115 cubic centimeters per minute. During treatment period T_2, the baboon's own red blood cells were returned after being washed in isotonic saline solution and packed to a hematocrit value of 70%. No other fluid was given during treatment period T_2.

Saline Solution - Group 3. Baboons in this group received, as required, an infusion of 0.9% sodium chloride during treatment periods T_1, T_3, and T_4, at an average rate of 160 cubic centimeters per minute. During treatment period T_1, the baboon's own red blood cells were returned, as in group 2, after being washed in isotonic saline solution and packed to a hematocrit value of 70%. No other fluid was given during treatment period T_2.

Infusion Protocol: The test fluids in the three treatment groups were infused until either the mean arterial pressure had returned to its baseline value or the mean right atrial pressure was 7 millimeters of mercury higher than its baseline value, at which time infusion was stopped. Infusion was resumed whenever arterial pressure decreased below its baseline and the mean right atrial pressure did not exceed its baseline by more than 4 millimeters of mercury.

Data Collection: During each experiment, ten data collection points S_1 through S_{10} were scheduled (Figure 1). At each of these points, pressures were recorded from the polygraph. In addition, cardiac output determinations, in replicate, were estimated by the dye dilution method by use of a cardiodensitometer system. Known amounts of idocyanine green were injected into the pulmonary artery catheter followed by a 7 cubic centimeter flush with isotonic saline solution. Arterial blood was aspirated at 20 cubic centimeters per minute for dye sampling by means of a withdrawal pump. After each determination, the blood was reinfused. The calibration factor for the cardiodensitometer was determined during the baseline interval and again after the first and second treatment periods.

Pulmonary vascular resistance (PVR) was calculated from the following standard formula:

$$PVR = (MPAP - MLAP)/CO$$

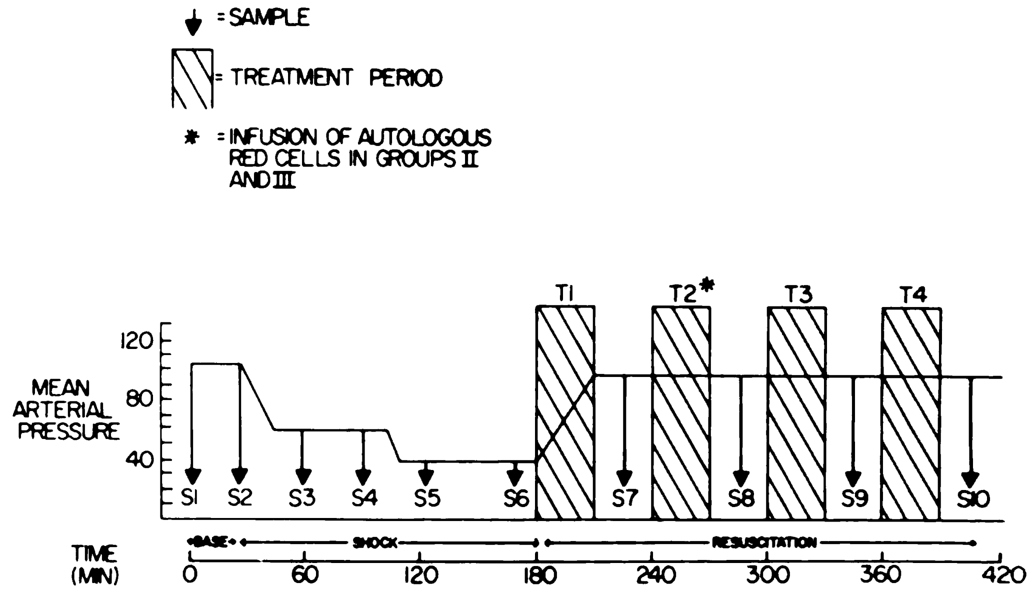


Figure 1 — Experimental design and sampling periods. In subsequent figures, the results measured at several periods have not been presented for the sake of brevity. These include the first baseline sample, S_1, and the first three shock samples, S_3 through S_5.

Where MPAP is the mean pulmonary artery pressure; MLAP, the mean left atrial pressure; and CO, the cardiac output.

Also, at each sampling point, 10 cubic centimeters of blood was withdrawn for replicate chemical studies. Arterial lactic acid was determined by an enzyme method. Each sample was immediately deproteinized and anaerobically withdrawn from the aortic catherter. For determination of pO_2 levels, blood was anaerobically withdrawn from the aortic catheter. Measurements were immediately made using an ultramicro pH-blood gas analyzing system. A Goldberg hand refractometer was used to measure plasma total protein. For measurement of hematocrit, capillary tubes and a microcentrifuge were used. All information for subsequent computer analysis was recorded on coding sheets and punch cards.

Electron Microscopy Studies (2)

Technique of Lung Fixation with Buffered Glutaraldehyde: At the conclusion of the experiment, the baboon was placed in the supine position and the extremities were restrained. A small dose of pentobarbital was given intravenously. The thoracic cavity was entered through a midline sternal-splitting incision. Then, a purse string suture was placed in the main trunk of the pulmonary artery and a plastic siliconized catheter threaded into the left pulmonary artery. A similar catheter was threaded through the endotracheal tube to the left main bronchus. By cross-clamping the hilus of the right lung, the left lung was isolated. A dual method of perfusion fixation was initiated. The perfusion pressure in the arterial system was maintained at a steady 40 centimeters of water. After a few minutes of perfusion with buffered glutaraldehyde through the vascular bed, the ascending aorta was clamped, thus reducing the quantity of the perfusate needed. Approximately 500 to 700 milliliters of the perfusate was given in 30 minutes. Another 20 to 40 milliliters - the volume of fluid to fill the main stem bronchus and its branches - was instilled into the bronchus manually through the catheter. The catheter then was removed and the endotracheal tube clamped. At the end of 30 minutes of this dual fixation, the lung was firm in consistency and resembled liver in gross appearance. The lung was removed, and tissue samples were taken from different areas. Next, the baboon was sacrificed. With this method, the lung is fixed in a living animal, which reduces artifacts to a minimum. Further fixation of lung tissue was achieved by immersion in the perfusate for two hours at 4 degrees C and, subsequently in 2% osmium tetroxide in Veronal buffer (barbital buffer) for two hours at 4 degrees C. Fixed tissues were dehydrated quickly in acetone and embedded in Araldite or Epon 812.

Technique of Electron Microscopy: Ultrathin sections were cut from adjacent areas of sections used for light microscopy and mounted on a copper grid, where they were stained with an alcohol solution with uranyl acetate and viewed in an RCA EMU 3H 4 microscope.

Results

Circulatory Indexes

All three groups (Table 1) lost approximately 35 cc/kg during the hemorrhage period, which is about 50% of their total blood volume.

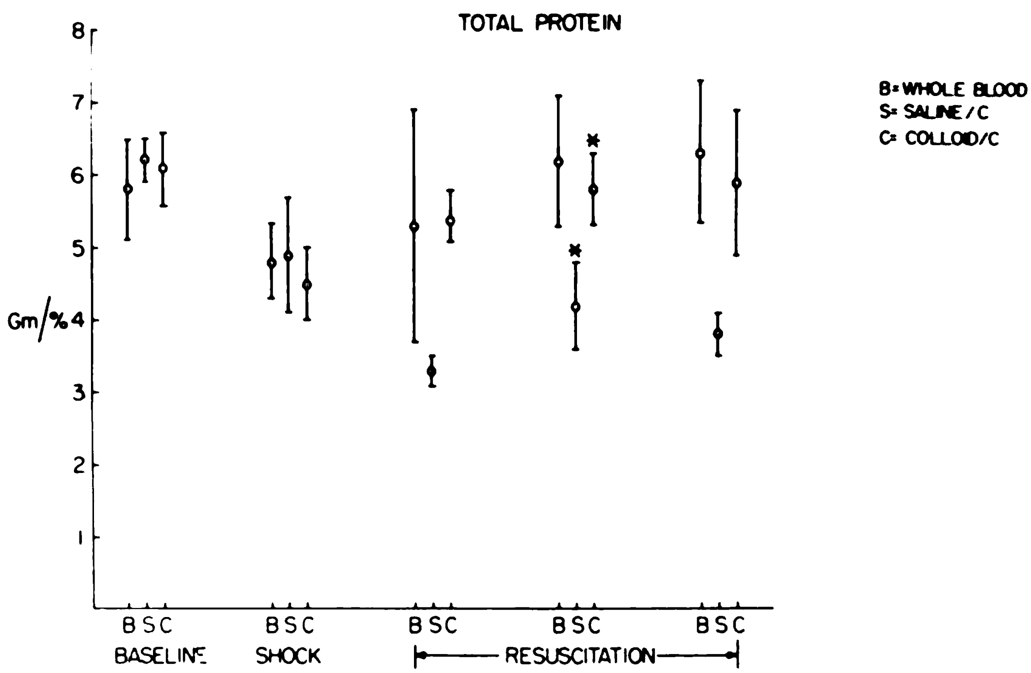
TABLE 1
Mean Volumes Removed and Infused in the Three Groups Receiving Test Fluid (standard deviations are shown next to the mean values)

Treatment Group	Number of Animals	Mean Volumes Removed (cc/kg)	Mean Volume Infused (cc/kg)	Infused Volume ÷ Removed Volume
Whole Blood	9	37.8 ± 5.3	52.1 ± 20.8	1.37
Colloid/Cells	13	37.2 ±7.1	52.6± 18.9	1.41
Saline/Cells	11	34.7 ±8.9	143.9 ± 22.4	4.14

To restore and maintain their circulation during the resuscitation period for four hours, the blood group required about 50 cc/kg. The colloid group required a slightly greater volume. In contrast, the amount of saline required to achieve resuscitation was three times as high as the other groups.

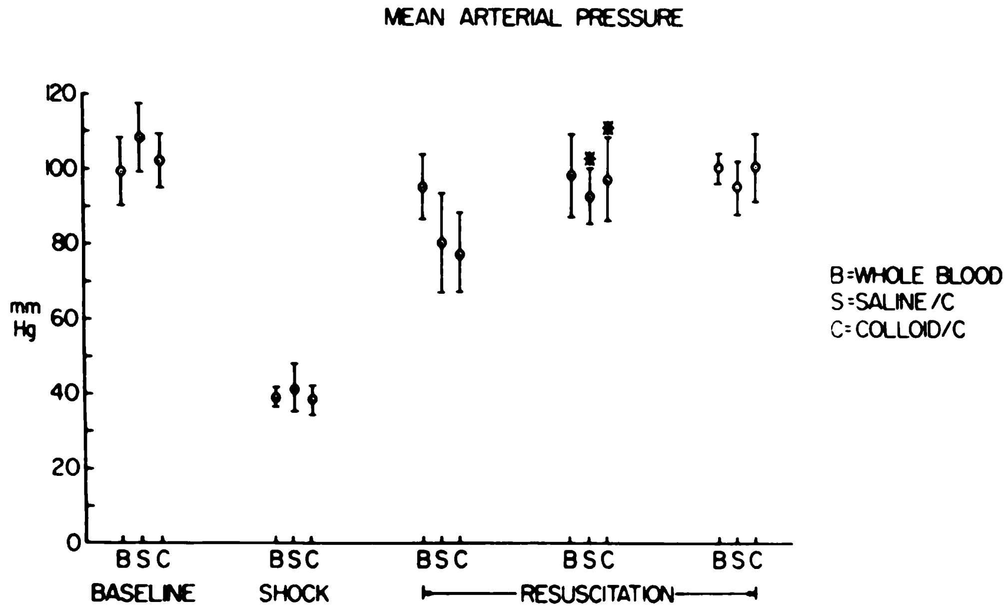
Figure 2a contains the plasma total protein in grams % during baseline shock, and various period of resuscitation. We see the mean and standard deviation for the blood group (B), for the colloid group (C) and the saline group (S). This trio will be represented at each of the observation points. In shock the total protein concentration falls and then with treatment the groups separate. The whole blood and colloid groups return to control values, 6 gms %, whereas the saline group falls to close to 4 gms %.

The arterial pressure changes are seen in Figure 2b. There are no differences during resuscitation at any point between the groups. We can restore the arterial pressure and hold it there for four hours with any one of the three treatments. The variation in pulmonary artery pressure is seen in Figure 2c. It falls in shock, and at the end of the study, all values have returned to basal levels.

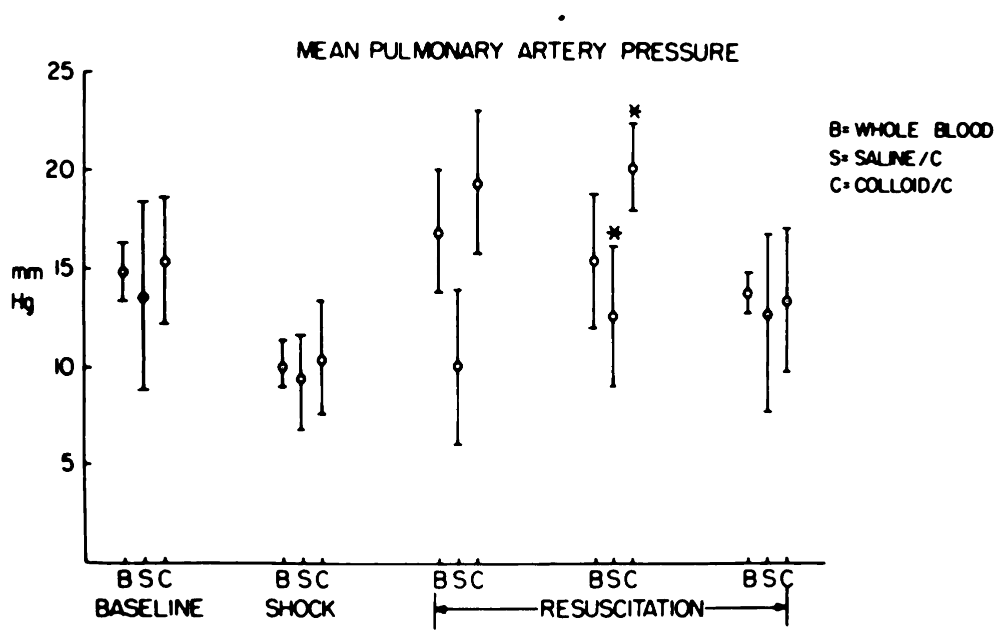


(a)

Figure 2a-2g — Total Protein show the mean value for seven circulatory indexes measured at selected sampling points. The bars indicate one standard deviation above and one standard deviation below the mean. In this and subsequent figures, the treatment groups are presented in the same order at each sampling point — B, whole blood; C, colloid; S, saline solution. The asterisks indicate the first sampling period following infusion of the shed red blood cells in the colloid and saline solution group.

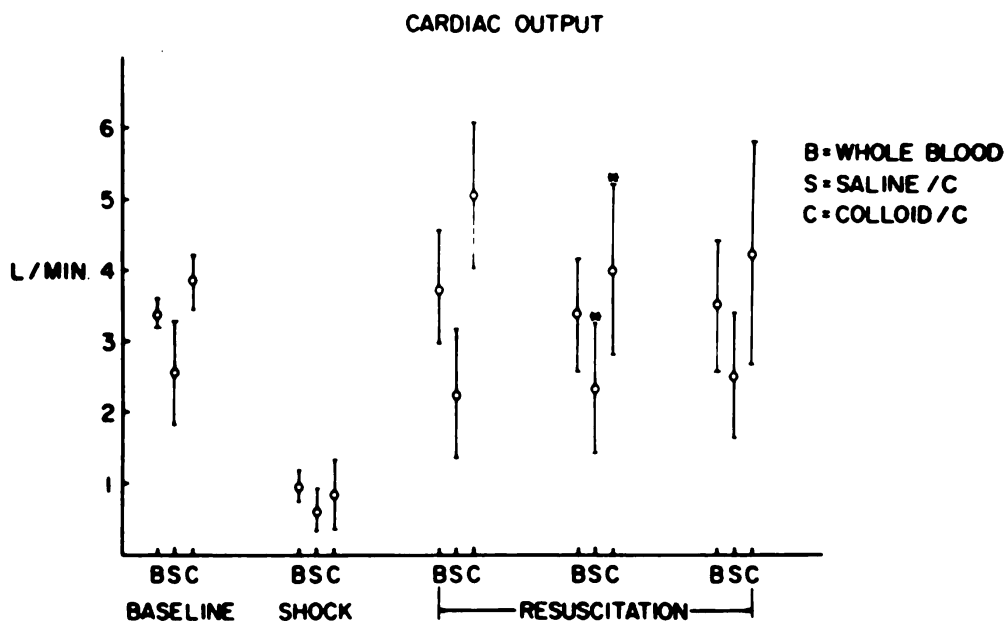


(b)

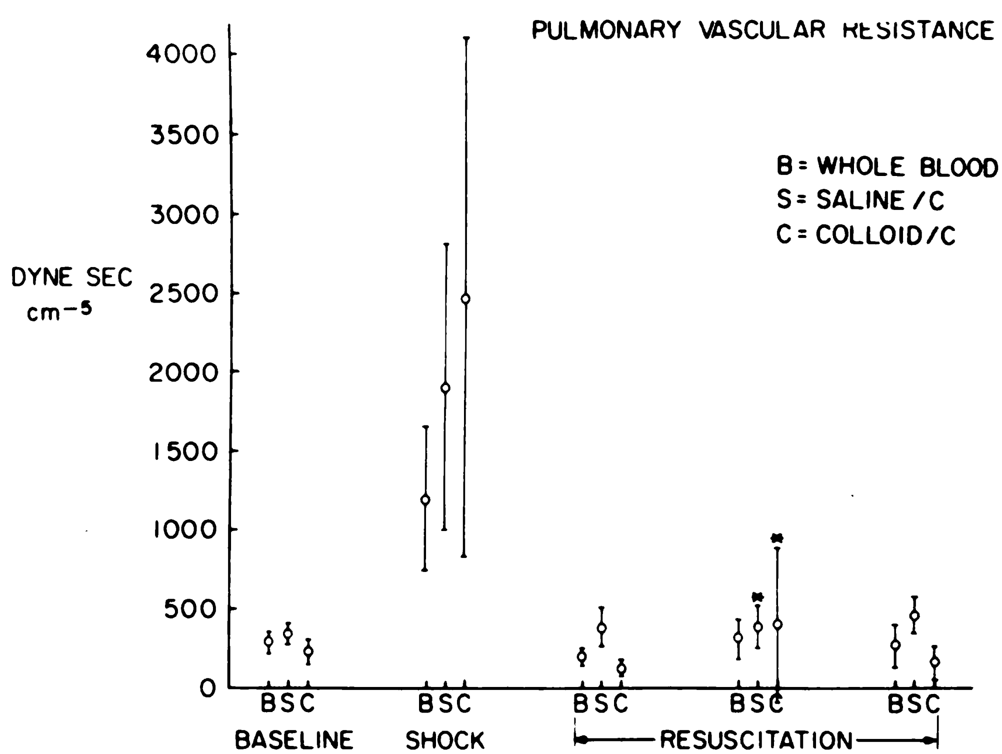


(c)

Figures 2a-2g (continued) — Total Protein show the mean value for seven circulatory indexes measured at selected sampling points. The bars indicate one standard deviation above and one standard deviation below the mean. In this and subsequent figures, the treatment groups are presented in the same order at each sampling point — B, whole blood; C, colloid; S, saline solution. The asterisks indicate the first sampling period following infusion of the shed red blood cells in the colloid and saline solution group.

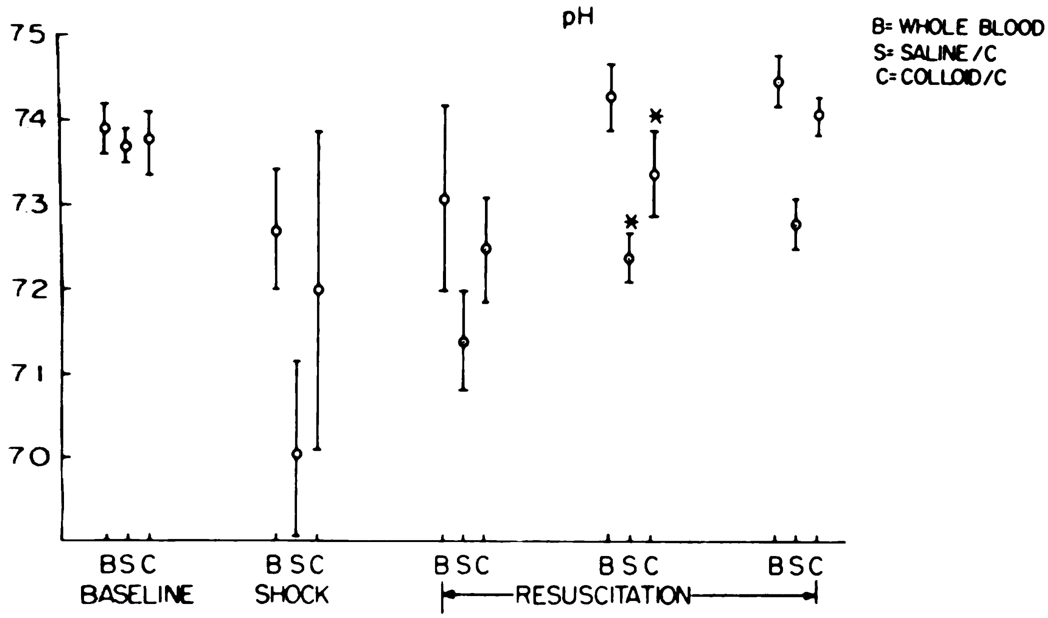


(d)

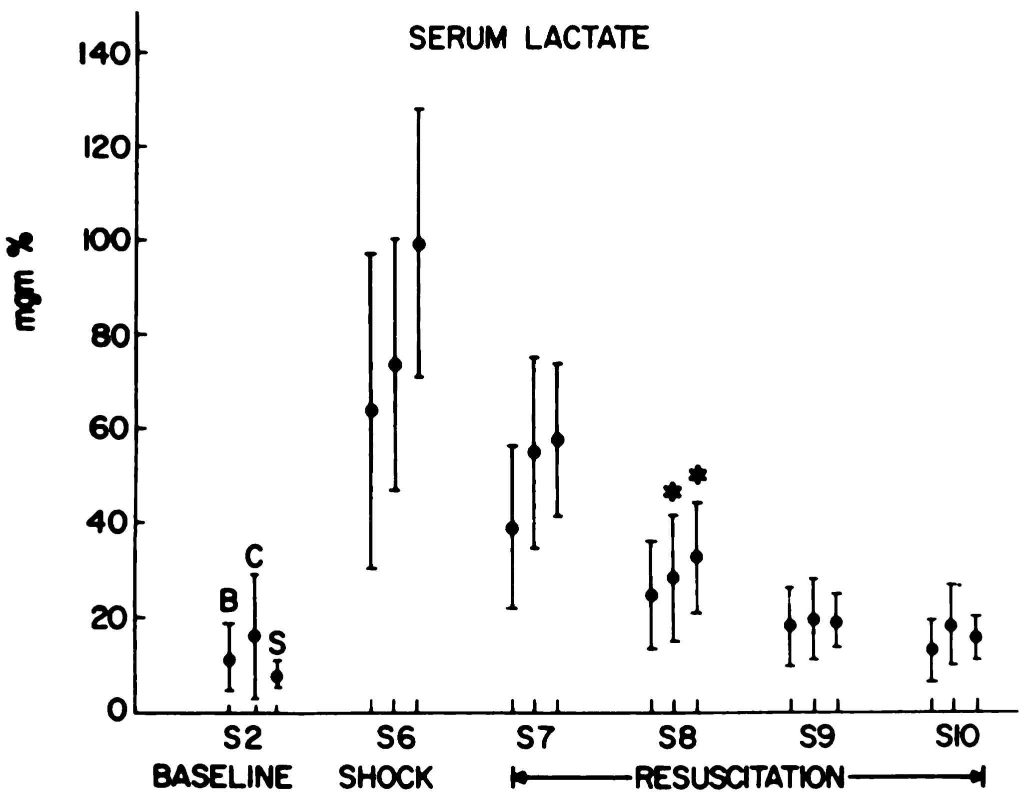


(e)

Figures 2a-2g (continued) — Total Protein show the mean value for seven circulatory indexes measured at selected sampling points. The bars indicate one standard deviation above and one standard deviation below the mean. In this and subsequent figures, the treatment groups are presented in the same order at each sampling point — B, whole blood; C, colloid; S, saline solution. The asterisks indicate the first sampling period following infusion of the shed red blood cells, in the colloid and saline solution group.



(f)



(g)

Figures 2a-2g (continued) — Total Protein show the mean value for seven circulatory indexes measured at selected sampling points. The bars indicate one standard deviation above and one standard deviation below the mean. In this and subsequent figures, the treatment groups are presented in the same order at each sampling point — B, whole blood; C, colloid; S, saline solution. The asterisks indicate the first sampling period following infusion of the shed red blood cells in the colloid and saline solution group.

The cardiac output is seen in Figure 2d. The output falls in shock, as expected. With resuscitation it returns to control levels.

Pulmonary vascular resistance is shown in Figure 2e. The values go up in shock and then with treatment they come back to normal and are not different in any of the three groups Also there are no differences from their basal values.

The changes in pH are seen in Figure 2f. In shock the pH falls. With treatment the groups separate. The saline group has a lower pH than either of the other two groups. This difference is related to excess chloride in isotonic saline.

A more direct way to look for defects in perfusion is the serum lactate level (Figure 2g). If saline was less effective in restoring perfusion to the cells, then it should be reflected in an inability of the cells to clear the elevated lactate level that was observed during shock. The data show that the lactate goes up in shock, but there are no differences between groups in the decline in lactate. By the end of the study there are no differences from control levels.

Pulmonary Studies

Figure 3 contains the experimental model. Lungs are excised at the end of the study, or 24 hours later, and desiccated to constant

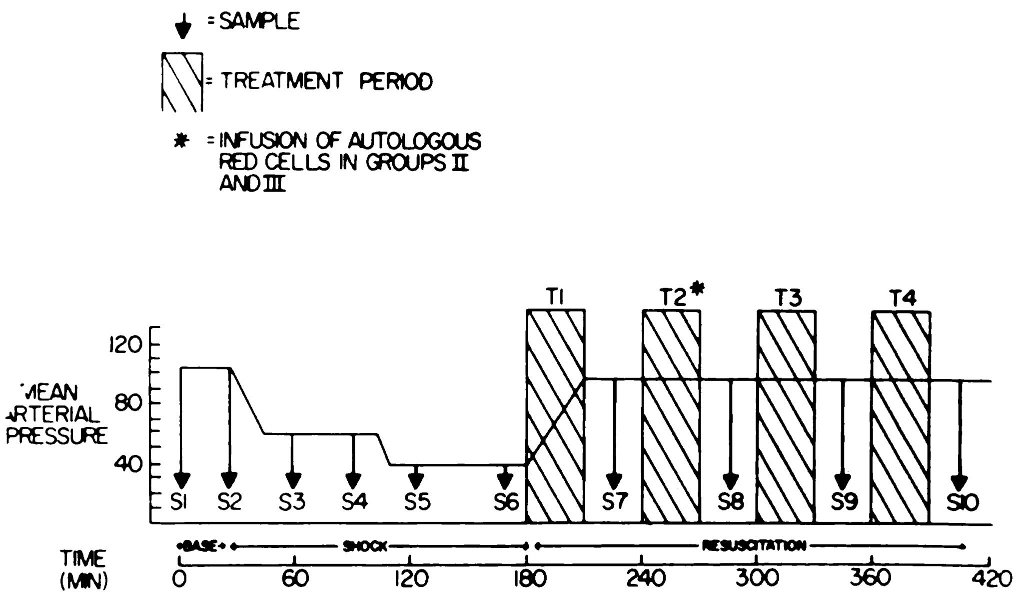


Figure 3 — Schematic representation of experimental model. After 60-minute baseline rest period, shock induced by arterial hemorrhage and mean arterial pressure reduced to 60 mm Hg for one hour, then to 40 mm Hg for a second hour. Resuscitation during periods T_1, T_3, and T_4 with one of the test solutions. Shed packed red cells returned during T_2. Blood and expired air samples, as well as measurements of respiration, accomplished at points S_1, S_2, S_3, and S_4. Half of animals killed at points S_3 and remainder at S_4

weight. The amount of water in the lungs is then calculated. The first two groups (Figure 4), groups 1 and 2, are animals shocked and resuscitated with saline. Group 1 was sacrificed the day of the study and group 2 was sacrificed the day after. Groups 3 and 4 were treated with albumin and sacrificed the same day (group 3) or 24 hours later (group 4). For the numbers not to be significantly different from controls, the 95% confidence intervals must intercept the control interval. They do in each case, indicating no increase in lung water in any group.

Figure 5 shows the changes in the dead space to tidal volume ratio. That is, pulmonary edema should be reflected in a relative increase in dead space. We see that the confidence intervals intercept zero, so the dead space to tidal volume ratios at the end of the study with Ringer's or with albumin were not different.

Electron Microscopy Observations: Figure 6 shows a cross section through an alveolar capillary region from the lung of the control baboon.

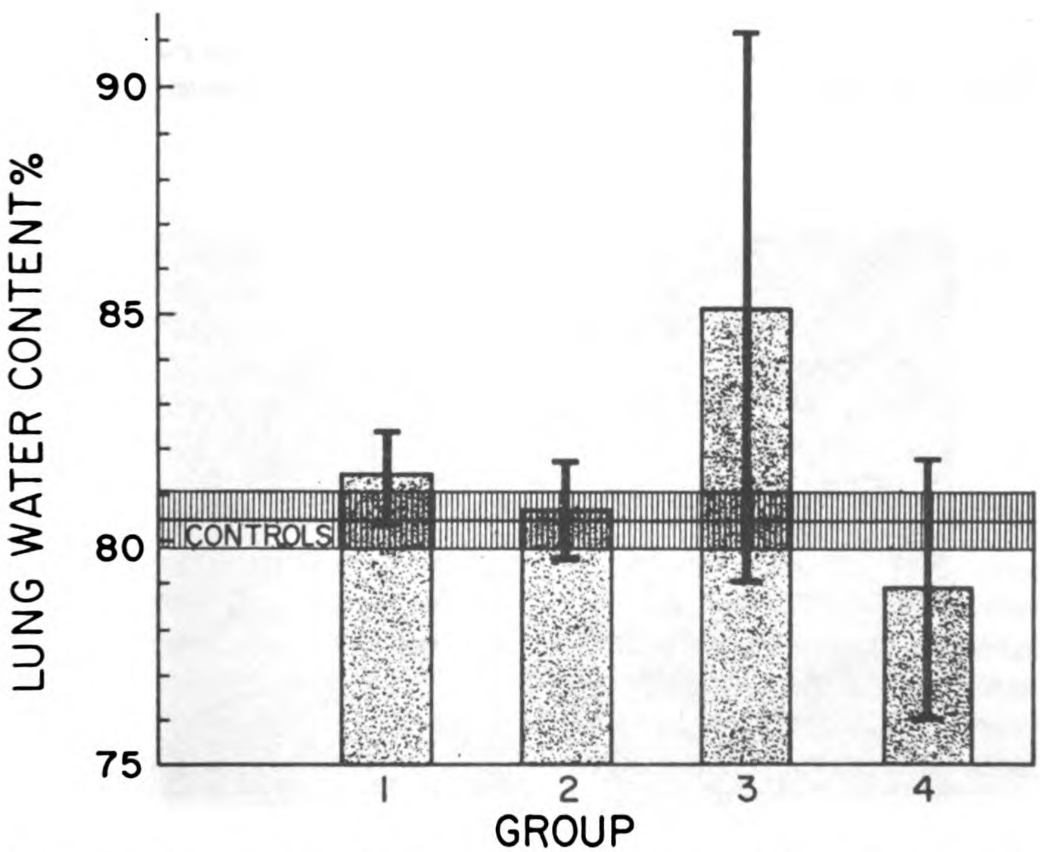


Figure 4 — Mean value (± 95% confidence interval) for control lung water content is represented by vertically lined strip. Group 1 portrays the mean value ± 95% confidence interval for saline-treated animals sacrificed the same day; Group 2 represents saline-treated animals killed 24 hours after the study; Group 3 shows the albumin-treated group sacrificed the same day; Group 4 represents albumin-treated animals sacrificed 24 hours after the study.

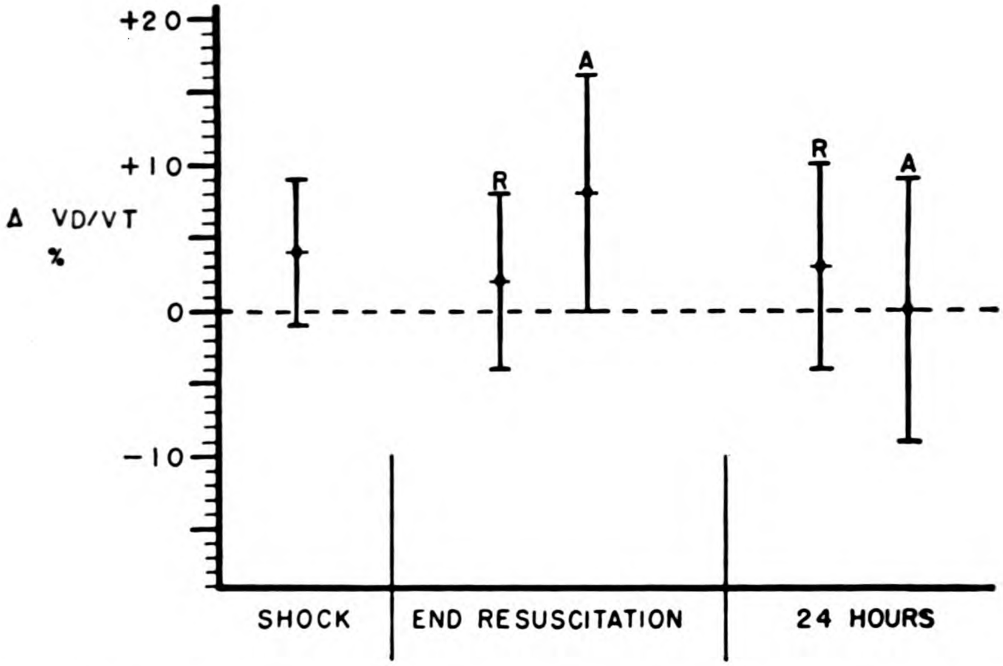


Figure 5 — Change in dead space to tidal volume ratio. Baseline VD/VT was 44 ± 5%. Shown is the mean change ± 95% CI during shock and after resuscitation with either 5% albumin in Ringer's lactate (A) or Ringer's lactate alone (R).

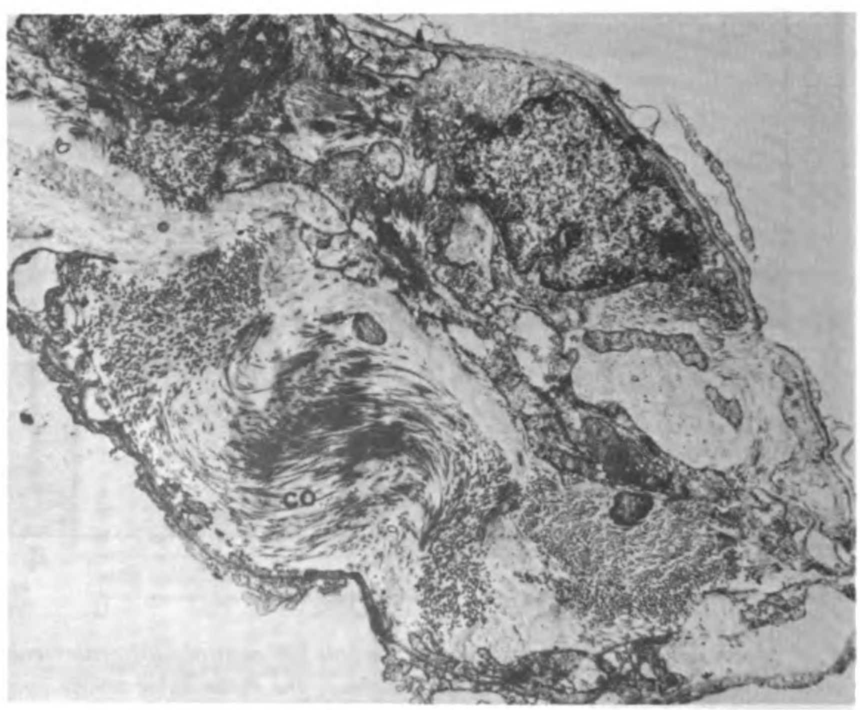


Figure 6 — The thick portion of the alveolar capillary membrane is shown in detail. The endothelial and epithelial layers are separated by whorling bands of collagen fibers (Co). The distribution and disposition of collagen fibers are well seen. X6,480.

Clear separation of the main components of the barrier can be seen. The endothelium forms an uninterrupted lining characterized by the presence of numerous, densely arranged pinocytotic vesicles distributed throughout the cytoplasmic processes of these cells. The alveolar wall is lined by epithelial cells which, in structure, are quite similar to the endothelial cells and possess similar thin cystoplasmic extensions. The cystoplasmic processes in either type of cell have a paucity of organelles. In the normal lung, the interstitium is narrow, and several distinct zones can be differentiated. Most of the area usually consists of the fusion of the basement membrane of the endothelial and epithelial layers. The minimal interstitial space measured about 800 Angstrom units and is most prominent where the capillaries come in closest contact with the alveolar area and where both alveolar capillary linings are thinnest. In other regions, the basement membrane of the endothelium and the epithelium are separated by extensions of fibroblast, which makes the width of separation quite variable. In some other areas, the gap is filled primarily with collagen fibers and fibroblastic extensions as well. These wide areas usually contain larger and coarser collagen fibers. The interstitial collagen fibers are of special interest, because the earliest sign of interstitial edema is dispersion of these individual fibers.

Effects of Hemorrhagic Shock: Figure 7a shows the principal changes in lung structure after hemorrhagic shock. The development of interstitial edema and increased endothelial pinocytosis are the most important changes. Dispersion of the individual collagen fibers – an indication of interstitial edema – and increased endothelial pinocytosis are clearly evident. The smudged areas represent pools of edematous fluid. In Figure 7b, dispersion of the individual fibers is shown in greater detail.

Effects of Saline Solution Resuscitation: (3,4). After saline solution resuscitation (Figures 8a-8d), there was a decrease in the number of endothelial pinocytotic vesicles, collagen fibers regained their packed periodic configuration, and the concentration of interstitial sodium precipitate declined to a prehemorrhage appearance. The only evidence of residual interstitial edema was the occasional presence of small, smudged areas. In none of the lung sections was there any evidence of the increased interstitial edema present in the shock state, and, in fact, most of these sections were indistinguishable from those of the control state. In contrast, in the albumin-resuscitated animals, the alveolar capillary membrane resembles the appearance seen in the shock state, i.e., a substantial degree of interstitial edema surrounding collagen fibers (Figure 9). The importance of this observation remains to be defined.

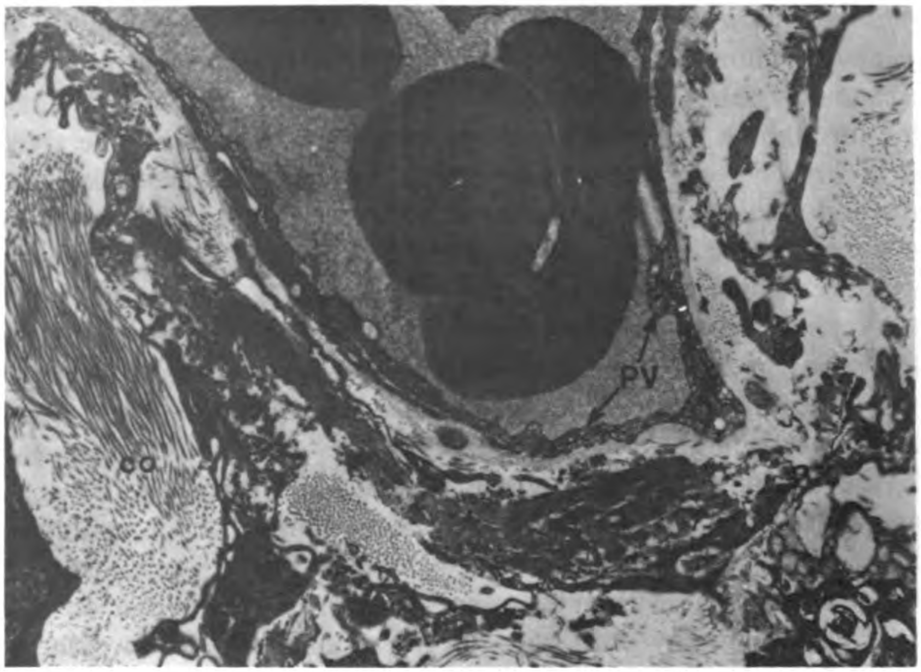


Figure 7a – The architecture of a baboon lung is shown after hemorrhagic hypotension. Note the marked increase in pinocytotic vesicles (PV) in the endothelial lining. Within the interstitium the presence of edema, osmophilic smudges and dispersion of collagen (Co) are evident. In the lower right, the cytoplasm of a granular pneumocyte is seen. No structural alteration can be found within the cell. X5,982.

Figure 7b – Dispersion of individual collagen fibers can be seen in greater detail. At the left, the osmophilic smudges can be seen. X21,315.

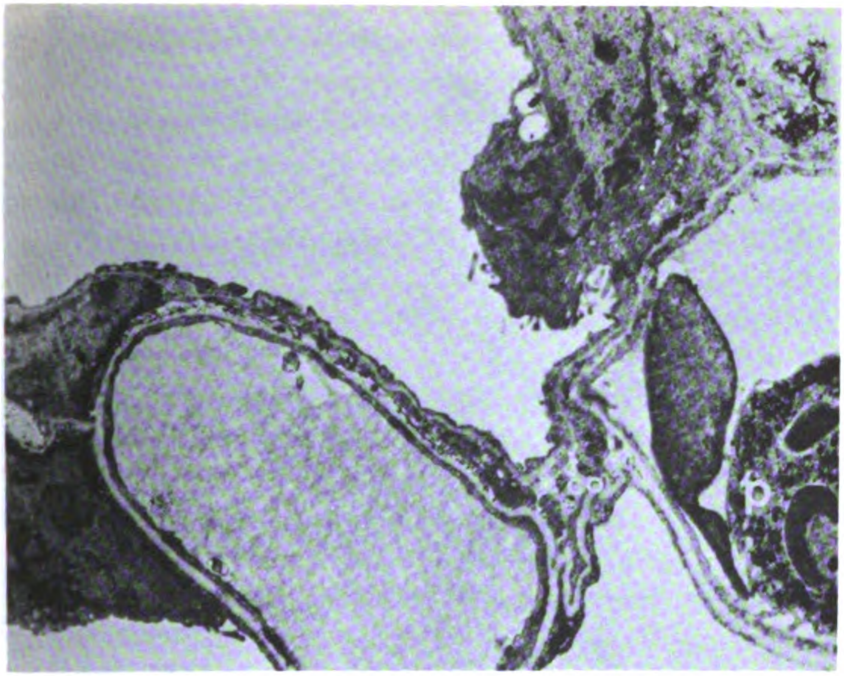


Figure 8a — Low power view of a pulmonary alveolar capillary membrane after resuscitation with saline solution. A platelet (P) and collagen fibers (Co) can be seen. Comparison with normal lung (Figure 6) fails to show any significant difference from the control state. X5,935.

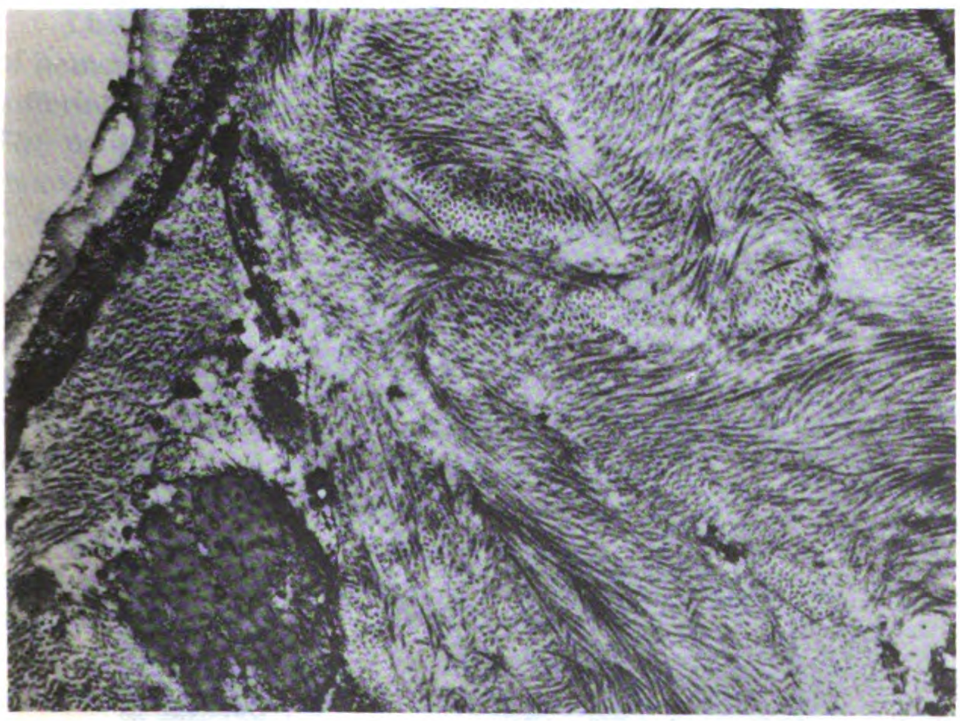


Figure 8b — The area of the interstitial membrane shows the distribution of collagen fibers. Although an area of smudging and some areas of edema are noticeable, the majority of the area appears to be normal. X9,329.

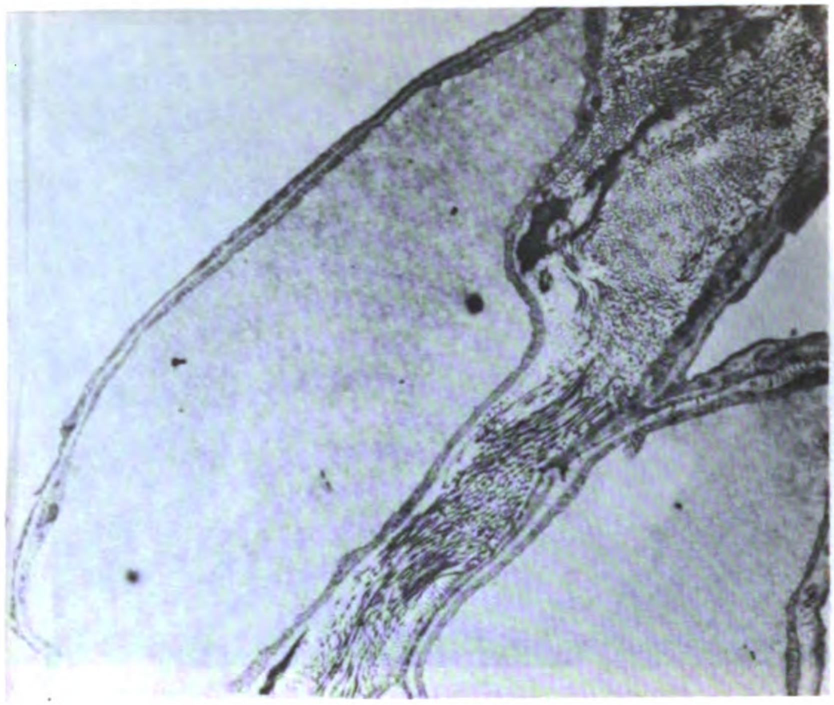


Figure 8c — Distribution of sodium pyroantimonate deposits after saline solution resuscitation appears similar to that of the control state. X7,269.

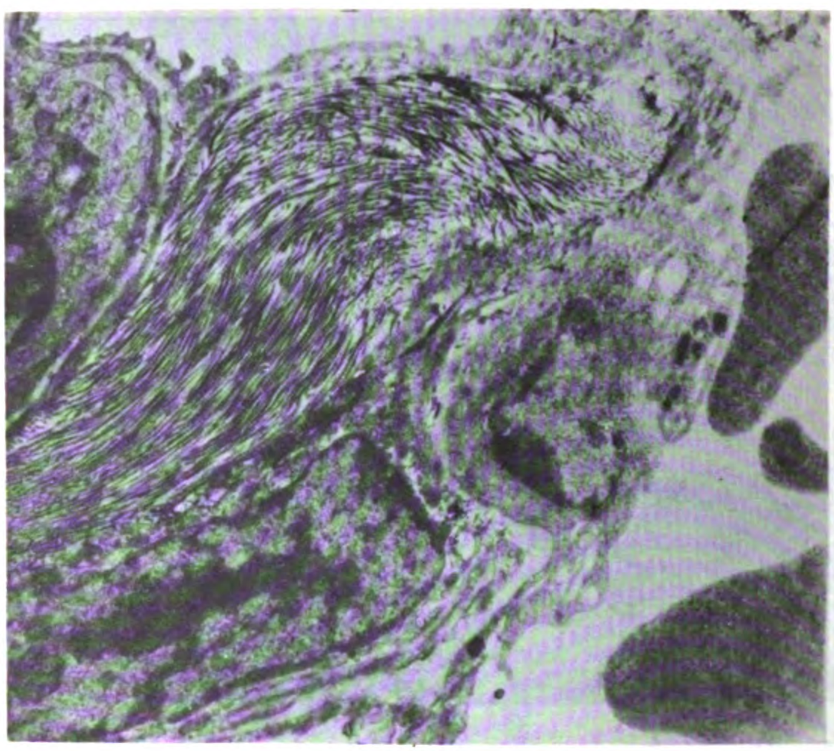


Figure 8d — Sodium pyroantimonate deposit in collagen fibers appears to be similar to control lungs after saline solution treatment. X9,300.

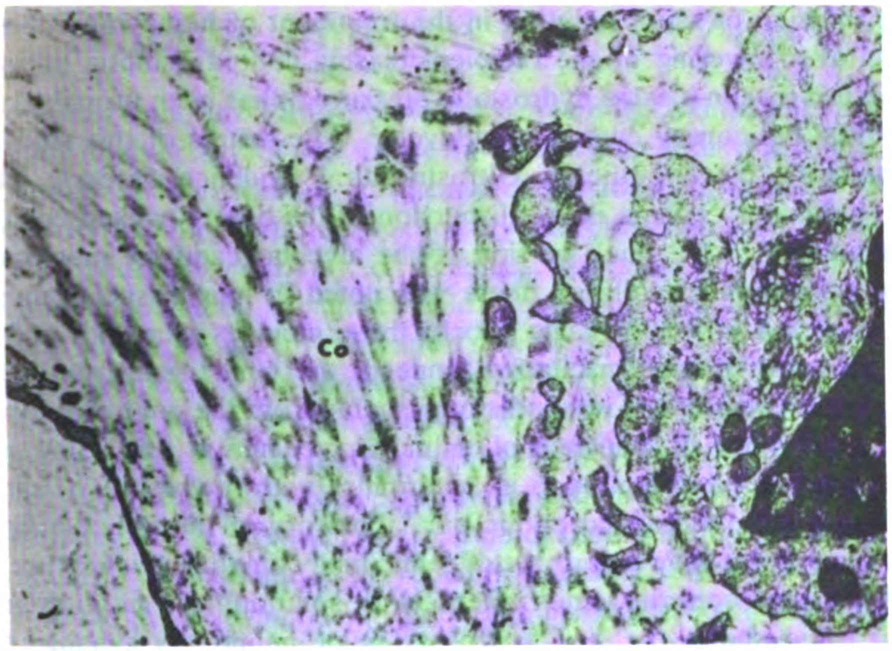


Figure 9 — Electron micrograph of alveolar-capillary diffusion membrane of albumin-treated baboon. Note swollen, plump collagen fibers (Co), with loss of periodicity. X21,080.

Discussion

The controversy regarding the types of fluid to use in the treatment of hemorrhagic shock is not new (5). In 1891, W. Lane treated a patient suffering from hemorrhagic shock with an infusion of saline solution. The patient recovered, and Lane thought he had found the remedy for shock. However, his conclusion was challenged by two physiologists, C. S. Sherrington and S. W. Copeman, who studied the changes in plasma specific gravity in rabbits and found that infused saline solution rapidly left the intravascular space. Thus, began an interesting and important issue that is not yet settled (6,7).

Previous reports have focused this issue to a debate on the relative merits of various asanguineous fluids in early resuscitation from hemorrhagic shock, specifically saline solution versus colloid solution. We have searched for differences in circulatory parameters after resuscitation with either saline or colloid solution. Both asanguineous fluids were found to be equally effective in restoring circulatory and metabolic parameters.

A further objective of this study was to test the hypothesis that saline solution infusion in the treatment of hemorrhagic shock induces interstitial pulmonary edema. This hypothesis is based on Starling's Law stating that the net movement of fluid across semipermeable capillary membranes is governed by the algebraic sum of the hydrostatic and colloid osmotic pressures on the two sides of the membrane.

Since infusion of saline solution in the treatment of hemorrhagic shock results in a lowering of the recipient plasma colloid osmotic pressure and an increase in plasma hydrostatic pressure, it has been proposed that interstitial pulmonary edema may develop. The results of this study do not support this hypothesis. Ultrastructural evidence of early interstitial pulmonary edema is the dispersion of the tightly packed collagen fibers located in the thick portion of the alveolar capillary membrane. While dispersion of collagen fibers was noted in lung tissue examined after a period of hemorrhagic shock, these changes were not present after saline solution resuscitation. Indeed, the lung tissue from saline solution-treated animals was indistinguishable from the control samples.

The absence of evidence of pulmonary edema in this study after saline solution resuscitation is in accordance with the results of earlier physiologic studies carried out in our laboratory in the intact baboon. For example, we have found that dynamic lung compliance levels are not different from control values after saline solution resuscitation from hemorrhagic shock (6). In known states of pulmonary edema, lung compliance values fall as the lungs stiffen. In addition, measurements of alveolar arterial oxygen gradients are not increased after saline solution resuscitation. Pulmonary edema causes an increase in the gradient by enhancing ventilation perfusion imbalances. Furthermore, direct measurement of lung water content by desiccation techniques has failed to show evidence of increased pulmonary water content after saline solution resuscitation.

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Science and the Future Navy

"Science and the Future Navy" was a two-day symposium marking the 30th anniversary of the Office of Naval Research which was held in October at the Eisenhower Theater of the John F. Kennedy Center for the Performing Arts. Sponsored by the Office of Naval Research and the National Academy of Sciences, the symposium focused on anticipated advances in science and technology and the implications of these developments for the nation's defense effort.

The symposium was aimed at the knowledgeable layman. Speakers described current issues in science policy as they affect the future Navy. Although it is customary to dwell on past accomplishments at anniversary occasions, this symposium stimulated penetrating discussions about the scientific and technological issues and opportunities facing the Navy by some of our country's leading scientists.

Following the symposium there was a banquet at the Washington Hilton Hotel to give public recognition to science and naval research and to honor major contributors of recent years.

During the course of ONR's 30th anniversary year there will appear several commerative publications. These will include the proceedings of the symposium and two volumes of papers by distinguished scientists, who will provide interpretations of scientific progress and its implications to the nation.

Dr. Philip Handler, President of the National Academy of Sciences, introducing Admiral J. L. Holloway, III, USN, Chief of Naval Operations, who gave the keynote address at the symposium.

ıe Honorable J. William Middendorf, II Secretary the Navy (left), Chairman of the first session of the mposium, is shown introducing Dr. Edward Teller of ? Lawrence Livermore Laboratory.

Rear Admiral Robert K. Geiger, Chief of Naval Research and Mrs. Geiger talking with guests at the banquet.

Left to right, The Honorable H. Tyler Marcy, Assistant Secretary of the Navy (Research and Development), Dr. James Van Allen, and Rear Admiral Geiger. At the banquet Dr. Marcy presented Dr. Van Allen the Navy's Distinguished Public Service Award.

Left to right, Dr. William Fowler, President of the American Physical Society and Dr. William Raney, Chief Scientist for the Office of Naval Research at the banquet.

The Deadly Shipmate*

Called the deadliest shipmate of all, fire has been dreaded by sailors since man first went to sea. Unless it is discovered promptly and checked rapidly, fire can develop into a holocaust generating three ravaging products: flames, smoke and toxic fumes. Flames can reduce materials to ashes and metals to a molten mass. Inhalation of smoke and toxic fumes can be fatal to shipboard personnel.

In conventional Navy ships and advanced, high-performance ships, there are materials and equipment which incorporate substances as lethal as aviation and rocket fuels. These explosive materials, common to the working environment within many naval ships, pose serious problems. Lightweight structural materials such as aluminum, replacing the traditional heavy steels, bronze and copper, are used for hulls, helicopter pads and hangars. But aluminum has its drawbacks because it melts at 1184° Fahrenheit or 640° Celsius, a temperature much lower than that produced by shipboard fires.

The habitability materials for carpeting, curtains, mattresses and upholstery fabrics burn, smolder, and give off toxic fumes. Fuels, explosives, metals and plastic materials all compound the danger of shipboard fire.

If the phenomena which generate a climate conducive to ignition can be anticipated, the risk of fire can be dramatically reduced. If not, what are the prospects of mitigating or eliminating fire? The obvious solution is to develop, through continuing research, more effective methods to prevent fire and more efficient equipment with which to fight fire.

Among the major tasks at the David W. Taylor Naval Ship Research and Development Center is that of improving fire safety throughout the Fleet. Sound fire-safety measures are being implemented in existing ships as well as being incorporated in designs for future generations of high-performance ships. The Center is equipped with a number of facilities and devices which determine fire-safety parameters for structural and habitability materials. Selected fire-fighting equipment is subjected to exhaustive evaluation before being adapted for shipboard use.

Center engineers perform investigative studies on the fire and smoke characteristics of both structural and habitability materials. The results of these studies are evaluated. By process of comparison, the most

*Reprinted from a news release by Julia Ford from The Naval Ship Research and Development Center, Annapolis Maryland.

hazardous combustible materials, especially those that disintegrate, smoke, and produce toxic fumes, are listed among banned items and then removed from the Fleet. Materials which Navy procurement presently lists as approved for shipboard use have been tested at the Center for their safer, more effective fire-retardant properties. These materials replace items deemed too dangerous.

Fire-Fighting Equipment

In some of the newer ships, superstructures and helicopter landing pads are fabricated from aluminum, a metal which melts at 640°C. Fuel fires produce temperatures in the range of 950°C. Landing pads subjected to such intense heat buckle or are totally destroyed if the fires are not quickly controlled.

As an improvement to the present practice of having fire fighters man hose lines along the sides of the helicopter hangar during flight operations, the Center recommends the use of a foam monitoring system. To evaluate the effectiveness of its fire-fighting performance, technical personnel prepared a mock-up of the type of helicopter landing pad used on non-aviation type ships, and installed an aqueous, film-forming foam monitor. This oscillating monitor, which can be operated manually or hydraulically, is so balanced that it can be spun from side to side as well as up and down with minimum effort. This easy mobility permits excellent control and direction of the fire-fighting stream. A lightweight plastic nozzle, which exhibited satisfactory performance with regard to water pressure and the scope of its spray patterns, replaced the heavier, more expensive bronze unit. The new nozzle adjusts to produce either a fog patter or a straight stream, as required. The characteristics of both water and foam fire-fighting streams were investigated under various wind conditions to determine the pressure, volume, and range of the monitoring system.

As a result of this investigation at the Center's Fire-Fighting and Survivability Laboratory, a full-scale prototype monitor has been installed and tested aboard a destroyer escort. Ship alteration proposals have been prepared for future installations.

Materials

In response to the Navy's requirements for new lightweight materials for high-speed ships, the Center conducts studies on the expediency of replacing heavier piping materials such as steel, copper-nickel and aluminum with corrosion-resistant glass-reinforced plastic (GRP). To ensure that the safety factor is not sacrificed for speed in such craft, sections of GRP piping, copper-nickel piping, and aluminum piping were prepared for and exposed to liquid fuel fires in a special fire-test chamber. The pipes were first tested dry, then with stagnant water, and finally with flowing water. Under dry conditions, both GRP and aluminum piping failed in two minutes. With the addition of lightweight protective insulation, the dry pipes remained functional for eight minutes. Under stagnant water, they survived a little longer. Dramatic improvement was noted, however, when the pipes were filled with flowing water. After being exposed to fire for an hour, the glass-reinforced plastic piping remained functional.

Electrical cables are the lifelines in Navy ships. Control and power cables transmit the force that drives complex electrical and electronic systems within these high-performance craft. Communication cables carry the message between components within the systems. However sophisticated these systems are, they cannot function without the interconnecting cableways. Running like veins and arteries throughout the ship, these cableways are heavily insulated with polyvinyl chloride, a highly flammable material which, when ignited, produces a dense toxic smoke. At the same time, the burning cables carry the fire from one compartment to another.

In their Fire-Fighting and Survivability Laboratory, Center engineers have initiated several methods to overcome this potentially fatal situation.

As an immediate remedy, a fire-retardant, clay-like compound was used to caulk the holes in the compartment bulkheads through which cables passed. This caulking prevents the spread of fire. In a subsequent study, several fire-retardant mastic coatings were prepared for test in the fire chamber. Cables were painted with the various mastics, then run up the bulkhead and across the overhead of the chamber to simulate shipboard conditions. The set-up was then subjected to fire from hexane, a relatively clean burning fuel, for approximately ten minutes at temperatures up to 815° C. Following a cooling period, the cables were examined and determination was made as to which material had best withstood the test. This material was then applied to protect long cable runs.

In addition to the mastic-type coatings, Center engineers recommended that cables be wrapped with an aluminum/silicon oxide insulation. The material which covered the cables was secured by steel mesh; the set-up was fired by the hexane flame (Figure 1). At the conclusion of the test, the thermal insulation was removed and the cables were examined. No perceptible damage was noted; the thermal insulation proved to be a most effective protection. Research is presently underway to determine proper installation procedures as well as the possibility of spraying the aluminum/silicon oxide material onto cables.

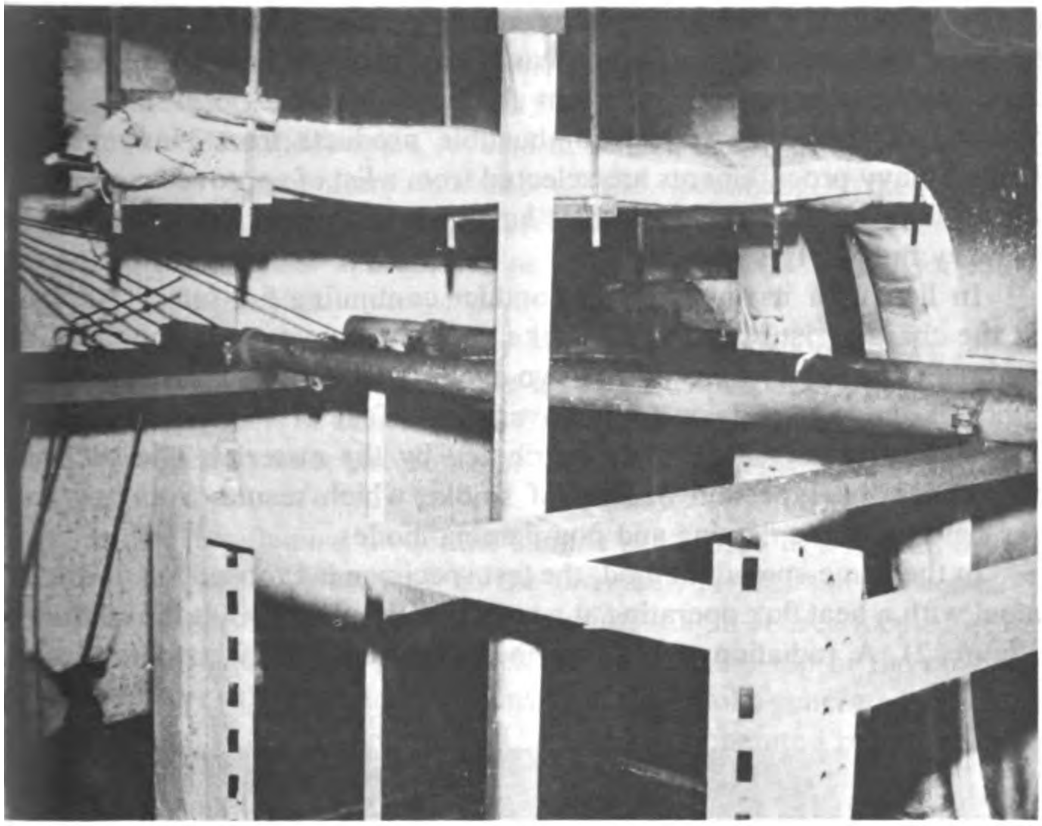

Figure 1 – Cableways wrapped with aluminum/silicon oxide insulation are ready to be fired by hexane.

As a follow-on to determine the suitability of insulation and mastic coating materials, additional investigations are underway to ascertain the degree of deterioration to which the insulation and mastic coatings are subject. Covered samples of cable are placed in a high-heat, high-humidity chamber and exposed to temperatures of 93° C and to 95% humidity for approximately three weeks. At the conclusion of this period, the cable coatings are examined for deterioration by softening, drying out and cracking, or loss of adhesion. Covered cables are also placed in a salt-spray cabinet to measure the extent of deterioration under constant exposure to seawater.

Habitability

Habitability is an all-encompassing term to describe housekeeping amenities which make for a more comfortable living atmosphere aboard ship. Among these items are carpeting, carpet padding, privacy curtains, mattresses, upholstered furniture, vinyl title deck coverings, wallboard, insulating materials, and bulkhead and overhead sheathing. Such items are comfort producing, but what about their fire-safety aspects? Could a crew survive a major fire in surroundings such as these? It is doubtful for most of these materials ignite easily and produce heavy volumes of toxic smoke. The severity of recent shipboard fires has necessitated the removal of these hazardous, combustible products from Navy ships. Today, Navy procurements are selected from a list of approved materials whose fire retardant characteristics have met the stringent requirements of Navy fire-safety standards.

In line with its mandate to conduct continuing fire-safety studies on the characteristics of flame, smoke, and noxious gases in habitability materials, the Center has utilized two experimental procedures. The first indicates the rate of flame spread over the surface of a specific material as well as the degree of heat contributed by the material. The second determines the type and density of smoke which results from testing the material in the flaming and non-flaming modes.

In the flame-spread method, the test specimen is exposed to a radiant panel with a heat flux operating at a temperature of 670° C at the surface (Figure 2). A radiation pyrometer measures the energy output of the

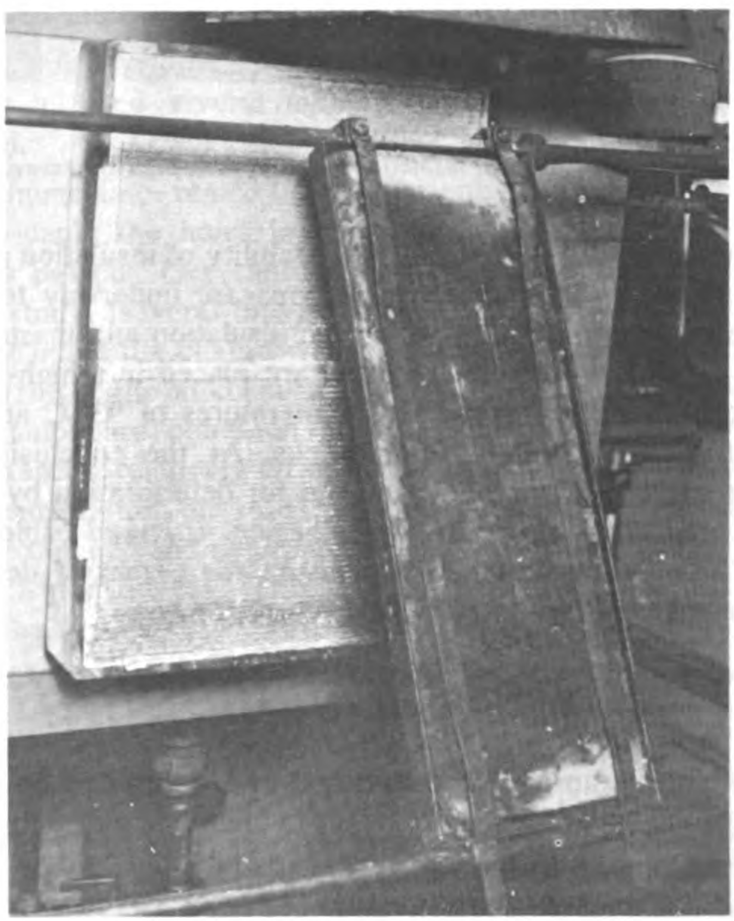

Figure 2 – Radiant panel test setup for evaluating habitability materials.

panel. A pilot igniter, fed by an air-acetylene mixture, initiates flaming at the upper edge of the specimen. The progress of the flame as it travels down the surface of the specimen is timed by a digital clock at three-inch increments. Thermocouples, located in a stack above the test specimen, measure the temperature increase of the specimen. A flame-spread index, derived from the flame-spread factor and the heat evolution factor, is established and applied as a measurement standard for rating habitability materials.

Center scientists also employ both flaming and non-flaming modes in a smoke chamber to analyze the levels, densities, and types of smoke and toxic products of combustion. Carbon monoxide, hydrogen chloride, and hydrogen cyanide are some of the more lethal gases to be found in smoke.

In the non-flaming mode, the sample is exposed to a radiant source of heat flux at 2.5 watts/cm² in the chamber. As the sample begins to smolder, it gives off smoke which obscures a light source located at the bottom of the chamber. A photoelectric cell in the top of the chamber then measures the rate and the density of the smoke generated. The rate is plotted on a graph (Figure 3). Using a hand-operated pump which is

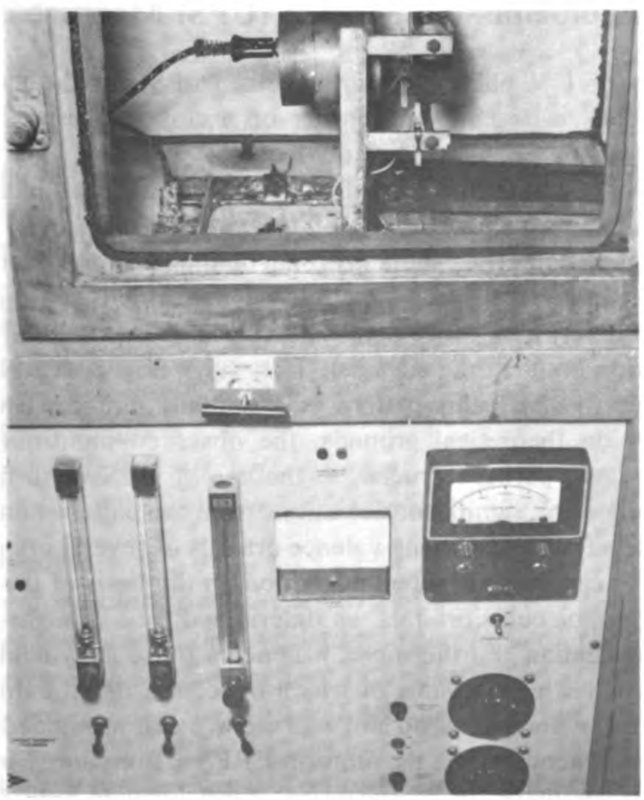

Figure 3 – Smoke chamber for evaluating smoke density and products of combustion in habitability materials.

manipulated the same number of times for each tube, the scientist draws smoke specimens from the chamber into chemical detector tubes for discrete identification of toxic gases and to quantify the amounts. Discoloration of the tube indicates that a particular gas is present in the smoke in so many parts per million.

Propane gas jets ignite the base of the sample to initiate the flaming mode. Levels and densities of smoke and identification of specific toxic gases are determined in a manner identical to the procedures for the non-flaming mode.

The fire-fighting and survivability technology developed at the David W. Taylor Naval Ship Research and Development Center have culminated in the establishment of reliable, fire-safety standards which can be applied to the civilian sector. In this program the Center's main purpose is the successful assurance that standards which they have developed will save lives and promote the safety of all who serve in the U.S. Navy.

UV Photoemission Spectra (UPS) Measurements

The utility of UV photoemission spectra (UPS) for the study of surface chemistry depends in significant measure on a close correspondence between gas phase and adsorbed phase spectra features. Previous UV photoemission measurements by Demuth and Rubloff at IBM, have shown that extramolecular relaxation/polarization shifts (ERPS) of the valence molecular orbitals of adsorbed organic molecules (i.e., shifts in orbital binding energies from free molecule values) are essentially the same for all adsorbate orbitals of a given molecule/surface system (except for those high-lying orbitals directly involved in forming the chemisorption bond to the surface). They have now collected much experimental evidence to verify this pattern of essentially uniform ERPS. Although not understood on theoretical grounds, the observed uniformity of ERPS is very important, and perhaps crucial, to the use of UPS in surface chemistry. Also, they report some significant deviations from the pattern of uniform ERPS, which occur for a few deeper-lying valence orbitals of several organic molecules. These anomalies can, however, be understood on the basis of the atomic orbital character of the molecular orbitals, as determined by a straight-forward molecular orbital calculation. Furthermore, it appears that such calculations make it possible to predict which orbitals of which molecules might exhibit anomalous ERPS. Thus, these anomalies do not represent a serious impediment to UPS studies of surface chemistry via the uniform-ERPS assumption. Finally, the interpretation of an anomaly for chemisorbed formaldehyde (H_2CO) appears to resolve a long-standing controversy between theory and experiment regarding the ordering of orbitals in the free molecule.

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Air Ions may Affect Health

Unstable air particles called ions affect the health and life processes of microbes, animals, and most likely humans, according to a report on long-term findings compiled by two scientists at the University of California in Berkeley. Research in the field, in progress for several decades, has often been greeted by skepticism.

The researchers claim that an accumulation of new findings from around the world builds a strong case for taking a second look at the particles called air ions. The particles are created when common atmospheric gases either lose or gain one or more electrons through natural causes. Life functions best when it has access to plenty of negative air ions, according to the scientists. Conditions that mimic clean, country air and have over 4,000 ions per cubic centimeter are ideal, they say.

Air pollutants quickly remove these ions from the atmosphere, which is yet another reason for trying to reverse pollution. Since research also indicates that ion depletion affects one's overall alertness, the scientists also suggest that it may be time to install ion generators in living and work areas. The ion levels could be adjusted just as temperature and humidity levels are regulated now.

The report was published in *Science*, the journal of the American Association for the Advancement of Science. Authors are Dr. Albert P. Krueger, emeritus professor of bacteriology and lecturer in medicine, and Eddie J. Reed, research associate, both with University of California's School of Public Health. This work has been supported for many years by The Office of Naval Research.

For the past 20 years, they have followed the research in the field and conducted numerous studies of their own to determine the effects of air ions and its deprivation on all forms of life. Their concern stems from evidence, for example, that mice kept in a de-ionized area are twice as susceptible to influenza as normal mice.

Negatively charged ions have been linked to retarded growth and increased death rates for bacteria and virus particles, including those that cause cholera, diarrhea, and boils.

Through basic research, the scientists made a major contribution when it showed that air ion levels influence the amount of serotonin, a versatile and powerful hormone in animals and humans. The hormone helps transmit nervous impulses and plays an important role in wound healing and such basic patterns of life as sleep and mood, including anxiety levels.

The scientists found that high concentrations of positive ions raise the blood levels of the hormone, while high concentrations of negative ions have the opposite effect. They also found that the level of serotonin in the brain fluctuated with the concentrations of ions in the air.

The work was based on analyses on over 12,000 brain and 36,000 blood samples from normal and ion-treated mice.

Israeli scientists later used the information to help explain why some "weather sensitive" people become ill before storms like the notorious "mistral" of France, the "sharav" of Israel, the "sirocco" of northern Africa, the "foehn" of Bavaria, and the "Santa Ana" of California. Some 24 to 48 hours before these dry air storms hit, the scientists recorded a significant increase in the positive air ions and a parallel increase in serotonin. The result was migraines, nausea, vomiting, irritability, and swelling and congestion of the respiratory tract for as many as 30 per cent of the population.

Investigators in many parts of the world have conducted experiments with air ions under rigorously controlled test conditions and have demonstrated measurable changes in living forms clearly related to the ion content of the air.

Unique Millimeter Communications Antenna

A team of electronic researchers at the Naval Research Laboratory (NRL) has developed and tested a special millimeter wave antenna that will greatly reduce extraneous signal radiation levels outside the main-beam region of secure communication systems.

Such an antenna could greatly reduce present day problems of communication intercept and minimize the likelihood of transmitter detection and location. The new antenna may be used at ground stations or aboard ships.

The antenna, which has a low sidelobe configuration and is highly directional, may also be used to enhance the capability of microwave-relay systems. Such systems are presently handicapped by interference between separate antennas in the relay chain. NRL's new antenna would alleviate this problem by diminishing radiation outside the main beam region.

The new antenna has a parabolic reflector, offset fed with an internally corrugated conical horn. The low sidelobe performance of the antenna is enhanced by a shield which encloses the space between the feed horn and reflector, and terminates in a cylindrical tunnel surrounding the antenna aperture. It is the combination of corrugated horn and shield that drastically reduces spillover radiation that is normally encountered in offset reflector systems

Correction for the September Issue

The article "NORPAX and the Upper Ocean" appeared in the September issue of *Naval Research Reviews* with one byline for Klaus Wyrtki. Two other authors should have been listed along with Wyrtki: Warren B. White and Robert L. Bernstein of Scripps Institution of Oceanography. The Editor apologizes to these gentlemen for this mistake.

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Cover Caption

The destroyer USS Rogers (DD-876) aids crewman of the nuclear powered attack aircraft carrier U.S.S. Enterprise (CVAN−65) as they fight a fire on the after flight deck. *See page 22.*

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