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SPANISH PLANS FOR COLUMBUS UTILIZATION

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For the time being, plans for Spanish activities related to Columbus utilization are in a very early stage, rather in the stage of identification of potential users.

As the Columbus Utilization is a natural continuation of the Spacelab Utilization, the starting point has been to review the plans of the groups already related to Spacelab. This is a very easy task as users of Spacelab are limited to two groups, both in the field of microgravity but in two different areas, fluid physics and biology.

The first group, under the direction of Dr. Da Riva, has developed a sound theoretical and experimental work, during several years, in floating zone. The experiment has flown in the first Spacelab mission and will refly again the D 1 mission this year. Dr. Da Riva has also flown experiments in sounding rockets, in the Texus programme, and in airplane KC-135, within the Esa Microgravity programme.

Later on, the paper prepared by the Dr. Da Riva, who was not able to attend the workshop, is presented.

The second group, under the direction of Dr. Marco, will fly a first experiment related to the effects of microgravity on genetics in the D 1 mission. This is a first approach to Genetics in space, the matter of research is the determination of the effects of gravitational forces on the topological distribution of the cytoplasmatic determinants in the embryo of *Drosophila melanogaster*.

This is an old problem in biology that has been approached on the ground by submitting the embryos to rather high centrifugal forces, but no definitive results have been reached.

Dr Marco suggests that gravitational forces have a main effect during the oogenesis and that in order to demonstrate that the gravitational force has a physiological influence on the topological distribution of the embryo components it is more appropriate to eliminate their action than to increase them.

The choice of *Drosophila melanogaster* as the most appropriate organism for the experiment is based on the following:

—Its short life cycle makes possible to expose the embryo to microgravity conditions during the whole period of development, including the oogenesis.

—*Drosophila* has been one of the organisms more used in space experiments; therefore, compatibility with space conditions, including ability to produce eggs and for growing, is known.

—Previous space experiments show anomalous embryos at the end or after the flight, while embryos were normal at the beginning of the flight. This suggests that embryos from oogenesis on the ground have a normal development in space, while this is not the case for embryos from oogenesis in space.

The experiment requires to collect and fix the embryos for further morphological study. The ESA Biorack facility provides support to the experiment.

Dr Marco will extend the experiment to a long duration mission, a EURECA mission lasting six months in space, in order to achieve 12 generations of flies with the scientific objective to study the evolution of living beings under the effect of microgravity. The proposal, approved by ESA, will fly in the first EURECA mission which carries the botanical facility.

The space activities of Dr. Marco's groups will follow this line of research.

A third group, without space experience but with a sound background, related to combustion research, has shown interest in space experiments. For the time being, it is starting space activities within the ESA microgravity programme.

Summarizing, there are three fields in which we will apply the initial efforts, fluid physics, genetics and combustion. In the coming months we will extend the contacts to other fields in order to cover the wide spectrum of science, technology, applications and commercialization. We hope that the name Columbus, extremely significant to us, will motivate not only our community of potential users but, also, those institutions which must support their activities. The following text is the paper prepared by Dr. Da Riva on the fluid physics activities of his group.

Spain, a small country with very limited resources, which traditionally devotes a minimal fraction of its GNP to scientific and technical affairs, will participate with a fraction of the order of 7% to Project Columbus. This represents, by all standards, an astronomical amount of money, which resulted from a political decision and which parallels the situation, five centuries ago, when Queen Isabel sold her jewels to financiate Columbus' enterprise.

I think that the Spanish scientific community will support this decision as modest sailors engaged in the traffic of spices did in the past. Unfortunately, I am afraid that the important task of convincing people to leave their comfortable small business and embark on the new uncertain endeavour is still to be done.

Columbus offers greater time, space and flexibility to the would-be investigator. Time is a paramount variable. Greater time means less tight a schedule, which was one of the most demanding restrictions on board Spacelab, but also requires a new philosophy, a new open mind to devise new experiments.

Although several Spanish groups are active in the fields of material sciences, life sciences, com-

PREPARATORY WORK ON EARTH	
Analysis	
Simulation	
FLIGHT OPPORTUNITIES	
Spacelab SL 1	December 1983
Texus 10	May 1984
Airplane KC-135	December 1984
Texus 12	May 1985
Airplane KC-135	June 1985
Spacelab SL-D1	October 1985
ANALYSIS OF THE RESULTS	
ANALYSIS OF RESULTS FROM OTHERS	
FUTURE OPPORTUNITES	

Fig 1

bustion ... I will take a few minutes of your time talking about the activity of a group engaged in fluid-dynamics research. The choice is due to the fact that the present speaker is familiar with such work and in no way implies demerit in the work by others.

In 1974, answering to a call for ideas from ESA the group proposed an experiment, to be performed on board the Spacelab 1st mission, on the stability of liquid bridges. Activity since then is summarized in Fig 1

Figure 2 shows liquid bridge configurations which have been considered up to now.

*A fairly recent list of references can be seen in: I Da Riva and I Martinez, Long Liquid Bridges, *Eurospace Symposium on Industrial Activity in Space*, Stresa, Italy, 2–4 May, pp. 137–178 (1984)

†See a list of references in: I Da Riva and L G. Napolitano, Fluid Physics under Reduced Gravity—An Overview, *ESA SP-191*, pp 5–12 (1983).

‡W J Ward III and O H Le Blanc Jr. Rayleigh–Benard convection in an electrochemical redox cell *Science* **225**, 1471–1472 (1984)

Several of the results of this systematic investigation have been discussed in previous meetings and most of them have already appeared in learned international journals of fluid mechanics, crystal growth and interface science *

SURFACE TRACTION INDUCED CONVECTION

Buoyancy induced convection almost disappears in reduced gravity, but since interfaces are usually larger than on Earth, convection induced by surface tractions could overcome that produced by buoyancy.

Surface tractions can be produced, among other causes, by surface tension gradients due to temperature or to concentration gradients. Most of the recent work involves temperature gradients, because this is relevant in the field of crystal growth from the melt.

Much work has been and is being undertaken on the so called thermocapillary convection†. Reduced gravity is simulated on Earth by use of the millimetric zone technique. In this type of experiment the environment disturbs the bridge and a quantitative analysis of the results is difficult.

The situation with concentration-induced surface tension gradients could in some aspects be easiest to analyze; the disturbing effect of the environment is reduced. These experiments however, cannot be performed on a steady state basis since the composition of the interface changes with time. In electrochemical cells, for example ferrous-ferric redox cells, the migration of the electrolytes to or from the electrodes interferes with buoyancy induced convection in a way which can be easily monitored‡. The analysis is not simple anyway: two complex phenomena interfere with each other. The parallel phenomenon of surface traction induced convection is worth being considered. Transients after shutting-on or off the electrical current through a liquid bridge between two electrodes are presumably very sensitive to surface traction induced convections within the bridge.

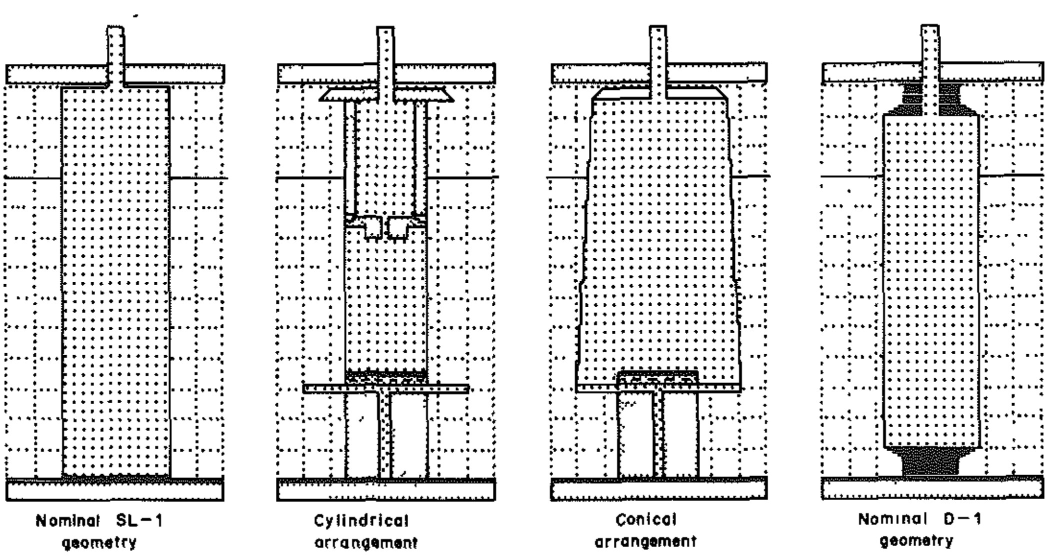

Fig 2 Long liquid columns aboard Spacelab

A third problem I would like to talk about concerns two-phase flow in ducts (in the simpler, adiabatic, case).

It is unnecessary to comment here the importance of these problems. Applications to pipe-lines, evaporators, chemical reactors, heat exchangers and other types of processing equipment are well known. The literature on the field is immense.

For large Space Stations, thermal conditioning using two-phase liquid–vapor working fluids presents the main advantage that heat of phase-change and not sensible heat is involved in the process. As a result the fluid temperature is nearly uniform and the system becomes less dependent on the heat load locations.

Two-phase flow, with large pumping requirements, is unavoidable in a series circuit. Figure 3 shows a simple series circuit with partial fluid acquisition, which has been studied by Grumman. Parallel circuits where the liquid-feed line and vapor-return line are separated would partially solve the problem of large power expenses, provided that the mass flow rate through each evaporator is exactly tailored to the heat source.

The difficulty in the calculation of the two-phase pressure drop in long ducts lies on the varied flow pattern which depends on very complex interface phenomena. How important gravity is?

Figures 4 and 5 show maps of fluid flow patterns for air–water mixtures in vertical upward and in horizontal flows. U is the superficial velocity, that is the volume flow rate of each fluid divided by the duct cross-sectional area.

This type of map is usually criticized on the grounds that so different transition processes can hardly be controlled by the same parameters. Thus, different investigators use different maps, with different boundaries and intermediate states. But for our present purposes these maps are useful since they illustrate what is obvious...Gravity is paramount.

Curiously enough annular flow remains in the same position in both maps: (but not too low) liquid

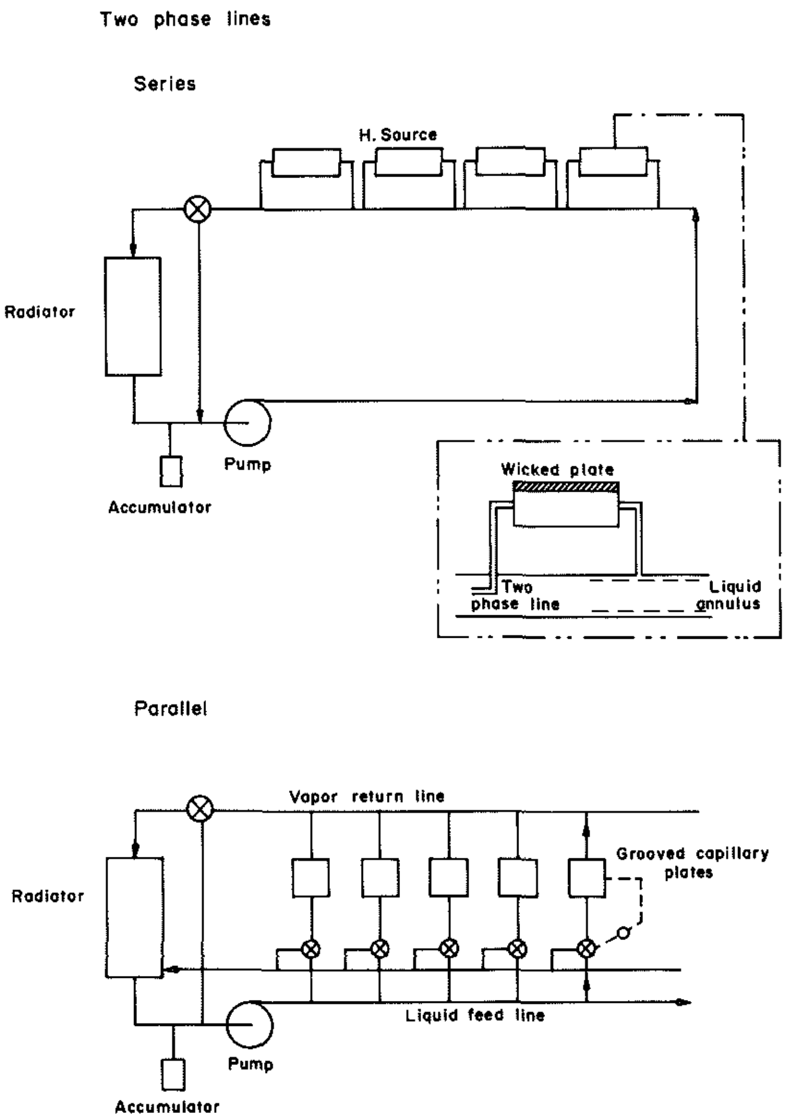

Fig. 3. Two phase lines.

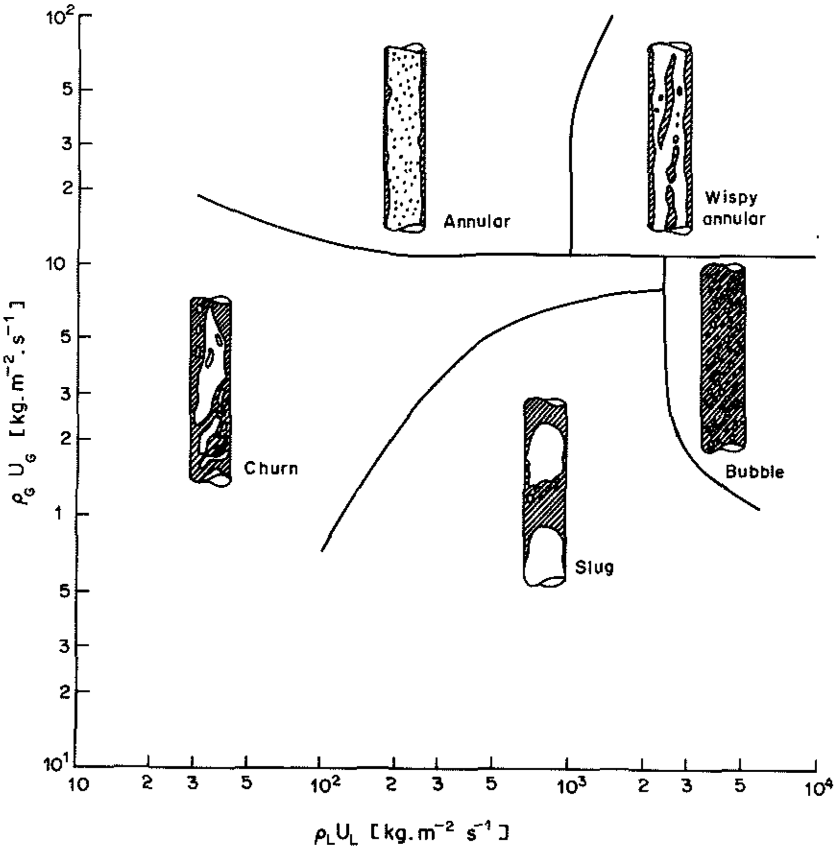

Fig. 4. Vertical upward.

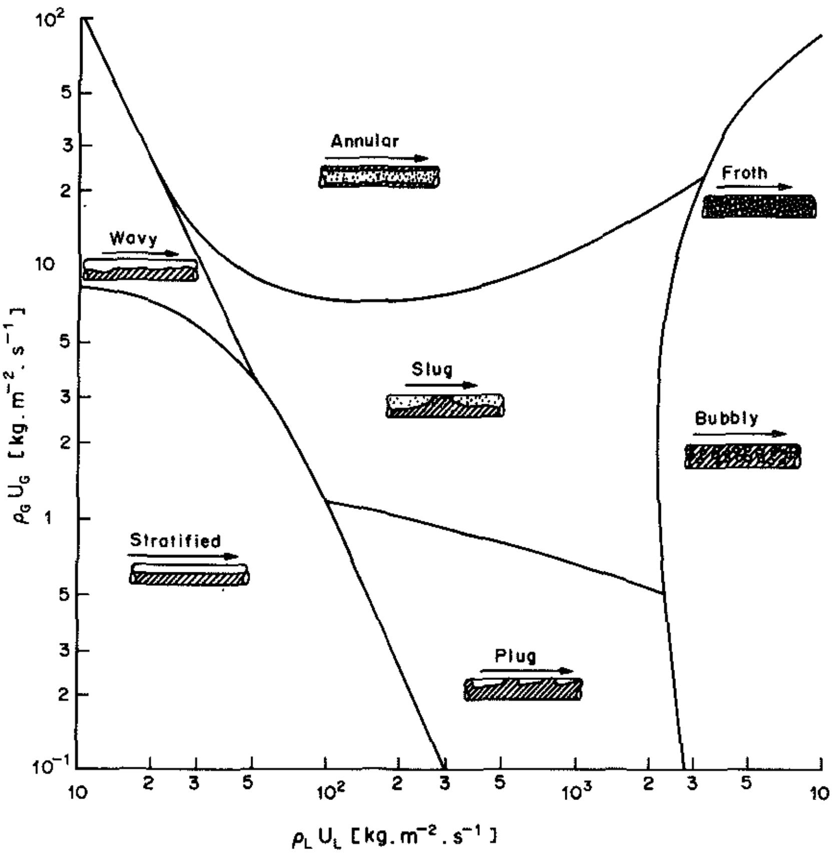

Fig. 5. Horizontal.

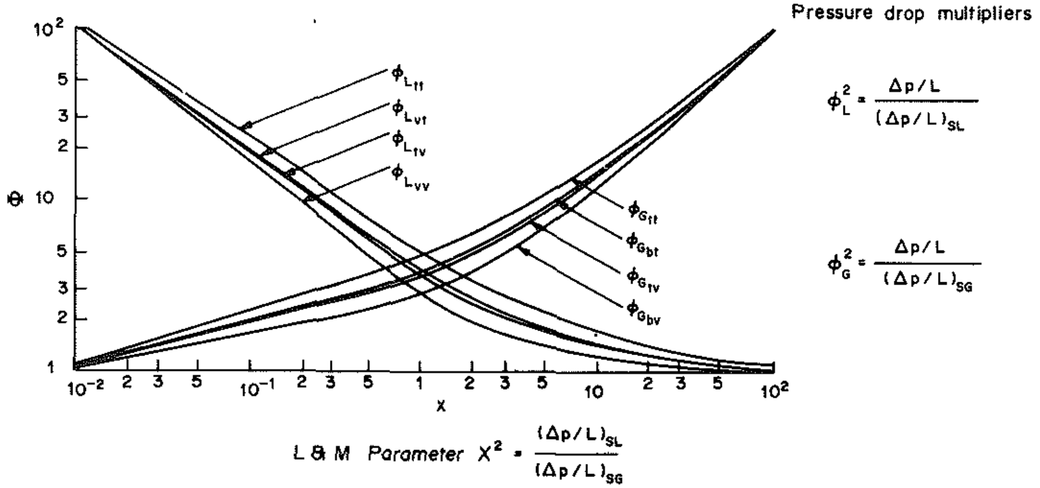

Fig. 6. Lockhart–Martinelli correlation.

velocity and large gas velocity. In trade-offs performed on different systems for heat management in large space platforms, the annular flow pattern is assumed to prevail. In addition, the flow can be forced into the annular pattern by means of helicoidal vanes, tangential injection, etc.

Knowledge of the flow patterns could be crucial for the optimization of many space processes. How important is in, for example, the pressure drop through ducts? Probably not very much.

For horizontal flow through tubes of small diameters (few inches), the Lockhart-Martinelli (Fig. 6) correlation has been widely used for decades, and improved many times.

Once known the pressure drop in single-phase flow of one of the fluids but for the total mass flow rate, the pressure drops for any of the two fluids in two-phase flow (both pressure drops are the same) is expressed as the above value times an appropriate multiplier. These pressure drop multipliers are functions of a parameter X, which is the square root of the ratio of the pressure drop that would occur if the liquid were flowing alone at a velocity equal to its superficial velocity divided by the pressure drop corresponding to the gas if flowing alone.

When both single-phase flows are laminar or both turbulent, X only depends on the superficial velocity ratio and on the density and viscosity ratio of the fluids. When one of the fluids flows laminarly and the other turbulent, the mass flow rate appears in X but in any case *THE FINE DETAILS OF THE FLOW PATTERN DO NOT APPEAR.*

This is almost a miracle, since separate curves for each flow pattern should be required, and have been suggested by different investigators. But when the results of these partial correlations are compared with those from Lockhart and Martinelli, the agreement is poor although it could suffice for many engineering purposes.

CONCLUSIONS

Let me briefly summarize some thoughts from my own recent experience in the field.

1st. Scientific content. If I can mention an outstanding single field, interface phenomena is probably the main object of scientific interest in space based material sciences.

2nd. To develop a systematic research on a given problem requires time:

(1) The preparatory work, with the conflicting requirements from other investigators who will share the same facility.

(2) Flight opportunities are scarce.

(3) The score of successes is still small.

3rd. Comments on a national basis. If Spacelab involvement was expensive, the next step will be more so. An active effort should be made on a national basis to acquaint the members of the scientific community with the difficulties of the endeavour and the promise of scientific and technical returns.