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AEROSPACE LIFE SUPPORT SYSTEMS AND CREW PROTECTIVE EQUIPMENT

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AEROSPACE LIFE SUPPORT SYSTEMS AND CREW PROTECTIVE EQUIPMENT

ATD Work Assignment # 22

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FOREWORD

This report is prepared in response to the first two parts of Work Assignment No. 22 requirements: "Spacecraft Life Support Systems" and "Aircrew Protective Equipment." The third part of these requirements, "Aircraft Mechanical Subsystems" will be published as a separate report.

INTRODUCTION

The first part of this report, dealing with high-altitude crew protection, is based almost entirely on a detailed review of selected portions of a monograph by S. P. Umanskiy entitled, *Pilot and Cosmonaut Equipment*. It contains a section on flight clothing suitable for various seasons of the year, gloves and foot gear, helmet liners, ventilated suits, anti-G suits, and survival equipment (sea survival gear, survival suits, life jackets, life rafts, and an emergency survival pack). Special attention is called to the notes revising or supplementing ATD Report No. 66-67 which call special attention to changes in Umanskiy's present book from his previously published material. In addition, the first part of this report contains a brief glossary of abbreviations used in Soviet aircrew equipment designations and a brief commentary on the *Handbook on Astronautics* by N. Ya. Kondrat'yev and V. A. Odintsov.

The second part of this report contains 30 abstracts related to spacecraft life-support systems. They deal largely with recent developments in Soviet *Chlorella* research which are directly applicable to the use of *Chlorella* for regeneration of spacecraft cabin air and to the possible use of algae as a source of food for cosmonauts on extended spaceflights. These developments deserve comment. The reader should note that the reference numbers in the commentary refer to a bibliographic entry accompanied by an abstract in the last section of this report.

PART I. AIRCREW PROTECTIVE EQUIPMENT

SOURCE: Umanskiy, S. P. Snaryazheniye letchika i kosmonavta (Pilot and cosmonaut equipment). Moscow, Voyennoye Izd-vo MO SSSR, 1967. 192 p. 10,000 copies printed

This book is primarily intended for DOSAAF members, military and civil aviators, and students of aviation. It contains information on high-altitude equipment for aircrew protection currently in use or under development in the Soviet Union. Much of the material in this book has already been published in two chapters of an earlier book by the same author [Umanskiy, S. P., Bar'yer vynoslivosti letchika (The pilot endurance barrier), Moscow, Mashinostroyeniye, 1964, Chapters 4 and 5] and has been reported in ATD Report No. 66-67, 9 June 1966, "Soviet High-Altitude Equipment for Aircrew Protection", pages 1-44. These two chapters were the only portion of the earlier book containing information on protective equipment, the other chapters being given to a detailed discussion of the various flight factors and stresses which protective equipment is designed to counteract (e.g., acceleration, vibration, stresses during ejection, etc.).

In the present book, Ch. 1 covers various kinds of protective clothing: flight suits, footgear and gloves, ventilated suits, equipment and clothing for aircrews forced to abandon ship over bodies of water, a sea survival suit, and general survival equipment. Since all this material is new and has not been reported before, this chapter has been abstracted in full.

On the other hand, Ch. 2 and 3 of the present book consist almost entirely of matter already reported from the earlier book. The material has been re-arranged and a few minor changes made, but even the wording of the earlier book is for the most part unaltered. To avoid useless and expensive reduplication of the earlier ATD Report, a page number guide has been prepared showing the location in that report (ATD Report No. 66-67) of all the information in the new book. Where the new book corrects or modifies information in ATD Report No. 66-67, a note is made to that effect. Where the new book presents material not included in ATD Report No. 66-67, an abstract of the new information is given, with an indication of where it belongs in the ATD Report.

Ch. 4 of the present book, on space crew equipment, is based entirely on U.S. materials and contains no information on Soviet equipment at all. Accordingly, no attempt has been made to summarize this chapter for inclusion in this report.

Chapter 1. Protective Clothing for Fliers

Flight Clothing

Various types of flight clothing are issued to Soviet flight personnel depending on their duties, their location, and the season of the year. Standard issue items include the following:

- Fleece-lined flight suit with fabric shell
- Reversed sheepskin flight suit
- Medium weight (Fall--Spring) flight suit
- Summer flight suit
- Leather windbreaker
- Fur vest
- Woolen sweater
- Woolen or synthetic underwear
- Leather knee boots (fur-lined)
- Fur leggings ("unty")
- Pressure books (altitude-compensating boots)
- Leather helmet with headset (fur-lined for winter wear)
- Rubber shoepacks (for use with fur leggings)
- Lightweight summer headset helmet (leather or net)
- Cotton headcover
- Fur-lined leather gloves
- Unlined leather gloves
- Fur-lined mittens
- Woolen socks, cushion knit
- Woolen socks, plain

Winter, summer, and intermediate season issues of the above-listed basic equipment are as follows:

<u>Winter Issue</u>

- Fleece-lined flight suit with fabric shell (or sheepskin suit)
- Fur vest (for Arctic flights)
- Woolen sweater
- Woolen underwear
- Fur leggings with shoepacks (or fur-lined knee boots)
- Winter leather headset helmet
- Cotton head cover
- Fur gloves
- Double knit woolen (or fur) socks

Intermediate (Fall--Spring) Issue

- Medium-weight flight suit
- Leather windbreaker
- Woolen sweater
- Synthetic fiber underwear
- Pressure boots
- Cotton head cover
- Leather gloves
- Woolen socks

Lightweight Summer Issue

- Summer flight suit
- Synthetic fiber underwear
- Pressure boots
- Lightweight summer headset
- Cotton head cover

DESCRIPTIONS OF FLIGHT CLOTHING

Flight Suits

The winter flight suit (Fig. 1) consists of a sheepskin suit (jacket and trousers) with a cotton fabric shell. This suit has several advantages over the winter coverall used previously (Fig. 2). Elimination of one-piece construction makes it easier to don and doff, and permits use of either jacket or trousers alone.

The jacket has two breast pockets for pistol, spare magazines, and emergency radio set, and two "muff" pockets at the sides. The lower edge of the jacket is belted around the body. The trousers run up under the jacket for 30--40 cm, to prevent drafts.

The winter flight suit may be worn directly over the underwear, or a woolen sweater may be worn under the jacket. Special protective equipment (altitude compensating suit, G-suit, etc.) is worn under the winter flight suit with the connecting hoses led out over the trouser waistband and under the jacket. These suits are expected to last 5 years.

Fig. 1. Winter flight suit. (Sheepskin with fabric shell)

Fig. 2. Winter flight suit coverall. (Cotton fabric shell filled with cotton wool)

The reverse sheepskin flight suit (Fig. 3) is equivalent to the winter flight suit just described. Omission of the fabric shell saves some weight. The sheepskin is specially tanned to make it more resistant to temperature fluctuations. Efforts to develop an electrically heated flight suit have been abandoned for the present due to the fragility of the heating wires which must be buried in the fabric and the danger of fire.

The medium-weight (fall and spring) flight suit (Fig. 4) also consists of a jacket and trousers of strong cotton fabric. Insulation is provided by a 50% wool "vatin" lining. The jacket of the medium-weight suit, like that of the winter suits described above, is fastened by a zipper and has 4 pockets. The sleeves end in knitted woolen cuffs. The trousers (Fig. 5) consist of a bib-type coverall with an old-fashioned drop seat. The breeches carry side pockets at the seams, external

Fig. 3. Winter flight suit. (Reversed sheepskin)

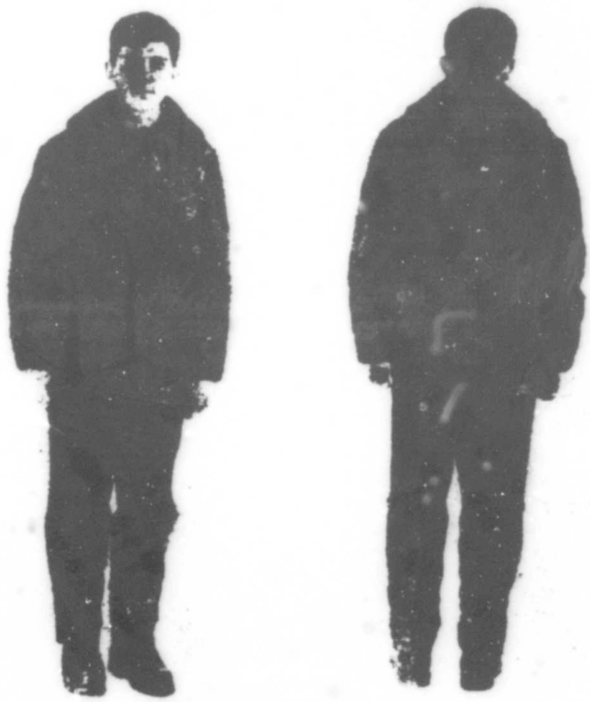


Fig. 4. Medium-weight (Fall--Spring flight suit. (Outer shell of dark blue cotton fabric, satin lined, with 50% wool felt filling)

pockets over each knee, and a knife pocket on the right leg below the knee. An opening is provided for pressure suit couplings. The medium-weight suit is worn over the underwear and wool sweater. A special sweater is issued for wear with the pressurized suit with sealed helmet. The medium-weight suit can also be worn with the kid leather windbreaker, which has a removable 50% wool knitted lining. The medium-weight flight suit is expected to wear for 4 years.

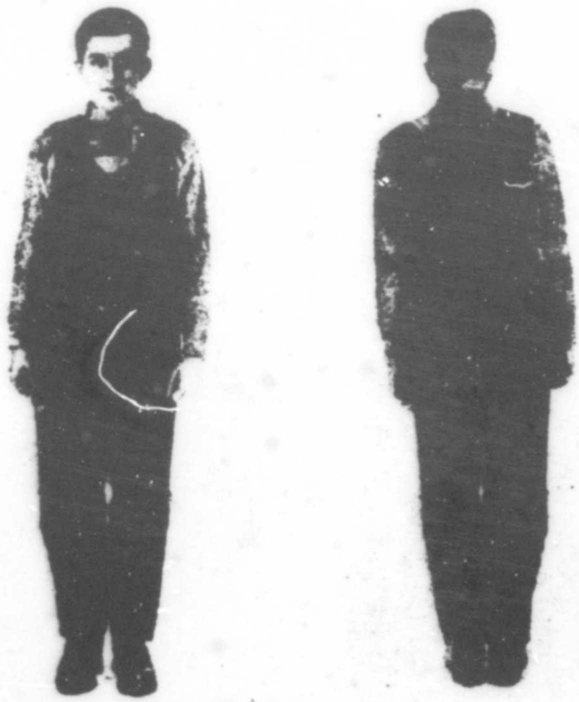


Fig. 5. Trousers of medium-weight suit.

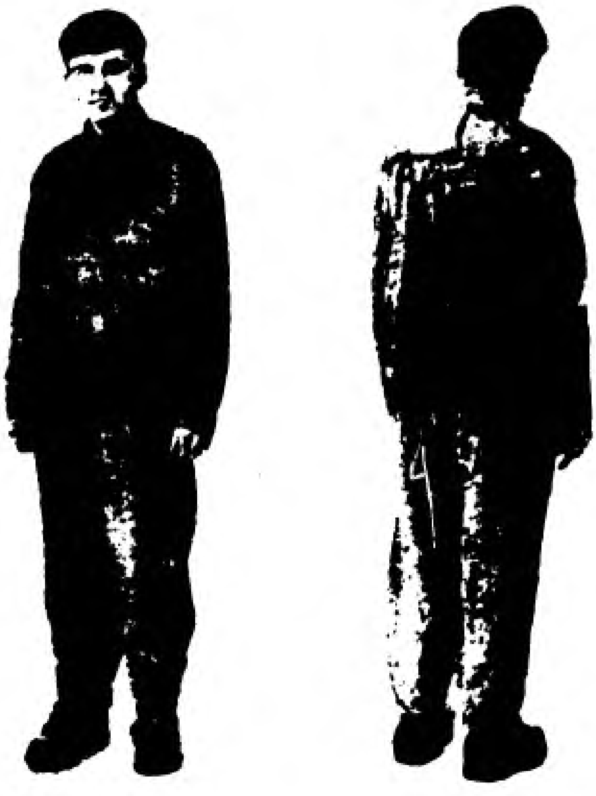


Fig. 6. Summer flight suit
(Khaki colored cotton cloth)

The summer flight suit (Fig. 6) is also worn directly over the underwear, or over the altitude-compensating pressure suit or G-suit if these are worn. Consisting of zipper jacket and trousers, the summer flight suit is made of cotton cloth. The trousers are made with suspenders so that no belt is needed. The inside waistband of the trousers has vents for air circulation. An opening is provided for a pressure suit hose along the left trouser seam. Combined with underwear and an altitude suit, the summer flight suit will enable an ejected pilot to withstand an air temperature of -50°C and a wind blast of 6--8 m/sec for up to 10 min, sufficient for parachute descent. The summer flight suit is expected to wear for 2 years.

The weight characteristics of the flight clothing described above are as follows:

<u>Winter Issue</u>

Sheepskin coverall with fabric shell	5.5 kg
Sheepskin flight suit with fabric shell	
Jacket	2.6 kg
Trousers	2.2 kg
Reversed sheepskin flight suit	
Jacket	2.2 kg
Trousers	1.8 kg

Thermal insulating suit (caprone fabric shell, caprone fiber lining)	
Jacket	2.0 kg
Trousers	1.6 kg

Fall--Spring Issue

Medium-weight flight suit	
Jacket	1.6 kg
Trousers	2.0 kg
Leather windbreaker	1.8 kg

Summer Issue

Summer flight suit	
Jacket	0.8 kg
Trousers	0.9 kg

Footgear and Gloves

Soviets fliers may be equipped with "unty" (shoepacks with fur leggings attached), fur-lined leather knee boots, or altitude-compensating flight boots (for use with altitude suits).

Fig. 7. Fur unty (Double layer of dog fur)

"Unty" (Fig. 7) have the best thermoinsulation characteristics (2.5--3 clo) of all types of footgear*. They consist of knee-length leggings made of two layers of dog fur, combined with shoepacks (felt-lined leather uppers and heavy felt soles). The upper ends of the leggings wrap around the calves outside the trousers and are held in place by tapes which tie around the leg.

Fur-lined leather knee boots (Fig. 8) have several advantages over "unty": they are lighter, less bulky, and less susceptible to wetting. Knee boots are made of cowhide, horsehide, or pigskin leather, the legs lined with dog fur and the last with sheepskin. These boots open and close with a zipper.

* "Unty" is the plural of "unta", a word of non-Slavic origin borrowed from dwellers in the Soviet Arctic, like our "mukluks". "Clo" is a unit of thermal insulation defined in Burton, A. C., and O. G. Edholm, Man in a cold environment, London, Edward Arnold Ltd., 1955, 34-36.

Fig. 8. Fur-lined leather knee boots.

Fig. 9. Altitude compensating boots.

Altitude-compensating boots (Fig. 9) with crepe rubber soles have laces for size adjustment as well as zippers for putting them on or taking them off. The rubber soles have good thermoinsulating properties and wear much better than leather.

The double-knit cushion sole socks (cotton and wool) worn with the above footgear are expected to last 2 years.

Gloves are cut and sewn with the fingers semiflexed, for better thermoinsulation and greater freedom of movement. Mittens with two layers of fur (the inner lambskin, the outer calf with the hair left on) and long gauntlets are used to keep the hands and arms warm. The palms are made of chamois leather or kid or other soft leather. The mittens are cut with the index finger separate. They weigh about 800 g.

Fur-lined leather flight gloves are made of natural kid with lambskin linings.

Woolen gloves are knitted of 100% wool or 45% wool yarn.

The characteristics of the footgear described above are as follows:

Description	Weight per pair, kg	Thermoinsulating characteristics m^2.hr.deg.$kcal^{-1}$	clo units
Boots, chrome-tanned, leather sole (with cotton lining)	0.86	0.22-0.24	1.22-1.34
Knee boots, leather, fur-lined	2.7	0.32	1.78
Knee boots, leather (leather sole)	1.9	0.24	1.3
"Unty" with double layer of fur, felt soles (25 mm thick)	3.0	0.45--0.54	2.5--3.0
Valenki (pile-felt boots) with rubber overshoes	2.2	0.29	1.6
Valenki without rubber overshoes	1.4	0.27	1.5
Ordinary valenki (plain felt)	1.6	0.32	1.8
Altitude-compensating flight boots	1.6	0.24	1.34
Altitude-compensating flight boots with cushion sole wool socks	---	0.33	1.82
Fur or sheepskin socks	10 mm*	0.3	1.67
Cushion-sole wool socks	4.2 mm	0.12	0.66
Wool socks	1.5 mm	0.04	0.22
Cotton baize socks (2 layers)	4.2 mm	0.08	0.44

* For socks the dimension given is thickness in millimeters instead of weight per pair in kilograms.

Helmet Liners

The helmet liner (Fig. 10) serves several functions. It protects the head against cold and windblast, and provides a means of anchoring other equipment such as the helmet itself (the ZSh-3), earphones and throat mike, oxygen mask, and O_2 mask strap tension regulator (see below, pp. 23 on protective helmets).

Three types of helmet liners are in use: 1) winter model, fur-lined; 2) summer model, silk-lined; and 3) lightweight, with net body. The body of the liner is normally made of soft leather, the fur lining of lambskin or sheepskin.

Earphones with a doughnut-shape "silencer" are built into the sides of the helmet liner. Voice communication by the wearer is accomplished with a microphone inside the O_2 mask or by throat mikes held against the larynx with straps. A cotton headcover is usually worn under the helmet liner.


Fig. 10. Helmet liner
1 - transverse ridge,
2 - chin strap, 3 and 5 - fasteners for mask, 4 - hose for mask tension compensator,
6 - throat microphone coupling,
7 - communication coupling.

Ventilated (Air-Conditioned) Suits

It is not possible to design any conventional type of clothing capable of protecting the wearer against extremely high or low temperatures. A solution has therefore been sought in the creation of ventilated or air-conditioned clothing inside which a favorable microclimate is maintained independently of enviromental extremes. Such suits may be ventilated with hot or cold air (10° to 80°C), depending on outside temperature. At an outside temperature of 20°--30°C, an airflow of 100--100--150 liter/min suffices to ventilate the suit. At higher (or lower) outside temperatures, the airflow required may increase to 250--300 l/min. System resistance (the "head" required to force air through the suit) is 7--15 mm Hg at 200 l/min, and varies with airflow according to the law of squares.

The ventilation suit (Figs. 11 and 12) may consist of a coverall worn over regular flight clothing or over an altitude suit, or it may consist of an airtight coverall worn under a high-altitude or sea survival suit. The first type protects the wearer from temperature extremes of +50° to -50°C. Made of tough fabric, it is closed by zippers. Entering air is carried to all parts of the suit by flexible hoses with 1-mm perforations sewn to the inner surface of the suit. In the summer time, this type of suit is worn as an outer coverall. In the winter, the warmer heavy flight clothing is worn over it.

Fig. 11. Ventilation suit (to be worn over outer clothing)

Fig. 12. Ventilation suit (to be worn under altitude or sea survival suit).

The second type of ventilated suit, to be worn under an altitude suit or sea survival suit, consists of a double-walled coverall of rubberized fabric with air circulating between the walls. The walls are held apart by foam rubber washers arranged in a checkerboard pattern (Fig. 13).

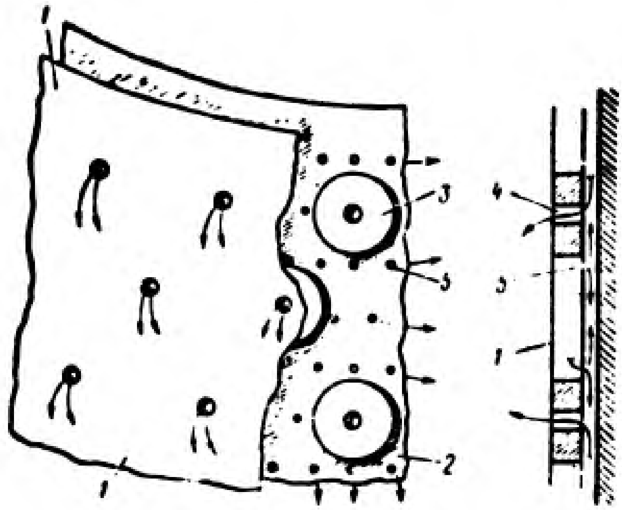


Fig. 13. Detail of ventilation suit construction.
1 - outer shell; 2 - inner shell; 3 - washer; 4 - air outlet hole; 5 - hole letting air into inner shell.

Important adjuncts to the ventilated suit are ventilated gloves and socks, which keep the hands and feet warm and dry even during increased perspiration due to tension. These socks are worn over the issue wool socks. The gloves are ordinary gloves with holes for air to exit at the fingertips and an airfeed hose at the wrist.

The fabric helmet liner (described above, p. 12) may also be ventilated to keep the head comfortable. The weight of ventilated clothing is 3.2 kg (suit, 2 kg; socks, 0.4 kg; gloves, 0.3 kg; helmet liner, 0.5 kg).

SURVIVAL EQUIPMENT

Individual Ocean Survival Gear

Thermal insulation is the main problem in protecting a man in the water, which conducts heat away from the body 27 times as fast as air at any given temperature. Standard ocean survival kits used in most countries include: 1) a sea survival suit, 2) a flier's life jacket (Mae West), 3) an inflatable raft or boat, and 4) an emergency survival pack containing rations and special equipment.

Sea Survival Suit

The Soviet sea survival suit (Fig. 14) consists of a waterproof outer shell or coverall which is worn over a special thermal protective suit, described below, and a ventilation suit (second type), together with appropriate footgear, gloves, underwear, and socks.

The sea survival suit can protect a man for many hours in water at 0°C with winds of force 5 (Beaufort scale) or higher. During non-emergency in-flight wear the suit must be continuously ventilated, and so is normally worn only on an aircraft or at airfields where compressed air for ventilation heating or cooling is available. Ventilation requires an airflow of 50 to 300 l/min.

The waterproof shell is made of tough rubberized fabric. The neck and wrist openings are sealed against water by elastic cuffs and collar. The front of the suit (which opens for donning and doffing) is sealed by an "appendix", an extra fold of waterproof material attached at both sides of the opening which is rolled and tied inside the buttondown flap at the front when the suit is being worn (Fig. 15).

Ventilation is regulated by adjustable valves which control the escape of air from the suit.

The legs of the shell end in rings designed to mate with waterproof boots, or in one-piece waterproof socks.

Fig. 14. Sea survival suit. (Note tube for inflation by mouth hanging from shoulder)

Fig. 15. "Appendix" (closure flap) of sea survival suit.

To float a man in the water right-side-up, the suit has an inflatable collar or jacket, which normally lies flat over the shoulders and which can be inflated by a tube equipped with mouthpiece and one-way valve. Figure 16 shows the suit in the water with the collar inflated.

Fig. 16. Sea survival suit in the water.

A battery-operated rescue beacon (signal light), packets of yellow-green dye, a whistle, signal flares, a pistol, and other aids to rescuers are placed in the outer pockets of the suit.

The thermal protective suit (Fig. 17) worn under the sea survival suit has a thermal resistance of at least 1.5--2 clo. It consists of a wool or porolon knit coverall.

The ventilation suit is the second type described above, and is worn under the thermal suit. Two pairs of socks are usually worn: one of light cotton, the other of wool or fur. The boots worn with the sea survival suit are zipper boots of rubberized fabric or rubber. Leather flight gloves are normally worn with the suit. Waterproof gloves or mittens are donned only after ditching; they are kept in one of the pockets of the suit.

The sea survival suit may also be worn over an altitude-compensating suit. In this case provision must be made for the air-hose and the sealed helmet of the altitude suit.

Life Jackets

There are three types of life jackets currently in use. The ASZh-58 (Fig. 18) is for military fliers; the ASZh-60 and ASZh-63P (Fig. 19) are for passengers and crew on civilian aircraft. Life jackets are made of bright orange rubberized fabric and have both a CO_2 cartridge for automatic inflation and a hose with mouthpiece.

Pockets of the jacket contain a signal light (rescue beacon); some models are equipped with a miniaturized 2-way battery radio with antenna. The jacket provides a positive buoyancy of 10--20 kg, well over the 5--7 kg required to hold a man's head out of the water. Inflated, the jacket occupies a volume of 15 liters and weighs no more than 2 kg.

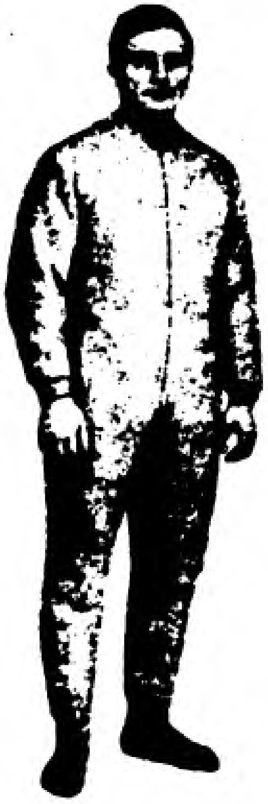


Fig. 18. ASZh-58 life jacket.
1 - CO_2 cartridge; 2 - deflation valve; 3 - mouthpiece; 4 - lifting strap; 5 - belt buckle; 6 - size adjustment; 7 - flat anchoring fitting strap; 8 - packet of fluorescein dye.

Fig. 17. Thermal suit.

Fig. 19. ASZh-60 life jacket. 1 - signal light (beacon); 2 - mouthpiece; 3 - whistle; 4 - CO_2 cartridge; 5 - deflation valve.

Fig. 20. One man inflatable raft. 1 - CO_2 tank for inflation; 2 - mooring tab; 3 - anchor rope; 4 - ballast sack; 5 - gun-whale handgrips; 6 - hand bellows; 7 - packet of emergency repair patches.

Fig. 21. Emergency survival pack showing attachment to parachute harness.

Life Raft

The MLAS-1 life raft (Fig. 20) is made of tough rubberized fabric and inflated either by CO_2 cartridge or by mouth. For greater reliability, the air space is divided into compartments. The raft has a positive buoyancy of 100--150 kg and is seaworthy in winds up to force 5. It is provided with a canopy for shelter from sun or rain. Total weight of the raft with CO_2 tank is 3.5--5 kg; its dimensions when inflated are 1.9 x 0.92 x 0.27 m.

Emergency Survival Pack

The NAZ emergency survival pack for fighter pilots weighs 10--15 kg; that for fliers on heavier aircraft weighs 25 kg. It contains rations sufficient for 3--5 days, rescue signal equipment, a radio set, clothing, fishing tackle, and other survival gear. The pack is worn attached to the parachute harness (Fig. 21).

Depending on the area to be overflown, the pack may contain various kinds of special equipment, such as the life raft described above, folding skis for polar flights, drinking water for desert conditions, etc.

Chapter 2. G-Loads and Anti-G Equipment

The chapter opens with a summary of Newton's Second Law and its implications for the crews of aircraft and spacecraft, which occupies pages 54-58. The second and third sections of the chapter, on anti-G suits and protective helmets, occupy pages 58-67 and 67-69, respectively. Page numbers may be cross-referenced as follows:

Present book	ATD Report 66-67
58	1-2, 3
59	3
60-61	4
62	4,5
63-64	6,7
64-67	(new material, see below)
67	42-43
68-70	43
70	8-9
71	9
72-74	10-12
74-79	(new material, see below)

Notes Revising or Supplementing ATD Report No. 66-67.
(page numbers refer to ATD Report)

Page 3, para. 3, line 9: For "It has been estimated...." read "It has been shown by tests that G-suits and pressure suits increase the resistance of the organism to head-pelvis accelerations by 1.5 to 2 G. Tests have also shown that...." (present book, p. 59).

Page 4, add at the end of page: "Tests of the effectiveness of bladders placed over various parts of the body have shown that if pressure is increased only in the knee and thigh bladders, acceleration tolerance increases by 0.3 G, while if only the abdominal bladder is inflated, tolerance increases by 0.6 G" (present book, p. 62).

Page 5, para. 1, line 6: Read: "The suits are made in 6 basic sizes to fit all crew members." (present book, p. 61).

Page 5, para. 4: Read: "The efficiency of a G-suit depends to a considerable degree on correct fit. The suit must fit snugly but prior to inflation must not cause discomfort or hamper respiration or movement.

"The suit is worn over ordinary flight clothing, outside the trousers. The girdle part is covered by the flight jacket or blouse. Winter clothing, including "unty" and fur boots, are worn over the suit. Wearing the anti-G suit over quilted clothing reduces its effectiveness, since the pressure characteristics are thereby drastically changed.

"The suit weighs 1.5--2 kg." (present book, p. 62-63).

Page 5, add after para. 4:

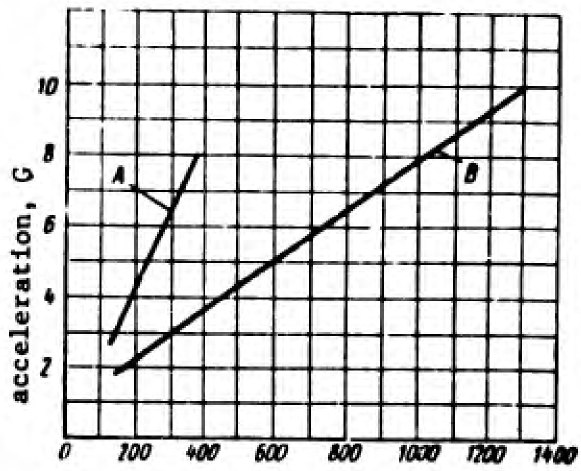


Fig. 22. Excess pressure in the bladders of anti-G and pressure suits as a function of acceleration. A - for a G-suit with multiple bladders; B - for a pressure suit with constricting mechanism.

Pages 5-6, full description of automatic pressure regulator.

The system for supplying air to the bladders of G-suits and pressure suits consists of an automatic pressure regulator, filter, detachable hose coupling, and other accessories. On turbojets the air for filling the suit bladders is obtained directly from the engine compressor.

The main component of the automatic pressure regulator is a two-stage throttle (see Fig.23). When the pressure regulator is set for the first ("low") regime, the sliding weight 4 is locked in place. The valve stem is depressed by weight 3, which is counterpoised by spring 11. When there are no G-forces, spring 11 is just strong enough to keep the inlet channel 7 closed by valve slide 5 and air cannot enter the suit bladders.

As soon as G-forces exceeding 2.5 G are created, inertial force causes the weight and valve slide to compress spring 11 and move downward. This aligns the channel in the valve slide with the inlet channel, permitting air to pass through the valve into the G-suit hose. Part of the air passes through the aperture in the neck of the valve slide into the lower chamber D, creating counterpressure tending to raise the slide and close the valve. These counterpoised forces create an equilibrium state which varies with the magnitude of the G-forces acting on the regulator. When the G-forces cease to exist, valve slide 5 returns to the upper (closed) position where it is aligned with the outlet channel, venting the suit.

When the pressure regulator is set for the second ("high") regime, sliding weight 4 is released to add its weight to that of weight 3. This causes the valve slide to respond to a given G-force with greater air pressure. Lag in valve response must not exceed 0.5 sec. The automatic pressure regular must be carefully installed in a vertical position on the aircraft.

The air filter cleans the air entering the suit of impurities likely to damage the valve or suit, such as dust kicked up by the engine on takeoff or oil droplet and gasoline combustion products. The filter consists of a housing, removable canister, paper filter, and coil spring. The filter paper is corrugated, which increases its effective area and rigidity. Dirty air enters the space between the canister wall and the filter paper, which removes solid particles and droplets.

A plug-type hose coupling is used to connect the suit hose to the pressure regulator. A hard pull of at least 7-10 kg is required to disconnect the hose coupling, to prevent accidental disconnection in flight.

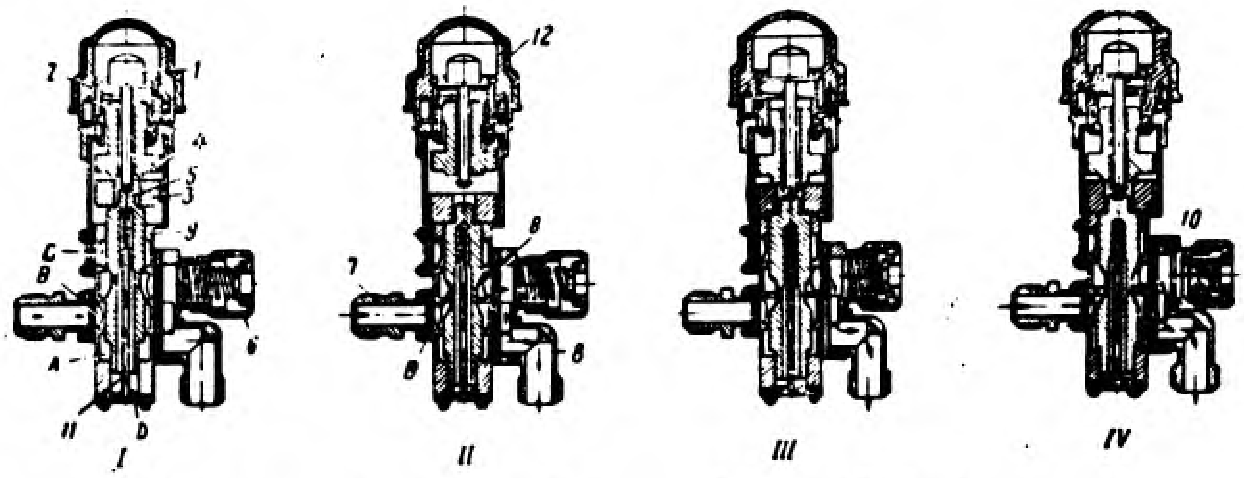


Fig. 23. Operating regime of automatic pressure regulator. I - G-force less than 2.5 G, "low" pressure setting; II - G-force greater than 2.5 G, "low" pressure setting; III - G-force greater than 2 G, "high" pressure setting; IV - G-force greater than 10 G, "high" pressure setting.
1 - manual suit inflation button; 2 - safety valve; 3, 4 - weights; 5 - valve slide; 6 - vent regulator; 7 - inlet channel; 8 - outlet connector (to suit hose); 9 - housing; 10 - vent valve; 11 - spring; 12 - soft rubber dome; A, B, C, D - chambers.

Pages 8-12, material supplementing information given in ATD Report No. 66-67 on protective helmets. The ZSh-1 helmet consists of a white textolite shell (made in 2 sizes to fit head sizes 51-58 and 58-60), suspension system, visor, noise baffles, earphones, oxygen mask strap tension regulator, and chin strap. The helmet shell has two slots cut in the crown to relieve inside air pressure from windblast during ejection. The ZSh-1 helmet is fully illustrated and described (but without being specifically identified) in Umanskiy's earlier book and in ATD Report No. 66-67, pp. 10-12. The ZSh-1 is worn with the KM-30M oxygen mask (ceiling 18 km, maximum ejection speed 800 km/hr). The ZSh-1 weighs 1.8 kg.

A later type, the ZSh-3, is the helmet with aluminum shell and shock-absorbent foam rubber or felt lining (in place of suspension harness) described in ATD Report No. 66-67, pp. 12-13. It is worn with the KM-32 oxygen mask and permits a maximum ejection speed of 900--1000 km/hr. The ZSh-3 weighs 2.1 kg (helmet and visor, 1 kg; helmet liner headset, 0.55 kg; and KM-32 oxygen mask, 0.55 kg).

SOURCE: Umanskiy, S. P. Snaryazheniye letchika i kosmonavta (Pilot and cosmonaut equipment). Moscow, Voyennoye izd-vo MO SSSR, 1967.

BRIEF GLOSSARY OF ABBREVIATIONS USED IN SOVIET AIRCREW EQUIPMENT DESIGNATIONS

AD	automatic pressure regulator (for G-suit)
ASZh	life jacket
BVS	maskless ventilation suit (see also MVS)
DEMSh	built-in oxygen mask microphone
FK	restraint suit
IK	oxygen indicator
KAB	aircraft oxygen and compressed air system
KKO	oxygen equipment set
KM	oxygen mask
KP	oxygen supply,oxygen device
KPZh	LOX equipment
KR	oxygen reduction valve
M-1000	manometer
MLAS	life raft
MSK	(see SKN-3) ocean survival suit, sea survival suit
MVS	mask-type ventilation suit
NAZ	survival equipment pack
ORK	umbilicus, suit line
PKP	parachute oxyten equipment
PPK	G-suit, anti-acceleration suit
RD	pressure regulator
RSD	oxygen ratio regulator, mixer
ShL	helmet-liner headset, summer
ShZ	helmet-liner headset, winter
SKN	inflatable sea survival suit
TK	thermal protective suit
VK	ventilation suit, air-conditioned suit
VKK	altitude-compensating suit, pressure suit
VMSK	high-altitude sea-survival suit (altitude-compensating suit with sea survival suit)
ZSh	protective helmet, hard hat, crash helmet

SOURCE: Kondrat'yev, N. Ya., and V. A. Odintsov, eds. Spravochnik po kosmonavtike (Handbook on astronautics). Moscow. Voyennoye Izd-vo MO SSSR, 1966. 325 p. 15,000 copies printed.

The book contains the basic principles of spaceflight and interplanetary navigation. Much attention is given to trajectories, and to the characteristics of rocket engines and space objects. Information on planets which may be habitable by man and on the conditions of manned spaceflight is also given. The book is intended for a general audience.

The main chapter headings are as follows: Ch. 1. Structure of the Universe; Ch. 2. Physical characteristics of the upper atmosphere and circumterrestrial space; Ch. 3. Spacecraft flight dynamics; Ch. 4. Spacecraft orbits and trajectories; Ch. 5. Navigation of spacecraft; Ch. 6. Flight and attitude control; Ch. 7. Manned spaceflight; Ch. 8. Spacecraft propulsion systems; Ch. 9. Spacecraft; Ch. 10. Spacecraft applications and exploitation; Appendix of navigational tables and parameters.

The chapter on manned spaceflight (Chapter 7, pp. 208-225) contains brief sections on acceleration (p. 208)(magnitudes encountered, countermeasures); weightlessness (p. 209) (effects of autonomic functions, spatial orientation, motor coordination, and cardiovascular aftereffects during reentry and after landing); life support systems (p. 213) (general considerations); spacesuits (p. 215) (discusses and illustrates the Mercury and Apollo systems and prototype lunar suits and tractor developed by Republic Aircraft and NASA). The chapter ends with a short section on regenerative systems (pp. 221-225).

Parameters of the "Vostok-3" cabin atmosphere at launch and during flight, given at the end of the general section on life support systems (p. 215) are as follows:

Parameter	One hour before launch	In flight (range of variation)
Total pressure	760 mm Hg	755-775 mm Hg
O_2 content	21%	21%-25%
CO_2 content	0.4%	0.35%-0.50%
Relative humidity	52%	51%-57%
Temperature	25°C	26°C--13°C*

* Temperature was regulated in flight according to a predetermined program, from 26° at launch to 13°C at the end of the flight.

The following is a translation of the section on regenerative systems (pp. 221-225).

38. Regeneration of the Artificial Environment in Space Cabins

1. A prolonged stay in an environment devoid of everything necessary to maintain the life of higher organisms except solar energy poses the problem of life support of space crews in small sealed cabins.

Assuming the 24-hr energy loss of a man under flight conditions to be 2700 kcal, and the food ration to contain the normal requirements of protein, fats, and carbohydrates, the 24-hr requirements will be 800 g of O_2, not less than 600 g (dry weight) of food, and 2200 g of water. Counting the weight of O_2 apparatus and CO_2 and water vapor sorbents, the total weight required to sustain one man in space for 24 hrs can be no less than 6 kg. Therefore to support one man in flight for one month will increase the weight of the spacecabin by at least 180 kg. A flight of up to a year's duration would increase this weight penalty to over 2 tons.

2. If the weight increment per unit time could be decreased, flight duration could be increased or the launch weight of the vehicle could be reduced. This can be accomplished by regeneration of some of the substances required to support human life.

The most efficient and technically the simplest of these processes is the regeneration of water from human vital activity products. By eliminating water storage and the moisture from some foodstuffs, the weight penalty for 24-hr support of one man can be reduced to 2.9 kg. However, this method of reducing weight is not practicable for brief spaceflights, since the equipment for recovering and purifying water from human vital activity products may weigh more than the eliminated water stores.

The 24-hr weight increment can also be reduced by regeneration of the CO_2 absorbents, using calcium hydroxide, zeolites, freezing equipment, and so forth.

3. The next step in developing methods for weakening the dependence of spacecraft environment weight on flight duration is to obtain oxygen from human vital activity products (CO_2 and water). This may be done both by physical-chemical and by biological (photosynthesis of green plants) means. Oxygen regeneration by biological methods may simultaneously solve the problem of food regeneration, and thus become the basis for a closed cycle of all substances in the space cabin. In that case the duration of flight will no longer have any effect on the launch weight of the spacecraft.

Based on the above, the following main types of life support systems may be distinguished:

1) A system based on stores of food, oxygen, water, and CO_2 and water vapor sorbents (24-hr weight increment of at least 6 kg per man).

2) A system based on stored food, oxygen, and CO_2 sorbents with water regeneration (24-hr increment of 3.9 kg per man).

3) A system based on stored food and oxygen, with regeneration of water and CO_2 sorbent (24-hr increment of 2.4 kg per man).

4) A system based on stored food and regeneration of water and oxygen (24-hr increment of 0.6 kg per man).

5) A system based on full regeneration of food, water, and oxygen (24-hr increment equal to zero).

4. Oxygen regeneration, like water regeneration, is practicable only for flights in excess of a certain duration (on the order of several months). To determine the practicability limits of various regenerative cycles in terms of flight duration, the extra weight of the regenerating equipment must be considered.

Assuming the weight of some cabin equipment components to remain constant during flight, while the weight of the regenerating equipment varies in proportion to flight duration, the efficiency of a regeneration system will be greater as the difference between proposed and calculated flight duration increases. The calculated flight duration is obtained by the formula

$$t = \frac{G_k}{\alpha_1 - \alpha_2},$$

where G_k is the constant excess weight of the regeneration equipment and α_1 and α_2 are the coefficients of weight increase per unit time for the two systems being compared.

Development of an oxygen regeneration system, however, presents serious difficulties.

The simplest and easiest method of obtaining oxygen is by electrolysis of water, which requires great amounts of electrical energy. Furthermore, it is not possible to obtain more than one-third of the respiratory oxygen requirement from the water formed by metabolism.

The necessity for supplementary water or liquid oxygen storage reduces the efficiency of this oxygen regeneration method.

Other promising research trends are the development of CO_2 degradation by hard UV radiation or spark discharges, and also the choice of catalysts and temperature conditions which will cause CO_2 to enter into reaction with the hydrogen obtained by the electrolysis of water. The latter reaction may either yield oxygen directly or after further processing of intermediate reaction products.

Besides research on physical-chemical methods of oxygen regeneration, considerable interest is attached to other efforts aimed at the regeneration of oxygen by biological methods using green plant photosynthesis. The latter will provide a simultaneous solution to the problem of reduplicating several links of the natural process, which operates continuously in nature to maintain the oxygen and CO_2 content of the Earth's atmosphere at constant levels.

5. The ultimate solution to the problem of human life support will consist in the realization of Tsiolkovskiy's idea of a closed cycle of substances in space cabins (creation of an ecological system). The basic requirement for making this idea a reality is the full regeneration of food from human vital activity products, based on higher plant photosynthesis. Calculations show that this type of regeneration can be achieved, notwithstanding considerable scientific and engineering obstacles, in the near future.

In conclusion it may be said that for orbital aircraft and satellite spacecraft performing brief flights near the Earth, the most efficient way of meeting human life support requirements is to carry supplies of oxygen, water, and food for the entire flight. Cosmonaut life support systems based on storage of the necessary substances were used on the "Vostok" type spacecraft. They can obviously also be used for the orbital aircraft of the near future.

PART II. SPACECRAFT LIFE-SUPPORT SYSTEMS

Recent Developments in Space-Oriented *Chlorella* Research in the USSR

After a period of disenchantment with the possibility of using *Chlorella* for regenerative life-support systems, *Chlorella* research in the USSR during the last two or three years has shown a definite upsurge. At the Institute of General Genetics of the Academy of Sciences, USSR, a team of researchers headed by Emma Vaulina has studied more than 2,000 varieties of *Chlorella* in an effort to identify a strain best suited for spaceflight purposes. Radiation and chemicals have been used to produce new mutational varieties with higher productivity and lower nutritional requirements in order to make space-cabin regeneration systems more compact [3].

Some of the more promising varieties of *Chlorella* (LARG-1, -3, and -5) were exposed to spaceflight factors on Kosmos-109 and Kosmos-110. It should be noted that the varieties of *Chlorella* investigated were *C. vulgaris* and *C. ellipsoidea* rather than *C. pyrenoidosa*, which was investigated by the Soviets during the 1960 series of spaceflights. The results of the 22-day exposure on Kosmos-110 are of particular interest since the orbit of that satellite passed through part of the radiation belt. Investigation of the effects by E. N. Vaulina, I. D. Anikeyeva, and G. P. Parfenov [20] and by V. A. Shevchenko and his co-workers [15] revealed that a 22-day exposure to spaceflight factors did not have any particular effect on viability of and mutation processes in the particular *Chlorella* strains studied.

I. D. Anikeyeva, E. N. Vaulina, and V. A. Shevchenko have also studied the effect of UV-rays on *Chlorella vulgaris* during various stages of its life cycle. Unlike other researchers, this team analyzed only entire mutant colonies [1]. Another team, E. K. Rodicheva, I. I. Gitel'zon, and I. A. Terskov analyzed the effects of UV-radiation on *Chlorella vulgaris* populations under conditions of continuous intensive cultivation [12]. They found that the inhibiting effect of UV-radiation on a *Chlorella* population was less pronounced during intensive growth phases. L. V. Kirenskiy, I. A. Terskov, I. I. Gitel'zon and others [28] have modeled various algal culture methods mathematically in order to find the most suitable culture method for use as an atmosphere-regeneration link in a closed ecological system. They have

have found that turbidostatic culturing is preferrable to chemostatic, since the turbidostatic method lends itself to quasi-continuous culturing, where only temperature and cell concentration need to be stabilized by the automatic control system. On the basis of this research they obtained an experimental culture which produced oxygen at a daily rate of 100 liters/m^2 of illuminated surface and 40 liters/liter of suspension. An automatic system meeting daily human oxygen requirements has been built on the basis of this research system [28].

It is evident that considerable time was required for the development of an automatic algal cultivation system capable of meeting human oxygen requirements, and that a large number of basic studies were necessary. *Chlorella* culture studies have been carried on at the Institute of Plant Physiology for several years. More specifically, Yu. N. Filippovskiy, V. Ye. Semenenko, and A. A. Nichiporovich have been studying the problem of radiant energy distribution in *Chlorella* suspension using plane-parallel cultivators. Their work has indicated that spectral hemispheric translucence coefficients for *Chlorella* suspensions depend exponentially on cell concentration and thickness of the culture layer for all practical variations of these two parameters. This appears to be true for xenon lamps, fluorescent lamps, and incandescent mirror lamps. [24, 25]. At the Institute of Biophysics, A. B. Brandt has also studied the optical characteristics of *Chlorella* suspensions as light-diffusing media. Brandt's interest was largely in the changes in the light diffusion characteristics of algal suspensions at different stages of culture growth and cell development [4]. At the same time, T. V. Demidova, I. A. Terskov, and F. Ya. Sid'ko have been developing a system for stabilizing the optical density of algal cultures during continuous cultivation. In their system, biomass concentration is maintained at the desired level by automatic stabilization of the optical density of the solution. While this work was carried out at the Physics Institute of the Siberian Department of the Academy of Sciences [5], V. Ye. Semenenko along with L. N. Tsoglin and A. K. Polyakov were doing selective genetic work to develop new, highly productive strains of unicellular algae on the basis of mathematical modeling of growth dynamics of multi-component populations under continuous cultivation conditions [22].

The culmination of this entire research effort was reported in a paper by L. V. Kirenskiy, I. A. Terskov, I. I. Gitel'zon, and others at the COSPAR Meeting in London in July 1967. According to this report, human subjects have been maintained in sealed cabins on oxygen regenerated exclusively by *Chlorella vulgaris* cultures for periods of up to 30 days. These experiments have shown that man and *Chlorella vulgaris* are biologically compatible and that the metabolic products of each are not toxic to the other [29]. In short, the Soviets have succeeded in creating automatic, biologically regenerative life-support systems for supplying man with oxygen for periods of up to 30 days.

Vaulina also pointed out that the research program at the Institute of General Genetics has also revealed that *Chlorella* has the capacity to purify contaminated water and to assimilate part of the waste products, thus rendering a truly closed biological system for spaceflight a possibility. Vaulina also points out that extensive research on the nutritional qualities of *Chlorella* is being carried on. This research has shown that algae contain all the necessary dietary components (50% protein, 35% carbohydrates, 5% fat, and all necessary vitamine and amino acids) [3]. V. I. Fofanov and his co-workers have made several studies on the possible utilization of algal proteins in closed ecological systems. In the first of these studies [9], white rats were fed an algal diet consisting of a bleached dehydrated biomass of 50% *Chlorella* and 50% *Scenedesmus*. It was found that the viability of the second and third generations of rats raised on algae was higher than that of the control group which was fed a standard casein diet [9]. In another experiment [7], Fofanov and his co-workers investigated the effects of algal diets on human subjects. It was found that the use of algal proteins in the diet is accompanied by a number of hormonal shifts, including shifts in natural immunity. A third paper by Fofanov and co-workers [27] also dealt with the effects of algal diets on human subjects. Although no abnormalities in protein metabolism occurred, the food value and digestibility of this diet were found to be less than a diet containing animal proteins. In fact, Fofanov concludes that algal biomass is unsuitable for direct human consumption, but its nutritional value makes it worthwhile to seek ways of converting algal biomass by lower heterotrophs (such as hydrogen reducing bacteria) to a form usable by man.

In view of the magnitude of the research effort expanded on *Chlorella*, it appears that the Soviets are committed to the use of *Chlorella* as a regenerative component of life-support systems for spaceflight. What is not clear is how the Soviets propose to cultivate *Chlorella* under weightlessness. To date, no evidence has been found of engineering systems or devices which would permit the automatic culturing of algae in the absence of gravity.

1. EFFECT OF UV-RAYS ON VARIOUS STAGES OF THE CELL CYCLE OF *CHLORELLA*

Anikeyeva, I. D., E. N. Vaulina, and V. A. Shevchenko. AN SSSR. Nauchnyy sovet Radiobiologiya. Vliyaniye ioniziruyushchikh izlucheniy na nasledstvennost' (Effect of ionizing radiation on heredity). Moscow, Izd-vo Nauka, 1966, 16-21. AT7002492

This investigation carried out on *Chlorella vulgaris* demonstrated the high sensitivity of various stages of two successive cell cycles and the DNA synthesis period to ultraviolet rays. Unlike other researchers who have analyzed chromosomal aberrations or lethal mutations, this work was carried out on visible gene mutations. The authors limited themselves to an analysis of whole mutant colonies. The observed appreciable increase in the quantity of whole mutant colonies during the period of synthesis was difficult to explain if one proceeded from the fact that mitosis followed after each doubling of the quantity of DNA. In this case the predominance of mutant sectors should have been observed, but in actuality they were encountered by an order more rarely than whole mutant colonies, even after three syntheses. This indicated to the authors that after synthesis of DNA all genetic material was situated in structures which could be damaged as a whole by one hit. Such a structure was the polytene chromosome. As to how the multithread chromosome is damaged as a whole, the authors indicate the predominance of isolocus breaks of sister chomatids and the appearance of isochromatid fragments after the synthesis of DNA. UDC: none

Asso: Institut biologicheskoy fiziki AN SSSR (Institute of Biophysics, Academy of Sciences, USSR), Moscow

2. THE CHARACTER OF THE ASSIMILATING ACTIVITY AND COMPOSITION OF *SCENEDESMUS QUADRICAUDA* CELLS OF DIFFERENT AGES

Baslavskaya, S. S. and L. S. Bamburova. Moscow. Universitet. Vestnik. Seriya VI. Biologiya, pochvovedeniya, no. 5, 1966, 27-34. AP7007506

Characteristics of the assimilation activity and composition of *Scenedesmus quadricauda* cells of various ages were studied. The following indices were calculated: growth, photosynthesis and respiration, accumulation of dry mass, and the nitrogen, phosphorus, and chlorophyll content of cells at various phases of development. Data showed that cell dimensions and volume increased with age. Dry cellular weight also increased in proportion to age, but relatively less than the volume. Photosynthetic intensity in algal ontogenesis was not constant. The youngest cells were distinguished by the greatest photosynthetic intensity according to calculation (1 mm^3 of cellular substance). Intensity of the process gradually dropped in proportion to cell growth. The greatest quantity of oxygen liberated in photosynthesis by a cell as a whole was found in mature cells 3—6 hr after the beginning of their growth. The youngest cells possessed a maximum content of nitrogen, protein, chlorophyll, and phosphorus per unit volume of dry biomass. However, the content of these substances in cells dropped in proportion to cell age. The general quantity of the above substances in a cell increased in proportion to its growth and attained maximum values in mature cells. Results confirm the need for further investigation of growth changes in cell metabolism, with a comparison of data obtained from calculation in various units. UDC: 581.13 : 582.26

3. A SPACE FACTORY FOR AIR AND FOOD

Belikov, D., V. Vysokov.
VDNKH SSSR. Informatsionnyy byulleten', no. 3, 1967, 38. AP7010049

This article states that the Laboratory of Space Genetics, Institute of General Genetics, USSR Academy of Sciences, is actively pursuing research on the use of *Chlorella* for space-cabin life-support systems. The primary mission of researchers, according to Emma Vaulina, the head of the Laboratory, and a Candidate of Biological Sciences, is to "provide the cosmonaut with air." Here, the use of *Chlorella* as an air-regeneration source is being investigated. Previous experiments showed that this alga thrives in an artificial nutrient medium (not specified). Wild species have been cultivated and a highly productive variety (strain not given) has been isolated. More than 2000 varieties of *Chlorella* have been studied. Using gamma and roentgen radiations, as well as chemical preparations (not specified), new varieties twice as productive and requiring half the normal nutrient medium have been developed. Further research will entail increasing *Chlorella* productivity to a maximum level, thus rendering the space-cabin regeneration system more compact.

Research on the nutritional qualities of *Chlorella* is also being pursued relative to its inclusion in the space diet. The alga has been found to contain all of the necessary dietary components (50% protein, 35% carbohydrate, 5% fat, and all necessary vitamins and amino acids). The inclusion of small animals such as chickens and rabbits whose diet would be composed of algae is also being investigated.

This research program has also revealed that *Chlorella* has the capacity to purify contaminated water and partially assimilate waste products, thus rendering feasible a truly closed biological cycle in the space cabin. In the process of selection, researchers are striving to create a more "universal" variety of *Chlorella* which would be capable of satisfying a whole range of biological requirements. It is hoped that this program will make possible the provision of life-support systems for prolonged manned spaceflights without having to increase space-cabin dimensions. UDC: none

4. OPTICAL CHARACTERISTICS OF *CHLORELLA* SUSPENSIONS AS LIGHT-DIFFUSING MEDIA

Brandt, A. B. Soveshchaniye po problemam upravlyayemogo biosinteza i biofiziki populyatsiy, 1965. Bioenergetika i biologicheskaya spektrofotometriya (Bioenergetics and biological spectrophotometry); doklady soveshchaniya. Moscow, Izd-vo "Nauka", 1967, 224-231. AT7017645

A study was made of changes in the light-diffusion characteristics of algae suspensions at different stages of culture growth and cell development. *Chlorella* was cultured from autospores on Tamiya's medium in plane-parallel cuvettes of clear plastic illuminated with DS fluorescent lamps. Test suspensions were taken systematically at various stages of culture growth. Diffusion was determined by passing a beam of light through the sample suspension. The scatter coefficient was taken as the percent ratio of the intensity of light flux scattered in all directions by the suspension, to the intensity of light flux falling on the specimen. It was found that in less dense suspensions, the scatter coefficient increases with cell size and chlorophyll content. In denser suspensions, where light absorption plays a larger role, the scatter coefficient tended to decrease with increasing cell size and chlorophyll content, and increased only in the spectral region (λ = 796 mμ) not absorbed by chlorophyll. In homogeneous suspensions of autospores and young cells without much chlorophyll, the scatter coefficient increases with suspension density only in the weakly absorbed regions of the spectrum. In homogeneous cultures of mature cells, scatter coefficients increasing with density are seen only with a small range of densities (below 10×10^6 cells/ml). At higher densities, light diffusion remains almost constant. To determine the scattering capacity of individual cells, tests were made with highly dilute suspensions having negligible absorption. It was found that in the weakly absorbed green region of the spectrum, small cells (autospores) have a greater light diffusion capacity at both large and small scattering angles than do larger, mature, chlorophyll-bearing cells. In the strongly absorbed (red and blue) regions, autospores possessed considerable scattering capacity only at small scattering angles; at angles greater than 10°, mature spores had the greater light-diffusion capacity. These preliminary data confirm the great importance of cell size and chlorphyll content as determinants of the light transmission characteristics of *Chlorella* suspensions. It is tentatively concluded that the previously observed higher culture productivity of algae strains with smaller cells is due to better penetration of illumination into the culture mass, and that the most productive strains for culturing would be those with cells measuring between 3—5 μ.

UDC: 577.3+543.42

Asso: Institut biologicheskoy fiziki AN SSSR (Institute of Biophysics, Academy of Sciences, USSR), Moscow

5. SYSTEM FOR STABILIZING OPTICAL DENSITY OF MICROALGAE CULTURES DURING CONTINUOUS CULTIVATION

Demidova, T. V., I. A. Terskov, and F. Ya. Sid'ko. Soveshchaniye po problemam upravlyayemogo biosinteza i biofiziki populyatsiy, 1965. Bioenergetika i biologicheskaya spektrofotometriya (Bioenergetics and biological spectrophotometry); doklady soveshchaniya. Moscow, Izd-vo "Nauka", 1967, 271-276. AT7017648

A system for maintaining the biomass concentration of continuously cultured algae within preset limits between 20 and 30 g dry matter per liter of suspension with an accuracy of ± 1% is described. Biomass concentration is maintained at the desired level by automatic stabilization of the optical density of the solution. The system consists of an optical-density sensor (1), a recording device (2), a control circuit (3) linking the sensor to a dosing pump (4) for drawing off or adding nutrient medium to the cultivator (5). Two types of circuits for the

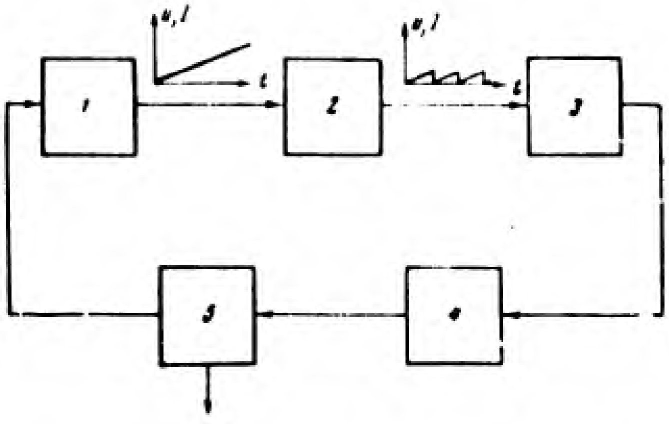


Fig. 1. System for stabilizing optical density.

optical sensor are described, one based on paired selenium photoelements, the other on paired vacuum photocells. Proper pairing of the photoelements decreases the requirement for stability of the light source. The type of recording potentiometer chosen depends on which type of photoelement is used. Accuracy characteristics of the potentiometer are given for various biomass concentrations and photocell input resistances. Two control circuits are also shown, one for each type of recording potentiometer. Considerable noise resistance is gained by inclusion of a condenser lengthening reaction time of the control circuit to 30 sec. In addition to radiofrequency noise, false signals also may originate with the culture itself; these include uneven culture flow, changes in the liquid-gas phase ratio, and agglutination of cells. Noise of this type, which has a frequency characteristic of 0.01—0.1 Hz, is eliminated by including a filter with $\tau \geq$ 10—100 sec. The system described is considered reliable and is ready for production.

UDC: 577.3+543.42

Asso: Institut fiziki SO AN SSSR (Institute of Physics, Siberian Department of the Academy of Sciences, USSR), Krasnoyarsk

6. DETERMINATION OF THE NUTRITIONAL VALUE OF GREEN ALGAE

Fodor, G., G. Racz, and K. Bedo. Magyar Mikrobiologiai Tarsasag. Proceedings of the Fourth Congress of the Hungarian Association of Microbiologists, Budapest, 1964. Budapest, AK, 1966, 404. AT7014975

Scenedesmus algae were grown in a swimming pool in 26°C water, purified by aluminum sulphate adsorption and chlorine treatment. Presence of human urine in the water was found to stimulate algal growth. Biomass recovered from the water and purified by repeated washing and sun-dried yielded several kilograms of algal powder per week. The nutritional value of powdered alga was tested on albino rats which were fed on a semisynthetic diet for 30 days. In the control group, the total protein requirement (18%) was supplied in the form of casein, while in the experimental group, 50% of the casein ingredient was replaced by powdered alga. Weight gain and nitrogen balance of the animals were carefully controlled throughout. Weight gain was 25.6% in the experimental group and 11.9% in the control group. Rats given algal powder had better appetite than controls. Examination of the influence of algal powder on liver regeneration after partial hepatectomy showed that the division of parenchymal cells was much more intensive in treated than in untreated animals. No toxic symptoms were observed during the experiment.

Asso: University Medical School, Targu Mures, Rumania

7. SOME INDICES OF NATURAL IMMUNITY AFTER REPLACEMENT OF ANIMAL PROTEINS IN THE DIET BY *CHLORELLA* PROTEIN

Fofanov, V. I., M. I. Kozar', and N. N. Dobronravova. Kosmicheskaya biologiya i meditsina, v. 1, no. 3, 1967, 77-80. AP7022631

The effect on natural immunity of replacing animal proteins in the diet with proteins derived from *Chlorella* (algae) was studied in healthy men aged 24 to 30 yr and weighing 70—79 kg. The subjects ate a control diet (3000 kcal; proteins, fats, and carbohydrates in a ratio of 1:1:4) for 15 days; then for 30 days they were fed the experimental diet, identical with the control diet but with animal proteins replaced by algal proteins; finally for 10 days more they returned to the control diet. Approximately half the total protein in both diets was plant protein (potato, cabbage, flour, buckwheat), the other half being of animal or algal origin. Immunological indices studied were lysozyme activity in saliva and blood serum, complement titers, and bactericidal (*E. coli*) activity of the serum. The results are shown in the following tables:

Table 1. Saliva lysozyme activity during the experiment and the aftereffect period

Time sample taken	Amount of lysozyme in dilution units (based on titration) (Average of five subjects)	
Baseline	1280 ± 106.2	
During experiment		
2d day	854	70.5
8th day	980	66.7
14th day	627	75.5
19th day	730	83.4
30th day	710	42.7
After experiment		
7th day	850	81.7
10th day	560	52.6

Table 2. Serum lysozyme (bacteriolytic activity (in dilution units)

Time sample taken	Lysozyme activity (Average of five subjects)	
Baseline	110 ± 10	
During experiment		
18th day	26	2.4
30th day	41	3.75
After experiment		
7th day	25	5.0

These results establish a statistically reliable decrease in saliva and serum lysozyme activity, which remained depressed throughout the aftereffect observation period. Unfortunately, observations were not continued long enough to provide any data on recovery to initial levels. Uniform behavior of these two indices indicates that a single mechanism is responsible. Changes in the protein component of the diet are accompanied by a number of hormonal shifts; for instance, a low-protein diet increases thyroid secretion. Increased thyroxin blood levels inhibit lysozyme synthesis; increased thyroxin and thyroglobulin cause lysozyme to be precipitated out of the serum. The lower resistance to bacterial infection observed in animals fed low-protein diets for long periods may be due to inhibition of lysozyme activity. A number of other functional disturbances (weight loss, dyspepsia, buccal dysbacteriosis) accompanied the decrease in lysozyme activity noted above. Complement titers ranged from 0.15—0.11, but changes noted were not statistically reliable ($t \leq 0.03$). Bactericidal activity of the serum was essentially unchanged during and after the experiment. UDC: 612.017.1:[612.398:582.26

8. THE EFFECT OF INHIBITORS OF THE CYTOCHROME LINK OF ELECTRON TRANSFER ON THE NITROGEN FIXATION OF PHOTOSYNTHESIZING BACTERIA (*Chromatium minutissimum*)

Ivanov, I. D., N. S. Demina, and T. V. Gogoleva. Mikrobiologiya, v. 36, no. 1, 1967, 8-12. AP7009797

A culture of photosynthesizing sulfur bacteria (*Chromatium minutissium*) was grown on a Larsen (1952) medium for 5—6 days at 30°C, with daily illumination from a 60-w lamp. It was found that the main locus of the reduction of neotetrazol to formazan was at the flavoprotein level. Potassium cyanide (10^{-2} and 10^{-3} M), sodium azide (10^{-3} M), and antimycin A (2—6 μg/ml) all inhibit nitrogen fixation in light or darkness. Under both conditions the cytochrome system of this bacteria participates in nitrogen fixation. UDC: 576.851.126.095.312: 577.158.83 [CD]

Asso: Institut mikrobiologii AN SSSR, Moskva

9. THE STUDY OF THE BIOLOGICAL VALUE OF PLANT PROTEINS IN RELATION TO THEIR POSSIBLE UTILIZATION IN A CLOSED ECOLOGICAL SYSTEM

Klyushkina, N. S., V. I. Fofanov, and I. T. Troitskaya. Kosmicheskaya biologiya i meditsina, v. 1, no. 2, 1967, 38-43. AP7017370

It is highly probable that closed ecological systems will require that many of the animal proteins in the diet be replaced by plant proteins derived from unicellular algae and higher plants. Experiments with the nutritional value of plant proteins have not as yet exceeded one to two months' duration. In this experiment, two generations of white rats were raised on plant proteins obtained from unicellular algae or soya. A standard casein diet developed by the Institute of Nutrition served as a control. The algal feed consisted of a bleached dehydrated biomass containing 50% *Chlorella* and 50% *Scenedesmus*. White rats were divided into three groups and fed casein, soya, and algae diets. After three months the experimental animals (P_1) were bred. The offspring (F_1) were in turn bred at the age of four months, and produced third-generation (F_2) offspring. The following parameters were measured: body weight, nitrogen balance, urea content of urine, the amine nitrogen of urine, albumins in the blood serum, fat content of the liver, and the nitrogen content of the liver, of the urine, of the feces, and of the food. In the parent generation the average weight of the "casein" group was somewhat higher than that of the "algae" and the "soya" groups. In the F_1 and F_2 generations, animals kept on an algae diet were more active and more viable than those of the other two groups. The soya-diet F_1 and F_2 generations were weaker and lost more weight than the other two groups. During the entire experiment animals of all three groups retained a positive nitrogen balance; the two groups kept on vegetable protein diets were on almost the same level as those kept on a casein diet. Neither the nitrogen and fat content nor the albumin and general protein content of the blood serum in the animals in the three diet groups showed any substantial differences. In general, the experiments showed that the protein content of green algae has high biological value, as far as such indices as nitrogen and fat content of the liver, albumins in the blood, positive nitrogen balance, and high viability of the offspring are concerned. The increased amino-acid content in the young animals of the "algae" group as compared to the "casein" controls indicates a certain imbalance in the amino-acid content of the algae diet in respect to rats in the initial period of growth. At the age of six months, however, there was no substantial difference between the experimental and control groups. In general, a somewhat lower urea content in urine is characteristic for rats on the soya and the algae diet. Animals of the "algae" group had smaller body weight than those raised on a casein diet. On the other hand, the viability of the F_1 and F_2 generations of rats raised on algae was higher than that of the control, "casein" group. The soya diet was found to be unsatisfactory for young rats, as is evident from loss of weight, low nitrogen balance, and significant excretion of amino acids in urine.

UDC: 612.398:612.392.7]:582.26

10. COMPARISON OF THE PHOTO-OXIDATION OF BACTERIOVIRIDIN AND BACTERIOCHLOROPHYLL REACTION OF PHOTOPRODUCTS WITH REDUCING AGENTS

Krasnovskiy, A. A., Ye. V. Pakshina, and I. M. Sapozhnikova. AN SSSR. Doklady, v. 172, no. 3, 1967, 727-730. AP7007301

The present study was designed to compare the features of products resulting from photochemical oxidation of bacteriochlorophyll and bacterioviridin. The pigments were extracted from photosynthesizing bacteria (species not given) employing conventional methods with final chromatography on saccharose. Four spectrographs showing the photo-oxidation of bacterioviridin and bacteriochlorophyll in various media are presented. From this and other studies, it was proposed that the formation of phycobilins in the process of the evolution of photosynthetics might be the result of the photo-oxidation of chlorophyll pigments due to a shift by autotrophs from anaerobic to aerobic metabolism. UDC: 576.851.12

Asso: Institut biokhimii im. A. N. Bakh AN SSSR (Institute of Biochemistry im A. N. Bakh, Academy of Sciences, USSR)

11. EFFECT OF CULTIVATION CONDITIONS ON THE METABOLISM OF INORGANIC POLYPHOSPHATES AND OTHER PHOSPHORUS COMPOUNDS IN *SCENEDESMUS OBLIQUUS*

Kulayev, I. S., and V. M. Vagabov. Biokhimiya, v. 32, no. 2, 1967, 253-260. AP7016182

During the phosphorus starvation of *Scenedesmus obliquus*, inorganic polyphosphate metabolism is not directly associated with the photosynthetic process but rather depends upon the presence of glucose. In the absence of phosphorus and in the presence of glucose, polyphosphate biosynthesis is identical both in light and in darkness. Phosphate absorption by this green alga is an active process closely associated with oxidative phosphorylation at the respiratory level. Phosphorus intake by *S. obliquus* cells is heavily inhibited by 2-4- DNP (10^{-3} M) and to a far lesser extent by iodoacetic acid ($5 \cdot 10^{-5}$ M). In contrast, the biosynthesis of polyphosphates by *S. obliquus* is apparently a primary function of glycolytic phosphorylation since it is heavily inhibited by iodoacetic acid. When oxidative phosphorylation is inhibited by 2-4-DNP at the respiratory level, the biosynthesis of polyphosphates not only is not inhibited but even somewhat intensified. It was found that among the phosphorus compounds accepting external phosphorus in *S. obliquus* an important role is played by certain very labile phosphoorganic compounds whose phosphorus is determined as "orthophosphate." The three different fractions of these compounds were found to be closely associated with one another in the metabolism of this alga and apparently assume different functions. UDC: 661.632.9

Asso: Biologo-pochvennyy fakul'tet Moskovskogo gosudarstvennogo universiteta im. M.V. Lomonosov (Biology and Soil Study Department, Moscow State University, im. M.V. Lomonosov)

12. THE EFFECT OF ULTRAVIOLET RADIATION ON *CHLORELLA* IN CONDITIONS OF CONTINUOUS INTENSIVE CULTIVATION

Rodicheva, E. K., I. I. Gitel'zon, and I. A. Terskov. AN SSSR. Sibirskoye otdeleniye. Izvestiya. Seriya biologo-meditsinskikh nauk, no. 3, 1966, 33-37. AP7011710

The behavior of a *Chlorella* population (thermophylic strain *Chlorella vulgaris)* during UV-radiation and the dynamics of restoration during continuous intensive cultivation under constant conditions were investigated. A diagram of the cultivator used in the experiments is shown in Fig. 1. The effect of UV-radiation was evaluated by the bio-

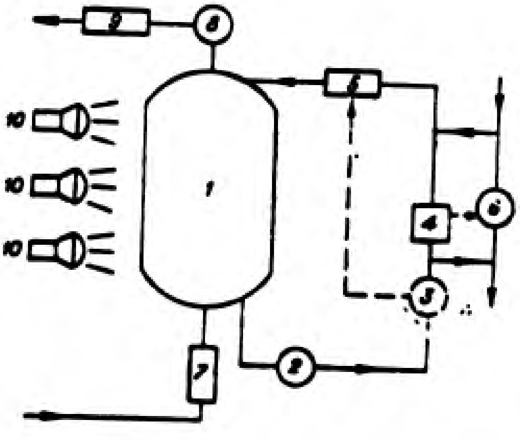


Fig. 1. Diagram of cultivator.

1 - Reactor; 2 - main pump; 3 - temperature sensor; 4 - optic density sensor; 5 - heat exchanger; 6 - dispenser; 7 - flow meter; 8 - foam separator; 9 - gas cooler; 10 - light source.

mass growth rate (productivity in g/liter/day) during the test. The relative chlorophyll content in the dry biomass with different UV-radiation doses, cell division and cell dimensions, suspension pH, and other cultivation parameters were determined. The relation between inhibition and restoration of the *Chlorella* population with different UV-radiation doses, and various levels of *Chlorella* productivity produced by change in illumination intensity were studied. It is seen from Fig. 2 that change in productivity depending on dose can be reversible or irreversible. The dose-productivity curve in Fig. 3 shows the dependence of maximum drop in productivity on UV-radiation dose. Data also indicated that changes in chlorophyll content depending on dose may also be reversible or irreversible. The diagrams revealed the fluctuating character

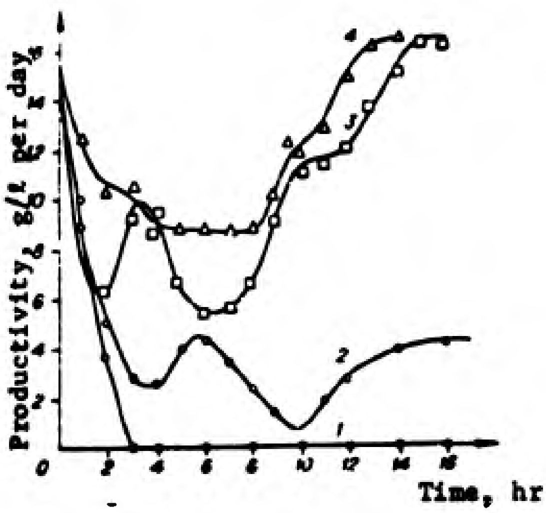


Fig. 2. Change in productivity at different UV-radiation doses.

1 – $24 \cdot 10^9$; 2 – $12 \cdot 10^9$; 3 – $8 \cdot 10^9$; 4 – $6 \cdot 10^9$ erg/g of dry biomass.

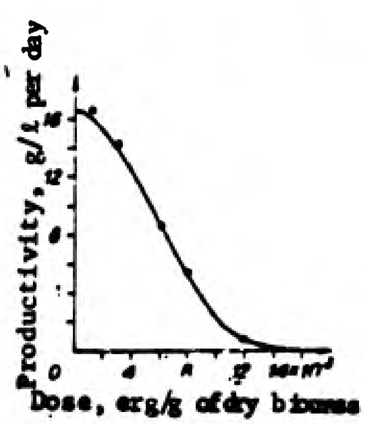


Fig. 3. Dependence of maximum drop of productivity on UV-radiation dose

(surface illumination of the suspension -- 160 $kerg/cm^2 \cdot sec$).

of the restoration curve. Since change in culture growth intensity in the experiments was regulated by changing the surface illumination of the suspension, changes in the productivity drop at different UV-radiation doses can be explained both by the effect of a different radiation intensity and by the different effect of photoreactivation. The inhibiting effect of UV-radiation on the *Chlorella* population has less affect at greater than at weaker growth intensities.

UDC: 582.26+578.088.5

Asso: Institut fiziki Sibirskogo otdeleniya AN SSR (Institute of Physics of the Siberian Department of the Academy of Sciences, USSR), Krasnoyarsk

13. THE KETOACIDS AND ALDEHYDO-ACIDS OF *CHLORELLA*

Shatilov, V. R., N. S. Geyko, Z. G. Yevstigneyeva, and V. L. Kretovich. AN SSSR. Doklady, v. 172, no. 3, 1967, 731-732. AP7007302

This study was designed to determine the keto-a and aldehydo-a compliment of *Chlorella pyrenoidosa* Pringsheim 82T. The algae were cultured according to the method of V. I. Romanov et al. (Prikladnaya biokhimiya i mikrobiologiya, 1, 1965, 494). Ater three days of growth, cells from one chamber were centrifuged, washed in distilled water, and transferred to the same culture

Table 1. Content of keto- and aldehydo-a in *Chlorella pyrenoidosa* cells (mol/1000 mg dry weight

Keto- and aldehydo-a	Nitrogen starved cells	Normal cells
Alpha ketoglutaric	2.53	1.05
Pyruvic	1.59	0.96
Hydroxypyruvic	1.10	0.53
Oxalacetic	1.05	0.11
Gyloxalic	0.33	0.10

medium lacking nitrogen. Nitrogen starvation lasted four hr, facilitating an increase in keto- and aldehydo-a, which were assayed by hydrogenolysis of 2,4-dinitrophenylhydrazones. The cells were then centrifuge, washed in distilled water, and disintegrated in a solution of 2,4-dinitrophenylhydrazine in 2N HCl for one hr. Hydrazones were then drawn off. Three parallel tests were conducted yielding completely coincidental results, some of which are shown in Table 1. Of interest was the fact that these acids accumulated in a fairly short period of time (4 hr) compared to other more prolonged (24 hr) studies. UDC: 581.192

Asso: Institut biokhimii im. A. N. Bakh AN SSSR (Institute of Biochemistry im. A.N. Bakh of the Academy of Sciences, USSR) Tekhnologicheskiy institut pishchevoy promyshlennosti (Technical Institute of Food Industry), Moscow

14. ANALYSIS OF THE NATURE OF RADIATION DAMAGE TO *CHLORELLA* CELLS

Shevchenko, V. A. AN SSSR. Nauchnyy sovet Radiobiologiya. Vliyaniye ioniziruyushchikh izlucheniy na nasledstvennost' (Effect of ionizing radiation on heredity). Moscow, Izd-vo Nauka, 1966, 8-15. AT7002491

An analysis of the picture of radiation damage to *Chlorella* cells showed cytoplasmatic death of the cells and death due to lesion of the genetic structures. Cell death in a wide range of doses was caused exclusively by genetic damage. Death without preliminary growth at the young cell stage was manifested only at a dose of 40 kr, when the survival rate of the culture did not exceed 1—2%. In this case most cells that died as a consequence of cytoplasmic damage had lethal mutations. At doses up to 20 kr the cells mainly died as a result of lethal point mutations which produced, after a phenotypic lag, a characteristic picture of symmetric death. The duration of the phenotypic lag depended on the age of the cell at the moment of occurrence of the lethal mutation, on the nature of the mutation itself, and on the degree of radiation damage to the cytoplasm. The number of inactivated large and giant cells increased in proportion to some power of the dose greater than one which made it possible to relate the appearance of these cells with the occurrence of large chromosomal aberrations in them. UDC: none

Asso: Institut biologicheskoy fiziki AN SSSR (Institue of Biophysics of the Academy of Sciences, USSR), Moscow

15. THE VITAL ACTIVITY OF *CHLORELLA* UNDER SPACEFLIGHT CONDITIONS

Shevchenko, V. A., I. S. Sakovich, L. K. Meshcheryakova, and M. G. Petrovnin. Kosmicheskaya biologiya i meditsina, v. 1, no. 3, 1967, 25-28.

AP7022618

The possibility of using *Chlorella* as a link in a closed ecological system for spacecraft requires study of the effect upon it of such spaceflight factors as ionizing radiation, vibration, and weightlessness. Controlled studies have been made with laboratory material and with material subjected to spaceflight. This article reports on viability and mutability of various strains of *Chlorella vulgaris* Beyer obtained from the Institute of General Genetics, USSR Academy of Sciences, and subjected to the 22-day Cosmos-110 orbital flight. The strains were distinguished by such morphological indices as reproductivity, thermostability, and radiosensitivity. Synchronous, sterile suspensions of each strain (density $1 \cdot 10^6$ cells/ml; volume 2 ml) in Tamiyya medium were sealed in glass ampuls and special opaque containers and placed on board the spacecraft. After the flight the *Chlorella* samples were seeded on agar and studied by the methods of micro- and macrocolonies. With the former, sporulation and viability in comparison to controls were observed, while mutations were detected with the latter method. Data on the viability and mutability of the various strains are presented in Table 1. For the sake of accuracy, 400 colonies were studied in each case. The incidence of mutation in experimental and control samples showed only insignificant differences. The dynamics of the first sporulation were also studied and though the process was occasionally delayed in experimental specimens, the rate normalized completely by

Table 1. Changes in the viability and mutability of various *Chlorella* strains following the Cosmos-110 spaceflight.

Strain	Survival (%)		Mutant colonies (%)	
	Control	Exptl.	Control	Exptl.
LARG-1	92,5 ± 1,37	67,5 ± 2,58	0,13 ± 0,01	0,15 ± 0,05
LARG-3	91,2 ± 1,50	92,8 ± 1,50	no data	no data
LARG-5	89,0 ± 1,53	91,0 ± 1,42	0,25 ± 0,06	0,25 ± 0,09
U-158	86,8 ± 1,91	87,2 ± 1,61	0,71 ± 0,21	0,81 ± 0,24
U-125	90,0 ± 1,72	87,5 ± 1,89	0,15 ± 0,07	0,10 ± 0,06

the end of the second sporulation. The data obtained in this study are in accord with analagous data obtained from the Cosmos-109 flight, even though that flight did not cross the earth's inner radiation belts and the radiation dose was 100 times smaller than that received by the Cosmos-110 spacecraft. In both cases, mutation rates were within normal limits. Use of more sensitive methods in such studies as these (such as the method of secretory mutants [Shevchenko V. A., Anikeyeva I. D., Vaulina E. N. Tezisy dokl. Simpoziuma "Eksperimental'nyy mutagenez zhivotnykh, rasteniy, mikroorganizmov." M., 1965, v.1, p. 149]) is suggested. Also, it is known that a dose of at least 1 krad of ionizing radiation is required to produce a noticeable effect on biomass increase. The authors conclude that spaceflight, prolonged to the extent of 22 days, has no particular effect on the viability and mutation processes of the *Chlorella* strains studied. UDC: 582.264.45-11:629.198

16. SEMIAUTOMATIC EQUIPMENT FOR MASS CULTIVATION OF PROTOPHYTIC FRESHWATER ALGAE

Szekely, K.. Magyar Mikorbiologiai Tarsasag. Proceedings of the Fourth Congress of the Hungarian Association of Microbiologists, Budapest, 1964. Budapest, AK, 1966, 404 AT7014976

Development of an apparatus for semi-mass production of algae and for comparative studies of different algal species and culture media is reported. The apparatus is not only economical, simple, and easy to operate, but also ensures optimal cultivation conditions and independent variation of all culture conditions and factors. The biomass produced was sufficient for limited feeding experiments and biochemical studies. The semiautomatic CO_2 generator, aerator, and mixing apparatus and the method used for rapid harvesting of the biomass are described.

Asso: Research Station of the Academy of Sciences, Targu Mures, Rumania

17. STUDIES ON THE DIGESTIBILITY OF PROTOPHYTIC ALGAE. I. EFFECTS OF DIGESTIVE ENZYMES ON DRIED ALGAE *IN VIVO*

Szekely, K., S. Bedo, B. Sebo and G. Fodor. Magyar Mikrobiologiai Tarsasag. Proceedings of the Fourth Congress of the Hungarian Association of Microbiologists, Budapest, 1964. Budapest, 1966, 405
AT7014977

Chicks fed for 2 weeks with food containing air-dried *Scenedesmus* sp. and *Chlorella vulgaris* algae were found to excrete microscopically intact algae cells in the feces, which were viable when cultured from fresh fecal samples. The imperfect digestion of algae dried by mild procedures indicates that, besides procedures for economical mass cultivation, it will be necessary to devise adequate pretreatment to increase the digestibility of algae cells intended for use as food.

Asso: Research Station of the Academy of Sciences, University Medical School, Targu Mures, Rumania

18. STUDIES OF THE DIGESTIBILITY OF UNICELLULAR ALGAE. II. *IN VITRO* EFFECTS OF PROTEOLYTIC ENZYMES ON DRIED ALGAE

Szekely, K, A. Eperjessy, M. Kerekes, and M. Bedo. Magyar Mikrobiologiai Tarsasag. Proceedings of the Fourth Congress of the Hungarian Association of Microbiologists, Budapest, 1964. Budapest, AK, 1966, 405.
AT7014978

Suspensions of identical concentrations of dried *Chlorella vulgaris* and *Scenedesmus* sp. specimens were prepared and incubated for 24 hr at 38°C under adequate pH conditions in the presence of 0.4% pepsin, trypsin, or papain. A certain degree of digestion of algal proteins was demonstrated. The level of protein decomposition was estimated by determining the free cyclic amino-acid concentration by the Folin-Ciociltau test. The individual amino acids were analyzed by two-dimensional paper chromatography. It was found that pepsin and papain had a remarkable effect, while trypsin had a poor effect on algal proteins. Successful digestion of the preparations by pepsin and trypsin enhanced the decomposition of proteins, as was demonstrated by increase in the number and concentration of free amino acids.

Asso: Research Station of the Academy of Sciences, University Medical School, Targu Mures, Rumania

19. MATHEMATICAL APPROACH TO STUDYING THE DYNAMICS OF HUMAN METABOLISM IN A CLOSED SPACE

Vasil'yev, V. K. Simpozium posvyashchennyy izucheniyu kislorodnogo rezhima organizma i yego regulirovaniya. Kanev, 1965. Kislorodnyy rezhim organizma i yego regulirovaniye (Oxygen system of the organism and its regulation); materialy simpoziuma. Kiev, Naukova dumka, 1966, 60-64. AT7017594

The authors discuss the theoretical feasibility of continuously monitoring the dynamics of human metabolism (gas exchange) in a hermetic chamber. A mathematical approach is proposed by which the inertial qualities of the chamber-analyzer system are considered and readout of integral indices of human gas exchange and of the dynamics of these indices for any given period of time is made possible. A chamber is proposed (Fig. 1) with automatic regulation of the basic environmental factors. In Fig. 1, $P_0(P)$ is the real

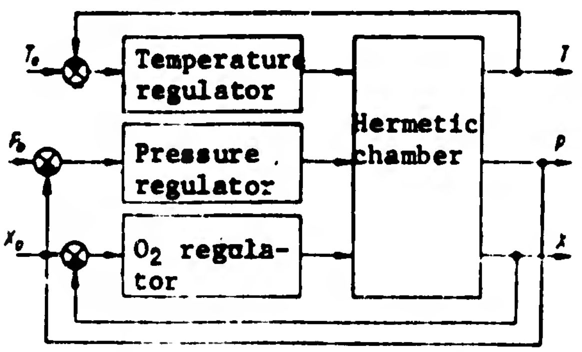


Fig. 1. Functional diagram of a system regulating the stability of environmental factors in a hermetic chamber

value of absolute pressure, $T_0(T)$ is the actual temperature, and $X_0(X)$ is the actual percentage content of oxygen. Oxygen level decreases due to human consumption actuating an oxygen regulator which feeds fresh air into the chamber via a valve. The excess portion of introduced air increases the absolute pressure, P, which causes a pressure regulator to vent some of the air through an escape valve. Human oxygen consumption is considered as the main disturbing factor in this system. The authors also describe the quantitative relationship between human oxygen consumption and environmental regulation.

20. *CHLORELLA* ON BOARD THE KOSMOS-110

Vaulina, E. N., I. D. Anikeyeva, and G. P. Parfenov. Kosmicheskiye issledovaniya, v. 5, no. 2, 1967, 285-292. AP7015125

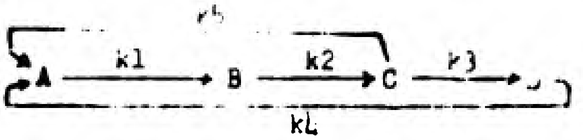
This article summarizes the effects of the Kosmos-110 flight on the mutability, viability, and dynamics of cellular development in *Chlorella* cultures (LARG-1, 3, and 5). This spaceflight did not result in a decrease or increase in the percentage of pigmented, mottled, or morphological mutations. An analysis of LARG-1 and 3 varieties revealed a delay in the first sporulation and an increase in the number of cells which had divided into a lesser than normal number of autospores. In experimental groups, somewhat decreased viability was noted in comparison to control groups (only the LARG-3 variety showed a statistically reliable decrease). LARG-3 cells were more sensitive to spaceflight factors than cells of the other varieties. This article will be summarized in more detail in an upcoming issue of the ATD Foreign Science Bulletin.

UDC: 581.057

21. EXPERIMENTAL INVESTIGATION OF MASS EXCHANGE IN LIFE-SUPPORT SYSTEMS BASED ON RECIRCULATION OF SUBSTANCES

Tereshchenko, A. P. Kosmicheskaya biologiya i meditsina, v. 1, no. 3, 1967, 48-51. AP7022624

Life-support systems for maintaining human vital activity during prolonged spaceflights or duty tours in extraterrestrial stations will be of the recirculation type, in which man, aided by technology, forms the basic link of a closed cycle. This basic link may be called the salvage link; its function is to salvage the end products of the vital activity of all the links (defined as those unusable by the biological links producing food, water, and oxygen) by transforming them so that they can be fed back into the cycle. The author considers the design of experiments for combining the separate links into an ideal closed ecological system. An artificial ecosystem, because of its very limited size (compared to the terrestrial cycle) must be very stable in operation, in a state of dynamic equilibrium. To design such a system it is not necessary to know the details of chemical and other processes occurring within each link. The system is like an electrical circuit in which each link is a component having input and output characteristics to be matched with those of adjacent links. The signal characteristics are the amounts of individual chemical substances (water, CO_2, etc.) and solid matter (garbage, excreta, plant biomass) produced and consumed or left over at each interface. Important characteristics of each component link are the speed and directionality of its signal-modifying processes. Notwithstanding the general forward movement of chemical substances through the system, feedback loops—exchanges of matter and energy between individual links—may occur. The author proposes mathematical modeling as a means for analyzing mass and energy exchanges in a closed ecosystem, illustrated with a simplified system (consisting of man himself, the salvage link, the biological link, and the food preparation link). If we write the letters A, B, C, and D for the amount of dry solid output from each link, the mass-exchange scheme can be represented as follows:



where the short loop C—A represents the combining of garbage (inedible wastes) with excreta (human metabolic wastes). Mass exchanges between the various links can be written as a system of differential equations:

$$dA/dt = k4DA = k5CA - k1AB,$$
$$dB/dt = k1AB - k2BC,$$
$$dC/dt = k2BC - k3CD,$$
$$dD/dt = k3CD - k4DA,$$

where k's are constant rates of transformation of one mass into another. Similar systems of equations may be written for individual chemical substances participating in mass exchanges in all links of the cycle. Energy exchanges can be similarly represented. The same approach may be used for open systems. Solution is by finding analytical expressions for the individual components of each differential equation. These may be based on experimental data obtained for each link under various experimental conditions. These data must be obtained for the individual chemical substances H_2O, CO_2, and O_2, total dry mass, and heat of combustion of the latter. Only biologically active chemical substances need be considered. This type of mass exchange description does not include quantitative or qualitative variation of the compounds input to or output from each link. In actual practice some of these values will have to be determined, e.g. the fat, protein, hydrocarbon, and cellulose content of foodstuffs, or the concentrations of inorganic salts in culture media. Microanalysis will indicate how well the system is working; gas-chromatograph tests of drinking water, for instance, will provide a means of monitoring the water-regeneration unit of the salvage link.

UDC: 613.693:629.198.5

22. THEORETICAL SUBSTANTIATION OF THE PRINCIPLE OF AUTOMATIC COMPETITIVE SELECTION OF PRODUCTIVE FORMS OF UNICELLULAR ALGAE ON THE BASIS OF MATHEMATICAL MODELING OF THE GROWTH DYNAMICS OF THE MULTICOMPONENT POPULATION UNDER CONTINUOUS CONDITIONS

Tsoglin, L. N., V. Ye. Semenenko, and A. K. Polyakov. Biofizika, v. 12, no. 4, 1967, 704-714.
AP7025618

In the selective genetic work of developing new, highly productive strains of unicellular algae, there arises the complex problem of isolating from the population, after action of the mutation factor, species with the required mutation. Moreover, this selection must be made directly under intensive cultivation conditions. A mathematical model of the growth of multicomponent populations of unicellular algae under accumulative and under continuous (circulating-system) cultivation conditions was examined. The growth dynamics of multicomponent populations of unicellular algae in the exponential and linear growth stages in a circulating system were analyzed. Relationships were developed for the changes of the quantitative ratios of the individual components of the population, which differ according to specific growth rates. A theoretical basis is given for the principle of automatic competitive selection of unicellular algae strains according to their productivity under given external conditions. The applicability of continuous cultivation of algae for the selection of highly productive forms is shown. Mathematical relationships and graphic plots are given from which the time at which productive strains should be isolated from the complex population can be determined, depending on differences in the specific growth coefficients of the strains in population, on their initial concentrations, and on the density of the suspensions in which the continuous cultivation is carried out.

Asso: Institut fiziologii rasteniy im. K.A. Timiryazev AN SSSR (Institute of plant physiology im K.A. Timiryazev of the Academy of Sciences, USSR), Moscow

23. METHODS OF MAINTAINING A CONSTANT pH LEVEL IN CULTURES OF MICROORGANISMS

Yelizarova, T. N. Mikrobiologiya, v. 36, no. 1, 1967, 38-45. AP7009798

Cultivation of *Pseudomonas pyocyanea* P. on media containing amino acids as carbon and nitrogen sources resulted in a significant increase in pH. Maintenance of the initial pH level was accomplished by including a 0.5-M phosphate buffer or about 20 g of IRC-50 amberlite/100 ml of culture medium. The use of a 0.5-M phosphate buffer in a medium with glutamic acid resulted in pH control within 0.5 unit; the use of amberlite resulted in control within 0.1 unit. It was found that optimum buffer concentration depends on the characteristics of the amino acid used and should be experimentally determined in each case. Biomass yield of the variety studied here increased in comparison to a control culture. [CD]

UDC: 576.8.093.33

Biologo-pochvennyy fakul'tet Moskovskogo gosudarstvennogo universiteta im. M.V. Lomonosov (Biology and Soil Science Department of the Moscow State University im. M.V. Lomonosov)

24. THE PROBLEM OF RADIANT ENERGY DISTRIBUTION IN CHLORELLA SUSPENSIONS

Filippovskiy, Yu. N., V. Ye. Semenenko, and A. A. Nichiporovich. Fotosinteziruyushchiye sistemy vysokoy produktivnosti (Photosynthesizing systems of high productivity). Moscow, Izd-vo "Nauka", 1966, 193-203.

The article presents a method of determining radiant energy intensity in plane-parallel Chlorella cultivators. It is shown within the accuracy limits of this method that the spectral hemispheric translucence coefficients of a Chlorella suspension depend exponentially on cell concentration and thickness of the culture layer for all practicable variations of these two parameters assuming that there is no edge effect; and that this exponential dependence holds with the same accuracy for all wave lengths in the photosynthetically active region of the spectrum. The maxima of spectrally oriented translucence coefficients of a Chlorella suspension are displaced 5 mμ toward the longer wave lengths from the maxima of spectral hemispherical translucence coefficients. Spectrally oriented translucence coefficients show selectivity at cell concentrations over 150 x 10^6 cells per milliliter, but are dependent on c and d in accordance with Buger's law for smaller concentrations. Values for the spectral hemispherical coefficient of unit absorption were experimentally obtained for *Chlorella sp.* K which can be used to calculate the light field in the suspension (assuming no edge effect).

25. OPTICAL CHARACTERISTICS OF CHLORELLA SUSPENSIONS EXPOSED TO COMPLEX SPECTRA

Filippovskiy, Yu. N., V. Ye. Semenenko, and A. A. Nichiporovich. Fotosinteziruyushchiye sistemy vysokoy produktivnosti (Photosynthesizing systems of high productivity). Moscow, Izd-vo "Nauka", 1966, 204-212.

The dependence of the energy and quantum coefficients of translucence of *Chlorella sp.* K suspensions on density and culture layer thickness are computed for the radiation spectra of the light sources commonly used for intensive cultivation. The deep layers of a Chlorella suspension are more transparent than the surface layers to light flux in the photosynthetically active range from xenon lamps with a near-solar spectrum, mirror lamps with an incandescence $T_1 = 3000°K$, and BS-type fluorescent lamps. Qualitative characteristics of this phenomenon are given. The quantum content of a unit of photosynthetically active radiation is constant for any unit volume in the Chlorella cultivator, regardless of depth differences in the spectral composition of the light. Based on the fact that the range of sets of spectral translucence coefficients for Chlorella at various cell concentrations and layer thicknesses generates a curve similar to that obtained for the leaves of higher plants, the hypothesis is suggested that the quantum-energy composition of light is also constant for higher plant cenoses. The dependence of Chlorella cell photosynthesis on the density of quantum flux penetrating an optically thin layer of suspension can be used as a basis for calculating the photosynthetic productivity of a cultivator and for designing equipment with specified productivity and dimensions.

26. MATHEMATICAL MODEL OF AN AQUATIC ECOLOGICAL SYSTEM

Vinberg, G. G., and S. I. Anisimov. Fotosinteziruyushchiye sistemy vysokoy produktivnosti (Photosynthesizing systems of high productivity). Moscow, Izd-vo "Nauka", 1966, 213-223.

The authors present a mathematical model of an aquatic ecological system of the pond or reservoir (pelagic) type, containing phytoplankton, zooplankton, planktonivorous fish, dead matter produced by dying organisms and unassimilated food particles, and bacteria which subsist on the dead organic matter and support the zooplankton. The photosynthesizing links of such a system (phytoplankton) are not directly usable by man, who exploits primarily the animal links at the 3rd or 4th level of radiant energy utilization (fish). Mathematical expressions are given for each link relating time in days, biomass growth, daily food intake, unused food, metabolic energy loss, biomass attrition by death of organisms, etc. The growth curve obtained with this mathematical modelling method for the fish biomass agrees well with the S-curve observed in actually fishery ponds. The authors are unwilling at this point to regard this as more than an indication that their approach to the modelling problem is soundly based, and that mathematical modelling techniques are applicable to the problem of predicting the productivity and utilization of photosynthesis in complex natural and artificial ecosystems.

27. PROBLEM OF REPRODUCTION OF FOOD PROTEIN BY AUTOTROPHIC ORGANISMS IN EXTRATERRESTRIAL CONDITIONS

Fofanov, V. I., A. S. Ushakov, N. S. Klyushkina, and K. V. Smirnov. Paper delivered at the 10th Annual Meeting of COSPAR, London, July 1967.

Experiments were conducted on 4 generations of white rats which received a diet with protein derived exclusively from algae (partly decolorized mixed biomass of *Chlorella* and *Scenedesmus*). High survival and viability of offspring and the absence in all generations of abnormalities in nitrogen balance, blood protein levels, liver nitrogen and lipids, etc., show algal protein to be of sufficient nutritional value. Increased urine excretion of amino nitrogen indicates some amino acid imbalance in the algal diet. A group of 5 men received a 30-day diet of plant protein (50% of algal origin). Food value and digestibility of this diet was less than for a diet containing animal protein. No abnormalities in protein metabolism occurred. Although algal biomass was found to be unsuitable for direct human consumption (the large quantities used in the experiment were not only unappetizing but caused gastrointestinal upset), its nutritional value makes it worthwhile to seek ways of converting algal biomass by lower heterotrophs (such as hydrogen reducing bacteria) to a form usable by man. Bacterial cells produce a high quality protein richer in tryptophan, lysin, and methionine than algae. *In vitro* digestibility of bacterial protein is similar to that of casein. Addition of higher plant links to convert algal and bacterial protein to a form suitable for man seems the most feasible means of obtaining plant proteins usable by man and containing sufficient amounts of essential amino acids.

28. EXPERIMENTAL BIOLOGICAL LIFE SUPPORT SYSTEM. 1. CONTINUOUS CULTIVATION OF ALGAE AS A LINK OF CLOSED ECOSYSTEM

Kirenskiy, L. V., I. A. Terskov, I. I. Gitel'zon, G. M. Lisovskiy, B. G. Kovrov, and Y. N. Okladnikov. Paper delivered at the 10th Annual Meeting of COSPAR, London, July, 1967

Various algae culture methods and variants are modelled mathematically to find that most suitable for use as an atmosphere regeneration link is a closed ecological system. Turbidostatic culturing is preferred over chemostatic as offering constant cell concentration and maximum productivity for any given set of culture conditions. Light limited cultures are best for single-celled autotrophs. This type of system lends itself to quasicontinuous culturing, in which fluctuations in culture conditions due to periodic rather than continuous replenishment are kept within limits which do not affect productivity. In turbidostatic cultures only two parameters need be stabilized by automatic control systems: temperature and cell concentration. A culture was experimentally obtained which produced O_2 at a daily rate of 100 liters per square meter of illuminated surface and 40 liters per liter of suspension, and an automatic system meeting the daily human O_2 requirement was built around it. Productivity fluctuations remained less than 15% with this control system, which gave 1500 hrs of trouble-free operation. Direct and dispersed sunlight and gas-discharge xenon and fluorescent lamp light were found to be equally efficient for illumination.

29. EXPERIMENTAL BIOLOGICAL LIFE SUPPORT SYSTEM. 2. GAS EXCHANGE BETWEEN MAN AND MICROALGAE CULTURE IN A 30-DAY EXPERIMENT

Kirenskiy, L. V., I. A. Terskov, I. I. Gitel'zon, G. M. Lisovskiy, B. G. Kovrov, and Y. N. Okladnikov. Paper delivered at the 10th Annual Meeting of COSPAR, London, July, 1967.

Healthy men and women 20 to 33 years old remained up to 30 days in sealed cabins containing stabilized microalgae cultures. Maximum activity was maintained by scheduled physical exercise and encouraging movement about the cabin. The following indices were monitored: body temperature, body weight, blood pressure, pulse and respiration rates, vital capacity, respiratory minute volume, alveolar CO_2, visual and motor reflexes, mechanical memory, attention span, dynamometry, EKG, and oxygenometry. Gas levels in the atmosphere of O_2, CO_2, CO, ammonia, hydrogen sulfide, mercaptan, nitric oxide, indole and skatole were also monitored. Cabin microflora were assayed once a day. The following conclusions were drawn from the experiments: Continuous biological (microalgae) regeneration of a closed cabin atmosphere containing man was attained. Man and *Chlorella vulgaris* are biologically compatible: the gas excreta of neither are toxic to the other. Any discrepancy between the respiratory ratio of man and the assimilation ratio of the algae can be adjusted by altering the man's diet, and the types of diet which this may require fall in the physiological optimum range for man.

30. MAN AS THE MAIN COMPONENT OF THE CLOSED ECOLOGICAL SYSTEM OF A SPACECRAFT OR PLANETARY STATION

Parin, V. V., and B. A. Adamovich. Paper delivered at the 10th Annual Meeting of COSPAR, London, July, 1967

The authors review concepts basic to closed ecosystem design. Life support systems must provide a normal environment which will secure high performance over long periods. Problems affecting design of the basic environment are mainly related to available power constraints and weight penalties; the problems of long-term operation are mainly related to man-system interactions which can significantly change the environment. Not only the optimal values, but also the permissible limits of variation of environmental parameters must be established and incorporated into system design. Man is not only a passive consumer link in long-term closed ecosystems, but an active system control link as well. This mains making the human organism itself function as a biosensor in system control feedback loops, and basing control of the system on changes introduced by the presence of man in the system. A recovery coefficient (weight ratio of expendable substances with and without regeneration) is proposed as an index of system efficiency. Automatic biomonitoring, on-board telemetry (from the organism to on-board monitoring equipment), biomedical data processing, and diagnosis and prognosis of functional state are other development problems of life support systems design.