X-327-67-574
PREPRINT

NASA TM X- 63133

DYNAMIC PRESSURE OF A VOLUME WITH VARIOUS ORIFICES AND OUTGASSING MATERIALS

GPO PRICE $ ______

CSFTI PRICE(S) $ ______

Hard copy (HC) 3.00

Microfiche (MF) .65

ff 653 July 65

NOVEMBER 1967

GSFC — GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

X-327-67-574

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Test and Evaluation Division
Systems Reliability Directorate

November 1967

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

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PROJECT STATUS

This report is a part of the development of an analytical method to calculate pressure versus time for each of the compartments of a multicompartment system such as a spacecraft.

AUTHORIZATION

Test and Evaluation Charge No. 327-124-12-03-02

DYNAMIC PRESSURE OF A VOLUME WITH VARIOUS ORIFICES AND OUTGASSING MATERIALS

John J. Scialdone
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SUMMARY

The dynamic pressure of a spacecraft compartment exposed to a known external pressure profile is investigated. The compartment contains outgassing materials and has known orifice passages. Outgassing materials are: silicone rubber, epon, PTFE, mylar, epoxy, polyurethane, and silastic. The passages considered have areas of .01, .1, and 1.0 cm^2. A computer program is used to obtain the internal dynamic pressure. The results have been generalized by grouping in terms of a pumping time constant, the outgassing rate of the material at 1-hour vacuum exposure, and a quasi-steady pressure corresponding to the outgassing rate and the orifice molecular flow rate. Additional plots included here can be used to obtain pressures and times for other systems when the geometry and the behavior of the outgassing material are known. The plots can be used to identify objectionable pressure time conditions in a spacecraft and to indicate ways to avoid them by appropriate adjustment of parameters. The results obtained by the computer program have been compared to those obtained experimentally.

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ILLUSTRATIONS

ILLUSTRATIONS (continued)

DYNAMIC PRESSURE OF A VOLUME WITH VARIOUS ORIFICES AND OUTGASSING MATERIALS

John J. Scialdone
Test and Evaluation Division

INTRODUCTION

A study has been made of the transient pressure in a volume containing an outgassing material. The study is a part of the development of an analytical tool to calculate the pressure versus time for each of the volumes of a multivolume system (reference 1) such as a spacecraft. A mathematical description was developed for many volumes arranged in series, in parallel, or in combination. The volumes were assumed to be at constant temperature, containing materials outgassing with known characteristics, connected with passages of different geometry, and exposed to a general time-varying pressure environment.

As a result, a computer program was developed and is now being checked and debugged. The program will provide the numerical solution to the set of differential equations with variable coefficients representing the viscous, intermediate, and molecular flow-passage conductances. In this process, several computations have been made and some of the results are presented here.

Although the computations cover three regions of flow, the curves presented here have been grouped according to the molecular flow regime time constants and the outgassing characteristics of the materials. It is shown that with parameters and plots derived from computed profiles, one may estimate the pressure versus time for other arrangements of volume which has an orifice and contain an amount of outgassing material. This may provide an estimate of the balanced pressure and the time to reach them without performing a computer calculation or an actual test. In addition, pressure profiles of computed and experimental results have been superposed on the same graphs and compared.

Volume-Orifice Outgassing Material Combination Systems

The pressure profiles for the cases listed in Table 1 have been examined. These volume-orifice-material combinations were assumed to be exposed to a pressure-time environment obtained experimentally in an empty bell-jar pumping system used for investigation of corona (reference 2).

The figures in this document are graphs of the results of the computation. The curves, which were produced separately for each case, have been superposed for convenience. A sample of the data input needed for the computation

Table 1

Volume/Orifice/Material Combinations and Calculated Parameters

Volume V (l)	Orifice Area A_o (cm^2)	Pumping Speed S (l/s)	Surface Area And Material A_G (cm^2)	*Rate Material Outgassing @ 1 Hour Q_G (torr-l/sec-cm^2)	System Outgassing Rate After 1 Hour Q_L (torr-l/sec)	Time Const. - (sec)	Quasi-Steady Equilibrium Pressure P_L (torr)	Time For Quasi-Steady Pressure t_L (hr)
1	.975	11	80.5 Silic. Rubb.	7.0×10^{-6}	5.64×10^{-4}	0.1	5.12×10^{-5}	99
1	.975	11	80.5 Epon	4.0×10^{-6}	3.22×10^{-4}	0.1	2.92×10^{-5}	1.30
1	.975	11	80.5 PTFE	3.0×10^{-7}	2.42×10^{-5}	0.1	2.19×10^{-6}	2.80
1	.975	11	80.5 Mylar	1.3×10^{-7}	1.05×10^{-5}	0.1	9.55×10^{-7}	3.0
1	.975	11	120.0 Epoxy "200"	2.0×10^{-8}	2.4×10^{-6}	0.1	2.18×10^{-7}	4.4
1	.975	11	140.0 Polyuret.	5.0×10^{-7}	7.0×10^{-5}	0.1	6.36×10^{-6}	1.75
1	.975	11	140.0 Silastic	2.8×10^{-6}	3.92×10^{-4}	0.1	3.56×10^{-5}	1.35
1	.0914	1.032	80.5 Silic. Rubb.	7.0×10^{-6}	5.64×10^{-4}	1.0	5.45×10^{-4}	.82
1	.0914	1.032	80.5 Epon	4.0×10^{-6}	3.22×10^{-4}	1.0	3.11×10^{-4}	1.0
1	.0914	1.032	80.5 PTFE	3.0×10^{-7}	2.42×10^{-5}	1.0	2.34×10^{-5}	1.08
1	.0914	1.032	80.5 Mylar	1.3×10^{-7}	1.05×10^{-5}	1.0	1.01×10^{-5}	1.30
1	.0914	1.032	120.0 Epoxy "200"	2.0×10^{-8}	2.4×10^{-6}	1.0	2.32×10^{-6}	1.95
1	.0914	1.032	140.0 Polyuret.	5.0×10^{-7}	7.0×10^{-5}	1.0	6.78×10^{-5}	1.10
1	.0914	1.032	140.0 Silastic	2.8×10^{-6}	3.92×10^{-4}	1.0	3.79×10^{-4}	1.0
1	.00862	.0975	80.5 Silic. Rubb.	7.0×10^{-6}	5.64×10^{-4}	10.0	5.78×10^{-3}	1.09
1	.00862	.0975	80.5 Epon	4.0×10^{-6}	3.22×10^{-4}	10.0	3.3×10^{-3}	1.14
1	.00862	.0975	80.5 PTFE	3.0×10^{-7}	2.42×10^{-5}	10.0	2.48×10^{-4}	1.10
1	.00862	.0975	80.5 Mylar	1.3×10^{-7}	1.05×10^{-5}	10.0	1.075×10^{-4}	1.04
1	.00862	.0975	120.0 Epoxy "200"	2.0×10^{-8}	2.4×10^{-6}	10.0	2.46×10^{-5}	1.10
1	.00862	.0975	140.0 Polyuret.	5.0×10^{-7}	7.0×10^{-5}	10.0	7.18×10^{-4}	.90
1	.00862	.0975	140.0 Silastic	2.8×10^{-6}	3.92×10^{-4}	10.0	4.02×10^{-3}	.95

*Data from reference 3

and the corresponding numerical and graphical results appears in the Appendix. Outgassing characteristics for the material and its surface area are given input quantities. The outgassing characteristics were obtained from data available in literature (references 3 and 4) extrapolated to provide data for times less than 1 hour. The legend for the conductance (type 1) specifies that the passage is an orifice. Other passage geometries can be specified.

Parameters of the Evaluated Systems

The computed pressure profiles for one-liter volume with orifice passages, outgassing areas, and outgassing materials as indicated in Table 1 are shown in Figures 1, 2 and 3. These profiles show that the pressure drops very rapidly and within a short period of time to a quasi-steady value. This is the region of viscous and transitional flow regime. In this region, the relations expressing the passage conductance are nonlinear and dependent on pressure and viscosity (Ref. 1). Beyond this region, the flow is molecular and the conductance depends only on geometry. The pressure and the corresponding time for a system being evacuated are mainly a function of the parameters characterizing the flow in the molecular flow regime. In view of this, we have grouped the curves in accordance with certain parameters in the molecular region of the curves which are amenable to generalization, namely, molecular time constant τ, outgassing material gas load at 1 hour vacuum exposure Q_L, and a quasi-steady pressure P_L.

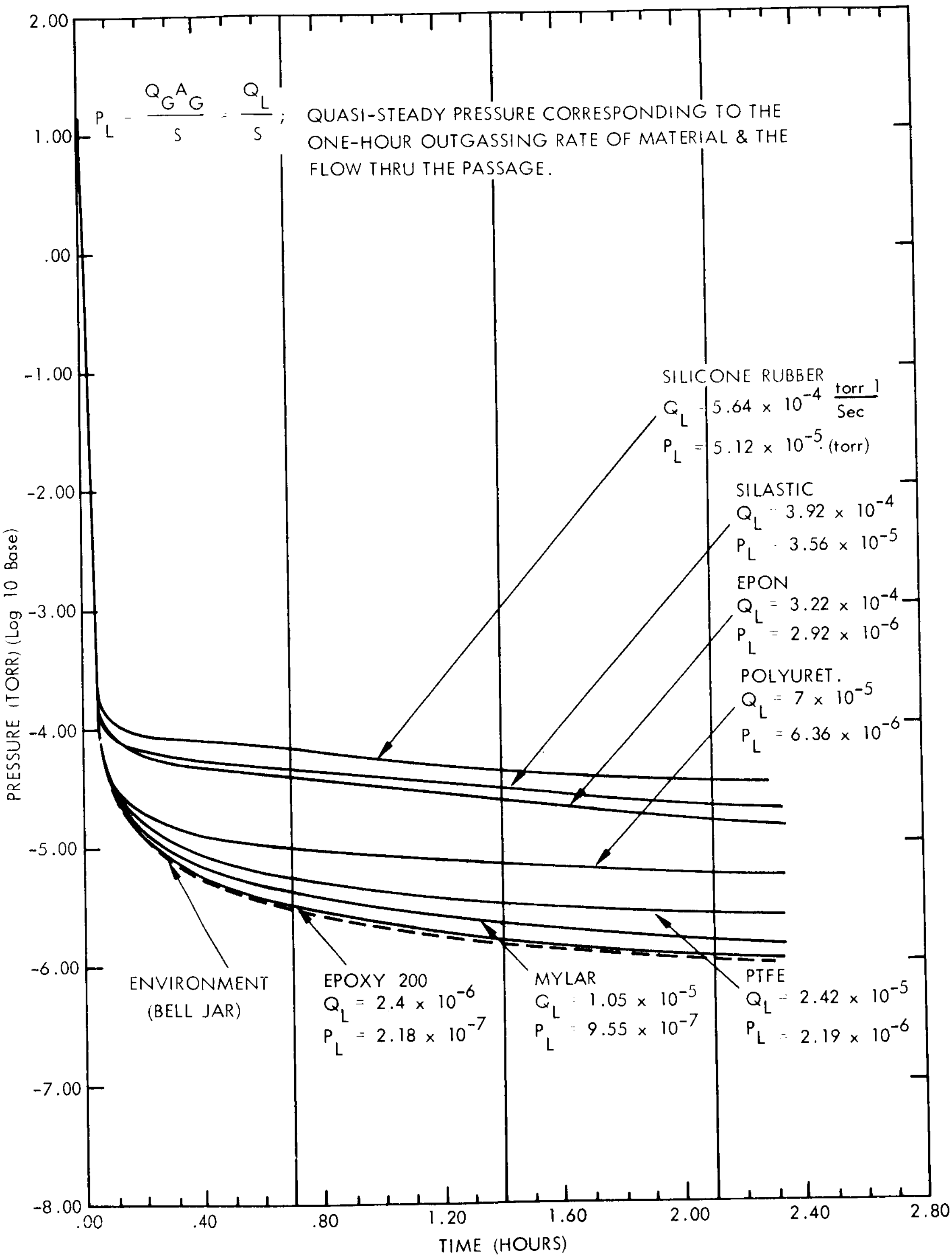
The time constant, which relates the size of the volume to the pumping speed in the molecular flow region of the passage, represents the time needed for the pressure to drop to $1/e = 0.368$ of the initial pressure and is given in reference 4 as

$$\tau = \frac{V}{S} \text{ (sec)}, \tag{1}$$

where V (liter) is the volume of the container to be evacuated and S (lit/sec) is the pumping speed of the passage. The pumping speed for an orifice of area A (cm^2) in the molecular flow region (corresponding to a pressure of $10^{-2} - 10^{-3}$ torr for the present orifice diameters and air at 20°C), is a constant:

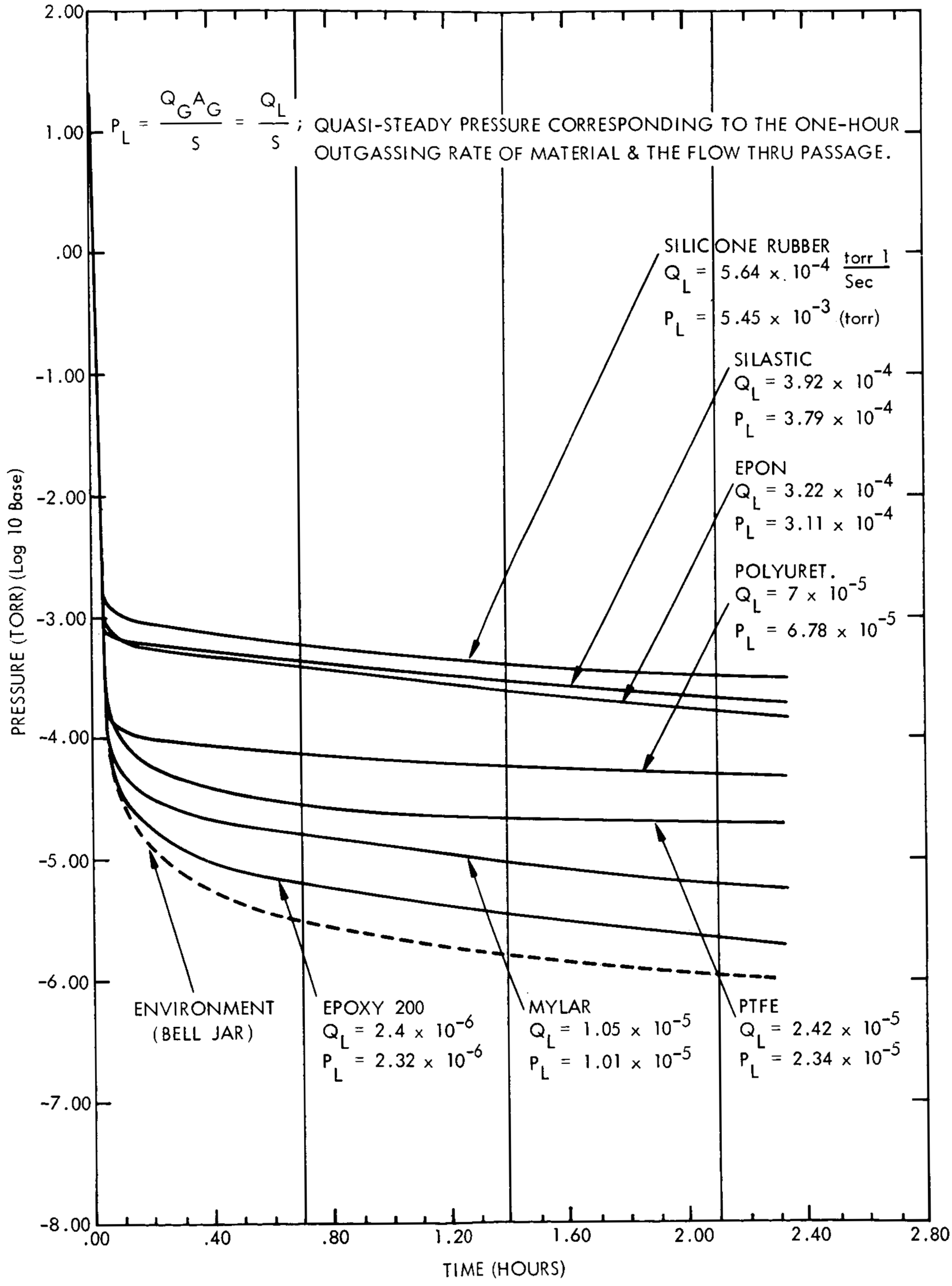
$$S = 11.6A \text{ (lit/sec)}. \tag{2}$$

The time constant, which presupposes molecular flow with constant conductance and no source of gas in the volume being evacuated, results from the solution of the linear differential equation expressing the flow balance $-V\frac{dp}{dt} = SP$, in the molecular region:



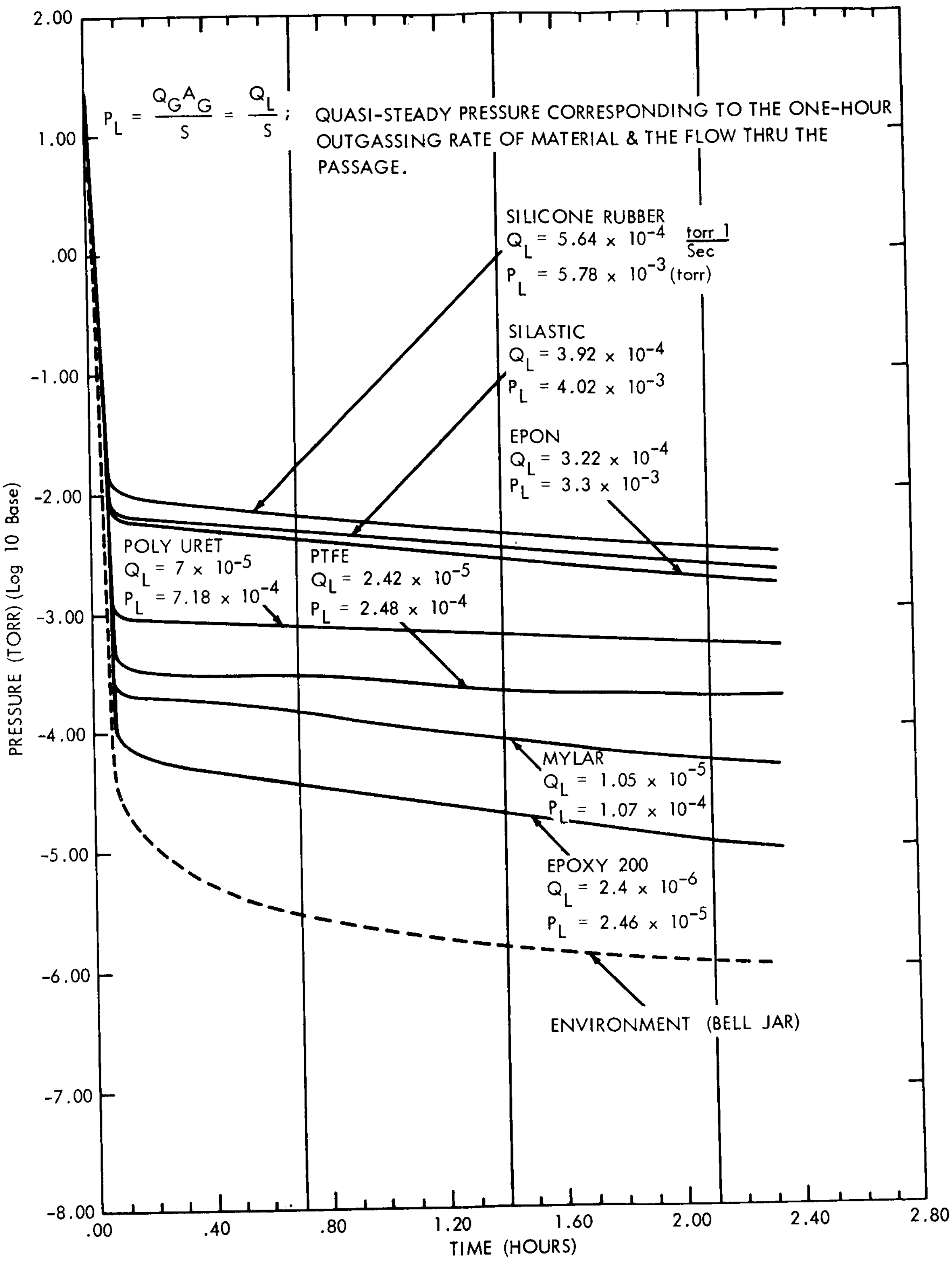
Passage: thin orifice; temperature: ambient; gas: air; with outgassing material

Figure 1. One-Compartment Pressure Simulation ($\tau = 0.1$ sec)



Passage: thin orifice; temperature: ambient; gas: air; with outgassing material

Figure 2. One-Compartment Pressure Simulation ($\tau = 1.0$ sec)



Passage: thin orifice; temperature: ambient; gas: air; with outgassing material

Figure 3. One-Compartment Pressure Simulation (τ = 10 sec)

$$P = P_i e^{-\frac{S}{V}t}. \tag{3}$$

This time constant can be visualized as the slope of the log of the pressure profile at time zero.

Where a constant source of gas Q_L (torr lit/sec) exists, such as that provided by a leak into the volume, the differential equation given in reference 4 is:

$$-V\frac{dp}{dt} = SP - Q_L, \tag{4}$$

and its solution is

$$P = P_i e^{-\frac{S}{V}t} + \frac{Q_L}{S}. \tag{5}$$

This equation shows that, when the first term becomes very small, the second term controls the pumpdown. For Q_L constant, an equilibrium pressure,

$$P_L = \frac{Q_L}{S}, \tag{6}$$

would be obtained. The pressure represents the condition of equilibrium between the inflow leakage, Q_L, and the outflow through the orifice, SP_L. For the present cases, the in-leakage is represented by material outgassing not at constant rate, but at a decreasing function of time. The pressure consequently decays slowly. However, we can define a quasi-steady-state gas leak as one that is produced by the material after 1 hour of outgassing in vacuum and then use the corresponding quasi-steady-state equilibrium pressure as one of the parameters describing the system. This pressure would be:

$$P_L = \frac{Q_L}{S} = \frac{A_G Q_G}{S}, \tag{7}$$

where A_G (cm^2) is the surface area of the outgassing material; $Q_G \left(\frac{\text{tor lit}}{\text{sec-cm}^2}\right)$ is the material rate of gas output after 1 hour of vacuum exposure, as given in literature (references 3 and 4); and S (lit/sec) is the pumping speed for the orifice, as given by equation (2). This pressure is not the ultimate pressure obtained in the volume but is a condition of slowly decaying pressure. Table 1 lists the geometric data, outgassing material, characteristic rate at 1 hour Q_G, corresponding load Q_L rate, calculated pumping speeds S, and finally, the resulting parameter τ and P_L.

APPLICATION OF THE PARAMETRIC PRESENTATION OF THE COMPUTER RESULTS

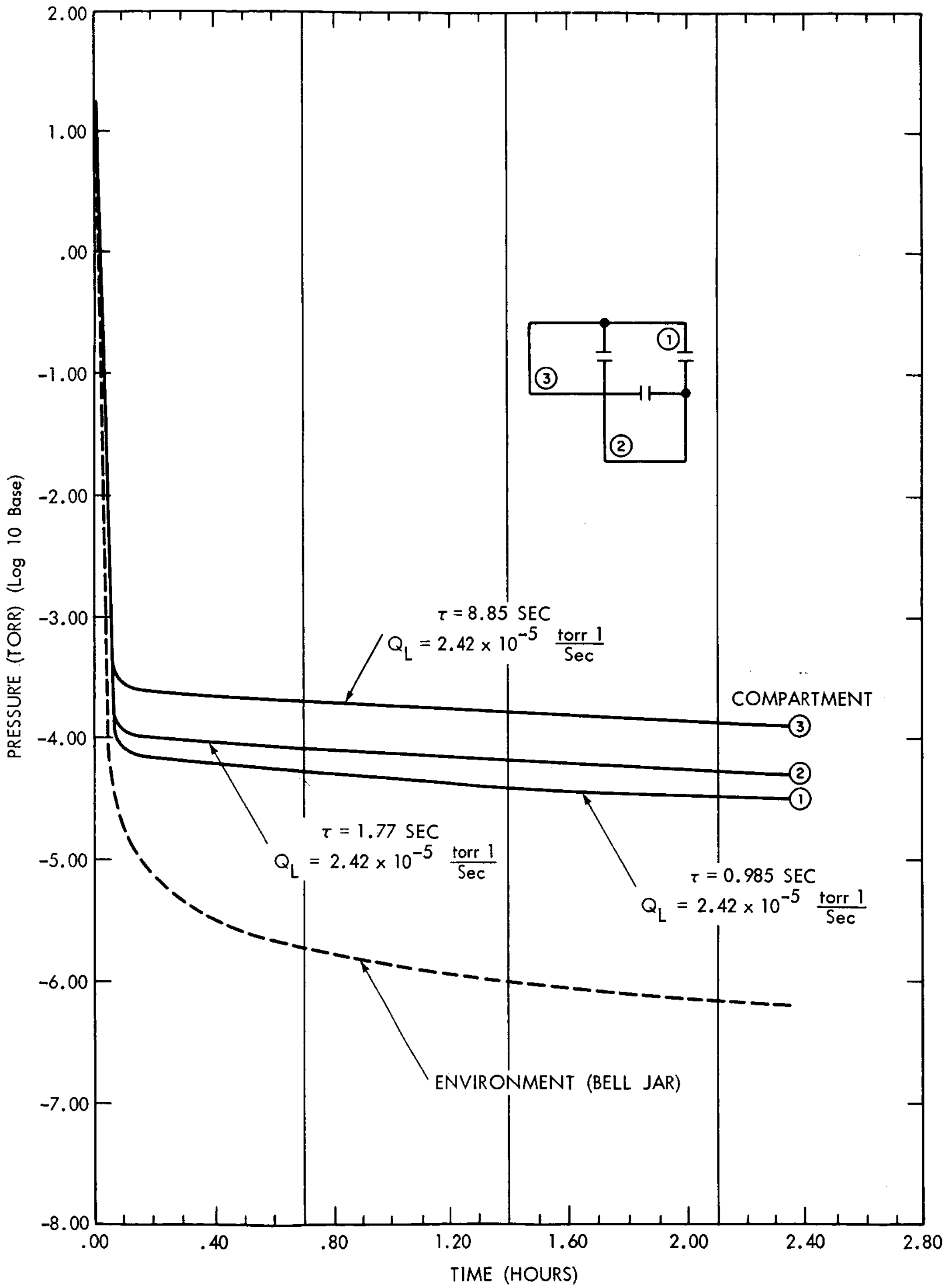
The primary use of this program is to obtain pressure profiles (such as those of Figures 1, 2, and 3, or for a more complicated system, as those of Figure 4 for a three-volume system) without the necessity of running an actual test. Another use is to establish times during which certain spacecraft operations which depend on pressure can be safely performed. Any variation in flow passage, temperature for the entire system, type of gas, material contained in the volumes, and leakages can be included and the results checked for any environment. This calculation provides an indication of pressures for volume arrangements where gages cannot be installed. Where actual pressures-versus-time data for a system are known from experiments, the behavior of the material can be determined by comparing the experimental results with the analytical (i.e., an equivalent pumping speed for the system can be found). The equivalent pumping speed can then be used to check other conditions.

For the present analysis, the curves of Figures 1, 2, and 3 can be used to estimate the pressure versus time for a system having time constants τ, obtained from equation (1), between 0.1 sec and 10 sec, with outgassing quasi-steady pressures P_L (equation (7)) between 3.3×10^{-3} torr and 9.55×10^{-7} torr, and gas load Q_L between 3.22×10^{-4} and 2.4×10^{-6} (torr lit/sec). This was accomplished by providing plots as in Figures 5 and 6.

Figure 5 plot (obtained from curves of Figures 1, 2, and 3) shows the quasi-steady pressure P_L versus the time constant for the outgassing material and corresponding gas loads investigated here.

Figure 6 plot shows the pressure versus time obtained by plotting the time to reach the quasi-steady pressure for the three time constants $\tau = 0.1$, $\tau = 1$, and $\tau = 10$ sec.

The information from Figures 5 and 6 and from the previous equations will permit an estimate of the pressure versus time for a single-volume system by using either of the following procedures:



Passage: thin orifices; temperature: 270°K; gas: air; in each compartment 80 cm² "PTFE" outgassing material

Figure 4. Three-Compartment Pressure Simulation

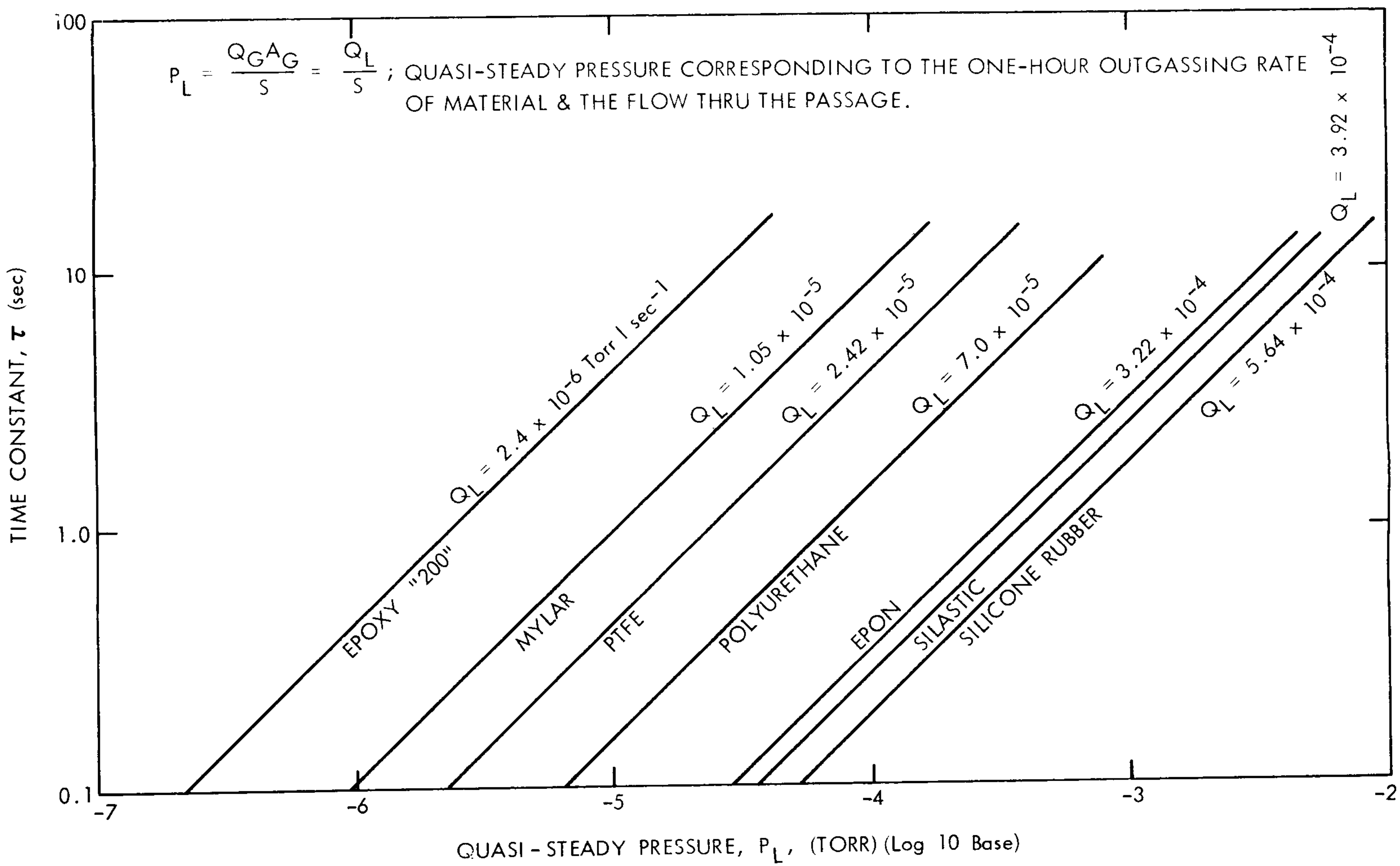


Figure 5. Time Constant versus Quasi-Steady Pressure Equilibrium for Material Outgassing Flow Rate

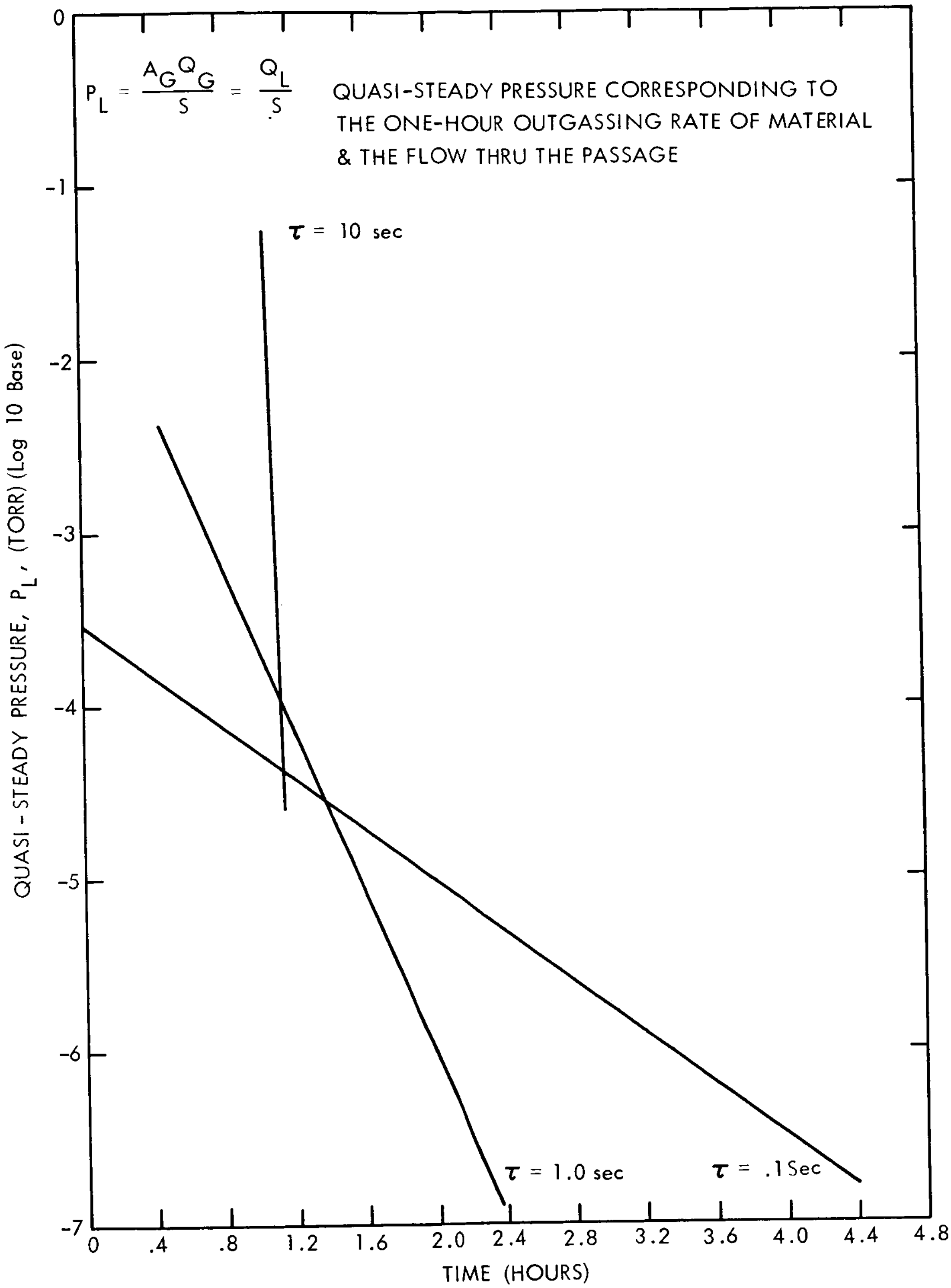


Figure 6. Time to Reach Quasi-Steady Pressure for $\tau = 0.1$, $\tau = 1.0$, and $\tau = 10$ sec

- For a single-volume system without outgassing: Calculate the pumping speed for the orifice, S (equation (2)), and the time constant, τ (equation (1)); estimate the time to obtain P from the solution of equation (3) valid in the molecular region, i.e., $t = \tau \ln_e \frac{760}{P}$.

  For a case in which the time t is known to reach pressure P for a system having time constant τ, the time t_1 to reach the same pressure for another system having a time constant τ_1 will be

$$t_1 = t\left(\frac{\tau_1}{\tau}\right).$$

- For a single-volume system with outgassing: Calculate the pumping speed and the time constant as in preceding paragraph. Obtain data on the outgassing material, Q_G (reference 3), and calculate Q_L knowing the area of outgassing using equation (7). From Figure 5, or by calculation, obtain quasi-steady pressure P_L; with this information estimate from Figure 6 the time needed to obtain pressure P_L.

Comparison of Experimental and Computed Results

As indicated in the introduction, this analysis resulted from developmental work on a computer program. The choice of the dimensions and outgassing material in each system resulted from the desire to check results of experimental tests performed in the laboratory in order to establish container pressure and the corresponding times of onset and extinction of corona for electrodes in a container (Ref. 2). The plots of Figures 7, 8, and 9 show superposed the results obtained experimentally and those obtained with the computer program. Figure 10 is a schematic of the pressure-time setup and the orifice construction. The one-liter volume was fitted with one of three different orifices connecting the compartment to the simulated space environment of the 12-inch diameter by 18-inch bell jar. The evacuation was provided by a 140-cfm mechanical roughing pump and 2-1500 l/sec oil-diffusion pumps baffled with liquid nitrogen. The bell-jar pressure profile simulates the launch and the orbital phases of a spacecraft. It approximates the pressure-time curve of a Thor-Agena B rocket carrying a 1000-pound payload into a 160-mile orbit. A Hastings thermocouple pressure gage and a nude ionization gage were used to record the pressure in the compartment. The pressure in the bell jar was recorded by a Hastings thermocouple gage and an ionization gage. The polymeric materials included in the compartment, selected as being typical encapsulants used in flight systems, were: Eccofoam FPH, 4 pounds/cubic foot; silicone rubber, RTV 11; and epoxy, Biggs 823 resin. The test specimens of these materials were produced in the laboratory

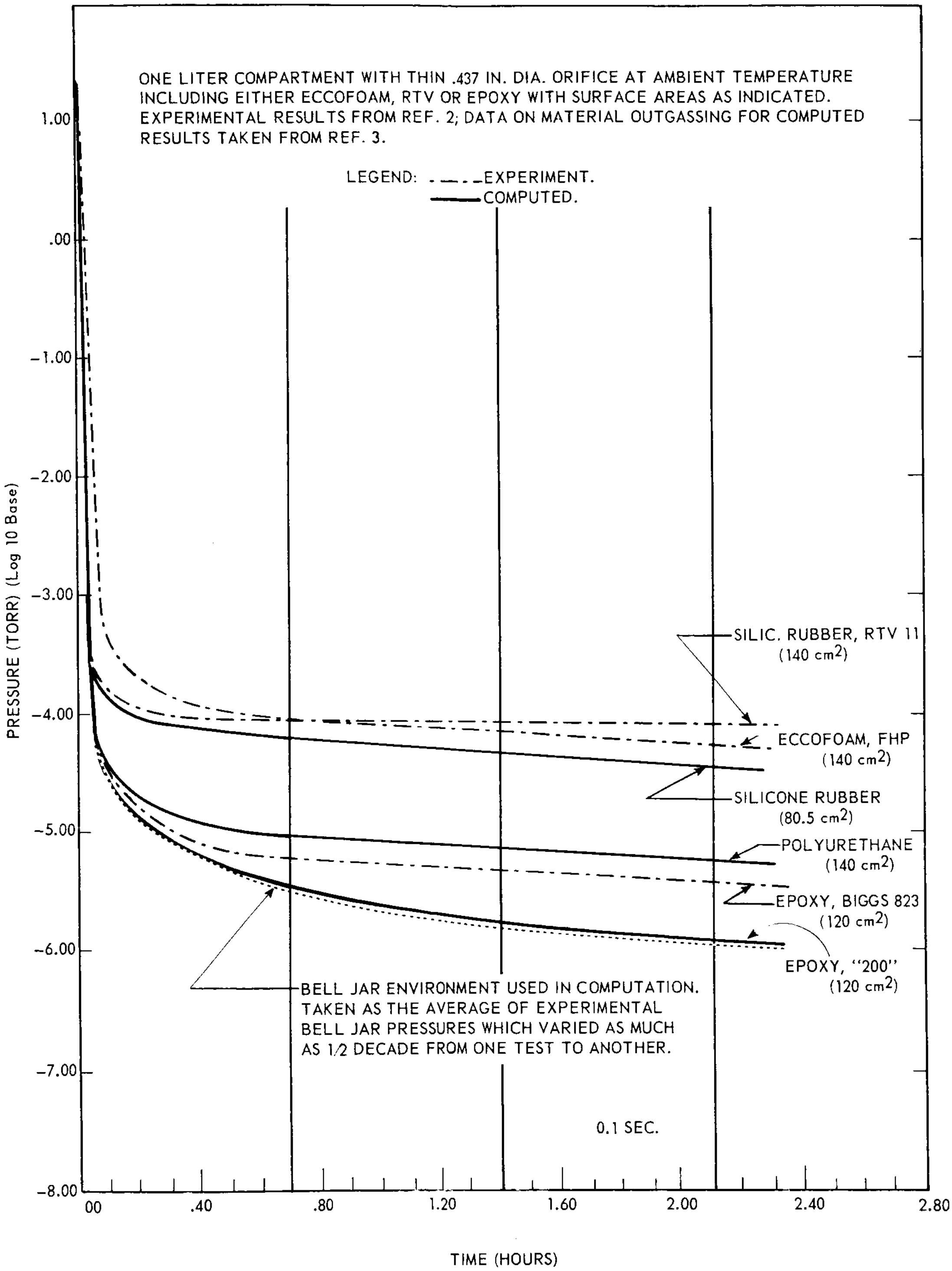


Figure 7. Comparison of Experimental and Computed Results (τ = 0.1 sec)

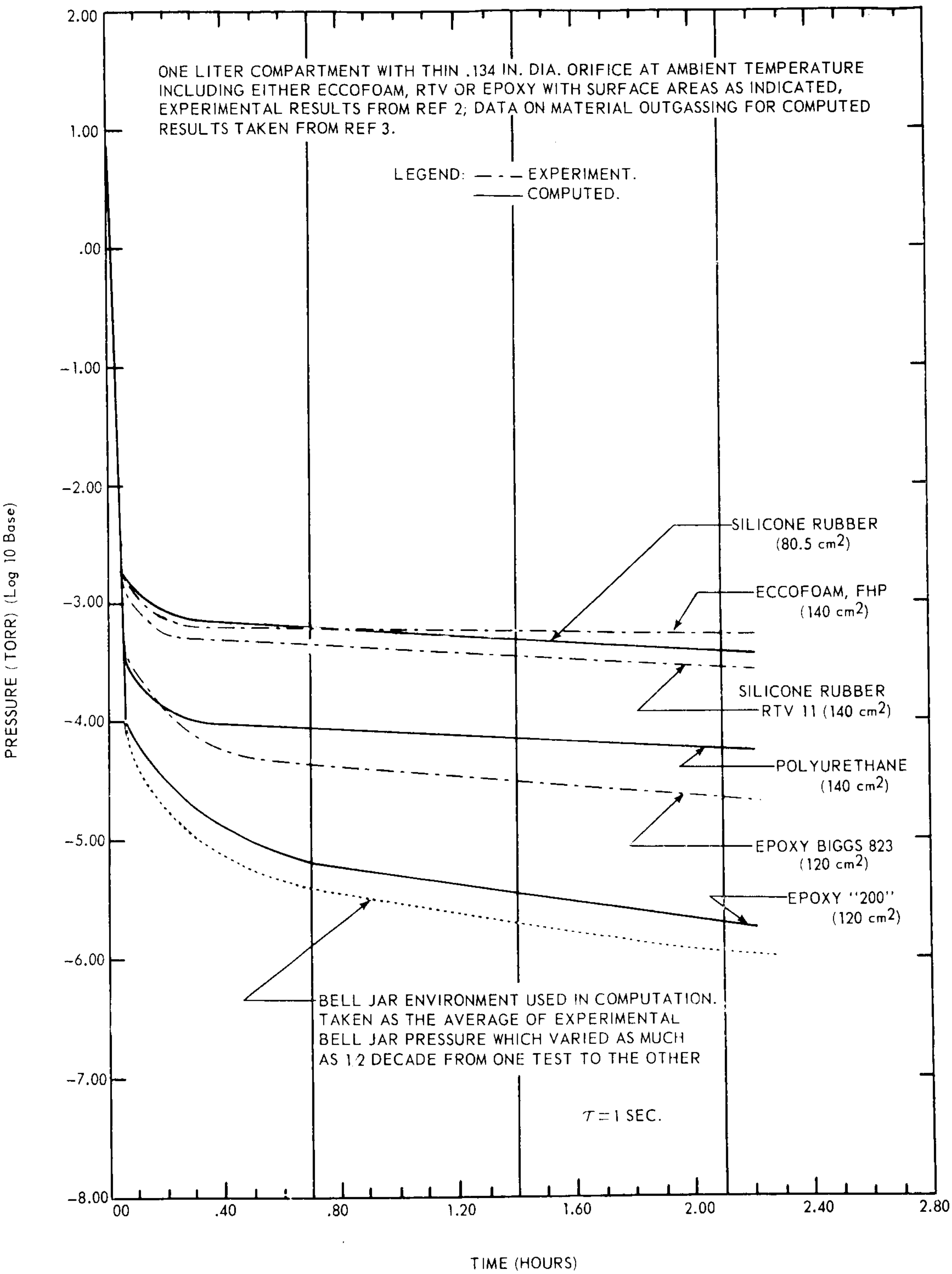


Figure 8. Comparison of Experimental and Computed Results (τ = 1.0 sec)

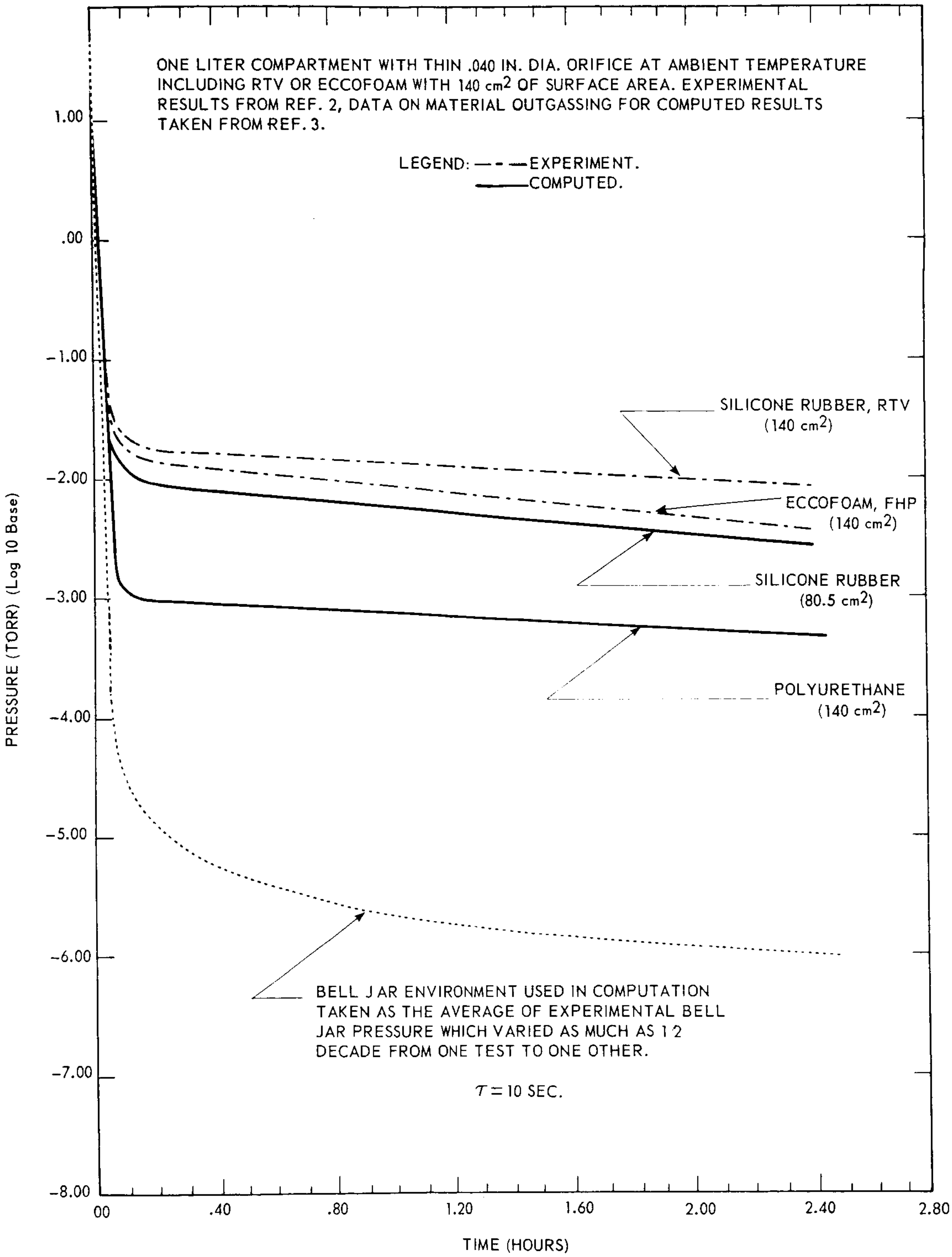


Figure 9. Comparison of Experimental and Computed Results (τ = 10 sec)

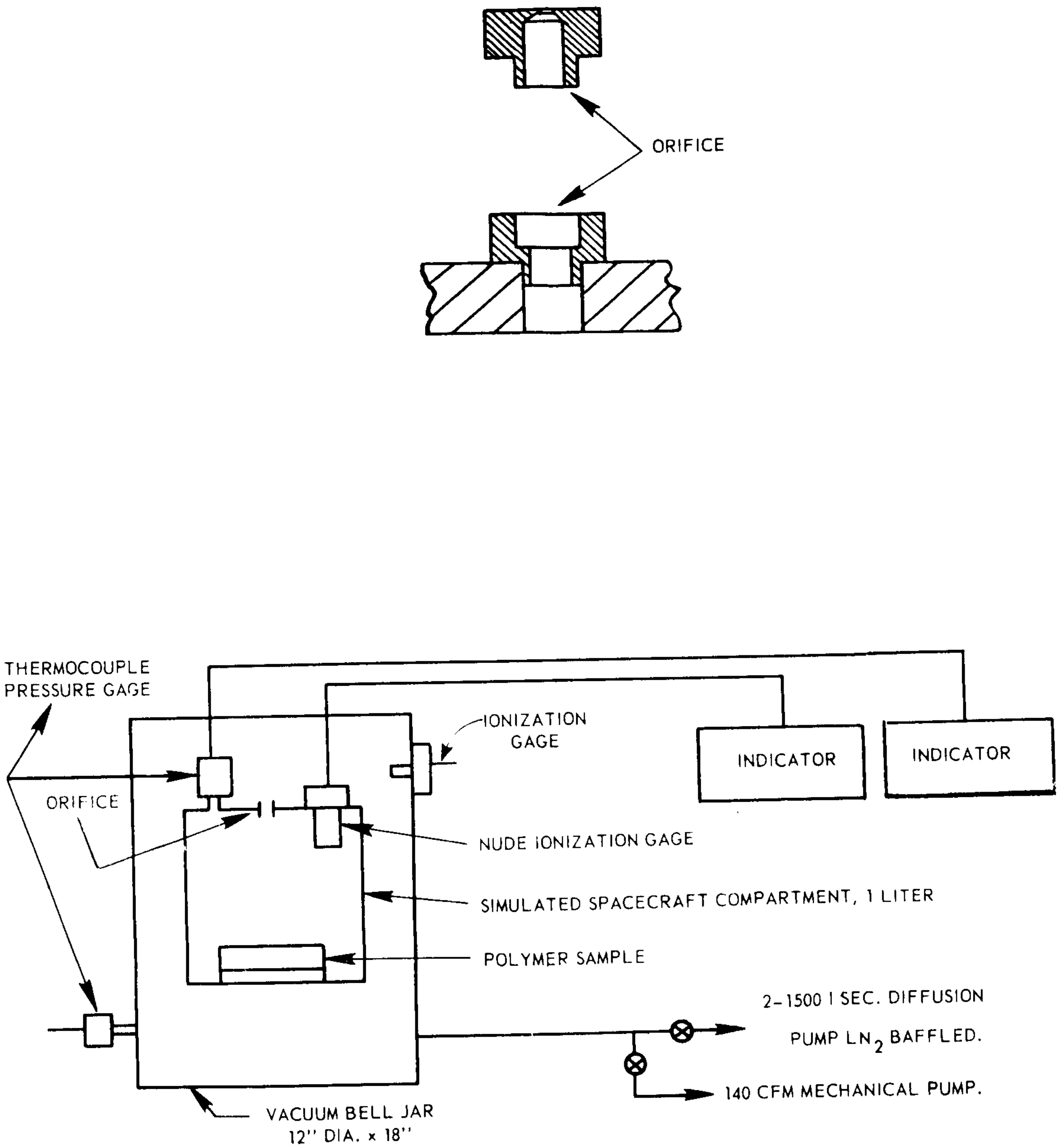


Figure 10. Pressure-Time Test Setup

in accordance with accepted spacecraft application techniques. The Eccofoam and the RTV samples had a surface area of 140 cm^2, and the epoxy sample consisted of a conformal coating about 0.015 inch thick over an aluminum tube with a surface area of 120 cm^2. The coating was vacuum-processed while curing. The RTV samples were outgassed for 24 hours before the test. Non-outgassed RTV caused fluctuating ionization-pressure gage readings in the 10^{-4} torr region. This was attributed to contamination of the gage elements which rendered the gage useless for pressure measurements. The 24-hour outgassing phase is, however, typical of space hardware exposure in environment-chamber tests. The pressure vs. time in the bell jar did not follow the same profile in each test but showed a variation of about one-half decade because of the influence of the variable gas load and orifice sizes. The temperature in these tests was about 70°F.

Figures 7, 8, and 9 show that the computer results compare favorably with the experimental results. The difference (values in the same decade) is justified by: the uncertainties of reproducing the same pressure profiles in the vacuum jar for different runs; the difficulty of gage-reading and gage errors; surface-handling of materials previous to vacuum exposure; and the material properties used in computation which may differ from those used in testing. For the computer, a mathematical description of the outgassing material is used. The data for this representation are obtained from the literature and, unless data are available on the specific material being tested, divergence may be expected between test and analytical results. However, comparison of the experimental and analytical results indicates a difference in the same decade. Better definition of the materials should produce closer results, if needed. Improvements in computed results are also expected when the computer program is modified to handle temperature gradients between compartments. At present the computer program is written for constant temperature.

CONCLUSION

A successful computer program has been developed which provides the pressure profile within a volume with material outgassing. The program is general and can be used for many interconnected volumes with various types of passages and containing materials outgassing in a known manner such as in a spacecraft. The present application considers one-liter volume with 0.975, 0.0914, and 0.00862 cm^2 orifice including each of these materials used in space applications: silicone rubber, epon, PTFE, mylar, epoxy, polyurethane, and silastic. The pressure profiles obtained with the computer have been grouped according to a molecular flow time constant of 0.1, 1.0, and 10 seconds which relates the volume and the orifice sizes. Two additional parameters have been introduced to offer a generalization of these results: one relates the outgassing material flow rate at 1 hour; the other relates a quasi-steady pressure corresponding to that flow rate. A plot showing the quasi-steady-pressure variation with the system time constant and the outgassing rates was obtained from the calculated profiles. Another plot was drawn to show the time required to obtain the quasi-steady pressure for the three time constants.

It has also been shown that, given a knowledge of the material behavior and the geometry of the system, these two plots will enable one to obtain information on pressure and corresponding time. With the parameters introduced here, these plots can be used as a tool to define objectionable conditions, or to avoid those conditions with appropriate changes in volume and/or passage. In addition, pressure versus time can be obtained for a spacecraft system. The results of computer program, as shown by comparison with experimental data, can be reliably used.

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APPENDIX
TYPICAL COMPUTER INPUT DATA AND CORRESPONDING SOLUTION

```
                              * I N P U T   D A T A *
                ******************************************************
                              NUMBER OF CHAMBERS = 1
                     TEMPERATURE =  290.0000 DEGREES KELVIN
                     MOLECULAR WEIGHT OF GAS =   29.0000 GRAMS
          SIMULATION PERFORMED FROM        0 SECONDS UP TO    8400.000 SECONDS
             WITH INITIAL INTEGRATION STEP SIZE OF     .001000000 SECONDS
*******************************************************************************************
CHAMBER 1          VOLUME =      1.0000 LITERS             INITIAL PRESSURE =  760.0000 TORR

                   SURFACE AREA NO. 1 =   140.0000 SQ.CM.,  MATERIAL IS POLYURET.
                                              1) Q(INITIAL) = 5.3142E-07 TORR-LITER/SEC/SQ.CM.
                        OUTGASSING CHARACTERISTICS - 2) Q(FINAL) = 1.4994E-07 TORR-LITER/SEC/SQ.CM.
                                              3) TAU = 8.6240E 03 SECONDS

                   CONDUCTANCE NO. 1 - C( 1, 0) OF TYPE 1    8.62000E-03            0            0
*******************************************************************************************

                         TIME VERSUS PRESSURE ENVIRONMENT
               1)             0 SECONDS  -    760.0000000000 TORR
               2)    120.000000 SECONDS  -        .0001800000 TORR
               3)    240.000000 SECONDS  -        .0000500000 TORR
               4)    360.000000 SECONDS  -        .0000250000 TORR
               5)    480.000000 SECONDS  -        .0000180000 TORR
               6)    600.000000 SECONDS  -        .0000145000 TORR
               7)    720.000000 SECONDS  -        .0000120000 TORR
               8)    840.000000 SECONDS  -        .0000100000 TORR
               9)    960.000000 SECONDS  -        .0000085000 TORR
              10)   1080.000000 SECONDS  -        .0000072000 TORR
              11)   1200.000000 SECONDS  -        .0000065000 TORR
              12)   1320.000000 SECONDS  -        .0000058000 TORR
              13)   1440.000000 SECONDS  -        .0000053000 TORR
              14)   1560.000000 SECONDS  -        .0000046000 TORR
              15)   1680.000000 SECONDS  -        .0000043000 TORR
              16)   1800.000000 SECONDS  -        .0000040000 TORR
              17)   1920.000000 SECONDS  -        .0000037500 TORR
              18)   2040.000000 SECONDS  -        .0000035000 TORR
              19)   2160.000000 SECONDS  -        .0000034000 TORR
              20)   2280.000000 SECONDS  -        .0000033000 TORR
              21)   2400.000000 SECONDS  -        .0000032500 TORR
              22)   2760.000000 SECONDS  -        .0000027500 TORR
              23)   3120.000000 SECONDS  -        .0000025000 TORR
              24)   3600.000000 SECONDS  -        .0000022500 TORR
              25)   4200.000000 SECONDS  -        .0000019000 TORR
              26)   4800.000000 SECONDS  -        .0000016500 TORR
              27)   5400.000000 SECONDS  -        .0000015000 TORR
              28)   6000.000000 SECONDS  -        .0000014000 TORR
              29)   7200.000000 SECONDS  -        .0000011000 TORR
              30)   8400.000000 SECONDS  -        .0000010000 TORR
              31)  43200.000000 SECONDS  -        .0000007000 TORR

                              * *  S O L U T I O N  * *
           T =          0      0)  7.60000000E 02      1)  7.60000000E 02
           T =    84.1355      0)  2.27142149E 02      1)  2.30314632E 02
           T =   173.9956      0)  1.21504745E-04      1)  1.85907475E-01
           T =   266.1143      0)  4.45595118E-05      1)  1.14773874E-03
           T =   339.4261      0)  2.92862237E-05      1)  9.71821231E-04
           T =   432.0815      0)  2.07952440E-05      1)  9.52124784E-04
           T =   531.1716      0)  1.65074955E-05      1)  9.39300091E-04
           T =   599.2311      0)  1.45224276E-05      1)  9.31724315E-04
           T =   707.9405      0)  1.22512394E-05      1)  9.20547410E-04
           T =   789.1608      0)  1.08473197E-05      1)  9.12580641E-04
           T =   882.3989      0)  9.47001430E-06      1)  9.03711672E-04
           T =   935.7704      0)  8.80287044E-06      1)  8.98995357E-04
           T =  1025.7402      0)  7.78781437E-06      1)  8.90717563E-04
           T =  1119.8364      0)  6.96762109E-06      1)  8.82686798E-04
           T =  1183.9344      0)  6.59371626E-06      1)  8.77398674E-04
           T =  1284.8116      0)  6.00526595E-06      1)  8.69157684E-04
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T = 1358.3974	0)	5.64001079E-06	1)	8.63248024E-04
T = 1441.0975	0)	5.29359789E-06	1)	8.56748687E-04
T = 1538.4996	0)	4.72541878E-06	1)	8.48987249E-04
T = 1667.5807	0)	4.33104836E-06	1)	8.37895927E-04
T = 1695.5807	0)	4.26104836E-06	1)	8.36737530E-04
T = 1789.6607	0)	4.02584836E-06	1)	8.30160636E-04
T = 1853.3246	0)	3.88890710E-06	1)	8.25512391E-04
T = 1952.2068	0)	3.68290240E-06	1)	8.18364828E-04
T = 2022.8399	0)	3.53575023E-06	1)	8.13307634E-04
T = 2100.7274	0)	3.44939387E-06	1)	8.07839556E-04
T = 2190.1394	0)	3.37488382E-06	1)	8.01662231E-04
T = 2297.6204	0)	3.29265815E-06	1)	7.94322756E-04
T = 2370.8099	0)	3.26216255E-06	1)	7.89407651E-04
T = 2447.8099	0)	3.18359739E-06	1)	7.84253123E-04
T = 2531.8099	0)	3.06693072E-06	1)	7.78598602E-04
T = 2615.8099	0)	2.95026406E-06	1)	7.73055377E-04
T = 2699.8099	0)	2.83359739E-06	1)	7.67508076E-04
T = 2783.8099	0)	2.73346536E-06	1)	7.62084392E-04
T = 2867.8099	0)	2.67513203E-06	1)	7.56689195E-04
T = 2951.8099	0)	2.61679870E-06	1)	7.51422111E-04
T = 3035.8099	0)	2.55846536E-06	1)	7.46130381E-04
T = 3119.8099	0)	2.50013203E-06	1)	7.40963285E-04
T = 3203.8099	0)	2.45634902E-06	1)	7.35784074E-04
T = 3287.8099	0)	2.41259902E-06	1)	7.30733062E-04
T = 3371.8099	0)	2.36884902E-06	1)	7.25653482E-04
T = 3455.8099	0)	2.32509902E-06	1)	7.20698557E-04
T = 3539.8099	0)	2.28134902E-06	1)	7.15716633E-04
T = 3623.8099	0)	2.23611090E-06	1)	7.10854588E-04
T = 3707.8099	0)	2.18711090E-06	1)	7.05964194E-04
T = 3791.8099	0)	2.13811090E-06	1)	7.01189710E-04
T = 3875.8099	0)	2.08911090E-06	1)	6.96393176E-04
T = 3959.8099	0)	2.04011090E-06	1)	6.91709405E-04
T = 4043.8099	0)	1.99111090E-06	1)	6.87004905E-04
T = 4127.8099	0)	1.94211091E-06	1)	6.82320686E-04
T = 4211.8099	0)	1.89507922E-06	1)	6.76299808E-04
T = 4301.9493	0)	1.85752114E-06	1)	6.72957932E-04
T = 4378.2386	0)	1.82573392E-06	1)	6.68891970E-04
T = 4467.8271	0)	1.78840536E-06	1)	6.64159932E-04
T = 4555.8326	0)	1.75173641E-06	1)	6.59564655E-04
T = 4637.8048	0)	1.71758134E-06	1)	6.55558902E-04
T = 4714.8921	0)	1.68546163E-06	1)	6.51437687E-04
T = 4793.5315	0)	1.65269522E-06	1)	6.47392579E-04
T = 4876.4495	0)	1.63088762E-06	1)	6.43221782E-04
T = 4969.7741	0)	1.60755648E-06	1)	6.38666314E-04
T = 5053.7115	0)	1.58657214E-06	1)	6.34519523E-04
T = 5127.6451	0)	1.56808872E-06	1)	6.30838776E-04
T = 5231.5201	0)	1.54211997E-06	1)	6.25812798E-04
T = 5320.1376	0)	1.51996559E-06	1)	6.21594333E-04
T = 5389.7050	0)	1.50257376E-06	1)	6.18408762E-04
T = 5472.5345	0)	1.48791092E-06	1)	6.14501614E-04
T = 5549.7596	0)	1.47504007E-06	1)	6.10859925E-04
T = 5630.1204	0)	1.46164661E-06	1)	6.07154618E-04
T = 5718.2506	0)	1.44695823E-06	1)	6.03161618E-04
T = 5815.9234	0)	1.43067943E-06	1)	5.98965045E-04
T = 5888.5251	0)	1.41857915E-06	1)	5.95533271E-04
T = 5988.0210	0)	1.40199649E-06	1)	5.91109161E-04
T = 6068.4699	0)	1.38288254E-06	1)	5.87589348E-04
T = 6161.6690	0)	1.35958276E-06	1)	5.83572149E-04
T = 6229.1726	0)	1.34270686E-06	1)	5.80776011E-04
T = 6311.3259	0)	1.32216853E-06	1)	5.77239971E-04
T = 6387.9206	0)	1.30301985E-06	1)	5.73950253E-04
T = 6495.5343	0)	1.27611643E-06	1)	5.69447944E-04
T = 6555.0361	0)	1.26124097E-06	1)	5.67000068E-04
T = 6651.9116	0)	1.23702211E-06	1)	5.63161361E-04
T = 6729.9213	0)	1.21751968E-06	1)	5.59902556E-04
T = 6827.3831	0)	1.19315423E-06	1)	5.55940031E-04
T = 6904.8387	0)	1.17379032E-06	1)	5.52859541E-04
T = 6992.0153	0)	1.15199619E-06	1)	5.49433897E-04
T = 7060.4514	0)	1.13488715E-06	1)	5.46810049E-04
T = 7143.7517	0)	1.11406207E-06	1)	5.43574912E-04
T = 7233.3363	0)	1.09722197E-06	1)	5.40111525E-04
T = 7329.8655	0)	1.08917788E-06	1)	5.36470726E-04
T = 7414.8326	0)	1.08209728E-06	1)	5.33303253E-04
T = 7483.5755	0)	1.07636871E-06	1)	5.30786348E-04
T = 7575.9119	0)	1.06867401E-06	1)	5.27452738E-04
T = 7655.7966	0)	1.06201695E-06	1)	5.24515765E-04
T = 7738.9250	0)	1.05508958E-06	1)	5.21522216E-04
T = 7830.0904	0)	1.04749246E-06	1)	5.18336827E-04
T = 7909.9289	0)	1.04083926E-06	1)	5.15477140E-04
T = 8003.6138	0)	1.03303218E-06	1)	5.12168954E-04
T = 8078.0679	0)	1.02682768E-06	1)	5.09595955E-04
T = 8161.8661	0)	1.01984449E-06	1)	5.06730331E-04
T = 8265.3065	0)	1.01122446E-06	1)	5.03292884E-04
T = 8324.9540	0)	1.00625383E-06	1)	5.01332075E-04
T = 8404.7491	0)	9.99959059E-07	1)	4.98623339E-04

THIS EXECUTION TOOK .0494 HOURS