CR 86339

FLUIDIC PLASMA DISPLAY STUDY
SECOND QUARTERLY REPORT
PHASE III

By Jacq Van Der Heyden

October 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

FLUIDIC PLASMA DISPLAY STUDY
SECOND QUARTERLY REPORT
PHASE III

By Jacq Van Der Heyden

October 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

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 second quarter of the third phase of this contract from 5 July 1969 to 5 October 1969 (report no. OR 10,320).

CONTENTS

PRECEDING PAGE BLANK NOT FILMED.

ILLUSTRATIONS

INTRODUCTION

This report cites the program objectives and the progress made during the second 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. During this quarter construction of experimental hardware as well as experiments with gas cell matrices and fluidic control circuits was continued.

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.

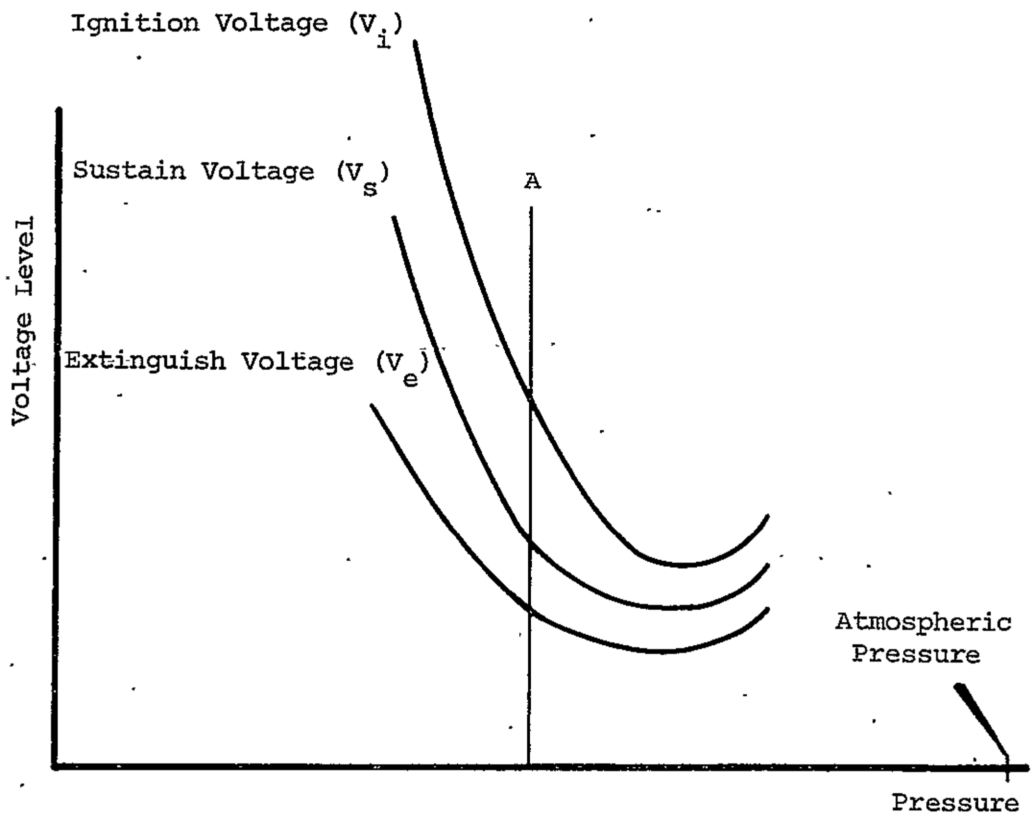

Figure 1. Typical Relationship of Voltage and Internal Cell Pressure

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.

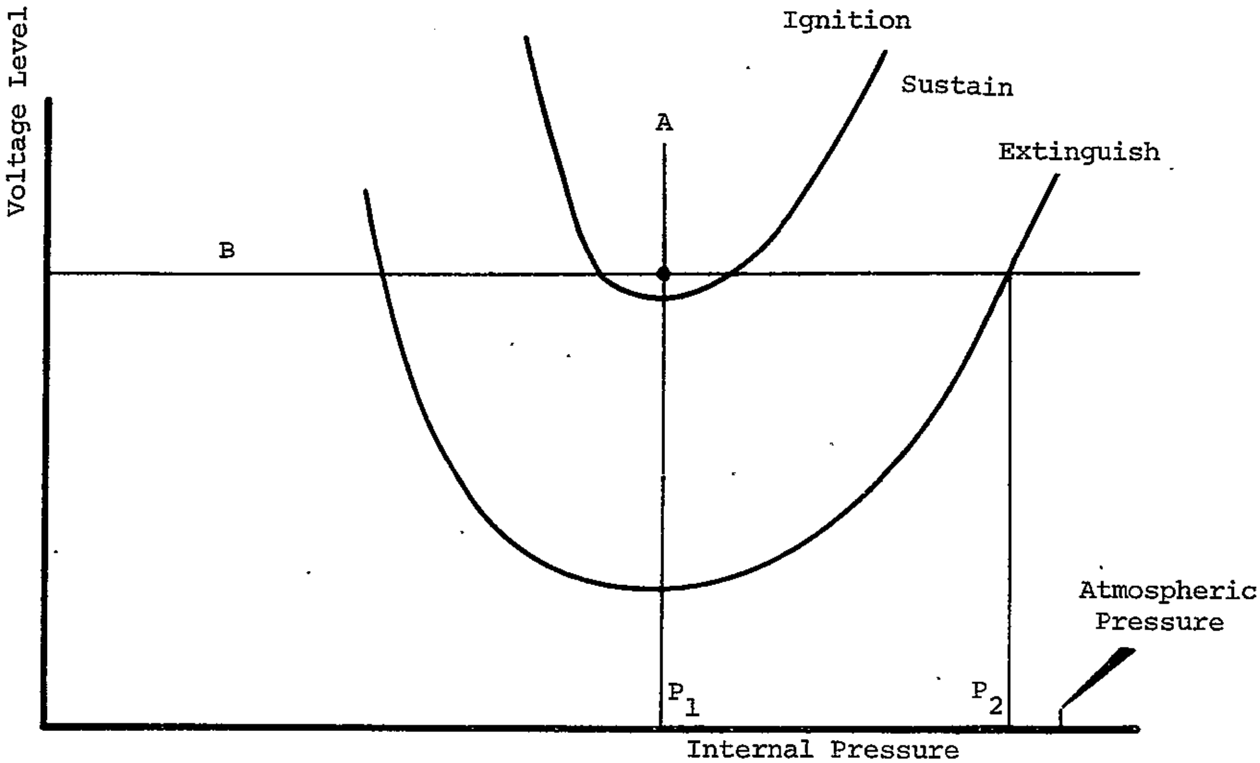

Figure 2. Fluidic Control Mechanization

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.

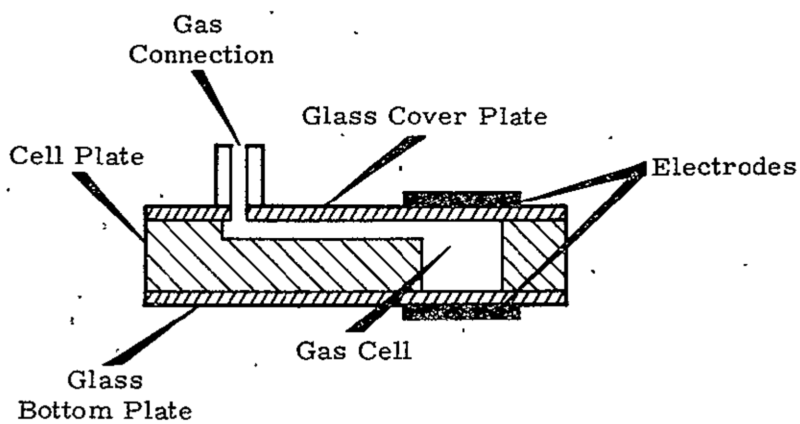

Figure 3. Experimental Cell Construction

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.

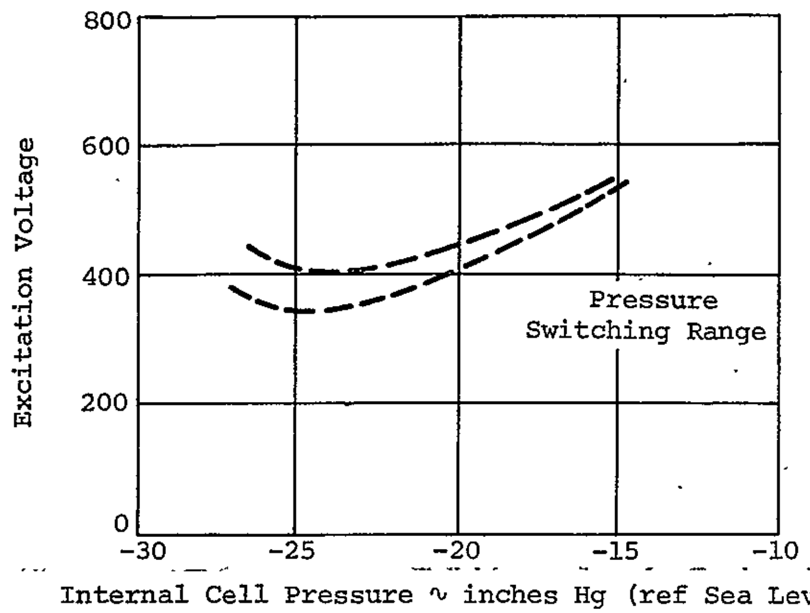

Figure 4. Plasma Cell Test Results

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.

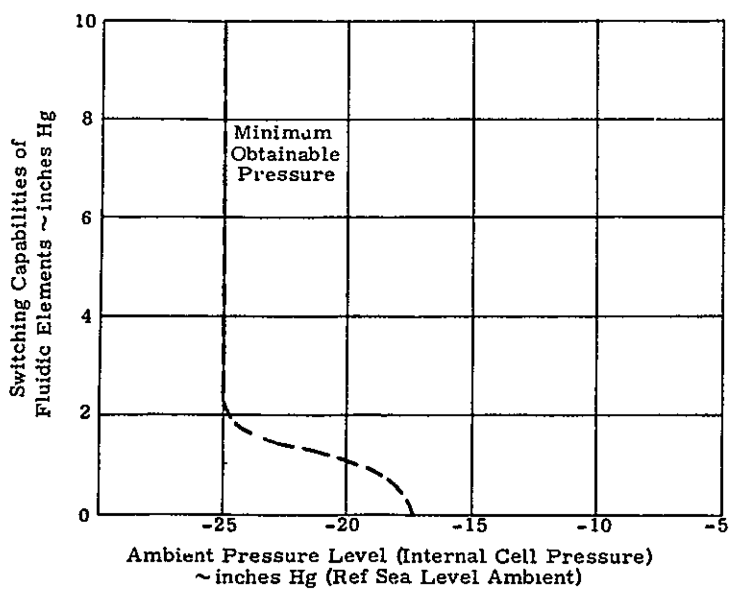

Figure 5. Maximum Switching Capabilities versus Internal Cell Pressure

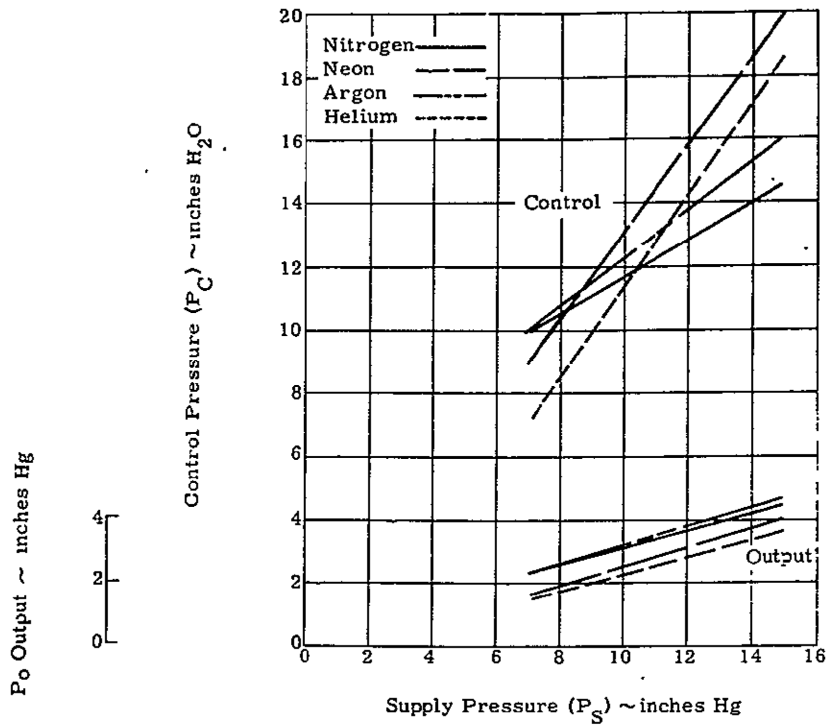

Figure 6. Four mil OR-NOR Element

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.

PRECEDING PAGE BLANK NOT FILMED.

III. PROGRAM PROGRESS

Progress made during this second reporting period includes the investigation of crosstalk problems on fluidic line and column control and construction of experimental hardware. Testing of hardware obtained thus far is progressing as planned.

A. CROSSED GRID CONTROL

Simple cross grid control systems and crosstalk generated by such a system were described in the first quarterly report. It was shown that crosstalk was within limits which would give acceptable performance, but variations in operating characteristics found from display cell to display cell would probably cause some malfunctions. Better systems could be developed using oscillatory cross grid control systems.

B. OSCILLATORY CROSS GRID CONTROL

It was shown in previous reports 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 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. The resulting five distinct levels that can be present in any of the cells are shown in Figure 8. For proper operation of the system, three pressure levels (P_1, P_q, and P_i) should all fall within the plasma cell hysteresis band to prevent unwanted cell firing or extinguishing.

It was indicated that an improved control system can be obtained by using oscillatory signals as pressure excitation in combination with pneumatic filtering techniques. Figure 9 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.

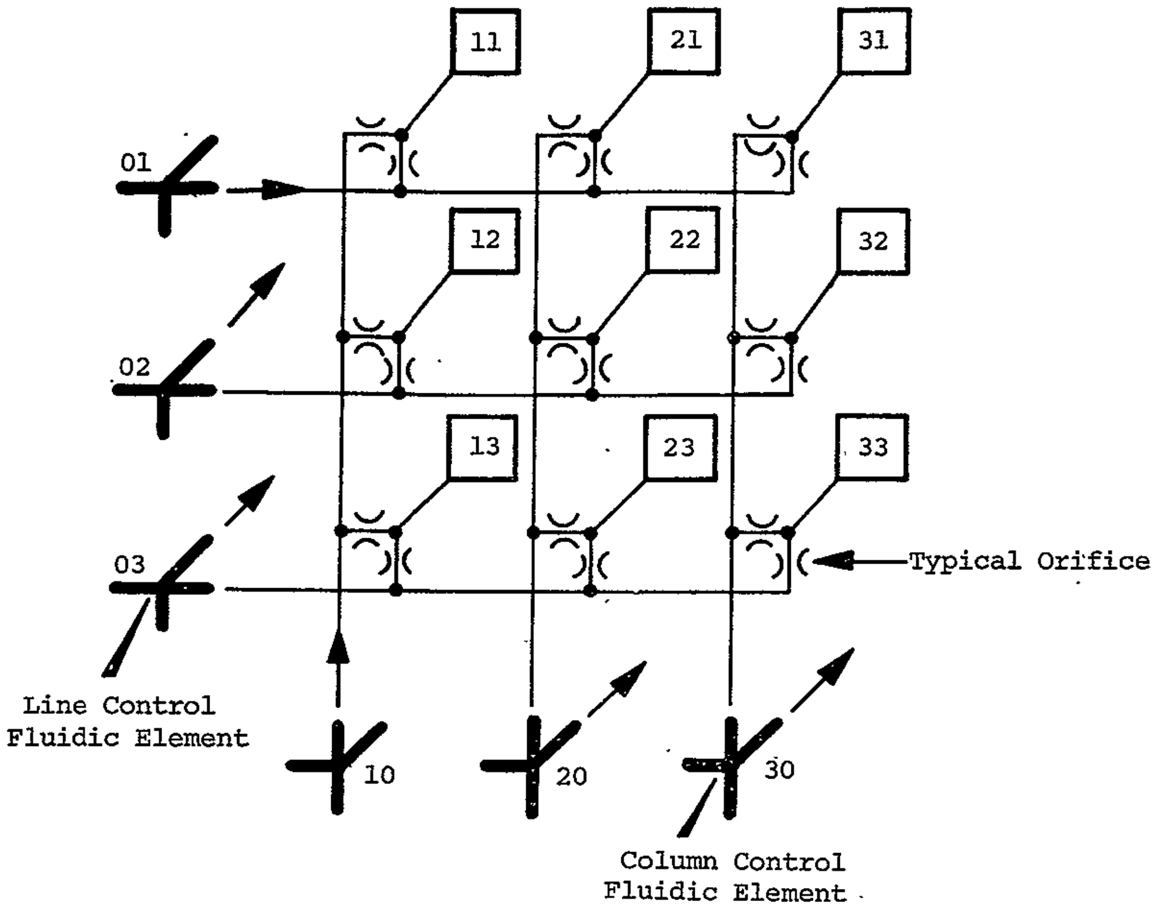

Figure 7. Cross Grid Control System

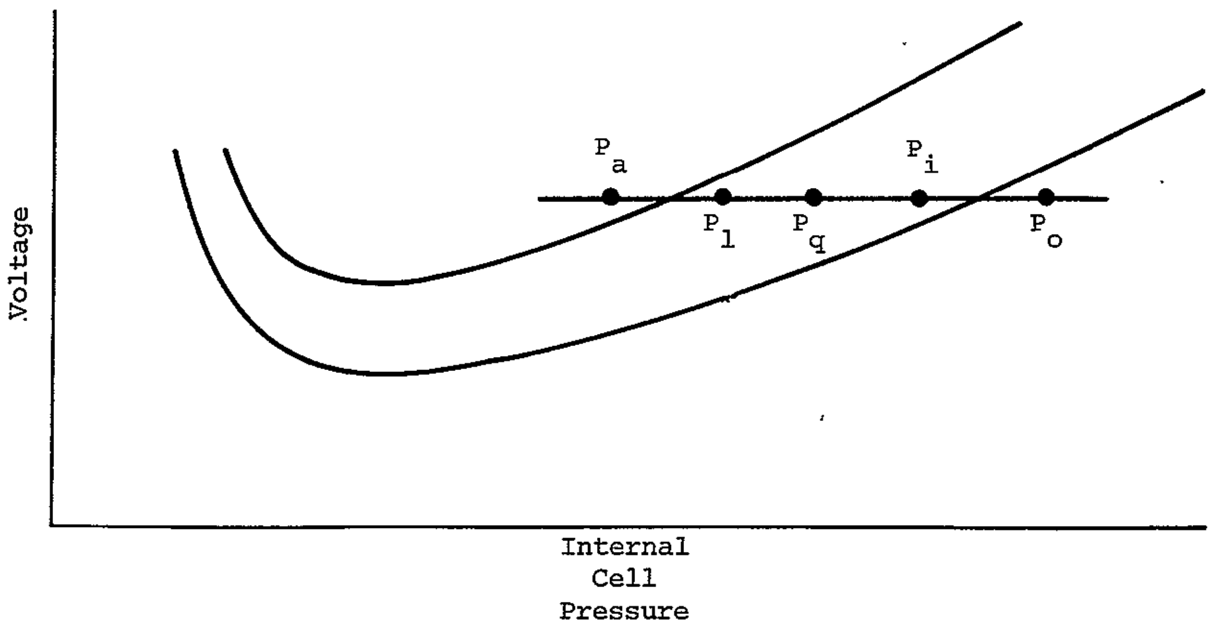

Figure 8. Pressure Levels versus Voltage

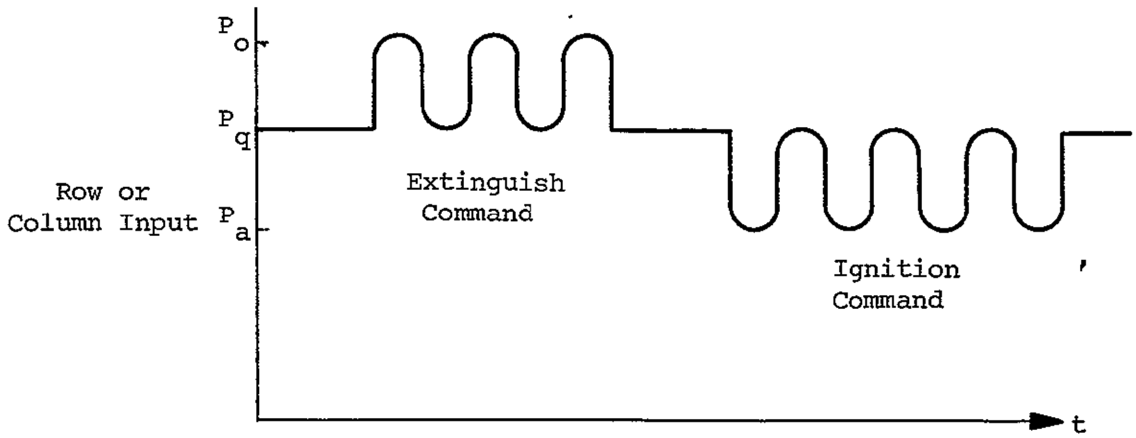

Figure 9. Oscillatory Control

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 10. 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 10 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 appreciable attenuation of the pressure signal will be present when both line and column are excited. Considerable attenuation is experienced at that same frequency when only one port is excited. Figure 11 shows the test results obtained with one orifice size selected for some experiments. Figure 12 shows that the crosstalk, when plotted against the allowable band formed by the hysteresis of the plasma cell, is within the allowable tolerances.

Since the oscillatory control system scheme depends upon signal filtering action caused by the combination of the size of the inlet orifices which connect the fluid control system with the plasma cell (the pneumatic resistance) and the volumetric effects of the plasma cell itself (the pneumatic capacitance) an analysis can be performed.

As previously explained five distinct pressure levels will be experienced in each cell at some point of the matrix fire and extinguish control cycle. Looking only at the extinguish cycle, the neutral pressure level will be the

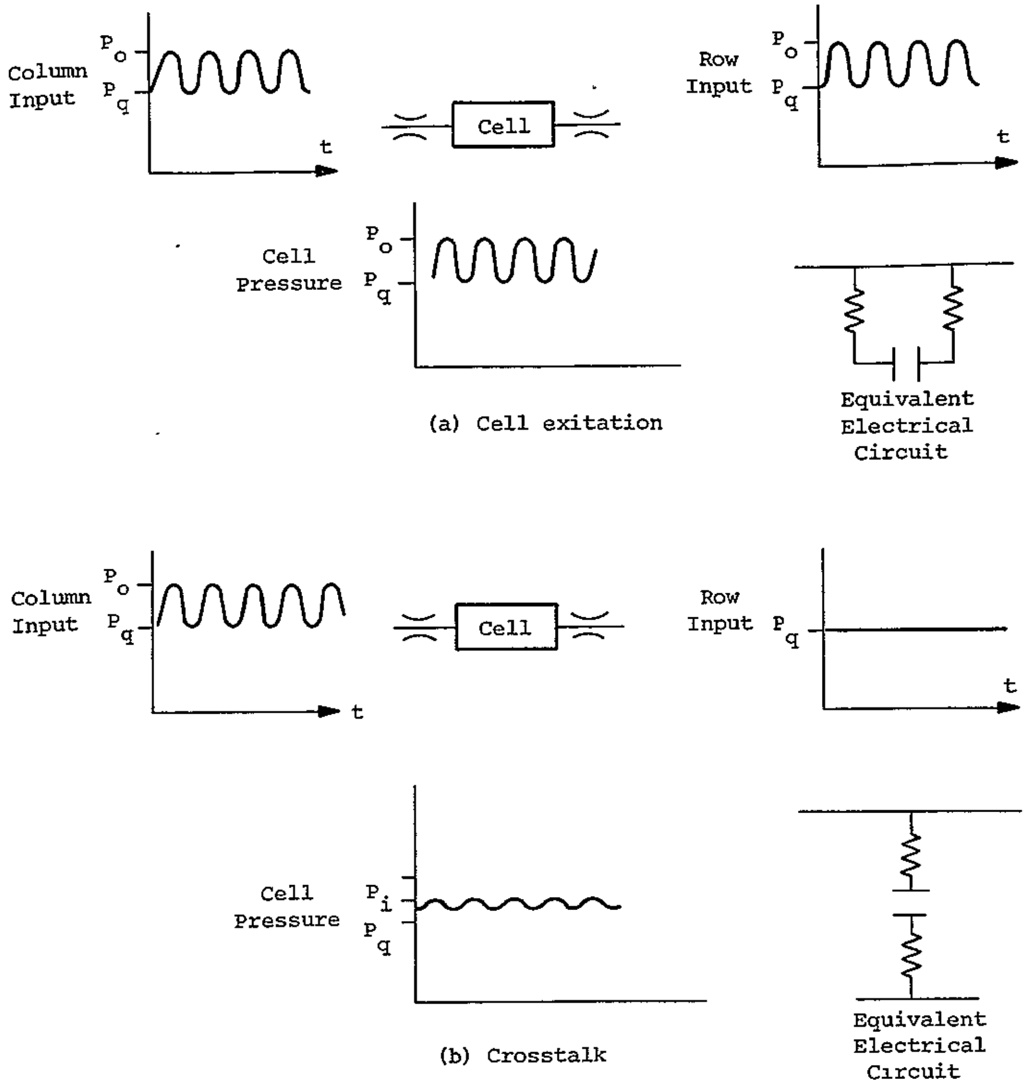

Figure 10. Pressure Excitation and Crosstalk

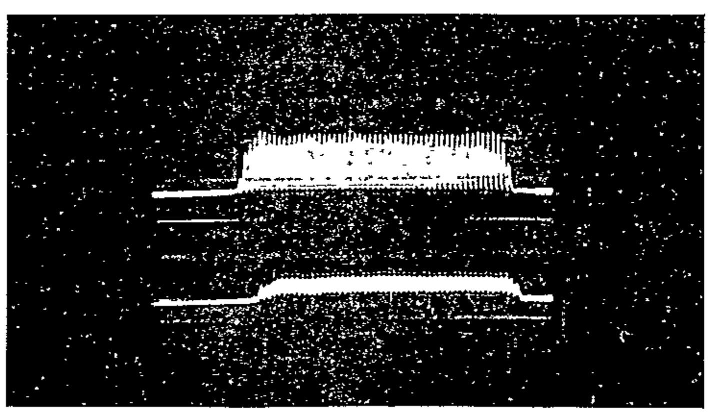

Figure 11. Experimental Cell Pressures Using Oscillatory Control Signal

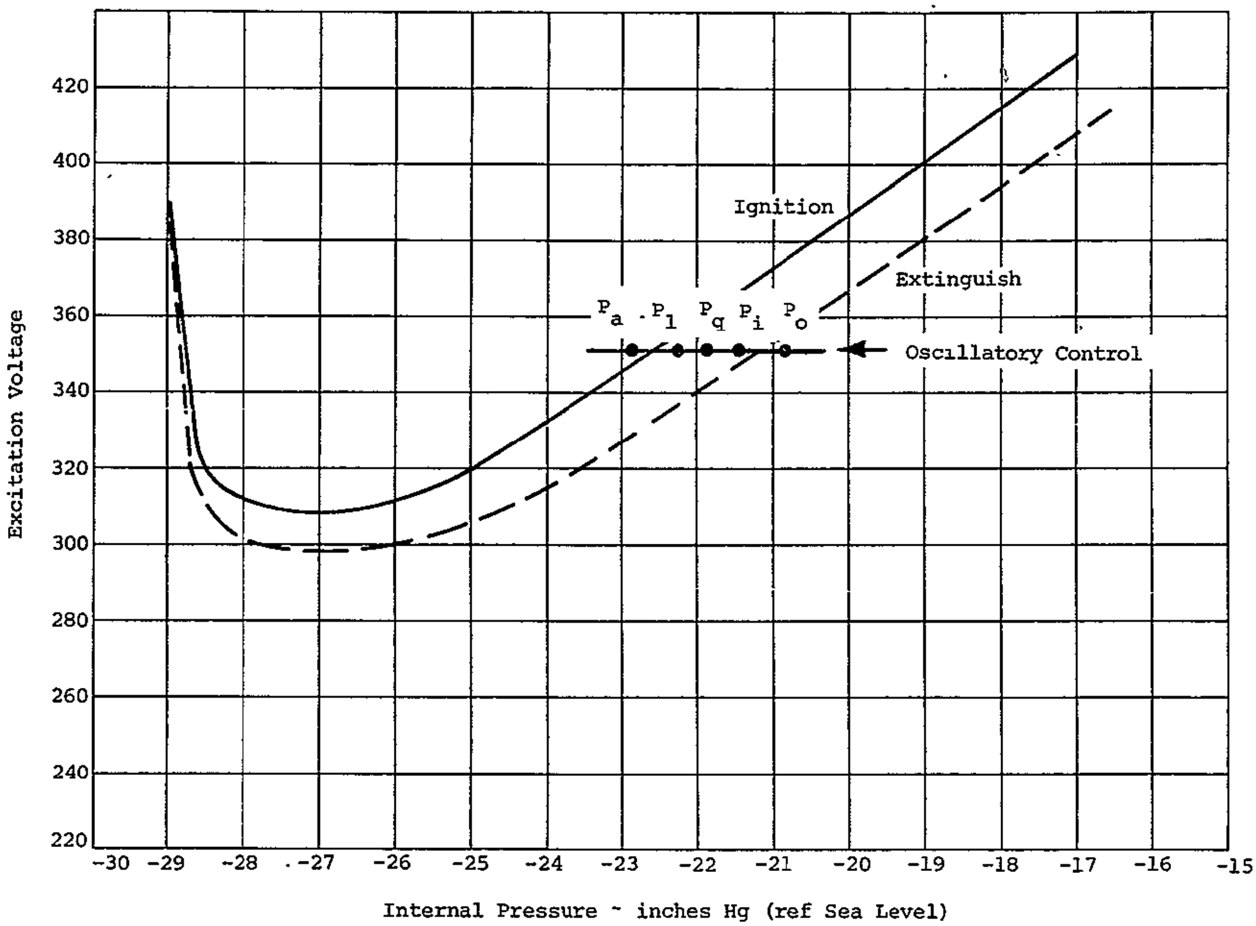

Figure 12. Plasma Cell Pressure Voltage Characteristics

sustain pressure P_q. Extinguish pressure P_o will be seen in the cell when both line and column corresponding to the cell are activated. Activation of either line or column but not both will result in pressure level P_i. In the oscillatory control system, the pressure levels P_i and P_o will fluctuate in an oscillatory manner. These oscillatory pressure levels can be described mathematically using the following analysis.

Assuming subsonic gas flow conditions are present, the flow of gas through an orifice is governed by the equation:

$$W = \left\{ \frac{P_u}{\sqrt{T_u}} \left(\frac{P_d}{P_u} \right)^{\frac{1}{k}} \sqrt{1 - \left(\frac{P_d}{P_u} \right)^{\frac{k-1}{k}}} \right\} C_1 C_D \; A \qquad (1)$$

where

W = weight flow in lb/s
P_u = upstream stagnation pressure psia

T_u = upstream stagnation temperature °R
P_d = downstream pressure psia
k = ratio of specific heats c_p/c_V
C_D = discharge coefficient
A = area of orifice in square inches

$$C_1 = g\sqrt{\frac{2k}{R(k-1)}} \tag{2}$$

g = acceleration of gravity
R = gas constant $in^2/s°R$.

A good approximation to equation (1) can be obtained from

$$W = \frac{C_D C_G A\sqrt{P_d\left(P_u - P_d\right)}}{\sqrt{T}} \tag{3}$$

where

W = weight flow of gas in lb/s
C_G = constant depending on gas
T = absolute temperature.

When cells are addressed by only one line or column signal Figure 13 represents the RC network formed by the cell volume and the two orifices.

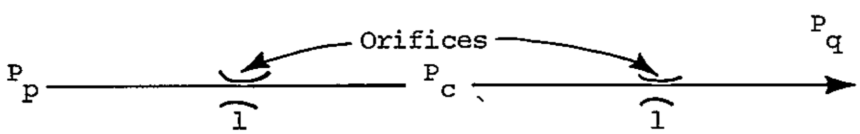

Figure 13. Cell Addressing Network

The oscillatory excitation pressure P_p causes fluctuations in the cell pressure P_c through the inlet orifice. The cell is connected through the second orifice to the quiescent pressure P_q. Utilizing equation (3) to obtain expressions for the flow through each of the two orifices we find

$$W_1 = \frac{C_D\ C_G\ A\sqrt{P_c\ \ (P_p - P_c)}}{\sqrt{T}} \tag{4}$$

and

$$W_2 = \frac{C_D\ C_G\ A\sqrt{P_q\ \ (P_c - P_q)}}{\sqrt{T}} \tag{5}$$

The rate of change of flow through the first orifice with respect to time will now be:

$$\frac{dW_1}{dt} = \frac{C_G\ A\ C_D\ P_c}{2\sqrt{T}\sqrt{P_c\left(P_p - P_c\right)}}\ \frac{\partial P_p}{\partial t} + \frac{C_G\ A\ C_D\ \left(P_p - 2P_c\right)}{2\sqrt{T}\sqrt{P_c\ \left(P_p - P_c\right)}}\ \frac{\partial P_c}{\partial t} \tag{6}$$

or

$$\frac{dW_1}{dt} = C_1 \frac{\partial P_p}{\partial t} + C_2\ \frac{\partial P_c}{\partial t}\quad \mathrm{lb/s^2} \tag{7}$$

where

$$C_1 = \frac{C_G\ A\ C_D\ P_c}{2\sqrt{\ T\ P_c\ \left(P_p - P_c\right)}} \tag{8}$$

and

$$C_2 = \frac{C_G\ A\ C_D\ \left(P_p - 2P_c\right)}{2\sqrt{T\ P_c\ \left(P_p - P_c\right)}} \tag{9}$$

Similarly, the rate of change of the flow through the second orifice is represented by

$$\frac{dW_2}{dt} = C_3\ \frac{\partial P_c}{\partial t} + \mathrm{lb/s^2} \tag{10}$$

where

$$C_3 = \frac{C_G\ A\ C_D\ P_q}{2\sqrt{T\ P_q\ \left(P_c - P_q\right)}} \tag{11}$$

The net rate of change of the flow through orifices 1 and 2 should be equal to the change of the mass of the gas accumulated inside the cell.

The gas inside the cell is governed by the universal gas law

$$P_c\ V = MRT \tag{12}$$

where

V = cell volume
M = mass of gas

Since volume and temperature can be considered constants the rate of change of the gas mass inside the cell can be described by

$$\frac{dM}{dt} = \frac{V}{RT}\frac{dP_c}{dt} \text{ lb/s} \tag{13}$$

The rate of change of the above quantity should be equal to the net flow into the cell or

$$\frac{d}{dt}\left(\frac{V}{RT}\frac{dP_c}{dt}\right) = \frac{dW_1}{dt} - \frac{dW_2}{dt} \tag{14}$$

Using the Laplace operator s to define differentiation

$$\frac{VS}{RT}\frac{dP_c}{dt} = C_1\frac{dP_p}{dt} + C_2\frac{dP_c}{dt} - C_3\frac{dP_c}{dt}$$

or after rearranging

$$\frac{dP_c}{dP_p} = \frac{\dfrac{C_1}{C_3 - C_2}}{1 + \dfrac{V}{RT\,(C_3 - C_2)}S} \tag{15}$$

is obtained as a relationship between cell pressure P_c and excitation pressure P_p.

This relationship is of the form

$$\frac{dP_c}{dP_p} = \frac{K}{1 + \tau s}$$

where K is the gain of the signal transmission and τ is the time constant. Substituting the original values

$$K = \frac{1}{\left(\dfrac{P_q}{P_c}\right)^2 + 1} \tag{16}$$

$$T = \frac{V\,C_G\,C_D\left(\dfrac{P_q}{P_c}\right)\sqrt{\dfrac{P_c}{P_q} - 1}}{2R\sqrt{T}\,A\left(\dfrac{P_q}{P_c}\right)^2 + 1} \tag{17}$$

Typical values for the plasma display cells previously developed under this contract are:

V for a 1 mm diameter cell of 1 mm thickness is 0.5×10^{-4} in ^{3}.

C_G for neon $= \sqrt{\frac{2g}{R}} = \frac{64.4}{76.5} = 0.842$

$C_D = 0.8$

R for neon = 76.5 ft lb/lb - R

T = room temperature in °R = 530

$A = \frac{\pi}{4} 0.008^2 = 0.5 \times 10^{-4}$ in ^{2}

$P_q = 9$ psia

$P_c = 10$ psia

Substituting these values into equation (17) will result in $\tau = 3.15 \times 10^{-4}$ seconds which is equivalent to a 500 Hz frequency.

At zero frequency or steady state no net mass of gas is accumulated in the cell, thus $W_1 = W_2$. Equating previously established relationships (Equations (4) and (5)) will result in

$$P_c (P_p - P_c) = P_q (P_c - P_q) \tag{18}$$

using $P_c = 10$ psia and $P_q = 9$ psia we find $P_p = 10.9$ psia.

Figure 14 shows the percentage of the magnitude of the oscillatory signal still admitted to the cell when the cells are constructed with the dimensions shown previously. At a frequency of 3000 Hz, only 20 percent of the oscillatory frequency is admitted to the cell when only one signal (either line or column) is present.

When both line and column control signals are oscillating in phase, it is expected that at least 90 percent of the amplitude of the signals will be transmitted to the cell. Figure 15 indicates the relative pressure levels which will be obtained with an oscillatory control system as described. The illustration also shows the pressure levels required for normal fluid control systems.

As shown in Figure 15, the extinguish and fire levels of a typical pressure controlled display cell may be 8 and 10 psia respectively. This means that a pressure level below 8 psia will cause the cell to fire, and a pressure level exceeding 10 psia will extinguish the cell. Typically, a safety margin to account for variations in different cells is required, thus necessitating a firing pressure level of approximately 7.75 psia (F_2) and an extinguish level of 10.25 psia (E_2). The construction of the pneumatic circuit will also cause a change in pressure level from the quiescent cell level (Q) when only one signal (either line or column) is sent to the cell. Since

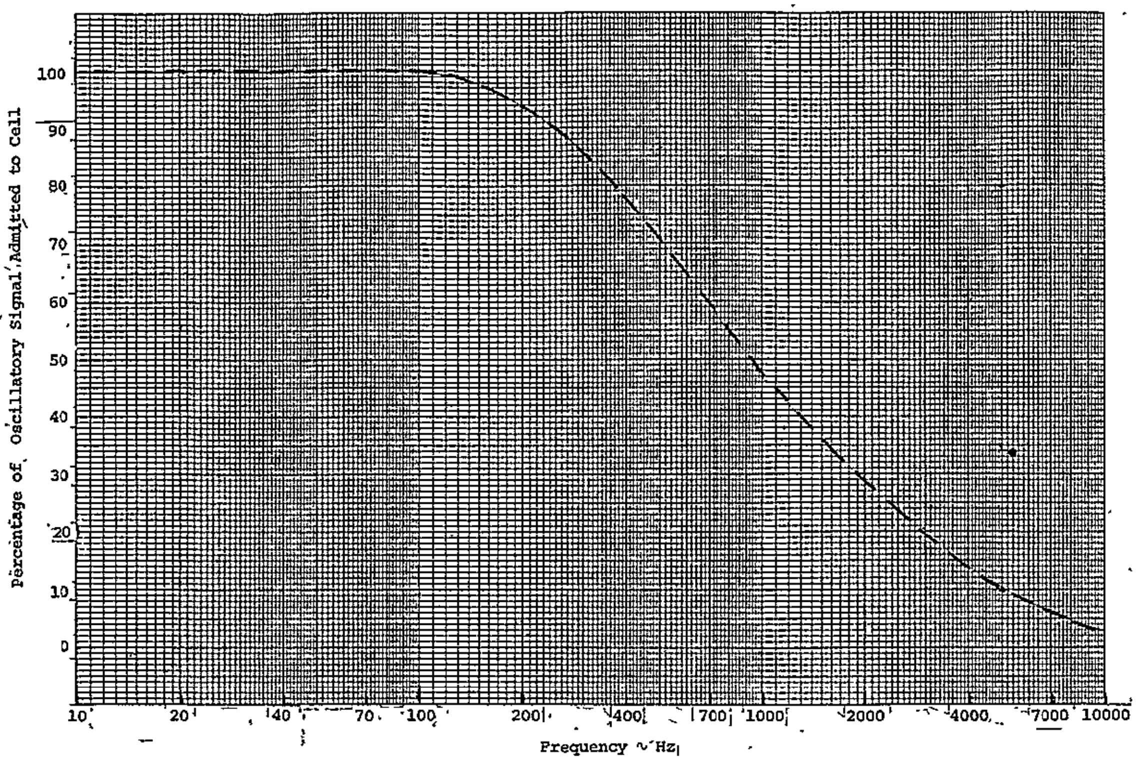

Figure 14. Control Signal Levels

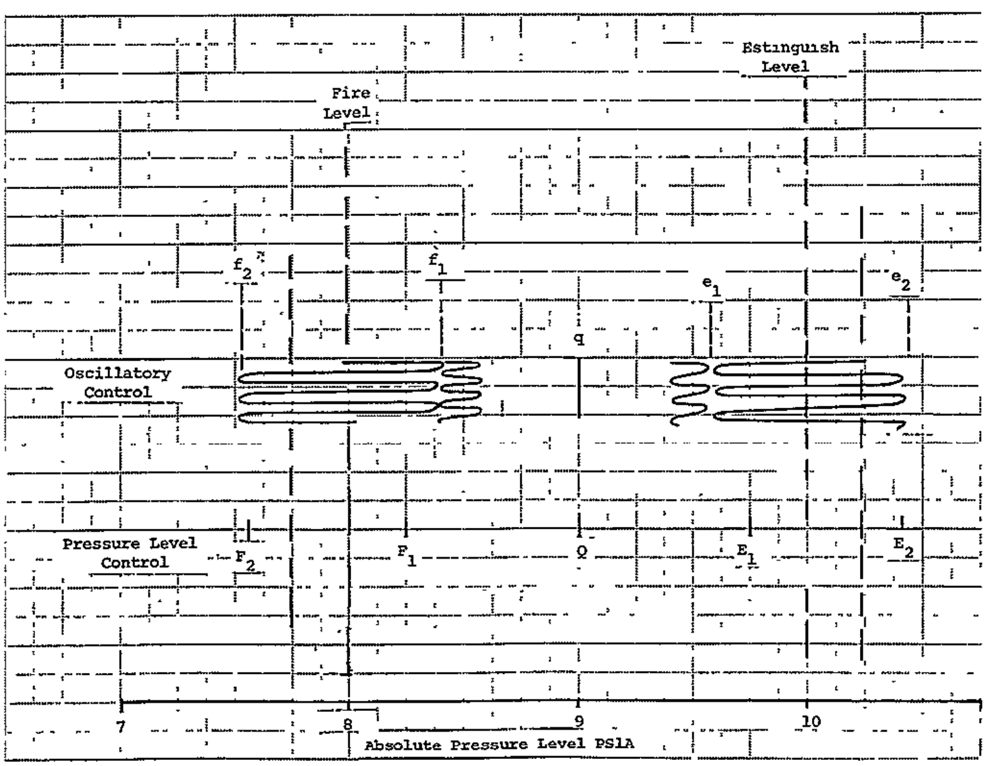

Figure 15. Cell Control Pressure Levels

a signal originating from only one source (line or column) should not change the state of that cell, these pressure levels, F_1 (one fire command) and E_1 (one extinguish command), should fall between the fire and extinguish levels. As can be seen in Figure 15, a safety margin of 0.25 psi is available. When oscillatory control is used, the sinusoidal peaks causing extinguishing and firing of the cell (at levels F_2 and E_2 respectively) are still of the same magnitude as used in the pressure level control system (F_2 and E_2). However the sinusoidal pressure peaks caused in the cell when either line or column command signals alone are received are at least 60 percent farther away from the fire and extinguish levels obeyed by the cell. The margin of safety, now increased to 0.4 psi, makes is possible to loosen tolerances on cell dimensions and electrode construction to a much wider range than previously allowable.

Since it should be possible to obtain a pneumatic system incorporating oscillatory control in mass production for roughly the same expenditure as estimated for pressure level control, further investigations of this system are in order.

C. EXPERIMENTAL HARDWARE

1. Experimental Plasma Cell Matrix

After several attempts to obtain a four cell matrix failed, due to inadequate sealing of the glass cells to their cover plates, the matrix was redesigned. Leakage paths developed from cell to cell due to adhesive shrinkage. These leakage paths caused changes in the pressure levels of some cells when adjacent cells were subjected to commanded pressure fluctuations.

The problem was solved by using one glass plate which contained the cell cavities in conjunction with individual glass covers for each cell. A liberal amount of epoxy around each cover ensured complete isolation from cell to cell. Indications are that presently used methods to manufacture electronically manipulated plasma display matrices may not be entirely useful for pressure operated displays, because of the cross leakage from cell to cell. In electronically operated displays a constant internal cell pressure is maintained so that leakage paths from cell to cell will not affect the working of the electronic device.

It is recommended that during succeeding development stages of the pressure operated plasma display, attention be paid to this problem. For research and exploratory development efforts, however, present methods of manufacturing are adequate.

The final design of the four-cell matrix to be used for further experiments is shown in Figure 16. The first series of experiments done with this matrix resulted in fire-extinguish pressure levels which varied considerably from cell to cell. These variations were mainly due to differences in cell dimensions. Experiments were conducted with various etched electrode geometries to determine whether cell-to-cell variations in operating characteristics could be adjusted for by varying electrode geometry and location.

The results proved that such an adjustment was possible, but not completely satisfactory. Figure 17 shows the voltage versus pressure traces after final adjustments of the electrodes.

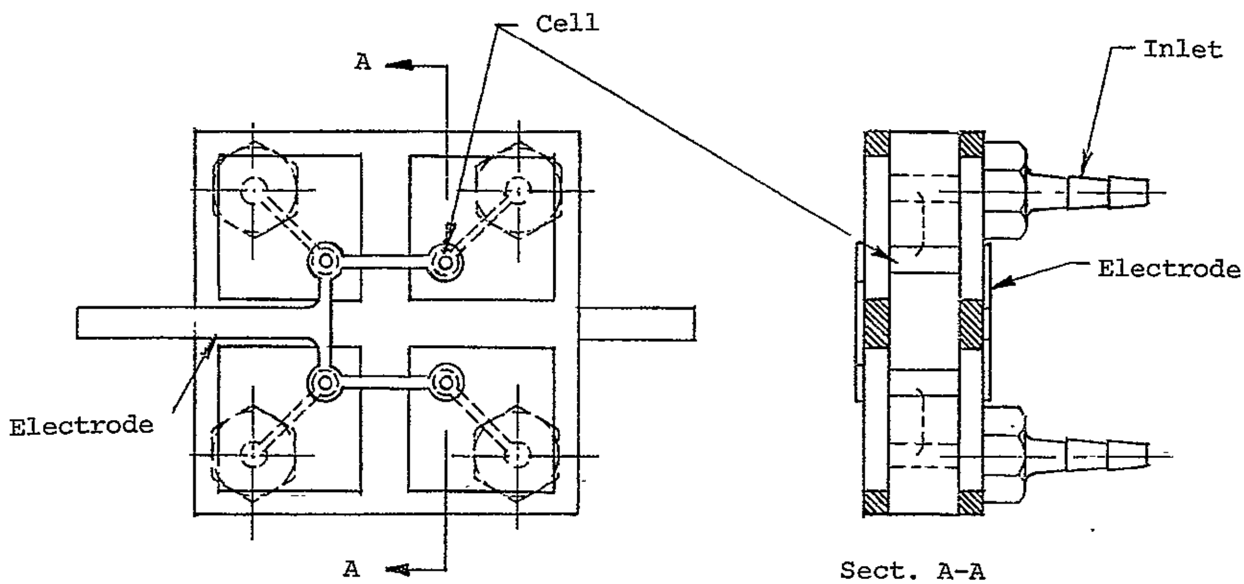

Figure 16. Four Cell Plasma Matrix

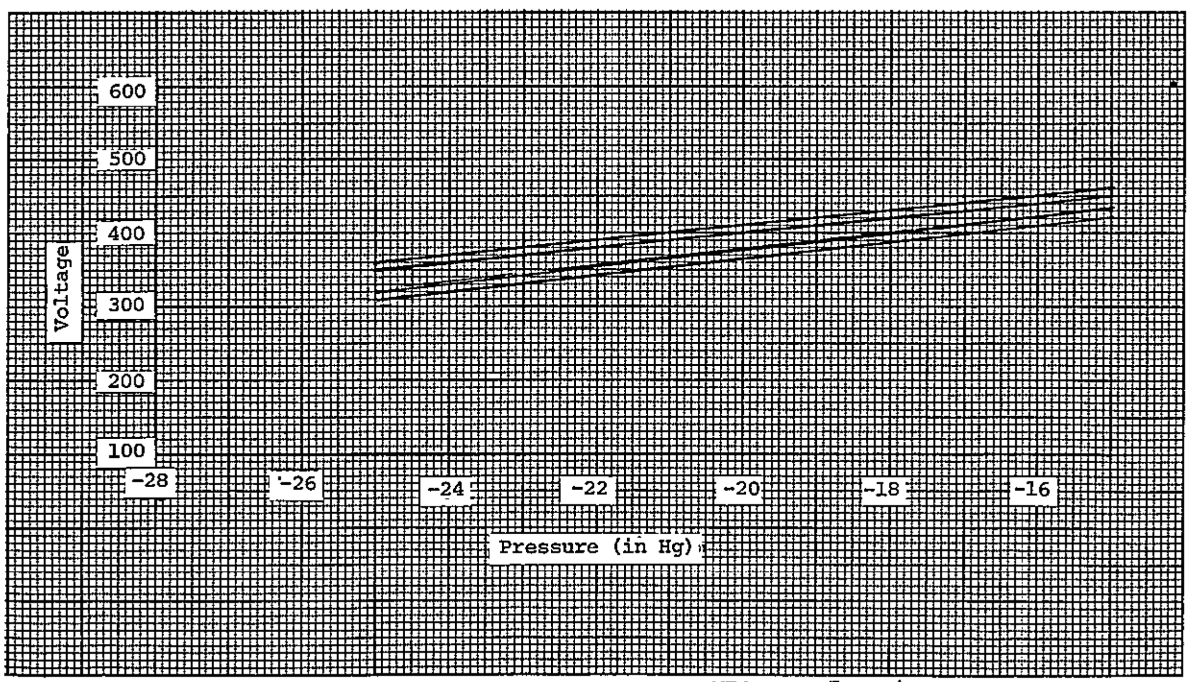

Figure 17. Cell Voltage-Pressure Relationship

2. Fluidic Control System

The fluidic control system designed to perform experiments with the plasma display matrix is presently under construction. Parts for this system are 85 percent complete. Figure 18 shows a cross section of the device. A schematic of the control module is shown in Figure 19. Each line and column is addressed by two fluidic logic gates to obtain the three pressure levels necessary to fire, sustain or extinguish the display matrix cells.

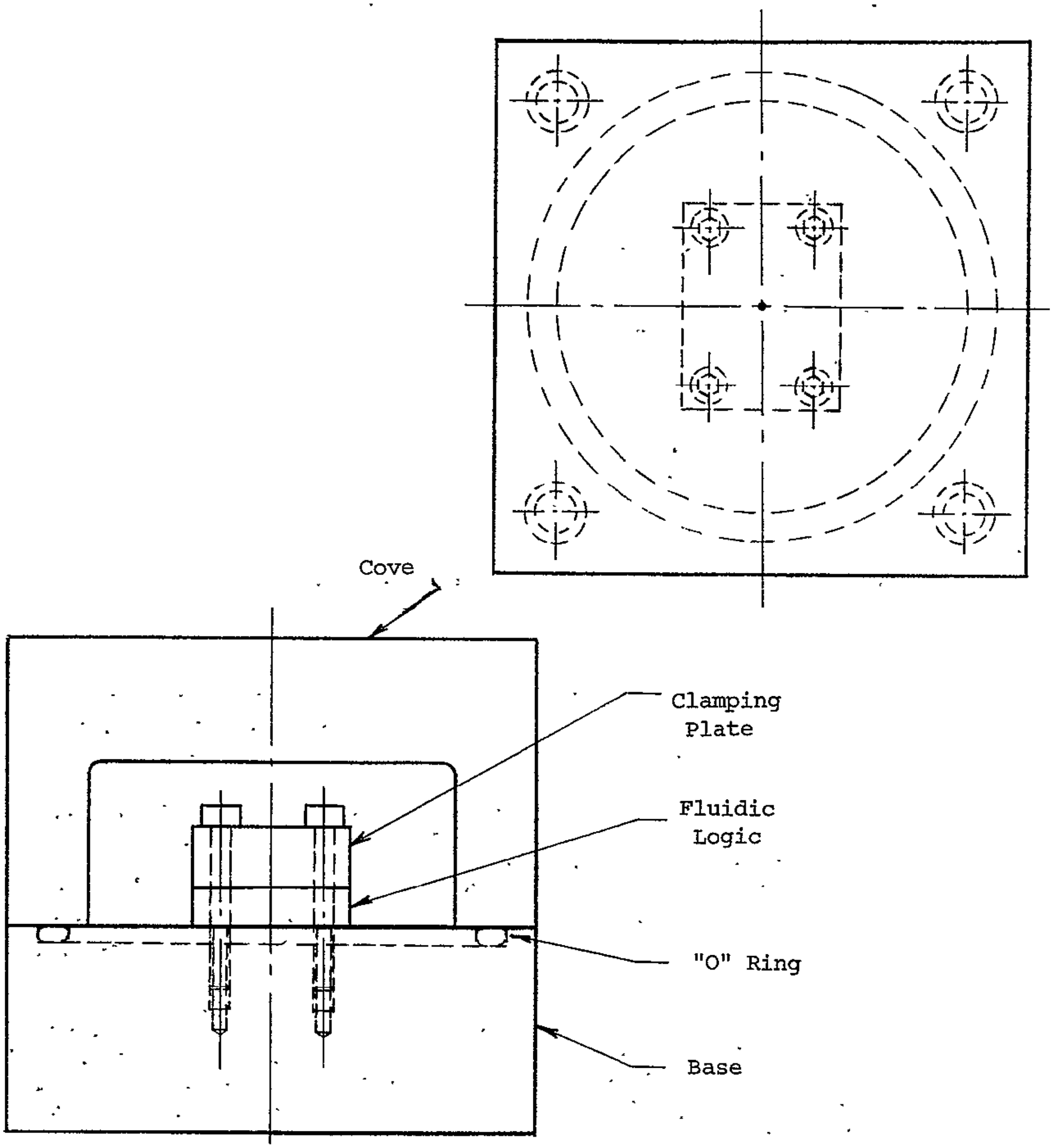

Figure 18. Fluidic Logic and Fixture Assembly

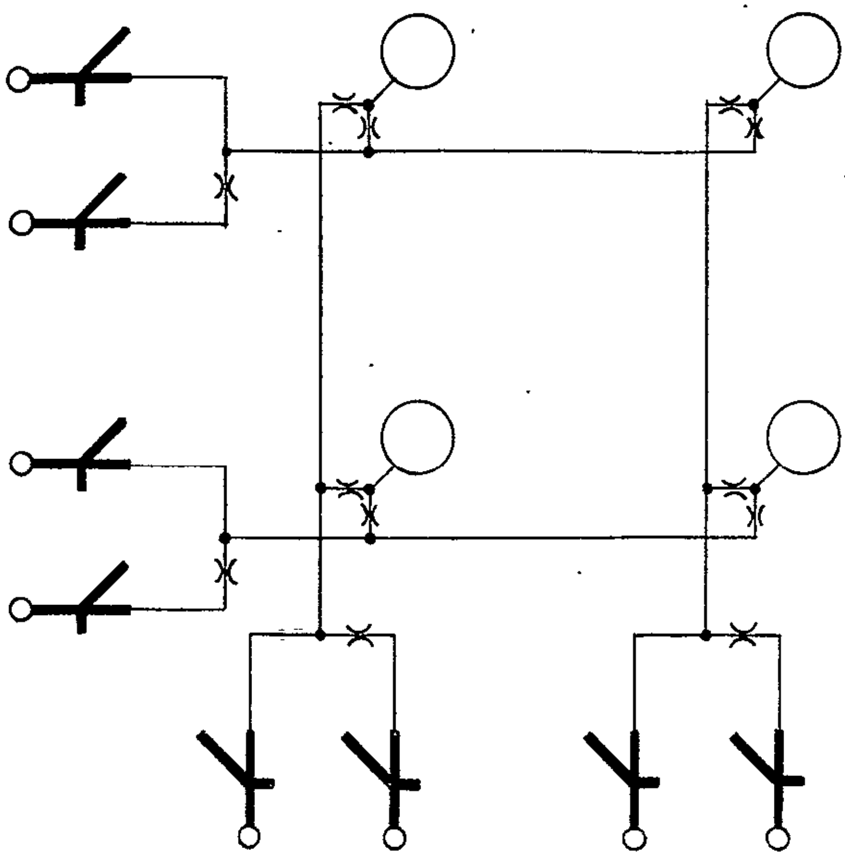

Figure 19. Schematic of Plasma Cells and Control Elements

3. Power Supply

A survey has been conducted to determine type, cost and capacity of pumps presently available on the market which are compatible with the requirements for operation of a pressure controlled plasma display matrix.

The survey showed that pumps with output characteristics matching the present scope of work were not available. Most of the units that met the specifications for pressure range and neon gas contamination had a flow capacity which exceeded the requirements by a considerable margin. All pumps surveyed which showed output flow rates compatible with a small plasma display matrix did not meet the specifications for leakage and contamination rates.

The in-house design and fabrication of a pump meeting all requirements has been considered. Cost for a project of that scope however proved beyond the available funding. Consequently, the choice was made to obtain the larger pump. This selection was based partly on the idea that matrices with an increased number of cells could be accommodated.

A Dia-Pump model 08-800-71 from Air Control Incorporated was selected as the unit most desirable for our purposes.

IV. FUTURE WORK

During the next reporting period the contract will be completed. Progress during this period will be reported in the final report of Phase III of this contract.

Specific tasks still remaining are

1 The completion of the studies on line and column control systems

2 Experiments with pressure controlled display matrices

3 Construction of the feasibility demonstration model

4. Writing and delivery of the final report.

V. NEW TECHNOLOGY

A review of the effort performed under this contract during this reporting period did not reveal any innovations suitable for a new technology report.