NASA CR-86338

Fluidic Plasma Display Study
First Quarterly Report
Phase III

By Jacq Van Der Heyden

July 1969

Prepared under Contract No. NAS 12-532 by

Martin Marietta Corporation

Orlando, Florida

for
Electronics Research Center
Cambridge, Massachusetts

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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TECHNICAL RESPONSIBILITY

This program is being sponsored by the Electronic Research Center of the National Aeronautics and Space Administration, Cambridge, Massachusetts, under Contract NAS 12-532. The NASA monitoring scientist is Mr. E. H. Hilborn. The program manager at Martin Marietta's Orlando Division is Mr. Harold S. Straut. The principal investigator is Mr. Jacq Van Der Heyden.

This report covers the third phase of this contract through 5 July 1969.

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ILLUSTRATIONS

INTRODUCTION

This report cites the program objectives and the progress made during the first quarter of Phase III of research contract NAS 12-532. This study is sponsored by the Electronics Research Center of the National Aeronautics and Space Administration, and covers fluidic plasma display techniques. The efforts during this quarter have been concentrated mainly on building experimental hardware and test setups, as well as conducting experiments on gas cell matrices and fluidic control circuits.

This report contains sections covering the background of fluidically controlled plasma display systems and the program objectives. A section on the progress of the program to date describes the advances made in line and column control systems for the plasma display matrices. Future plans and new technology sections are also included.

I. BACKGROUND

This section presents the state of the art of plasma display systems, the fluidic control system implementations, and significant accomplishments made during this contract prior to this reporting period.

A. PLASMA DISPLAY SYSTEMS

Recent progress in display techniques includes the development of plasma displays that appear especially promising both for large tactical display panels and for airborne and portable digitally controlled display systems.

Plasma displays for these applications are usually a matrix type. A display matrix consisting of n rows and m columns contains $m \cdot n$ individual display cells that should be controllable independently of each other to obtain a universally usable display system.

1. Plasma Display Cells

The several forms of plasma display cells are variations of the basic principle of a closed cell constructed from glass, filled with a suitable gas such as neon or a mixture of neon and other gases. Usually the gas cells are formed by laminating a glass honeycomb panel between two sheets of glass. Electrodes are deposited upon the two outer sheets. Two types of cells have been used successfully: those with exterior electrodes and those with interior electrodes. The holes in the honeycomb inner glass laminate are either drilled or etched chemically. Electrodes are generally deposited by state of the art deposition techniques. Generally the gas mixture pressure in the cell is somewhat lower than atmospheric.

When a voltage is applied across two electrodes placed on opposite sides of the enclosed cell, an electrical discharge is caused through the gas mixture. This electrical discharge causes emission of visible light when proper conditions are met. Normally the light emission is directly proportional to the voltage applied across the cell. Recent developments include cells that fire a burst of rapid discharges after reaching a certain voltage. They may exhibit an hysteresis effect in the relationship between the applied voltage and the emitted light. This hysteresis effect can be used to advantage as a memory device in matrix display systems.

Dependent upon the size of the cell, the gas mixture, and the gas pressure, a certain voltage applied across the plasma display cell will ignite the cell. This potential is called the ignition voltage, V_i. After initial ignition is obtained, light emission will continue at a lower voltage level;

this is called the sustain voltage level, V_s. When the voltage drops below the sustain level, the cell will extinguish. This voltage level is called the extinguish voltage level, V_e. Typically, these voltage levels will be a function of the internal pressure of the gas in the cell as shown in Figure 1. Obviously, when a constant pressure is maintained in the cell and the voltage is varied along line A as shown in Figure 1, hysteresis between the input voltage and light emission of the cell will be observed.

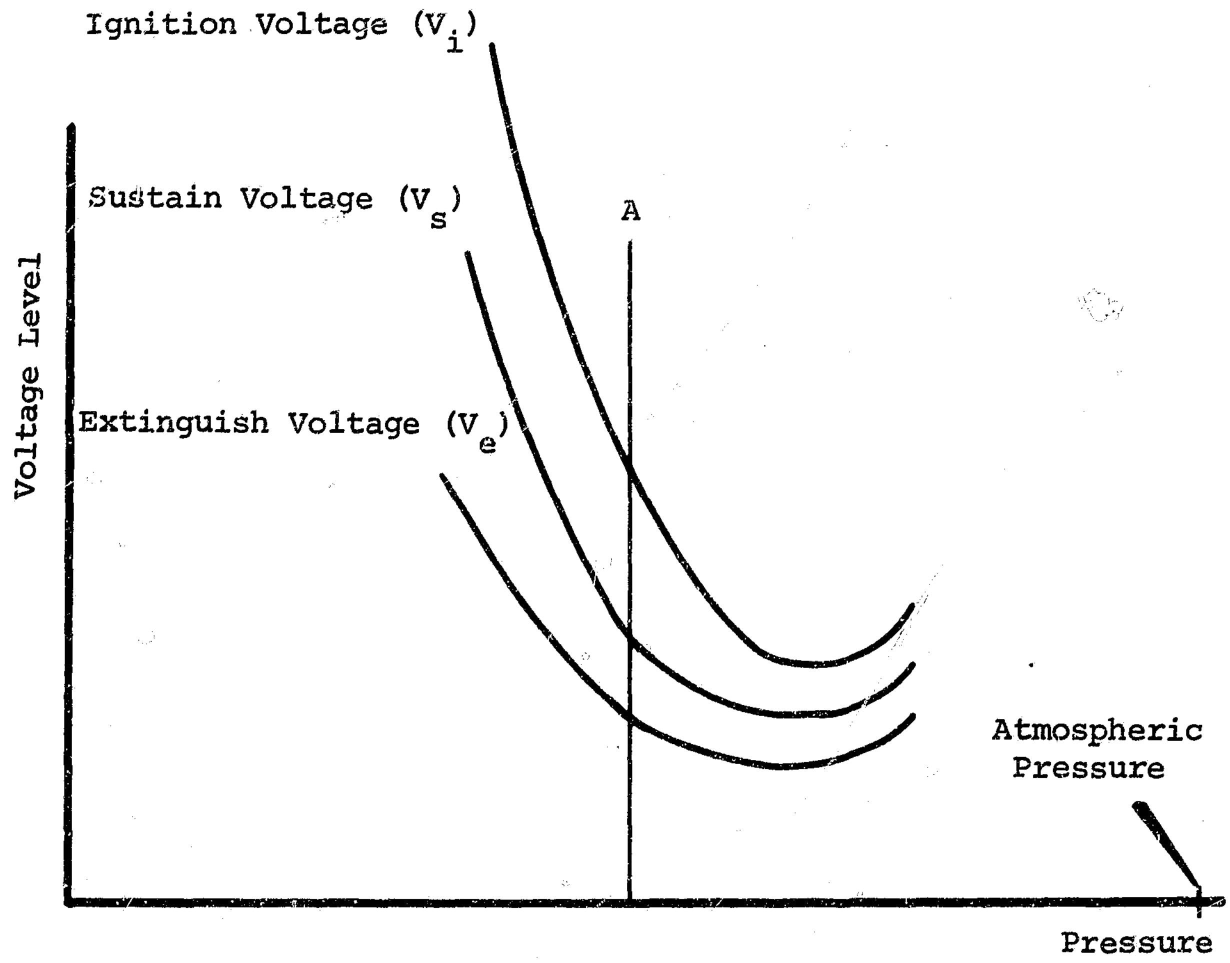


Figure 1. Typical Relationship of Voltage and Internal Cell Pressure

2. Conventional Plasma Display Control Systems

A plasma display matrix can be controlled in either of two ways. In the first system a separate control circuit is used for each cell in the matrix. For large matrices this control system becomes complex and costly because of the large number of control circuits required. For example, even if only one logic element per cell is required, a 1000 by 1000 cell matrix would require 10^6 logic elements.

An obviously better solution is offered by the second system where a crossed grid array is used. Each column and each row is controlled as an entity. Using one element per column and one per row, a 1000 by 1000 cell matrix will require 2000 control elements, an obvious improvement. The drawback of crossed grid control systems is that, when a complete column is addressed, all cells also having the corresponding line control circuits energized may light up. Conventional electronic control systems circumvent these difficulties by utilizing the inherent hysteresis effect of the cells as a memory, and by sequentially energizing (scanning) the electrodes of selected cells.

Even when utilizing the memory effects combined with the scanning type control system two problems remain to be solved before an electronic control system will be judged feasible; namely:

1. Large scale displays cannot be built economically because of the high cost involved in the control circuits; the reliability of circuits with a large amount of control elements is also unsatisfactory. Since the voltage levels required to control the plasma display cells are substantial, transistorized circuits cannot be counted on to provide low-cost systems. No immediate results can be expected from developments anticipated in microelectronic techniques.

2. The impedance of each plasma display cell basically has two distinct levels. Cells in the activated state exhibit less impedance than those which are extinguished. Consequently, the impedance seen by the excitation signals provided to the display cells will vary depending upon how many cells are fired or extinguished. The impedance changes are sufficient to fire unwanted cells.

Both problems can be solved with a fluidic control system.

B. FLUIDIC CONTROL SYSTEMS

Some problems in crossed grid control systems for plasma displays can be solved by fluidic techniques. The main advantage of a fluidically controlled plasma display system will be in the simplification of the control circuits and the reduction of its failure rate and cost, as compared to electronic control systems.

Since unwanted firings of adjacent cells are at least partly caused by the effects of a change in the impedance of the cell when it converts from the inactive to the active state, a control system that works on the internal cell pressure rather than the applied voltage will be advantageous. A fluidic control system that controls the internal pressure will be completely independent of the electrical impedance changes encountered in the plasma.

Fluidic control, rather than electronic control, can be mechanized as cited here. Figure 2 shows the typical relationship between internal cell pressure and ignition voltage levels as explained earlier. Electronic control of the cell firing is accomplished by varying the voltage level along line A in Figure 2. Fluidic control can be instigated by 1) maintaining the voltage constant on the cell, and 2) varying the internal cell pressure along line B. If the internal pressure is held at the P_1 level, the cell will fire. An increase in pressure to a level anywhere between P_1 and P_2 will still sustain the firing. At pressure level P_2 the cell will extinguish. Since pressure control can be accomplished fluidically, complete fluidic control, combined with a constant voltage supply, is possible.

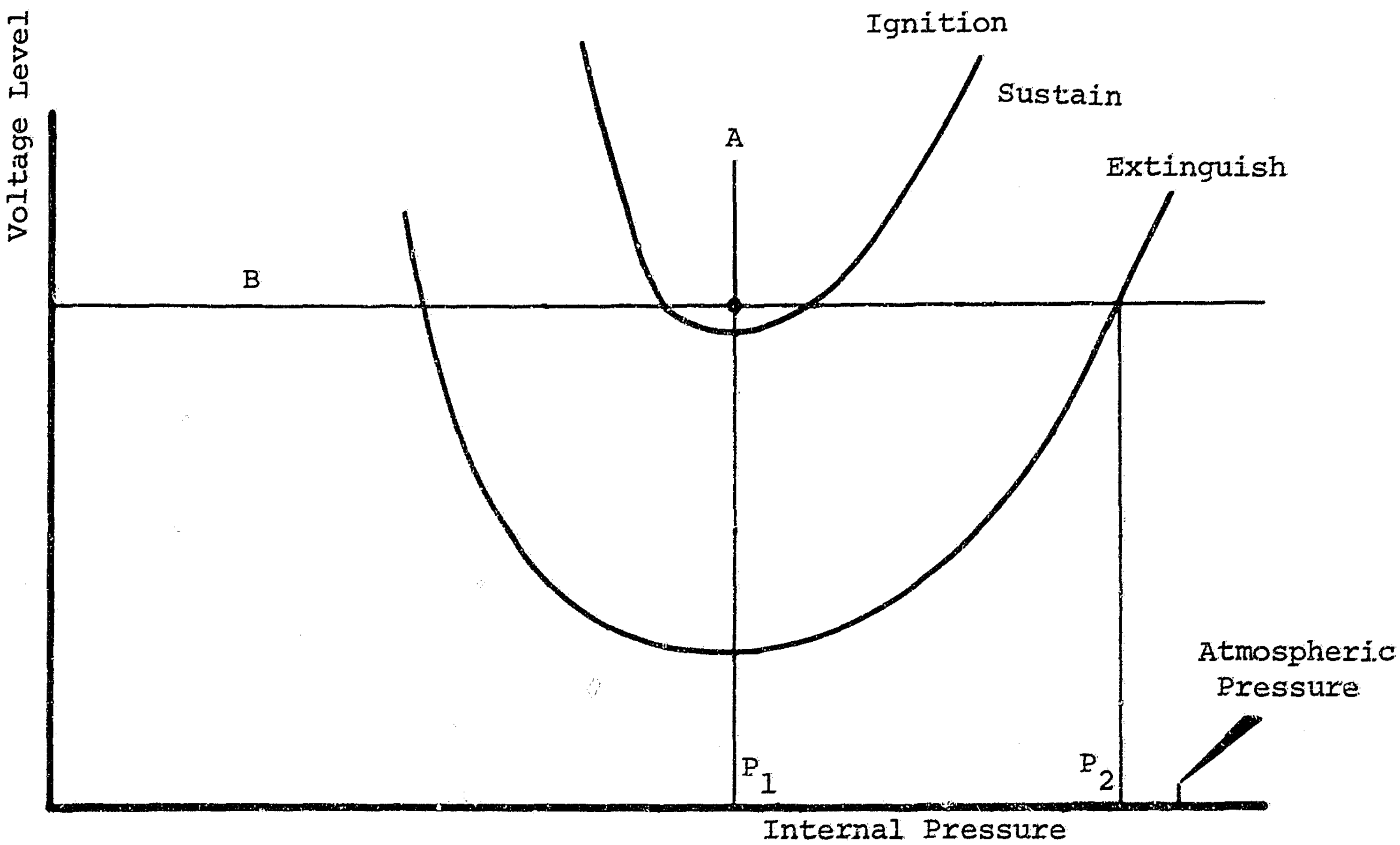


Figure 2. Fluidic Control Mechanization

C. PREVIOUS ACCOMPLISHMENTS IN FLUIDIC PLASMA DISPLAY SYSTEMS

The feasibility of using fluidic control techniques for plasma displays was ascertained during the second phase of this contract. Results of this study are reported in Phase II Final Report Contract NAS 12-532, "Fluidic Plasma Display Study." The report, dated March 1969, carries Martin Marietta's identification number OR 9930. Two significant problems were solved during Phase II of this contract. The first problem was to obtain plasma display cells which have gas pressures compatible with fluidic element pressure levels. The second problem was to ascertain if fluidic elements, which normally use air or nitrogen as a working fluid, can work with gases such as neon, normally used in display cells. Complete details of the investigations are contained in the above mentioned report. Highlights are described in the following sections for completeness only.

1. Plasma Display Cells

Since plasma display cells that were previously developed for use with electronic control systems worked at pressure levels which were not compatible with the pressure ranges obtainable with fluidic control systems, a new family of cells was developed.

To facilitate controlling plasma display cells with varying pressure conditions, it was necessary to construct cells with an external gas connection. The general shape of the gas cells used is shown in Figure 3. The cell is formed by a round hole in the glass cell plate, and the cell plate is grooved to connect the cell cavity with the hole in the glass cover plate. The cover plate and bottom plate are cemented to the cell plate. An external gas connection is cemented to the top plate and electrodes are deposited on the outsides of cover and bottom plates.

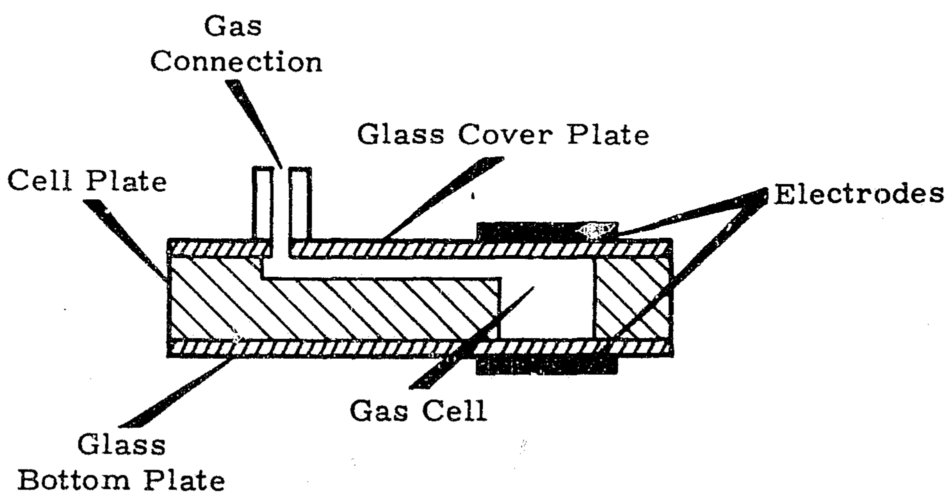


Figure 3. Experimental Cell Construction

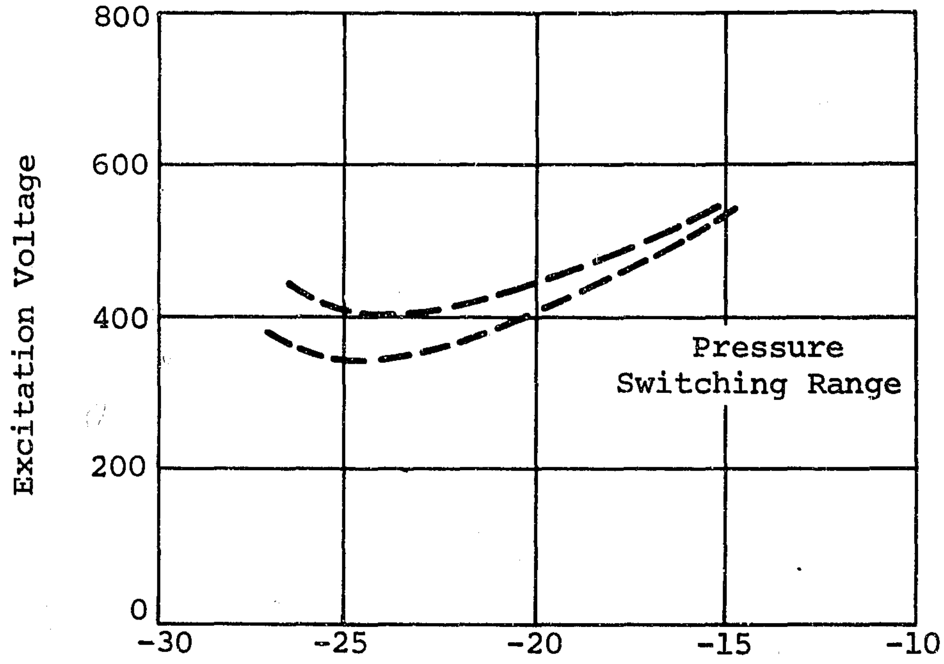
The most promising cell configuration developed thus far exhibited voltage pressure characteristics as shown in Figure 4. Constant excitation at 500 volts, will make it possible to switch the cell on and off with a pressure switching range of 4 inches Hg from -18 to -14 inches Hg. As will be shown these pressures are obtainable with current fluidic techniques.

2. Fluidic Logic Elements

Essential to the performance of a fluidic control system are proper performance characteristics of the fluidic logic elements to be used as pressure switches for the plasma cells. The fluidic elements to be used in the plasma display system deviate mainly in two aspects from conventional fluidic system elements:

1 Working pressure levels are lower than normally encountered in fluidic systems

2 Fluid media used are neon or a mixture of gases rather than air or nitrogen which are the gases normally used.



Internal Cell Pressure ∿ inches Hg (ref Sea Level)

Figure 4. Plasma Cell Test Results

Investigations were conducted to determine the capabilities of Martin Marietta's state of the art fluidic devices to operate under low pressure conditions. Figure 5 shows the maximum pressure level changes obtainable at various internal cell pressures. The lowest internal pressure obtainable with fluidic elements is approximately -25 inches Hg vacuum or approximately 5 inches Hg absolute. These capabilities are sufficient to switch plasma display cells. Figure 6 illustrates the control pressure levels and output pressure levels versus supply pressures for nitrogen, neon, argon, and helium. Neon will be used as the primary gas in the display systems.

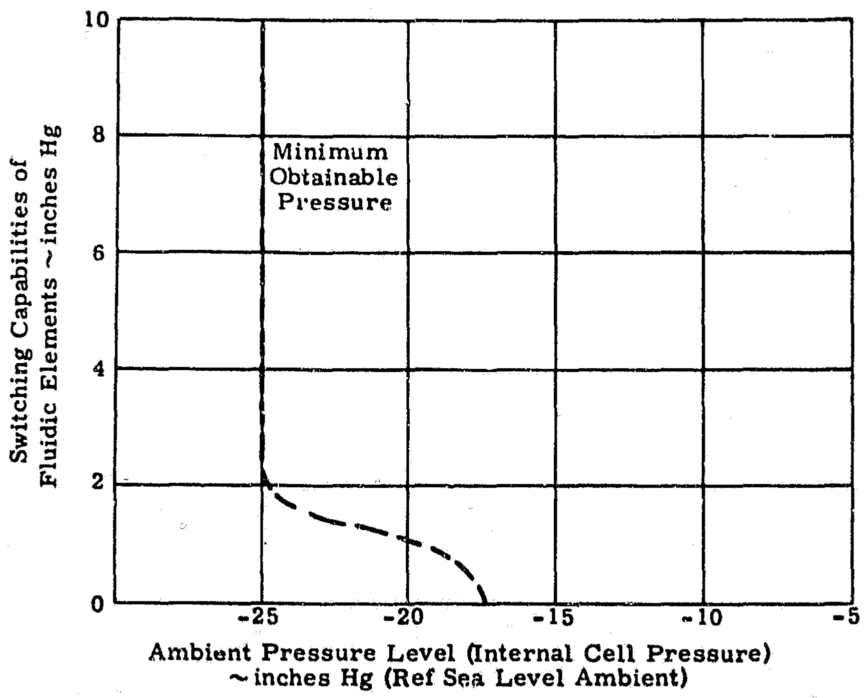


Figure 5. Maximum Switching Capabilities versus Internal Cell Pressure

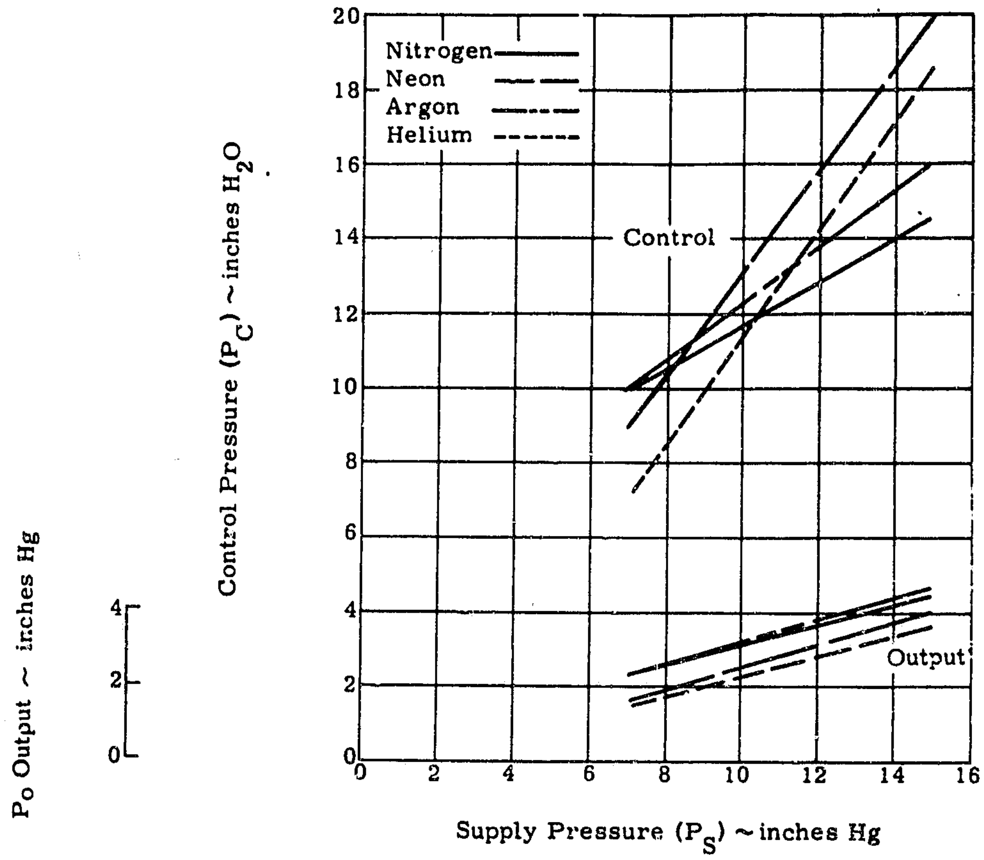


Figure 6. Four MIL-OR-NOR Element

II. PROGRAM OBJECTIVES

During this 9 month program, Martin Marietta will continue the investigation of fluidically controlled plasma display devices. Feasibility of control of single plasma display cells with fluidic techniques was proven under phase II of this contract.

The investigation will cover the control of multiple display cell arrangement such as matrix display configurations used for computer driven alphanumeric readout matrices. Specifically, the studies and experiments cover the development of cell matrices which can be controlled fluidically. These matrices differ from conventional plasma display arrangements in two ways. The display matrix requires input channels for the fluidic signals and cell firing characteristics should be compatible with the signal levels obtainable from fluidic logic circuits. Effort will be extended in the areas of optimization of display matrix design, design of cells, and interconnecting lines. Also, investigation of crosstalk problems encountered in line and column control systems will be conducted. Development of a simple experimental matrix will be undertaken to prove feasibility of fluidic line and column type control systems for plasma display matrices.

III. PROGRAM PROGRESS

Progress made during this first reporting period is in the investigation of crosstalk problems on fluidic line and column control and in the designing of experimental hardware. This section describes these control system investigations and other pertinent areas:

A. CROSSED GRID CONTROL

A theoretical analysis of the performance of a fluidic system for a row and column control scheme was performed during phase II of this contract. It was shown that if simple display cells were individually connected to one line and one column pressure signal channel as shown in Figure 7, five distinct pressure levels would result in the matrix, e.g., assuming that the internal pressure of cell 11 was to be increased to obtain the desired action in this cell, the fluidic elements 01 and 10 which are the line and column control elements of cell 11 are turned on. Output pressure levels of these elements are then P_o psi. The remaining control elements 02, 03, 20, and 30 are at the quiescent pressure level P_q. Cell 11, which is connected through two orifices to two lines in which a pressure of P_o is maintained, will be at pressure level P_o. The same reasoning holds for cells 22, 23, 32, and 33. They are connected on both sides to a pressure level P_q and will therefore be at pressure level P_q. Cells 12, 13, 21, and 31 are connected to a level P_o on one side and a level P_q on the opposite side. Since $P_o > P_q$, flow will occur and the pressure level of cells 12, 13, 21, and 31 will be at some intermediate pressure level P_i.

The fluidic logic system maintains the input pressure to the lines and columns at three distinct levels: P_a, P_q and P_o. This results in five distinct levels that can be present in any of the cells as shown in Figure 8. For proper operation of the system, three pressure levels (P_1, Pq and P_i) should all fall within the plasma cell hysteresis band to prevent unwanted cell firing or extinguishing.

During phase III of this contract it is shown theoretically that these pressures can be kept within the hysteresis band. Experiments were performed on a matrix constructed from metal laminates as shown in Figure 9. Provisions were made to apply pressure to one or more line or column input lines. Some of the simulated plasma cells were connected to pressure transducers in order to monitor pressure changes occuring inside the cell due to control signals applied to line and columns. Figure 10 shows test results obtained with this matrix. Relative levels of input signals and internal cell pressures are shown. Figure 11 shows these test results plotted on the plasma cell hysteresis band. The pressure range between pressure levels P_1 and P_i almost covers the complete hysteresis band. No margin for variations of individual cell dimensions, which have influence on the ignition and extinguishing levels for each cell, is available.

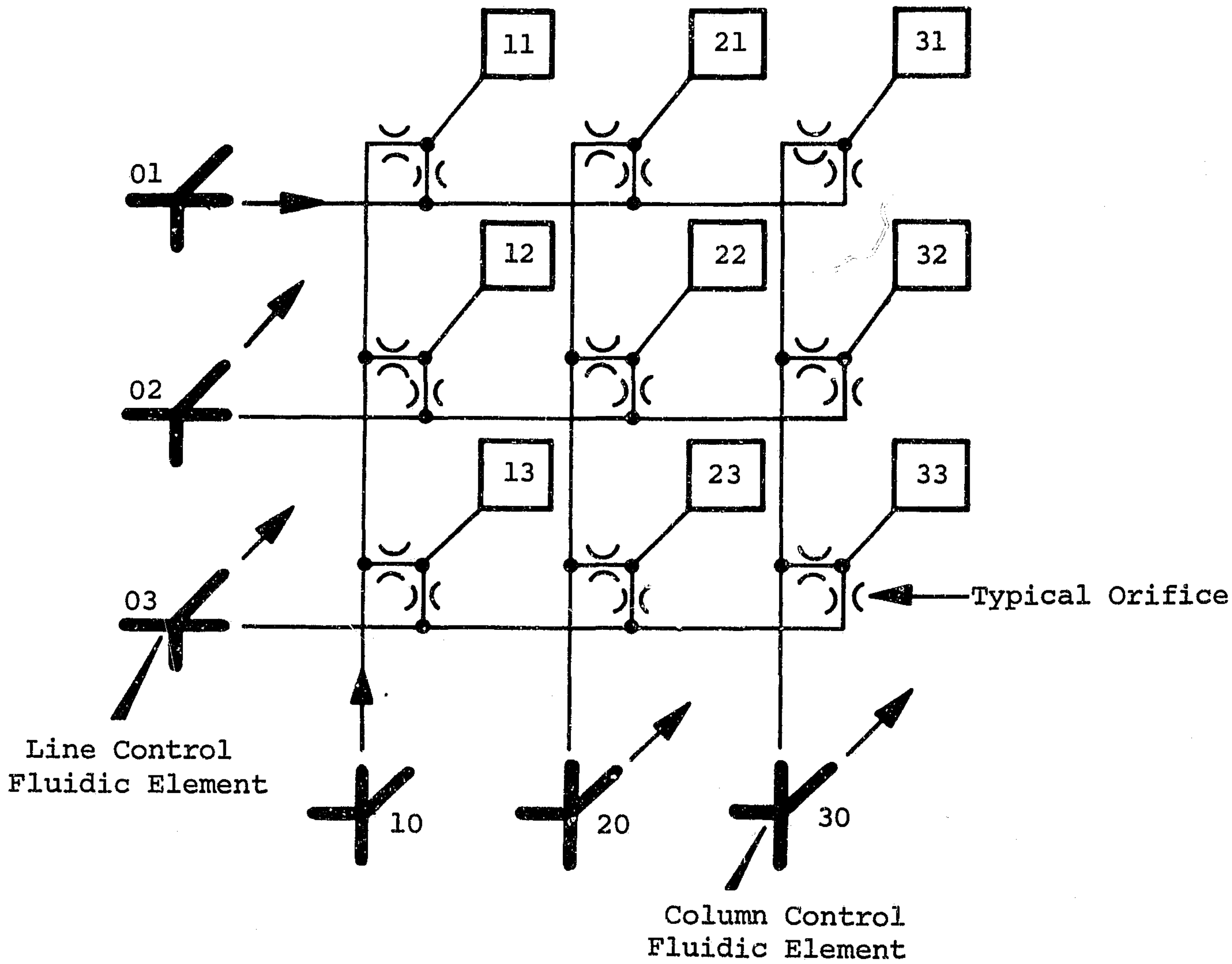


Figure 7. Cross Grid Control System

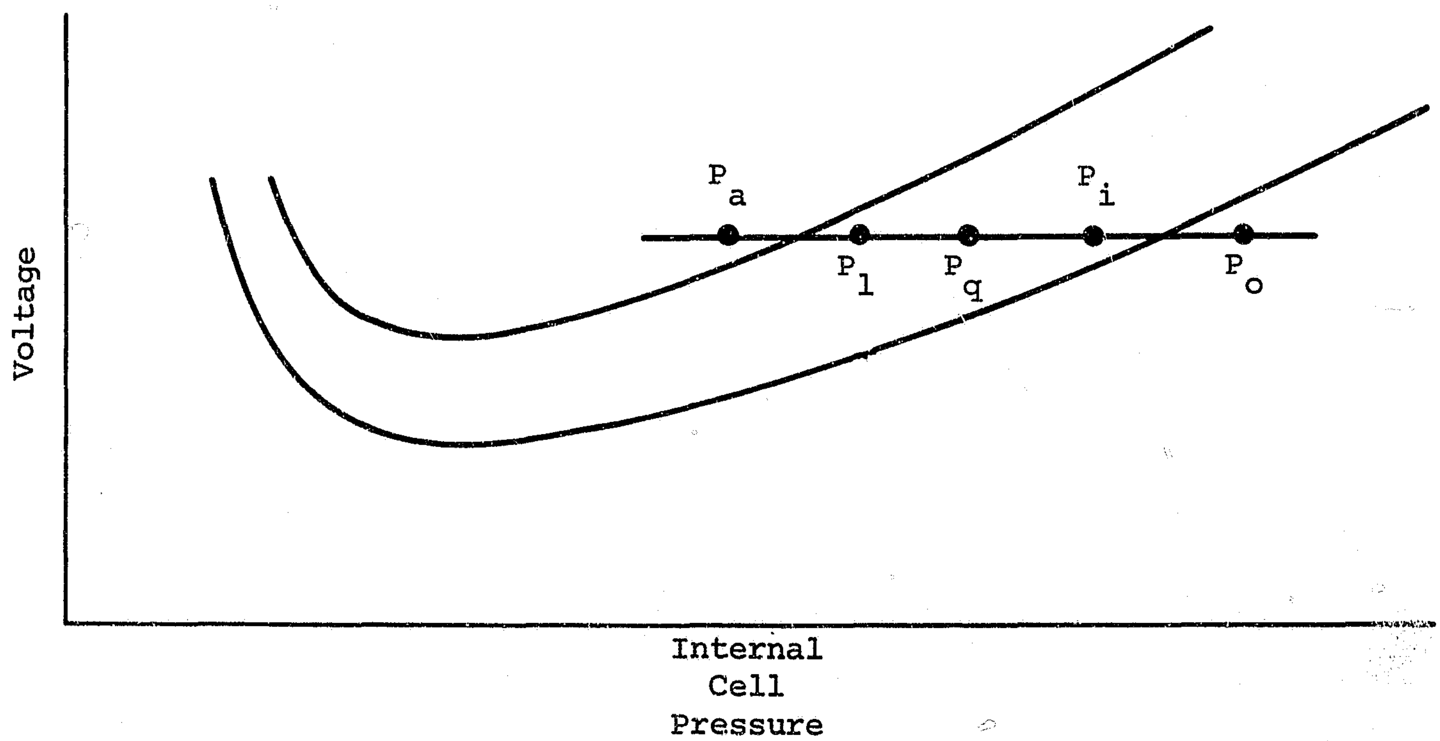


Figure 8. Pressure Levels versus Voltage

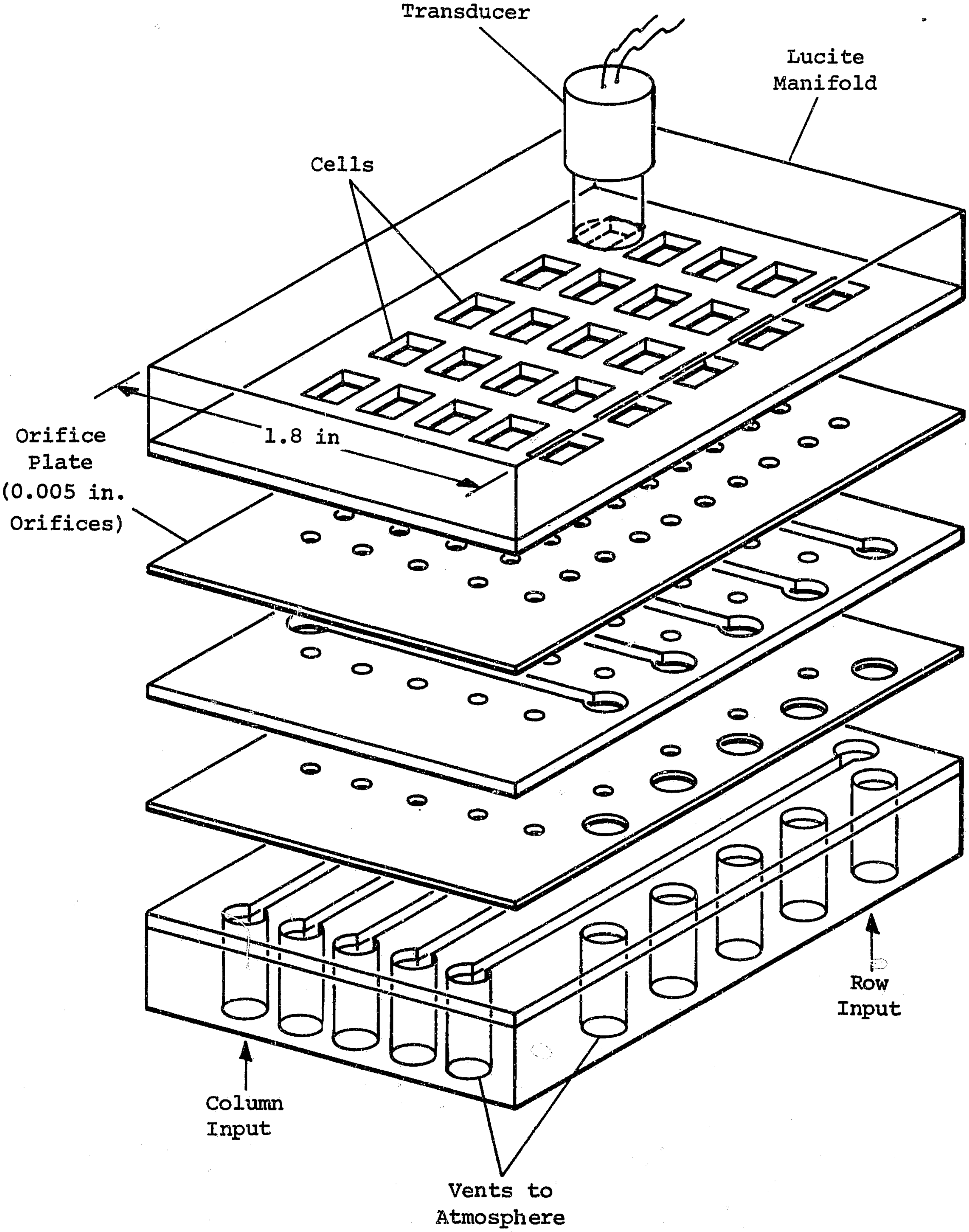


Figure 9. Fluidic Plasma Display Test Matrix

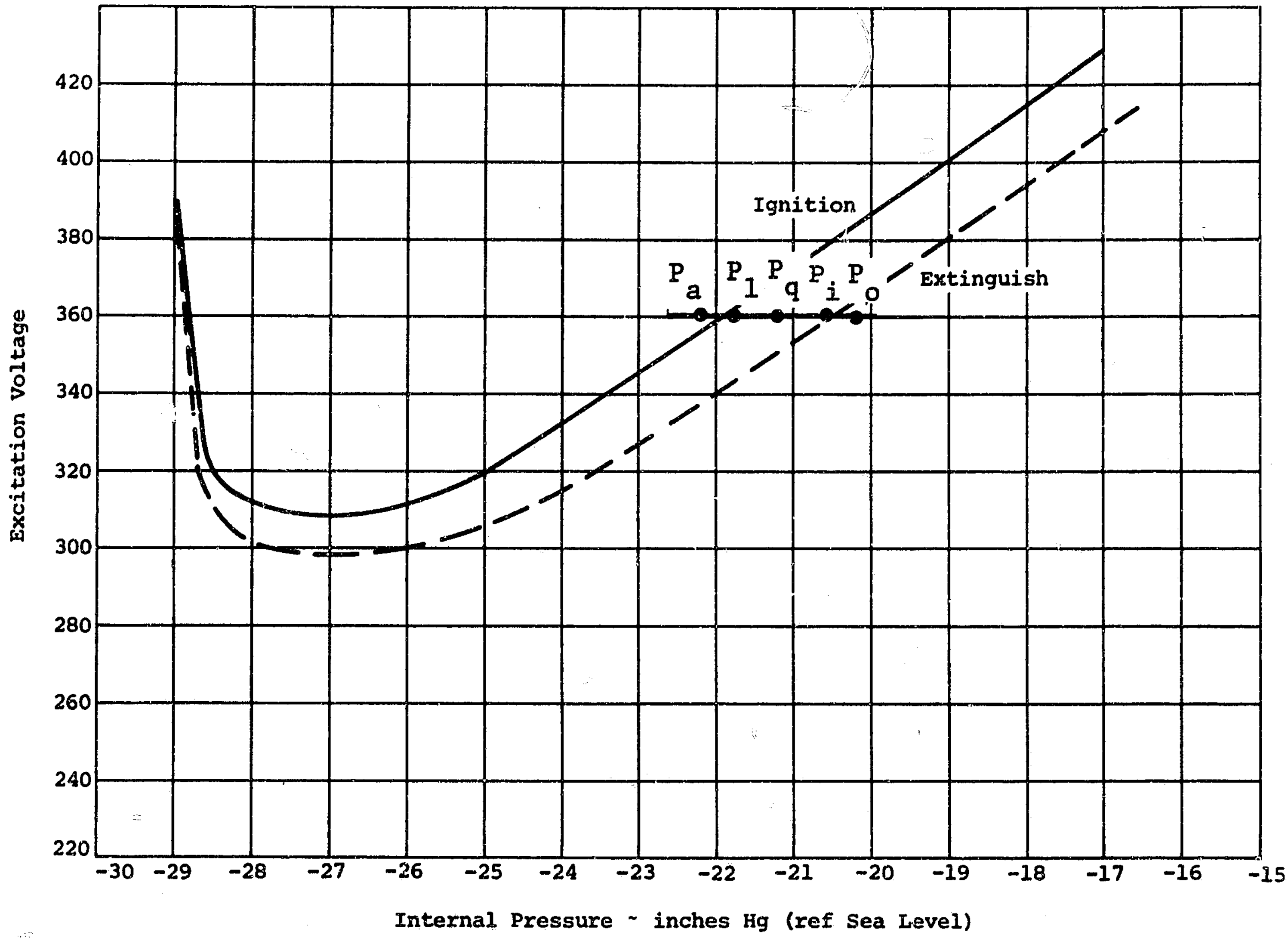


Figure 10. Plasma Cell Pressure Voltage Characteristics

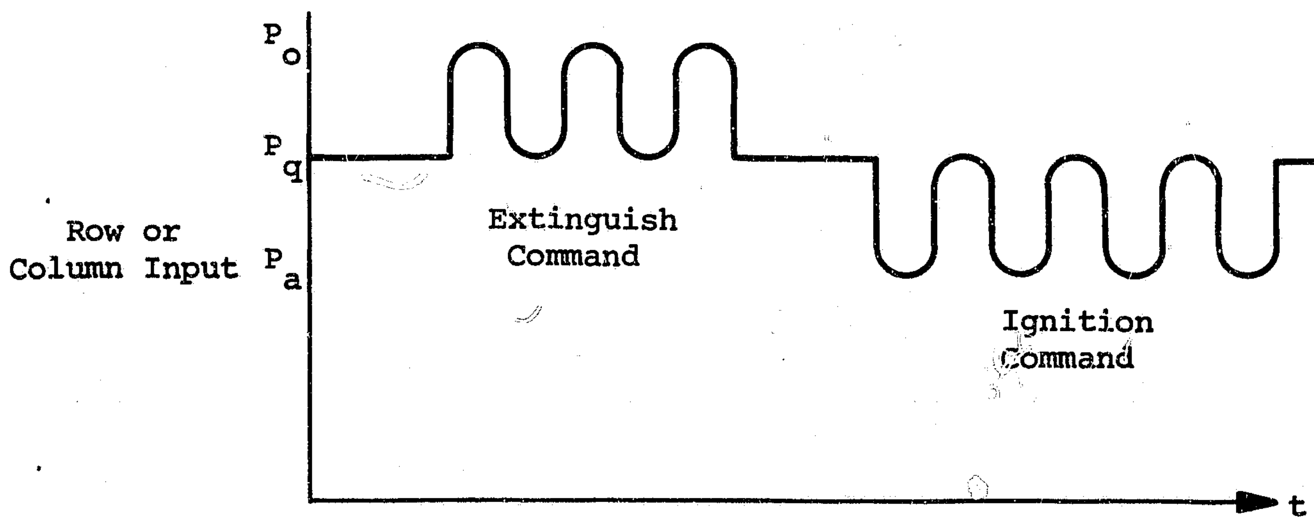


Figure 11. Oscillatory Control

B. OSCILLATORY CROSS GRID CONTROL

An improved control system can be obtained by using oscillatory signals as pressure excitation in combination with pneumatic filtering techniques. Figure 11 shows the type of input signals required for this oscillatory control system. The normal output of the control signal into each line and column is the steady-state pressure level P_q. The extinguish command is an oscillatory signal with P_o as the highest peak pressure. The ignition command is a pressure oscillation with level P_a as its lowest peak pressure.

The advantages of this scheme are illustrated in Figure 12. When a cell has to be activated, the oscillatory pressure signal is applied to both line and column signal ports of the cell. At low frequencies no signal attenuation is experienced and the equivalent electrical circuit that describes the fluidic action is a shorted capacitor.

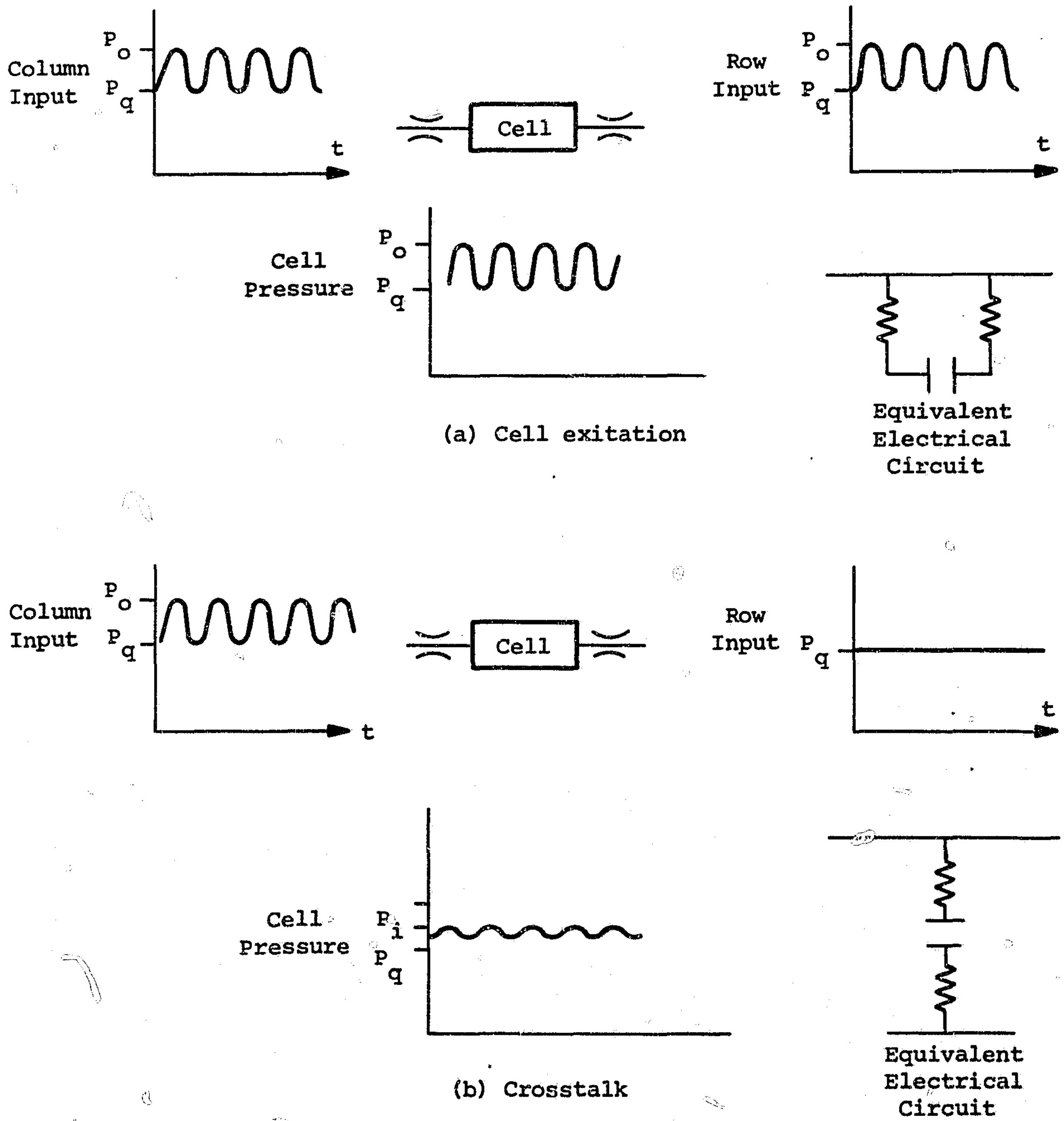


Figure 12. Pressure Excitation and Crosstalk

Figure 12 shows the amount of crosstalk experienced in a cell when one of the cell inputs is activated and the opposite inlet port is held at pressure P_q. The equivalent electrical circuit shows that the cell now acts as a capacitor to ground, causing attenuation of the excitation signal at higher frequencies.

Careful selection of the orifice size that connects the plasma display cell with the row or column signal channel will make it possible to select a signal frequency at which no appreciably attenuation of the pressure signal will be present when both line and column are excited. Considerable attenuation is experienced at that same frequency only when one port is excited. Figure 13 shows the test results obtained with one orifice size selected for some experiments. Figure 14 shows that the crosstalk, when plotted against the allowable band formed by the hysteresis of the plasma call, is within the allowable tolerances. The experimental results shown in Figure 13 are the first results obtained with this mode of control. Further analyses will be performed to ascertain if more improvement is possible. These analyses may be performed with the help of the equivalent circuit technique that was shown in Figure 12.

C. EXPERIMENTAL HARDWARE

In addition to the simulated display matrix described earlier in this report, other experimental hardware was built or is presently under construction. Four different pieces of hardware are necessary for this program:

<u>1</u> Plasma Cell Display Matrix Simulator - This device is used to obtain experimental data on signal propagation from row and column excitation channels (Figure 15). Adjustments to the relative size of row and column channels, inlet ports, and cell configurations are possible. Cell pressures can be monitored with pressure transducers. A schematic of a complete test matrix is shown in Figure 9.

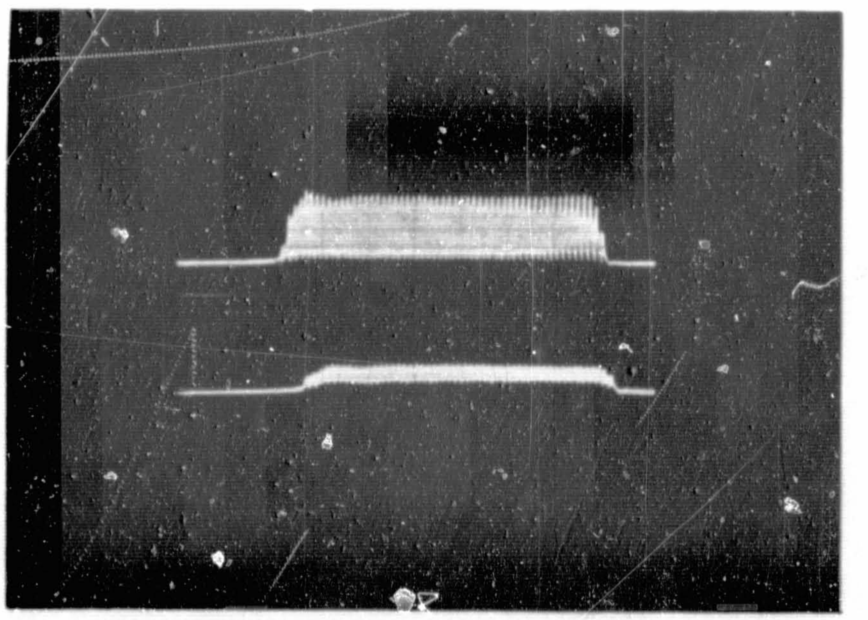


Figure 13. Experimental Cell Pressures Using Oscillating Control Signal

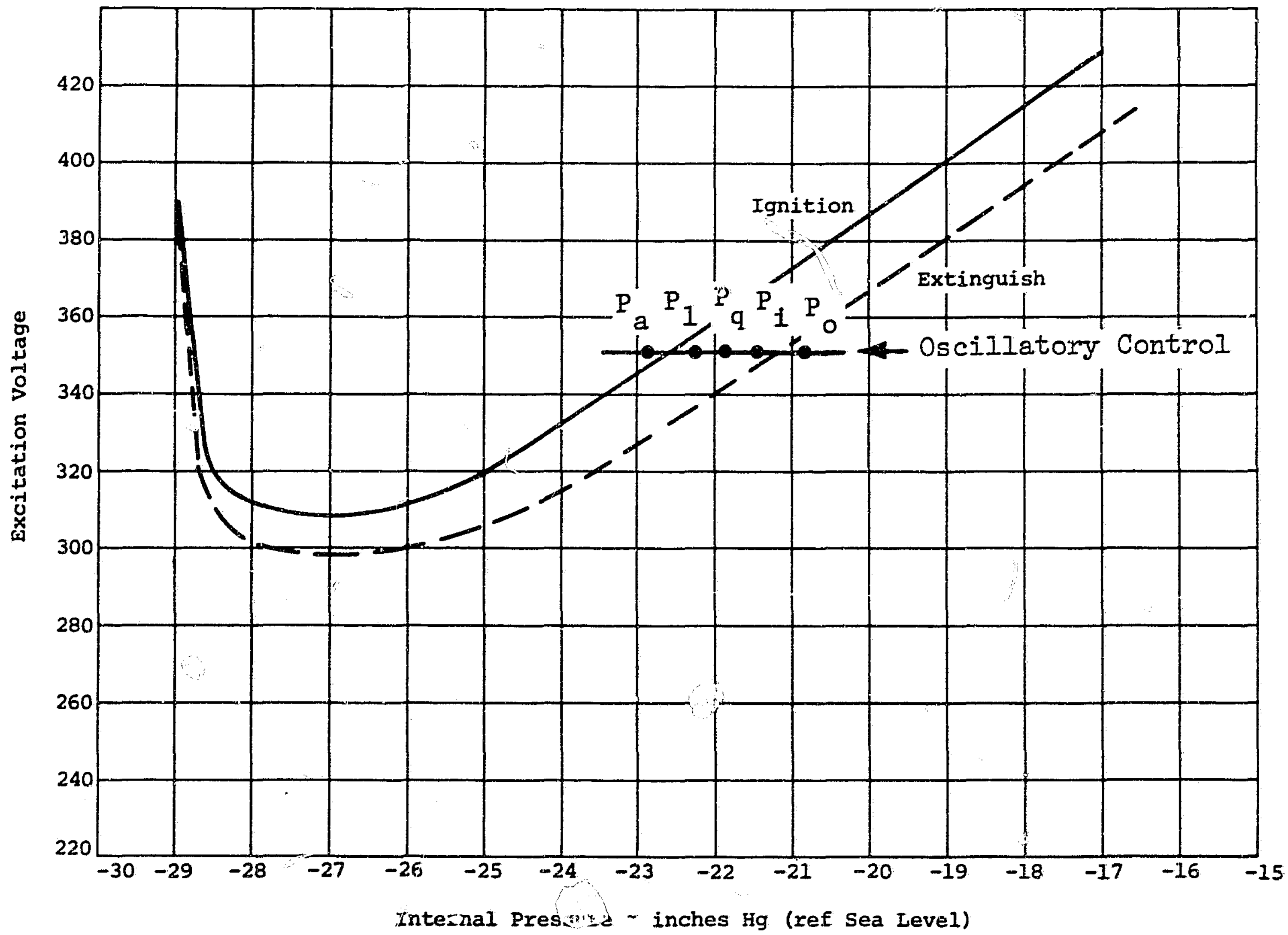


Figure 14. Plasma Cell Pressure Voltage Characteristics

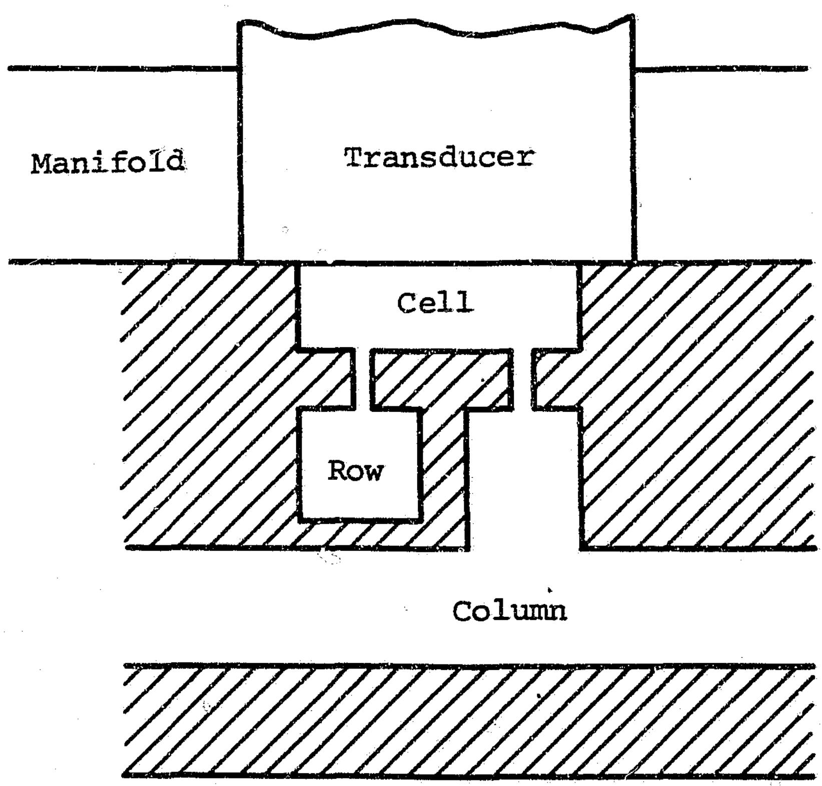


Figure 15. Cross-Section of Single Plasma Cell in Test Matrix

2 Neon Manifold and Test Panel - This test panel which will enable experiments with several plasma display cells at different pressures to be conducted is presently under construction. Specifications for a contamination free pump have been generated. This pump will make it possible to reuse neon rather than releasing it into the atmosphere. Additional data on the extent of gas contamination problems which may occur when recirculating pumps are used will be obtained.

3 Experimental Plasma Cell Matrix - Designs for an experimental four-cell matrix have been made and glass laminates have been obtained. The first attempt to build this matrix was unsuccessful. The assembly cracked during cooling after a glass fritting process was used to seal cells and interconnecting channels. Several other matrices are presently under construction. Cell dimensions used in the experimental design were determined previously (see Phase II, Final Report OR 9930, Contract NAS 12-532, Plasma Display Systems).

4 Experimental Fluidic Control System - A prototype fluidic system for control of a plasma display matrix is presently being designed. The system will use low level electrical signals as input commands to operate electro-to-fluidic interface devices that were developed during Phase I of this contract. The fluidic signals will operate fluidic elements which will provide the pressure signals to the line and column input channels of the display matrix.

IV. FUTURE WORK

The effort planned for the second quarter of this contract will be concentrated in the following areas:

1 The analysis of the oscillatory cross-grid control system will be completed.

2 Experimental hardware will be obtained and tested.

3 Design of the demonstration model of the plasma display matrix will be started.

V. NEW TECHNOLOGY

A review of the effort performed under this contract to date indicated that one innovation may be classified as novel. The concept of oscillatory control of plasma display matrices will be reported as a new technology item in a separate report as required by the contract.