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Syracuse University

Department of Mechanical and

Aerospace Engineering

Semi-Annual Progress Report

Unsteady Transonic Heat Transfer in a Transient Facility

NASA Grant # NAG 3-621

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Semi Annual Progress Report NASA Grant NAG 3-821

On March 1, 1985 work was begun on NASA grant # NAG 3-621 The main initial focus of the project is to construct a facility for making heat transfer measurements on solid surfaces using transient techniques. The facility being constructed is a Ludweig tube with isentropic compression heating (LICH tube).

The following report is the semi-annual progress report. The report details the work completed and the work remaining in order to complete the facility and make useful heat transfer measurements. The scope of the project is briefly discussed along with an overall appraisal of the progress made.

Project Description

As stated earlier the main focus of the project is to construct a facility for making heat transfer measurements into solid surfaces. The type of facility being constructed is called a Ludweig tube with isentropic compression heating or (LICH tube). A LICH tube (see fig. 1) consists of a high pressure gas reservoir which can be vented rapidly by a fast acting ball valve into a relatively low pressure tube which is fitted with a light weight piston. As the gas is vented from the high pressure reservoir it moves the piston down the tube to the test section and stops. Down stream from the test section is located a nozzle, a light weight diaphragm and dump tank.

As the piston travels down the tube the pressure ahead of the piston rises until the diaphragm breaks. When the diaphragm bursts, an isentropically compressed, heated gas flows into the test section with all stagnation conditions remaining essentially constant until the run time is terminated. The pressure rise as a function of time is shown in Fig. 2. The Mach number in the test section is controlled by the nozzle down stream from the test section. The run time is determined by one of two events, depending upon which is shorter;

1. The time needed for the piston to arrive at the test section, i.e. the time to deplete the heated test gas or,

2. The time needed for the rarefraction wave (due to diaphragm burst) to travel the length of the tube, reflect of the valve block, and return to the test section.

The predicted run time for the Syracuse University LICH tube is plotted in Fig. 3. for various test section areas and test conditions.

The project is being tackled from several different angles simultaneously. They are as follows:

1. Conversion of the existing Syracuse Universiy Shock Tube to a LICH tube.

2. Development of methods for constructing heat transfer gauges.

3. Design and construction of a test section and nozzle.

4. Implementation of a data acquisition system.

5. Construction of heat transfer analogue circuits.

The progress in each of these areas is discussed briefly below.

Conversion from Shock Tube to LICH Tube

The conversion from shock tube to LICH tube consisted mainly of replacing the diaphragm section of the shock tube with a ball valve fitted with a fast acting actuator. The system has an opening time of less than 0.5 secs. A second, hand operated, ball valve was also installed for safety purposes. The only other major modification to the existing shock tube was that the expansion section was fitted with a light weight nylon piston. Development of the piston is currently under way.

Heat Transfer Gauge Construction

Thin film gauge construction at Syracuse University has progressed markedly since January of 1985. A brief description of the progress made in each area of development is discussed below.

Substrate - the need for high machineability and low thermal and electricl conductivity has lead to the use of MACOR as substrate material. The surface is cleared and highly polished with sand paper and ceric oxide powder prior to application of the metallic ink.

Platinum Films - the development of a reliable technique for applying platinum films was a crucial step in the development of heat transfer guages. After much experimentation, a process of painting the ink with very fine brushes has proven successful. Using such a technique, guages of 50 Ω +/- 1Ω can be routinely developed.

Low Resistance Gold Leads - The application of the gold film initially followed the same course as that of the platinum films. However, in the case of gold it is often desirable to paint the film around a 90 degree corner. Many possible solutions have been attempted to solve this problem. These range from drilling holes in the substrate and leading the gold down the hole, to slightly rounding the 90 degree corner encountered. The most successful technique has been a slight rounding of the corner (radius less than 0.5 mm.) with 600 grit sand paper. Current plans include trying to electroplate the gold onto the substrate in search of a more efficient means of construction.

Lead Connection - Initially gauges were connected to leads using silver loaded epoxy. This technique still remains the most reliable means of lead attachment. However, due to the difficulty of working with this epoxy a great deal of effort has gone into improving this method. Most recently, solder connections have been attempted using various types of solder. These have met with only limited success. This is expected to change when electroplated gold tags have been developed.

Design and Construction of Test Section and Nozzle

Work in this area is still in the preliminary stages. The first nozzle is being designed to to produce a test section Mach number of 0.5. but is being built in such a way that the Mach number can be changed relatively easily. The test section is being designed to accommodate the first test model which is to be a cylinder, but will be versatile enough to allow the testing of many different model types. Initial tests will be on the unsteady heat transfer on a surface in the wake of a small cylinder.

Implementation of a Data Aquisition system

In order to record the heat transfer data being generated by the heat transfer analogues connected to the gauges it was necessary to purchase a high speed multi-channel data acquisition system. The system that was purchased was a Data Lab 1200. The DL 1200 is capable of sampling at 500 kHz on 8 channels with 32K of memory. A Hewlett Packard 9816 personal computer was successfully interfaced with the DL 1200 to provide a means of permanent data storage and manipulation and an efficient means of controlling the recorder itself. Data can be output via the CRT, printer or plotter, using the appropriate software that has been developed.

Construction of Heat Transfer Analouge Circuits

A logarithmic heat transfer analogue is being constructed. A similar analogue was obtained from NASA Lewis and tested. The NASA analogue appeared to have a 5mV rms noise level. Methods of reducing the noise are being investigated for possible use in future analogues as well as modifications to increase the bandwidth beyond the current 50kHz limit .

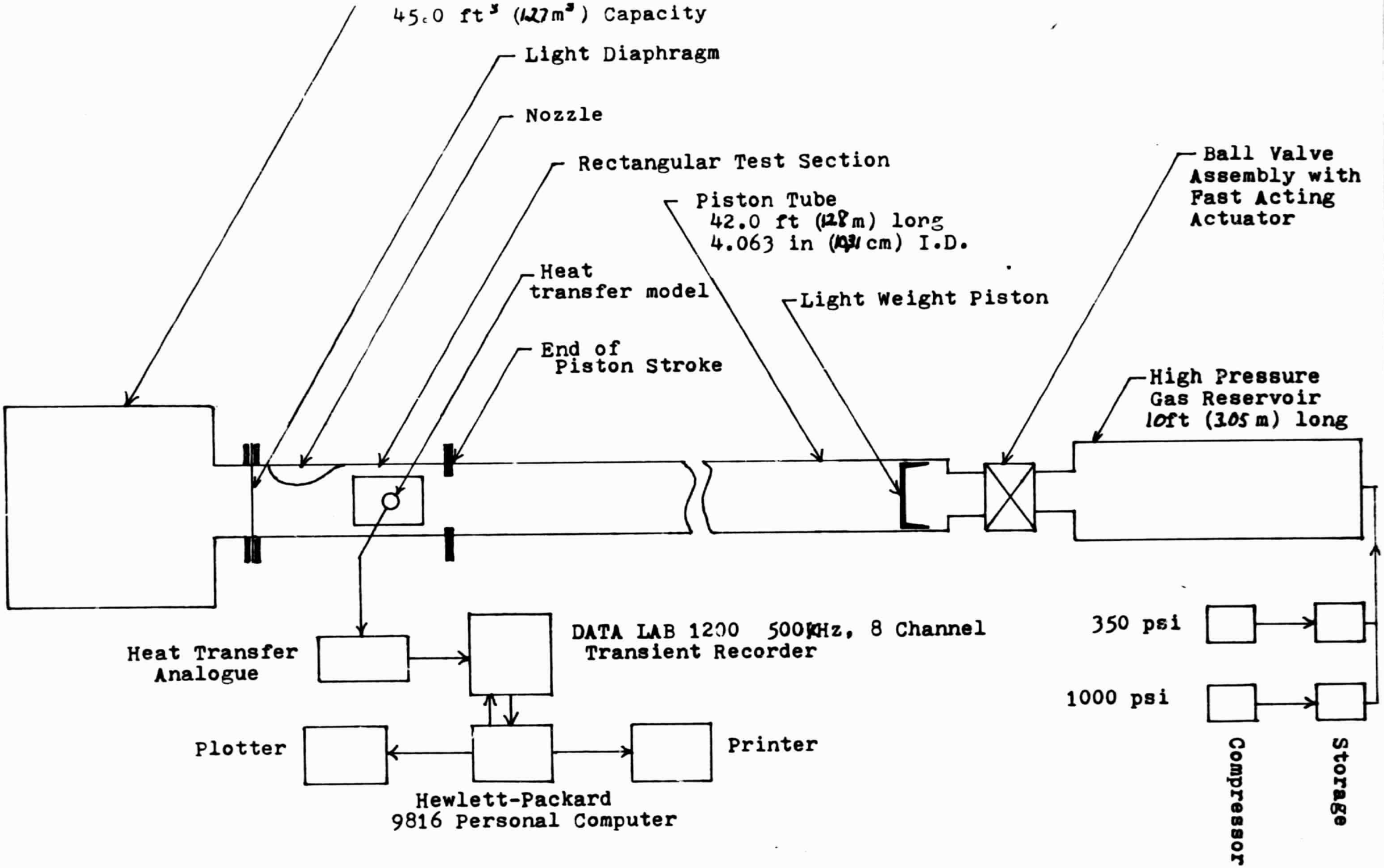

Fig. 1 Syracuse University LICH Tube

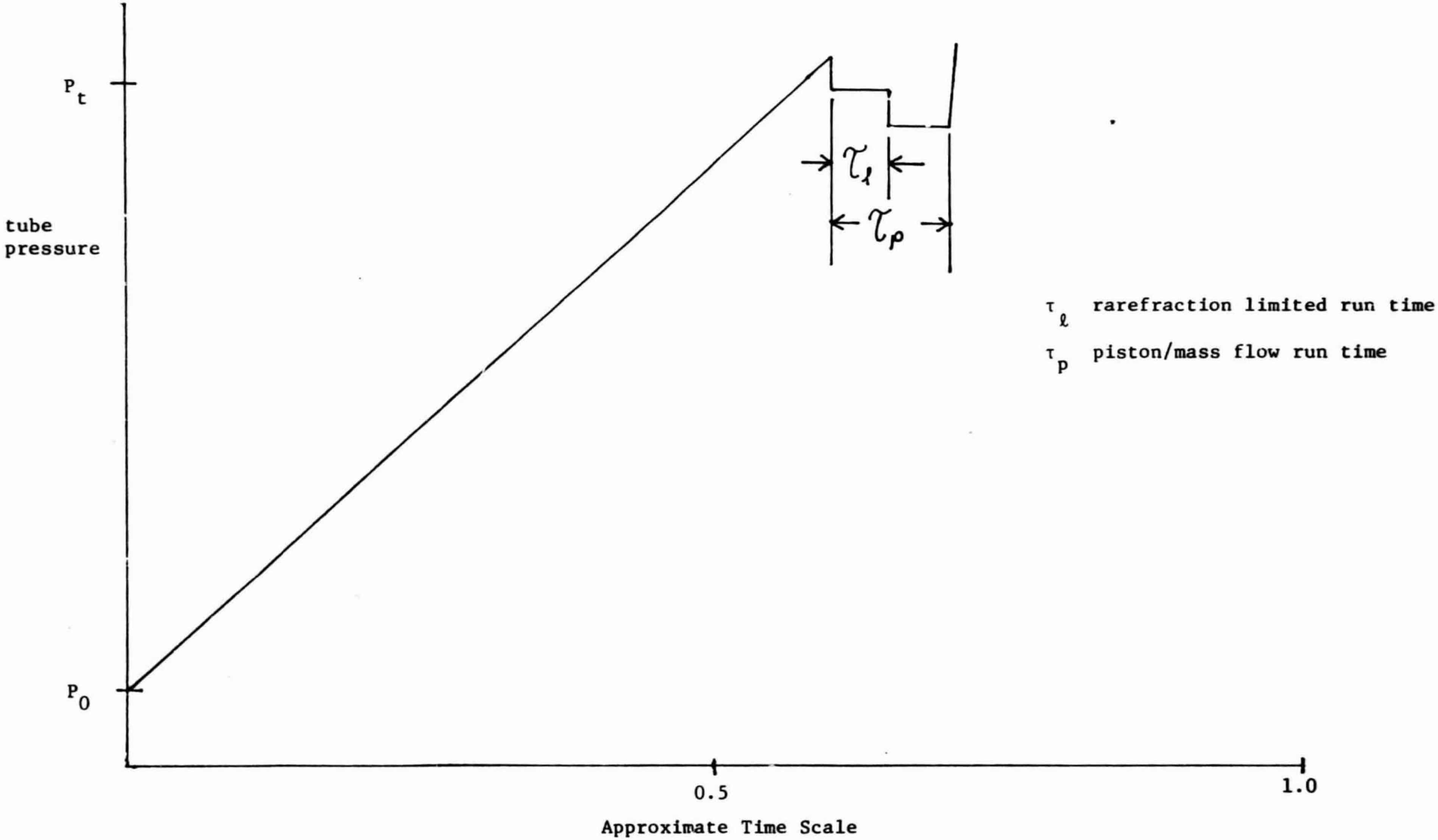

Fig. 2. A Schematic Diagram Showing the LICH Tube Pressure History.

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Fig. 3

Syracuse University LICH Tube

Running Time vs. Test Section Nozzle Area

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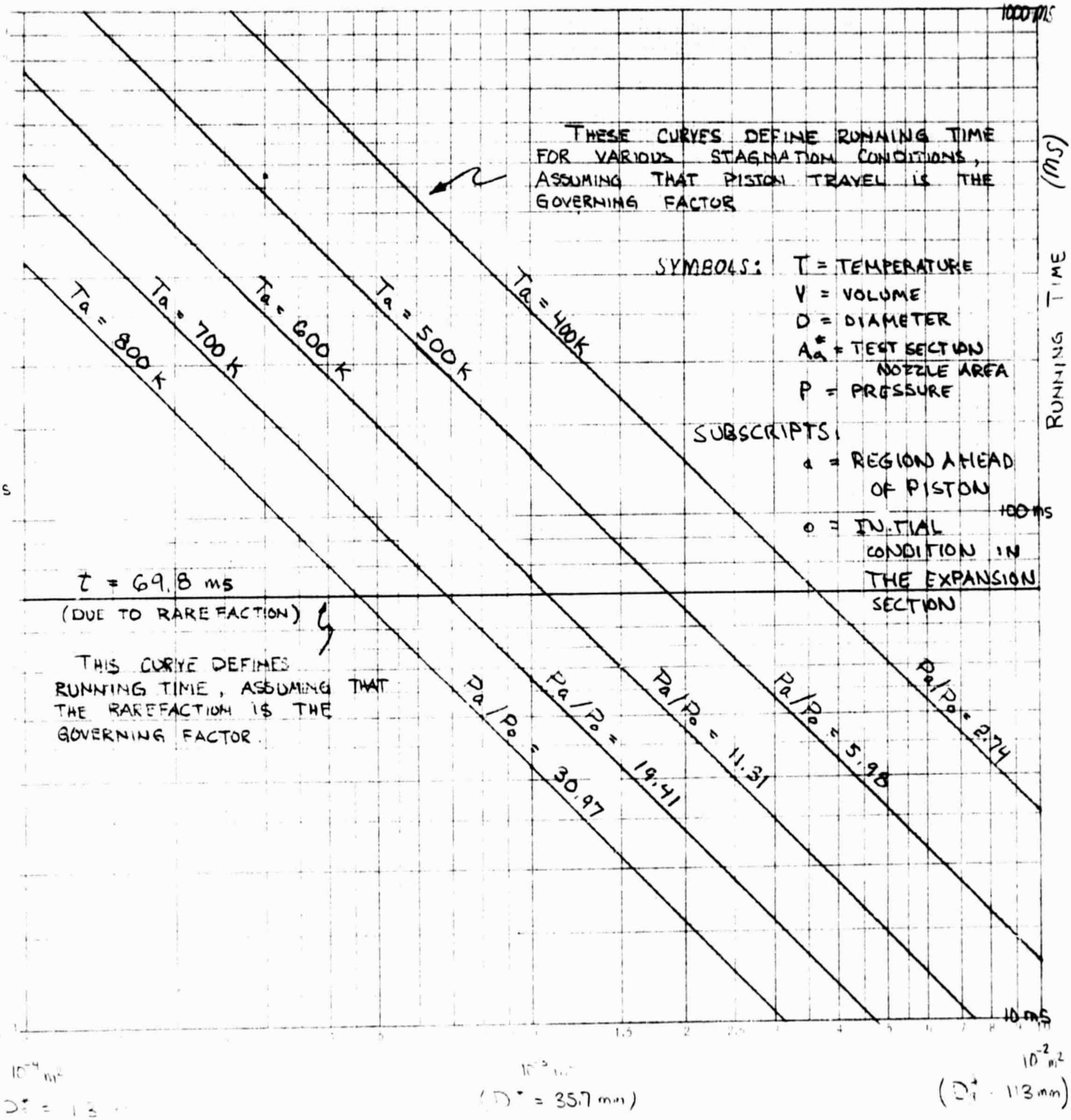
$T_o = 300$ K $V_o = .1216\ m^3$



TEST SECTION NOZZLE AREA – A_a^*

(WITH DIAMETERS)