



3 8006 10058 4179

## MANUFACTURING TECHNIQUES USING DYCRIL

prepared by

W. Morrison



### 1. INTRODUCTION

Fluidic elements are manufactured in various ways such as injection moulding, epoxy casting and from photo-sensitive ceramic and plastics. Most of the initial work on elements has been carried out using Dycril because of its ease in processing and the equipment required is fairly cheap and simple. Many companies have then developed satisfactory designs using Dycril and used them as 'masters' in other production processes.

Most users of Dycril have reported that nozzle widths of less than 0.015in cannot be satisfactorily etched from 0.040in thick Dycril. Various methods of etching have been tried at Cranfield and this report outlines some of the difficulties encountered and suggests a standard pattern to be followed from the drawings of the master at ten times full size through to the complete element.

### 2. THE ETCHING PROCEDURE

#### 2.1. General

Dycril is a photosensitive polymer produced by DuPont which, when exposed to U.V. light, becomes hard and will resist chemical attack. When a photographic negative is placed over raw Dycril the image (black portion of negative) is unexposed and remains soft. If a solution of sodium or potassium hydroxide is sprayed onto the Dycril, the unexposed parts are etched away. The rate of material removal is dependent upon the solution strength and of the etchant temperature and also on the capability of the flood of etchant to remove the unwanted material.

Potassium hydroxide (KOH) solution is used in the etching tank at the College, and the solution contains 16.6 gr/l of 0.85 per cent strength crystals. A general arrangement of the etching tank is shown in fig. 1. The reservoir of etchant is heated by pad heaters fixed to the underside. The temperature is thermostatically controlled, although the sensing point is not in direct contact with the liquid and so there is a long time lag between the liquid falling to the lower temperature and the thermostat actually cutting in. For this reason the thermostat is set to its highest position, and the heater is periodically switched off at the main plug.



The liquid is pumped by a simple chemical "Jabco" pump through flexible p.v.c. tube. A number of spray nozzle arrangements have been tried in an effort to obtain consistently good elements with nozzle widths of 0.010in or less. The various methods are now described in greater detail.

### 2.2. Single hand spray nozzle

Fig. 2 shows the original hand spray nozzle tested. This nozzle operated quite successfully although it required the continuous services of an operator. Several elements were produced using this nozzle and its success was attributed to the force of the fluid on the Dycril plate. The etching time was about 6 min, however, and it was found impossible to etch nozzles of less than 0.010 in. Another method was sought in an effort to etch finer nozzles and also to automate the process.

### 2.3. Coanda nozzles

#### 2.3.1. Principle of operation

Fig. 3 is a cross-section of a typical Coanda nozzle. Air at high pressure is forced out of the fine annular orifice. This air is attached to the walls of the nozzle and this flow causes a suction in the centre, and so locally contains the air. If the nozzle is held above a liquid surface, the liquid is sucked up and is ejected as a high velocity mist.

#### 2.3.2. Single nozzle system

The principle described above was applied to the etching tank. The etchant was pumped into the tank underneath a nozzle fixed in a special carrier which also held the Dycril plate. Air at about 100 lbf/in<sup>2</sup> was supplied to the nozzle through connections in the tank side. The configuration is shown in fig. 4. Two plate units were successfully etched (although the etching time was increased) and it was decided to proceed to automate the system.

#### 2.3.3. Four nozzle system

Not all of the units produced are as small as a single gate (about 1.25 in x 1 in) and the automated system was planned to accept plates about 6 in square. Alternatively several single units could be etched simultaneously. Fig. 5 shows the four nozzles mounted on their carrier in the tank and the rotating Dycril plate holder which was an integral part of the tank lid.

Several difficulties were encountered using this arrangement. The Dycril was unevenly etched and this was shown to be as a result of the narrow beam of the spray. The etching time was as long as 20 min and both supply and control nozzles of the elements were not completely etched.



It was first thought that this was because of the non-collimated UV light source, but this was discounted because when the hand spray was used these nozzles were being etched satisfactorily. It was then attributed to the deflection of the droplets from the vertical upon striking the plate caused by the high spray velocity.

#### 2.3.4. Using fluid injection

To overcome this, it was decided to inject the fluid into the base of the nozzles, and then lean the nozzles over so that the spray would strike in all directions as the plate rotated the full circle. Another advantage was thought to be that the spray would be more stable and then droplets consistently more fine. The nozzles were held in a crude arrangement of clamps in which the injectors were in a fixed position relative to the nozzles.

Again the results were disappointing and the supply and control nozzles of the element were not etched. It was decided that the etching fluid was being cooled excessively by the quantity of flowing and because of the amount of mixing taking place in the Coanda nozzle. Also it was noted that potassium hydroxide has an affinity for carbon dioxide according to the following reaction equation :



This reaction must be considerably accelerated because of the warm solution and the great surface area generated with the fine mist droplets.

#### 2.3.5. Conclusions

The following reasons seem to have caused the failure of Coanda nozzles as a method of producing a suitable spray for etching :-

- a) The air flowing causes considerable lowering of the etchant temperature, with a consequent loss in effectiveness and lengthening of etching time;
- b) The  $\text{CO}_2$  in the air causes excessive deterioration of the etchant;
- c) Although the velocity of the droplets is high, their mass is small, and so their 'scouring' action is much reduced. A measure of the force due to impact is given by the rate of destruction of momentum which is equal to the mass flow per second x the velocity of impact; and
- d) the quantity and velocity of air causes uneven flow patterns especially over the sharp edges and in the corners of the etched channels.



Apparently these cannot be overcome simply by setting the spray direction at an angle, and a more random motion of the Dycril plate within the spray would be necessary. It is recommended that an automated system based on the hand spray principle be considered.

### 3. ARTWORK AND PHOTOGRAPHIC REDUCTION

#### 3.1. Master drawing

The master drawing is generally made 10 x full size, suitable for photographic processing. Since the geometry of elements is highly critical to their performance, it follows that a correct master is an essential beginning to the whole process. In the past, a thick photograph mounting card has been used. This has a rough surface and it was considered very unsuitable for although the black portions could be made dense, the edges of lines were feathered, and this was considered most undesirable.

Kodatrace, a bluish plastic drafting film, has been much used recently but this has two disadvantages; the black cannot readily be made dense, and being a thin material, glass has to be used to hold the master during photographing. However, the lines remain very sharp. Ordinary tracing linen tends not to produce such a clean line as Kodatrace, but the ink density is far superior. It is recommended that this material be given a greater trial.

#### 3.2. Photographic reduction

It is only necessary to make a few comments under this heading. Firstly, care must be taken to ensure that the masters lie perfectly flat during photography. Secondly, the black (i.e. channels) on the transparencies must be very dense so as not to create problems with the etching process; and finally it must be remembered that the photographic film is processed using liquid chemicals and so it is unstable, giving rise to dimensional errors. These errors are not necessarily uniform in the same negative.

#### 3.3. Conclusions

Insufficient attention seems to have been paid to the production of the master and subsequently its transparency. It must be remembered that as each part of production process tends to introduce errors, the tightest control throughout each part becomes increasingly important.

### 4. RECOMMENDED PROCEDURE FOR ELEMENT MANUFACTURE

#### 4.1. Master

(a) Draw the master ten times full size on a smooth surface material which will also give dense black lines. Dimensional accuracy

is of utmost importance.

(b) The master should be marked with its screw location holes and an element reference number, and be surrounded by a border.

(c) The ports should be at right angles to the border and be straight for a distance of at least 1.5 in. The width of the port in this straight portion should be no more than 0.5 in. (This will subsequently be drilled out on element manufacture).

(d) The load vents location holes should be drawn in accordance with the size of drill to be used (normally

(e) Channel edges should be sharply defined, and the channels should be dense black.

#### 4.2. Photography

(a) Ensure that the photographic department are aware of the necessity for dimensional accuracy and good density of black on the transparency.

#### 4.3. Etching

(a) The etchant temperature should be thermostatically controlled to  $50 \pm 2^{\circ}\text{C}$ .

(b) The spray should be as forceful as possible (as it is from the hand nozzle), and should strike the element from all directions.

(c) The solution strength should be about 16 g/l.

(d) The solution should be changed fairly frequently - about 12 single gates per charge.

#### 4.4. Covering of elements

(a) The covering lid may be made of Perspex and should be kept scratch free. Six BA countersunk lead screws 0.25 in long are suitable for attaching the cover to the base.

(b) The ports should be carefully drilled 0.125 in diameter to accept a short length of tube and de-burred. Barbs are also considered desirable to assist the fixing of the tube.

(c) The edges of the units should be fixed square to the inside of the border and preferably finished with fine emery.

(d) Brass tube is recommended because of its better compatability with the Araldite adhesive.

(e) The tubes should preferably be machine cut.



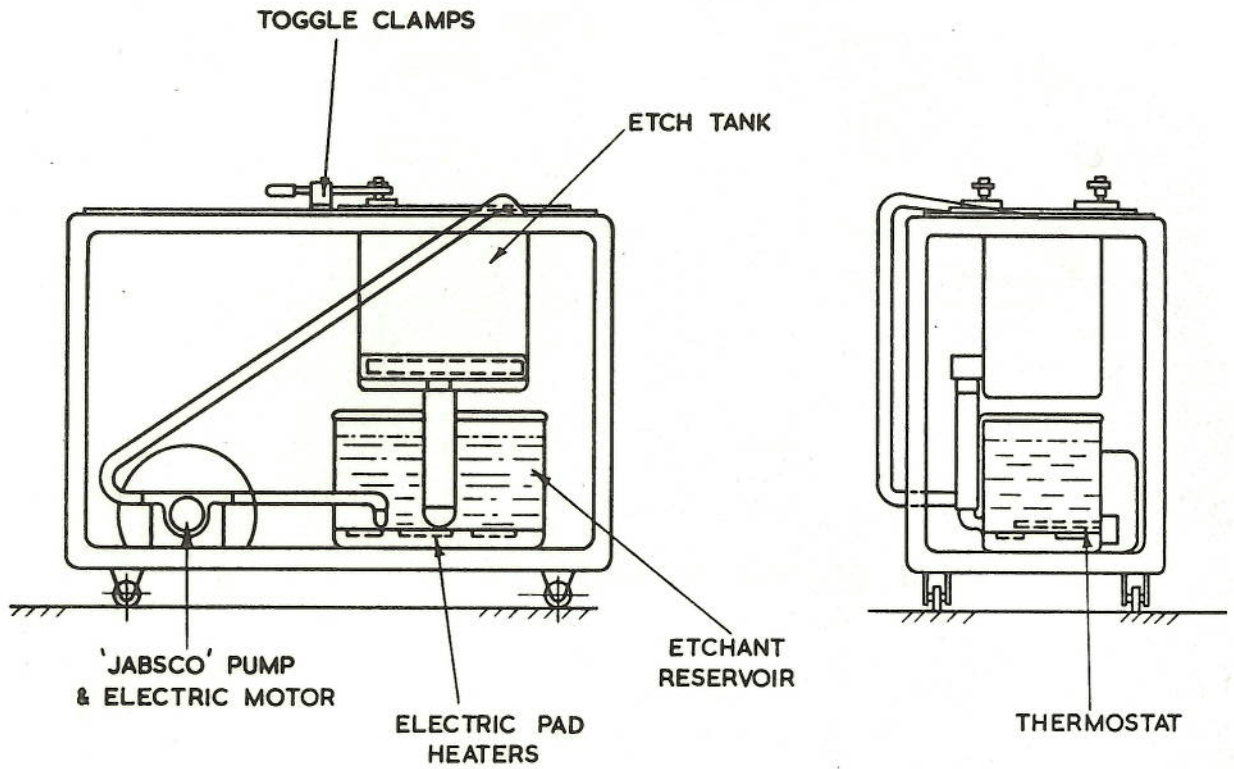


FIG.1. GENERAL ARRANGEMENT OF ETCHING TANK.

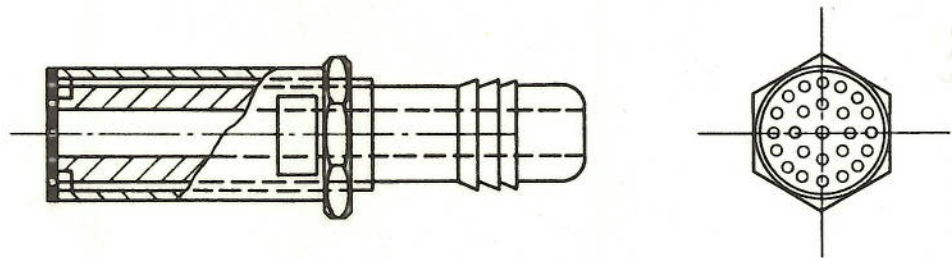


FIG.2. HAND SPRAY NOZZLE

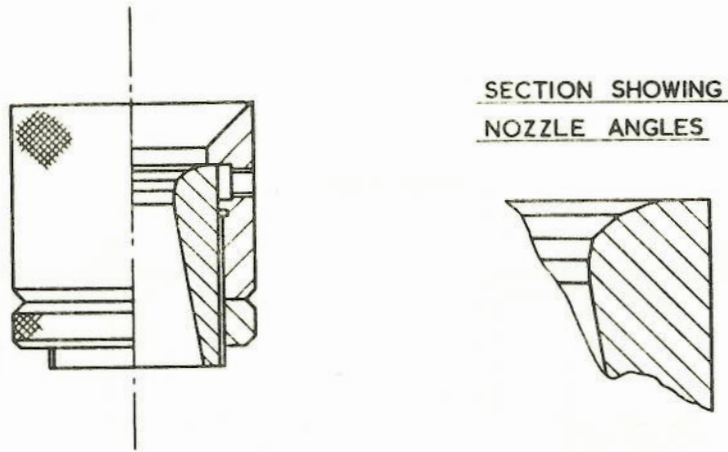


FIG.3. COANDA NOZZLE

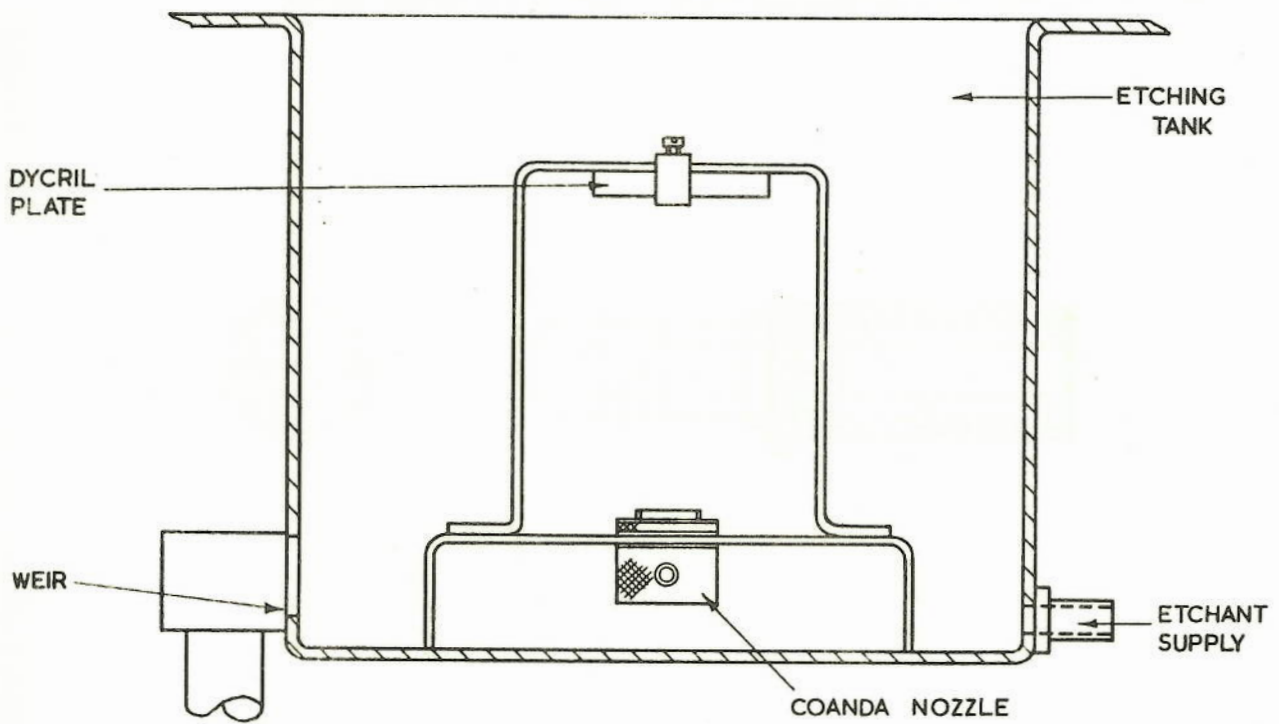


FIG.4. SINGLE COANDA NOZZLE SYSTEM.



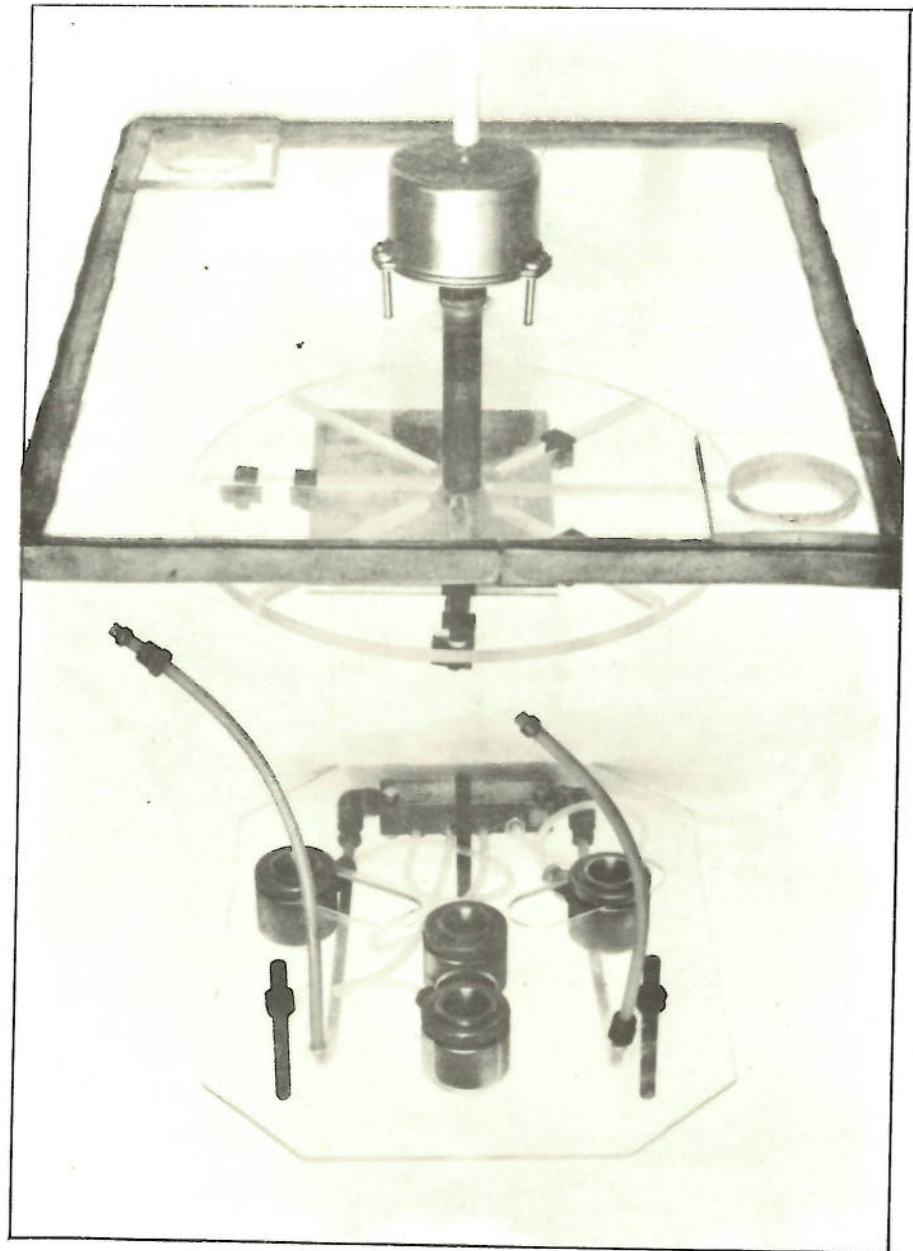


FIG. 5 - FOUR NOZZLE SYSTEM.