Papers on the Lunar Settlement

Life Support 1 : Atmosphere

0. Summary The atmosphere maintained in the inhabited sections of Luna City shall consist principally of oxygen gas, at a pressure of approximately 30 kPa.

1. Selection The atmosphere selected must support human life and must be adaptable to various conditions, and to the purification systems and life-support arrangements which may be required in differing situations. It must also be readily producible using resources available at Luna, as owing to its great volume, it constitutes one of the largest single uses of resources in the entire project.

2. Biological Suitability Oxygen is a required component of any atmosphere which is intended to support human life. In the sea-level standard atmosphere its partial pressure is about 20 kPa ; at high altitudes, where life can be supported with some difficulty, the partial pressure can be 10 kPa or below. We prefer an atmosphere with more oxygen, rather than less, even though the risk of fire is increased. In such an atmosphere, breathing difficulties and the like are proportionally lessened, hypoxia becomes less likely, and the operation of the aerobic metabolism may be improved.

Water vapour and carbon dioxide are necessary minor constituents. A very dry atmosphere tends to dehydrate body tissues and produce discomfort. Only relatively little, however, can be used. At 30° C, the vapour pressure of water is only about 4 kPa, and an atmosphere saturated with water tends to produce discomfort again with a clammy feeling, as well as condensation on surfaces, damage to absorbent materials, mildew growth, and other undesirable effects. Relative humidity of about 50%, or a partial pressure of 2 kPa, is probably indicated. Carbon dioxide has a stimulating effect on human respiration, but in concentrations higher than a few per centum it produces a “prickly” sensation and can encourage hyperventilation ; strongly charged atmospheres are known to produce a sensation of panic and terror. Plant nurseries will presumably employ a higher proportion of this gas, but its use in ordinary spaces must be restricted.

Nitrogen gas does not appear to be of any biological significance except to certain kinds of plant growth. In general, fixed nitrogen in soils or hydroponic nutrient solutions will suffice. If a special greenhouse atmosphere is provided, it may incorporate some nitrogen gas as needed. No other substances present themselves for consideration as biological necessities.

Any atmosphere intended for human respiration must also exert enough pressure to allow the breathing apparatus to function normally. The minimum pressure, it would appear, lies in the region of 10 to 20 kPa.

3. Availability The internal volume of Luna City is many hundreds of cubic kilometers, making it important not to consume scarce substances. As a by-product of metals refining, oxygen is definitely non-scarce, and can be used to practically any extent desired. Both water and carbon dioxide are composed primarily of oxygen by weight, although they do consume scarce carbon and hydrogen as well. As noted above, the

required quantities of each are small in proportion to that of oxygen.

Some consideration should be given to diluent gasses, which increase the atmospheric pressure without any biological effect. One possible purpose of such a gas is to augment the atmospheric pressure for some purpose, such as ensuring the operation of the human respiratory system, raising the boiling point of water, or increasing the efficiency of balloons, while controlling oxygen content. Helium is likewise used in deep-sea diving to maintain pressure equilibrium while preventing oxygen or nitrogen narcosis. It is not clear that such measures are needed. A second purpose is to prevent fire. It is supposed that, if part of the thermal energy in an environment is spread to an inert gas, rather than all being confined to oxygen molecules, the propagation of flame becomes more difficult. Since organic matter is to be confined principally to the life cycle, fixtures and furnishings at Luna City will be fabricated generally from ceramics, glass, stone, and bulk metal, none of which poses a fire danger comparable to that from the plastics, vegetable-fibre cloth, and other organic substances widely used on Earth.

Possible diluent gasses include helium and argon, derived from radioactive decay and recovered in the course of gas drilling. Helium increases the thermal conductivity of an atmosphere, making it feel cold, and shifts the pitch of the voice towards shrillness. In general, as there seems no specific need for them in the general air, it seems best to confine the use of these to industrial uses and atmospheres for special applications.

4. Processability It seems clear that, the simpler in composition an atmosphere is, the easier it will be to process. In the reductive case of a single component, it is necessary only to regulate the pressure. For the case of a mixture of gasses, the fewer the components, the easier to keep the composition in balance.

It does not appear that any added gasses would contribute to ease of processing. Diluents will increase the quantity of air which must be handled by the ventilation and purification apparatus, and some components such as nitrogen could form undesirable compounds in some processing conditions. This argues for an atmosphere composed principally of oxygen, with traces of water and carbon dioxide.

5. Pressure It is desirable to maintain a shirtsleeve environment in the inhabited spaces, for convenience and for the sake of infants and the infirm. At too low pressures, the fluid balance of the body is affected, and breathing can become difficult owing to the lack of external pressure. Although we have above indicated a preference for more oxygen rather than less, at too high pressures intoxication becomes a problem.

The Apollo spacecraft were pressurized to approximately 35 kPa under service conditions, using pure oxygen, and inhabited for a period of several days ; the Skylab employed a mixture of 24 kPa oxygen and 10 kPa nitrogen, during missions up to 84 days. In neither case, nor in similar experiments in Earthbound pressure chambers, were any considerable ill effects observed, and we may suppose that altitude sickness does not occur in this range of pressures, as

long as sufficient oxygen is supplied.

There are other issues to be considered. At a pressure of 30 kPa, the boiling temperature of water falls to about 70° C, which will result in changes to cooking practices and other matters which rely on boiling water. Various other processes which depend implicitly on atmospheric pressure are likely to be affected in the same manner.

Therefore, an atmosphere consisting principally of oxygen is employed. The partial pressure of oxygen is nominally 30 kPa ; principal additional components are water and carbon dioxide, both in the range 0.5 to 5 kPa typically. Caution is required when applying these figures. While the maintenance of constant airflow in the ventilation system prevents stratification of the atmosphere, relative humidity and carbon dioxide will vary with position and time based on temperature, occupancy, and other figures ; and over the 5+ km variation in height within the city envelope, a 4 kPa altitude effect will be observed (far less than for a comparable scale on Earth, due to the lower gravity). To avoid an excessive rarefaction in the upper levels, it is probably best to specify this pressure at nominal grade, 5000 m above concourse level, since moderate increase in pressure is less likely to lead to problems than a decrease.

6. Conclusion A description of the Luna City primary habitat atmosphere has been developed, based on biological and engineering requirements. Some reference has been made to the necessity of providing separate atmospheres for special purposes.