THERMAL CONTROL FOR PLANETARY PROBES

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DR. MCMORDIE: Now, the area that I want to focus in on is the thermal control of the probes, and particularly the descent phase of the mission.

Notice that I will not be addressing the entry problem, rather strictly the descent problem.

Now, if you ask ten thermal control engineers to devise a chart describing the technique for the development of a thermal control subsystem, you would probably get ten different graphs, or charts. Figure 9-38 illustrates one of these approaches, and I think it is fairly representative. You are given temperature limits; equipment limits; constraints such as power, volume, weight; and the environments that your equipment must survive in. Then you perform analyses, starting with studies on your conceived design, and often you will need to perform some development tests to support your trade studies.

For a probe mission you might conceive of a design that has insulation on the exterior of a pressure vessel, or the interior of a pressure vessel, or a vented design. In the case where you have the exterior insulation, or a vented design, you need to know how the insulation performs in the environment. In the case of the planetary-probe mission, you need to know how the insulation performs when subjected to hydrogen/helium atmosphere.

Also, it appears there are some problems in defining the environments and, particularly, the wide variation in the temperatures that you might encounter.

In Figure 9-39 the nominal environments for a nominal descent into three planetary atmospheres are shown. The important point here is the wide variation in temperatures between the Jupiter and Uranus missions. This is not an overwhelming problem, but it certainly has to be considered by the thermal control designer.

THERMAL CONTROL ENGINEERING

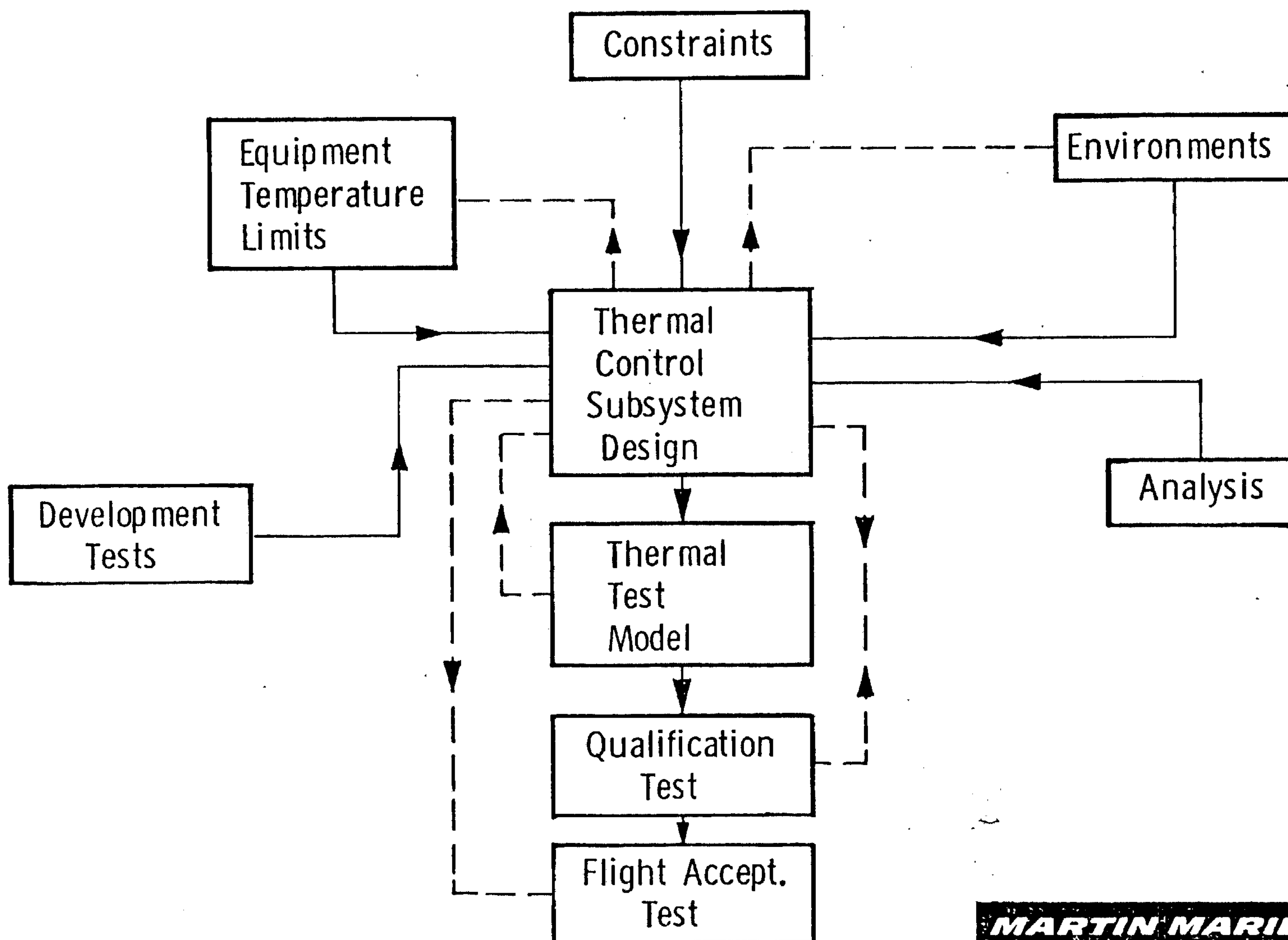

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FIGURE 9-38

COMPARISON OF PLANETARY DESCENT TEMPERATURE PROFILES

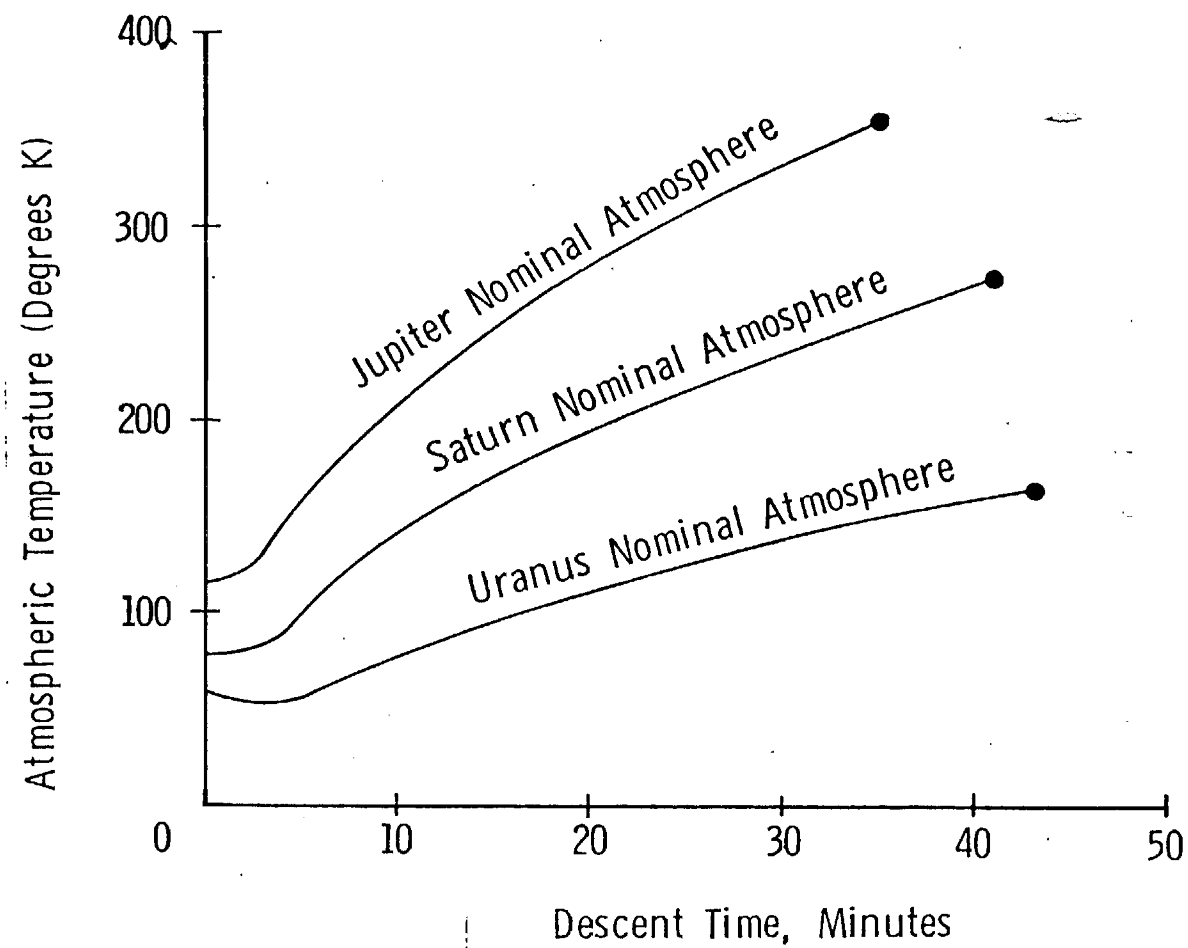

FIGURE 9-39

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Figure 9-40 shows temperature vs. time plots for Uranus descents. Here the temperature difference between a cold and warm model atmosphere is as large (approximately 200°C) as it is between the Jupiter and Uranus nominal descents.

Figure 9-41 shows data for a Venus descent probe. The test article was a solid sphere that was insulated with a fibrous, porous insulation. The test article was placed in a chamber that was controlled to match the pressure and temperature versus time for a Venus descent. The analysis, with and without mass transfer considered, did not match the test data even though experimental valves of the insulation conductivity was used.

The thing that we discovered was that there were two reasons why our analytical model, using steady-state test data, did not allow us to predict the performance. One was that free convection actually took place within the insulation. This is something that you would never expect, or at least I would never have expected to take place. In an earth environment, with the type of insulation we are using, you would never have any free convection or actual mass movement within the insulation.

The second thing that occurred that we feel accounts for some of the differences is that during a descent, when the CO_2 is moving into the insulation, you get an absorption effect which represents an energy release that caused the difference between the tests and the analyses.

The whole point here, then, is that for a new environment, such as the hydrogen/helium that we will encounter in the outer planets, I think transient tests of candidate insulations should be performed. Then we can perform the trade studies, trading interior, exterior or vented designs and determine the optimum design.

Figure 9-42 is a logic diagram for a generalized descent probe program. This program can be used for any planetary descent

DESCENT PROFILES AT URANUS

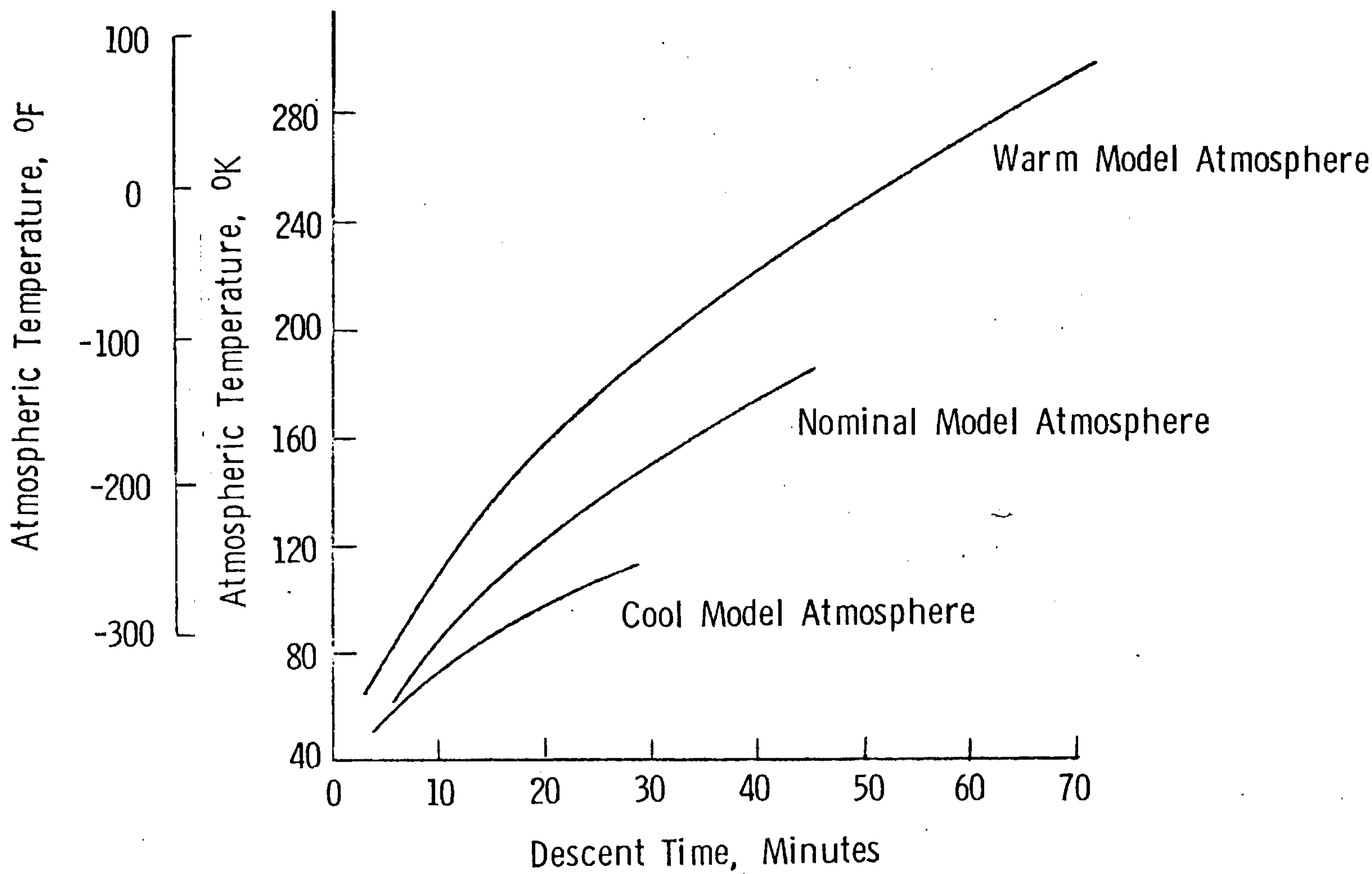

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FIGURE 9-40

DESCENT SIMULATION CORRELATIONS

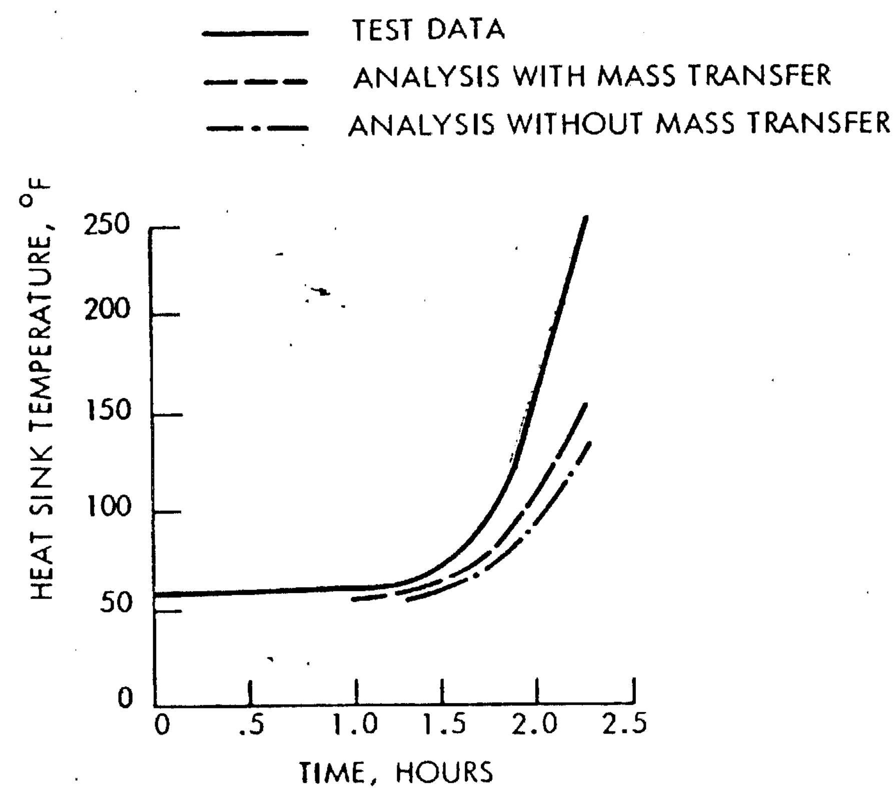

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FIGURE 9-41

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DESCENT PROBE THERMAL AND STRUCTURAL DESIGN PROGRAM

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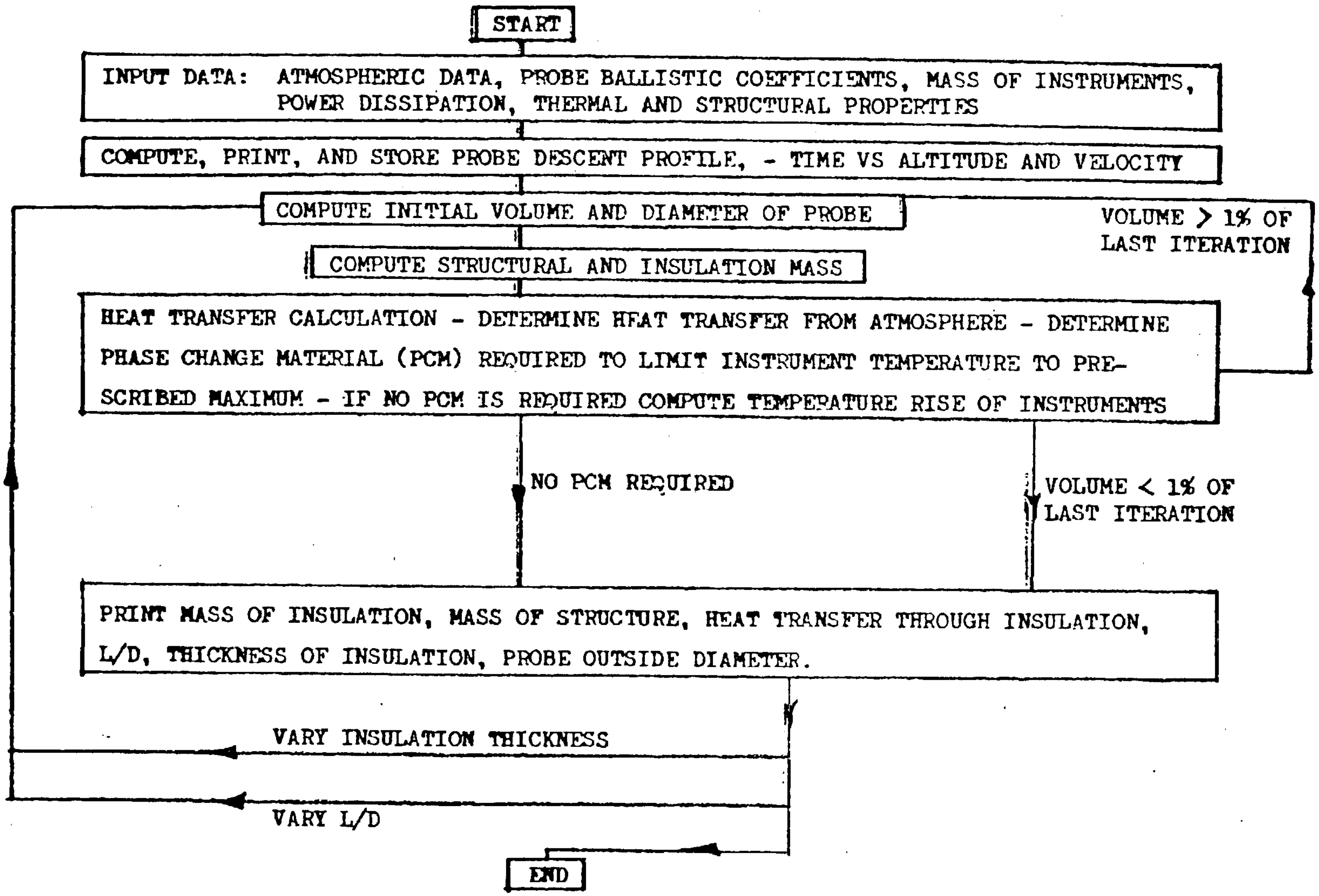

FIGURE 9-42

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and couples the structural and thermal aspects of the problem. At the same time, it performs weight calculations and analyzes the need for phase-change material, if needed. Aerodynamic equations are also used to compute the time-temperature and time-pressure profiles which would, in turn, define the environment for the probe.

In summary, this program provides a powerful tool to perform trade studies for planetary probes.

Figure 9-43 shows diagram of a test fixture that has been used to test an almost full-scale Pioneer-Venus large probe. The diameter of the test article was twenty-two inches. This facility was used to perform a test matching the Venus descent profile, both pressure and temperature in a CO_2 environment.

The problem areas relative to the thermal control of an outer planet descent probe are given in Figure 9-44. Relative to insulation performance, I would suggest that we perform transient tests on the candidate insulations in a helium/hydrogen atmosphere so that we can, in turn, perform trade studies, looking at various probe designs.

MR. TOMS: I think Bob McMordie made an important point about the atmospheric uncertainties. Particularly with the Uranus probe, the atmosphere definition needs to be refined if we are going to get a design we can live with.

If there are no more questions, I want to thank the speakers for being so well prepared and for giving us a good session this morning.

ATMOSPHERIC DESCENT TEST CHAMBER

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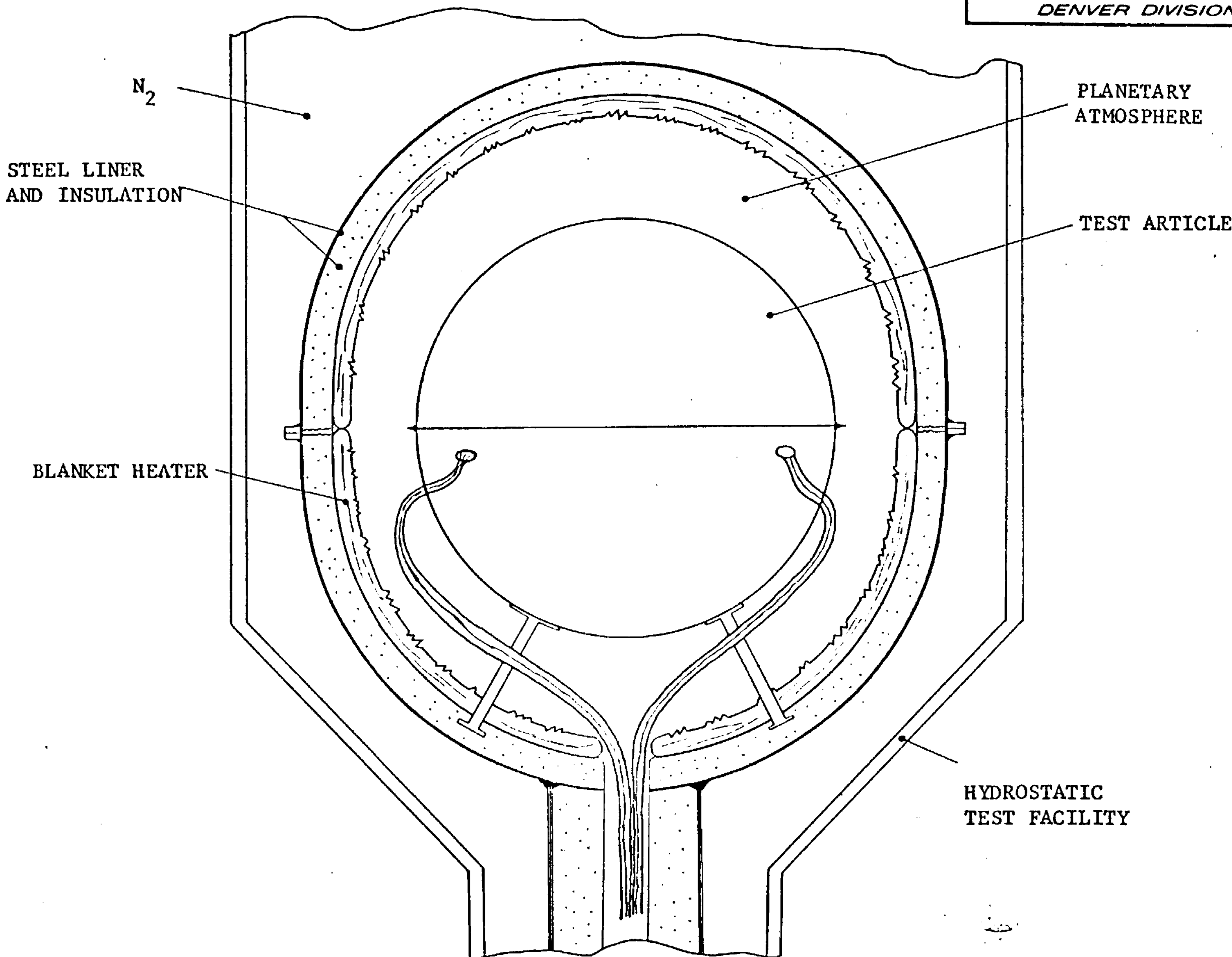

FIGURE 9-43

THERMAL CONTROL STATUS FOR PLANETARY PROBE MISSIONS

PROBLEM AREAS:

- o Atmospheric Uncertainties
- o Insulation Performance

FIGURE 9-44

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SESSION X

MISSION COST ESTIMATION

Chairman: N. Vojvodich
NASA Ames Research Center

MR. VOJVODICH: I would like to welcome you to the last session which is, in many respects, probably one of the most important sessions because it deals with the question of cost. It is not necessary for me to remind you that because of NASA's constrained fiscal situation, technical feasibility, which has been discussed for the past two and a half days, is certainly necessary but, unfortunately, not a sufficient condition for us to undertake these missions. More than ever before we are going to have to do them in a cost-effective manner if they are going to be, in fact, accomplished.

Now, as many of you know, the art of cost estimation has evolved over the years to become a relatively sophisticated combination of analytical capability and what I call black art, or a certain amount of magician's quality to it.

We have three distinguished practioners here. Unfortunately, one of the practitioners, Steve Duscai of Martin Marietta, could not make it because he is home in Denver costing out a new proposal, actually working a problem from the standpoint of a cost estimator.

We have changed the order of speakers around. Instead of having Bill Ruhland of JPL speak third, he will speak second, and Fred Bradley from McDonnell-Douglas will speak third.

The first speaker that we have on the agenda is eminently qualified to address the question. He is John Niehoff, Senior Engineer with the responsibility of planetary program manager with Science Applications, Inc. He is in the process of working parametric cost estimates for many of the outer-planet mission options under contract to Dan Herman at NASA Headquarters.